Oracle Database 12c Release 2 Performance Tuning Tips and Techniques

Up-to-Date Strategies for Optimizing Oracle Database Performance

Richard Niemiec
Oracle Certified Master, Oracle ACE Director
“Rich continues to be one of the foremost authorities on tuning the Oracle Database. His collection of tuning tips and tricks is a must-have for any database professional.”

—Judith Sim, Chief Marketing Officer, Oracle

“This is a timely update of Rich’s classic book on Oracle Database performance tuning to cover hot new topics like Oracle Database 12c Release 2, Oracle Exadata, and Oracle Cloud Database as a Service. This is a must-have for both traditional DBAs and DBAs in Cloud DevOps teams moving to these new products.”

—Andrew Mendelsohn, Executive Vice President, Oracle Corporation

“Packed with tips and tuning tricks, Rich draws from a lifetime of Oracle experience. This book is essential reading for every Oracle DBA who wants to stay current with the nuances of Oracle Database performance tuning.”

—Sohan DeMel, Vice President of Product Strategy, Oracle Corporation

“Another ‘must have’ technical reference for the Oracle professional. Rich’s books provide invaluable insight that allows you to get the most out of Oracle and push it to the limit and beyond.”

—Matt Swann, Vice President of Software Development, Amazon.com

“Rich makes most complex concepts in Oracle simple and interesting. His deep passion to educate everybody is unique in all his books. I remember 12 years back when I started learning Oracle reading Rich Niemiec books, and even today I consider his books the most reliable source in decision making. No DBA library in this world is complete without Rich Niemiec books.”

—Shiv Iyer, Founder & CEO, Ask DB Experts, Bangalore, India

“When I was a junior DBA in Chicago sixteen years ago, Rich Niemiec’s brilliant and unique DBA/developer topics exposed me to the wonderful world of performance tuning. In today’s era of Oracle Exadata when hardware and software are engineered to work together, I find Rich still at the forefront of this technology.”

—Steven Xueyong Lu, iTech Consultant Lead, Oracle China

“Tuning Oracle Databases is a science. When I need to have an answer to any tuning issue, I always turn to Rich’s Oracle Tuning Books. Whether it is 9i, 10g, 11g, or 12c, I know I can find the correct solution to the problem.”

—Stan Novinsky, Senior Oracle DBA/VMware Engineer, The Johns Hopkins University Applied Physics Laboratory

“To every difficult problem exists a simple solution; this is what I’ve learned from Rich’s books”

—Ghazi Ben Youssef, MBA, Senior Oracle DBA, Sogique, Canada

“If you could buy only one book this is the one to have in your DBA arsenal. If it’s not on your shelf, consider yourself unarmed. Rich does an excellent job of piecing the puzzle of performance tuning in an easy to follow outline.”

—Jerry D. Robinson Jr., Senior DBA, Northrop Grumman
"I admire Rich for his knowledge on Oracle Technology. This book from him is another masterpiece useful for anyone who would like to excel in Oracle Performance Tuning. The book encompasses Rich’s rich Oracle expertise and experience and is a must read for all Oraclelites."

—Hardik Bhatt, Chief Information Officer, State of Illinois

“If you need the best tuning DBA: call Rich Niemiec! Or get his Oracle tuning book”

—Julian Dontcheff, Global Database Lead, Accenture, Finland

“There is nothing more rewarding than to see someone from your family succeed in life. Rich being from our Purdue Upward Bound Family has brought much pride to us with not only his expert Oracle technology knowledge but also with his caring attitude and dedication to help others!”

—Joseph Flores, Director Upward Bound, Purdue University Calumet

“Rich Niemiec is a phenomenal entrepreneur with incredible depth of knowledge regarding Oracle applications.”

—Prof. Gerald Hills, Coleman Chair of Entrepreneurship, University of Illinois at Chicago

“We have learned much from Rich.”

—Nguyen Hoang, Information Expert, Ministry of Finance, Viet Nam

“Rich Niemiec had the courage to make his dreams come true. Through hard work and determination he overcame obstacles and serves as a role model for all students in TRiO Pre-College Programs. His knowledge and passion go beyond computers; he seeks to inspire others to have the courage to make their dreams come true too!”

—Bobbi Jo Johnson, Upward Bound Advisor, UW-Sheboygan

“The best Oracle Tuning book that I ever read is from Rich Niemiec and I would recommend his book to anyone who needs a better understanding about performance tuning and to enhance their skills in Oracle.”

—Shaharidan Karim, Senior DBA, Commerce Dot Com Sdn Bhd, Malaysia

“Rich’s boundless passion for technology combined with his zeal to share provides him the unique advantage to create a profound product that is rich in every way—he provides an insider’s view that you cannot afford to miss.”

—Anil Khilani, Global Technical Lead, Oracle Corporation

“Back in the time before MetaLink when Oracle Support was measured in hold time and pounds of manuals, I was lost in the darkness between unrealistic expectations and unreasonable demands. And then there was Rich. Years later, Rich is still a beacon whose insights light the path to my own discovery.”

—Fran Koerner, LAOUG Treasurer, DIRECTV, Oracle DBA

“Developers take note: Tuning is not just for DBAs. The proven techniques Rich explains in this book will help you create the most efficient application possible. Every developer who works with the Oracle database should own and read this book.”
“Michelangelo tells us that our problem is not aiming too high and missing but in aiming too low and hitting every time. With a master like Rich on your bookshelf, you can aim high with confidence.”

—Peter Koletzke, Quovera

“Rich Niemiec’s record as an expert speaks for itself. His diverse and extensive skills in Oracle technology with infinite possibilities impacts various aspects of life’s application.”

—Ronan Miles, British Telecommunications, London

“Rich doesn’t just know Oracle—he is THE Oracle!”

—Dennis Remmer, MD, E2 Australia, National President, Australian Oracle User Group (AUSOUG)

“Rich is not only a subject matter expert with Oracle technologies, he is also an outstanding author and friend. He consistently contributes his time, knowledge, and professional experience with the Oracle user community by introducing new features or helping others in need of support. It’s individuals like Rich who truly make an impact for the greater good in the Oracle community.”

—Albert Nashon Odhoji, Project Coordinator, THE SLUMCODE GROUP, Nairobi, Kenya

—Richard Stroupe, President, TRS Consulting Inc., Co-author Oracle Database 10g Insider Solutions

“The knowledge and skills from Mr. Niemiec are a unique experience within tuning issues.”

—Filipe Texeira de Souza, Systems Manager, Rio de Janeiro City Hall’s Secretary of Education, Brazil

“Rich is a true expert in Oracle tuning. He not only masters the theory and tools, but is also able to perform insightful analyses of real-world problems and present the results in a way that makes sense even to people not so experienced with database technologies. This is important since business people are getting more and more interested in IT performance in general—as they really should.”

—Jussi Vira, Manager, SAP Technologies and Infrastructure, Nokia Corporation

“Rich Niemiec is the Oracle expert on tuning and we can all learn from Rich.”

—Dr. Oleg Zhooravlev, CEO, Adit Information Technologies, Israel

“Someone said that smart people learn from their mistakes while wise people learn from others’ mistakes. When involved in performance and tuning issues I think that both smart and wise ones can learn from the vast and valuable experience Rich has documented within these pages.”

—Maurizio Bonomi, Italy
COMPLETENESS OF OR RESULTS TO BE OBTAINED FROM USING THE WORK, INCLUDING ANY INFORMATION THAT CAN BE ACCESSED THROUGH THE WORK VIA HYPERLINK OR OTHERWISE, AND EXPRESSLY DISCLAIM ANY WARRANTY, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. McGraw-Hill Education and its licensors do not warrant or guarantee that the functions contained in the work will meet your requirements or that its operation will be uninterrupted or error free. Neither McGraw-Hill Education nor its licensors shall be liable to you or anyone else for any inaccuracy, error or omission, regardless of cause, in the work or for any damages resulting therefrom. McGraw-Hill Education has no responsibility for the content of any information accessed through the work. Under no circumstances shall McGraw-Hill Education and/or its licensors be liable for any indirect, incidental, special, punitive, consequential or similar damages that result from the use of or inability to use the work, even if any of them has been advised of the possibility of such damages. This limitation of liability shall apply to any claim or cause whatsoever whether such claim or cause arises in contract, tort or otherwise.
About the Author

Rich Niemiec is a world-renowned IT Expert. Rich is an Oracle Ace Director, Oracle Certified Master, and was a cofounder and the CEO of TUSC: a Chicago-based, Inc. 500, systems integrator with ten U.S. offices focused on Oracle-based business solutions. TUSC was started in 1988. Rich also has served as an Executive Advisor to Rolta International Board of Directors, President of Rolta TUSC, and President of Rolta EICT International. TUSC was the Oracle Partner of the Year in 2002, 2004, 2007, 2008, 2010, 2011, and 2012 (Rolta TUSC for the last two). Rolta is an international market leader in IT-based geospatial solutions and caters to industries as diverse as infrastructure, telecom, electric, airports, defense, homeland security, urban development, town planning, and environmental protection. Rich is the past president of the International Oracle Users Group (IOUG) and the current president of the Midwest Oracle Users Group (MOUG). Rich has spoken in virtually every major U.S. city and many major international cities over the past three decades and has been named by attendees as the Top Speaker at Collaborate/IOUG (six times), MOUG (ten times), as well as at Oracle OpenWorld. Rich has architected and tuned many Fortune 500 systems over the past 25 years. Some Fortune 500 accounts he has managed and tuned include ACT, M&M Mars, McDonald’s Corp., Nokia, Navteq (MapQuest), University of Michigan, AT&T, and PepsiCo. His experience in data processing ranges from innovation and architecture to teaching and consulting, with an emphasis on executive direction, database administration and architecture, performance tuning, project management, and technical education. Rich was one of six Oracle Certified Masters originally honored worldwide and works cooperatively with Oracle development from time to time, especially during the beta process. In 2011, he authored the Oracle best seller Oracle 11g Performance Tuning Tips & Techniques (McGraw-Hill), an update of his previous three Oracle best sellers on Oracle8i, Oracle9i, and Oracle 10g performance tuning. He was awarded the National Trio Achiever Award in 2006 and the Purdue Outstanding Electrical & Computer Engineer award in 2007. He has also won IOUG’s prestigious Chris Wooldridge award twice. Rich was inducted into the Entrepreneurship Hall of Fame in 1998.

About the Technical Reviewer

Michelle Malcher is a data and security professional with several years of experience in database development, design, and administration. She has expertise in security, performance tuning, data modeling, and database architecture of very large database environments. As an Oracle ACE Director, she enjoys sharing knowledge about best practices involving database environments. Her experience is focused on designing, implementing, and maintaining stable, reliable, and secure database environments to support business and important business processes. She has held several positions on the IOUG Board of Directors. She has authored articles for the IOUG Select Journal and a book, Oracle Database Administration for the Microsoft SQL Server DBA (McGraw-Hill/Oracle Press, 2010) and is a co-author of Oracle Database 12c: Install, Configure & Maintain Like a Professional and Securing Oracle Database 12c (McGraw-Hill/Oracle Press).
“We’ve all been touched by the hand of God and Greatness is within us.”

To Regina, the love of my life…

I was sitting in the Sweet Shop at Purdue University, where I was a student, when I noticed Regina; one look stopped me in my tracks. I was instantly attracted to her. She was dressed for the working world, unlike most college students, and she had a laser focus and concentration while she studied that appealed to me as well. She was stunning in every way that mattered to me. What are all those things you see in a single moment that leads you to your eventual spouse, the person you’ll spend your entire adult life with? I don’t know. I know it’s different for everyone, but for me, the world stood still for that moment. What is it that the mind sees that you don’t notice until much later? Maybe I was just getting older, looking for something deeper; maybe it was the Marine in me that was looking for that super, well-put-together, sharp looking, fine young lady. I don’t know, but I sure didn’t pass her up. I boldly sat down at her booth; she was not amused, perhaps even slightly irritated by this. Regina had worked hard at a job during the day and gone to college at night to get her two-year degree focused on management. Now, she had transferred to Purdue and was working on her four-year
degree; she had no plans to be distracted from her goals. I asked her about her class. She was in Speech Pathology. She said the homework was pretty hard (it was the physics of sound waves and frequencies—I was in Electrical Engineering—child’s play, I thought). I told her that I could teach her this in about 10 to 15 minutes and then we could go catch a movie. No, she wasn’t looking to go to a movie with me or anyone else. I quickly read the examples in her book and started teaching her how to do these problems (scanning the examples and figuring it out like the true DBA I would become). If she was impressed, she sure didn’t show it. She hesitantly let me help her through her homework, kindly thanked me, and she said she had to go now. *Wouldn’t see a movie, wouldn’t let me walk her home, and wouldn’t give me her number—that was three strikes if ever I saw it.* It was back to the game room for me and pinball, Asteroids, or Space Invaders.

She was across the room when I walked in a week later, same booth, same look, focused as ever, but a hint of concern. I walked over and could see graphs on the page. It was physics class homework again…I was in luck. I actually asked to sit down this time (figuring that was the right thing to do, and figuring she’d say yes this time). “No,” she said, explaining she was really too busy with physics homework and then French class homework (I figured that I was in luck again—three years of high school French class just might come in handy for the very first time in my life). I took a look at her physics book and said that I could help her with this in no time and then I could help her with French as well. Reluctantly she agreed, and I sat down. When we were done, I asked if she wanted to go do something. “Not right now,” she said, indicating she really needed to get home and prepare a bit more for French class. (“How much does she study?” I thought. It was early in the semester and I wasn’t even considering picking up a book until the first test.) I tried again, “How about a movie sometime?” “Maybe, sometime, if I see you here.” “Can I get your number?” “No, my mother told me never to give out my number. Maybe, if I see you here, sometime.” I persisted, “How about Tuesday?” (Tuesday was dollar movie night and that’s really about all I could afford anyway.) “Okay,” she relented, “I’ll meet you here next Tuesday.”

So I met her there the next Tuesday, driving up in my beat-up Pinto wagon with the clutch going out. Halfway there, startled, Regina noticed the road going by under her feet (I had a reasonably sized hole in the floor)—I instructed her to slide the cardboard a little to the right to cover the hole. “Ohhhhh…okay,” she said slowly. So I took her to see *Platoon,* being the Marine I am (yes, I should have taken her to a romantic comedy, seeing it was a first date, but I wasn’t quite that smart—I was still just a kid who really didn’t know a lot about anything). After the movie, I told her I would spring
for another movie since it was dollar night. She agreed. It was a magical night; as I drove her home, she was a bit warmer to me, but still not willing to get too close—but, she did give me her number to study again some time together. A week or two later after seeing her in the Sweet Shop another couple of times and studying with her, I told Regina that I’d like to cook dinner for her. I couldn’t do it at my place since my room consisted of a bed and a desk (it had a community bathroom), but I told her I would cook at her place if her roommate allowed that (and since she had a stove). I actually couldn’t remember having cooked anything to that point in life. (I had sisters, and my brothers and I would wash dishes or do other odd jobs for them and they would cook things for us in return.) So I went to the store, bought a couple of steaks, potatoes, and a vegetable. In the checkout line I asked the older ladies in front of me: “How long do I cook this stuff, about an hour or so each?” They give me this concerned look and instantly started instructing me, but the line was too fast and I didn’t fully comprehend everything they were saying. I arrived at Regina’s apartment and nervously started to prepare things, and when I was about to put the steaks on, she asked: “You want me to help? We might want to put those potatoes on first.” She’d keenly figured out that unless she helped, we would probably have to eat out, and given my financial situation, she may even have to buy. She pretty much cooked the whole dinner and then thanked me multiple times for cooking such a wonderful dinner. We were hitting it off, and after that night we started to study together a whole lot more.

I grew up in poverty at times, so I can handle anything that comes my way. I didn’t really date too many people in high school, and it was a tough place (we called it “Teenage Wasteland,” after the song by The Who). Before meeting Regina, I had never really found that special person who I liked well enough to live with forever and who would live with me through better or worse—plenty who would live with me through better, but not worse. I used to study with Regina all night for tests (my professors started wondering why my grades were so good this early in the semester). One day I told her to keep in mind that I may not turn out to be much…not many from my neighborhood ever did. I might even just end up as a homeless person. She said if I did, she would be the homeless person by my side. Wow, now that’s the woman I wanted to marry—someone who would stick by me! I was 100 percent sure now! It was probably there from the first time I looked at her. What is it that your mind sees that you just can’t walk by? Something deeper, maybe just God taking you right to the person at just the right time, the person who fits you perfectly in life. For me, Regina is the best person I’ve ever met, and she makes me a better person every day of life! She quietly helps people from the shadows of life; with no praise, she tenaciously continues on. My prayers were answered the day of our wedding, and I can honestly say that marriage has continued to get even better the longer we’ve been married (it will be 30 years for us in 2018). How lucky I was to have met Regina on that first day!

Regina is wonderful, because she focuses on what’s really important in life. Neither one of us had too much materially while growing up, but we learned important lessons in life. Most things that really matter in life don’t cost too much. Regina always values the things that matter most in life: God, family, close friends, a cool night, a day in the country, a fall day with a cup of hot pumpkin spice coffee, a gentle breeze, a field of wildflowers (God’s natural beauty); it’s the simple things that matter a lot, not the artificial things in the world that are shiny on the outside and hollow on the inside. It’s not that we don’t need some things, and we can buy some cool things here and there as well (God gave us all this, too, to enjoy), but we have to be careful that things don’t weigh us down and take away from life either. Regina always knows that balance and keeps me balanced. I had just gotten out of being with the regular Marines (and into the Reserves) and starting a new semester when I met her. Regina showed me that college was a rare privilege and she was going to study hard until she
graduated. Regina was never perfect, but she was always a perfect fit for me. She is indeed one of those Uncommon Leaders the Marines taught me that I’d meet in life. The things that the Marines taught me to work on to better myself were the things I saw in Regina, and still do:

- **Integrity** She has a deep love and commitment to her family and to her faith.
- **Physical courage** She endures all things and motivates others to do the same.
- **Initiative** She helped create something from nothing in our period of history (TUSC and Cornerstone Young Women’s Learning Center), and was always there when I needed her.
- **Mental courage** Her courage to look past criticism and still work to make a difference.
- **Unselfishness** She shares all she has—both the first and last of what she has at times.
- **Tact** She always tries to find a way through and never loses her desire to help.
- **Tenacity** She attacks issues head-on. Her parents passed to her an incredibly rare tenacity.
- **Respect** She shows respect for everyone, *but still pushes them hard to better themselves.*
- **Humility** She humbly makes a difference from the shadows of life.
- **Fortitude** Fortitude is strength of mind to endure pain and adversity with courage and character. Regina has had fortitude above and beyond the call of duty over the years!

Regina is a rare find and truly the diamond in the rough (that’s hard to spot unless you look for exactly this). Success doesn’t happen overnight; it includes many painfully long nights, tender patience, rigid tenacity, deep learning, and most of all adapting and overcoming...for me, I had a woman by my side who helped me with all of these attributes. She allows me to see the future while not missing the present. The Purdue Sweet Shop led me to the sweetest sweet—Regina!
Contents at a Glance

1 Introduction to Oracle Database 12c R1 & R2 New Features (DBA and Developer)
2 Basic Index Principles (Beginner Developer and Beginner DBA)
3 Pluggable Databases, Disk Implementation Methodology, and ASM (DBA)
4 Tuning the Database with Initialization Parameters (DBA)
5 Tuning with Enterprise Manager Cloud Control (DBA and Developer)
6 Using EXPLAIN, TRACE, and SQL Plan Management (Developer and DBA)
7 Basic Hint Syntax (Developer and DBA)
8 Query Tuning (Developer and Beginner DBA)
9 Table Joins and Other Advanced Tuning (Advanced DBA and Developer)
10 Using PL/SQL to Enhance Performance (Developer and DBA)
11 Oracle Cloud, Exadata, Tuning RAC, and Using Parallel Features
12 The V$ Views (Developer and DBA)
13 The X$ Tables and Internals Topics (Advanced DBA)
14 Using Statspack and the AWR Report to Tune Waits, Latches, and Mutexes
15 Performing a Quick System Review (DBA)
16 Monitor the System Using Unix Utilities (DBA)
A Key Initialization Parameters (DBA)
B The V$ Views (DBA and Developer)
C The X$ Tables (DBA)

Index
Introduction to Oracle Database 12c R1 & R2 New Features (DBA and Developer)

Oracle Database 12cR1 (12.1.0.1)
- Increased Size Limit to 32K for VARCHAR2 and NVARCHAR2
- Partial Indexes
- Invisible Columns
- Multiple Indexes on the Same Column List
- Fetch First $x$ Rows
- Pluggable Databases (PDBs)
- Oracle Database Cloud Service (Database as a Service)
- PDB Level: MEMORY_LIMIT and MEMORY_MINIMUM (12cR2)
- Change Compression at Import Time
- Adaptive Query Optimization
- PGA_AGGREGATE_LIMIT
- Concurrent Execution for UNION/UNION ALL
- Invoker Rights Function Can Be Results Cached
- New DBMS.Utility.EXPAND_SQL_TEXT
- Default for Columns Based on Sequence
- Multiple SSD Devices for Smart Flash Cache
- Concurrent Cost-Based Optimizer Statistics Gathering
- Enhanced System Statistics
- Resource Manager for Runaway Queries
- Automatic Data Optimization (ADO)
- Global Index Maintenance: Drop and Truncate Partition Operations
- ASM Disk Scrubbing
- Online Capability Improvements
- Data Guard Improvements
- RMAN Improvements

Oracle Database 12cR1 (12.1.0.2)
- In-Memory Database
- Advanced Index Compression
- Automatic Big Table Caching
- FDA Support for Container Databases
- Full Database Caching
2 Basic Index Principles (Beginner Developer and Beginner DBA)

Basic Index Concepts
Invisible Indexes
Multiple Types of Indexes on the Same Column(s)
Concatenated Indexes
Suppressing Indexes
Using the NOT EQUAL Operators: <>!, !=
Using IS NULL or IS NOT NULL
Using LIKE
Using Functions
Comparing Mismatched Data Types

Selectivity
The Clustering Factor
The Binary Height
Additional Details Concerning BLEVEL and Index Height

Using Histograms
Fast Full Scans
Skip-Scans
Types of Indexes
B-Tree Indexes
Bitmap Indexes
Hash Indexes
Index-Organized Tables
Reverse Key Indexes
3 Pluggable Databases, Disk Implementation Methodology, and ASM (DBA)

Pluggable Databases (New in Oracle 12c)
- CDB or PDB Created Objects
- Creating a PDB: Many Ways to Do It
- Great Pluggable Database Commands
- ALTER SYSTEM While in a PDB and Other Nice Commands
- Using In-Memory (IM) with Pluggable Databases
- Other 12cR2 Features with Pluggable Databases
- Subset Standby (New in Oracle 12cR2)

Disk Arrays
- Use Disk Arrays to Improve Performance and Availability
- How Many Disks Do You Need?
- What Are Some of the RAID Levels Available?
- The Newer RAID 5
- Solid-State Disks
- ASM Storage Management (Striping/Mirroring)

Setup and Maintenance of the Traditional Filesystem
- What Is the Cost?
- Storing Data and Index Files in Separate Locations
- Avoiding I/O Disk Contention

The 12c Heat Map and Automatic Data Optimization (ADO)

12c I/O Performance Tracking Views (Outliers)

Oracle Bigfile Tablespaces

ASM Introduction
- Communication Across IT Roles
- ASM Instances
- ASM Initialization Parameters
- ASM Installation in 12c
- Srvctl Enhancements
- ASM Disk Scrubbing
- ASM Rebalance Enhancements
- ASM Fast Mirror Resync
- ASM Filter Driver
4 Tuning the Database with Initialization Parameters (DBA)

When Upgrading to Oracle Database 12c
Using SEC_CASE_SENSITIVE_LOGON
Crucial Memory Initialization Parameters for Performance
PDB Level: MEMORY_LIMIT and MEMORY_MINIMUM
In-Memory Database (INMEMORY_SIZE)
Changing the Initialization Parameters Without a Restart
Modifying an Initialization Parameter at the PDB Level
Insight into the Initialization Parameters from Oracle Utilities
Viewing the Initialization Parameters with Enterprise Manager
Increasing Performance by Tuning the DB_CACHE_SIZE
Using V$DB_CACHE_ADVICE in Tuning DB_CACHE_SIZE
Monitoring the V$SQLAREA View to Find Bad Queries
Setting DB_BLOCK_SIZE to Reflect the Size of Your Data Reads
Setting SGA_MAX_SIZE to 25 to 50 Percent of the Size Allocated to Main Memory
Tuning the SHARED_POOL_SIZE for Optimal Performance
Using Stored Procedures for Optimal Use of the Shared SQL Area
Setting the SHARED_POOL_SIZE High Enough to Fully Use the DB_CACHE_SIZE
Keeping the Data Dictionary Cache Objects Cached
Keeping the Library Cache Reload Ratio at 0 and the Hit Ratio Above 95 Percent
Using Available Memory to Determine If the SHARED_POOL_SIZE Is Set Correctly
Using the X$KSMSP Table to Get a Detailed Look at the Shared Pool
Points to Remember About Cache Size
Waits Related to Initialization Parameters
Using Oracle Multiple Buffer Pools
Pools Related to DB_CACHE_SIZE and Allocating Memory for Data
Modifying the LRU Algorithm
Pools Related to SHARED_POOL_SIZE and Allocating Memory for Statements
Tuning PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT
Modifying the Size of Your SGA to Avoid Paging and Swapping
Understanding the Oracle Optimizer
How Optimization Looks at the Data
Creating Enough Dispatchers
Have Enough Open Cursors (OPEN_CURSORS)
Don’t Let Your DDL Statements Fail (DDL_LOCK_TIMEOUT)
Two Important Exadata Initialization Parameters (Exadata Only)
Top 25 Initialization Parameters
Initialization Parameters over the Years
Finding Undocumented Initialization Parameters
Understanding the Typical Server
Modeling a Typical Server
Sizing the Oracle Applications Database
Tips Review
References

5 Tuning with Enterprise Manager Cloud Control (DBA and Developer)
Oracle Enterprise Manager Basics and Accessing OEM via Oracle Cloud
Starting with All Targets and Other Groupings
Monitoring and Tuning Using the OEM Performance Menu
  Performance Tab: Top Activity
  Performance Tab: SQL | SQL Performance Analyzer
  Performance Tab: Real-Time ADDM
  Performance Tab: SQL | Access Advisor
  Performance Tab: Manage Optimizer Statistics
  Performance Tab: AWR | AWR Administration
  Performance Tab: ASH Analytics
Monitoring and Tuning Using the OEM Administration Menu
  Database Administration Tab: Storage|Tablespaces
6 Using EXPLAIN, TRACE, and SQL Plan Management (Developer and DBA)

The Oracle SQL TRACE Utility
- Simple Steps for SQL TRACE with a Simple Query
- The Sections of a TRACE Output
- Digging into the TKPROF Output

Using DBMS_MONITOR
- Setting Trace Based on Session ID and Serial Number
- Setting Trace Based on Client Identifier
- Setting Trace for the Service Name/Module Name/Action Name
- Enabled Tracing Views
- TRCSESS Multiple Trace Files into One File

Using EXPLAIN PLAN Alone
- An Additional EXPLAIN Example for a Simple Query
- EXPLAIN PLAN—Read It Top to Bottom or Bottom to Top?
- Tracing/Explaining Problem Queries in Developer Products
- Important Columns in the PLAN_TABLE Table

Using DBMS_XPLAN
- Initialization Parameters for Undocumented TRACE

Using Stored Outlines
- Dropping Stored Outlines

Using SQL Plan Management (SPM) and SPM Example
- SPM Terms
- Using SPM
- Using Fixed SQL Plan Baselines
- Dropping a Plan
- Converting from Stored Outlines to SQL Plan Management
- Adaptive Plans (12c New Feature) and SPM

Tips Review
References
7 Basic Hint Syntax (Developer and DBA)

Top Hints Used
- Use Hints Sparingly
- Fix the Design First

Available Hints and Groupings
- Execution Path
- Access Methods
- Query Transformation Hints
- Join Operations
- Parallel Execution
- Other Hints

Specifying a Hint
Specifying Multiple Hints
When Using an Alias, Hint the Alias, Not the Table

The Hints
- The Oracle Demo Sample HR Schema
- The FIRST_ROWS Hint
- The ALL_ROWS Hint
- The FULL Hint
- The INDEX Hint
- The NO_INDEX Hint
- The INDEX_JOIN Hint
- The INDEX_COMBINE Hint
- The INDEX_ASC Hint
- The INDEX_DESC Hint
- The INDEX_FFS Hint
- The ORDERED Hint
- The LEADING Hint
- The NO_EXPAND Hint
- The DRIVING_SITE Hint
- The USE_MERGE Hint
- The USE_NL Hint
- The USE_HASH Hint
- The QB_NAME Hint
- The PUSH_SUBQ Hint
- The PARALLEL Hint
- The NO_PARALLEL Hint
- The PARALLEL_INDEX Hint
- The APPEND Hint
- The NOAPPEND Hint
- The CACHE Hint
8 Query Tuning (Developer and Beginner DBA)

Which Queries Do I Tune? Querying V$SQLAREA and V$SQL Views
Selecting from the V$SQLAREA View to Find the Worst Queries
Selecting from the V$SQL View to Find the Worst Queries

Oracle 12c Views for Locating Resource-Intensive Sessions and Queries
Selecting from V$SESSMETRIC to Find Current Resource-Intensive Sessions
Viewing Available AWR Snapshots
Selecting from the DBA_HIST_SQLSTAT View to Find the Worst Queries

When Should I Use an Index?
Selecting Query Text from the DBA_HIST_SQLTEXT View
Selecting Query EXPLAIN PLAN from the DBA_HIST_SQL_PLAN View

What If I Forget the Index?
Creating an Index
Invisible Index
Checking the Index on a Table
Is the Column Properly Indexed?

What If I Create a Bad Index?
Exercising Caution When Dropping an Index
Indexing the Columns Used in the SELECT and WHERE
Using the Fast Full Scan
Making the Query “Magically” Faster
Caching a Table in Memory
Using the Result Cache
Choosing Among Multiple Indexes (Use the Most Selective)
The Index Merge
Indexes That Can Get Suppressed
Function-Based Indexes
Virtual Columns
The “Curious” OR
Using the EXISTS Function and the Nested Subquery
That Table Is Actually a View!
SQL and Grand Unified Theory
Tuning Changes in Oracle Database 12c
- Oracle 12c Adaptive Query Optimization
- Adaptive Statistics
- Oracle 12c Changes in Statistics Gathering and Two New Histograms
- Oracle 12c Changes in SQL Plan Management
Oracle Automatic SQL Tuning
- Ensuring the Tuning User Has Access to the APIs
- Creating the Tuning Task
- Making Sure the Task Can Be Seen in the Advisor Log
- Executing the SQL Tuning Task
- Checking Status of the Tuning Task
- Displaying the SQL Tuning Advisor Report
- Reviewing the Report Output
Tuning SQL Statements Automatically Using SQL Tuning Advisor
- Enabling Automatic SQL Tuning Advisor
- Configuring Automatic SQL Tuning Advisor
- Viewing Automatic SQL Tuning Results
Using SQL Performance Analyzer (SPA)
Tips Review
References

9 Table Joins and Other Advanced Tuning (Advanced DBA and Developer)
Database Replay (capture/replay)
- Set Up Source Database for Database Replay Capture
- Prepare to Capture Workload
- Capture the Workload
- Prepare the Workload for Replay
- Process the Workload for Replay
- Prepare to Replay the Workload
- Execute the Workload Replay
SQL Performance Analyzer
- Create a SQL Tuning Set
- Create an Analysis Task
- Execute Analysis Task
- Query SQL Performance Analyzer Advisor Tasks
- Cancel an Executing SQL Performance Analyzer Analysis Task
Remove SQL Performance Analyzer Analysis Task
Determine Active SQL Tuning Sets
Remove SQL Tuning Set
Drop SQL Tuning Set

Join Methods
- NESTED LOOPS Joins
- SORT-MERGE Joins
- CLUSTER Joins
- HASH Joins
- INDEX-MERGE Joins

Table Join Initialization Parameters
- SORT-MERGE and HASH Join Parameters

A Two-Table Join: Equal-Sized Tables (Cost-Based)
A Two-Table INDEXED Join: Equal-Sized Tables (Cost-Based)
Forcing a Specific Join Method
Eliminating Join Records (Candidate Rows) in Multitable Joins
A Two-Table Join Between a Large and Small Table
Three-Table Joins: Not as Much Fun

Bitmap Join Indexes
- Bitmap Indexes
- Bitmap Join Index
- Best Uses for the Bitmap Join Index

Third-Party Product Tuning
- Example 1
- Example 2
- Example 3

Tuning Distributed Queries
When You Have Everything Tuned
Miscellaneous Tuning Snippets
- External Tables
- Snapshot Too Old: Developer Coding Issue
- Set Event to Dump Every Wait
- 14 Hours to 30 Seconds with the EXISTS Operator

Tuning at the Block Level (Advanced)
- Key Sections of a Block Dump
- A Brief Look at an Index Block Dump

Tuning Using Simple Mathematical Techniques
- Traditional Mathematical Analysis
- Seven-Step Methodology
- Deriving Performance Equations
- Pattern Interpretation
10 Using PL/SQL to Enhance Performance (Developer and DBA)

Leverage the PL/SQL Function Result Cache to Improve Performance (Improved in 12c)
Define PL/SQL Subprograms in a SQL Statement (New in 12c)
Reference Sequences Directly in PL/SQL Expressions
Identity Columns (New in 12c)
Max Size Increase to 32K for VARCHAR2, NVARCHAR2, and RAW Data Types (New in 12c)
Allow Binding PL/SQL-Only Data Types to SQL Statements (New in 12c)
Use Named Parameters in SQL Function Calls
Simplify Loops with the CONTINUE Statement
Leverage Compile-Time Warnings to Catch Programming Mistakes (Improved in 12c)
Increase Performance with Native Compilation
Maximize Performance with the Optimizing Compiler
Use DBMS_APPLICATION_INFO for Real-Time Monitoring
Log Timing Information in a Database Table
Reduce PL/SQL Program Unit Iterations and Iteration Time
Use ROWID for Iterative Processing
Standardize on Data Types, IF Statement Order, and PLS_INTEGER
  Ensure the Same Data Types in Comparison Operations
  Order IF Conditions Based on the Frequency of the Condition
  Use the PLS_INTEGER PL/SQL Data Type for Integer Operations
Reduce the Calls to SYSDATE
Reduce the Use of the MOD Function
Improve Shared Pool Use by Pinning PL/SQL Objects
  Pinning (Caching) PL/SQL Object Statements into Memory
  Pinning All Packages
Identify PL/SQL Objects That Need to Be Pinned
Use and Modify DBMS_SHARED_POOL.SIZES
  Find Large Objects
Get Detailed Object Information from DBA_OBJECT_SIZE
  Get Contiguous Space Currently in the Shared Pool
Find Invalid Objects
Find Disabled Triggers
Use PL/SQL Associative Arrays for Fast Reference Table Lookups
Find and Tune the SQL When Objects Are Used
Consider Time Component When Working with DATE Data Types
Use PL/SQL to Tune PL/SQL
Understand the Implications of PL/SQL Object Location
Use Rollback Segments to Open Large Cursors
Active Transaction Management: Process Large Quantities of Data
Use Temporary Database Tables for Increased Performance
Limit the Use of Dynamic SQL
Use Pipelined Table Functions to Build Complex Result Sets
Leave Those Debugging Commands Alone!
The “Look and Feel”: Just for the Beginners
   PL/SQL Example
   Create a Procedure Example
   Execute the Procedure from PL/SQL Example
   Create a Function Example
   Execute the GET_CUST_NAME Function from SQL Example
   Create a Package Example
   Database Trigger Example Using PL/SQL
Tips Review
References

11 Oracle Cloud, Exadata, Tuning RAC, and Using Parallel Features
The March to the Cloud (Past and Present)
The Oracle Cloud
Exadata Database Machine
   Exadata Terminology and the Basics
   Exadata Statistics
   Exadata Storage Expansion Rack Briefly
   Smart Scans
   Flash Cache
   Storage Indexes
   Hybrid Columnar Compression
   I/O Resource Management
   Use All Oracle Security Advantages with Exadata
   Best Practices
   Summary: Exadata = Paradigm Shift!
Oracle Database Appliance (ODA)
SuperCluster Using the M7 SPARC Chip
Other Oracle Hardware to Consider
   Oracle Big Data Appliance X6-2
   ZFS Storage Servers
   StorageTek Modular Library System
Parallel Databases
Real Application Clusters (RAC)
   Oracle RAC Architecture
   Internal Workings of the Oracle RAC System
RAC Performance Tuning Overview
RAC Cluster Interconnect Performance
Finding RAC Wait Events—Sessions Waiting
RAC Wait Events and Interconnect Statistics
Cluster Interconnect Tuning—Hardware Tier

Basic Concepts of Parallel Operations
Basic Concepts of Parallel Operations
Parallel DML and DDL Statements and Operations
Managing Parallel Server Resources and Parallel Statement Queuing
Parallelism and Partitions
Inter- and Intra-operation Parallelization
Examples of Using Inter- and Intra-operations (PARALLEL and NO_PARALLEL Hints)
Creating Table and Index Examples Using Parallel Operations
Monitoring Parallel Operations via the V$ Views
Using EXPLAIN PLAN and AUTOTRACE on Parallel Operations
Using the SET AUTOTRACE ON/OFF Command
Tuning Parallel Execution and the Initialization Parameters
Parallel Loading
Optimizing Parallel Operations in RAC
Objectives of Parallel Operations
RAC Parallel Usage Models
Parallel Initialization Parameters
V$ Views for Viewing Parallel Statistics
Create Table As
Parallel Index Builds
Performance Considerations and Summary
Other Parallel Notes

Oracle Documentation Is Online
Tips Review
References

12 The V$ Views (Developer and DBA)
Creating and Granting Access to V$ Views
  Obtaining a Count and Listing of All V$ Views
Getting a Listing for the X$ Scripts That Make Up the V$ Views
  Examining the Underlying Objects That Make Up the DBA_ Views
Using Helpful V$ Scripts
  Basic Database Information
  Basic Automatic Workload Repository (AWR) Information
  Basic Licensing Information
  Database Options Installed in Your Database
Summary of Memory Allocated (V$SGA)
  Querying V$IM_SEGMENTS After Setting the INMEMORY_SIZE
Automatic Memory Management and MEMORY_TARGET
Detailed Memory Allocated (V$SGASTAT)
Detailed Memory Allocated (V$SGASTAT) for a PDB vs. Root CDB
Finding spfile.ora/init.ora Settings in V$PARAMETER
Modifying an Initialization Parameter at PDB Level
Determining If Data Is in Memory (V$SYSSTAT & V$SYSMETRIC)
Determining Memory for the Data Dictionary (V$ROWCACHE)
Determining Memory for the Shared SQL and PL/SQL (V$LIBRARYCACHE)
Querying V$CONTAINERS and V$PDBS for Container Information
  Querying V$CONTAINERS When Using Pluggable Databases
  Querying V$PDBS for Pluggable Database Information
  Using the Result Cache
Identifying PL/SQL Objects That Need to Be Kept (Pinned)
Finding Problem Queries by Monitoring V$SESSION_LONGOPS
Finding Problem Queries by Querying V$SQLAREA
Finding Out What Users Are Doing and Which Resources They Are Using
  Finding Out Which Objects a User Is Accessing
  Getting Detailed User Information
Using Indexes
Identifying Locking Issues
  Killing the Problem Session
  Finding Users with Multiple Sessions
  Querying for Current Profiles
Finding Disk I/O Issues
Checking for Privileges and Roles
Wait Events V$ Views
Some of the Major V$ View Categories
Tips Review
References

13 The X$ Tables and Internals Topics (Advanced DBA)
Introducing the X$ Tables
  Misconceptions About the X$ Tables
  Granting Access to View the X$ Tables
Creating V$ Views and X$ Tables in 12c
  The X$ Tables Comprising the V$ Views
Obtaining a List of All the X$ Tables in 12c
Obtaining a List of All the X$ Indexes in 12c
Using Hints with X$ Tables and Indexes
Monitoring Space Allocations in the Shared Pool
Creating Queries to Monitor the Shared Pool
  ORA-04031 Errors
Large Allocations Causing Contention
Shared Pool Fragmentation
Low Free Memory in Shared and Java Pools
Library Cache Memory Use
High Number of Hard Parses
Mutex/Latch Waits and/or Sleeps
Miscellaneous X$ Table Notes

Obtaining Information About Redo Log Files
Setting Initialization Parameters
  Case 1
  Case 2
  Case 3
  Case 4
  Case 5

Exploring Buffer Cache/Data Block Details
  Buffer Statuses
  Segments Occupying Block Buffers
    Hot Data Blocks and the Causes of Latch Contention and Wait Events

Obtaining Database- and Instance-Specific Information
Effective X$ Table Use and Strategy
Oracle Internals Topics
  Traces
    DBMS_TRACE Package
  Events
  Dumps
  ORADEBUG
trcsess Utility

Reading the Trace File
  Wait Information and Response Time
  Recursive Calls
  Module Info
  Commit
  Unmap
  Bind Variables
  Errors

Some Common X$ Table Groups
Some Common X$ Table and Non-V$ Fixed View Associations
Common X$ Table Joins
X$ Table Naming Conventions (My Favorite Section of This Book!)
  X$ Table Naming Conventions with CON_ID, and INMEMORY

Future Version Impact in 12cR2
14 Using Statspack and the AWR Report to Tune Waits, Latches, and Mutexes

What’s New in 12cR2 (12.2) Statspack and the AWR Report

Installing Statspack
- Security of the PERFSTAT Account
- Post-Installation
- Gathering Statistics
- Running the Statistics Report

The Automatic Workload Repository (AWR) and the AWR Report
- Manually Managing the AWR
- AWR Automated Snapshots
- AWR Snapshot Reports
- Run the AWR Report in Oracle Enterprise Manager Cloud Control

Interpreting the Statspack and AWR Report Output
- The Header Information and Cache Sizes
- The Load Profile
- Instance Efficiency
- Shared Pool Statistics
- Top Wait Events
- Oracle Bugs
- The Life of an Oracle Shadow Process
- RAC Wait Events and Interconnect Statistics
- Top SQL Statements
- Instance Activity Statistics
- Tablespace and File I/O Statistics
- Segment Statistics
- Additional Memory Statistics
- UNDO Statistics
- Latch and Mutex Statistics
- Tuning and Viewing at the Block Level (Advanced)
- Dictionary and Library Cache Statistics
- SGA Memory Statistics
- Nondefault Initialization Parameters

Top 15 Things to Look for in AWR Report and Statspack Output
- Managing the Statspack Data
- Upgrading Statspack
- Deinstalling Statspack

Quick Notes on the New ADDM Report

Scripts in 12cR2

Tips Review
15 Performing a Quick System Review (DBA)

Total Performance Index (TPI)

Education Performance Index (EPI)

System Performance Index (SPI)

Memory Performance Index (MPI)
  Top 25 “Memory Abuser” Statements Tuned
  Top 10 “Memory Abusers” as a Percent of All Statements
  Buffer Cache Hit Ratio
  Dictionary Cache Hit Ratio
  Library Cache Hit Ratio
  PGA Memory Sort Ratio
  Percentage of Data Buffers Still Free
  Using the Result Cache Effectively
  Pinning/Caching Objects

Disk Performance Index (DPI)
  Top 25 “Disk-Read Abuser” Statements Tuned
  Top 10 Disk-Read Abusers as Percentage of All Statements
  Tables/Indexes Separated or Using ASM
  Mission-Critical Table Management
  Key Oracle Files Separated
  Automatic Undo Management
  Using Pluggable Databases Effectively

Total Performance Index (TPI)

Overall System Review Example
  Rating System
  Example System Review Rating Categories
  Items Requiring Immediate Action
  Other Items Requiring Action

System Information List
  Memory-Related Values
  Disk-Related Values
  CPU-Related Values
  Backup- and Recovery-Related Information
  Naming Conventions and/or Standards and Security Information Questions
  DBA Knowledge Rating

Other Items to Consider in Your TPI and System Review

Tips Review

References

16 Monitor the System Using Unix Utilities (DBA)
Unix/Linux Utilities
Using the sar Command to Monitor CPU Usage
  sar –u (Check for CPU Bogged Down)
  The sar –d Command (Find I/O Problems)
  The sar –b Command (Check the Buffer Cache)
  The sar –q Command (Check the Run Queue and Swap Queue Lengths)
Using the sar and vmstat Commands to Monitor Paging/Swapping
  Using sar –p to Report Paging Activities
  Using sar –w to Report Swapping and Switching Activities
  Using sar –r to Report Free Memory and Free Swap
  Using sar –g to Report Paging Activities
  Using sar –wpgr to Report on Memory Resources
Finding the Worst User on the System Using the top Command
Monitoring Tools
Using the uptime Command to Monitor CPU Load
Using the mpstat Command to Identify CPU Bottlenecks
Combining ps with Selected V$ Views
  CPU/Memory Monitoring Tool (Task Manager) on Windows
Using the iostat Command to Identify Disk I/O Bottlenecks
  Using iostat –d for Disk Drives sd15, sd16, sd17, and sd18
  Using iostat –D
  Using iostat –x
  Combining iostat –x with Logic in a Shell Script
Using the ipcs Command to Determine Shared Memory
Using the vmstat Command to Monitor System Load
Monitoring Disk Free Space
  The df Command
  The du Command
Monitoring Network Performance with netstat
Modifying the Configuration Information File
  Other Factors That Affect Performance
Other Sources to Improve Performance
Tips Review
References

A  Key Initialization Parameters (DBA)
  Obsoleted/Desupported Initialization Parameters
  Deprecated Initialization Parameters
  Top 25 Initialization Parameters
  Top 20 Initialization Parameters Not to Forget
  Top 13 Undocumented Initialization Parameters (As I See It)
  Bonus 11 Undocumented Initialization Parameters
Listing of Documented Initialization Parameters (V$PARAMETER)
Listing of Undocumented Initialization Parameters (X$KSPPI/X$KSPPCV)
Additional Oracle Applications Notes
  Concurrent Managers
  Applications—Finding Module-Specific Patches
  Diagnostics Data Collection: EBS Analyzers
  Web Server Tuning
  Timeouts
  Database Initialization Parameter Sizing
Top 10 Reasons Not to Write a Book
Tips Review
References

B The V$ Views (DBA and Developer)
  Creation of V$ and GV$ Views and X$ Tables
  A List of Oracle 12c (12.2.0.0.1) GV$ Views
  A List of Oracle 12c (12.2.0.0.1) V$ Views
  Oracle 12c Scripts for the X$ Tables Used to Create the V$ Views

C The X$ Tables (DBA)
  Oracle 12cR2 X$ Tables Ordered by Name
  Oracle 12cR2 X$ Indexes
  Oracle 12cR2 V$ Views Cross-Referenced to the X$ Tables

Index
“Perhaps, in order to really become free, we have to move from struggling to hear God’s Voice to letting God’s Voice speak through us.”

—Rabbi Jonathan Kraus

The goal of this book is primarily focused on helping beginner and intermediate Oracle professionals understand and better tune Oracle systems. Many expert topics are also covered, but the objective is primarily to assist professionals who are frustrated and looking for simple tips to help improve database performance. This book has one simple aim: to provide an arsenal of tips you can use in various situations to make your system faster.

I would like to thank Michelle Malcher, who writes great books herself, for her absolutely great job as a technical editor. Michelle is a very humble Oracle guru who ensured I wasn’t missing certain features that mattered to her. She added valuable content to every chapter she edited. She’s one of those Oracle professionals who constantly gives back to the community. I would like to thank Wendy Rinaldi, Editorial Director at the International & Professional Group at McGraw-Hill Education, for her positive attitude and professional direction in taking me through this edition of the book; and Claire Yee, Editorial Coordinator for the International & Professional Group at McGraw-Hill Education, for avidly keeping me on track through the very end—you are so wonderful to work with and you stay motivated throughout the process. Thank you Rachel Gunn, the Production Editor for this edition; she was patient, detailed, and wonderful to work with throughout the copyediting and proofreading part of production. Thanks to Janet Walden and Lynn Messina, who assisted Rachel during production. Lastly, thanks to Scott Rogers and Jeremy Judson for getting me through the first book after I’d let you guys know it would be done in a few weeks (and it took two years, for each)!

Thanks to the following people who helped in some way with the following chapters:

- Mike Messina, for your work in updating much of Chapter 1. You also do an outstanding job, and you are still an incredible Oracle talent!

- Dave Radoicic, for an excellent and thorough job writing and testing Chapter 2. Thanks Kevin Loney for your work in previously updating Chapter 2.

- Joe Mathew for the outstanding job updating Chapter 3 and the great ASM information and testing. Also, Sridhar Avantsa, Bill Callahan, and Nitin Vengurlekar for previous updates to Chapter 3.

- Mike Messina for updating Chapter 4. Also, Lucas Niemiec for testing scripts in Chapter 4 and Palani Kasi for additions on Oracle Applications to Chapter 4. Craig Shallahamer, Randy Swanson, and Jeff Keller for previous updates of Chapter 4.

- Asad Mohammed for the outstanding update to Chapter 5. Thanks for insights on EM from Werner DeGryter. Also, thanks Anil Khilani, Prabhaker Gonglloor (GP), David LeRoy, Martin Pena, Valerie Kane, and Mughees Minhas for your help with previous updates.
Warren Bakker for your always great update and additions to Chapter 6. Thanks to Mark Riedel and Greg Pucka for previous help on this chapter.

Mark Riedel for previous updates of Chapter 7. Thanks to Lucas Niemiec for additional hint research.

Janis Griffin for the wonderful additions to Chapter 8. Janis’s additions and material on the optimizer are fantastic; I consider Janis one of the best query tuning people on earth. Connor McDonald, Rama Balaji, and Rob Christensen helped with previous notes and versions.

Thanks for previous updates and tips by Joe Holmes, Mike Messina, Francisco Javier Moreno, Guillermo L. Ospina Romero, Rafael I. Larios Restrepo, and Roger Schrag to Chapter 9.

Greg Bogode for a great update of Chapter 10. Also thanks for great work by Bob Taylor on the 11g update; Joe Trezzo and Dave Ventura helped with previous versions.

Sridhar Avantsa for additional sections on HCC, Exadata, and RAC and Mike Messina for Exadata 6.2 information to Chapter 11. Thanks for some great additions by Richard Stroupe previously, along with contributions from Madhu Tumma, Brad Nash, Jake Van der Vort, and Kevin Loney.

Thanks for previous updates and tips by Rama Balaji, Kevin Gilpin, Bob Yingst, and Greg Pucka to Chapter 12.

Thanks for previous updates and excellent additions by Graham Thornton and Kevin Gilpin to Chapter 13. Steve Adams of Australia was a technical editor in the past and a great contributor to the X$ scripts.


Thanks for previous updates and tips by Brad Nash to Chapter 15 and Lucas Niemiec for testing the queries.

Thanks for new tips in Chapter 16 by Dana MacPhail and Alwyn Santos, and help from Mark Nierzwicki. Thanks for previous updates of Chapter 16 by Doug Freyburger, Judy Corley, Mike Gallagher, and Jon Vincenzo.

Lucas Niemiec for testing all of the queries in Appendix A and updating them, and Palani Kasi for additions on Oracle Applications to Appendix A.

Jacob Niemiec for testing all of the queries in Appendix C and updating them.

Melissa Niemiec for thoughts and suggestions for the introduction.

Thanks to those from Oracle who have made a big difference in my life:
Thanks Larry Ellison, Bob Miner, Bruce Scott, and Ed Oates for the great database and future thinking (cloud currently), and for creating the most innovative company in history!

The IOUG for making my Oracle life easier over the years by focusing on education.

Andy Mendelsohn—thanks for this incredible version of the database; Bob Miner would be proud of your leadership!

Judith Sim—you are one of the Oracle leaders who puts Oracle at the top. Thanks for all your help and leadership with user groups over the years!

Thomas Kurian—thanks for your Ace updates, putting Fusion Middleware on the map so that everything works together, and for taking Oracle Applications to the next level in the cloud.

Mary Ann Davidson—thanks for your leadership and keeping Oracle secure.

Tom Kyte—you are the ultimate Oracle tech guru; enjoy retirement—you’ve earned it!

Angelo Pruscino, Kirk McGowan, and Erik Peterson—without you three, there would be no RAC; without Angelo, RAC would be a mess. Dan Norris and Phil Stephenson for their help with Exadata.

Justin Kestelyn—you educate the world with OTN.

Tirthankar Lahiri—what a job on the buffer cache!

Bruce Scott—thanks for taking the time to do the Select article interview and for sending me the rare Oracle founders’ picture.

Thanks to the following people who in some way have contributed to this version of the book (in addition to those above):
David Anstey, Eyal Aronoff, Mike Ault, Penny Avril, Janet Bacon, Kamila Bajaria, Roger Bamford, Greg Bogode, Mike Broullette, Bill Burke, Don Burleson, Rachel Carmichael, Tony Catalano, Rob Christensen, Craig Davis, Sergio Del Rio, Dr. Paul Dorsey, Kim Floss, Khadish Franklin, K. Gopalakrishnan, Tim Gorman, Kent Graziano, Mark Greenhalgh, Damon Grube, Roman Gutfreynd, Vinod Haval, Scott Heaton, Gerry Hills, Steven Hirsch, Nguyen Hoang, Pat Holmes, Jeff Jacobs, Tony Jambu, Tony Jedlinski, Ron Jedlinski, Zhigang Ji, Jeremy Judson, Dave Kaufman, Mike
I want to thank the two best partners a person can ever have in Brad Brown and Joe Trezzo. We make a great band of brothers! I would like to thank many of the people at TUSC, Rolta, Piocon, and WhittmanHart (all now one global Rolta company), who work hard every day and are dedicated to excellence. Thanks Barb, Karen, Sandy, Kim, and Amy for keeping us sane. Thanks Tony, Dave, Barry, Burk, Bill, Bob, Janet, Terry, Heidi, John, Matt, and Mike for the leadership and memories. Thanks KK, Preetha, Ben, Mark, Sohrab, Vinay, Blane, Jack, Dave, and Rif for taking us into that global world. Thanks Sanjay, Narendra, Nimesh, and all of the others for keeping us sane on the other side of the world. I also want to thank Eric Noelke and Mike Simmons personally for giving me my first job at Oracle and Matt Vranicar for helping me understand indexes when I got there. Although I can’t thank the almost 4000 people at Rolta individually, thanks for all you do every day to improve the world!

I do want to thank those from Rolta and TUSC who assisted during the writing of the book (since it’s a smaller list of superstars):
I would also like to thank all of the people who make a difference in my life (in addition to those above and from the previous books):


Lastly, thanks to (your name goes here) for buying this book and being dedicated to improving your own skills (or if I forgot your name above). Father Tony once told me everything you need to know in life: “Nothing in life is so big that God can’t handle it and nothing is so small that God doesn’t notice it.” Thanks to all of those above who have made and continue to make both big and small differences in my life and in this book!

In Memory:
“Only a life lived for others is worth living.”
—Albert Einstein

Finally, we need to remember our friends we’ve lost over the recent years who always gave back to the community, especially Gary Goodman, Karen Morton, and John Nash.

God takes us home one day when our work is done; we’ll be with them soon enough to “run with angels on streets made of gold.” I look forward to that day, but until that day, let’s continue to make a difference and ensure that God speaks through us by our wonderful actions toward one another! By always looking to improve our integrity, knowledge, physical courage, loyalty, self-control, enthusiasm, unselfishness, tact, moral courage, respect, humility, and initiative, we will ensure that we have the fortitude to face any tough challenge ahead. And, of course, never forget, faith, hope, and love... “and the greatest of these is Love.” To make a difference in the world with character and with a heart that always brings out the best in others—this is my goal in life!
Introduction

“The enterprise that does not innovate inevitably ages and declines. And in a period of rapid change such as the present, an entrepreneurial period, the decline will be fast.”

—Peter F. Drucker (1909–2005)

Disruptive innovation occurred as postal mail moved to e-mail, as telegraph moved to telephone, as telephone moved to cell phones, computers moved to smartphones, encyclopedias moved to Wikipedia, and floppy drives moved to USBs. You don’t stop innovation! So what’s next? Most everything in Star Trek either has been invented or is in the process of being invented. Star Trek technology that once looked so futuristic now looks very old. Even Twilight Zone predictions pale in comparison to the reality we see unfold daily. E-mail has given way to texting and then to Snapchat, cell phones are now moving to smart watches, and the promise of Google Glass is now moving to virtual reality (VR) devices. Small plastic pieces that you picked up at Wal-Mart in the past can now be printed in the home. You no longer need Microsoft Office installed on every device as Google Docs will do it for free in the cloud from any device (Microsoft now has a cloud version—kids use Google). All of these technologies are already here; they are not what’s next. Innovation is the introduction of something new or different. Some companies embrace innovation and thrive, while others don’t, and fall behind or disappear. Some innovation is helpful or only mildly unsettling while other innovation radically disrupts people, countries, or businesses. When innovation occurs in a product category, no amount of new investment in the older product will yield a normal rate of return. Building a nicer, faster, better telegraph machine could not stop the telephone. Microsoft stayed flat as a stock for ten years until it came out with its Azure cloud computing platform. Oracle is embracing the cloud, not only because of Amazon’s amazing profits in the cloud services market, but because cloud computing is an innovation that is here to stay. Oracle has realized that it must embrace it to
survive. In Peter Drucker’s *Innovation and Entrepreneurship* book, he talks about the “deadly temptation to feed yesterday and starve tomorrow.” As clearly represented by Oracle Database 12c (the c standing for *cloud*), Oracle has resisted the temptation to feed its on-premises business at the expense of starving the cloud, knowing that it would be a losing proposition in the long run.

Many people think the cloud is the path to eliminating their job. If you are one of them, I have news for you: where there is more innovation, there is more business and more profit to be had than anywhere else. There will be greater demand as companies move at least part of their operations to the cloud, while keeping some of them in-house (a hybrid cloud model that will be used by many companies for a time). Companies requiring great control or security might allow little movement to the cloud, but the majority of IT innovation today is happening in the cloud. To be more precise, with mobile applications, cloud computing is where most mobile-enabling technologies live. When the operations department at a company resists the cloud, the development department moves their Agile development directly to the cloud with DevOps (a new person with Development combined with Operations experience) personnel. Big data and consumer applications are already in the cloud, as is the next-generation IT person. Is your job as a DBA or sysadmin going away? No, it’s just shifting, at least partly, to the cloud, to include managing the consolidation of applications, enabling faster development, working with throw-away architecture, and developing the future robotic helper (if you’re willing to educate yourself and embrace the bend in the road). Those who are educated and prepared for the cloud will be able to make more money in this demand area of the economy. Those who resist will find themselves with flat expectations, but still with more than enough work to manage operations that can’t be moved to the cloud. I see the industry bifurcating, or splitting into two: those who move to the cloud and have bots (computer robots) working for them to make them more productive, and those who stagnate and become workers of the future robot bosses (perhaps only a computer—not necessarily a robot walking around) that manage their operations, constantly looking for ways to eliminate them and save the company yet more money.

The first cloud warning shot from Oracle came with 12c Release 1 (as the c was for cloud), but the bigger shot came with Oracle Database 12c Release 2. Oracle 12.2 has been released first in the cloud (without a timetable for the on-premise release). Oracle 12cR2 was announced by Larry Ellison on September 18, 2016 to be released on the Oracle Exadata Express Cloud Service at $175/month (even Oracle salespeople selling Exadata complained about the low price). This announcement is Oracle telling you that the cloud is the most important focus that they will ever have. Larry Ellison calls it a once in a generation move to the cloud. Whether it’s Larry Ellison, Mark Hurd, Safra Catz, Thomas Kurian, Andy Mendelsohn, or Judith Sim, these Oracle leaders all talk about the cloud first or the cloud only. They’ll only accelerate this innovative arena and eventually starve their on-premises business.

As with many new technologies, the cloud is painful to adopt, with so many moving parts including your own personnel. But consider companies like Google, Amazon, Apple, and Oracle; what do they have in common? They are mature companies that innovate constantly and embrace or create the future, and they have all invested heavily in the future of the cloud. Even Facebook and Twitter succeed because they innovate; they grow despite their naive corporate youth. Facebook would have had LinkedIn’s market share as well were they more mature in their business growth. *Is your company as innovative and mature as Google*, which went from its origins as an Internet search service to offer mapping, images and video, translation, and Google Docs, and then expanded to encompass everything from the Android OS, smart watches, virtual reality, and Chromecast to a dashboard in your car, to driving your car, to Nest in your house, to robotics? Amazon comes closest
to Google. Oracle and Apple are mature leaders and innovators, but primarily limited to the tech world. Oracle went from 8-bit RDBMS, to 32-bit, to client-server, to 64-bit (way back in 1995), to web database, to Linux support, to RAC, to Grid, to BEA middle tier, to every major application including Financials, JDE, EBS, HCM, EPM (Hyperion), SCM, Retail, Data Warehousing, to hardware and Sun, to three to four new hardware appliances every year, to 128-bit with ZFS, to an all-flash server (1 petabyte available now), to In-Memory Database, to multitenant, to web-based and mobile applications, to Oracle Cloud. Don’t forget Oracle owns the largest offering of NoSQL databases with the Sleepycat software (Berkeley DB) acquisition (over 100M deployments) and MySQL databases with the Sun acquisition. Their Solaris machine has both security and queries running in the silicon with the new M7 chip, and their recent Ravello Systems acquisition hurts Amazon while helping Oracle. Oracle doesn’t have the breadth of Google or Amazon in the consumer market, but it has much greater depth and maturity. My calculations based on the number of servers and other data (unofficially) show Amazon, Microsoft, Google, and Oracle as the largest (by far) cloud providers, with HP, Facebook, Yahoo, Digital Ocean, OVH, China Telecom, SoftLayer, Rackspace, Akamai Tech, Intel, and Comcast on the distant second tier (tens to hundreds of thousands of servers). While Google, Amazon, and Microsoft are all in the 1M+ server range, Oracle with compression is the largest public cloud with over 10 exabytes of storage as of October 2016. Oracle is number one due to their own technology! I only see Oracle accelerating by further leveraging the technology they have. Oracle hasn’t moved their customers to the cloud yet, but the Oracle Public Cloud (OPC) will get a lot bigger when they do. In the past, most Oracle databases would not fit on an Oracle server in DRAM or even flash, but now they do. I remember seeing a 4000-node Hadoop big data warehouse with 16P (16,000T) of raw disk and people saying that you can’t fit big data on Oracle. That same 4000-node cluster would fit on this year’s X6-2 with 1.3P and 15× compression to give you 19.5P of raw disk equivalent. A single machine replacing an entire room of servers (a very large computer room)! Whether on premises or in the cloud, most databases would fit on one Oracle server. Think of the power savings and space savings alone, not to mention the maintenance. Think of the cloud you could build starting with this size Lego!

Because of the explosion of data through social media, sensor data, biological, traffic, RFID data, environmental, aerial, wireless, security, video, medical, and archived data, we now have data that will help businesses and individuals make better decisions. However, this widespread availability of data also puts our privacy at risk and requires greater security and products that will protect us. While big data helps us compete better, understand our customers better, grow business streams, and lower costs, we often resist it in IT because the security and maturity of the products in the big data world are lacking. Big Data is supposedly too big to fit in a normal database (which is true if you need a 4000-node Hadoop cluster—replace this with a couple of Exadata Servers instead). Oracle now provides a way to go from Oracle SQL directly to Hadoop, Hive, and other NoSQL databases by writing SQL. The enhanced security of Oracle now makes it possible to manage all of these data sources that are already in the cloud. Welcome to the future; it’s the best of both worlds! Many NoSQL database are eventually consistent; Oracle is just consistent (the correct data all the time). Many NoSQL databases have some security; Oracle has encryption at the chip level, auditing, virtual private databases, global roles, secure application roles, fine-grained auditing, transparent data encryption, audit vault, database vault, multitenant security, and many security evaluations. It will take decades for other vendors to catch up at a time when security is paramount to nations across the world. You want to use Spark? Oracle has a connector to that. You want to use Node.js or Angular JavaScript? Oracle now welcomes that code base.
Archived data used to tell you what happened and maybe even why it happened. Now we head into predictive and prescriptive analytics, where archived data tells you what will happen and what’s the best thing that could happen if you act correctly (it’s a lot like the movie *Minority Report*—perhaps even more advanced). Oracle has some of the most advanced data warehouse tools with Oracle Business Intelligence Enterprise Edition (OBIEE) in addition to Oracle R Enterprise (a component of Oracle Advanced Analytics) to leverage big data to write these programs. Those tools have been developed over the past two decades. My company once combined several of a customer’s systems to show what was going to break in a plant before it broke (reliability system), then checked when their supplier would have the part (supply chain system), ordered the part ahead of time (order entry), trained the correct person to fix it before it broke (training system), ensured that person wouldn’t be on vacation when it was probably going to break (HR system), etc. It saved the customer millions of dollars every year in lost downtime. BI tools like Oracle or Entrigna (the next-generation BI tool) will take every database source and allow you to build that future. Perhaps the big data world will be connected via pluggable databases (PDBs), with everyone using multitenant (as suggested by Oracle’s decision to deprecate non-CDB [container database] or non-multitenant as of 12.1.0.2). *But be quick*, because the Internet of Things (IOT) is also already here. We’ve used it at Rolta to build Smart Cities, Rockwell uses it to build smart manufacturing, GE uses it to put better devices in your home, grocery stores use it to market the right products to you, Google has it in your Nest thermostat, and Gartner recommends that companies don’t cross the “creepy line” when storing all that information. IOT is already here!

So if the cloud, big data, and IOT are the present, what’s the future? The future is robotics in every facet of life. There are robots that already look exactly like a real person, can recognize gestures, fetch a cup of coffee from Starbucks (complete with using the elevator), vacuum your rugs (Roomba—or as I call it, Skynet), water your grass or flowers based on weather data retrieved from the cloud via IOT devices, etc. Robotics is the future, it’s here now, it’s growing fast, and you should be building things that use these tools as a tech person.

*Your goals should be as follows:* Get on Oracle 12cR2, leverage all of the applicable features (this book will help), learn how to keep an encrypted backup on the cloud, learn how to spin up database cloud services for the development team quickly when they need them (so DevOps isn’t needed), learn which systems shouldn’t go to the cloud and why (be the knowledgeable and discerning person in the room), and then start fitting robotics into your competitive advantage as a company. *Oracle is the best tool in the world and is unbeatable if you can leverage it fully.* Every great carpenter uses the best tools and learns how to use them well; you need to do the same with Oracle. Read the whole book, implement the tuning techniques in your systems, and get working on what’s next for you and your company!

What’s coming next? Implants are next with virtual reality and exoskeletons. Those people you see wearing smart watches, Google Glass, or VR headsets will be same ones who also beta test the implants that are on the way. This is the first wave toward a future where you’ll no longer recognize the past. It’s been 13.7 billion years since the Big Bang to get to this acceleration point in history. What are you doing with this opportunity as you are at the exact right place at exactly the right time in history? What gifts has God given you that you can leverage? Don’t worry about losing your job to the cloud like the AT&T operators worried about losing their jobs to computers. Think about how you will react as the road bends ahead, and go where the opportunity lies. God has a place for you out there during this pivotal time in history!

Rod Serling said it well: “There is a fifth dimension beyond that which is known to man. It is a
dimension as vast as space and as timeless as infinity. It is the middle ground between light and shadow, between science and superstition, and it lies between the pit of man’s fears and the summit of his knowledge. It is an area which we call the Twilight Zone.” With Exadata, flash, and the cloud, we have started exploring this area in all corners of the world. It will prove to be an area of implants, augmentations of every kind, and one that will test our definition of what makes up a human being.

What amount of human augmentation transforms a human into a robot? What if you could transfer every experience you’ve ever had and every thought in your mind to a computer and then download that into a 3D printed replica of the brain, printed using your own cells? When incorporated into a 3D print of the rest of your body, is it a person or a robot at that point? (I think it would still be a clone of sorts, perhaps a facsimile, but not the real thing.) Could it go to work for you? When will we be able to 3D print ourselves to help us do chores? What happens when 75 percent of the body is robotic and only 25 percent is human? With human augmentations, the percentage of robotic parts will continue to rise. Will these replicated humans have rights? Consider that a recent U.S. Supreme Court ruling gave organizations the right to spend unlimited money on campaigns of candidates running for office; this was perhaps the largest right given to nonhumans in our history. In the future, Wall Street (“the bull” is primarily run by computer trading, or robots, today) could use its computer-driven trading profits to install these future robots as leaders of companies in the same way that it does most trading currently—by computer. Why wouldn’t they want a robot with the ability of many humans (or every human on earth) running the company instead of a mere mortal? Wall Street and those companies could then use their money to finance the campaigns of their own political candidates, quietly (even the U.S. president, who may potentially nominate Supreme Court justices that they choose). This is no longer science fiction, but challenges we face in the near future. There are now leaders of tech companies funding large projects to ensure our future as a species continues because of this coming shift.

Connecting into the brain has already occurred; what’s next will certainly lead us to something well beyond a Twilight Zone future. It is a future where arranging atoms to create objects, or transport them or hide them, will become more common. As Rod Serling said, “You unlock this door with the key of imagination.” We are no longer limited; what you can imagine, you can create. I think it’s an amazing time to live and to work! Perhaps knowledge-building edible technology will be the follow-up to wearable technology. What future will these primarily robotic systems and workers eventually build? It’s hard to predict, and hard to predict where we humans will fit in. Wall Street at times can be more beast than bull—it listens to no person or country, and it silently builds more efficiency and productivity into the corporate world based on algorithms of all of those traders throughout its history that made up almost all trading. There is a new world ahead that is part man, part machine, and for this there is a standing-room-only audience watching from the other side. What has God in store for all of us ahead? Is it the final act, or a better future that will bring out the best in each of us and to each of us? Some of us keep looking back for that wisp of what was; try looking forward! What’s on the signpost up ahead? Nobody knows for sure, but you’ll soon be at this fork in the road. Godspeed humans, and choose wisely!

Why is this brave new world coming so quickly whether we like it or not, and whether we are ready for it or not? We started on the mainframe with 8 bits and the ability to access 256 bytes of addressable memory, and then 16 bits and Windows with 64K of memory and, if you bought extra hardware, 1M of extended memory. Then came the Internet age, as we boldly headed into the gigabyte SGA world that 32 bits brought us and 4G of addressable memory. Now technology has grown to 64 bits and moves from the burdens of 4G max, which the 32-bit Internet world gave us. With 64 bits, the theoretical limit of directly addressable memory (2 to the power of 64) has become 16E (exabytes),
or 18,446,744,073,709,551,616 bytes ($2^{64}$ bytes), waiting for us to leverage its incredible power in every aspect of our lives. We will go from gigabyte SGAs to petabyte SGAs (where a petabyte is 1000 terabytes) with bigger data. **Make sure you take time to consider where you are in history and what role you want to play!** Consider how much memory computers could directly address (use), and remember that we’re using the latest technology to build the latest technology for even greater acceleration:

<table>
<thead>
<tr>
<th>Address Direct (Bytes)</th>
<th>Extended RAM (Result)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 bit</td>
<td>640 (dawn of computers)</td>
</tr>
<tr>
<td>8 bit</td>
<td>66,536 (mainframe)</td>
</tr>
<tr>
<td>16 bit</td>
<td>1,048,576 (Windows/PC)</td>
</tr>
<tr>
<td>32 bit</td>
<td>(Internet/social media)</td>
</tr>
<tr>
<td>64 bit</td>
<td>(Cloud/robots/implants)</td>
</tr>
</tbody>
</table>

Another way to put this comparison into perspective is to consider what it would mean in terms of miles per hour, with Windows as the starting point:

<table>
<thead>
<tr>
<th>Shift</th>
<th>Increase over Windows (Result)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 bit to 16 bit</td>
<td>1 mph (Windows)</td>
</tr>
<tr>
<td>16 bit to 32 bit</td>
<td>65K mph (Internet)</td>
</tr>
<tr>
<td>32 bit to 64 bit</td>
<td>300T mph (robotics/3D/VR/cloud/implants starting)</td>
</tr>
<tr>
<td>64 bit to 128 bit</td>
<td>5T<em>T</em>B mph (implants/brain augmentation)</td>
</tr>
</tbody>
</table>

---

**Oracle RDBMS History Over the Years**

1970 Dr. Edgar Codd publishes his theory of relational data modeling.
1977 Software Development Laboratories (SDL) is formed by Larry Ellison, Bob Miner, Ed Oates, and Bruce Scott with $2,000 of startup cash. Larry and Bob come from Ampex, where they were working on a CIA project code-named “Oracle.” Bob and Bruce begin work on the database.
1978 The CIA is SDL’s first customer, yet the product is not released commercially. SDL changes its name to Relational Software Inc. (RSI).
1979 RSI ships the first commercial version, Version 2, of the database, written in Assembler Language (no V1 is shipped based on fears that people won’t buy a first version of software). The first commercial version of the software is sold to Wright-Patterson Air Force Base. It is the first commercial RDBMS on the market.
1981 The first tool, Interactive Application Facility (IAF), which is a predecessor to Oracle’s future SQL*Forms tool, is created.
1982 RSI changes its name to Oracle Systems Corporation (OSC) and then simplifies the name.
to Oracle Corporation.
1983 Version 3, written in C (which makes it portable) is shipped. Bob Miner writes half, while also supporting the Assembler-based V2, and Bruce Scott writes the other half. It is the first 32-bit RDBMS.
1984 Version 4 is released, along with some first tools (IAG-genform, IAG-runform, RPT). Version 4 is the first database with read consistency. Oracle is ported to the PC.
1985 Version 5 is released, first Parallel Server database on VMS/VAX.
1986 Oracle goes public March 12 (the day before Microsoft and eight days after Sun). The stock opens at $15 and closes at $20.75. Oracle Client/Server is introduced, which is the first client/server database. Oracle 5.1 is released.
1987 Oracle is the largest DBMS company. Oracle Applications group started. First symmetrical multiprocessing (SMP) database introduced.
1987 Rich Niemiec along with Brad Brown and Joe Trezzo while working at Oracle implements the first production client/server application running Oracle on a souped-up 286 running 16 concurrent client/server users for NEC Corporation.
1992 Oracle V7 is released.
1993 Oracle GUI client/server development tools introduced. Oracle Applications moved from character mode to client/server.
1994 Bob Miner, the genius behind the Oracle database technology, dies of cancer.
1995 First 64-bit database developed.
1996 Oracle 7.3 released.
1997 Oracle8 is introduced. Oracle Application Server is introduced. Applications for the Web are introduced. Oracle is the first Web database. Oracle BI tools like Discoverer are introduced for data warehousing. Tools have native Java support.
1998 First major RDBMS (Oracle8) ported to Linux. Applications 11 shipped. Oracle is the first database with XML support.
1999 Oracle8i released. Integrates Java/XML into development tools. Oracle is the first database with native Java support.
2001 Oracle9i (9.1) released. Oracle is the first database with Real Application Clusters (RAC).
2002 Oracle9i Release 2 (9.2) released.
2003 Oracle at France Telecom is #1 on Winter Group’s Top Ten in DB size at 29T.
2003 Oracle 10g comes out, with grid focus, encrypted backups, auto-tuning, and ASM.
2005 Oracle RAC at Amazon hits the Winter Group’s Top Ten in DB size at 25T.
2005 Oracle acquires PeopleSoft (includes JD Edwards), Oblix (Identity Management), Retek (Retail) for $630M, TimesTen (in memory DB), and Innobase (InnoDB Open Source).
2006 Oracle buys Siebel for $5.8B, Sleepycat Software (Open Source), and Stellant (Content Management). Oracle with an open source push offers “unbreakable” support for Red Hat Linux.
2006 Oracle 10g Release 2 comes out in fall
2007 Oracle buys Hyperion for $3.3B. Oracle 11g comes out (2009 was the first release of 11gR2).
2008 Oracle Exadata announced; Oracle buys BEA.
2009 Oracle releases 11gR2. Oracle buys Sun (which includes Java, MySQL, Solaris, hardware, Open Office, StorageTek).
2010 Oracle announces MySQL Cluster 7.1, Exadata 2-8, Exalogic, and 11.2.0.2 released. 2011 Oracle 11gR2 (11.2.0.4) terminal release (all Exadata line is 11gR2) and Oracle 11g Express Edition released (September 24, 2011). Oracle announces Exalytics, SuperCluster, Oracle Data Appliance, Exadata Expansion Rack, and Oracle Cloud 12c (late 2011).
2012 Exadata X3-2 released; Oracle expands cloud offerings; Solaris 11.1.

2013 12cR1 is released; Exadata X3-8 released; Oracle acquires Acme Packet and Reponsys.
2014 Oracle releases In-Memory on 12.1.0.2; X4 released; acquires Corente.
2015 X5-2 and X5-8 released; FS1 Flash Array; acquires StackEngine (Docker tool).
Oracle is a company that has matured in breadth, ability, and character over the years. Oracle’s leaders live to innovate, and they’ve always hired for that next leader and visionary like Larry Ellison, or the next quietly driven Bob Miner, that next superstar developer like Bruce Scott. Somehow Oracle finds that creative/innovative special something in every employee they hire. Oracle hires unique, incredibly intelligent, intensely driven, and innovative people! It started with the attitude of Larry, and his ability to get more out of people than they are aware they have within them, and his ability to reward them when they deliver. Oracle also has the genius, spirit, and “blue collar–like” hard-working drive of a Bob Miner in all of those in the development world who have followed him. Oracle is well run because they have leaders in Safra Catz and Mark Hurd balancing out operations; Judith Sim driving marketing at an always “catch us if you can,” too-fast speed; and delivery on products due to Andy Mendelsohn and his tremendously intelligent team inventing the next bend in the road. Thomas Kurian and his ever-growing, accelerating team are always finding new ways to integrate applications on the cloud and make businesses even more successful. Then there’s Mary Ann Davidson’s silent warriors in security, and many more.
Lastly, I want to provide a quick note on TUSC, The Ultimate Software Consultants. At TUSC, I was blessed to work with the best of the best. We were often called the Navy Seals or the Marines of the Oracle world (being a former Marine, I like the latter description). We were called into Fortune 500 companies across the globe to solve various complex problems, and we always delivered! Thanks Brad Brown, Joe Trezzo, and all TUSC members of yesteryear.

I’ve tuned systems across the globe and I believe you will find something in this book that will help you. I’ve traveled to Australia, Austria, Belgium, Canada, China, the Czech Republic, Denmark, Finland, Germany, Italy, India, Ireland, Luxembourg, Mexico, Poland, Slovakia, Spain, Sweden, Switzerland, the U.A.E., and the United Kingdom. I’m always available as an architect or advisor at richniemiec@gmail.com and work with a great tuning product at http://tuningace.com/partners/RichNiemiec.html.

To my fellow Marines, Semper Fi, and to all servicemen and women, government workers, and agencies that protect freedom, thanks for making the world a safer and better place. The Marines always taught me God, Family, Country, and Corps. Add to that, the golden rule, not the version that goes “He who has the gold makes the rules,” but the true golden rule: “To love your neighbor as yourself.” Somehow, these two versions of the golden rule contrast the worst values, at times, on Wall Street with the best values on Main Street. Although it’s tough to do, loving your neighbor as yourself will take you a whole lot further in life, and even if it leads you to a tough life, it will certainly lead you to a better place just after life. That’s the best advice I could give you to prepare for the challenging future ahead!

How This Book Is Organized and Changes in This Version
If you read this entire book and apply it, you will be in the top 1 percent of Oracle Tuning professionals. Over 425 Tuning experts have added to this book in some manner. For those who read the last version of the book, here are some changes and/or additions for each of the chapters:

- **Chapter 1** Rewritten completely for basic Oracle 12cR2 new features
Chapter 2 Expanded to cover all of the index types and tested for 12cR2

Chapter 3 Updated for 12cR2: ASM, LMT, Auto UNDO, and improved I/O sections

Chapter 4 Added PGA_AGGREGATE_LIMIT, INMEMORY_SIZE, and In-Memory sections and updated initialization parameters for 12cR2

Chapter 5 Added 12c screenshots and Application Performance Monitoring (APM)

Chapter 6 Updated EXPLAIN, SQL Plan Management, DBMS_MONITOR, and TRCSESS

Chapter 7 Added new hints and updated others—the best resource for hints!

Chapter 8 Updated for 12cR2; added Result Cache and SQL Performance Analyzer

Chapter 9 Updated and tested for 12cR2; includes block tuning and added DB Replay

Chapter 10 Expanded again as PL/SQL tuning expands; added 12cR2 changes

Chapter 11 Added cloud, updated Exadata, RAC, and Parallel Query operations

Chapter 12 Expanded again to show more V$ view queries, especially those new in 12cR2

Chapter 13 Expanded X$ view queries, trace section, and X$ naming conventions

Chapter 14 Updated AWR, Statspack for 12cR2; updated mutexes and block tuning

Chapter 15 Updated for 12cR2 and for much larger systems

Chapter 16 Unix chapter updated to include a couple more commands

Appendix A Updated queries for 12cR2 and new Top 25 initialization parameters

Appendix B Updated for 12cR2 with updated V$ view queries

Appendix C Updated for 12cR2 with updated X$ queries

References

Twilight Zone series, Rod Serling.


Wikipedia website: Googol, Exabyte.

Mike Wilson, The Difference Between God and Larry Ellison (William Morrow, 1997).

First, I want to note that this book is primarily focused on helping beginner and intermediate Oracle professionals understand and better tune Oracle systems. Many expert topics are also covered in the later chapters, but the objective is primarily to assist professionals who are frustrated and looking for simple tips to help improve performance. This book has one simple goal: to provide an arsenal of tips you can use in various situations to make your system faster.

Chapter 1 is a new features chapter covering the new features focused on tuning. The new features chapter has been so popular in past editions of this book that I continue to make it the first chapter. The rest of the chapters gradually increase in complexity and provide a wide range of tips to help you in your tuning adventures. I am sure that you will encounter at least some information that you won’t find elsewhere. With Oracle’s relatively new focus on the cloud, I’ve included a section on the cloud here as an introduction to the more detailed information in Chapter 11. It’s important to note that on September 18, 2016, Larry Ellison introduced 12cR2 on the cloud-first. The Oracle Exadata Express Cloud Server had an introductory price of only $175/month including all database options!

If you want a single method or an all-encompassing way of tuning a database (in a single chapter), I provide a few options for those who don’t have the time to read the whole book. The first is Chapter 14 on Statspack and the AWR Report (Statspack is free, but AWR is better). The second option is the combination of two incredible chapters that include most of the common scripts that the majority of experts use to tune a system using V$ views and X$ tables (covered in Chapters 12 and 13). The third option is Chapter 5 on Oracle Enterprise Manager Cloud Control (OEM), which includes Database Control and Cloud Control; it is a tool of the future that provides a graphical way to tune your system, including many features for both RAC systems and large-scale cloud control. This tool gives you the ability to view and tune multiple systems through one single interface. There is also a great tuning product at http://tuningace.com/partners/RichNiemiec.html.

This first chapter will discuss, briefly, some of the more interesting new features that are included in Oracle Database 12c Releases 1 and 2 covering 12.1.0.1, 12.1.0.2, and 12.2. Many new and improved features are included in this latest version. Oracle’s goal in 12c was not only to create a more robust database management system, but also to include a cloud solution, multitenant database, In-Memory column store, and management improvements to simplify the installation/administration activities, thereby enhancing availability. Oracle’s strategic direction is to provide a fully integrated set of features that replaces the third-party software that DBAs typically use to help them manage their environments. Not all features listed in this chapter are detailed in the book (since they are not
directly tuning related and the size of the book is limited), yet I wanted a chapter to mention some of
the best features whether directly tuning related or not to give you an overview of the latest version of
Oracle Database 12c. Security is the focus of several other books, but it is important to state here that
12c is a critical release for security features. Not only does 12c contain the most security changes in a
long time, but it also has performance enhancements for auditing, access controls, and encryption as
security becomes more embedded in the database engine. Lastly, we cannot cover all the new features
here, since the Oracle Database New Features Guide for 12.1.0.1, 12.1.0.2, and 12.2 combine to
make up 240 pages. We will just highlight the more significant improvements (note that in some
sections of 12.1, there will be notes about enhancements to 12.2).

The new features covered in this chapter include the following, listed by release:

- Oracle Database 12cR1 (12.1.0.1)
  - Increased size limit to 32K for VARCHAR2 and NVARCHAR2
  - Partial indexes on partitioned tables
  - Invisible columns in 11g lead to multiple indexes on the same column(s) in 12c
  - Fetch first $x$ rows
  - Pluggable databases (multitenant DB)
  - Oracle Database Cloud Service (Database as a Service)
  - Change compression at import time
  - Adaptive Query Optimization
  - PGA_AGGREGATE_LIMIT, new initialization parameter
  - Concurrent execution for UNION/UNION ALL
  - Invoker rights function can be Results Cached
  - New DBMS_UTILITY.EXPAND_SQL_TEXT
  - Default for columns based on sequence
  - Interval-REF partitioning
  - Multiple SSD devices for Smart Flash Cache
  - Concurrent cost-based optimizer statistics gathering
  - Enhanced system statistics
  - Resource Manager for runaway queries
  - Automatic Data Optimization (ADO)
  - Global index maintenance for DROP and TRUNCATE Partition operations
  - ASM disk scrubbing
  - Online capability improvements
  - Data Guard improvements
- RMAN improvements
  - Active database duplication improvements
  - Cross-platform backup and restore
  - Table-level recovery
  - Pluggable database backup and recovery
  - Network-enabled restore

- Oracle Database 12cR1 (12.1.0.2)
  - In-Memory Database
  - Advanced index compression
  - Automatic big table caching
  - Flashback Data Archive support for container databases
  - Full database caching
  - JSON support
  - FIPS 140 parameter for encryption
  - PDB subset cloning
  - Rapid Home Provisioning

- Oracle Database 12cR2 (12.2)
  - Application development
    - Improved SQL and PL/SQL
    - Reduced costs and complexities for migration to Oracle
  - Availability
    - Accelerated Active Data Guard adoption
    - Best-of-breed logical replication
    - Online operations
    - Recovery Server and RMAN improvements
    - Sharding
    - Simplified upgrades and data redaction for testing
  - Big data
    - Big data management system infrastructure
    - Enhanced query processing and optimization
  - Compression and archiving
Hybrid Columnar Compression improvements
- Index compression enhancements
- Oracle RAC and Grid Infrastructure
- Automatic Storage Management
- Rapid Home Provisioning and patch management
- Security
  - Increased adoption of encryption
- New background processes in 12c
- Exadata—new with X6!
- Version 12c feature comparison chart

CAUTION
Because these features are new, you should use them cautiously and test them completely until you are sure they work without causing problems for your database. If you have access to My Oracle Support, I strongly advise you to determine whether any known problems exist with the feature you are preparing to use. There are also many experts and Oracle Aces out there with blogs and websites that give information that is well worth searching for.

Oracle Database 12cR1 (12.1.0.1)
Oracle Database 12cR1 is often referred to as the pluggable database (PDB) version of Oracle. Oracle made it possible to aggregate the many databases that people had invested in over the years. Oracle also added several new features; many are contained in this chapter.

Increased Size Limit to 32K for VARCHAR2 and NVARCHAR2
The maximum value for a VARCHAR2 and an NVARCHAR2 column in tables has been increased from 4000 to 32,767. This greatly expands that ability to use a VARCHAR2 data type before having to consider moving to a LOB column type. You do need to set the MAX_STRING_SIZE initialization parameter to EXTENDED (and you may not go back to the original STANDARD size). You also must shut down, restart in UPGRADE mode, change MAX_STRING_SIZE to EXTENDED, run the $oracle_home/rdbms/admin/utl32k.sql script, and then restart in NORMAL mode.
Partial Indexes

Partitioned tables have been providing management and performance improvements for quite some time. However, partitioned tables were typically very large tables and therefore had very large indexes as well. In Oracle 12c, partial indexes enable you to create an index and apply it only to specific partitions of the table, reducing the size of the index and only indexing partitions that get frequent use. The partial index can apply to both local and global indexes. To utilize this new feature, specify with the partition of a table if the partitioned table is to be indexed using the INDEXING clause (INDEXING ON/INDEXING OFF). For example:

```
CREATE TABLE orders partial idx {
  order_id NUMBER(12),
  order_date DATE CONSTRAINT order_date_nn NOT NULL,
  order_mode VARCHAR2(8),
  customer_id NUMBER(6) CONSTRAINT order_customer_id_nn NOT NULL,
  order_status NUMBER(2),
  order_total NUMBER(8,2),
  sales_rep_id NUMBER(6),
  promotion_id NUMBER(6),
  CONSTRAINT order_mode_lov CHECK (order_mode in ('direct','online')),
  CONSTRAINT order_total_min CHECK (order_total >= 0))
INDEXING OFF
PARTITION BY RANGE (ORDER_DATE)
(PARTITION ord_p1 VALUES LESS THAN (TO_DATE('01-MAR-1999', 'DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p2 VALUES LESS THAN (TO_DATE('01-JUL-1999', 'DD-MON-YYYY'))
INDEXING OFF,
PARTITION ord_p3 VALUES LESS THAN (TO_DATE('01-OCT-1999', 'DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p4 VALUES LESS THAN (TO_DATE('01-MAR-2000', 'DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p5 VALUES LESS THAN (TO_DATE('01 MAR 2010', 'DD MON YYYY')));
```

Then, create the index and indicate if it is a partial index with the PARTIAL INDEX clause. For example, on a global index:

```
CREATE INDEX ORDERS_GII ON orders_partial_idx (promotion_id) GLOBAL INDEXING PARTIAL;
```

Here's an example on a local index:

```
CREATE INDEX ORDERS_LII ON orders_partial_idx (order_date, customer_id) LOCAL INDEXING PARTIAL;
```
Other partitioning new features in 12cR2 include being able to split and merge partitions online; convert nonpartitioned tables to partitioned tables online; use multiple column list partitions; use list partitioning as a subpartitioning strategy for composite partitioned tables; and use read-only partitions.

### Invisible Columns

Invisible columns provide the ability for columns in a table to be invisible when someone tries to perform a SELECT *...; however, it is still possible to see the column if the column name is specified in the SELECT. Whether or not the column is displayed, it is still part of the table and continues to be subject to all DML UPDATE operations as well as DDL operations affecting the table. Marking a column invisible can be done with an ALTER TABLE command:

```sql
ALTER TABLE myemployees MODIFY (ssn invisible);
```

### Multiple Indexes on the Same Column List

Oracle 12c now allows multiple indexes to exist on the same column list. For example, we can create a unique index on the DEPT table as follows:

```sql
create unique index dept_uniqel on dept(deptno);
```

If we try to create an index on the same column list, we get an error:

```sql
create index dept_normal on dept(deptno);
create index dept_normal on dept(deptno)
+
ERROR at line 1:
ORA-01408: such column list already indexed
```

However, if we make the unique index invisible, we can create the index on the same columns list:

```sql
alter index dept_uniqel invisible;
```

Keep in mind we still cannot insert duplicate values into the table even though the index is invisible. It is a valid index and will still maintain the uniqueness of the table when DML operations are performed. The index will not be used when SELECT using the column is performed. Also, now that it’s invisible, we can create an additional index on the DEPT_NO column:
create index dept_normal on dept(deptno);
Index created.

It is possible to create two visible indexes on a column at once, if one of those indexes is a function-based index. Let’s make the third index invisible and add a fourth (and fifth):

```sql
alter index dept_normal invisible;
Index altered.
create index dept_reverse on dept(deptno) reverse;
Index created.
alter index dept_reverse invisible;
Index altered.
create bitmap index dept_bitmap on dept(deptno);
Index created.
create index dept_fb on dept(substr(deptno,1,1));
Index created.
```

Now when we check the index views, we see that we have five indexes on the same column with two indexes (one being a bitmap and another a function-based index) being visible:

```sql
select a.table_name, a.index_name,
       b.column_name, a.uniqueness, a.visibility
from user_indexes a, user_ind_columns b
where a.index_name = b.index_name
  and a.table_name = 'DEPT';
```

<table>
<thead>
<tr>
<th>TABLE NAME</th>
<th>INDEX NAME</th>
<th>COLUMN NAME</th>
<th>UNIQUENESS</th>
<th>VISIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT</td>
<td>DEPT_UNIQUE1</td>
<td>DEPTNO</td>
<td>UNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_REVERSE</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_NORMAL</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_BITMAP</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>VISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_FB</td>
<td>SYS_NC000045</td>
<td>NONUNIQUE</td>
<td>VISIBLE</td>
</tr>
</tbody>
</table>

(Index types: NORMAL, NORMAL/REV, UNIQUE, BITMAP, FUNCTION-BASED NORMAL)

We now have five indexes on the same column. Three indexes are invisible. One bitmap and one function-based index are visible and can be used. See Chapter 2 for more information on indexes.

Fetch First \( x \) Rows

Not only are you able to fetch the first \( x \) rows without scanning all rows, you can even skip some
rows (offset) to get rows from the middle of the table for a better sample. It is a fast way to retrieve a
certain number of rows from a table. The syntax is

```
FETCH FIRST \( x \) ROWS ONLY
```

or

```
OFFSET \( x \) ROWS FETCH FIRST \( x \) ROWS ONLY
```

Here’s a quick example that does not skip rows:

```
select count(cust_id), cust_id
from customers2
group by cust_id
fetch first 10 rows only;
```

<table>
<thead>
<tr>
<th>COUNT(CUST_ID)</th>
<th>CUST_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
</tr>
</tbody>
</table>

... 10 rows selected.

Here’s a quick example *skipping* rows:

```
select count(cust_id), cust_id
from customers2
group by cust_id
offset 10000 rows fetch first 10 rows only;
```

<table>
<thead>
<tr>
<th>COUNT(CUST_ID)</th>
<th>CUST_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>7700238</td>
<td>10001</td>
</tr>
<tr>
<td>1409320</td>
<td>10002</td>
</tr>
</tbody>
</table>

... 10 rows selected.

## Pluggable Databases (PDBs)

The pluggable databases (PDBs) feature in 12c (covered in detail in Chapter 3) enables you to have a
container database (CDB) with multiple PDBs within the container. Pluggable databases are also
called *multitenant* databases because each “tenant” can have its own PDB. “Pluggable” databases
can be unplugged from one container and plugged into another container easily, therefore making
databases portable between environments and allowing the upgrade of a database by unplugging it
from one environment at one version and plugging it into a new environment at a higher version. You
can also unplug a PDB from on premises and plug it into the cloud (or vice versa). This new feature
also allows a single PDB to be independently recovered (you can even flashback a PDB in 12cR2).
Each PDB looks to an application like any other traditional Oracle database (called a non-CDB), so no application changes are needed to work the PDB architecture. Non-CDBs are now deprecated as of 12.1.0.2.

The following are some notes to keep in mind when using container and pluggable databases:

- **CDB** = container database (has a root DB and also a seed PDB)
- **PDB** = pluggable database (plugged into a CDB)
- **Non-CDB** = traditional type of database (neither a CDB nor a PDB)
- Quickly create a new database (PDB) or clone an existing one (PDB)
- Move existing PDBs to a new platform or location or clone it (snapshot)
- Patch/upgrade a PDB by plugging it into a CDB at a later version
- Physical machine runs more PDBs and can be easier to manage/tune
- Back up entire CDB + any number of PDBs
- New syntax for commands: PLUGGABLE DATABASE
- Redo shared by CDB and all PDBs
- Undo shared by CDB and all PDBs
- TEMP can be created for each PDB
- SYSTEM and SYSAUX individually for each CDB and PDB
- Timezone, each PDB
- DB initialization parameters: some are CDB specific, but many are for each PDB

**Figure 1-1** shows a container database (CDB$ROOT) with a seed PDB (PDB$SEED) and two application PDBs (erppdb and dwpdb). Along with the logical/physical layout, it also shows a CDB administrator and two separate administrators for the two application PDBs. The physical files that are shared between the CDB and PDBs and those that can be at the PDB level only are discussed in the previous list. Since many PDBs can share application objects, such as code or metadata, Oracle introduced application containers in 12cR2. Now you just update the shared application container instead of updating all the PDBs.
FIGURE 1-1. A CDB with three PDBs (PDB$SEED and two application PDBs)

One reason to use PDBs is that you can consolidate hundreds of databases on one machine. Separate machines can mean too many resources are required when you add up all of the SGAs! The need to easily move data around becomes increasingly important in scenarios such as these: big data sources are needed; a company makes acquisitions; a company moves data to and from the cloud; partners need shared research; governments share security or other data.

The following are a few nice example commands for the multitenant world (see Chapter 3 for more).

**Is the database a CDB or non-CDB? (YES in CDB column = CDB)**

```
SELECT NAME, CREATED, CDB, CON_ID
FROM   V$DATABASE;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>CREATED</th>
<th>CDB</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19-FEB-12</td>
<td>YES</td>
<td>0</td>
</tr>
</tbody>
</table>

**Query the PDBs (three PDBs in this example)**
select name, open_mode, open_time
from v$pdb

<table>
<thead>
<tr>
<th>NAME</th>
<th>OPEN_MODE</th>
<th>OPEN_TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDB$SEED</td>
<td>READ ONLY</td>
<td>23 FEB 13 05.29.19.861 AM</td>
</tr>
<tr>
<td>PDB1</td>
<td>READ WRITE</td>
<td>23-FEB-13 05.29.25.846 AM</td>
</tr>
<tr>
<td>PDB SS</td>
<td>READ WRITE</td>
<td>23-FEB-13 05.29.37.587 AM</td>
</tr>
</tbody>
</table>

Clone PDB (source *no longer* needs to be read-only in 12cR2—hot cloning)

```sql
CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
PATH PREFIX = '/disk2/oracle/pdb2'
FILENAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/');

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
FILENAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/') Storage
(MAXSIZE 2G MAX SHARED TEMP SIZE 100M);

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1 pdb1 link;
```

Move around and start up PDBs

```sql
ALTER SESSION SET CONTAINER=CDP$ROOT;
Session altered.

ALTER SESSION SET CONTAINER=PDB$SEED;
Session altered.

ALTER SESSION SET CONTAINER=pdb_s; {not case sensitive}
Session altered.

Startup pluggable database pdb1 open; (read/write)
Pluggable Database opened.
(or while in pdb1 just run STARTUP)

Startup pluggable database pdb1 open read only;
Pluggable Database opened.

Startup pluggable database pdb1 force; {closes/opens}
Pluggable Database opened.
(or while in pdb1 just run STARTUP FORCE)
In 12cR2, you can also issue a FLASHBACK of a PDB and have restore points to only that PDB. This can be done using the SCN, Restore Point, Clean Restore Point, or Guarantee Restore Point. You can also use local UNDO in 12cR2. The FLASHBACK command for an individual PDB is shown here (you can get SCNs from V$ARCHIVED_LOG, V$DATABASE, V$FLASHBACK_DATABASE_LOG, or V$LOG):

```
FLASHBACK PLUGGABLE DATABASE pdb1 TO SCN 830124;
```

Oracle Database Cloud Service (Database as a Service)

There is a push to the cloud as mobile applications become a dominant consumer need. This includes either “hosting” or “outsourcing” IT operations completely. The new cloud players (led by Oracle, Amazon, Microsoft, and Google) are the gold standard of the IT industry. They now predict that everyone will soon be on the cloud as the smartphone market continues to dwarf all other markets.

What’s fueling the growth of the cloud:

1. Connecting to social media and accessing marketing big data are faster over the cloud, as are leveraging this data and connecting it to mobile applications.
2. Every company can have an encrypted backup that’s secure and offsite. This is a big plus to the many companies that still don’t have this protection.
3. Cloud services are great for smaller companies that can’t afford a real IT department. They can obtain IT servers and operations to any scale they’ll ever need.
4. It’s inexpensive to store archived data to the cloud for infrequent use.
5. You pay for what you use, scale up easily when you need to, and scale down easily when needed.
6. It’s relatively inexpensive for testing new applications, new servers, or new versions.
7. The current generation of developers and DBAs is cloud-ready. They don’t want to be tied to a specific computer and they already do almost everything in the cloud.

In the end, whether the cloud helps or detracts from your competitive advantage really depends on your costs, personnel, operations, and all of the preceding points. Keep in mind that, whether they realize it or not, everyone does something in the cloud already (known as the hybrid cloud model, a mix of cloud/on-premises, which is already at 100 percent). As Chapter 11 should convince you, a large portion of applications and IT operations will be hosted on the cloud. You need to be prepared for this generational switch to an era of cloud computing. Not all systems will move to the cloud though.

Setting up a Database Cloud Service instance for the first time takes a few hours, but setting up subsequent instances time takes only a few minutes. Database as a Service (DBaaS) will certainly be
a reality for many shops to quickly spin up development servers for DevOps (Development and Operations).

Oracle announced in late 2016 that 12c Release 2 of the database will be released on the cloud first. This is not just a cloud-first event, but an Oracle-first event. This is similar to Oracle releasing less important platform database software (AIX comes to mind) later than Linux. Another example is Oracle releasing 12c on Express Edition (the free version) much later than Standard Edition (SE) or Enterprise Edition (EE). Oracle has a way of creating a bend in the road that you’ll probably soon be following. Also, Oracle has available currently in the cloud a database that you can use anytime (https://livesql.oracle.com) to learn SQL and PL/SQL. When I tried it in early September of 2016, it was already the 12.1.0.2 database. When Larry Ellison introduced 12cR2, available on the cloud first via the Oracle Database Exadata Express Cloud Service, it had an introductory price of only $175/month—including all database options! This is one of the fastest servers on planet Earth I’ve ever seen, and for the lowest price in the cloud; it’s also on the 12cR2 database. The ability to run or test your development applications on a server of this size and potential scale (when needed) is unprecedented. Oracle also introduced (on the same day) Application Performance Monitoring (APM) for DevOps. APM enables DBAs and developers to pinpoint performance problems at every layer of the application. Chapter 11 goes into great detail on setting up an Oracle Cloud Database Service instance, but I’ll show a few of the major points here.

To begin to use the Oracle Cloud, you can simple go to https://cloud.oracle.com/tryit and choose to try it out for 30 days (see Figure 1-2). The website offers a lot of video tutorials and a lot of information about the different roles needed for the cloud. When we go to cloud.oracle.com/tryit, it will take us to this introductory page where we can click on the 30-Day Trial seen in Figure 1-2.
Click the Try It button and then choose Database (Your Oracle Database in the Cloud) to set up a Database Cloud Service instance. Note that these screens and information have changed three times in the past year. Information about your 30-Day Trial comes up next. It includes an overview of the process as well as the ability to start the Database as a Service Trial. You’ll also be asked to log in to your Oracle account. After you sign on with your single sign-on to Oracle, you will be ready to get a connection to the Oracle Cloud. Fill in the basic information about you and your company, click Sign Up, and, upon approval, Oracle sends a verification to my phone followed by an e-mail to officially sign in to the Oracle Cloud (Figure 1-3).
You’ll get a welcome message and an immediate offer to get some free training if you need it. Included in the Quick Start lesson is everything required to ensure you know how to set up Database as a Service. Those items include setting up SSH and using PuTTY, Creating a Service Instance, Finding the Connection Details about your Database Instance, Enabling Secure Access, Connecting via SQL Developer, Performing Operations on your Cloud Database, and Monitoring your Database Service. Once you’re ready, click Get Started and then click Create Service to launch the Create Database Cloud Service Instance wizard. Choose whether you want a VM preinstalled or want to set it up using DBCA. Also choose a billing frequency, either hourly or monthly. Click Next, and choose either 11g (11.2.0.4) or 12c (12.1.0.2) as the database and then choose the edition of the database (Figure 1-4).
Click Next, and on the Service Details page, choose the service name, size/shape of the server (very price specific), passwords, backup and recovery configuration, whether you’ll use an encrypted file to build the database from your on-premises database, etc. You can also set up a Standby Database using Data Guard, enable GoldenGate, and install the demo PDB. Click Next, and you’ll see that the process of building your Database Service is in progress (Figure 1-5) and then you will be told that your database is ready to use.
You’ve now successfully created an Oracle Database Cloud Service instance! You can use Oracle Enterprise Manager (OEM) to manage the Cloud Database with the pull-down menu (see Chapter 5 for OEM details that can be monitored). Click Open OEM Console to see details of your database (Figure 1-6 shows that my database has been up over 234 days). Also note that many of the settings and locations for files and the default that you would use if you installed the database.
From the screen shown in Figure 1-6, I can click “CDB (2 PDBs)” and get to the details of the containers. Note that one of the PDBs is the DEMOS PDB that I chose to install when I created the Database Cloud Service instance and the other is PDB1. I can take a look at Memory Management to see the various settings and allocation of memory similar to OEM in my on-premises database. You have many different choices (see the discussion of OEM in Chapter 5 for greater detail). You can easily check things like memory initialization parameters to see if the In-Memory Size is set (if you are using the In-Memory column store). You can then click Set to change a parameter.

Similar, but separate from OEM, you can also use a new tool within Oracle Management Cloud called Application Performance Monitoring (APM, shown in Figure 1-7) to see greater detail in the cloud at every tier of operations. This is a cloud-only product. It shows performance and details at the database, application server, application, and even page level of the customer screen (thanks Oracle for this screenshot and the next one).
special focus on the application web page, as shown in Figure 1-8.

![APM customer shopping cart](image)

**FIGURE 1-8. APM customer shopping cart**

By using this information, you can gauge the customer experience and limit problems with speed or errors before the customer complains.

The Oracle Cloud is here to stay! As the next few years go by, Oracle will accelerate their cloud and mobile offerings. It’s important to become educated on all of these products so that you can discern for your company which products fit now and which ones require a wait-and-see approach. See Chapter 11 for additional screenshots and information.

**PDB Level: MEMORY_LIMIT and MEMORY_MINIMUM (12cR2)**

In addition to the new MEMORY_TARGET initialization parameter to set all of memory for Oracle SGA+PGA, there are PDB-specific parameters to ensure a minimum amount and a maximum setting. Those parameters set at the PDB level using resource plan directives are

- **MEMORY_LIMIT** Limits the PDB to this percentage of PGA+SGA
MEMORY_MINIMUM Guarantees the PDB this percentage of PGA+SGA

You’ll also see in the In-Memory Database section in this chapter that there is an INMEMORY_SIZE parameter both at the CDB level and at the PDB level. Initialization parameters are covered in Chapter 4.

The following are some other 12cR2 new features with pluggable databases (see Chapter 3 for detailed coverage):

- The source no longer needs to be read-only when cloning a PDB (point-in-time clone).
- You can do a PDB refresh of clones manually or automatically (they must be read-only).
- You can create a class of PDB (Gold/Silver/Bronze) by setting DB PERFORMANCE PROFILE and then using Resource Manager to set directives for each class of PDB.
- You can do a FLASHBACK of a PDB and restore points to only that PDB!
- You can build a subset standby of just one or a portion of your PDBs!
- You can now have 4096 PDBs, not just 252.

Change Compression at Import Time

You use the impdp command-line option (or use DBMS_DATAPUMP) with the TABLE_COMPRESSION_CLAUSE to change the compression at import time. This is especially helpful for Exadata migrations where more compression options (HCC) are available. You can see listed below the following quick impdp example of changing the EMPLOYEES table to be NOCOMPRESS and the many options settings for the TABLE_COMPRESSION_CLAUSE:

```bash
$ impdp hr TABLES=hr.employees DIRECTORY=dpump_dirl DUMPFILE=hr.dmp
TRANSFORM=TABLE_COMPRESSION_CLAUSE=NOCOMPRESS

TABLE_COMPRESSION_CLAUSE=None
TABLE_COMPRESSION_CLAUSE=ncOMPRESS
TABLE_COMPRESSION_CLAUSE=COMpress BASIC
TABLE_COMPRESSION_CLAUSE=COMpress ROW STORE COMPRESS ADVANCED (used for OLTP)

Warehouse compression (low is faster load):
TABLE_COMPRESSION_CLAUSE=COMpress COLUMN STORE COMPRESS FOR QUERY LOW
TABLE_COMPRESSION_CLAUSE=COMpress COLUMN STORE COMPRESS FOR QUERY HIGH

Archive compression (low is faster load):
TABLE_COMPRESSION_CLAUSE=COMpress COLUMN STORE COMPRESS FOR ARCHIVE LOW
TABLE_COMPRESSION_CLAUSE=COMpress COLUMN STORE COMPRESS FOR ARCHIVE HIGH
```
The next basic example demonstrates using `impdp` and `COMPRESS` to compress the DEPT2 table as it’s being imported (note that the output below the `impdp` statement shows that the table is being transformed and compressed):

```
$ impdp scott2/tiger TABLES=dept2 TRANSFORM=TABLE_COMPRESSION_CLAUSE:compress:table

Master table "SCOTT2"."SYS_IMPORT_TABLE_01" successfully loaded/unloaded
Starting "SCOTT2"."SYS_IMPORT_TABLE_01": scott2/********** TABLES-dept2
TRANSFORM TABLE_COMPRESSION_CLAUSE:compress:table
Processing object type TABLE_EXPORT/TABLE/TABLE
Processing object type TABLE_EXPORT/TABLE/STATISTICS/TABLE_STATISTICS
Job "SCOTT2"."SYS_IMPORT_TABLE_01" successfully completed at Sat Mar 2
03:59:51 2013 elapsed: 0 00:00:12
```

Adaptive Query Optimization

The Adaptive Query Optimization feature in Oracle Database 12c allows the optimizer to adjust the execution plan, even changing join methods, during runtime. This feature is on by default and utilizes discovery of additional information that can ultimately lead to better statistics. This additional information allows the optimizer to adjust query plans and is very useful in situations where current statistics are not enough to get an optimal plan. The two main components that adaptive query optimization focused on improving is the execution time of the query and checking adaptive statistics (ensuring the expected statistics are the actual statistics when the query is running). Adaptive statistics can also provide additional information for future executions. By getting more information and utilizing the information better over time, better query adjustments can be made, thereby improving execution plans, which can improve query performance. This feature is covered in detail in Chapter 8, but a few notes are listed here:

- Adaptive Query Optimization allows the optimizer to adjust the execution plan at runtime when additional/better information is available. Oracle will then use Adaptive Plans based on that information. Those plans may employ different Join Methods (i.e., change NL to HASH “on the fly”) or different parallel query distribution. With adaptive statistics, the optimizer adapts plans based on not just the original tables’ statistics, but also additional adaptive statistics. Dynamic statistics are gathered, automatic reoptimization occurs on the very next execution, and SQL plan directives allow for permanent changes based on those new statistics.

- Adaptive plans do not pick the final plan until execution time based on statistics collectors. Information learned at execution time is used in future executions. You’ll see the following in the EXPLAIN PLAN table output (in the Note section):
There are three types of adaptive statistics:

- Dynamic statistics (previously dynamic sampling in 10g/11g) or runtime statistics
- Automatic reoptimization of statistics generated after the initial execution
- SQL plan directives direct the optimizer to use dynamic statistics and get accurate cardinality for the future.

In 12cR2, Oracle introduced Continuous Adaptive Query Plans (CAQP) where certain queries, based on input data, can benefit from continuous adaptive join methods (such as a recursive WITH that has different input data compared to previous iterations).

**PGA_AGGREGATE_LIMIT**

In 11g, you could set a target for the PGA with the initialization parameter PGA_AGGREGATE_TARGET. In 12c, there is a new initialization parameter called PGA_AGGREGATE_LIMIT to limit how high this value will go. The PGA makes up part of the MEMORY_TARGET. See Chapter 4 for a full discussion of initialization parameters, but here’s a quick example:

```
ALTER SYSTEM SET PGA_AGREGGAT
ALTERT SYSTEM SET PGA_AGREGGAT
```

When PGA_AGGREGATE_LIMIT is not set, it defaults to the largest of 2G, 200 percent of PGA_AGGREGATE_TARGET, or 3M times the number of processes.

**Concurrent Execution for UNION/UNION ALL**

Typically, the sections of a UNION and UNION ALL were executed serially; now with Oracle 12c the database is able to run the sections within a UNION and UNION ALL in parallel, which can greatly improve performance.

**Invoker Rights Function Can Be Results Cached**

The Results Cache can apply to both definer and invoker. This allows the results of all functions to utilize the Result Cache, helping to improve performance of function executions that have repeated
executions. The results in the Results Cache, however, are not passed between the instances within a RAC cluster.

New DBMSUTILITY.EXPAND_SQL_TEXT

This new feature is a big help for performance tuning when queries are using views. This allows the expanding of views to the base tables, which will allow better SQL performance investigation by being able to see the tables that make up the views to investigate table ordering, index utilization, and join types.

Default for Columns Based on Sequence

You no longer need to fetch a sequence value manually or through a trigger. This feature allows a column to be based on a sequence, which means a sequence can now be populated without the use of an INSERT trigger or the application having to prefetch the value from a sequence. For example:

CREATE SEQUENCE myseq;

CREATE TABLE mytable (id NUMBER DEFAULT myseq.NEXTVAL, description VARCHAR2(30));

Multiple SSD Devices for Smart Flash Cache

This feature improves the Smart Flash Cache feature to be able to utilize multiple SDD devices. The main challenge prior to this was that you needed to create an SSD disk device and utilize it for the Smart Flash Cache. However, to get larger spaces you sometimes had to use a volume manager, as the Smart Flash Cache could only use a single location. Now we can define and use multiple locations for the Smart Flash Cache. For example, the following sets the initialization parameters to use multiple devices with multiple sizes:

DB_FLASH_CACHE_FILE = /dev/sda, /dev/sdb, /dev/sdc
DB_FLASH_CACHE_SIZE = 32G, 64G, 128G

Concurrent Cost-Based Optimizer Statistics
Gathering

The gathering of statistics before Oracle 12c was a serial operation and therefore gathering cost-based optimizer statistics could take a very long time on a large database. In Oracle 12c, we can now gather cost-based optimizer statistics on multiple tables or multiple partitions of the same table in parallel.

To use this feature:

1. Enable Resource Manager:
   ```sql
   ALTER SYSTEM SET RESOURCE_MANAGER_PLAN = 'DEFAULT PLAN';
   ```
2. Set the JOB_QUEUE_PROCESSES initialization parameter; recommended setting is two times the number of cores available (max):
   ```sql
   ALTER SYSTEM SET JOB_QUEUE_PROCESSES=12 SCOPE=both;
   ```
3. Enable concurrent statistics:
   ```sql
   EXEC DBMS_STATS.SET_GLOBAL_PREFS('CONCURRENT', 'ALL');
   ```
4. Gather statistics:
   ```sql
   EXEC DBMS_STATS.GATHER_SCHEMA_STATS('OK');
   ```

Enhanced System Statistics

Enhanced system statistics in 12c allow the cost-based optimizer to account for storage hardware in query plan generation. The enhanced system statistics can now recognize the speed of the database storage and utilize that when making plan determinations. This is very useful for environments where SSD and other fast storage solutions such as Exadata are utilized. You get better-performing SQL by generating plans that understand that faster disk speeds may allow scan operations and hash joins to perform faster than normal storage solutions.

To use this feature:

1. Gather system stats on a typical workload:
   ```sql
   EXECUTE DBMS_STATS.GATHER_SYSTEM_STATS( gathering_mode => 'START' );
   ```
2. Allow the workload to run, to measure storage speed over time.
3. Stop the system stats gathering after a period of time:
   ```sql
   EXECUTE DBMS_STATS.GATHER_SYSTEM_STATS( gathering_mode => 'STOP' );
   ```
4. Check the results:
   ```sql
   SELECT PNAME, PVALL FROM SYS.AUX_STATS$ WHERE SNAME = 'SYSSTATS_MAIN';
   ```

There is also an Optimizer Statistics Advisor (in 12cR2) that tracks historical information on how statistics are gathered, the quality of the statistics gathered, and the status of automatic stats gathering. The advisor then suggests changes based on Oracle best practices, providing a report as well as a SQL script to run (see the Oracle Database Performance Tuning Guide for more information).
Resource Manager for Runaway Queries

The Resource Manager is a tool that creates limits for queries (and/or users) to prevent long-running, unimportant, resource-intensive queries from affecting the performance of the entire database. It also prevents one query from stopping an entire system. The database administrator can proactively prevent runaway queries by setting limits that are automatically enforced based on query thresholds (such as estimated execute time, actual execution time, amount of CPU used, physical I/Os used, and logical I/Os used). Based on the defined thresholds, once a query exceeds a threshold, the query will automatically be switched to a lower-priority consumer group or you can kill the session running the query, etc. The following example will kill a session that exceeds 60 seconds of CPU time:

```
BEGIN
  DBMS_RESOURCE_MANAGER.CREATE_PLAN_DIRECTIVE (
    PLAN => 'DAYTIME',
    GROUP_OR_SUBPLAN => 'OLTP',
    COMMENT => 'OLTP group',
    MGMT_P1 => 75,
    SWITCH_GROUP => 'KILL_SESSION',
    SWITCH_TIME => 60);
END;
/
```

Automatic Data Optimization (ADO)

In 12c, we are given the ability to implement automatic data lifecycle management. The Automatic Data Optimization feature allows for policies that will automatically move data between storage tiers and compression levels. This is done through the `ilm_clause` of the CREATE and ALTER table statements. The feature determines when data meets the policy standard for movement by the Heat Map, which tracks changes to the table and table partitions. There are two types of policies, a `table_compression` or `tiering_clause`. When data meets the policy, the data is either compressed row level or segment level, or is moved to a new storage tier based on the policy criteria supplied in the AFTER clause of the policy.

Some parts of the `ilm_clause` are as follows:

- **ADD_POLICY** Specify the policy to add to the table.
- **DELETE** Delete a policy from the table.
- **ENABLE** Enable a policy for the table.
- **DISABLE** Disable a policy on the table.

The following are some parts of the AFTER clause of the policy:
LOW ACCESS  For policy to take effect after a period of time of low table access

NO ACCESS  For policy to take effect after a period of time of no table access

NO MODIFICATION  For policy to take effect after a period of time with no table changes

CREATION  For policy to take effect after a period of time after table creation

This example shows how to compress a row after it has not been modified for seven days:

```
ALTER TABLE orders  ILM ADD POLICY ROW STORE COMPRESS ADVANCED ROW AFTER 7 DAYS OF NO MODIFICATION;
```

Global Index Maintenance: Drop and Truncate

Partition Operations

With 12c when you drop or truncate a partition, the global indexes are no longer invalid and managed automatically. Keep in mind that TRUNCATE now has a CASCADE function for tables, but you must be careful with this!

ASM Disk Scrubbing

In 12c, ASM has the ability to automatically repair logical corruption from the mirror disk within ASM. This feature can auto check, auto detect, and auto repair the logical corruption through the mirror that exists in normal and high redundancy diskgroups. See Chapter 3 for detailed ASM information. Here is an example:

```
ALTER DISKGROUP data SCRUB POWER LOW;
ALTER DISKGROUP data SCRUB FILE '/DATA_DG/DB1/DATAFILE/mtatablespace.dbf' REPAIR POWER HIGH FORCE;
```

Online Capability Improvements

Oracle Database 12c is taking availability to a new level with many new operations that can be performed online:

- New DDL online capability commands:
Drop index online
Drop constraint online
Set unused column online
Alter index unusable online
Alter index visible online
Alter index invisible online
Move database *datafile* online
Move table partition online:

```
alter table dept move partition d1 tablespace data2 online;
```
MERGE/SPLIT partitions online (12cR2)
Change nonpartitioned tables to partitioned tables online (12cR2)

---

**Data Guard Improvements**

There are several Data Guard improvements in 12c that are worth mentioning:

- **Broker support for cascaded standby databases** A standby database is tied off of a standby database and not the primary. Redo is shipped to the first standby, and then the first standby sends the redo to another standby.

- **Real-time apply** Now the default.

- **Active Data Guard support for global temporary tables** Capability to write to global temporary tables when a physical standby is open in read-only mode and applying logs.

- **Active Data Guard real-time cascade** A cascaded standby can get real-time apply via redo and no longer has to wait for standby archive redo log. This keeps the cascaded standby database more in sync with the primary database. (Note: Requires Active Data Guard License.)

- **Disaster protection during rolling database upgrade** The standby can continue to receive redo while the database is in upgrade mode.

- **Broker support for rolling database upgrade** The broker configuration no longer has to be rebuilt after a rolling database upgrade.

---

**RMAN Improvements**

These are the notable RMAN improvements in 12c:
Active database duplication improvements SECTION SIZE can be used to parallel an active duplicate with very large datafiles. This supports compression during the restore, which helps reduce duplicate time by better using the network.

Cross-platform backup and restore Allows the backup from one platform to be restored on another platform without any extra work.

Table-level recovery Enables recovery of a table or set of tables using an RMAN backup directly using RESTORE TABLE.

Pluggable database backup and recovery A new feature added to support the PDB feature of 12c, allows a backup, restore, and recovery of a single PDB. It also allows a backup of a single tablespace within a CDB or PDB. Examples of this include the following:

- BACKUP PLUGGABLE DATABASE pd1, pd3
- BACKUP TABLESPACE USERS
- BACKUP TABLESPACE pb1:SYSASUX

Network-enabled restore Adds the ability to restore/recover one or more datafiles from a live database or running standby database. This feature supports compression and multissection operations as well.

Oracle Database 12cR1 (12.1.0.2)

Oracle Database 12cR1 (12.1.0.2) is often referred to as the In-Memory (IM) version of Oracle. Oracle made it possible to have an additional memory area for data warehousing operations. This area is a compressed memory area with an In-Memory column store. In this area you are able to place specific columns in memory for faster warehousing applications while continuing to use Oracle’s original memory area for transactional queries, as in past versions.

In-Memory Database

This is by far the best new feature for improving database performance in 12c. This capability is perfect for many types of workloads and, best of all, does not require any application changes to make use of it. Describing this new feature in full could fill an entire chapter, therefore we will cover it in more detail in Chapter 4.

This feature is made possible through the unique dual memory areas. The first is the main database memory cache (it used to be the only one) where the Oracle queries for individual rows are maintained primarily for OLTP (DB_CACHE_SIZE of the SGA). The second area is a new In-Memory column store (set using the INMEMORY_SIZE initialization parameter), which gives the capability to store compressed column(s) from tables (and other objects) and is primarily used for analytical processing (making it fast to perform functions on just a column). Now Oracle maintains both the row and columnar formats at the same time without any changes to the application. You can enable this feature without having to change a single line of code in your applications. It also is fully
compatible with all existing Oracle database features and options, and can be used with RAC, partitioning, compression, pluggable databases, Exadata, and so on.

The In-Memory database option is an In-Memory column store that is an addition to the database System Global Area (SGA) buffer cache. It is known as the In-Memory (IM) area or the In-Memory column store. This will not “double” memory requirements for the database. It is estimated that only 20 percent overhead is expected to make full use of this feature with a huge impact. This feature maintains the buffer cache as it normally would in a row-format-based store, which is most efficient for DML activity. However, at the same time it will maintain a columnar-based format (the data is also compressed), which is most effective for query and analytical activities. Not all tables or columns should be part of the In-Memory area. The IM should only be populated with the tables that are most critical to overall database performance related to analytics. When the IM and the buffer cache are combined with now lower-cost flash storage, huge performance improvements can be realized. The In-Memory database option is turned on by setting the INMEMORY_SIZE to a non-zero value (don’t set this until you are ready to be licensed for it). It must be set to at least 100M and it is part of the SGA_TARGET (and therefore the MEMORY_TARGET depending on if one or both of these parameters are used). Figure 1-9 shows an SGA which is using the In-Memory column store as set below using the INMEMORY_SIZE initialization parameter.

```
Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0
With the Partitioning, OLAP, Advanced Analytics and Real Applications
SQL> show sga
Total System Global Area 4194304000 bytes
Fixed Size 2932336 bytes
Variable Size 579425744 bytes
Database Buffers 2013265920 bytes
Redo Buffers 13844480 bytes
In-Memory Area 1593835520 bytes
SQL>
```

**FIGURE 1-9. SGA listing showing the In-Memory area**

The following is an example of using this new feature (see Chapter 4 for setting initialization parameters):

```
inmemory_size=1520M
```

For an object to be populated in the new In-Memory area, the INMEMORY attribute is set for the given object. Setting the attribute can be a default at the tablespace level, for a table, set for specific column(s) of a table, and partition(s) of a table. Here are some examples:
The In-Memory area has the option for objects to be populated immediately upon database startup or when the object is first read/queried. This is controlled by the PRIORITY keyword. It allows some objects to be immediately populated to the In-Memory area upon database startup so that those objects are in memory upon first access, which helps avoid the performance hit of a first-time read. The PRIORITY keyword also allows you to assign to objects a priority for entering the In-Memory column store. This is all controlled by the following five priority levels, which control the loading of objects into the In-Memory area:

- **CRITICAL** Object is populated immediately after the database is opened.
- **HIGH** Object is populated after all CRITICAL objects have been populated, if space remains available in the IM column store.
- **MEDIUM** Object is populated after all CRITICAL and HIGH objects have been populated, if space remains available in the IM column store.
- **LOW** Object is populated after all CRITICAL, HIGH, and MEDIUM objects have been populated, if space remains available in the IM column store.
- **NONE** Objects only populated after they are scanned for the first time (default), if space is available in the IM column store.

Setting the priority determines how and when the objects are loaded into the In-Memory column store and in which order. For example, to set mytable into the In-Memory column store at database startup (to be one of the first loaded), set the priority to CRITICAL:

```
alter table mytable INMEMORY PRIORITY CRITICAL;
```

The In-Memory area also is compressed and creates In-Memory compression units. There are several In-Memory compression options:

- **NO MEMCOMPRESS** Data is populated without any compression
- **MEMCOMPRESS FOR DML** Minimal compression optimized for DML performance
- **MEMCOMPRESS FOR QUERY LOW** Optimized for query performance (default)
- **MEMCOMPRESS FOR QUERY HIGH** Optimized for query performance and space saving
- **MEMCOMPRESS FOR CAPACITY LOW** Balanced, with a greater bias toward space saving
MEMCOMPRESS FOR CAPACITY HIGH Optimized for space saving

By default, the In-Memory compression is FOR QUERY LOW. This provides the best performance while still getting some benefits from compression. The amount of compression experienced can vary anywhere from 2× to 20× and is based on data type, compression type, and the physical data within the table. The following example shows how we can apply compression, as well as other In-Memory settings, all in the same operation. In this example, we specify where we do not want In-Memory for a large LOB column (c4) and that we want to compress the table for In-Memory at QUERY HIGH, but want to use CAPACITY HIGH for column c2.

CREATE TABLE mytable
(c1 NUMBER,
c2 NUMBER,
c3 VARCHAR2(10),
c4 CLOB)
INMEMORY MEMCOMPRESS FOR QUERY
NO INMEMORY(c4)
INMEMORY MEMCOMPRESS FOR CAPACITY HIGH(c2);

Oracle also automatically creates and maintains storage indexes on each column in the In-Memory Compression Unit (IMCU). The performance benefits for In-Memory get even better with these storage indexes (as needed based on queries), which allow data pruning from the SQL WHERE clause directly. This lessens the number of rows returned to the optimizer. SIMD (single instruction, multiple data values) vector processing scans multiple data values in the same CPU instruction (this is commonly used in gaming; consider the online game League of Legends has 27M daily users). In-Memory joins take advantage of Bloom filters to transform a join and improve the overall performance during the scan of larger tables. In 12cR2, the join group (column joined between two tables) is also compressed so that decompression is not needed when tables are joined (a potential issue prior to 12cR2). Also in 12cR2 is the ability to have In-Memory virtual columns, and Active Data Guard can now use the In-Memory column store while open in read-only mode.

In 12cR2, Automatic Data Optimization (covered in Chapter 3) is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics. In 12cR2, you can now dynamically resize the INMEMORY_SIZE while the system is running, provided you have the memory available in SGA_TARGET (and MEMORY_TARGET). In-Memory is supported with PDBs since 12.1.0.2, and 12cR2 Data Guard can now use the In-Memory column store. You can also now use DBMS_STATS functions on In-Memory statistics. While statistics are managed automatically by Oracle based on objects In-Memory and evictions, in 12cR2, Oracle has improved the transparency of the statistics.

Advanced Index Compression

Oracle 12.1.0.2 improved index compression so that the size of all indexes is reduced, including
those that did not benefit from prior index compression due to not having leading columns in the index that repeated. Even unique indexes are smaller and benefit from this new index compression.

**Automatic Big Table Caching**

Database 12c adds a big table cache that provides huge performance improvements for full table scans where the table being scanned will not fit inside the database buffer cache. To turn this feature on, set the `DB_BIG_TABLE_CACHE_PERCENT_TARGET` initialization parameter to the amount of the database buffer cache memory that should be targeted for use. The `PARALLEL_DEGREE_POLICY` initialization parameter must be set to AUTO or ADAPTIVE as well for the feature to be turned on.

**FDA Support for Container Databases**

Flashback Data Archive now provides support for multitenant database configurations (pluggable databases).

**Full Database Caching**

This feature provides the ability to cache the entire database in memory. With server RAM capabilities getting larger, some databases really are able to completely fit in the server RAM. In a RAC environment where services divide the application data to multiple database instances, the ability to fit in the combined RAC configuration is even more likely. Keep in mind that there is additional room required for duplicate blocks/objects across the instances, so the combined RAM of the buffer caches has to be larger than the database. This new feature can provide huge performance boosts to database performance by eliminating I/O to disks or flash.

**JSON Support**

Oracle 12c added support for storing JavaScript Object Notification (JSON). The Oracle database allows the storage and enforcement of JSON rules for JSON objects stored in the database. It also allows the access to the data stored via PATH notation and integrated into SQL.

**FIPS 140 Parameter for Encryption**

Oracle 12c has a new parameter, `DBFIPS_140`, which provides the ability to utilize the Federal
Information Processing Standards (FIPS) 140 cryptographic processing mode. This feature allows companies and government agencies to meet this standard.

**PDB Subset Cloning**

PDB subset cloning enables you to specify the tablespaces that need to be available in a new pluggable database via the USER_TABLESPACES clause. This can be used in cases where you have a schema that is divided by tablespace that will go into multiple pluggable databases.

**Rapid Home Provisioning—Creating “Gold Images”**

Rapid Home Provisioning (RHP) provides the ability to have multiple predefined ORACLE_HOMEs creating “gold_image” homes stored in a catalog of pre-created ORACLE_HOMEs. This allows ORACLE_HOMEs to be provisioned from the catalog of “gold images.” This decreases deployment or ORACLE_HOMEs to new environments and updating of ORACLE_HOMEs based on updates to the “gold images” and sharing, which can reduce storage space.

**Oracle Database 12cR2 (12.2)**

Oracle Database 12cR2 is the version of Oracle that most companies will migrate to and continue to run for many years. Oracle 12cR2 has many new features that enhance pluggable databases and the In-Memory column store. There are also additions that make it easier to move things to and from the cloud in this release. Additionally, there are many security enhancements.

**Application Development**

In addition to some of the features listed above, there are some fantastic features for the developers as well. While I will cover some of the SQL and PL/SQL improvements, they are too numerous to list them all here.

**Improved SQL and PL/SQL**

Improvements in SQL and PL/SQL are always welcome. PL/Scope Reports allow common SQL statements within PL/SQL code to be identified. This includes SELECT, INSERT, UPDATE, and DELETE statements. The reporting identifies the statement type, SQL text, and the sql_id of the statement. This is useful when you identify a poorly performing SQL statement and need to identify all PL/SQL locations where that SQL is utilized (which is achieved via the new DBA STATEMENTS view).

There is an enhancement of the CAST function with error handling so that a user-specified value
can be returned when a conversion error happens, rather than an error. The next highlight for SQL and PL/SQL is a new function that will allow you to pass a value and determine if it can be converted to a requested data type.

The best enhancement in 12cR2 is that a 32K VARCHAR is available by default. This allows the extending of the VARCHAR data types without having to enable the extended mode specifically.

Approximate query processing is a new feature that counts distinct values and adds approximate percentile aggregation. This allows faster processing of large data sets using approximation instead of exact aggregation. Since this is an aggregation, it is not assured to be completely accurate; however, in most cases it is very close and acceptable considering the large performance boost it provides. Note that the results returned are 100 percent accurate—only how the query is processed is approximated (lowers time to figure out how to execute the query efficiently). In 12cR2, there are additional approximate percentile functions and the capability to reuse approximate aggregations for multiple queries (via materialized views and query rewrite).

Instead of using this to achieve 100 percent accuracy:

```sql
select count (distinct (empno)) from emp;
use this for speed (97 percent accurate):
```

```sql
select approx_count_distinct (empno) from emp;
```

Oracle says the approximate amount will be within 97 percent or so from the actual.

---

**Enhanced Features to Reduce Costs and Issues for Migration to Oracle**

In 12c, object names for users, roles, tables, columns, indexes, constraints, and so forth have been increased from 30 bytes to 128 bytes, with a few limitations. The limit for tablespace names and pluggable databases is still 30 bytes, but others all increase to 128 bytes. You will notice this change in the dictionary views, where the VARCHAR2 columns will show as 128 bytes instead of 30 bytes. This is to overcome some limitations for multibyte character set languages, where in some languages, when non-Unicode, the name fits fine, but changing database to Unicode character set the name became too long. It also helps in migrations from non-Oracle systems where the name is longer than 30 characters.

---

**Availability**

There are several improvements to increase availability when implemented. Many options will
accelerate Active Data Guard adoption such as accepting more data types, distributed transaction support, and a compare tool. Logical replication and more ONLINE operations will help keep your system up 24/7.

**Accelerated Active Data Guard Adoption—12cR2 Improvements**

There are several improvements in 12cR2 focused on the adoption of the Active Data Guard option. Distributed transactions are now allowed on CLOB, BLOB, and XMLType data types. Distributed transactions are transactions that occur over a database link. These new capabilities for these data types over database links open the possibility for more transactions over database links. This flexibility is important for pluggable databases, especially where schemas that used to live in the same database and could communicate directly and share data now go across database links, as they now live in separate PDBs.

Next, there is an improvement to multi-instance redo apply. In prior releases, RAC primary databases funneled all redo apply to a single standby instance. This limited the standby apply to one instance. With 12cR2, redo apply can be configured to one or more instances on the standby side, which allows redo apply performance to scale where previously, in some cases, the standby would fall behind when it was doing multiple instance redo apply on a single instance on the standby. Also, allowing multi-instance standby databases is incorporated into the broker so that broker configuration can handle multi-instance apply.

On Oracle Data Guard for Data Warehouses, we now have NOLOGGING operations on the primary that can be tracked. Originally, blocks on the standby would be marked unrecoverable when NOLOGGING was used on the primary. With the new tracking, Data Guard can track the blocks for loads with NOLOGGING and, using RMAN, recover the blocks using the new RMAN command RECOVER DATABASE NOLOGGING.

There is also an Oracle Data Guard Database compare tool that compares the blocks in a primary database to the blocks in a physical standby database. This helps to find disk errors that otherwise are not located by tools such as DBVERIFY. The DBA can now identify block issues in a standby that could otherwise be missed, ensuring the standby has no physical corruption.

With pluggable databases, Oracle 12cR2 introduces the concept of a subset standby. This allows a standby database in a multitenant environment to have a standby without having to take all the PDBs into the standby. Keep in mind this impacts switchover and failover operations, so you should understand the impact that only a subset of PDBs has on switchover and failover operations.

In 12cR2, the Data Guard Broker can handle multiple automatic failover targets for fast-start failover capability. When multiple standby databases exist and have multiple fast-start failover targets, if one standby is not in a state to fail over, another standby allows the failover to complete to this alternate standby rather than having the failover outright fail. The Data Guard Broker also now supports multiple observers from many fast-start failover configurations.

Data Guard now supports the ability to transport redo to a database destination with a different Endian than the primary. This is to allow the redo transport to the Zero Data Loss Recovery Appliance (ZDRLA), where the Endian format is different from that of the primary database.

Lastly, Data Guard provides an auto sync of database password files between primary and standby. This feature will automatically sync the password file between the primary and standby databases in a Data Guard Configuration when the password file changes on the primary.
Best-of-Breed Logical Replication

Oracle Database 12cR2 made some improvements geared toward replication, including GoldenGate. GoldenGate integrated capture mode error-handling improvements have been made to allow the viewing of conflict management configuration within the database using a new set of views:

- DBA_APPLY_REPERROR_HANDLERS
- DBA_APPLY_HANDLECOLLISIONS
- DBA_APPLY_DML_CONF_HANDLERS
- DBA_APPLY_DML_CONF_COLUMNS

GoldenGate also adds a new view for conflict detection and resolution exception handling: DBA_APPLY_EXCEPTIONS

There is also the ability to handle DDL with Oracle GoldenGate Integrated Replicat using a stored procedure, as well as the ability to replicate procedure executions for certain DBMS packages such as DBMS_REDEFINTION.

Online Operations

Several improvements have been made to improve availability in Database 12cR2, including many operations that can be performed online. Oracle now also introduces the ability to restart a redefinition from a failure. There is also the ability to roll back a redefinition using DBMS_REDEFINTION.ROLLBACK, which essentially swaps the original table back into place. There is also a redefinition progress-monitoring capability view (V$ONLINE_REDEF). The redefinition has support for BFLIE columns in tables.

Some of the online features include the online conversion of a nonpartitioned table to a partitioned table, and the ability to online split or merge a partition or subpartition of a partitioned table.

We can now move a table to a new tablespace online, which helps reduce downtime when we do a table reorg/move. We can also move to a new tablespace using information lifecycle management with no outages.

Recovery Server and RMAN Improvements

RMAN improvements in Database 12cR2 include disk space checking for the recover table feature and the ability to import pluggable databases into a multitenant database across platforms. This allows cross-platform migration by plugging the database into a new container database on a different platform (or the cloud). There is also support for cross-platform migration for encrypted tablespaces, enabling you to migrate databases to a new platform where encrypted tablespaces are utilized. There is DUPLICATE command support for encrypted backups that are not auto login wallet based. Lastly, there is cross-platform migration support (over the network) allowing a duplicate over the network in that process. See Oracle-specific documentation on these new very helpful improvements.
Sharding

*Sharding* is the concept of physically dividing the database objects for an entire application between multiple separate databases called *shards* (for horizontal scaling). From the application point of view, things are presented as a single large database (logically). This has been done for applications and environments for a long time before RAC and other cluster solutions became available (to scale an application without using sharding). However, 12cR2 adds capabilities to sharding for automated deployments, high-performance routing, and lifecycle management. Sharding is used for OLTP applications as a way to scale at the database level and is designed to be used with applications that were specifically designed to be sharded. See Oracle documentation for further details.

Simplified Upgrades and Data Redaction for Testing

Upgrade improvements include online patching for critical updates so that security patches no longer should require database downtime! Oracle Data Guard Rolling Upgrade now has Label Security support and Database Vault support, therefore databases using Label Security and/or Database Vault can now perform rolling upgrades. Database Vault now has support for flashback operations such as PURGE TABLE, PURGE TABLESPACE, PURGE RECYCLEBIN, and PURGE DBA_RECYCLEBIN. Oracle also provides a DBMS_REDACT package for Data Redaction (DBMS_REDACT is now available in 11g and 12cR1 because it was backported). This is great for testing! You can also GRANT only READ privilege, instead of SELECT (which could be used to lock a table with SELECT...FOR UPDATE).

Big Data

One of the biggest paradigm shifts in the business world is the rapid shift to finding, retaining, and helping customers through the use of big data. Oracle has several new features that help companies use big data along with the Oracle database. Oracle also offers solutions to securely access big data from the Oracle database, eliminating the massive security hole that big data created in most IT systems.

Big Data Management: External Tables Can Access Data Stored in Hadoop

Oracle Database 12cR2 has incorporated some improvements geared toward “big data” such as partitioned external tables, which allows you to map partitioned Hive tables into the Oracle environment and also allows you to define partitioning on top of Hadoop Distributed File System (HDFS). These features extend external tables to access data stored in HDFS and HIVE via the external table functionality of the Oracle database. In 12cR2, there is also Parallel Query Services for Oracle RAC environments with read-only nodes. This allows a RAC environment with read-only nodes to spread parallel query execution across many read-only nodes within a RAC cluster. This in turn allows large amounts of data to be queried very quickly.
Enhanced Query Processing and Optimization

The Oracle database is constantly being enhanced with improvements that help performance. In 12cR2, the following are enhanced query processes and optimization improvements:

- **Optimizer Statistics Advisor** Provides a way for the database to track and analyze how the optimizer statistics are collected and then utilize that information to report issues with current statistics collection and make suggestions for improvement.

- **SQL Plan Management** Has been enhanced to be able to use AWR data as a source for SQL plan baselines.

Compression and Archiving

Oracle also improved the storage and speed of accessing data. With Oracle you store much more data in less space due to compression algorithms that Oracle employs. Oracle also allows different ways to archive information.

Hybrid Columnar Compression (HCC) Improvements

Oracle 12cR2 adds the capability for HCC to be used with array-level inserts, essentially allowing HCC compression with the SQL INSERT SELECT without having to use the APPEND hint. This also applies to array-level inserts from applications using the Oracle Call Interface (OCI) and PL/SQL. Oracle Database 12cR1 introduced the ability to do information lifecycle management within the database (ADO). With 12cR2, HCC can compress data with a ADO row-level policy.

Index Compression Enhancements

In Oracle 12c, better index compression is available with the HIGH compression option now available for compressing indexes (LOW compression is the default). Since index reads are a huge activity for most databases, compressing indexes can offer performance improvements as well as disk space improvements.

Oracle RAC and Grid Infrastructure

Oracle has also made many improvements to ASM, including better use of “gold images.” ASM continues to be the standard when setting up Oracle.

Automatic Storage Management

Oracle 12cR2 adds a few improvements for Automatic Storage Management (ASM), such as ASM Split Mirror for Oracle Exadata. This feature supports the split of an ASM mirror to allow a read-
Another improvement is the Flex disk group quota management in ASM. The “Flex” disk groups allow the control of storage consumption by a database via a “quota” in environments where multiple databases utilize the same ASM disk groups. Additionally, “Flex” disk groups offer the capability to prioritize rebalance operations. This will be useful in multitenant environments because not all databases in a multitenant environment need the same priority (due to differences in the critical nature of the PDBs to the business).

Rapid Home Provisioning and Patch Management
A “gold image” of Oracle database software and Grid homes can be used to automatically provision, patch, and upgrade the ORACLE_HOMEs from the “gold image.”

Security
Oracle has led the way in database security for over forty years! Many newer Wall Street backed databases lack even basic security that Oracle employed decades ago. Despite that lead, Oracle continues to implement better security with every version of the database with the expansion of TDE, encryption at multiple object levels, and encryption at the chip level with the M7.

Increase Adoption of Encryption
Oracle Database 12cR2 adds the ability to encrypt, decrypt, and rekey tablespaces with Transparent Data Encryption (TDE). This allows a live conversion and initial encryption of a tablespace to a new encrypted tablespace, allowing easy deployment of TDE into the database. This also allows the encryption keys to be rotated without downtime, which allows keys to be changed, for security reasons, without impact to availability. You can also set the INACTIVE_ACCOUNT_TIME parameter within a user profile to lock out a login if it’s been idle for a specified amount of time.

Also, SYSTEM, SYSAUX, and UNDO can have tablespace encryption applied to them. In prior versions, we could have encrypted tablespaces, but the database in SYSTEM, SYSAUX, and UNDO was left unencrypted.

New Background Processes in 12c
Here is a table listing the new Oracle Background Processes in 12c.
Exadata—New with Exadata X6!

Oracle 12cR2 was officially released on September 18, 2016 on cloud-first and on an Exadata Database Machine. Oracle is officially a software, cloud, and hardware company! Exadata is introduced in this first chapter because hardware determines where you tune next (Chapter 11 looks at Exadata and Cloud in detail). Oracle has accelerated the hardware world in the same way they accelerated the software world. Exadata is great, but HP, EMC, IBM, and many others continue to put out great hardware to run your Oracle database. The Exadata X6-2 (just came out in 2016) has 14.6T

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Process Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWnn</td>
<td>Database Writer Process (20 possible)</td>
<td>Writes modified blocks from the database buffer cache to the datafiles. The names of the 37th through 100th Database Writer Processes are BW36–BW99. See DBWn for more information on these processes.</td>
</tr>
<tr>
<td>LGn</td>
<td>Log Writer Slave</td>
<td>On multiprocessor systems, LGWR creates slave processes to improve the performance of writing to the redo log. LGWR slaves are not used when there is a SYNC standby destination.</td>
</tr>
<tr>
<td>LREG</td>
<td>Listener Registration Process</td>
<td>LREG notifies the listeners about instances, services, handlers, and endpoint.</td>
</tr>
<tr>
<td>RM</td>
<td>RAT Masking Slave Process</td>
<td>This background process is used with Data Masking and Real Application Testing.</td>
</tr>
<tr>
<td>RPOP</td>
<td>Instant Recovery Repopulation Daemon</td>
<td>The RPOP process is responsible for re-creating and repopulating datafiles from snapshots files. It works with the instant recovery feature to ensure immediate datafile access. The local instance has immediate access to the remote snapshot file's data, while repopulation of the recovered primary datafiles happens concurrently. Any changes in the data are managed between the instance's DBW processes and RPOP to ensure the latest copy of the data is returned to the user.</td>
</tr>
<tr>
<td>SAnn</td>
<td>SG Allocator</td>
<td>A small fraction of SGA is allocated during instance startup. The SAnn process allocates the remainder of the SGA in small chunks. The process exits and no longer exists once SGA allocation is completed.</td>
</tr>
</tbody>
</table>
of DRAM and an all flash option with 179.2T of all flash storage, or 1.3P of disk storage (although higher numbers are possible in other configurations). It also has around 1200 CPUs when you count the ones on the storage as well. Speed ranges from 2M to over 5M reads or writes per second.

The Exadata X6 got a CPU upgrade using the latest 22-core Intel Xeon E5-2699 v4 processors, which gives each Exadata compute node 8 extra cores per server over the X5 but gives each core a boost in performance as well. The storage cell CPUs got an upgrade using the latest 10-core Intel Xeon E5-2630 v4 processors. This is a big improvement over the older 8-core processors used in the X5, which was the same as in the X4. This is a welcome improvement in core performance and an increase of 4 cores per storage cell, which should help those times we have seen the storage cell performance on a Hybrid Columnar Compressed table using a Smart Scan (in the past hindered by CPU in the storage).

Storage has been significantly increased for both Flash and High Capacity storage. Flash has been increased from 1.6T per flash card to 3.2T per flash card, which doubles the size of the solid-state storage for the Exadata X6 over the X5. There are four flash cards per server, increasing flash storage per server from 6.4T per server to 12.8T per server. The full rack has a total of 179.2T of flash (230T of all flash in some configurations). The High Capacity disk size has been increased to 8T, which is double the size of the X5, which was 4T. The X6-2 has a maximum disk storage capacity of 1.344P (1.7P in some configurations is possible).

The upgraded storage cell performance allows you to apply an upgrade in just over an hour. In the past, storage cell upgrades have taken over 2 hours, so in some cases this has been cut in half. Storage indexes are now preserved through a cell reboot; until now you always lost your storage indexes when you rebooted a cell. This means not only that you can upgrade your storage cell software in an hour, but that the storage cells indexes are still safe after the cell reboots as part of the upgrade. Another huge improvement for the storage indexes is that they will also now move along with the data for device-predictive or true failures. This means that when a drive fails, the storage indexes are not lost and move along with the data to another drive.

Using the Oracle Exadata Deployment Assistant, you can set up VLAN tagging; prior to this any VLAN tagging had to be done after the initial installation and setup of the Exadata.

The capacity on-demand minimums have been slightly adjusted. The minimum for an X6-2 is 14 cores per server, and the X6-8 minimum cores total is 56. This makes the minimum basically the same as the X5 even though there were core count increases in the X6.

**Version Comparison Chart**

The following chart shows which components or options are available in the various editions of Oracle 12c (and if they are an additional cost). Note that a free limited version of Oracle called Oracle Express Edition (XE) is also available; in 11g, it had an 11G database, 1 CPU, and 1G of memory. This is subject to change for 12c, so please check Oracle.com to verify any features. If you can afford it, you definitely want the Enterprise Edition! This chart shows features that are available for a given version of Oracle, but keep in mind, some cost extra to add (i.e., RAC, Oracle Tuning Pack, Advanced Compression, In-Memory column store, Multitenant [pluggable databases], etc.). Standard Edition (SE/SE1) is available for 12.1.0.1 and Standard Edition 2 (SE2) is available starting with 12.1.0.2. Consult with your salesperson for pricing and licensing and see [www.oracle.com/us/products/database/index.html](http://www.oracle.com/us/products/database/index.html) for the latest information.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>In-Memory Column Store*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>In-Memory Aggregation*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multitenant (PDBs)*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Advanced Security*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Advanced Compression*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Database Vault*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnostic Pack*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oracle OLAP*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Partitioning*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oracle RAC* (for EE)</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Oracle RAC One Node*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Oracle Spatial*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Application Testing*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Data Guard*</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuning Pack* (need Diagnostics Pack)</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DB Resource Manager</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

**VLDB, Data Warehousing, Business Intelligence**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitmapped indexes</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Export transp ts</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Import transp ts</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summary Management</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Advanced Analytics</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hybrid Columnar</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Compression* (Exadata, ZFS, FST)</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Descending indexes</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Direct Path Load API</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>External tables</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Function-based indexes</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Long operations monitor</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Materialized views</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>MERGE</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Optimizer stats mgt</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Feature</td>
<td>PL/SQL Only</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Pipelined table functions</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Sample scan</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Star query optimization</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Parallel Operations**

<table>
<thead>
<tr>
<th>Feature</th>
<th>PL/SQL Only</th>
<th>Y</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel query</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel DML</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel index build</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel stats gathering</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel Data export and Data Pump</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>In-Memory Parallel (needs In-Memory*)</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel backup &amp; recovery</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel analyze</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel bitmap star query</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel index scans</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>

**High Availability**

<table>
<thead>
<tr>
<th>Feature</th>
<th>PL/SQL Only</th>
<th>Y</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oracle Data Guard*</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Fast-start fault recovery</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Online operations</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Parallel Backup</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Oracle Flashback features (Table, Database, Transaction, Total Recall)</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Automatic Storage Management (ASM)</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Information Integration**

<table>
<thead>
<tr>
<th>Feature</th>
<th>PL/SQL Only</th>
<th>Y</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oracle Streams</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Oracle Messaging Gateway</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
</tbody>
</table>

**Database Features**

<table>
<thead>
<tr>
<th>Feature</th>
<th>PL/SQL Only</th>
<th>Y</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database event triggers</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>DBMS_REPAIR package</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Drop column</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Feature</td>
<td>Development</td>
<td>Distributed</td>
<td>Networking</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>Flashback Query</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Globalization</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Index coalesce</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Invisible index</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Query Result Cache</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Index-organized tables</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>INSTEAD OF Triggers</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Plan stability</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Reverse key indexes</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SQL Plan Management</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Temporary tables</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Autonomous transactions</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Client-Side Query Cache</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Java support</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>JDBC drivers</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>MS Trans Server</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Object/Relational Ext</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>PL/SQL native compilation</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>PL/SQL Function Result Cache</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>PL/SQL stored procedures in triggers</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>PL/SQL Server embedded</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SQL*Plus</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>XML</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Advanced replication</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Basic replication</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Distributed queries</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Distributed transactions</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Connection Manager</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SDP for InfiniBand</td>
<td>N</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>
This is by no means a complete list of features in Oracle Database 12c. Overall, Oracle has made major strides in providing enhanced functionality and automating many administrative tasks, reducing the total cost of ownership. RAC and Grid Computing are mature technologies that have now been extended to multitenant and the cloud. Oracle is leading the effort at integrating this technology and engineering it together with their Exadata and Exalogic, providing features like Flash Data...
New Features Review

- 12cR2 increases the size limit for VARCHAR2 and NVARCHAR2 to 32K.
- In 12c, there is a feature for partial indexes on partitioned tables.
- In 12cR2, new partitioning features include: SPLIT and MERGE partitions online, convert nonpartitioned tables to partitioned tables online, and leverage read-only partitions.
- In 12cR1 you can build multiple indexes on a column by leveraging invisible indexes.
- For fast testing, you can fetch first \( x \) rows, and also skip rows before fetching them.
- You can change the compression of a table at import time (great for migrations).
- Pluggable databases are new with 12c and help with consolidation or moving to the cloud.
- PGA_AGGREGATE_LIMIT now limits the PGA original set with PGA_AGGREGATE_TARGET in 12cR1.
- Oracle now has an Adaptive Query Optimization method that changes a driving method for queries to fix slow queries (as they are executing).
- There is a new Resource Manager for preventing runaway queries.
- In 12.1.0.2, Oracle introduced the In-Memory (IM) column store, giving the ability to have an In-Memory data warehouse (columns are stored compressed in this new memory area).
- The source no longer needs to be read-only when cloning a PDB (point-in-time clone).
- You can do a PDB refresh of clones manually or automatically (they must be read-only).
- You can do a FLASHBACK of a PDB and restore points to only that PDB in 12cR2. This can be done using the SCN, Restore Point, Clean Restore Point, or Guarantee Restore Point. You can also use local UNDO in 12cR2.
- You can build a subset standby of just one or a portion of your PDBs in 12cR2.
- You can now have 4096 PDBs, not just 252, in 12cR2.
- Oracle introduced a number of online operations in 12cR2.
- Oracle now features sharding for horizontal scaling.
- Oracle provides a big data management system infrastructure including a feature that uses external tables to read Hadoop data.
- With Oracle Database 12cR2 the ability to encrypt, decrypt, and rekey tablespaces with Transparent Data Encryption (TDE) has been added.
- Oracle added a number of new background processes in 12c, detailed in this chapter.
- X6-2 is what is new with Exadata, including over 1P of storage or 180T of flash. Oracle also
has an all-flash server (FS1), which includes around 1P of flash.

References
My Oracle Support documents (several listed in the chapter).
Oracle Database SQL Language Reference, 12c Release 2 (12.2) (Oracle Corporation).

Many thanks to Mike Messina, who did half of the upgrade of this chapter to Oracle 12c! Thanks to Jacob Niemiec for providing Figure 1-1, created in Blender.
This chapter is neither for the experts nor for those looking for fast answers. This is a chapter (maybe the only one) that looks at very basic indexing theory, including some new features in version 12c Release 2 (12cR2), such as multiple types of indexes on the same column(s).

The toughest part of being a beginner is finding information that will fill in the most basic gaps and enable visualization of Oracle’s indexing capabilities. This chapter is intended to serve that purpose. While a considerable amount of material is published at the intermediate and advanced level, the beginner’s information that is useful is usually scarce, yet highly desirable. Chapter 5 has additional index information on query tuning and the Access Advisor (using Cloud Control—or as some still call it, Oracle Enterprise Manager [OEM]), which suggests indexes that should be created. Chapters 8 and 9 cover specific query tuning and driving tables (which heavily influence which indexes are used). Index information related solely to Exadata or the Oracle Cloud is located in Chapter 11.

Oracle offers a variety of indexing options. Knowing which option to use in a given situation can be crucial to an application’s performance. A wrong choice may cause performance to come to a grinding halt or cause processes to be terminated because of deadlock situations. By taking processes that previously took large amounts of resources and hours or even days to run and having them finish in minutes can make you an instant hero. This chapter will discuss each of the indexing options and point out the benefits and limitations of each. The introduction of the invisible index in Oracle Database 12cR2 adds a new way to turn off unused or potentially harmful indexes before you delete them (when you are sure that you don’t need them). Tips covered in this chapter include the following:

- Basic index concepts
- Leveraging invisible indexes
- Multiple indexes on the same column(s)—12c only
- Finding which tables are indexed and which have concatenated indexes
- How concatenated indexes are used
- The Oracle ROWID
- Using functions and indexes
Basic Index Concepts

When accessing data from tables, Oracle has two options: to read every row in the table (also referred to as a full table scan) or to access a single row at a time via ROWID. When accessing a small percentage of the rows of a large table, you would want to use an index. For example, if you only wanted to select 5 percent of the rows in a very large table, you would do fewer I/Os if you used the index to identify which blocks to read. If you don’t use an index, you will read all of the blocks in the table (this changes with INMEMORY; see Chapter 4 for more information).

The degree to which indexes help performance depends partly on the selectivity of the data and the way in which the data is distributed among the table’s blocks. If the data is very selective, there will be few rows in the table that match the indexed value (such as a passport number). Oracle will be able to query the index quickly for the ROWIDs that match the indexed value, and the small number of related table blocks can be quickly queried. If the data is not very selective (such as the country name), then many ROWIDs may be returned by the index, resulting in many separate blocks being queried from the table.

If the data is selective but the related rows are not stored near each other in the table, then the benefit of indexing is further reduced. If the data that matches the indexed value is scattered throughout the table’s blocks, then you may have to select many individual blocks from the table to satisfy your query. In some cases, you will find that when the data is dispersed throughout the table’s blocks you are better off bypassing the index and performing a full table scan instead (or doing an INMEMORY scan). When doing a full table scan, Oracle uses a multiblock read, enabling it to scan a table quickly. Index-based reads are single-block reads, so your goal when using an index should be
to reduce the number of single blocks needed to resolve the query.

With some of the options available in Oracle, such as partitioning, parallel DML, parallel query operations, and larger I/O using the DB_FILE_MULTIBLOCK_READ_COUNT, the balance point between full table scans and index lookups is changing. Hardware is getting faster, disks cache more information in on-disk caching, and memory and flash continue to get cheaper. At the same time, Oracle has enhanced the indexing features to include skip-scan indexes and other internal operations that reduce the time needed to retrieve your data.

**TIP**

As you upgrade Oracle versions, be sure to test your application’s queries to determine whether the execution paths for your queries still use the indexes that were used prior to the upgrade. See if the execution plan has changed and if it is better or worse.

Indexes will generally improve performance for queries. The SELECT statement, the WHERE clauses of UPDATE commands, and the WHERE clauses of DELETE statements (when few rows are accessed) can benefit from indexes. In general, adding indexes will decrease performance for INSERT statements (since INSERTs to both the table and the index must be performed). UPDATEs of indexed columns will be slower than if the columns were unindexed because the database has to manage the changes to both the table and the index. Additionally, DELETEs of large numbers of rows will be slowed by the presence of indexes on the table.

A DELETE statement deleting half of a table will also need to delete half of the rows for the index (very costly for this specific situation). In general, every index on a table slows INSERTs into the table by a factor of 3. Two indexes generally make the INSERT twice as slow as one does; however, a two-column single index (either concatenated index or two-part single index) is not too much worse than a one-column single index (a one-part single index). UPDATEs of the indexed columns and DELETEs may be similarly slowed. You need to balance the query performance benefits of indexes against their impact on your data manipulation performance.

To get a listing of all of the indexes on a table, query the DBA_INDEXES view. Also, note that you can retrieve the indexes for your schema by accessing USER_INDEXES. To see the indexes on all tables to which you have access, query ALL_INDEXES.

Shown here, for example, is a creation of indexes on the EMP table owned by SCOTT from the original Oracle demo tables provided as part of the product. You can use any of the old or new demo tables to test queries:

```sql
create index emp_id1 on emp(empno, ename, deptno);
create index emp_id2 on emp(sal);
```

When you issue those commands, the database creates two separate indexes on the EMP table. Each of the indexes contains the specified values from the EMP table along with the ROWID values for the rows that match them. If you want to find an EMP record that has a SAL value of 1000, the
The optimizer could use the EMP_ID2 index to find that value, find the related ROWID in the index, and then use that ROWID to find the right row(s) in the table.

The following USER_INDEXES (you could also look in DBA_INDEXES) query shows the new indexes on the EMP table:

```
select table_name, index_name
from user_indexes
where table_name = 'EMP';
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMP</td>
<td>EMP_ID1</td>
</tr>
<tr>
<td>EMP</td>
<td>EMP_ID2</td>
</tr>
</tbody>
</table>

The output shows the two indexes, but it does not show the columns in each index. To get the specific columns that are indexed for a given table for the current user, access the USER_IND_COLUMNS view. Also note that DBAs can retrieve the columns that are indexed for all schemas by accessing DBA_IND_COLUMNS, and you can see the indexed columns for all of the tables you can access via ALL_IND_COLUMNS. To get the specific columns that are indexed for a given table, access the USER_IND_COLUMNS view, shown next.

```
column index_name format a12
column column_name format a8
column table_name format a8
select table_name, index_name, column_name, column_position
from user_ind_columns
order by table_name, index_name, column_position;
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NAME</th>
<th>COLUMN_NAME</th>
<th>COLUMN_POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMP</td>
<td>EMP_ID1</td>
<td>EMPNO</td>
<td>1</td>
</tr>
<tr>
<td>EMP</td>
<td>EMP_ID1</td>
<td>ENAME</td>
<td>2</td>
</tr>
<tr>
<td>EMP</td>
<td>EMP_ID1</td>
<td>DEPTNO</td>
<td>3</td>
</tr>
<tr>
<td>EMP</td>
<td>EMP_ID2</td>
<td>SAL</td>
<td>1</td>
</tr>
</tbody>
</table>

The EMP table has two indexes. The first, EMP_ID1, is a concatenated index that indexes the EMPNO, ENAME, and DEPTNO columns. The second, EMP_ID2, indexes the SAL column only. The COLUMN_POSITION displayed in the listing shows the order of columns in a concatenated index—in this case, EMPNO, then ENAME, then DEPTNO.

**TIP**
Query DBA_INDEXES and DBA_IND_COLUMNS to retrieve a list of the indexes on a given table. Use USER_INDEXES and USER_IND_COLUMNS to retrieve information for only your schema.

Invisible Indexes

Deciding which columns to index is hard. The primary key is automatically indexed, the foreign keys should also be indexed, but then what? Even more difficult is deciding which index to remove that might be a bad index. Every time a record is inserted, all of the indexes have to be updated. If the column of an index is updated, the index has to be updated. Deciding which index to drop without causing a slew of full table scans or Cartesian joins for subsequent user queries is difficult, especially when tuning third-party applications where the code cannot be changed. The solution just might be the invisible index! Oracle allows you to turn off the index (make it invisible), yet continue to maintain the index (during any DML operation—INSERT/UPDATE/DELETE) in case you need to turn it back on quickly. You can do this by making the index visible or invisible:

- ALTER INDEX idx1 INVISIBLE;
- ALTER INDEX idx1 VISIBLE;
- CREATE INDEX … INVISIBLE;

The following query shows the creation of a new invisible index on the DEPTNO column of the EMP table and subsequent query where the index is not seen:

```sql
create index dept_rich_inv_idx on dept_rich(deptno) invisible;
Index created.

select count(*)
from dept_rich
where deptno = 30;  {doesn't see the index}

COUNT(*)
------
512
```

Execution Plan

```
Plan hash value: 3024585593

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>2</td>
<td>4 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>2</td>
<td>4 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>* 2</td>
<td>TABLE ACCESS FULL</td>
<td>DEPT_RICH</td>
<td>512</td>
<td>1024</td>
<td>4 (0)</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>
```

I can still force the use of the index if I use a hint. This only worked in the earliest versions of 11g
with an INDEX hint; in 12cR2, with a USE_INVISIBLE_INDEXES hint—or by setting the initialization parameter OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE (see Appendix A):

```sql
select /*= USE_INVISIBLE_INDEXES */ count(*)
from dept_rich
where deptno = 30;  -- forces the index with hint

COUNT(*)

512
```

**Execution Plan**

Plan hash value: 3699452051

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost ($CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>2</td>
<td>INDEX RANGE SCAN</td>
<td>DEPT_RICH_INV_IDX</td>
<td>512</td>
<td>1024</td>
<td>1 (0)</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

If I make the index visible, I no longer need to use the hint:

```sql
alter index dept_rich_inv_idx visible;
Index altered.

select count(*)
from dept_rich
where deptno = 30;  -- it does see the index

COUNT(*)

512
```

**Execution Plan**

Plan hash value: 3693452051

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost ($CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>2</td>
<td>INDEX RANGE SCAN</td>
<td>DEPT_RICH_INV_IDX</td>
<td>512</td>
<td>1024</td>
<td>7 (0)</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

I can also use the NO_INDEX hint to turn off an index (before making it invisible) to see if another
index (or no other index) will be used, other than the one that I intend to make invisible. In other words, use any index except the one listed in the NO_INDEX hint. Here is an example:

```sql
SELECT /*= no_index(dept rich dept rich_inv_idx) */ COUNT(*)
FROM dept rich
WHERE deptno = 10; --forces not using the index with hint

COUNT(*)
512
```

Execution Plan

Plan hash value: 3024585593

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>00:00:01</td>
</tr>
<tr>
<td>2</td>
<td>TABLE ACCESS FULL</td>
<td>DEPT RICH</td>
<td>512</td>
<td>1024</td>
<td>4</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

I can make the index invisible again at any time:

```sql
ALTER INDEX dept rich_inv_idx INVISIBLE;
Index altered.
```

I can check visibility by querying USER_INDEXES or DBA_INDEXES:

```sql
SELECT index_name, visibility
FROM dba_indexes (or go to USER_INDEXES)
WHERE index_name = 'DEPT RICH_INV_IDX';
```

<table>
<thead>
<tr>
<th>INDEX_NAME</th>
<th>VISIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT RICH INV IDX</td>
<td>INVISIBLE</td>
</tr>
</tbody>
</table>

**TIP**

By using invisible indexes, you can “turn off” indexes temporarily (make them invisible) to check how queries perform without them. Because invisible indexes continue to be maintained while
Multiple Types of Indexes on the Same Column(s)

There can be multiple types of indexes on the same column(s), but only one index may be set to visible at the same time, unless the other index is a function-based index (since a function-based index isn’t really on the same column; it’s on the function of the column). This feature is great for variable workloads on the same table. It is great to use different types of indexes for batch, query, or data warehousing at different times of the day or night. There are some restrictions: For a given column(s), you cannot create a B-tree and B-tree cluster index. Also, you cannot create a B-tree and an index-organized table (IOT). All indexes are maintained during DML operation (even when set to invisible). Keep in mind, DML operations may run slow if too many indexes are created.

The following is a basic SELECT to DEPT table that we will use for the examples in this section:

```sql
select *
from dept;
```

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>DNAME</th>
<th>LOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>ACCOUNTING</td>
<td>NEW YORK</td>
</tr>
<tr>
<td>20</td>
<td>RESEARCH</td>
<td>DALLAS</td>
</tr>
<tr>
<td>30</td>
<td>SALES</td>
<td>CHICAGO</td>
</tr>
<tr>
<td>40</td>
<td>OPERATIONS</td>
<td>BOSTON</td>
</tr>
</tbody>
</table>

First, create a unique index into which duplicates may not be inserted:

```sql
create unique index dept_unique1 on dept(deptno);
```

Even if indexes are set to invisible, duplicates still cannot be inserted:

```sql
insert into dept(deptno) values (10);
insert into dept(deptno) values (10)
* 
ERROR at line 1:
ORA-00001: unique constraint (SYS.DEPT UNIQUE1) violated
```
The following example checks to see that the indexes are set to invisible:

```
alter index dept_unique1 invisible;
Index altered.

insert into dept (deptno) values (10);
insert into dept (deptno) values (10)
*
ERROR at line 1:
ORA-00001: unique constraint (SYS.DEPT UNIQUE1) violated
```

To make indexes visible again:

```
alter index dept unique1 visible;
Index altered.
```

We can't create another index on the same column:

```
cREATE index dept_normal on dept (deptno);
cREATE index dept_normal on dept (deptno)
*
ERROR at line 1:
ORA-01408: such column list already indexed
```

But, we can if we make the first index invisible and then create the second index:
alter index dept_unique1 invisible;
Index altered.

create index dept_normal on dept(deptno);
Index created.

Now if we check our index views, we find two indexes are on the exact same column:

```
select a.table_name, a.index_name,
    b.column_name, a.uniqueness, a.visibility
from user_indexes a, user_ind_columns b
where a.index_name = b.index_name
and a.table_name = 'DEPT';
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NAME</th>
<th>COLUMN_NAME</th>
<th>UNIQUENESS</th>
<th>VISIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT</td>
<td>DEPT_UNIQUE1</td>
<td>DEPTNO</td>
<td>UNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_NORMAL</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>VISIBLE</td>
</tr>
</tbody>
</table>

If we try to make both indexes visible, it will result in an error, as shown next. Only one index may be visible at a time (except function-based indexes).

```
alter index dept_unique1 visible;
*  
ERROR at line 1:
ORA-14147: There is an existing visible index defined on the same set of columns.
```

Note that despite a unique index (that is invisible), only the visible index is used:
To add a third index, we must make the first two indexes invisible:

```
alter index dept_normal invisible;
  index altered.
```

It is possible to create two visible indexes on a column at once, if one of those indexes is a function-based index. Let's make the third index invisible and add a fourth (and fifth):

```
alter index dept_reverse invisible;
  Index altered.

create bitmap index dept_bitmap on dept(deptno);
  Index created.
```

```
create index dept_fb on dept(substr(deptno,1,1));
  Index created.
```
Now when we check the index views, we see that we have five indexes on the same column, with two (one being a function-based index) indexes being visible:

```sql
select a.table_name, a.index_name, 
       b.column_name, a.uniqueness, a.visibility 
from user_indexes a, user_ind_columns b 
where a.index_name = b.index_name 
and a.table_name = 'DEPT';
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NAME</th>
<th>COLUMN_NAME</th>
<th>UNIQUENESS</th>
<th>VISIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT</td>
<td>DEPT_UNIQUE1</td>
<td>DEPTNO</td>
<td>UNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT.Reverse</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_NORMAL</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>INVISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_BITMAP</td>
<td>DEPTNO</td>
<td>NONUNIQUE</td>
<td>VISIBLE</td>
</tr>
<tr>
<td>DEPT</td>
<td>DEPT_PB</td>
<td>SYS_NC00004$</td>
<td>NONUNIQUE</td>
<td>VISIBLE</td>
</tr>
</tbody>
</table>

[Index types: NORMAL, NORMAL/REV, UNIQUE, BITMAP, FUNCTION-BASED NORMAL]

**TIP**

By using invisible indexes, in 12c, you can now create multiple indexes on the same column or columns. This can be helpful with variable workloads. Perhaps use a b-tree index for the daily workload and use a reverse key index at night. But, keep in mind that there is internal index maintenance and also costs for INSERT, DELETE and when you update the indexed column on all of these indexes.

**Concatenated Indexes**

When a single index has multiple columns that are indexed, it is called a *concatenated* or *composite* index. While Oracle’s introduction of skip-scan index access has increased the optimizer’s options when using concatenated indexes, you should be careful when selecting the order of the columns in the index. In general, the leading column of the index should be the one most likely to be used in WHERE clauses and also the most selective column of the set.

Prior to the introduction of skip-scan functionality, queries could only use the index if the leading column of the index was in the WHERE clause. Consider the example in the following listing where the EMP table has a concatenated index (three parts) on EMPNO, ENAME, and DEPTNO. Note that EMPNO is the first part; ENAME is the second part; and DEPTNO is the third part. If you are not making use of the skip-scan functionality, Oracle will generally *not* use this index unless your WHERE clause specifies a value for the leading column (EMPNO).
Since ENAME is not the leading column of the index, the optimizer may elect not to use the index. With the skip-scan functionality the optimizer may choose to use the index, even though an EMPNO value is not specified in the WHERE clause. Instead, the optimizer could choose to perform a fast full scan of the index or a full scan of the table.

The same holds true if the third column of the index is used in the WHERE clause:

```sql
select job, empno
from emp
where empno = 'RICH';
```

In this listing, the WHERE clause specifies a value for the third column in the index. The optimizer may select to perform an index skip-scan access, an index fast full scan, or a full table scan. By creating the index, you have given the database more choices to consider when executing the query, hopefully improving overall performance. Note that the user's code does not change; the optimizer is aware of the index and bases its decisions on the anticipated cost of each alternative.

In the following example, a part of the index is used. The leading column, EMPNO, is used as a limiting condition in the WHERE clause so that Oracle can use the first part of the index (if the second part, ENAME, was in the WHERE clause in addition to EMPNO, it would use two parts; if all three parts were there, it would use the whole index—the best and most limiting solution). In this example, we just use the first part of the index by a condition on EMPNO:

```sql
select job, empno
from emp
where deptno = 30;
```

The two most common types of index scans are unique scans and range scans. In a unique scan, the database knows that the index contains a list of unique values. In a range scan, the database returns multiple values from the index according to the query criteria. To create a unique index, use the CREATE UNIQUE INDEX command when creating the index.

When you create a primary key or a UNIQUE constraint, Oracle automatically creates a unique index based on the columns you specify (unless the constraint is created with the DISABLE clause). If you create a multicolumn primary key, Oracle creates a concatenated index with the columns in the same order in which you specified them when creating the primary key.

Creating range scan indexes provides Oracle with the ability to access a single row of data by supplying the ROWID of the individual row as it is returned for a given query. The ROWID is a pointer directly to the physical location of the individual row.
TIP
Avoid hard-coding Oracle’s ROWID into specific code. The ROWID structure in the past has changed from version to version and will probably change again in future releases. I recommend never hard-coding a ROWID.

Suppressing Indexes
Unintentionally suppressing indexes is one of the most common mistakes made by an inexperienced developer. SQL contains many traps that cause indexes not to be used. Some of the most common problems are discussed in the following sections.

The Oracle optimizer works behind the scenes to try to choose and exploit the most effective methods possible for retrieving your data. For example, there are multiple cases in which you don’t need to specify a WHERE clause for Oracle to use an index. If you query the MIN or MAX value of an indexed column, Oracle retrieves that value from the index rather than from the table. Similarly, if you perform a COUNT function on an indexed column, Oracle can count the index instead of the column. In the following sections, you will see situations in which the logic of the WHERE clause prevents Oracle from using an index.

Using the NOT EQUAL Operators: <>, !=
Indexes can only be used to find data that exists within a table. Whenever the NOT EQUAL operators are used in the WHERE clause, indexes on the columns being referenced cannot be used. Consider the following query on the CUSTOMERS table, which has an index on the CUST_RATING column. The following statement would result in a full table scan (since most records would usually be retrieved) even though the CUST_RATING column has an index:

```sql
select cust_id, cust_name
from customers
where cust_rating <> 'AAA';
```

When you analyze your tables, Oracle collects statistics about the distribution of data within the table. Using that analysis, the cost-based optimizer may decide to use the index for some values in your WHERE clause but not for other values. During application development and testing, you should use a representative set of rows so you can simulate the actual distribution of data values in the production environment.
TIP
You can create your indexes and analyze them in a single step by using the COMPUTE
STATISTICS clause of the CREATE INDEX command, but, as of 10g, Oracle always computes
statistics on all index create/rebuild operations when the index is not empty. You can also import
statistics from a production database to test out execution paths (refer to the Oracle 12cR2
Database Performance Tuning Guide). Oracle 12cR2 also has a V$INDEX_USAGE_INFO view for
additional information.

Using IS NULL or IS NOT NULL

When you use IS NULL or IS NOT NULL in your WHERE clauses, index usage is suppressed
because the value of NULL is undefined. There is no value in the database that will equal a NULL
value; not even NULL equals a NULL.

NULL values pose several difficulties for SQL statements. Indexed columns that have rows
containing a NULL value do not have an entry in the index (except for bitmapped indexes—which is
why bitmap indexes are usually fast for NULL searches). Under normal circumstances, the following
statement would cause a full table scan to be performed, even if the SAL column is indexed:

```sql
select empno, ename, deptno
from emp
where sal is null;
```

To disallow NULL values for the columns, use NOT NULL when creating or altering the table.
Note that if the table already contains data, you can only set a column to NOT NULL if it has a non-
NULL value for every row or if you use the DEFAULT clause of the ALTER TABLE command. The
following listing shows the modification of the EMP table’s SAL column to disallow NULL values:

```sql
alter table emp modify
(sal not null);
```

Note that an error will be returned if insertion of a NULL value is attempted for the SAL column.

TIP
Creating a table specifying NOT NULL for a column causes NULL values to be disallowed and
eliminates the performance problems associated with querying NULL values.

The following table creation statement provides a default value for the DEPTNO column. When a
value for the column is not specified during INSERTs, the default value is used. If a default value is specified and you do want a NULL value, then you need to insert a NULL into the column.

```
create table employee
(empl_id number(8) not null, first_name varchar2(20) not null,
 last_name varchar2(20) not null, deptno number(4) default 10);

insert into employee(empl_id, first_name, last_name)
values (8100, 'REGINA', 'NIEMIEC');
1 row created.

select *
from employee;

+----------+----------+----------+
<table>
<thead>
<tr>
<th>EMPL_ID</th>
<th>FIRST_NAME</th>
<th>LAST_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>8100</td>
<td>REGINA</td>
<td>NIEMIEC</td>
</tr>
</tbody>
</table>

insert into employee
values (8200, 'RICH', 'NIEMIEC', NULL);  
1 row created.

select *
from employee;

+----------+----------+----------+
<table>
<thead>
<tr>
<th>EMPL_ID</th>
<th>FIRST_NAME</th>
<th>LAST_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>8100</td>
<td>REGINA</td>
<td>NIEMIEC</td>
</tr>
<tr>
<td>8200</td>
<td>RICH</td>
<td>NIEMIEC</td>
</tr>
</tbody>
</table>
```

**TIP**

NULL values often cause indexes to be suppressed. Create a table specifying NOT NULL and DEFAULT for an unspecified column to help avoid a potential performance issue.

---

**Using LIKE**

LIKE, in some cases, uses an index, while in others, it does not. The most common uses of LIKE are LIKE ‘%somevalue%’ or LIKE ‘somevalue%’ (where the % is only at the end of the search string). Only one of these cases uses the index—the case where the value is first, LIKE ‘somevalue%’.

Let’s examine this using a set of examples. First, create an index on the SCOTT.EMP table for the ENAME column so you can use an index when looking up employee names. This allows you to see
when the index is used with a LIKE and when it is not.

Now let's examine what happens when using LIKE with ‘%somevalue%’:

```
SQL> create index emp_ename_nu on emp (ename);
Index created.

Now let’s examine what happens when using LIKE with ‘%somevalue%’:

SQL> set autotrace traceonly
SQL> select empno, ename, hiredate
2   from scott.emp
3   where ename like '%BLAKK%';

Execution Plan

Plan hash value: 3988160932

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>18</td>
<td>3</td>
<td>00:00:01</td>
</tr>
<tr>
<td>* 1</td>
<td>TABLE ACCESS FULL</td>
<td>EMP</td>
<td>1</td>
<td>18</td>
<td>3</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

Now let’s put the value first, before the ‘%’:

```
SQL> set autotrace traceonly
SQL> select empno, ename, hiredate
2   from scott.emp
3   where ename like 'BLAKK%';

Execution Plan

Plan hash value: 3415075538

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td>EMP</td>
<td>1</td>
<td>18</td>
<td>2</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>TABLE ACCESS BY INDEX ROWID</td>
<td>EMP</td>
<td>1</td>
<td>18</td>
<td>2</td>
<td>00:00:001</td>
</tr>
<tr>
<td>* 2</td>
<td>INDEX RANGE SCAN</td>
<td>emp_ename_nu</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>00:00:001</td>
</tr>
</tbody>
</table>

Notice that when the ‘%’ appears first, the index is not used, but when you put the value first, Oracle is able to utilize the index.
Using Functions

Unless you are using function-based indexes, applying functions on indexed columns in the WHERE clause of a SQL statement causes the optimizer to bypass indexes. Some of the most common functions are TRUNC, SUBSTR, TO_DATE, TO_CHAR, and INSTR. All of these functions alter the value of the column. Therefore, the indexes on the columns being referenced are not used. The following statement causes a full table scan to be performed, even if there is an index on the HIRE_DATE column (as long as it isn’t a function-based index):

```sql
select empno, ename, deptno
from emp
where trunc(hiredate) = '01-MAY-01';
```

Changing the statement to the following would allow for an index lookup:

```sql
select empno, ename, deptno
from emp
where hiredate >'01-MAY-01'
and hiredate < (TO_DATE('01-MAY-01') + 0.99999);
```

TIP

*By altering the values being compared to the column, and not the columns themselves, the indexes become available. Use this to eliminate full table scans.*

For further details on function-based indexes, see the “Function-Based Indexes” section later in this chapter.

Comparing Mismatched Data Types

One of the more difficult performance issues to resolve is caused by comparing differing data types. Oracle does not complain about the types being incompatible—quite the opposite. For example, Oracle implicitly converts the data in the VARCHAR2 column to match the numeric data type that it is being compared to. Consider the following example where ACCOUNT_NUMBER is a VARCHAR2.

If the ACCOUNT_NUMBER column uses a VARCHAR2 data type, the following statement may cause a full table scan to be performed, even if the ACCOUNT_NUMBER column is indexed:
Oracle internally changes the WHERE clause to be

```
SELECT bank_name, address, city, state, zip
FROM   banks
WHERE  account_number = 990354;
```

which suppresses the index. An EXPLAIN PLAN of this query only shows that the table was accessed using a “FULL SCAN” (usually to the coder’s bewilderment). To some DBAs and developers, this appears to be a rare situation, but in many systems, numeric values are zero-padded and specified as VARCHAR2. Rewrite the preceding statement as follows to use the index on the account number by correctly including the single quote marks for the field:

```
SELECT bank_name, address, city, state, zip
FROM   banks
WHERE  account_number = '000990354';
```

Alternatively, the ACCOUNT_NUMBER column could be defined to use the NUMBER data type, providing the leading zeros are not critical information for the column.

**TIP**

Comparing mismatched data types can cause Oracle to suppress an index internally. Even an EXPLAIN PLAN on the query will not help you understand why a full table scan is being performed. Only knowing your data types can help you solve this problem.

**Selectivity**

Oracle offers several methods to determine the benefit of using an index. Which method you should choose depends upon both the query and the data. First, determine the number of unique or distinct keys in the index. You can determine the number of distinct values by analyzing the table or the index. You can then query the DISTINCT_KEYS column of the USER_INDEXES view to examine the results of the analysis. By comparing the number of distinct keys to the number of rows in the table (as shown in the NUM_ROWS column of USER_INDEXES), you can determine the index’s selectivity. The greater the selectivity, the better an index will be for returning small numbers of rows.
TIP

An index's selectivity is what helps the cost-based optimizer determine an execution path. The more selective the index is, the fewer the number of rows that are returned, on average, for each distinct value. For concatenated indexes, the additional columns added to the index do not improve the selectivity greatly, and the cost of the additional columns may outweigh the gain.

The Clustering Factor

The clustering factor is a measure of the ordered-ness of an index in comparison to the table that it is based on. It is used to check the cost of a table lookup following an index access (multiplying the clustering factor by the index’s selectivity gives you the cost of the operation). The clustering factor records the number of blocks that will be read when scanning the index. If the index being used has a large clustering factor, then more table data blocks have to be visited to get the rows in each index block (because adjacent rows are in different blocks). If the clustering factor is close to the number of blocks in the table, then the index is well ordered, but if the clustering factor is close to the number of rows in the table, then the index is not well ordered. The clustering factor is computed by the following (explained briefly):

1. The index is scanned in order.
2. The block portion of the ROWID pointed at by the current indexed value is compared to the previous indexed value (comparing adjacent rows in the index).
3. If the ROWIDs point to different TABLE blocks, the clustering factor is incremented (this is done for the entire index).

The CLUSTERING_FACTOR column in the USER_INDEXES view gives an indication as to how organized the data is compared to the indexed columns. If the value of the CLUSTERING_FACTOR column value is close to the number of leaf blocks in the index, the data is well ordered in the table. If the value is not close to the number of leaf blocks in the index, then the data in the table is not well ordered. The leaf blocks of an index store the indexed values as well as the ROWIDs to which they point.

For example, say the CUSTOMER_ID for the CUSTOMERS table is generated from a sequence generator, and the CUSTOMER_ID is the primary key on the table. The index on CUSTOMER_ID would have a clustering factor very close to the number of leaf blocks (well ordered). As the customers are added to the database, they are stored sequentially in the table in the same way the sequence numbers are issued from the sequence generator (well ordered). An index on the CUSTOMER_NAME column would have a very high clustering factor, however, because the arrangement of the customer names is random throughout the table.

The clustering factor can impact SQL statements that perform range scans. With a low clustering factor (relative to the number of leaf blocks), the number of blocks needed to satisfy the query is reduced. This increases the possibility that the data blocks are already in memory. A high clustering factor relative to the number of leaf blocks may increase the number of data blocks required to satisfy a range query based on the indexed column.
The clustering of data within the table can be used to improve the performance of statements that perform range scan–type operations. By determining how the column is being used in the statements, indexing these column(s) may provide a great benefit.

The Binary Height

The binary height of an index plays a major role in the amount of I/O that needs to be performed to return the ROWID to the user process. Each level in the binary height adds an extra block that needs to be read, and because the blocks are not being read sequentially, they each require a separate I/O operation. In Figure 2-1, an index with a binary height of three returning one row to the user would require four blocks to be read: three from the index and one from the table. As the binary height of an index increases, so does the amount of I/O required to retrieve the data.
After analyzing an index, you can query the BLEVEL column of DBA_INDEXES to see its binary height:

```
EXECUTE DBMS_STATS.GATHER_INDEX_STATS ('SCOTT', 'EMP_ID1');
PL/SQL procedure successfully completed.

SELECT blevel, index_name
FROM dba_indexes
WHERE index_name = 'EMP_ID1';
  BLEVEL  INDEX_NAME

------------------------
  0  EMP_ID1
```

**TIP**
Analyzing the index or the table will provide the binary height of the index. Use the BLEVEL column in the USER_INDEXES view to check the binary height of the indexes.

The binary height increases mainly because of the number of non-NULL values for the indexed column in the table and the narrowness of the range of values in the indexed columns. Having a large number of deleted rows in the index can also increase the height. Rebuilding the index may help to decrease the height. While these steps reduce the number of I/Os performed against the index, the performance benefits may be small. If the number of deleted rows within an index approaches 20–25 percent, then rebuild the indexes to help reduce the binary height and the amount of empty space that is being read during an I/O.

**TIP**
In general, the larger the database block size, the smaller the binary height of the index. Each additional level in binary height (BLEVEL) adds additional performance costs during DML operations.

---

**FIGURE 2-1. Index with binary height or BLEVEL = 3 (Level 3 is where the leaf blocks reside.)**
The b-tree level (BLEVEL) is the depth of the index from its root block to its leaf blocks. A depth of 0 indicates that the root block and leaf block are the same. All indexes start out with a single leaf node (block), which represents a b-tree level of 0. As rows are added to the index, Oracle puts the data into the block/leaf node. Once the initial block fills as rows are inserted, two new blocks are created. Oracle handles this in two ways, typically known as a 90-10 index split or a 50-50 index split. Each type of split (only one or the other is executed) depends on the value being inserted:

- If the new value is greater than any values already in the index, then Oracle executes a 90-10 split by copying the values of the block into one of the new blocks and placing the new value in the other block.
- If the new value being inserted is not the maximum indexed value, then Oracle splits the block 50-50. It places the lower half of the indexed values in one of the new blocks and the higher half of the indexed values into the other new block.

The existing block, which was originally full, is updated to contain only pointers to the new leaf nodes and becomes a branch, specifically the root branch of the index. The resulting index now has a branch level of 1. As rows continue to be inserted into the index, when a leaf node fills, Oracle creates a new leaf block. If the value being inserted is greater than any value currently in the leaf node block, then Oracle places the new value into the new block. If the value is not MAX value, then Oracle splits the values of the block in half (50-50) by value, keeping the lower values in the current block and placing the higher values in the new block. Then the branch block for these leaf nodes is updated with the pointer for the new block and existing block. This continues until the branch node/block fills. When the branch node fills, the same block-split operation is performed. A new branch block is added and half the block is copied to the new block and the other half remains in the existing branch block. This does not increase either the height or BLEVEL of the index; it simply provides a new branch for a query to take when traversing the index. Only when a root branch block fills and splits does the height of the index increase.

**NOTE**
The only time two new blocks are created for an index is when the root branch block splits. The content in the current root block is split between the two new branch blocks, which form the top level of a higher index tree. The root block does not change its block address, and by adding two blocks when the split occurs at the root, the index tree is always balanced.

**Effects on Index from UPDATE Operations**
The index is only affected by an UPDATE if the columns in the table that make up the index are updated. Therefore, in many cases, UPDATE operations do not affect an index at all. When the table columns that make up the index are updated, the operation within the index is a DELETE and INSERT. The old value is marked as deleted, and a new value for the entry is inserted. Therefore, no true “update” is performed within the index, in the way you would typically think of an update being performed. Index entries are also cleaned out by Oracle’s delayed block cleanout feature. Only after
Effects on Index from DELETE Operations

DELETE operations for an index do not really remove the entry from the index to create empty space. When a DELETE operation occurs on a row in the table, the corresponding index entry is marked as deleted but remains in the index until it is cleaned out. The most common way to clean out an index entry is during an INSERT operation on that block. Index entries are also cleaned out by Oracle’s delayed block cleanout feature (this happens on a subsequent query, which could be a SELECT statement). After the index entry is deleted and the block cleaned, the space in the index block can be reused by new entries.

Effects on Index from UPDATE and DELETE Operations

There has been much debate and many myths about indexes regarding the effects DELETEs and UPDATEs have on them. I have explained how basic DELETEs and UPDATEs work in Oracle indexes, so let’s examine the true effect in detail. In DELETE operations, deletes are done by marking the index entry as deleted in the index, meaning that DELETE operations leave behind data in the leaf blocks that needs to be cleaned up. An INSERT operation in a leaf block, with rows marked for deletion, forces the cleanout of these rows, allowing the space to be “reused” by further inserts in that leaf block. Are there circumstances when that insert will not occur? Yes, but the index block is eventually cleaned out by the delayed block cleanout process.

UPDATE operations, along with DELETEs/INSERTs within the same transaction, tend to increase the size of an index greatly, but only if you perform these operations in large numbers within the same transaction (which is not recommended anyway). DELETEs in and of themselves do not cause higher index heights or BLEVELs, but are merely a symptom of the larger issue of reusing deleted row areas. This means that a high number of DELETE operations or UPDATE operations, or a large number of deleted/updated entries in a single transaction, can potentially cause the size, height, and BLEVEL to increase (but Oracle does not recommend you perform lots and lots of DML operations within the same transaction). The solution for this is to break up your transactions with commits, effectively creating multiple transactions for larger numbers of DELETE+INSERT operations. This helps reuse space and does not cause the index to grow artificially larger than it needs to be. This also explains why large DELETE operations that contain large INSERTs within the same transaction usually cause index growth.

In Oracle’s useful Ask Tom blog (https://asktom.oracle.com), Tom Kyte puts it this way:

Well, the fact is that indexes, like people, have a certain “weight” they like to be at. Some of us are chubby—some skinny—some tall—some short. Sure, we can go on a diet—but we tend to gravitate BACK to the weight we were. The same is true for indexes—what happened to this person is their index wanted to be wide and fat and EVERY MONTH they rebuilt it (put it on a diet). It would spend the first half of the month then getting fat again and generating gobs of redo due to the block splits it was undergoing to get there.

The moral of the story is to use locally managed tablespaces to avoid fragmentation and to rebuild indexes rarely (build them right the first time and only rebuild when performance degrades versus on
a regular basis).

**Effects on BLOCKSIZE**
As just covered, the height and branch level of an index only increase when a block split occurs and causes all the branch blocks up to the root block to also be split. The number of block splits, or more specifically, branch block splits, can be minimized by using larger block sizes for indexes. This is a reason why some experts believe that indexes should be created in larger block size tablespaces. If each block can hold more data, the need to split would occur far less frequently. Therefore, the overall number of branches and leaves could be reduced. This greatly depends on the size of the data for the indexed values—old block size versus new block size. Be careful when measuring the impact of a higher block size tabletop on an index. Moving an index to a larger block size tabletop involves rebuilding the index, which removes all entries marked for deletion and compresses space within the index, reclaiming the space of not only entries marked for deletion, but also entries deleted where space was not reclaimed or reused. Therefore, the full impact of a larger block size may not be as expected or as impressive when you consider what is truly going to occur.

**Using Histograms**

*Histograms* record the distribution of data when you analyze a table or index. With this information in hand, the cost-based optimizer can decide to use an index for conditions it knows will return a small number of rows and bypass the index when the condition will return many rows based on the limiting condition. The use of histograms is not limited to indexes. Any column of a table can have a histogram built on it.

The main reason for generating histograms is to help the optimizer plan properly if the data in a table is heavily skewed. For example, if one or two values make up a large percentage of a table, the related indexes may not help to reduce the number of I/Os required to satisfy the query. Creating a histogram lets the cost-based optimizer know when using the index is appropriate, or when 80 percent of the table is going to be returned because of the value in the WHERE clause.

When creating histograms, specify a size. This size relates to the number of buckets for the histogram. Each bucket will contain information about the value of the column(s) and the number of rows.

```sql
EXECUTE DBMS_STATS.GATHER_TABLE_STATS
('scott', 'company', METHOD_OPT=>'FOR COLUMNS SIZE 10 company code');
PL/SQL procedure successfully completed.
```

The preceding query creates a ten-bucket histogram on the COMPANY table, as shown in Figure 2-2. The values for the COMPANY_CODE column are divided into the ten buckets as displayed in the figure. This example shows a large number (80 percent) of the COMPANY_CODE is equal to 1430. As is also shown in the figure, most of the width-balanced buckets contain only 3 rows; a single bucket contains 73 rows. In the height-balanced version of this distribution, each bucket has the same number of rows and most of the bucket endpoints are 1430, reflecting the skewed distribution of the
Oracle’s histograms are height-balanced as opposed to width-balanced. Consequently, all of the buckets in the histogram contain the same number of rows. The starting and ending points for a bucket are determined by the number of rows containing those values. The width-balanced histogram specifies the range values for each bucket and then counts the number of rows within that range, not an ideal option.

**TIP**

*If the data in a table is skewed, histograms will provide the cost-based optimizer with a balanced picture of the distribution (by balancing it into buckets). Using the histograms on columns that are not skewed will not provide an increase in performance.*
By default, Oracle creates 254 buckets in a histogram. You can specify SIZE values ranging from 1 to 254.

**Fast Full Scans**

During a fast full scan of an index, Oracle reads all of the leaf blocks in a b-tree index. The index is being read sequentially, so multiple blocks can be read at once. The DB_FILE_MULTIBLOCK_READ_COUNT parameter in the initialization file controls the number of blocks that can be read simultaneously. The fast full scan usually requires fewer physical I/Os than a full table scan, allowing the query to be resolved faster.

The fast full scan can be used if all of the columns in the query for the table are in the index with the leading edge of the index not part of the WHERE condition (you may need to specify the INDEX_FFS hint as detailed in Chapter 7). In the following example, the EMP table is used. As shown earlier in this chapter, it has a concatenated index on the columns EMPNO, ENAME, and DEPTNO.

```sql
select empno, ename, deptno
from emp
where deptno = 30;
```

Because all of the columns in the SQL statement are in the index, a fast full scan is available. Index fast full scans are commonly performed during joins in which only the indexed join key columns are queried. As an alternative, Oracle may perform a skip-scan access of the index; the optimizer should consider the histogram for the DEPTNO column (if one is available) and decide which of the available access paths yields the lowest possible performance cost.

**TIP**

If the indexes are relatively small in comparison to the overall size of the table, the fast full scan may provide the performance burst necessary for the application. With concatenated indexes that contain most of the columns of a table, the index may be larger than the actual table and the fast full scan could cause performance degradation.

**Skip-Scans**

As discussed in the section “Concatenated Indexes” earlier in this chapter, the index skip-scan feature enables the optimizer to use a concatenated index even if its leading column is not listed in the WHERE clause. Index skip-scans are faster than full scans of the index, requiring fewer reads to be performed. For example, the following queries show the difference between a full index scan and a
skip-scan. See Chapter 6 to better understand the execution plan or the statistics displayed in the following listing. In this listing, the EMP5 table has many hundreds of thousands of rows.

Following the execution of the queries, the listing shows the time the query took, its execution path within the database, and statistics showing the number of logical reads (consistent gets) and physical reads required to resolve the query:

```sql
create index skip1 on emp5(job, empno);
Index created.

select count(*)
from emp5
where empno = 7900;
Elapsed: 00:00:03.13 (Result is a single row...not displayed)

<table>
<thead>
<tr>
<th>Execution Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>0  SELECT STATEMENT Optimizer=CHOOSE (Cost=4 Card=1 Bytes=5)</td>
</tr>
<tr>
<td>1  0  SORT (AGGREGATE)</td>
</tr>
<tr>
<td>2  1  INDEX (FAST FULL SCAN) OF 'SK1P1' (NON-UNIQUE)</td>
</tr>
</tbody>
</table>

Statistics
6826  consistent gets
6819  physical reads

select /*+ index_ss(emp5 skip1) */ count(*)
from emp5
where empno = 7900;
Elapsed: 00:00:00.56

<table>
<thead>
<tr>
<th>Execution Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>0  SELECT STATEMENT Optimizer=CHOOSE (Cost=6 Card=1 Bytes=5)</td>
</tr>
<tr>
<td>1  0  SORT (AGGREGATE)</td>
</tr>
<tr>
<td>2  1  INDEX (SKIP SCAN) OF 'SK1P1' (NON-UNIQUE)</td>
</tr>
</tbody>
</table>

Statistics
21  consistent gets
17  physical reads
```

As shown in the listing, the second option used an INDEX_SS (SKIP SCAN) operation to read the index. That execution path required 21 logical reads, which, in turn, required 17 physical I/Os. The first option performed an INDEX (FAST FULL SCAN) operation, which required a significantly greater number of logical and physical I/Os.

To influence the optimizer to choose a skip-scan, you may need to use a hint in the query as shown in the listing. The hint influences the optimizer and biases it toward the execution path you specify.
For large tables with concatenated indexes, the index skip-scan feature can provide quick access even when the leading column of the index is not used in a limiting condition.

Types of Indexes
The following is a list of indexes discussed in this section:

- B-tree
- Bitmap
- Hash
- Index-organized table
- Reverse key
- Function-based
- Partitioned (local and global)
- Bitmap join indexes

B-Tree Indexes

_B-tree_ indexes are the general-purpose indexes in Oracle. They are the default index types created when creating indexes. B-tree indexes can be single-column (simple) indexes or composite/concatenated (multicolumn) indexes. B-tree indexes can have up to 32 columns.

In Figure 2-3, a b-tree index is created on the LAST_NAME column of the EMPLOYEE table. This index has a binary height of three; consequently, Oracle must go through two branch blocks to get to the leaf block containing the ROWID. Within each branch block, there are branch rows containing the block ID of the next block ID within the chain.
A leaf block contains the index values, the ROWID, and pointers to the previous and next leaf blocks. Oracle has the ability to transverse the binary tree in both directions. B-tree indexes contain the ROWIDs for every row in the table that has a value in the indexed column. Oracle does not index rows that contain NULL values in the indexed column. If the index is a concatenation of multiple columns and one of the columns contains a NULL value, the row will be in the index and the column containing the NULL value will be left empty.

**TIP**

The values of the indexed columns are stored in an index. For this reason, you can build concatenated (composite) indexes that can be used to satisfy a query without accessing the table. This eliminates the need to go to the table to retrieve the data, reducing I/O.
Bitmap Indexes

**Bitmap** indexes are ideal for decision support systems (DSSs) and data warehouses. They should not be used for tables accessed via transaction-processing applications. Bitmap indexes provide fast access to very large tables using low to medium cardinality (low to medium number of distinct values) columns. Although bitmap indexes can have up to 30 columns, they are generally used for a small number of columns.

For example, your table may contain a column called **GENDER** with two possible values: male and female. The cardinality would be only 2, and it would be a prime candidate for a bitmap index if users frequently query the table by the value of the **GENDER** column. The real power of the bitmap index is seen when a table contains multiple bitmap indexes. With multiple bitmap indexes available, Oracle has the ability to merge the result sets from each of the bitmap indexes to eliminate the unwanted data quickly.

The following listing shows an example of creating a bitmap index:

```sql
create bitmap index dept_idx2_bm on dept (deptno);
Index created.
```

**TIP**

*Use bitmap indexes for columns with a low cardinality. An example would be a column called GENDER with two possible values of “male” or “female” (the cardinality is only 2). Bitmaps are very fast for low-cardinality columns (few distinct values) because the size of the index is substantially smaller than a b-tree index. Since they are very small when compared to a low-cardinality b-tree index, you can often retrieve over half of the rows in the table and still use a bitmap index.*

Bitmap indexes usually outperform b-trees when loading tables (INSERT operations) in batch (single-user) operations when the bulk of the entries do not add new values to the bitmap. You should not use bitmap indexes when multiple sessions will be concurrently inserting rows into the table, as occurs in most transaction-processing applications.

**Bitmap Index Example**

Consider a sample table called **PARTICIPANT** that contains surveys from individuals. Each of the columns **AGE_CODE**, **INCOME_LEVEL**, **EDUCATION_LEVEL**, and **MARITAL_STATUS** has a separate bitmap index built on it. The balance of the data in each histogram and the execution path for a query accessing each of the bitmap indexes are displayed in Figure 2-4. The execution path in the figure shows how the multiple bitmap indexes have been merged, creating a significant performance gain.
As shown in Figure 2-4, the optimizer uses each of the four separate bitmap indexes whose columns were referenced in the WHERE clause. Each bitmap contains binary values (like 1 or 0) that indicate which rows (often ranges of rows, making it smaller than a normal index) contain the indexed value. Given that, Oracle then performs a BITMAP AND operation on the table containing the indexed value. Given that, Oracle then performs another BITMAP AND operation to find which rows would be returned from all four of the bitmaps. That value is then converted into a ROWID value and the query proceeds with the rest of the processing. Note that all four of the columns had very low cardinality, yet the index allowed the matching rows to be returned very quickly.

**TIP**

Merging multiple bitmap indexes can lead to significant performance improvement when combined in a single query. Bitmap indexes also work better with fixed-length data types than they do with variable-length data types. Large block sizes improve the storage and read performance of bitmap
The following query displays index types. B-tree indexes are listed as ‘NORMAL’; bitmap indexes will have an INDEX_TYPE value of ‘BITMAP’.

```sql
select index_name, index_type
from user_indexes;
```

**TIP**

To query a list of your bitmap indexes, query the INDEX_TYPE column in the USER_INDEXES view.

Bitmap indexes are not generally recommended for online transaction processing (OLTP) applications. B-tree indexes contain a ROWID with the indexed value. So, when updating tables and their indexes, Oracle has the ability to lock individual rows. Bitmap indexes are stored as compressed indexed values, which can contain a range of ROWIDs. Therefore, Oracle has to lock the entire range of the ROWIDs for a given value. This type of locking has the potential to cause deadlock situations with certain types of DML statements. SELECT statements are not affected by this locking problem. A solution to updates is to drop the index, do the updating in batch during off-hours, and then rebuild the bitmap index (you could also add/drop an index on a column(s) that makes the update faster possibly as well).

Bitmap indexes have several restrictions:

- Bitmap indexes are not considered by the rule-based optimizer.
- Performing an ALTER TABLE statement and modifying a column that has a bitmap index built on it invalidates the index.
- Bitmap indexes do not contain any of the data from the column and cannot be used for any type of integrity checking.
- Bitmap indexes cannot be declared as unique.
- Bitmap indexes have a maximum length of 30 columns.

**TIP**

Don’t use bitmap indexes in heavy OLTP environments. Bitmap indexes are often much smaller than other indexes.
Hash Indexes

Using hash indexes requires the use of hash clusters. I don’t see many people using these! When you create a cluster or hash cluster, you define a cluster key. The cluster key tells Oracle how to store the tables in the cluster. When data is stored, all the rows relating to the cluster key are stored in the same database blocks, regardless of what table they belong to. With the data being stored in the same database blocks, using the hash index for an exact match in a WHERE clause enables Oracle to access the data by performing one hash function and one I/O—as opposed to accessing the data by using a b-tree index with a binary height of three, where potentially four I/Os would need to be performed to retrieve the data. As shown in Figure 2-5, the query is an equivalence query, matching the hashed column to an exact value. Oracle can quickly use that value to determine where the row is physically stored, based on the hashing function.

![Diagram of hash indexing](image)

**FIGURE 2-5. Using hash indexes**

Hash indexes can potentially be the fastest way to access data in the database, but they do come with their drawbacks. The number of distinct values for the cluster key needs to be known before creating the hash cluster. This value needs to be specified at the time of creation. Underestimating the number of distinct values can cause collisions (two cluster key values with the same hash value) within the cluster, which are very costly. Collisions cause overflow buffers to be used to store the
additional rows, thus causing additional I/O. If the number of distinct hash values has been underestimated, the cluster will need to be re-created to alter the value. An ALTER CLUSTER command cannot change the number of HASHKEYS.

Hash clusters have a tendency to waste space. If it is not possible to determine how much space is required to hold all of the rows for a given cluster key, space may be wasted. If it is not possible to allocate additional space within the cluster for future growth, then hash clusters may not be the best option.

If the application often performs full table scans on the clustered table(s), hash clusters may not be the appropriate option. Because of the amount of empty space within the cluster to allow for future growth, full table scans can be very resource-intensive.

Caution should be taken before implementing hash clusters. Revise the application fully to ensure that enough information is known about the tables and data before implementing this option. Generally, hashing is best for static data with primarily sequential values.

**TIP**

Hash indexes are most useful when the limiting condition specifies an exact value rather than a range of values.

---

**Index-Organized Tables**

An *index-organized table* alters the storage structure of a table to that of a b-tree index, sorted on the table’s primary key. This unique type of table is treated like any other table—all DML and DDL statements are allowed. ROWIDs are not associated with the rows in the table because of the structure of the table.

Index-organized tables provide faster key-based access to the data for statements involving exact match and range searches on the primary key columns. UPDATE and DELETE statements based on the primary key values should perform better because the rows are physically ordered. The amount of storage required is reduced because values of the key columns are not duplicated in the table and then again in an index.

If you do not frequently query the data by the primary key column, then you will need to create secondary indexes on other columns in the index-organized table. Applications that do not frequently query tables by their primary keys do not realize the full benefits of using index-organized tables. Consider using index-organized tables for tables that are always accessed using exact matches or range scans on the primary key.

**TIP**
Reverse Key Indexes

When sequential data is loaded, the index may encounter I/O-related bottlenecks. During the data loads, one part of the index, and one part of the disk, may be used much more heavily than any other part. To alleviate this problem, you should store your index tablespaces on disk architectures that permit the files to be physically striped across multiple disks.

Oracle provides reverse key indexes as another solution to this performance problem. When data is stored in a reverse key index, its values are reversed prior to being stored in the index. Thus, the values 1234, 1235, and 1236 are stored as 4321, 5321, and 6321. As a result, the index may update different index blocks for each inserted row.

TIP
If you have a limited number of disks and large concurrent sequential loads to perform, reverse key indexes may be a viable solution.

You cannot use reverse key indexes with bitmap indexes or index-organized tables.

Function-Based Indexes

You can create function-based indexes on your tables. Without function-based indexes, any query that performed a function on a column could not use that column’s index. For example, the following query could not use an index on the JOB column unless it is a function-based index:

```
select *
from emp
where UPPER(job) = 'MGR';
```

The following query could use an index on the JOB column, but it would not return rows where the JOB column had a value of ‘Mgr’ or ‘mgr’:

```
select *
from emp
where job = 'MGR';
```
You can create indexes that allow function-based columns or data to be supported by index accesses. Instead of creating an index on the JOB column, you can create an index on the column expression UPPER(job), as shown in the following listing:

```sql
CREATE INDEX EMP_UPPER_JOB ON
   EMP (UPPER(job));
```

Although function-based indexes can be useful, be sure to consider the following questions when creating them:

- Can you restrict the functions that will be used on the column? If so, can you restrict all functions from being performed on the column?
- Do you have adequate storage space for the additional indexes?
- How will the increased number of indexes per column impact the performance of DML commands against the table?

Function-based indexes are useful, but you should implement them sparingly. The more indexes you create on a table, the longer all DML statements (INSERTs, UPDATEs, and DELETEs) will take.

**NOTE**

For function-based indexes to be used by the optimizer, you must set the `QUERY_REWRITE_ENABLED` initialization parameter to `TRUE`.

To see the magnitude of the benefit of function-based indexes, consider the following example that queries a table named SAMPLE that contains 1.4 million rows (note that you must first create the RATIO function; it is not built in):
Partitioned Indexes

A partitioned index is simply an index broken into multiple pieces. By breaking an index into multiple physical pieces, you are accessing much smaller pieces (faster), and you may separate the pieces onto different disk drives (reducing I/O contention). Both b-tree and bitmap indexes can be partitioned. Hash indexes cannot be partitioned. Partitioning can work several different ways. The tables can be partitioned and the indexes are not partitioned; the table is not partitioned but the index is; or both the table and index are partitioned. Either way, the cost-based optimizer must be used. Partitioning adds many possibilities to help improve performance and increase maintainability.

There are two types of partitioned indexes: local and global. Each type has two subsets, prefixed and non-prefixed. A table can have any number or combination of the different types of indexes built on its columns. If bitmap indexes are used, they must be local indexes. The main reason to partition the indexes is to reduce the size of the index that needs to be read and to enable placing the partitions in separate tablespaces to improve reliability and availability.

Oracle also supports parallel query and parallel DML when using partitioned tables and indexes (see Chapter 11 for more information), adding the extra benefit of multiple processes helping to process the statement faster.

Local (Commonly Used Indexes)

Local indexes are indexes that are partitioned using the same partition key and same range boundaries as the partitioned table. Each partition of a local index will only contain keys and ROWIDs from its corresponding table partition. Local indexes can be b-tree or bitmap indexes. If they are b-tree indexes, they can be unique or non-unique.

Local indexes support partition independence, meaning that individual partitions can be added, truncated, dropped, split, taken offline, etc., without dropping or rebuilding the indexes. Oracle maintains the local indexes automatically. Local index partitions can also be rebuilt individually while the rest of the partition is unaffected.
Prefixed indexes are indexes that contain keys from the partitioning key as the leading edge of the index. For example, let’s take the PARTICIPANT table again. Say the table was created and range-partitioned using the SURVEY_ID and SURVEY_DATE columns and a local prefixed index is created on the SURVEY_ID column. The partitions of the index are *equipartitioned*, meaning the partitions of the index are created with the same range boundaries as those of the table (see Figure 2-6).

![Partitioned, prefixed indexes](image)

**FIGURE 2-6.** Partitioned, prefixed indexes

**TIP**
Local prefixed indexes allow Oracle to prune unneeded partitions quickly. The partitions that do not contain any of the values appearing in the WHERE clause will not need to be accessed, thus improving the statement’s performance.

Non-prefixed indexes are indexes that do not have the leading column of the partitioning key as the leading column of the index. Using the same PARTICIPANT table with the same partitioning key (SURVEY_ID and SURVEY_DATE), an index on the SURVEY_DATE column would be a local non-prefixed index. A local non-prefixed index can be created on any column in the table, but each partition of the index only contains the keys for the corresponding partition of the table (see Figure 2-7).
For a non-prefixed index to be unique, it must contain a subset of the partitioning key. In this example, you would need a combination of columns, including the SURVEY_DATE and/or the SURVEY_ID columns (as long as the SURVEY_ID column was not the leading edge of the index, in which case it would be a prefixed index).

**TIP**

*For a non-prefixed index to be unique, it must contain a subset of the partitioning key.*

**Global**

*Global* partitioned indexes contain keys from multiple table partitions in a single index partition. The partitioning key of a global partitioned index is different or specifies a different range of values from the partitioned table. The creator of the global partitioned index is responsible for defining the ranges and values for the partitioning key. Global indexes can only be b-tree indexes. Global partitioned indexes are not maintained by Oracle by default. If a partition is truncated, added, split, dropped, etc., the global partitioned indexes need to be rebuilt unless you specify the UPDATE GLOBAL INDEXES clause of the ALTER TABLE command when modifying the table. With Oracle Database 12c, when you drop or truncate a partition, the global indexes are no longer invalid and managed automatically.

**Prefixed** Normally, global prefixed indexes are not equipartitioned with the underlying table. Nothing prevents the index from being equipartitioned, but Oracle does not take advantage of the equipartitioning when generating query plans or executing partition maintenance operations. If the index is going to be equipartitioned, it should be created as a local index to allow Oracle to maintain the index and use it to help prune partitions that will not be needed (see Figure 2-8). As shown in the figure, the three index partitions each contain index entries that point to rows in multiple table partitions.
If a global index is going to be equipartitioned, it should be created as a local index to allow Oracle to maintain the index and use it to help prune partitions, or exclude those partitions that are not needed by the query.

**Non-prefixed** Global non-prefixed indexes should not be used as Oracle does not support them. They do not provide any benefits over normal B-tree indexes on the same columns, so they have no value.

New 12cR2 Features for Partitioned Indexes
Several new features for partitioned tables are discussed in Chapter 3, which covers partitioned tables in detail. Those new features affect the underlying partitioned index, so I list them here (see Chapter 3 for more detail):

- **SPLIT** and **MERGE PARTITION** are now online operations for heap-organized tables.
- A nonpartitioned table can be converted online to a partitioned table (including indexes).
- List partitioning may now be on multiple partitioned columns.
- Composite partitioned tables may use list partitions on subpartitions.
- Partitions and subpartitions can be set to read-only.

**TIP**

*In 12cR2 you can do an online conversion of a nonpartitioned table to a partitioned table, including the indexes. You can also set partitions and subpartitions to be read-only.*

**Bitmap Join Indexes**

A **bitmap join** index is a bitmap index based on the join of two tables. Bitmap join indexes are used in data warehousing environments to improve the performance of queries that join dimension tables to fact tables. When creating a bitmap join index, the standard approach is to join a commonly used dimension table to the fact table within the index. When a user queries the fact table and the dimension table together in a query, the join does not need to be performed because the join results are already available in the bitmap join index. Further performance benefits are gained from the compression of ROWIDs within the bitmap join index, reducing the number of I/Os required to access the data.

When creating a bitmap join index, you specify both tables involved. The syntax should follow this model:

```sql
create bitmap index FACT_DIM_COL_IDK
  on FACT(DIM.Descr_Col)
from FACT, DIM
where FACT.JoinCol = DIM.JoinCol;
```

The syntax for bitmap joins is unusual in that it contains both a FROM clause and a WHERE clause, and it references two separate tables. The indexed column is usually a description column within the dimension table—that is, if the dimension is CUSTOMER and its primary key is CUSTOMER_ID, you would normally index a column such as CUSTOMER_NAME. If the FACT table is named SALES, you might create an index using the following command:
If a user then queries the SALES and CUSTOMER tables with a WHERE clause that specifies a value for the CUSTOMER_NAME column, the optimizer can use the bitmap join index to return the rows quickly that match both the join condition and the CUSTOMER_NAME condition.

The use of bitmap join indexes is restricted; you can only index the columns in the dimension tables. The columns used for the join must be primary key or unique constraints in the dimension tables, and if it is a composite primary key, you must use each of the columns in your join. You cannot create a bitmap join index on an index-organized table, and the restrictions that apply to regular bitmap indexes also apply to bitmap join indexes.

Fast Index Rebuilding

The REBUILD option of the ALTER INDEX statement is executed to rebuild an index quickly using the existing index instead of the table:

```sql
alter index cust_idx1 rebuild parallel
tablespace cust_tblspc1
storage (pctincrease 0);
Index altered.
```

Modifications to the STORAGE clause can be made at this time and the parallel option may also be used.

**TIP**

Use the REBUILD option of the ALTER INDEX statement for quickly rebuilding an index using the existing index instead of the table. You must have enough space to store both indexes during this operation.

Rebuilding Indexes Online

You can create or rebuild indexes even when doing DML (INSERT/UPDATE/DELETE) statements on the base table. However, rebuilding during low DML activity is still better. Prior to Oracle 11g, this required an exclusive lock at the beginning and end of the rebuild. This lock could cause DML delays and a performance spike. This lock is no longer required for this operation, and rebuilding
indexes online is now much faster! Rebuilding is also faster than a DROP and CREATE index. Here’s the basic syntax:

```sql
CREATE INDEX index_name ON table (col1,...) ONLINE;
Index created.

ALTER INDEX index_name REBUILD ONLINE;
Index altered.
```

Note that rebuilding an index is not the same as coalescing an index. A nice comparison is shown here:

**Rebuild**
- Quickly moves index to another tablespace
- Requires more disk space
- Creates new index tree and shrinks heights
- Changes storage/tablespace w/o dropping

**Coalesce**
- Can’t move index to another tablespace
- Requires much less disk space than rebuild
- Coalesces leaf blocks that are in the same branch
- Quickly frees index leaf blocks for use

**TIP**
You can use the REBUILD ONLINE option to allow DML operations on the table or partition during the index rebuild. You cannot specify REBUILD ONLINE for bitmap indexes or for indexes that enforce referential integrity constraints.

**TIP**
Rebuilding indexes online during high levels of DML activity in 12cR2 is much faster than it was in 10g.

**Tips Review**

- As you upgrade Oracle versions, be sure to test your application’s queries to determine whether the execution paths for your queries still use the indexes that were used prior to the upgrade. See if the execution plan has changed and if it is better or worse.
- Query DBA_INDEXES and DBA_IND_COLUMNS to retrieve a list of the indexes on a given
By using invisible indexes, you can “turn off” indexes temporarily (make them invisible) to check how queries will perform without them. Since invisible indexes continue to be maintained while invisible, turning them back on (making them visible again) if needed is fast and simple.

In 12c, invisible indexes are also the means for creating multiple indexes on the same column(s). This allows for one type of index for daytime processing and another for nightly processing, and perhaps even another type for monthly processing. Only one index may be visible at a time (other than function-based indexes).

You can create your indexes and analyze them in a single step by using the COMPUTE STATISTICS clause of the CREATE INDEX command, but, as of 10g, Oracle always computes statistics on all index create/rebuild operations when index is not empty.

Using the default values clause for a table column causes NULL values to be disallowed and eliminates the performance problems associated with using NULL values.

By using functions (such as a TO_DATE or TO_CHAR) that alter the values being compared to a column and not the columns themselves, the indexes are used. The indexes might have been suppressed had you used the function on the column itself.

Comparing mismatched data types can cause Oracle to suppress an index internally. Even an EXPLAIN PLAN (covered in Chapter 6) on the query will not help you understand why a full table scan is being performed.

An index’s selectivity is what helps the cost-based optimizer determine an execution path. The more selective, the fewer number of rows will be returned. Improve selectivity by creating concatenated/composite (multicolumn) indexes.

Analyzing the index or the table provides the binary height of the index. Use the BLEVEL column in the USER_INDEXES view to check the binary height of the index.

If the number of deleted rows within an index approaches 20–25 percent, rebuild the index to help reduce the binary height and the amount of empty space that is being read during an I/O.

If the data in a table is skewed, histograms provide the cost-based optimizer with a picture of the distribution. Using the histograms on columns that are not skewed will not provide a performance increase but will probably degrade it.

For large tables with concatenated indexes, the index skip-scan feature provides quick access even when the leading column of the index is not used in a limiting condition.

The values of the indexed columns are stored in an index. For this reason, you can build concatenated (composite) indexes that can be used to satisfy a query without accessing the table. This eliminates the need to go to the table to retrieve the data, reducing I/O.

Use bitmap indexes for columns with a low cardinality. An example is a column called GENDER with two possible values of “male” or “female” (the cardinality is only 2).

To query a list of your bitmap indexes, query the USER_INDEXES view.
Don’t use bitmap indexes to avoid locking issues, where many INSERTs occur on tables, such as heavy OLTP environments; learn the restrictions associated with bitmap indexes.

Consider using index-organized tables for tables that are always accessed using exact matches or range scans on the primary key.

If you have a limited number of disks and large concurrent sequential loads to perform, reverse key indexes may be a viable solution.

For function-based indexes to be used by the optimizer, you must set the QUERY_REWRITE_ENABLED initialization parameter to TRUE.

Local prefixed indexes allow Oracle to prune unneeded partitions quickly. The partitions that do not contain any of the values appearing in the WHERE clause will not need to be accessed, thus improving the statement’s performance.

Specify the UPDATE GLOBAL INDEXES clause of the ALTER TABLE command when modifying a partitioned table. By default, you need to rebuild global indexes when altering a partitioned table.

Use bitmap join indexes to improve the performance of joins within data warehousing environments.

Use the REBUILD option of the ALTER INDEX statement for quickly rebuilding an index using the existing index instead of the table.

You can use the REBUILD ONLINE option to allow DML operations on the table or partition during the index rebuild. You cannot specify REBUILD ONLINE for bitmap indexes or for indexes that enforce referential integrity constraints. This option has been improved and is faster and better in 12cR2.

In 12cR2 you can do an online conversion of a nonpartitioned table to a partitioned table, including the indexes. You can also set partitions and subpartitions to be read-only.

References
Kevin Loney and Bob Bryla, Oracle Database 11g DBA Handbook (Oracle Press, 2007).
My Oracle Support NOTE: 39836.1.
Server Concepts and Server References (Oracle Corporation).
Server Concepts (Oracle Corporation).
Server Reference (Oracle Corporation).

Dave Radoicic did the main update for 12cR2. Greg Pucka contributed a major portion of this original chapter. Kevin Loney contributed the major portion of the 10g update to this chapter. Rich Niemiec added 11g new content and Mike Messina tested queries and added BLEVEL detail for the
11g version.
With 12c, Oracle has changed the structure of a database. We now have multitenant databases with the introduction of pluggable databases (PDBs). Oracle also changed the landscape of disk access in Oracle 10g with the release of Automatic Storage Management (ASM). With the releases of Oracle 11g and 12c, more features have been added to ASM to make it even more robust. ASM is now the standard for Oracle databases! This chapter will focus heavily on pluggable databases and ASM in addition to the non-ASM-specific disk implementation methodology in Oracle.

In addition to its broad coverage of ASM and disk management, this chapter will start with an introduction to 12c multitenant databases, which include container databases (CDBs) and PDBs. Starting with 12c, Oracle supports a new architecture that lets you have subdatabases inside a single database. Oracle calls the subdatabases PDBs and the main database a CDB. Within the main CDB, there can be a maximum of 252 subdatabases (PDBs) in 12cR1 and 4096 in 12cR2. With this new feature, you can consolidate databases rather than having them scattered in multiple instances, which makes patching and provisioning of databases simpler.

In the last several years, disk configuration techniques seemed to be reaching the point where you couldn’t do much more to improve the performance of your system without greatly complicating your life as a DBA. If your system operated with some unique qualities, or you chose to review the I/O activity on your tablespaces on a frequent basis, you might be able to achieve slightly better performance than simply mashing all your disk use into a single logical device, but for most DBAs, this just wasn’t worth it. If you used raw partitions and were diligent, you could get some performance advantages from using that “technology,” but again, it didn’t simplify your life as a DBA. Then with the enormous leap in the capacity of single devices, even in the high-end Fibre Channel sector, things were further complicated; restricting yourself to only four or six very large disks was simple, whereas before you may have had a full array or multiple arrays of disks. In the most recent releases of the Oracle Database, you have been given a whole new toolbox. With a full X6-2 Exadata with an entire flash array of storage, you can now have 180T of flash. The Oracle FS1 flash array has almost a petabyte of flash (912T).

More features are now available for managing how the data resides on disk. And more have been released in the last 24 months with Exadata (most recently X6). To make it even better, almost anyone running an Oracle database can use these new features. Don’t worry, this chapter will still talk about balancing your disk (including 12c sharding) and eliminating fragmentation, but it will also discuss
new features you can utilize to rid yourself of the repeated effort these activities required in the past or, very possibly, prevent you from having to do them altogether.

To keep your system running at its peak, this chapter offers the following tips:

- Exploiting 12c new features for pluggable databases and 12cR2 features
- Understanding storage hardware and its performance implications
- Understanding RAID levels
- Using the 12c Heat Map and 12c I/O performance views
- Understanding bigfile tablespaces and getting to the 8-exabyte Oracle 12c database
- Understanding ASM instances including the 12c install and 12c new features
- Understanding ASM disks, diskgroups, and multipathing
- Avoiding disk contention and managing large tables by using partitions
- Sizing extents properly to eliminate fragmentation, reduce chaining, and keep performance optimal
- Managing redo and rollbacks in the database for speed
- Having multiple control files on different disks and controllers
- Understanding issues to consider in the planning stages of your system

Pluggable Databases (New in Oracle 12c)

I’m starting the chapter with an introduction to pluggable databases since it is such a key feature in 12c. While the focus of the book is tuning, I do want to ensure you have an arsenal of commands to be able to work with this new feature, but please read the Oracle Database Administrator’s Guide for complete coverage of this topic (this chapter will only get you started and exposed to PDBs).

“Pluggable” databases can be unplugged from one container database (CDB) and plugged into another CDB easily, therefore making databases portable between environments and allowing the upgrade of a database by unplugging it from one environment at one version and plugging it into a new environment at a higher version. You can also unplug a PDB from on premises and plug it into the cloud (or vice versa). This new feature also allows a single PDB to be independently recovered (you can flashback a PDB in 12cR2). Each PDB looks to an application like any other traditional Oracle database (called a non-CDB), so no application changes are needed to work with the PDB architecture. Non-CDBs are now deprecated. The following are some notes to keep in mind when working with a CDB and PDBs. Keep in mind that these are subject to change.

- CDB = container database (has a root database and also a seed PDB).
- PDB = pluggable database (plugged into a CDB).
- Non-CDB = traditional Oracle database instance (neither a CDB nor a PDB).
- Why PDBs? To consolidate hundreds of databases on one machine. Too many resources are
required when you add up the System Global Areas (SGAs) for each of the instances when not using PDBs. One CDB has one SGA and resources shared for multiple PDBs.

- Share PDBs (e.g., big data sources, acquisitions, partners, shared research, governments).
- Quickly create a new database (PDB) or copy an existing one (PDB).
- In 12cR2, can refresh a read-only PDB.
- In 12cR2, can flashback an individual PDB.
- Recover an individual PDB.
- Move existing PDBs to a new platform or location or clone them (snapshot).
- Patch/upgrade a PDB by plugging it into a CDB at a later version.
- Physical machine runs more PDBs the old way; easier to manage/tune.
- Back up entire CDB + any number of PDBs.
- New syntax for commands: PLUGGABLE DATABASE.

The following sections show a few commands that you can run with pluggable databases. The need to easily move data around is becoming increasingly important in many scenarios: integrating big data sources; company acquisitions; moving data to/from the cloud; sharing research among partners; and governments sharing security or other data. To give you a taste of what’s possible, the following are a few nice examples of queries for the multitenant world.

Is the database a CDB or non-CDB?

```sql
select name, created, cdb, con_id
from v$database;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>CREATED</th>
<th>CDB</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDB1</td>
<td>19-FEB-12</td>
<td>YES</td>
<td>0</td>
</tr>
</tbody>
</table>

This example is a CDB, as indicated by YES in the CDB column.

You can also query the PDBs. In this example, I have three PDBs, but only PDB_SS and PDB1 were created by me. PDB$SEED was created by Oracle when I installed the database. I can clone the seed PDB to create new, empty PDBs.
CDB or PDB Created Objects

Some items are specific to only the CDB, some are specific to only the PDB, and some are shared by both (or the DBA can choose to create separate or shared). The following list details which items are specific to the CDB, PDB, or shared by both:

- **Background processes/SGA** Shared by root and all PDBs
- **Character set** Shared by root and all PDBs
- **Redo** Shared by root and all PDBs
- **Undo** Shared by root and all PDBs
- **Time zones** Shared or can be set for each PDB
- **Initialization parameters** Some can be set by PDB
- **Temporary tablespace** Shared by PDBs or create your own local TEMP
- **SYSTEM and SYSAUX** Separate for root and each PDB
- **Datafiles** Separate for root and each PDB (same block size)

**Pluggables 0 – 254+**

Oracle has the capability to support up to 252 PDBs in 12cR1 and 4096 PDBs in 12cR2. Here is what is in each container:

- **Entire CDB** => Container ID = 0
- **Root (CLBSROOT)** => Container ID = 1
- **Seed (PDBSSEED)** => Container ID = 2
- **PDBs** => Container ID = 3 to 1000s

- **Whole CDB or non-CDB**
- **All objects about PDBs stored**
- **Used as a source to clone**
- **PDBs used for applications**
Creating a PDB: Many Ways to Do It

There are many ways to create a PDB. Most DBAs create new PDBs by cloning the seed PDB and then going from there. For example, creating a PDB to use for a warehouse application may be accomplished by cloning from another PDB that holds OLTP data. You may also get a clone from another system, which includes the XML file (small) and datafiles (large), and create your PDB based on those files, which is fast since the data only needs to be attached, not imported. The commands for many of these options are provided in the following section, but these are the ways to create a PDB:

- Create a PDB by copying the seed PDB (common way)
- Create a PDB by cloning another PDB (very common way)
- Create a PDB by using the XML metadata files and other files and plugging them into a CDB (very common way)
- Create a PDB using a non-CDB (multiple ways):
  - Use DBMS_PDB to create an unplugged PDB (less common)
  - Create an empty PDB and use Data Pump to move data (common way)
  - Use GoldenGate replication (common for initial migration)

Great Pluggable Database Commands

This section contains many of the commands that you’ll be using with multitenant (pluggable) databases. These include commands for creating pluggable databases, moving between containers (most of which are different PDBs or the main root), starting and shutting down, and finding out where the actual data in tables resides (in which PDB).

Cloning a PDB
The following three examples show how to create a PDB from another PDB. All three allow different settings for the new PDB, and the last example shows how to do it over a link.

NOTE
The source no longer needs to be read-only in 12cR2 (PDB hot clone as long as the database is in ARCHIVELOG mode and local undo mode).

```
CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
PATH_PREFIX = '/disk2/oracle/pdb2'
FILE_NAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/');

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1
FILE_NAME_CONVERT = ('/disk1/oracle/pdb1/', '/disk2/oracle/pdb2/') STORAGE
(MAXSIZE 2G MAX SHARED TEMP SIZE 100M);

CREATE PLUGGABLE DATABASE pdb2 FROM pdb1 pdb1 link;
```

Unplugging and Dropping PDBs
This section provides a few examples of unplugging and dropping PDBs. The first query shows the most common way to unplug a PDB so that someone else can create a PDB using it (that is, plug in the PDB). This operation completes very fast, even if the set of datafiles or the PDB is very large. It’s fast because you are only creating an XML file and then copying the datafiles (instead of unloading them) to an additional location and plugging in the PDB.

```
ALTER PLUGGABLE DATABASE dwpdb UNPLUG INTO '/oracle/data/dwpdb.xml';
```

These two commands show how to drop PDBs with and without the datafiles, respectively:

```
DROP PLUGGABLE DATABASE dwpdb KEEP DATAFILES;
DROP PLUGGABLE DATABASE dwpdb INCLUDING DATAFILES;
```

How to Move Between Containers (CDB/PDB)
The following commands show how to move between containers:
Opening and Closing PDBs
The following examples show different ways for opening and closing PDBs:

alter session set container=pdb_ss; --Commands for only pdb_ss
Session altered.

alter pluggable database close immediate;
Pluggable database altered.

alter pluggable database open read write;
Pluggable database altered.

alter pluggable database close; --(shutdown)
Pluggable database altered.

alter pluggable database open upgrade; --(to migrate)
Pluggable database altered.

alter session set container=CDB$ROOT; --Now for all PDBs
Session altered.

alter pluggable database ALL open read only; --(from CDB)
Pluggable database altered.

alter pluggable database pdb_ss, pdb1 close;
Pluggable database altered.

Starting Up an Individual PDB from the CDB (Root)
The following examples show how to start up an individual PDB when you are in the CDB.
Starting Up the CDB
(Note that I am not using In-Memory here.)

The following command shows how to start the CDB and the resulting feedback upon startup.

```
startup pluggable database pdb1 open; (read/write)
Pluggable Database opened.
(or while in pdb1 just run STARTUP)

startup pluggable database pdb1 open read only;
Pluggable Database opened.

startup pluggable database pdb1 force; (closes/opens)
Pluggable Database opened.
(or while in pdb1 just run STARTUP FORCE)
```

```
SQL> startup
ORACLE instance started.
Total System Global Area       626327552 bytes
Fixed Size                     2276008 bytes
Variable Size                  524289368 bytes
Database Buffers               92274688 bytes
Redo Buffers                   7487488 bytes
Database mounted.
Database opened.

select name, open_mode, open_time
from v$pdbs;

NAME      OPEN_MODE      OPEN_TIME
---------- ----------- --------------------------
PDB$SEED   READ ONLY     27-MAR-13 02.04.46.883 AM
PDB1       MOUNTED
PDB_SS     MOUNTED
```

Also note that in 12cR2, the PDBs are opened on startup if they were in an open state when the container was shut down.

### Tracking PDBs to Datafiles (Where Is Everything?)

One of the tougher things to find out is where the data is for a given PDB, or what table is in which PDB. The following query shows you how to map PDBs to datafiles, and the second query shows you how to map tables to PDBs. You can do this similarly with all objects by accessing the V$ related to the object.
Map tables to PDBs:

```
SELECT p.PDB_ID, p.PDB_NAME, t.OWNER, t.TABLE_NAME
FROM CDB_PDBS p, CDB_TABLES t
WHERE p.PDB_ID = t.CON_ID
AND t.OWNER = 'ORDDATA'
ORDER BY t.TABLE_NAME;
```

**PDB_ID** | **PDB_NAME** | **OWNER** | **TABLE_NAME**
---|---|---|---
2 | PDB$SEED | ORDDATA | ORDDCM_ANON_ACTION_TYPES
3 | PDB1 | ORDDATA | ORDDCM_ANON_ACTION_TYPES
2 | PDB$SEED | ORDDATA | ORDDCM_ANON_ATTRS
3 | PDB1 | ORDDATA | ORDDCM_ANON_ATTRS
3 | PDB1 | ORDDATA | ORDDCM_ANON_ATTRS_TMP
2 | PDB$SEED | ORDDATA | ORDDCM_ANON_ATTRS_TMP
2 | PDB$SEED | ORDDATA | ORDDCM_ANON_ATTRS_WRK

---

**Checking PDB History (When Was It Created?)**

Important information about where a PDB came from (where was it cloned from), how it was created, and when it was created is located in the CDB_PDB_HISTORY, which you can query as follows:

```
SELECT s.COM_ID, p.PDB_NAME, d.FILE_ID, d.TABLESPACE_NAME, d.FILE_NAME
FROM CDB_FDBS p, CDB_DATA_FILES d
WHERE p.FDB_ID = d.COM_ID
ORDER BY d.COM_ID;
```

<table>
<thead>
<tr>
<th>COM_ID</th>
<th>FDB</th>
<th>FILE_ID</th>
<th>TABLESPACE_NAME</th>
<th>FILE_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>6</td>
<td>USERS</td>
<td>/u01/app/oracle/oradata/cdb1/users01.dbf</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>UNDOTBS1</td>
<td>/u01/app/oracle/oradata/cdb1/undotbs01.dbf</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
<td>SYSTEM</td>
<td>/u01/app/oracle/oradata/cdb1/system01.dbf</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
<td>SYSTEM</td>
<td>/u01/app/oracle/oradata/cdb1/pdbseed/system01.dbf</td>
</tr>
<tr>
<td>2</td>
<td>PDB$SEED</td>
<td>5</td>
<td>SYSAUX</td>
<td>/u01/app/oracle/oradata/cdb1/pdbseed/sysaux01.dbf</td>
</tr>
<tr>
<td>3</td>
<td>PDB1</td>
<td>7</td>
<td>SYSAUX</td>
<td>/u01/app/oracle/oradata/cdb1/pdb1/sysaux01.dbf</td>
</tr>
<tr>
<td>4</td>
<td>PDB$SS</td>
<td>8</td>
<td>SYSAUX</td>
<td>/u01/app/oracle/oradata/cdb1/pdb1/sysaux01.dbf</td>
</tr>
<tr>
<td>4</td>
<td>PDB$SS</td>
<td>9</td>
<td>SYSAUX</td>
<td>/u01/app/oracle/oradata/cdb1/pdb$ss/sysaux01.dbf</td>
</tr>
<tr>
<td>4</td>
<td>PDB$SS</td>
<td>10</td>
<td>SYSAUX</td>
<td>/u01/app/oracle/oradata/cdb1/pdb$ss/sysaux01.dbf</td>
</tr>
<tr>
<td>4</td>
<td>PDB$SS</td>
<td>11</td>
<td>EXAMPLE</td>
<td>/u01/app/oracle/oradata/cdb1/pdb$ss/example01.dbf</td>
</tr>
</tbody>
</table>

11 rows selected.
Identifying Which Services You Have

The following query enables you to find out which services you have:

```sql
SELECT name, service_id, con_name, con_id
FROM v$active_services
ORDER BY l;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>SERVICE_ID</th>
<th>CON_NAME</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS$ BACKGROUND</td>
<td>1</td>
<td>CDB$ROOT</td>
<td>1</td>
</tr>
<tr>
<td>SYS$ USERS</td>
<td>2</td>
<td>CDB$ROOT</td>
<td>1</td>
</tr>
<tr>
<td>cdb1</td>
<td>6</td>
<td>CDB$ROOT</td>
<td>1</td>
</tr>
<tr>
<td>cdb1XDB</td>
<td>5</td>
<td>CDB$ROOT</td>
<td>1</td>
</tr>
<tr>
<td>pdb1</td>
<td>3</td>
<td>PDB1</td>
<td>3</td>
</tr>
<tr>
<td>pdb SS</td>
<td>3</td>
<td>PDB SS</td>
<td>4</td>
</tr>
</tbody>
</table>

ALTER SYSTEM While in a PDB and Other Nice Commands

The following powerful DBA commands are not only part of the root database, but can be run at an individual PDB level:

**CAUTION**

These are very powerful commands to run at the PDB level (you should usually not run these in production). If you FLUSH the caches or change initialization parameters, it could seriously affect the performance of other sessions.
ALTER SYSTEM FLUSH SHARED_POOL
ALTER SYSTEM FLUSH BUFFER_CACHE
ALTER SYSTEM SET USE_STORED_OUTLINES
ALTER SYSTEM CHECKPOINT
ALTER SYSTEM KILL SESSION
ALTER SYSTEM DISCONNECT SESSION
ALTER SYSTEM SET initialization_parameter

Modifying Initialization Parameters for a Given PDB

There are also initialization parameters that can be set even at an individual PDB level (Chapter 4 covers initialization parameters in detail), as follows:

```sql
select name from v$parameter
where ispdb_modifiable = 'TRUE'
and name like 'optim%';
```

<table>
<thead>
<tr>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>optimizer_adaptive_reporting_only</td>
</tr>
<tr>
<td>optimizer_capture_sql_plan_baselines</td>
</tr>
<tr>
<td>optimizer_dynamic_sampling</td>
</tr>
<tr>
<td>optimizer_features_enable</td>
</tr>
<tr>
<td>optimizer_index_caching</td>
</tr>
<tr>
<td>optimizer_index_cost_adj</td>
</tr>
<tr>
<td>optimizer_mode</td>
</tr>
<tr>
<td>optimizer_use_invisible_indexes</td>
</tr>
<tr>
<td>optimizer_use_pending_statistics</td>
</tr>
<tr>
<td>optimizer_use_sql_plan_baselines</td>
</tr>
</tbody>
</table>

10 rows selected.

Using RMAN Commands

The RMAN commands that can be executed for a database are the same for a given PDB. A few examples are displayed here:

```
RMAN> alter pluggable database pdb1 close;
RMAN> restore pluggable database pdb1;
RMAN> recover pluggable database pdb1 until SCN 777070;
RMAN> alter pluggable database pdb1 open resctlogs;
```
Using In-Memory (IM) with Pluggable Databases

Pluggable databases can also use the In-Memory (IM) column store (which is an option you must license and is covered in Chapter 4). While you can set the INMEMORY_SIZE parameter for the entire database, you can also set the INMEMORY_SIZE for individual PDBs. You can additionally oversubscribe the INMEMORY_SIZE of the main database (the sum of the PDBs can be more than the main database setting). What will happen as you use up the memory? When you are out, you are out, so whoever gets it first when it is oversubscribed is how it works.

The following are some other notes on using IM with PDBs:

- All PDBs within a CDB share a single IM column store set at the CDB.
- There is an INMEMORY_SIZE initialization parameter on the CDB.
- Each PDB also sets an INMEMORY_SIZE and anything put in IM comes from total CDBs IM.
- All PDBs added together can be higher than CDBs IM (oversubscribed); used on a first-come basis, by design, to ensure this CDB IM is not wasted.
- One PDB can take up the entire CDB IM and starve other PDBs.
- Each PDB has its own PRIORITY list (see Chapter 4 for additional information; which PDB starts first will matter a lot because it will get more IM!). When you are out of space, you are out until a PDB shuts down or something is removed from the IM.

Other 12cR2 Features with Pluggable Databases

The following are other 12cR2-only features of pluggable databases:

- The source no longer needs to be read-only when cloning a PDB (point-in-time clone).
- You can do a PDB refresh of clones manually or automatically (they must be read-only).
- You can create a class of PDB (Gold/Silver/Bronze) by setting DB_PERFORMANCE_PROFILE and then using Resource Manager to set directives for each class of PDB.
- You can do a flashback of a PDB and restore points to only that PDB!
- You can build a subset standby (introduced next) of just one or a portion of your PDBs!
- You can now have 4096 PDBs, not just 252.

Subset Standby (New in Oracle 12cR2)

The new subset standby feature allows a standby database in a multitenant environment to have a
standby without having to take all the PDBs into the standby. Keep in mind this impacts switchover and failover operations, so you should understand the impact that only a subset of PDBs has on switchover and failover operations.

TIP
One of the best features of 12cR1 is pluggable databases. It offers the ability to consolidate hundreds of databases into a single container database (CDB) with hundreds of pluggable databases (PDBs). Two of the best features of 12cR2 are the ability to flashback pluggable databases (PDBs) and the ability to build a subset standby with only some PDBs.

Disk Arrays
Configuring disks with RAID (Redundant Array of Independent/Inexpensive Disks) is now the norm. RAID is here to stay, and one would be hard pressed to buy even a midrange system without it. Later in this chapter, you’ll see that ASM also provides levels of redundancy. Even in the personal computing area, using some hardware-based configuration of redundant disks has become more commonplace. For the DBA, this means that more than ever, care must be taken to ensure that the disk array configuration used enhances I/O while also providing appropriate protection against drive failure. Regardless of whether the RAID configuration is hardware- or software-based (hardware-based is usually faster), the configuration should be configured properly for best performance, without sacrificing protection.

& Use Disk Arrays to Improve Performance and Availability
A RAID logical unit number (LUN) is created by grouping several disks in such a way that the individual disks act as one logical disk (grouped into a volume or virtual disk). Prior to the advent of the storage area network (SAN), a LUN was the address (number) for the disk drive. During normal operation, a single logical device now gets the benefit of having multiple physical devices behind it, which means faster access to data (when configured properly) and the ability to have storage volumes that are significantly greater than the physical limit of an individual device. If a disk fails and all the data on the disk is destroyed, the group of disks can be structured so the data exists in more than one place. The system never goes down because of the failure of a single disk (when the proper RAID level is employed). Users continue to operate as if nothing has happened. The system alerts the system administrator that a specific disk has failed. The administrator pulls out the disk and slides in a new disk. The hardware controller or operating system automatically writes the missing information on the new disk. The system goes on without missing a beat.
How Many Disks Do You Need?

I know the hardware vendors out there are going to love me for saying this, but it is true. A good rule of thumb on buying disks in today’s market is “Don’t buy disks on the basis of capacity alone.” If you have a moderately sized database at 10T, where performance is very important, why would you buy 600G SAS disks instead of 2T SATA disks to run it? Speed and data distribution—that’s why. SAS disks at 15,000 RPMs are much faster than SATA at 7,200 RPMs, but the infrastructure and tools surrounding SAS are also faster. With disk capacities hovering between 300G to 2T, this choice can be hard to rationalize, but too often lately I have seen people make disk purchase choices on capacity alone. This leaves them with inadequate redundancy (when they forget about mirroring costs), poor performance (using slower disks), or both. You can certainly still use the slower 2T disks for online backups, archived information, or very old information. Remember, after you configure that 2T disk properly, you may have only less than 1T of usable storage (after mirroring, etc.). Whatever you do, try to use the high-speed 15,000 RPM SAS disks for your most important databases. There are now 8T drives in a full X6-2 Exadata or an entire Flash Array of storage, but you only get 180T in the same X6-2. These are the questions that techs must ask the business so the correct choices are made.

Consider speeds of different types of hardware:

- Memory: Nanoseconds
- 10 Gigabit Ethernet (GbE) network: 50 microseconds
- Flash: 20 to 500 microseconds
- Disk: 4 to 7 milliseconds

What Are Some of the RAID Levels Available?

Almost every midrange to enterprise-class server today offers a hardware RAID solution either built into the server or as an attached storage device. Using the various available RAID levels is pretty much standard, regardless of the type of array you buy. The following list describes some of the more common options that Oracle database administrators will want to consider:

- **RAID 0 (Striped Set)** Automatic disk striping means that the Oracle datafiles are automatically spread across multiple disks. The tablespace’s corresponding datafile pieces can be spread across and accessed from many disks at the same time instead of from one (a large savings in disk I/O). Just be wary; this isn’t a solution for high availability or fault tolerance, as a loss of one disk in the group means all the data needs to be recovered.

- **RAID 1 (Mirrored Set)** Automatic disk mirroring is available on most systems today. It’s generally used for the operating system itself but can be used with the Oracle database for higher availability. You need twice the storage compared to the amount of data that you have for RAID 1.

- **RAID 5 (Striped Set with Parity)** This level carries the parity on an extra disk, which allows
for media recovery. Heavy read applications get the maximum advantage from this disk array distribution. This solution is low-cost and generally very bad for write-intensive Oracle applications. I will discuss improvements to this more in the next section.

- **RAID 1+0 (RAID 10, a Stripe of Mirrors)** Mirrored disks that are then striped. This level is a common Oracle OLTP production RAID level, also known as “RAID 10.” RAID 1+0 incorporates the advantages of the first two RAID levels by adding the disk I/O striping benefit of RAID 0 to the mirroring provided by RAID 1. For high read/write environments such as OLTP, where sporadic access to data is the norm, this RAID level is highly recommended.

- **RAID 0+1 (RAID 01, a Mirror of Stripes)** Striped disks that are then mirrored. Often confused with RAID 10 or thought not to exist, this level incorporates the advantages of the first two RAID levels by providing the disk I/O striping benefit of RAID 0 to the mirroring provided by RAID 1. For high read/write environments such as OLTP, where sporadic access to data is the norm, this RAID level is good, but it is *not* as robust as RAID 10, and it cannot tolerate two disk failures if they are from different stripes. Also, in a rebuild after failure, all the disks in the array must participate in the rebuild, which is also not as favorable as RAID 10.

- **RAID 1+0+0 (RAID 100, a Stripe of RAID 10s)** Mirrored disks that are then striped and then striped again (usually with software, the top-level stripe is a MetaLun or soft stripe). The advantages are mainly for random read performance improvement and the elimination of hotspots.

---

#### The Newer RAID 5

Many hardware vendors configure systems with a RAID 5 configuration to maximize the utilization of available space on disk and reduce the overall cost of the array. Although RAID 5 is a good choice for inexpensive redundancy, it is usually a poor choice for write-intensive performance. At the most general level, when a write request is made to a RAID 5 array, the modified block must be changed on disk; a “parity” block is read from disk; and using the modified block, a new parity block is calculated and then written to disk. This process, regardless of the size of the write request, can limit throughput because for every write operation, there are at least two more I/O operations. I recommend RAID 5 only for mostly read or read-only filesystems. Most storage vendors realize that this parity write is a penalty and have come up with various solutions to reduce the impact of this additional operation. The most common solution is to implement a memory cache on the array to speed up the write performance of all I/O on the array. For periodic or light write activity, this solution may be completely suitable for your system, but you need to remember that eventually those write operations need to make it to disk. If you overload that disk cache with heavy write activity, you may produce what is often referred to as a “serialized I/O” condition. This is where the array can’t write to disk fast enough to clear the cache, essentially neutralizing the benefit of your cache. Be sure to check out other solutions that your vendor may have implemented. Don’t be afraid to ask them how they handle heavy I/O. Some solutions to look for are
Dynamic cache management  This is the ability for the array to adjust the way that the cache is being used. Some vendors simply split the cache down the middle—if you have 1G of cache, 500M is for read and 500M is for write. Because the Oracle buffer cache is essentially already a read cache, being able to adjust the array cache so it is primarily a write cache can give you some flexibility. This ability to adjust the array cache to be primarily a write cache goes for other configurations other than just RAID 5.

Bundled writes  Generally, the maximum size of a write operation is larger than an Oracle block. Some vendors have implemented intelligence into their arrays that allows them to group multiple parity operations into a single I/O operation. Because this requires fewer round trips to the physical disk, it can greatly improve the performance and effectiveness of the cache when running RAID 5.

RAID 6 is another variant of RAID 5 that you may also see advertised. RAID 6 behaves just like RAID 5, except it utilizes corresponding parity blocks for every set of data block stripes. While this does carry the added benefit of more fault tolerance, because you can lose two disks, it also brings with it even lower performance.

I still prefer to see RAID 1+0 (mirroring and then striping). RAID 1+0 (aka RAID 10) is generally going to be faster or at least as fast as RAID 5 and natively more fault tolerant to multiple device failures. Because you may be in a situation where you have multiple physical enclosures for your disk, using striping and mirroring allows you to build fault tolerance between enclosures too.

Solid-State Disks

Solid-state disk (SSD) data is stored and accessed in dynamic random access memory (DRAM), which in turn improves performance by avoiding the disk I/O that is typical of magnetic disks. Magnetic disk latency includes rotational delay, which is the time taken for a disk platter to revolve until the desired storage address is found. Disk I/O service time influences performance on databases and applications; with SSDs, service times are very fast because SSDs do not perform the costly disk operations such as disk rotation that cause the delays incurred by magnetic disks. Oracle recommends storing REDO logs, undo datafiles, and TEMP tablespace on SSD storage media to achieve better read/write performance and reduce I/O waits. What do Google, Facebook, and Amazon all have in common? Their data centers are “racks of flash” as far as the eye can see! Do you want your company to be a leader? Get an X6-2 with all flash storage (180T) or, if you need more storage, get an FS1 (Oracle’s all flash array) with a petabyte of storage. Be the leader or be left behind!

ASM Storage Management (Striping/Mirroring)

A database created under the constructs of ASM (much of this chapter is dedicated to ASM) will be striped by default and mirrored as specified in the stripe-and-mirror-everything (SAME) methodology (i.e., the I/O load is evenly distributed and balanced across all disks within the diskgroup). The striping is done on a file-by-file basis, using a 1M stripe size, as opposed to other
logical volume managers (LVMs) that perform striping and mirroring at a disk-volume level. Oracle states that an ASM 1M stripe depth has proved to be the best stripe depth for Oracle databases. This optimal stripe depth, coupled with even distribution of extents in the diskgroup, reduces the occurrence of hot spots.

ASM allocates space in units called allocation units (AUs). ASM always creates one-AU extents (not the same as tablespace extents) across all of the disks in a diskgroup. For diskgroups with similarly sized disks, there should be an equal number of AU extents on every disk. A database file is broken up into file extents. There are two types of AU extent distributions: coarse and fine. For coarse distribution, each coarse-grain file extent is mapped to a single AU. With fine-grain distribution, each grain is interleaved 128K across groups of eight AUs. Fine distribution breaks up large I/O operations into multiple 128K I/O operations that can execute in parallel, benefiting sequential I/Os. Coarse- and fine-grain attributes are predefined, as part of system templates, for all system-related files.

TIP
Redo and archive log files are defined as fine-grained, whereas datafiles are coarse.

Setup and Maintenance of the Traditional Filesystem
Using RAID-configured groups of physical devices and traditional filesystems makes Oracle datafile setup and maintenance much easier for the DBA because manually balancing disks is not as arduous. With the large disk sizes in today’s storage systems, dissecting filesystem configuration between four or six devices quickly becomes an exercise in splitting hairs. Unless you are utilizing a system where 12 or more physical disks are involved, dividing these up into more than one logical disk device provides only a small benefit. Even if you have a case where two datafiles are heavily utilized, the cache or host bus adapter (HBA) that they share on the array may be a common avenue to the disk. Finally, depending on your expected growth, the number of filesystems you end up managing could, in time, make keeping all of this in balance a frustrating exercise.

TIP
Try to avoid splitting a logical device in a disk array into more than one filesystem. Splitting may seem to give you flexibility, but it can also increase the number of datafile locations you have to manage.

What Is the Cost?
To support disk arrays that mirror data, you need more—sometimes much more—raw disk storage (for RAID 1, you need at least double the space). While this requirement can increase the price of your initial system, the benefits are usually well worth it. For these reasons, while you are deciding how to configure the new storage system you are going to buy, think about the return on investment (ROI) for keeping the system up and running and also the value of great performance.

This leads me to another class of storage system that is becoming more popular. With the rising capacity of even the most basic storage array, companies are looking to leverage that storage space with multinode access technologies. Whether the implementation is as a storage area network (SAN) or network-attached storage (NAS), the initial investment and added benefit of being able to “plug in” another server to your storage system is often well worth it. So when you are faced with the dilemma of having a 4-Gbit/sec Fibre Channel (Exadata has 40-Gbit/sec each direction with InfiniBand) storage array with four disks and are feeling a bit like you aren’t utilizing the resource to its maximum, consider expanding that purchase into an infrastructure decision that allows your enterprise to grow and share that resource among all your important systems.

TIP

Use disk arrays to improve performance and protect your data against disk failure. Choose the proper RAID level and technology solutions that enable you to maintain the availability your organization needs. Don’t go “good enough,” because you will regret it at 2 a.m. when you lose a disk.

Storing Data and Index Files in Separate Locations

Tables that are joined (simultaneously accessed during a query) often could also have their data and index tablespaces separated. The following example shows a table join and one possible solution for managing the data:

```sql
select COL1, COL2, ...
from CUST_HEADER, CUST_DETAIL
where ...;
```

Here is a data management solution:

```
Disk1: CUST_HEADER Table
Disk5: CUST_HEADER Index
Disk8: CUST_DETAIL Table
Disk12: CUST DETAIL Index
```
This solution allows the table join to be done while accessing four different disks and controllers. Separate data and index files onto different physical disk devices and controllers; consequently, when tables and indexes are accessed at the same time, they will not be accessing the same physical devices. You could expand this to involve a larger number of disks. You will see later in the chapter that table and index partitioning will help you to accomplish this more easily. Oracle’s ASM does a great job of assisting with this when you set it up, but it also has ways of moving hot data to a different part of a disk.

TIP
Separate key Oracle datafiles in traditional filesystems to ensure that disk contention is not a bottleneck. By separating tables and indexes of often-joined tables, you can ensure that even the worst of table joins do not result in disk contention. In Enterprise Manager (Cloud Control), Oracle makes it easy to move data to a hotter or colder region of a disk.

Avoiding I/O Disk Contention

Disk contention occurs when multiple processes try to access the same physical disk simultaneously. Disk contention can be reduced, thereby increasing performance, by distributing the disk I/O more evenly over the available disks. Disk contention can also be reduced by decreasing disk I/O. To monitor disk contention, review the Database Files Metrics in Cloud Control. This Metric group contains two sets of metrics. The Average File Read Time and Average File Write Time apply to all datafiles associated with your database. If you find that one or two datafiles seem to have especially high values, you click one and then use the Compare Objects File Name link to view collected statistics between them. If they are both busy at the same time and are on the same disk, you may choose to relocate one datafile to another filesystem, if you are concerned about performance during that time.

You can also determine file I/O problems by running a query:
Here is a partial query output:

```sql
SELECT name, phyhrs, phywrs, readtim, writetim
FROM v$filystat a, v$datafile b
WHERE a.file# = b.file#
ORDER BY readtim DESC
/
spool off
```

Here is a partial query output:

```
Fri Mar 24

Disk Balancing Report

<table>
<thead>
<tr>
<th>NAME</th>
<th>Phyhrs</th>
<th>Phywrs</th>
<th>ReadTim</th>
<th>WriteTim</th>
</tr>
</thead>
<tbody>
<tr>
<td>/d01/pindex_1.dbf</td>
<td>48,310</td>
<td>51,798</td>
<td>200,564</td>
<td>903,199</td>
</tr>
<tr>
<td>/d02/pindex_02.dbf</td>
<td>34,520</td>
<td>40,224</td>
<td>117,925</td>
<td>611,121</td>
</tr>
<tr>
<td>/d03/pdataa_01.dbf</td>
<td>35,189</td>
<td>36,904</td>
<td>97,474</td>
<td>401,290</td>
</tr>
<tr>
<td>/d04/umtbs01.dbf</td>
<td>1,320</td>
<td>11,725</td>
<td>1,214</td>
<td>39,892</td>
</tr>
<tr>
<td>/d05/system01.dbf</td>
<td>1,454</td>
<td>10</td>
<td>10</td>
<td>956</td>
</tr>
</tbody>
</table>
```

**NOTE**

You may also have SYSAUX01.DBF, USERS01.DBF, and EXAMPLE01.DBF.

A large difference in the number of physical writes and reads between disks may indicate that a disk is being overburdened. In the preceding example, filesystems 1–3 are heavily used whereas filesystems 4–5 are only lightly used. To get a better balance, you’ll want to move some of the datafiles. Splitting datafiles across multiple disks or using partitions would also help move access to a table or an index to an additional disk.

**TIP**

Query V$FILESTAT and V$DATAFILE to see how effectively datafiles have been balanced. Note that temporary tablespaces are monitored using V$TEMPFILE and V$TEMPSTAT.
The 12c Heat Map and Automatic Data Optimization (ADO)

Even with better data/index placements on disks, there can be problems with how data inside the disks is stored. If a process is constantly accessing a certain data block, and that data block is on a disk that has poor latency, performance will be degraded. If multiple SAN tiers are used, and each SAN has different I/O capabilities, then it would be advisable to move the objects that are frequently used into one of the faster SAN disks and have the less-accessed data on slower SAN disks. Prior to 12c, we would manually move the hot objects to faster disks. We would query the V$SEGMENT_STATISTICS view and extract objects that are frequently used and manually move them to faster disks to eliminate issues. Starting with 12c, the process can be automated via the Heat Map and Automatic Data Optimization (ADO).

The new Heat Map is a feature in 12c that tracks usage information at a row and segment level. Data modifications are tracked at the row level and aggregated to the block level. The Heat Map tracks data modifications, table full scans, and index lookups at the segment level. It provides a detailed view of how data is being accessed and how access patterns are changing over time. The Heat Map, when enabled, automatically collects segment- and row-level statistics that can be used to define compression and storage policies, which will then be automatically maintained throughout the life cycle of the data (often referred to as information lifecycle management [ILM]). The Heat Map skips internal system tasks like gathering stats and system DDLs.

To enable the Heat Map:

```
SQL> alter system set HEAT_MAP = ON;   -- By default the value of OFF
```

DBA tables (see Figure 3-1) can be queried to retrieve detailed information for any objects captured. The V$HEAT_MAP_SEGMENT view displays real-time segment access information.
Automatic Data Optimization allows the creation of policies for data compression and data movement. ADO works in conjunction with the Heat Map where information from the Heat Map is used in the compression policies. The Oracle database evaluates ADO policies during database maintenance windows and uses the information collected by the Heat Map to determine which operations to execute. ADO operations are executed automatically in the background with no user intervention. The policies ADO uses can be specified at the segment or row level for tables and table partitions. Policies will be executed automatically in the background when policy criteria are satisfied. Policies can also be executed manually.

This is done through the `ilm_clause` (ilm referring to information lifecycle management) of the `CREATE TABLE` and `ALTER TABLE` statements. The feature determines when data meets the policy standard for movement by the Heat Map, which is tracking changes to the table and table partitions. There are two types of policies, a `table_compression` or `tiering_clause`. When data meets the policy, the data is either compressed row level or segment level, or is moved to a new storage tier based on the policy criteria supplied in the AFTER clause of the policy.

Some parts of the `ilm_clause` are as follows:

- **ADD_POLICY** Specify the policy to add to the table.
- **DELETE** Delete a policy from the table.
- **ENABLE** Enable a policy for the table.
- **DISABLE** Disable a policy on the table.

The following are some parts of the AFTER clause of the policy:

- **LOW ACCESS** For policy to take effect after a period of time of low table access
NO ACCESS For policy to take effect after a period of time of no table access

NO Modification For policy to take effect after a period of time with no table changes

CREATION For policy to take effect after a period of time after table creation

The following example shows how to compress a row after it has not been modified for seven days:

```
ALTER TABLE orders 1 EM ADD POLICY ROW STORE COMPRESS ADVANCED ROW AFTER 7 DAYS
OF NO MODIFICATION;
```

Even though ADO uses the Heat Map to determine which segments to move, you can also create custom conditions using PL/SQL functions to extend the flexibility of ADO (to use your own data to determine when to move or compress data). The Heat Map and ADO require purchasing the Advanced Compression option. In 12cR2, ADO is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics.

12c I/O Performance Tracking Views (Outliers)

Starting with 12c, Oracle provides dynamic views that give detailed analysis of I/O that takes a long time to complete (i.e., a large, slow report). The views are dynamically populated when the I/O has taken longer than 500 ms to complete. The default threshold of 500 ms can be modified by the hidden parameter _IO_OUTLIER_THRESHOLD.

- **V$IO_OUTLIER** Use this view to see if there are any occasional delays in servicing a disk I/O request by the storage subsystem.

- **V$LGWRIO_OUTLIER** Contains entries corresponding to Log Writer process that have taken longer than the default 500 ms to complete.

- **V$KERNEL_IO_OUTLIER** Use this view to see the individual kernel components of the I/O subsystem that have taken more than 500 ms to complete; this view is specific to Solaris operating systems and must meet conditions for it to be populated. On Solaris platforms, to have the view populated, the database should be configured to use ASM or raw devices and have the initialization parameter DISK_ASYNCH_IO=FALSE. Oracle uses Solaris DTrace functionality to populate this view.

Oracle Bigfile Tablespaces

Introduced in Oracle 10g was a locally managed tablespace type for extreme-size databases: Bigfile tablespaces allow for the creation of tablespaces with one file where the size of that datafile fully incorporates the power of 64-bit systems. When implemented with Oracle Managed Files (OMF) or ASM, bigfile tablespaces can greatly simplify the management of your storage system. Additionally, because you should have fewer datafiles, performance of database management operations such as
Now you may be asking: “Then what is the benefit of bigfile tablespaces?” A bigfile tablespace, with a typical 8K block size, can contain a single 32T datafile. If you’re using a 32K block, it can contain a 128T datafile. This is achieved by changing the way ROWIDs are managed within the tablespace. In a traditional tablespace, three positions in the ROWID are used to identify the relative file number of the row. Because you only have one datafile in bigfile tablespaces, these three positions are instead used to lengthen the data block number for the row, thereby allowing for a much larger number of ROWIDs from traditional smallfile tablespaces.

NOTE
To have the largest Oracle 12c database possible, 8 exabytes, you must use 128T datafiles (and must also use bigfile tablespaces and a 32K block size).

To use bigfile tablespaces, you must be using locally managed tablespaces with Automatic Segment Space Management (ASSM), discussed later in the chapter. Also, you cannot use bigfile tablespaces for UNDO, TEMP, or SYSTEM. If you are thinking of using bigfile tablespaces to reduce the amount of management needed for your system, consider also using OMF and ASM (covered next). Also, if you are using traditional filesystems, make sure you are using a logical volume manager that provides the flexibility to map out your storage system appropriately so the single datafile can grow as needed.

ASM Introduction

In Oracle Database 10g Release 2, storage management and provisioning for the database has been greatly simplified using Automatic Storage Management (ASM). ASM provides filesystem and volume manager capabilities built into the Oracle database kernel. In Oracle Database 11g and 12c, Oracle ASM as a technology is the best of all worlds, combining the benefits of using raw devices with the ease of management as seen with standard volume managers in UNIX. With this capability, ASM simplifies storage management tasks, such as creating/laying out databases and disk space management. Because ASM allows you to manage disks using familiar CREATE/ALTER/DROP SQL statements, DBAs do not need to learn a new skill set or make crucial provisioning decisions to use ASM. ASM is basically built on raw devices; therefore, it is also inherently cluster aware. The initial release of ASM was first built for a clustered database and then made available for nonclustered databases. An Enterprise Manager interface (see Chapter 5 for additional information), as well as a new command-line utility (new in Oracle Database 10g Release 2 and available in 11g and 12c), ASMCMD, is also available for those ASM administrators who are not familiar with SQL.

ASM is a management tool specifically built to simplify the DBA’s job. It provides a simple storage management interface across all server and storage platforms. ASM provides the DBA with flexibility to manage a dynamic database environment with increased efficiency. This feature is a key component of grid computing and database storage consolidation.
The following are some of ASM’s key benefits:

- As good as raw devices from a performance perspective.
- An extremely simple, but powerful, volume manager toolkit/utility for managing the space from a database perspective.
- Spreads I/O evenly across all available disk drives to prevent hot spots and maximize performance.
- Eliminates the need for overprovisioning and maximizes storage resource utilization facilitating database consolidation.
- Inherently supports large files.
- Performs automatic online redistribution after the incremental addition or removal of storage capacity.
- Maintains redundant copies of data to provide high availability or leverage third-party RAID functionality.
- Supports Oracle Database 10g, 11g, 12c, and Oracle Real Application Clusters (RAC).
- The OCR and voting disk can be on the ASM diskgroup and cluster filesystem with ASM in 11gR2. With 12c password files can also be stored in the ASM diskgroup.
- Can leverage third-party multipathing technologies.
- Inherently capable of supporting async I/O as well as direct I/O.
- Fully integrated into Oracle Managed Files (OMF), thereby reducing complexity without compromising performance.
- Exadata only allows ASM!

For simplicity and easier migration to ASM, an Oracle 10gR2 and above database can contain ASM and non-ASM files. You can use the RMAN COPY command to move datafiles from the filesystem to an ASM diskgroup.

DBAs have much to consider before they deploy and create a database. They must consider and determine the following:

- Plan filesystem layout and device usage
- Determine application workload characteristics (random read/write for OLTP versus sequential I/O for DSS systems)
- Calculate storage capacity and sizing for the database

ASM addresses these concerns in the following ways:

- Traditionally, DBAs would create filesystems to store their database files, and then create additional filesystems as needed. Doing this can become a manageability and provisioning nightmare since DBAs also have to manage the I/O load on each filesystem. ASM presents a
single storage pool (*diskgroup*), so there is no need to maintain several filesystem containers and no need to worry about the placement of the next datafile.

- One of the core benefits of ASM is the ability to expand storage to meet an application’s capacity needs. Thus, the ASM diskgroup that houses the database can be expanded without worrying excessively about storage capability management.
- Using ASM and applying the defined general best practices, ASM-based databases should be able to handle any workload. Additionally, because ASM inherently uses raw devices, considerations such as async I/O and direct I/O become nonissues.

### Communication Across IT Roles

Sometimes there is a disconnect among the DBA, system admin, and storage admin. The DBA asks for a 200G filesystem, the storage/system admin provides a 200G RAID 5 device or RAID 10 device that has an improper or inefficient stripe size, and performance starts to suffer. Later, the DBA finds out what was actually provisioned and isn’t very happy.

DBAs and other technical IT roles will always experience some inherent level of disconnect because these groups think and operate differently. As this disconnect is mostly a communication issue, ASM doesn’t necessarily fix it. However, several things come into play with ASM that have lessened this communication issue. First, Oracle published a paper called “Optimal Storage Configuration Made Easy.” This paper proposed a stripe-and-mirror-everything (SAME) methodology. With this paper came a standard methodology for database deployment, which made DBA-storage admin communication much simpler because DBAs had a way to express what they needed.

**NOTE**

*You can access “Optimal Storage Configuration Made Easy” at OTN: [www.oracle.com/technetwork/database/focus-areas/performance/opt-storage-conf-130048.pdf].*

ASM incorporates all the essentials of the SAME methodology. ASM also offers a streamlined approach to storage capacity management. With ASM, database storage can be expanded as business or capacity plans dictate, all with no application downtime.

### ASM Instances

Starting with Oracle Database 10g (and continuing through 11gR2 and 12c), there are two types of instances: database and ASM instances. The ASM instance, which is generally named +ASM, is started with the `INSTANCE_TYPE=ASM` initialization parameter. This parameter, when set, signals
the Oracle initialization routine to start an ASM instance, not a standard database instance. Unlike the standard database instance, the ASM instance contains no physical files, such as log files, control files, or datafiles, and requires only a few initialization parameters for startup.

Upon startup, an ASM instance will spawn all the basic background processes, plus some new ones that are specific to the operation of ASM. The STARTUP clauses for ASM instances are similar to those for database instances. For example, NOMOUNT starts up an ASM instance without mounting any diskgroup. The MOUNT option simply mounts all defined diskgroups. Oracle has continued to make great strides in how disks are accessed and configured using ASM. Prior to 12c, Oracle had tightly coupled configuration between databases and ASM instances on servers. Versions 10g and 11g required ASM and database instances to be on the same server. With new features of 12c ASM, this tightly coupled configuration for ASM and database instance has been loosened, and this provides for greater flexibility when managing ASM instances in a RAC environment.

Here is an example to query for the instance name that you are connected to:

```
select instance_name
from v$instance;
```

<table>
<thead>
<tr>
<th>INSTANCE_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ASM</td>
</tr>
</tbody>
</table>

The next example lists the various views that you can query to see the ASM configuration:

```
select name, type
from v$fixed_table
where name like 'GV$%ASM%'
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GV$ASM_TEMPLATE</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_ALIAS</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_FILE</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_VOLUME</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_FILESYSTEM</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_ACFSVOLUMES</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_ACFSSNAPSHOTS</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_ACF_SECURITY_INFO</td>
<td>VIEW</td>
</tr>
<tr>
<td>GV$ASM_ACF_ENCRYPTION_INFO</td>
<td>VIEW</td>
</tr>
</tbody>
</table>

SYSD> /
These views are also available under the database that is using ASM, sometimes with slightly different information, such as V$ASM_CLIENT.

**ASM Initialization Parameters**

The list that follows shows some of the basic initialization parameters required to start ASM (in 12c). Observe that all ASM processes begin with *asm*, as opposed to the database processes, whose names begin with *ora*.

```
+ASM1._oracle_base='/u01/app/grid_base'#ORACLE_BASE set from in memory value
+ASM2._oracle_base='/u01/app/grid_base'#ORACLE_BASE set from in memory value
*.asm_diskgroups='DB_DISK'#Manual Mount
*.asm_diskstring='AFD:*'
*.asm_power limit=1
*.large pool size=12M
*.remote login passwordfile='EXCLUSIVE'
```

In 11g and 12c, DBAs who use ASM tend to use AUTOMATIC MEMORY MANAGEMENT, so it uses the initialization parameters MEMORY_TARGET and MAX_MEMORY_TARGET:

```
SYS@ASM> show parameter mem    (partial listing of key values only)
NAME             TYPE     VALUE
----------------- -------- ------------------
memory_max_target big integer 272M
memory_target    big integer 272M
```

**ASM Installation in 12c**
Installation of 12c Grid Infrastructure (GI) is very similar to the 11g version except for the additional features related to Flex ASM and the option for using IPv4/IPv6, ASM private network, and Grid Infrastructure Management Repository (MGMTDB, required on 12.1.0.2, Doc ID 1568402.1). During the GI installation, you have the option to choose the typical cluster (similar to 11g) or to enable Flex Cluster. If you choose the standard-cluster option and then the advanced configuration option during installation, it will provide an option for configuring Flex ASM (see Figure 3-2).

![ASM installation—storage options](image)

**FIGURE 3-2.** ASM installation—storage options

One of the requirements for configuring Flex ASM is Grid Naming Service (GNS). GNS simplifies client connections to servers, especially when the cluster has a large number of nodes. The GNS daemon dynamically collects cluster information and passes it to the DNS server for name resolutions. To configure GNS you must obtain a static public IP address from your network administrator. The DNS server must be configured to forward all cluster IPs to the GNS VIP. The GNS daemon and VIP will run on a single node of the cluster. Oracle clusterware manages the GNS services and will perform failover if GNS service fails.

**Figure 3-3** must be completed if Flex ASM is to be configured; the GNS VIP is required even if you are not planning on using GNS.
How does GNS get the cluster names and the corresponding node addresses? This information is collected when cluster services start and DHCP provides cluster IPs to the clusterware during startup; the cluster IPs are then automatically registered with GNS. After installation, you can view which node is running the GNS VIP by issuing the following command:

```
[oracle@Linux71 ~]$ olsnodes -n -a
linux71 1     Hub
linux72 2     Hub

[oracle@Linux71 ~]$ srvctl status gns -node linux72
GNS is not running on node linux72.
GNS is enabled on node linux72.

[oracle@Linux71 ~]$ srvctl status gns -node linux71
GNS is running on node linux71.
GNS is enabled on node linux71.

[oracle@Linux71 ~]$ srvctl status gns
GNS is running on node linux71.
GNS is enabled on node linux71.
```
Oracle 12c Has Introduced Oracle Flex ASM

Flex ASM can be enabled during the initial installation of Grid Infrastructure by choosing Advanced Installation and choosing Use Oracle Flex ASM for Storage. This is relevant only when the cluster is installed and not for a single-instance configuration. Also, an existing non-Flex cluster can be converted to Flex using the “asmca” GUI tool. Once Flex ASM is configured, the process cannot be reverted to a standard ASM cluster.

To confirm Flex is enabled:

```
ASMCMD> showclustermode
ASM cluster : Flex mode enabled
ASMCMD>
ASMCMD> showclusterstate
Normal
```

Oracle Flex ASM allows database clients to connect to remote ASM instances if the local ASM instance fails. When configuring Flex ASM, a private ASM network is added during installation for communicating between ASM instances in a cluster. When an ASM instance fails, databases running on the failed ASM instance are automatically connected to surviving ASM instances on the cluster via the ASM network. It is strongly recommended to configure a separate network interface for ASM even though it is possible to use the private cluster interconnect for ASM communication. When an ASM instance fails in Flex configuration, Oracle Clusterware will start a new ASM instance on a different server to maintain the cardinality setting. ASM cardinality settings determine how many ASM instances will be available in a cluster at any time. The default value for ASM cardinality is 3, and this value can be changed using the `srvctl` command.

To view ASM cardinality value:

```
[oracle@Linux71 ~]$ srvctl config asm
ASM home: <CRS home>
Password file: +OCR_DISK/orapwASM
ASM listener: LISTENER
ASM instance count: 3
Cluster ASM listener: ASMNET1LSNR_ASM
[oracle@Linux71 ~]$ 
```

From the preceding output, “ASM instance count : 3” shows the default setting. This setting can be changed dynamically by `srvctl modify asm -count <value>`:

```
```
When the ASM cardinality value is modified, the clusterware automatically adjusts the number of ASM instances on the cluster. For example, before modifying the ASM cardinality value to 2, the two-node test RAC with Flex ASM configuration showed the third ASM instance as OFFLINE, which is due to the default cardinality value (3) for enabling Flex ASM. Even though there is not a third node, clusterware will show three entries for ASM. If we set the cardinality value to 5, it will show five ASM entries with three as OFFLINE, and this is done dynamically by clusterware. This configuration allows the flexibility to scale up or down as needed.

The following example shows cardinality value 5 where only two servers exist:

```
srctl modify asm -count 5
```

```
crctl stat res -t
ora.asm

  1  ONLINE  ONLINE  linux71  Started,STABLE
  2  ONLINE  ONLINE  linux72  Started,STABLE
  3  OFFLINE  OFFLINE  Started,STABLE
  4  OFFLINE  OFFLINE  Started,STABLE
  5  OFFLINE  OFFLINE  Started,STABLE
```

The minimum value for setting cardinality value is 2:

```
srctl modify asm -count 1
```

```
ORA-1123: The specified ASM cardinality 1 is less than the minimum cardinality of 2.
```

Figure 3-4 shows a three-node Flex ASM configuration using cardinality 2. ASM is running on Server1 and Server3 which is consistent with the cardinality rule of two ASM instances. Server2, where ASM is not running, is the client database server. This server uses the ASM network to communicate with the Flex ASM server to retrieve ASM metadata. If the ASM instance fails on Server3, clusterware will automatically start an ASM instance on Server2 to confine to the cardinality value 2 where at least two ASM instances need to be online, and the database on Server3 will automatically connect to the surviving Flex ASM instances.
In a Flex ASM environment, the database instances that are connected to ASM will seamlessly connect to the surviving ASM nodes. This can be tested by forcing the ASM instance down, as shown next. If a database instance is connected to an ASM instance, then we cannot just shut down the ASM instance; otherwise it will result in an error, stating the diskgroups will need to be relocated.

As the preceding error states, it will need to be forced down by executing the command following this paragraph. It’s very important to note that you should only try this when Flex ASM is enabled and the database version is 12.1 or higher. Database versions earlier than 12.1 will require an ASM instance running on the same node as the database, and if ASM is forced down on an 11g database, it will bring ASM and the database down. Execute this command on a Flex ASM 12c database to force ASM down on a node and have the database automatically connect to a surviving ASM instance:

```
srctl stop asm -node Linux72 -stopoption abort -force
```

When the force shutdown of the Flex ASM instance completes, the database alert log will show that the database has registered with the ASM instance on the surviving Flex ASM node. The database alert log will show entries similar to these:
Once the database has switched over to the surviving Flex ASM instance, all ASM metadata is retrieved from the surviving ASM instance. Output of `crsctl stat res -t` would show ASM and diskgroups as “offline” where the shutdown command was executed. The view V$ASM_CLIENT will show to which ASM instance the database has connected; the view can be queried from the database or from an ASM instance:

```
select inst_id, instance_name, db_name, status,
       software_version, COMPATIBLE_VERSION
from gv$asm_client;
```

<table>
<thead>
<tr>
<th>INST_ID</th>
<th>INSTANCE_NAME</th>
<th>DB_NAME</th>
<th>STATUS</th>
<th>SOFTWARE_V COMPATIBLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>+ASM1</td>
<td>oradb_cd</td>
<td>CONNECTED</td>
<td>12.1.0.2.0 12.0.0.0.0</td>
</tr>
<tr>
<td>1</td>
<td>+ASM1</td>
<td>oradb_cd</td>
<td>CONNECTED</td>
<td>12.1.0.2.0 12.0.0.0.0</td>
</tr>
</tbody>
</table>

The preceding output shows a two-node RAC instance (column INST_ID 1 and 2) where +ASM1 is hosting both RAC databases (oradb_cd). Typically you would see +ASM1 for the first instance and +ASM2 for the second instance. This is because the ASM instance is down on instance 2 and Flex ASM has connected the database to the surviving ASM instance on instance 1. Even after the failed ASM instance on Node 2 is brought online, the database connection will remain on instance 1 until it’s relocated back to instance 2 or a cluster bounce. To move the database back to the original ASM instance, first connect to the ASM instance that is currently hosting the database, and after confirming ASM and the diskgroup are online on the destination node, issue the RELOCATE command shown a bit later.

Before relocating the database:
Start ASM on Node 2:

Connect to the surviving ASM instance where the database that needs to be migrated resides and issue the RELOCATE command. We need to relocate the instance named oradbcd2 to ASM2.

```
[oracle@Linux72 ~]# srvctl start asm -n Linux72
[oracle@Linux72 ~]# ps -el | grep asm
root  3849  1 0 13:52 ? 00:01:21 /u01/app/12.1.0/grid/bin/osys
mond.bin 8033  1 0 16:18 ? 00:00:00 asm asm smon ASM2
```

Connect as sysasm:

```
SQL> alter system relocate client 'oradbcd2:oradb_cdb';
System altered.
```

After issuing the RELOCATE command, you can see that the INST_ID for oradbcd2 has changed to INST_ID 2, which means ASM2 is hosting the database:
You can confirm this by connecting to the oradbcd2 instance and querying V$ASM_CLIENT:

```sql
SELECT instance_name, db_name, status, software_version, compatible_version
FROM v$asm_client;
```

```plaintext
<table>
<thead>
<tr>
<th>INSTANCE_NAME</th>
<th>DB_NAME</th>
<th>STATUS</th>
<th>SOFTWARE_VERSION</th>
<th>COMPATIBLE_VERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ASM2</td>
<td>oradb_cdc</td>
<td>CONNECTED</td>
<td>12.1.0.2.0</td>
<td>12.0.0.0.0</td>
</tr>
</tbody>
</table>
```

Flex ASM uses the ASM network settings defined during the install. A new ASM listener is enabled with default port 1522 that connects to ASM on remote servers. Local ASM listener runs on each node where the Flex ASM instance is running. Connections are load balanced across the ASM cluster.

Connecting to the remote ASM instance requires an ASM password file. ASM password files are automatically created during installation. 12c ASM password files are kept in the ASM diskgroup, so this information is shared within the cluster. If there is a need to create the password file, the new `orapwd` utility now accepts a diskgroup for storing the password file.

To create an ASM password file:
To create a database password file:

```
orapwd file='+OCR_DISK' asm=y
```

To view the Flex ASM password file:

```
orapwd file='+OCR_DISK' password=****** dbunique=oracle
```

Importantly, note that Oracle 12c requires an ASM diskgroup compatibility setting of 12.1.0.0 or higher for storing password files in ASM. The compatibility setting can be modified by using the “asmca” GUI tool or by issuing the following command:

```
alter diskgroup <diskgroup name> attribute 'compatible.asm' = '12.1';
```

If the password diskgroup compatibility setting is incorrect, then you will receive an error when creating the database.

Oracle provides an option to convert from 12c standard ASM to Flex ASM using asmca:

```
asmca -silent -convertToFlexASM -asmNetworks eth1/192.168.1.121-AdministratorPort 1522
```

To complete ASM conversion, run the following script as privileged user in local node:

```
/u01/app/12.1.0/grid/otn/onlog/asmca/scripts/convertToFlexASM.sh
```

**Oracle 12c Flex Cluster**

Starting with Oracle 12c Grid Infrastructure, Oracle has introduced a new topology for RAC and how high-availability applications and databases are managed using RAC. Oracle Flex Cluster provides a platform for both applications and databases that are managed by cluster services. The correlation
between Flex ASM and Flex Cluster is that Flex ASM is required for Flex Cluster, but Flex ASM does not require Flex Cluster.

Oracle Flex Cluster contains two types of nodes, referred to as Hub Nodes and Leaf Nodes. Hub Nodes are considered similar to the standard cluster configuration where ASM and database instances run and have access to shared storage. The main difference between a Hub Node and a Leaf Node is that a Hub Node has direct access to shared storage whereas the Leaf Node does not. Leaf Nodes are different from standard Oracle grid nodes in that they don’t require VIPs or direct access to shared storage. The processes which run on Leaf Nodes are the cluster services without ASM or database. The main purpose for Leaf Nodes is to host high-availability applications that are registered and managed by cluster services. Leaf Nodes are not meant to host databases, as of this release. Leaf Nodes are intended for configuring high-availability applications similar to GoldenGate and WebLogic and Apps.

Use the following command to check if Flex Cluster is enabled:

```
ASMCMD> showclustermode
ASM cluster : Flex mode enabled
```

Check the role for each node in the cluster as follows:

```
[oracle@Linux72 ~]$ olsnodes -a -n
linux71 1   Hub
linux72 2   Hub
```

Options for converting from Leaf to Hub and vice versa are provided using the `runInstaller` - `updateNodList` command.

---

**Srvctl Enhancements**

With version 12c of ASM, Oracle has made several enhancements to commands that manage database and cluster services. One such enhancement is that you can now determine the steps a command would take when executing without actually executing the command. Unlike prior versions, which have no method to evaluate the execution path of the command, this version will provide detailed steps and show the impact on the database or cluster of executing the command. The Server Control Utility, `srvctl`, has been modified to predict or evaluate a command before actually executing. Not all `srvctl` commands are enabled to take advantage of this option; only a subset of commands has this feature enabled.

The `–eval` option of `srvctl` enables you to simulate running a command without having any impact on the system. The `–eval` option provides information about what will happen if the command is executed. The following `srvctl` commands can use the `–eval` option to simulate running the command:
If your databases are configured using the standard admin-managed configuration, then the preceding commands might fail as shown here:

```
srvc1 add database
srvc1 add service
srvc1 add srvpool
srvc1 modify database
srvc1 modify service
srvc1 modify srvpool
srvc1 relocate server
srvc1 relocate service
srvc1 remove srvpool
srvc1 start database
srvc1 start service
srvc1 stop database
srvc1 stop service
```

To confirm there are no server pools configured, execute the following:

```
oracle@Linux72 ~]$ srvc1 config srvpool
Server pool name: Free
Importance: 0, Min: 0, Max: -1
Category:
Candidate server names:
Server pool name: Generic
Importance: 0, Min: 0, Max: -1
Category:
Candidate server names: linux71,linux72
```

The output shows the default server pools available. There is a “Free” pool and a “Generic” pool, but there are no servers assigned to the pool. The `srvc1` command provides detailed help for each option. For example, to view the available options for starting a database using `srvc1`:
The `help` option of `srvctl` will provide details on all the command options, including `-eval`. In addition to the `-eval` commands, Oracle 12c ASM provides another useful command, `predict`, which predicts what will happen when a resource fails and cannot be restarted on the same node. Just as the `-eval` command, this command also does not make any modification to the system.

To view the list of `srvctl` commands that can be used with `predict`, add the `--help` option:

```
oracle@Linux72 ~]$ srvctl predict --help
```

The `srvctl predict` command evaluates the consequences of resource failure:

```
Usage: srvctl predict database -db <database_name> [-verbose]
Usage: srvctl predict service -db <database_name> -service <service_name> [-verbose]
Usage: srvctl predict asm [-node <node_name>] [-verbose]
Usage: srvctl predict diskgroup -diskgroup <diskgroup_name> [-verbose]
Usage: srvctl predict filesystem -device <volume_device> [-verbose]
Usage: srvctl predict vip -vip <vip_name> [-verbose]
Usage: srvctl predict network [-netnum <network_number>] [-verbose]
Usage: srvctl predict listener -listener <listener_name> [-verbose]
Usage: srvctl predict scan -scannumber <scan_ordinal_number> [-netnum <network_number>] [-verbose]
Usage: srvctl predict scan_listener -scannumber <scan_ordinal_number> [-netnum <network_number>] [-verbose]
Usage: srvctl predict oc4j [-verbose]
```

For example, to predict the outcome if ASM fails on a two-node RAC:
The preceding output from `predict` outlines the consequences if ASM is stopped. It shows that the diskgroups (DB_DISK01, OCR_DISK) will be stopped, database mgmtdb (single-node database) will be stopped, and database oradb_cdb (two-node RAC instance) will be stopped. So the `predict` command is predicting that if ASM crashes on both nodes on a two-node RAC environment, it will bring down everything. The two-node RAC test environment I’m using is configured for Flex ASM, so why is it bringing down the databases if ASM is down? The answer is that the command I issued to stop ASM was cluster wide, and not for a specific ASM instance running on a cluster server.

The following example predicts if ASM fails on a specific cluster node:

```
[oracle@Linux72 ~]$ srvctl predict asm -node linux72
Resource ora.asm will be stopped
Resource ora.Disk01 dg will be stopped
Resource ora.OCR DSK dg will be stopped
[oracle@Linux72 ~]$s
```

Note the preceding example is isolating ASM failure on node linux72; the output shows diskgroups only come down and does not show any impact on the database running on this node. If this was an 11g RAC environment, the databases running on cluster node linux72 would crash if ASM fails. With Flex ASM enabled with 12c, the database will automatically connect to the surviving ASM instance on the cluster via the ASM listener.

More detailed help for each `predict` command can be seen using the `-help` option:

```
[oracle@Linux72 ~]$ srvctl predict listener -h
Predicts the consequences of listener failure.
Usage: srvctl predict listener -listener <listener_name> [-verbose]
          -listener <listener_name> Listener name
          -verbose   Verbose output
          -help      Print usage
[oracle@Linux72 ~]$s
```

In addition to the preceding changes for `srvctl`, 12c has deprecated single-character parameters when executing commands. Version 12.1 of `srvctl` still is backward compatible and will allow for
single-character parameters, but for newer versions, the single-character parameter will be deprecated. For example, the -d parameter for database option would need to spelled out as follows:

11g: `srvctl status database -d oradb_cdb`
12c: `srvctl status database -database oradb_cdb`
(or `srvctl status database -db oradb_cdb`)

To see the improvement of 12c, consider the following list of new 12c `srvctl` commands that *did not exist* on 11g ASM. To understand how each command works, use the `-help` option for the command.

```
srvctl predict asm          srvctl disable mgmtdb
srvctl relocate asm         srvctl enable mgmtdb
srvctl predict database     srvctl getenv mgmtdb
srvctl update database      srvctl modify mgmtdb
srvctl predict diskgroup    srvctl relocate mgmtdb
srvctl add exportis         srvctl remove mgmtdb
```

```
srvctl predict network      srvctl predict oc4j
srvctl add rhpclient        srvctl config rhpclient
srvctl disable rhpclient    srvctl enable rhpclient
```
For `crsctl`, the only newly added command seems to be `crsctl eval`, which is similar to `srvctl -eval`. To get detailed help on `crsctl eval`, use the `-help` option.
ASM Disk Scrubbing

With Oracle ASM 12c, logical disk corruptions can be repaired by the scrubbing process. ASM disks that are configured with normal or high redundancy can take advantage of this process. Disk scrubbing works by using the mirror disks to fix logical corruptions, and the scrub operation has minimal impact to I/O. The scrub operation can be performed on a diskgroup, disks, or ASM datafile. The scrub operation provides four options for disk scrubbing:

1. **REPAIR**: `alter diskgroup DB_DISK01 scrub repair;`
   The REPAIR option automatically repairs disk corruptions. If the REPAIR option is not specified, the process only checks for logical corruption without fixing the corruption.

2. **POWER (AUTO, LOW, HIGH, MAX)**: `alter diskgroup DB_DISK01 scrub POWER HIGH;`
   The POWER option controls the resources ASM will allocate for the scrub operation. If the POWER option is not specified, then the default is AUTO, where ASM would evaluate the current system load and run the scrub process with minimal impact to the system.

3. **WAIT**: `alter diskgroup DB_DISK01 scrub wait;`
   When the WAIT option is used, the scrub operation is not added to the scrubbing queue; instead the process waits for the scrubbing operation to complete. If this option is performed using SQL*Plus, the prompt won’t return until the scrub wait completes. The alert log for ASM will show the “wait” process. For example:

   ```
   Thu Apr 14 12:44:26 2016
   SQL> alter diskgroup DB_DISK01 scrub wait
   Thu Apr 14 12:44:26 2016
   NOTE: Start scrubbing diskgroup DB_DISK01
   NOTE: Waiting for scrubbing to finish
   Thu Apr 14 12:44:26 2016
   ERROR: File /DB_DISK01/ORADB_CDB/TEMPFILE/TEMP.267.908469297 is not supported (6)
   ERROR: File /DB_DISK01/ORADB_CDB/2FD9B6D257BDA8E530F236B8000200/TEMPFILE/
   TEMP.279.908470915 is not supported (6)
   Thu Apr 14 12:47:33 2016
   NOTE: Scrubbing Finished
   Thu Apr 14 12:47:33 2016
   SQL> ALTER DISKGROUP DB_DISK01 scrub wait;
   ```

4. **FORCE**: `alter diskgroup DB_DISK01 scrub force;`
   This option is used to force a scrub operation even if the system load is high. As previously mentioned, the scrub operation can be performed on ASM diskgroups, disks, and files:

   - **Diskgroup**: `alter diskgroup DB_DISK01 scrub repair power high force;`
   - **Disks**: `alter diskgroup DB_DISK01 scrub disk DB_DISK01_0000 repair power high force;`
   - **ASM file**: `alter diskgroup DB_DISK01 scrub file '/DB_DISK01/ORADB_CDB/DATAFILE/users.259.908469163' repair power max force`
The exception to ASM files is the TEMP files, as shown in the previous log for WAIT:

```
ERROR: file 'DB_DISK1/ORA_DB/CDB/TEMPFILE/TEMP.267.902469297' is not supported (6)
```

The disk scrubbing process can be combined with a diskgroup rebalancing operation to reduce I/O resources. The progress of the scrub operation can be viewed using V$ASM_OPERATION, or use ASMCMD LSOP.

## ASM Rebalance Enhancements

One of the new options in 12c in regard to ASM disks is the choice of rebalancing ASM disks manually. Typically ASM disks are automatically rebalanced, where disk configuration changes by adding or removing disks from a diskgroup. With 12c ASM, Oracle provides the ability to run manual rebalance operations. The ALTER DISKGROUP REBALANCE operation uses the POWER value to allocate resources and speed up the rebalance operation. If the POWER value is not specified, the process uses the value in ASM_POWER_LIMIT specified in the ASM spfile, which by default is 1. In 12c ASM the POWER values range from 0 to 1024, and for setting the values larger than 11, you must set the COMPATIBLE.ASM parameter to 11.2.0.2 or higher. If the COMPATIBLE.ASM is set to less than 11.2.0.2, then the max POWER setting will be 11 even if you explicitly set the POWER limit to a higher value.

With the POWER settings of the rebalance operations, you can control the degree of parallelism and thus speed up the rebalance operation. This option also provides functionality to increase or decrease the POWER limit to accommodate for the server resource capacity. You can completely halt the rebalance operation by setting the POWER value to 0, and when you want it to resume, you can then increase the POWER setting to start the rebalance operation from where it stopped.

The EXPLAIN WORK SQL statement, which is new to 12c ASM, uses the V$ASM_ESTIMATE view to determine the amount of work required to add or drop disks. The EXPLAIN WORK statement populates the V$ASM_ESTIMATE view with the estimated work to complete the operation without actually executing the command. By modifying the POWER setting in the EXPLAIN WORK statement, you can view the adjustments made to the EST_WORK column of the V$ASM_ESTIMATE view. Column EST_WORK provides an estimate of the number of allocation units to be moved for the rebalance operation to complete. Oracle ASM tries to keep rebalance I/O for each unit of power. Each I/O requires Program Global Area (PGA) memory for the extent involved in the relocation, so increasing PGA might speed up the rebalance operation.

Rebalance behavior can be affected by modifying the CONTENT.CHECK and THIN_PROVISIONED diskgroup attributes. The CONTENT.CHECK attribute enables or disables content checking when performing data copy operations for rebalancing a diskgroup. The attribute value is either TRUE or FALSE (the default value). When the value is set to TRUE, logical content checking is enabled for all rebalance operations. The THIN_PROVISIONED attribute enables or disables the functionality to discard unused storage space after a diskgroup rebalance is completed; the default value is FALSE. This attribute is supported only on 12c with Oracle ASM Filter Driver
To view ASM attribute settings, you can query V$ASM_ATTRIBUTE or, if connected to ASMCMD, run the following command. Oracle 12c ASM has added more diskgroup attributes to those available in previous releases.

```
ASMCMD> lsattr -l

Name                              Value
access_control.enabled            FALSE
access_control.umask              066
au_size                           1048576
cell.smart_scan_capable          FALSE
compatible.asm                    12.1.0.0.0
compatible.rdbms                   10.1.0.0.0
content.check                     FALSE
content.type                      data
disk_repair_time                   3.6h
failgroup_repair_time             24.0h
idp.boundary                      auto
idp.type                          dynamic
phys_meta_replicated               true
sector_size                        512
thin_provisioned                   FALSE
access_control.enabled            FALSE
access_control.umask              066
au_size                           1048576
cell.smart_scan_capable          FALSE
compatible.asm                    12.1.0.0.0
compatible.rdbms                   10.1.0.0.0
content.check                     FALSE
content.type                      data
disk_repair_time                   3.6h
failgroup_repair_time             24.0h
idp.boundary                      auto
idp.type                          dynamic
phys_meta_replicated               true
sector_size                        512
thin_provisioned                   FALSE

ASMCMD>
```

The following is an example for EXPLAIN WORK:
You can use EXPLAIN WORK with almost any ALTER DISKGROUP commands and query V$ASM_ESTIMATE to better estimate the amount of work needed for completion.

With 12c ASM, we have V$ACTIVE_SESSION_HISTORY (ASH), which gives us the ability to query ASM SQL history and check when commands were executed in ASM; this requires using the “tuning-pack” license.

```
select sample_time, session_type, sql_id, sql_opname
from v$active_session_history
where sql_opname is not null
order by 1;
```

```
<table>
<thead>
<tr>
<th>SAMPLE TIME</th>
<th>SESSION TYPE</th>
<th>SQL ID</th>
<th>SQL OPNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-APR-16 12.25.30.807 PM</td>
<td>FOREGROUND</td>
<td>2652h26tjnm7k</td>
<td>ALTER DISK GROUP</td>
</tr>
<tr>
<td>22-APR-16 12.25.31.807 PM</td>
<td>FOREGROUND</td>
<td>2652h26tjnm7k</td>
<td>ALTER DISK GROUP</td>
</tr>
<tr>
<td>22-APR-16 12.25.32.807 PM</td>
<td>FOREGROUND</td>
<td>2652h26tjnm7k</td>
<td>ALTER DISK GROUP</td>
</tr>
</tbody>
</table>
```

```
select sql_text
from v$sqltext
where sql_id = '2652h26tjnm7k'
order by piece;
```

```
SQL_TEXT

ALTER DISKGROUP ALL MOUNT /* asm agent call crs */ /* {0:9:3} */
```
ASM Fast Mirror Resync

Oracle ASM fast resync significantly reduces the time to resynchronize a failed disk by quickly resynchronizing the Oracle ASM disk extents. Problems that make a failure group temporarily unavailable are considered transient failures that can be recovered from by the ASM fast mirror resync feature. This feature keeps track of pending changes to extents on an offline disk during an outage. When the disk is brought back online, the extents stored on the offline disk are resynced. When a disk is taken offline, Oracle ASM by default will drop the disk in 3.6 hours. By setting the DISK_REPAIR_TIME attribute you can delay the drop operation by specifying a time interval. The DISK_REPAIR_TIME attribute can only be set on diskgroups with high or normal redundancy, and the ASM compatibility setting must be set at 11.1 or higher. The REPAIR_TIME of V$ASM_DISK shows the amount of time left, in seconds, before the offline disk is dropped. When the REPAIR_TIME is elapsed, ASM will drop the disk.

You can use the ALTER DISKGROUP command to set the DISK_REPAIR_TIME attribute to a specified hour or minute value:

```sql
alter diskgroup DB_DISK01 set attribute 'disk_repair_time' = '4.0h';
alter diskgroup DB_DISK01 set attribute 'disk repair time' = '240m';
```

During the ALTER DISKGROUP operations, you can query V$ASM_OPERATION as follows to view the state of the current operation. The PASS column of V$ASM_OPERATION shows the type of operation performed.

```sql
select group_number, pass, state from v$asm_operation;
```

Use this query of V$ASM_OPERATION to verify what might be running to slow down I/O performance, noting the type of operation performed.

ASM Filter Driver

Starting with 12c ASM, for stand-alone and cluster environments, Oracle provides a kernel module called ASM Filter Driver (ASMFD) for managing ASM disks. As part of the 12c Grid Infrastructure (GI) install, ASMFD simplifies the configuration and management of disk devices by eliminating the need to rebind disk devices when Oracle ASM is restarted. ASMFD also filters any non-Oracle I/O request that could accidently overwrite ASM disks. If ASMLIB is already configured while installing 12c GI, then ASMFD will not automatically override ASMLIB configuration. After installing 12c GI, you will need to migrate disks manually from ASMLIB to ASMFD if you decide to not use ASMLIB. Oracle 12c GI will work with ASMLIB and this functionally will still be supported, but if the choice
is to migrate to ASMFD for better management and security for ASM disks, then after the 12c GI install, you will need to manually migrate to ASMFD.

One of the key benefits of migrating to ASMFD is the security it provides to the ASM disks. Once the disks are migrated to ASMFD, the ownership of the disks will be “root” and not “oracle” or “grid.” By having the ownership changed to root, the disks are better secured from non-root users accidentally damaging the header or contents of the disks. Oracle provides documentation on how to configure ASMFD with and without ASMLIB (Doc ID 2060259.1). Since the test environment I am using is a two-node 12c cluster without ASMFD, the following steps provide an example of how to convert from ASMLIB to ASMFD.

Before configuration of ASMFD, as you can see here, ASMFD is not loaded (run as root user):

```
[root@Linux71 -]# asmcmd afd state
SMCMD 9523: The AFD state is 'NOT INSTALLED' and filtering is 'DEFAULT' on host
```

And before configuration of ASMFD, my disks are owned by oracle:oinstall:

```
/dev/oracleasm/disks
brw-rw---- 1 oracle oinstall 8, 49 Apr 25 11:59 DB_DTSK_01
brw-rw---- 1 oracle oinstall 8, 33 Apr 25 12:00 OCR_DTSK
```

Now, I’ll configure ASMFD (run as root user). As the Oracle GI owner, I update the Oracle ASM disk discovery string to enable ASMFD to discover devices. You can check what the current ASM disk discovery string is as follows:

```
[oracle@Linux71 ~]$ asmcmd dsget
parameter:/dev/oracleasm/disks/*
profile:/dev/oracleasm/disks/*
```

So, the output shows the ASM disk discovery string is ‘/dev/oracleasm/disks/*’. I need to update this value to have ASM automatically discover ASMFD disks also:

```
[oracle@Linux71 ~]$ asmcmd dsset: '/dev/oracleasm/disks/*', 'AFD:*'
[oracle@Linux71 ~]$ asmcmd dsget
parameter:/dev/oracleasm/disks/*, AFD:* 
profile:/dev/oracleasm/disks/*,AFD:* 
```

As the preceding example shows, I used the ASMCMD DSSET command to add to the ASM disk discovery string ‘AFD:*’, so the disk discovery path has both the old and new search paths for ASM
disks. If you need to completely remove the old ASM disk discovery path, then issue `ASMCMD DSSET '/dev/oracleasm/disks/*'`, but for now, until I have completely configured ASMFD, I’ll leave the old disk path in place.

Since my test environment is two-node RAC 12c, I will need to shut down the CRS stack on all nodes before configuring ASMFD. To check how RAC nodes are configured:

```
[oracle@Linux71 ~]$ olsnodes -n -a
linux71 1         Hub
linux72 2         Hub
```

To stop CRS on all nodes, issue `crsctl stop has` as root for each node:

```
[root@Linux71 sbin]# crsctl stop has
CRS-2791: Starting shutdown of Oracle High Availability Services-managed resources on 'linux71'
CRS-2673: Attempting to stop 'ora.crf' on 'linux71'
CRS-2673: Attempting to stop 'ora.mdnsd' on 'linux71'
CRS-2677: Stop of 'ora.crf' on 'linux71' succeeded
CRS-2677: Stop of 'ora.mdnsd' on 'linux71' succeeded
CRS-2793: Shutdown of Oracle High Availability Services-managed resources on 'linux71' has completed
CRS-4133: Oracle High Availability Services has been stopped.

[root@Linux72 sbin]# crsctl stop has
CRS-2791: Starting shutdown of Oracle High Availability Services-managed resources on 'linux72'
CRS-2673: Attempting to stop 'ora.crf' on 'linux72'
CRS-2673: Attempting to stop 'ora.mdnsd' on 'linux72'
CRS-2673: Attempting to stop 'ora.gpnpd' on 'linux72'
CRS-2677: Stop of 'ora.crf' on 'linux72' succeeded
CRS-2677: Stop of 'ora.mdnsd' on 'linux72' succeeded
CRS-2677: Stop of 'ora.gpnpd' on 'linux72' succeeded
CRS-2677: Stop of 'ora.gipcd' on 'linux72' succeeded
CRS-2677: Stop of 'ora.gipcd' on 'linux72' succeeded
CRS-2793: Shutdown of Oracle High Availability Services-managed resources on 'linux72' has completed
CRS-4133: Oracle High Availability Services has been stopped.
```

After CRS is stopped on all nodes, I can start configuring ASMFD. As root user, I run `afd_configure`:  

Following are the details on my test system:

```
[root@Linux71 sbin]# asmcmd afd configure
Connected to an idle instance.
AFD-620: AFD is not supported on this operating system version: 'unknown
AFDM-9524: AFD configuration failed 'ERROR: afdroot install failed'
```

After applying patch 18321597, I try to configure AFD:

```
[oracle@Linux71 ~]$ asmcmd showpatches
List of Patches
18321597

[root@Linux71 sbin]# asmcmd afd configure
Connected to an idle instance.
AFDM-9519: ASMLib is present with ASM disk string '/dev/oracleasm/
disks/*,AFD:*'; command requires default ASM disk string
The above error is because ASMLIB is still running, will need to stop ASMLIB before executing above command. Stopping ASMLIB on both RAC nodes.
[root@Linux71 sbin]# ./oracleasm exit
Unmounting ASMLib driver filesystem: /dev/oracleasm
Unloading module "oracleasm": oracleasm
```

After stopping ASMLIB, I am able to successfully run the AFD_CONFIGURE command:
The preceding process will add AFD devices into /etc/udev/rules.d/53-afd.rules as listed here:

```
# AFD devices
KERNEL="oracleafd/.*", OWNER="oracle", GROUP="oinstall", MODE="0770"
KERNEL="oracleafd/*", OWNER="oracle", GROUP="oinstall", MODE="0770"
KERNEL="oracleafd/disks/*", OWNER="oracle", GROUP="oinstall", MODE="0660"
```

AFD_STATE reports LOADED on the first node, linux71. Since this is two-node RAC, I need to run ASMCMD AFD_CONFIGURE on the second node, also after stopping ASMLIB on the second node:

```
[oracle@Linux71 dev]$ ls -ld ora*
```

drwxrwx---. 3 oracle oinstall 80 Apr 26 10:54 oracleafd

drwxr-xr-x. 2 root root 40 Apr 26 10:13 oracleasm

On all RAC nodes, I disable oracleasm.service, to avoid ASMLIB from automatically starting up after rebooting:
I then confirm the AFD driver is loaded:

```bash
[root@Linux71 log]# asmcmd afd state
ASMCMDS-5126: The AFD state is 'LOADED' and filtering is 'DEFAULT' on host 'Linux71.localdomain'
```

Next, I migrate ASMLIB disks to AFD. Before you perform the `migrate` command, make sure you have the correct diskgroup and path; importantly, make sure you have the correct disk partition (in `sdc1`, for example, the `1` shows that it is partition one).

```bash
[root@Linux71 -]# asmcmd afd_label OCR_DISK '/dev/sdc1' --migrate
Connected to an idle instance.
```

After running the preceding command, an ASCII text file is created under the `/dev/oracleafd/disks/` directory, as shown next, and the content of the text file is the actual raw disk path. Also important to note is that root is the owner of the new ASCII text file.

```bash
root@Linux72 disks]# ls -1 /dev/oracleafd/disks
total 4
-rw-r--r--. 1 root root 10 May 2 12:53 OCR_DISK
```

```bash
[root@Linux72 disks]# [root@Linux71 disks]# cat OCR_DISK /dev/sdc1
```

```bash
root@Linux71 disks]# asmcmd afd_loadisk
Connected to an idle instance.
```

---

<table>
<thead>
<tr>
<th>Label</th>
<th>Filtering</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCR_DISK</td>
<td>ENABLED</td>
<td>/dev/sdc1</td>
</tr>
</tbody>
</table>

After executing the preceding command on all nodes, I start the cluster for each node:
Once the cluster is online, I connect to the ASM instance via SQL*Plus and confirm PATH is using AFD:

```sql
SELECT inst_id, name, state, path 
FROM gv$asm_disk;

<table>
<thead>
<tr>
<th>INST ID</th>
<th>NAME</th>
<th>STATE</th>
<th>PATH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OCR_DISK_0000</td>
<td>NORMAL</td>
<td>AFD:OCR_DISK</td>
</tr>
<tr>
<td>2</td>
<td>OCR_DISK_0001</td>
<td>NORMAL</td>
<td>AFD:OCR_DISK</td>
</tr>
</tbody>
</table>
```

```
SELECT SYS_CONTEXT('SYS_ASMFD_PROPERTIES', 'AFD_STATE') FROM DUAL;

SYS_CONTEXT('SYS_ASMFD_PROPERTIES', 'AFD_STATE')

CONFIGURED
```

Next I modify the settings for ASM_DISKSTRING and AFD_DISKSTRING:

```sql
SQL> ALTER SYSTEM set asm_diskstring = 'AFD:*';
System altered.
```
I confirm /etc/afd.conf file settings are correct on all nodes:

```
[root@Linux72 etc]# cat /etc/afd.conf
afd_diskstring='/dev/sd*'  
afd_filtering=enable
```

And then I confirm all cluster environments are online:

```
root@Linux72 disks]# crsctl check cluster -all
******************************************************************************
linux71:
CRS-4537: Cluster Ready Services is online
CRS-4529: Cluster Synchronization Services is online
CRS-4533: Event Manager is online
******************************************************************************
linux72:
CRS-4537: Cluster Ready Services is online
CRS-4529: Cluster Synchronization Services is online
CRS-4533: Event Manager is online
```

To add new disks to diskgroups, first partition the new disk using fdisk and then simply add the disks using `ASMCMD AFD_LABEL DB_DISK_01 '/dev/sdd1'` and then perform ASMCMD AFD_SCAN on the rest of the nodes. When creating a new diskgroup using “asmca”, make sure the discovery path is AFD during the Create Disk Group step. After adding the new disk, you should be able to list the newly added disk:

```
[root@Linux71 disks]# asmcmd afd_listdisk

  Label        Filtering    Path
  --------------------------
  OCR_DISK  DISABLED    /dev/sdcl
  DB_DISK_01 DISABLED    /dev/sdd1
```

Oracle has provided another new tool that displays GI/RAC cluster info (Doc ID 1568439.1). The Perl script `ols.pl` provides detailed information on the current configuration of the cluster, including Flex usage and AFD configuration and whether Hub/Leaf Nodes are configured. Sample output is
shown here:

```
[oracle@Linux71 ~]$ perl ols.pl
Local Time Now : 2016-05-18 15:01:52

The Cluster Nodes are : linux71, linux72
The Local Node is : linux71
The Remote Nodes are : linux72
```
Major Clusterware Software Version is: 12.1.0.2.0
Major Clusterware Active Version is: 12.1.0.2.0
Major Clusterware Release Version is: 12.1.0.2.0

CRS_HOME is installed at: /u01/app/12.1.0/grid
CRS_BASE is installed at: /u01/app/grid_base
CRS_OWNER is: oracle
CRS_GROUP is: oinstall
ORACLE_HOMES[0] is installed at: /u01/app/oracle_base/product/12.1.0/dbhome_1 (on Local FS)
ORACLE_BASES[0] is installed at: /u01/app/oracle_base (on Local FS)
ORACLE_OWNER[0] is:
ORACLE_GROUPS[0] is:

All databases created: orcl

<table>
<thead>
<tr>
<th>DB_NAME</th>
<th>MANAGEMENT</th>
<th>DB_TYPE</th>
<th>DB_VERSION</th>
<th>DB_HOME</th>
<th>DG/FS USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>orcl</td>
<td>administrator</td>
<td>RAC</td>
<td>12.1.0.2.0</td>
<td>/u01/app/oracle_base/product/12.1.0/dbhome_1</td>
<td>'+DB_DISK'</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NODE_NAME</th>
<th>NODE_ID</th>
<th>NODE_STATE</th>
<th>NODE_ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>linux71</td>
<td>1</td>
<td>Active</td>
<td>Hub</td>
</tr>
<tr>
<td>linux72</td>
<td>2</td>
<td>Active</td>
<td>Hub</td>
</tr>
</tbody>
</table>

Cluster Name: Linux-cluster
SCAN Name: Oracle-SCAN1
SCAN Listeners: LISTENER_SCAN1 (Port: TCP:1523), LISTENER_SCAN2 (Port: TCP:1523), LISTENER_SCAN3 (Port: TCP:1523)

CNS Status: configured and enabled
CNS Running Node: linux71
CNS Version: 12.1.0.2.0
CNS VIP: 192.168.56.55
CNS Subdomain: Linux.localdomain
CNS-to-DNS Port: 53
CNS-to-mDNS Port: 5353

Node VIP Version: 12.1.0.2.0
Local Node VIPs: ora.linux71.vip Linux71_vip.localdomain (static)
ora.linux72.vip Linux72_vip.localdomain (static)

<table>
<thead>
<tr>
<th>NIC</th>
<th>Subnet</th>
<th>Netmask</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>enp0s3</td>
<td>192.168.56.0</td>
<td>255.255.255.0</td>
<td>global public</td>
</tr>
<tr>
<td>enp0s9</td>
<td>192.168.1.0</td>
<td>255.255.255.0</td>
<td>global</td>
</tr>
</tbody>
</table>

cluster_interconnect,asm
linux71:
linux72:

OCR Location: '+OCR_DISK'
Voting Disk Location: '+OCR_DISK'

Cluster Mode: Flex Cluster

Hub Node =========
Node =========
linux71 (1, Active) =========
linux72 (2, Active) =========

MGMTDB Status: enabled and is running on linux72
MGMTDB HOME: <CRS home>
MGMTDB Spfile: '+OCR_DISK/_%MGMTDB/PARAMETERFILE/spfile.268.910717855'
MGMTDB Instance: '+MGMTDB'

MGMTLSNR Status: enabled and is running on linux72
MGMTLSNR HOME: <CRS home>
MGMTLSNR Port: TCP:1521
Detailed state:  

ASMNET1LSNR_ASM
=====================

Subnet: 192.168.1.0
End points: TCP:1522
Owner: oracle
Home: <CRS home>
Status: enabled

<table>
<thead>
<tr>
<th>DISKGROUP</th>
<th>REDUNDANCY</th>
<th>AU</th>
<th>COMPATIBILITY</th>
<th>DB_COMPATIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIZE_MB</td>
<td>FREE_MB</td>
<td>USABLE_MB</td>
<td>PATH</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>----------</td>
<td>------</td>
<td>----------</td>
</tr>
<tr>
<td>DB_DISK</td>
<td>EXTERN</td>
<td>1MB</td>
<td>12.1.0.0.0</td>
<td>10.1.0.3.0</td>
</tr>
<tr>
<td>AFD:LB_DISK_02 -&gt; /dev/sdcl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCR_DISK</td>
<td>EXTERN</td>
<td>1MB</td>
<td>12.1.0.0.0</td>
<td>10.1.0.3.0</td>
</tr>
<tr>
<td>AFD:OCR_DISK_02 -&gt; /dev/sdcl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ASM Host =========
Client =========

Linux71.localdomain(+ASM1)
'+ASM1 (linux71)'
More detailed output can be obtained by passing the parameter `ols.pl -f -v`; the script can also be run on 11g cluster environments.

**Table 3-1** lists some of the ASM background processes and briefly describes each process.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
<th>Required for Basic DB Operation</th>
<th>Started by Default</th>
<th>New in This Release</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACFS</td>
<td>Tracks the cluster membership in CSS and informs the filesystem driver of membership changes.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ARB 0..A</td>
<td>Rebalances data extents across the ASM filesystems.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ARSn</td>
<td>The ASM RBAL background process coordinates and spawns one or more of these slave processes to recover aborted ASM transactional operations. These processes run only in the Oracle ASM instance.</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>ASMB</td>
<td>Communicates with the ASM instance, managing storage and providing statistics.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B00 0..4</td>
<td>Performs maintenance actions on ASM diskgroups.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Bnnn</td>
<td>Performs maintenance actions on Oracle ASM diskgroups. Bnnn performs actions that require waiting for resources on behalf of GMON. GMON must be highly available and cannot wait.</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>FENC</td>
<td>Processes fence requests for RDBMS instances that are using Oracle ASM I/O Server instances.</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>GMON</td>
<td>Maintains disk membership in ASM diskgroups.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>MARK</td>
<td>Marks ASM Allocation Units as stale following a missed write to an offline disk.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>OCFn</td>
<td>Maintains a connection to the ASM instance for metadata operations.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Onnn</td>
<td>Maintains a connection to the ASM instance for metadata operations.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Process</td>
<td>Description</td>
<td>IST</td>
<td>OAM</td>
<td>RAC</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>RBAL</td>
<td>In an Oracle ASM instance, RBAL coordinates rebalance activity for diskgroups. In a database instance, it manages Oracle ASM diskgroups.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>RMON</td>
<td>Manages the rolling migration procedure for an Oracle ASM cluster. The RMON process is spawned on demand to run the protocol for transitioning an ASM cluster in and out of rolling migration mode.</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Rnnn</td>
<td>A database instance reading from an Oracle ASM diskgroup can encounter an error during a read. If possible, Oracle ASM asynchronously schedules an Rnnn slave process to remap this bad block from a mirror copy.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>SCCn</td>
<td>Acts as a slave process for SCRB and performs the checking operations.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>SCRB</td>
<td>Runs in an Oracle ASM instance and coordinates Oracle ASM disk scrubbing operations.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>SCRn</td>
<td>Acts as a slave process for SCRB and performs the repairing operations.</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>SCVN</td>
<td>Performs Oracle ASM disk scrubbing verify operation. SCVN acts as a slave process for SCRB and performs the verifying operations. The possible processes are SCV0–SCV9.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>TEMn</td>
<td>Emulates I/O errors on ASM disks through named events.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>VB Gn</td>
<td>Communicates between the ASM instance and the operating system volume driver.</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
ASM and Privileges

Access to the ASM instance is comparable to access to a standard instance, requiring a privilege level similar to that of SYSDBA and SYSOPER. Note, however, that since there is no data dictionary, authentication is done from an operating system level and/or an Oracle password file. Typically, the SYSDBA privilege is granted through the use of an operating system group. On Unix, this is typically the `dba` group, also referred to as the OSDBA group. With Oracle 10g, members of the `dba` group have SYSDBA privileges on all instances on the node, including the ASM instance. Users who connect to the ASM instance with the SYSDBA privilege have complete administrative access to all diskgroups in the system.

In 11g and 12c, Oracle has modified this concept and introduced the concept of ASMDBA, as well as the role of SYSASM. This role is tied to the OS-level group, logically called OSASM. This continues support for the separation-of-duties concept between system administrators and DBAs. The SYSDBA role can still be used when connecting to an ASM instance, but this role is not the all-powerful user. It has access capabilities to all the V$ views but does not have administrative privileges on ASM instances. The various roles are outlined here:

<table>
<thead>
<tr>
<th>OS-Level Logical Group</th>
<th>DBA Privilege Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSOPER</td>
<td>SYSOPER</td>
</tr>
<tr>
<td>OSDBA</td>
<td>SYSDBA</td>
</tr>
<tr>
<td>OSASM</td>
<td>SYSASM</td>
</tr>
</tbody>
</table>

| VDBG | Forwards ASM requests to perform various volume-related tasks. | No | No | No |
| VMBO | Maintains cluster membership on behalf of the ASM volume drivers. | No | No | No |
| VUBG | Relays messages between Oracle ASM instance and Oracle ASM Proxy instance that is used by ADVM (or ACFS). | No | No | Yes |
| Xnnn | Performs Oracle ASM post-rebalance activities. This process expels dropped disks at the end of an Oracle ASM rebalance. | No | No | Yes |
Three additional administrative users are introduced in 12c: SYSBACKUP, SYSDG, and SYSKM.

The following query lists who has been granted SYSDBA, SYSOPER, SYSASM, SYSBACKUP, SYSDG, or SYSKM as derived from the password file:

```
SQL> desc v$pwfile_users;
Name          Null?  Type
-------------  ------  -----------------
USERNAME               VARCHAR2(30)
SYSDBA                 VARCHAR2(5)
SYSOPER                VARCHAR2(5)
SYSAASM                VARCHAR2(5)
SYSBACKUP              VARCHAR2(5)
SYSDG                  VARCHAR2(5)
SYSKM                  VARCHAR2(5)
ContaID                NUMBER

select * from v$pwfile_users;

USERNAME | SYSDB | SYSOP | SYSA | SYSEA | SYSDG | SYSKM | ContaID
---------  -----  -----  ----  -----  -----  -----  -------
SYS       | TRUE  | TRUE  | TRUE | FALSE | FALSE | FALSE | 0
CRAMSER_ASM_001 | TRUE  | FALSE | TRUE | FALSE | TRUE  | FALSE | 0
ASM_SKM   | TRUE  | FALSE | FALSE| FALSE | FALSE | FALSE | 0
```

The SYSOPER privilege is supported in ASM instances and limits the set of allowable SQL commands to the minimum required for basic operation of an already-configured system.

The SYSASM privileges permit mounting and dismounting diskgroups and other storage administration tasks. SYSASM privileges provide no access privileges on an RDBMS instance. The following commands are available to SYSASM users:

- **STARTUP/SHUTDOWN**
- **ALTER DISKGROUP MOUNT/DISMOUNT**
- **ALTER DISKGROUP ONLINE/OFFLINE DISK**
- **ALTER DISKGROUP REBALANCE**
- **ALTER DISKGROUP CHECK**
- Access to all V$ASM_* views

All other commands, such as CREATE DISKGROUP, ADD/DROP/RESIZE DISK, and so on,
require the SYSDBA privilege and are not allowed with the SYSOPER privilege:

- SYSBACKUP is used to perform all backup and recovery operations (new to 12c).
- SYSDG is used for Data Guard activities (new to 12c).
- SYSKM is used for key management–related operations (new to 12c).

ASM and Multipathing

An I/O path generally consists of an initiator port, a fabric port, a target port, and a LUN. Each permutation of this I/O path is considered an independent path. Dynamic multipathing/failover tools aggregate these independent paths into a single logical path. This path abstraction provides I/O load balancing across the host bus adapters (HBAs), as well as nondisruptive failovers on I/O path failures. Multipathing (MP) software requires all the required disks to be visible on each available and eligible HBA. An MP driver detects multipaths by performing a SCSI inquiry command. Multipathing software also provides multipath software drivers. To support multipathing, a physical HBA driver must comply with the multipathing services provided by this driver. Please ensure that the configuration that you are considering is certified by the vendor. A multipathing tool provides the following benefits:

- Provides a single block device interface for a multipathed LUN
- Detects any component failures in the I/O path, for example, fabric port, channel adapter, or HBA
- When a loss of path occurs, ensures that I/Os are rerouted to the available paths with no process disruption
- Reconfigures the multipaths automatically when events occur
- Ensures that failed paths get revalidated as soon as possible and provides auto-failback capabilities
- Configures the multipaths to maximize performance using various load-balancing methods, for example, round robin, least I/Os queued, or least service time

TIP

Although ASM does not provide multipathing capabilities, it does leverage multipathing tools, as long as the path or device produced by the multipathing tool returns a successful return code from an FSTAT system call. My Oracle Support Note 294869.1 provides more details on ASM and multipathing.
The bigfile feature (as stated earlier in this chapter) is a perfect fit for VLDBs (very large databases) and ASM. Instead of managing several hundred datafiles, using bigfiles reduces the number of datafiles significantly. This improves checkpointing, and the time to open the database become significantly faster, as fewer file opens have to be performed. Using bigfiles reduces the internal overhead needed to manage a large number of datafiles. With ASM, bigfiles can be 32T for external redundancy and 12T for normal/high redundancy. This is based on an 8K block size. When using bigfiles, you have to review your backup and recovery strategy carefully. Obviously, you can’t do full datafile backup for a 36T datafile, so things like RMAN incremental and cumulative backups become an integral part of bigfile management.

Avoiding Disk Contention by Using Partitions

Partitioning is probably the single best option available for increasing the performance related to large tables. **Partitioning** is a way to increase efficiency by accessing smaller pieces of a table or index instead of accessing the full table or index. This can be particularly useful when one or more users are accessing multiple parts of the same table. If these partitions (pieces) of the table reside on different devices, the throughput is greatly increased. Partitions can also be backed up and recovered independently of each other (even while they are in use), eliminating potential disk I/O issues during backup times. Only when partitions are properly implemented are Oracle’s best performance-enhancing features realized. In 12cR2, Oracle also allows read-only partitions and subpartitions. The best way to understand partitioning is to look at an example. Consider the following simple example, where you partition the DEPT table into three partitions (pieces) using the DEPTNO column.

The TABLE DEPT is created with three range partitions:

```sql
create table dept
(deptno number(2),
 dept_name varchar2(30))
partition by range (deptno)
(partition d1 values less than (10) tablespace dept1,
 partition d2 values less than (20) tablespace dept2,
 partition d3 values less than (maxvalue) tablespace dept3);
```

This example builds three distinct partitions on the DEPT table. The key to getting better throughput is to ensure that each partition is placed on a different physical disk so that all three partitions can be accessed simultaneously if you are not using ASM. The tables spaces DEPT1, DEPT2, and DEPT3 must have physical files that are located on different physical disks. Remember that the tablespace is the logical holder of information where the datafile is the physical disk. You can have one tablespace that includes multiple datafiles, but a datafile can only relate to a single tablespace. The key to partitioning to improve disk I/O is to ensure that the partitions that will be accessed simultaneously either are located on different physical disks or use ASM.
Data is then entered into all three table partitions:

```
insert into dept values (1, 'ADMIN');
insert into dept values (7, 'MGMT');
insert into dept values (10, 'MANUF');
insert into dept values (15, 'ACCT');
insert into dept values (22, 'SALES');
```

The DEPT table still looks like a single table when you select from it:

```
select * 
from dept;
```

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>DEPT_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADMIN</td>
</tr>
<tr>
<td>7</td>
<td>MGMT</td>
</tr>
<tr>
<td>10</td>
<td>MANUF</td>
</tr>
<tr>
<td>15</td>
<td>ACCT</td>
</tr>
<tr>
<td>22</td>
<td>SALES</td>
</tr>
</tbody>
</table>

Here you selected all records from all of the partitions in the preceding example. In the next three examples, you select individually from each partition.

In this instance, you select from a single partition and access only a single partition:

```
select * 
from dept partition (d1);
```

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>DEPT_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ADMIN</td>
</tr>
<tr>
<td>7</td>
<td>MGMT</td>
</tr>
</tbody>
</table>

```
select * 
from dept partition (d2);
```

<table>
<thead>
<tr>
<th>DEPTNO</th>
<th>DEPT_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>MANUF</td>
</tr>
<tr>
<td>15</td>
<td>ACCT</td>
</tr>
</tbody>
</table>
select * from dept partition (d3);

DEPTNO  DEPT_NAME
-------  -----------
22      SALES

select * from dept
where deptno = 22;

DEPTNO  DEPT_NAME
-------  -----------
22      SALES

Note that in the final example, you eliminate the need to access the first or second partition (partition elimination). Partitioning indexes and using the parallel option along with partitions make partitioning even more powerful.

TIP
To minimize disk I/O on a single large table, you can break the table into multiple partitions that reside in tablespaces on different physical disks.

With interval partitioning (as of 11g), you no longer need to specify MAXVALUE in the upper partition. If you set it to 30 instead, and insert values above that, an additional partition will be built by Oracle:

```
cREATE TABLE dept
  (deptno NUMBER(2),
   dept_name VARCHAR2(30))

PARTITION BY RANGE(deptno)
PARTITION d1 VALUES LESS THAN (10) TABLESPACE dept1,
PARTITION d2 VALUES LESS THAN (20) TABLESPACE dept2,
PARTITION d3 VALUES LESS THAN (30) TABLESPACE dept3;
INSERT INTO dept VALUES (70, 'SALES');
```

A new partition will be created automatically (SYS_P41 in my case), which now holds the value of 70 in it. There are now four partitions in this table. Also, interval partitions in 12cR2 can be part of a subpartition (values can be inserted that are not in the range of the original table).
Getting More Information About Partitions

You can retrieve the information regarding partitions by accessing USER_TABLES, DBA_PART_TABLES, and USER_SEGMNENTS. Example queries to these three tables are displayed next with corresponding output for the examples in the preceding section.

```
select table_name, partitioned
from dba_tables
where table_name in ('DEPT', 'EMP');
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>PAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT</td>
<td>YES</td>
</tr>
<tr>
<td>EMP</td>
<td>NO</td>
</tr>
</tbody>
</table>

In the preceding example, the PAR (partitioned) column indicates whether a table is partitioned.

```
select owner, table_name, partition_count
from dba_part_tables
where table_name = 'DEPT';
```

<table>
<thead>
<tr>
<th>OWNER</th>
<th>TABLE_NAME</th>
<th>PARTITION_COUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>KEVIN</td>
<td>DEPT</td>
<td>3</td>
</tr>
</tbody>
</table>

In the preceding and following examples, there are three partitions on the DEPT table:

```
select segment_name, partition_name, segment_type, tablespace_name
from user_segments;
```

<table>
<thead>
<tr>
<th>SEGMENT_NAME</th>
<th>PARTITION_NAME</th>
<th>SEGMENT_TYPE</th>
<th>TABLESPACE_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEPT</td>
<td>D1</td>
<td>TABLE PARTITION</td>
<td>DEPT1</td>
</tr>
<tr>
<td>DEPT</td>
<td>D2</td>
<td>TABLE PARTITION</td>
<td>DEPT2</td>
</tr>
<tr>
<td>DEPT</td>
<td>D3</td>
<td>TABLE PARTITION</td>
<td>DEPT3</td>
</tr>
</tbody>
</table>

TIP

Tables can be easily partitioned for individual pieces to be accessed and/or manipulated; you can still access the entire table of a partitioned table. Accessing the tables DBA_TABLES,
DBA PART TABLE, and DBA SEGMENTS provides additional information concerning tables that have been partitioned. See Chapter 2 for more information on index partitioning.

Other Types of Partitioning

There are several types of partitioning. The main types are range, hash, composite, and list partitioning. There are also multiple index types associated with partitions. I covered range partitioning in the preceding section, but another partitioning option is multicolumn range partitioning.

Multicolumn Range Partitioning

*Multicolumn range partitioning* is the same as range partitioning except when using multiple columns to define the ranges. In the following example, the data is segmented into quarters so you can eliminate the quarters that are not needed when a single quarter is accessed, but also so the data can be archived one quarter at a time without interfering with another quarter. The data can also be segmented into multiple tablespaces so better I/O is achieved.

```sql
create table cust_sales
(
acct_no number(5),
cust_name char(30),
item_id number(9),
sale_day integer not null,
sale_mth integer not null,
sale_yr integer not null
)
partition by range (sale yr, sale mth, sale day)
(partition cust_sales_q1 values less than (2011, 04, 01) tablespace users,
partition cust_sales_q2 values less than (2011, 07, 01) tablespace users2,
partition cust_sales_q3 values less than (2011, 10, 01) tablespace users,
partition cust_sales_q4 values less than (2012, 01, 01) tablespace users2,
partition cust_sales_q5 values less than (maxvalue, maxvalue, maxvalue) tablespace users2);
```

TIP

You can also partition tables using multiple columns as the criteria. You must specify MAXVALUE for all columns that are part of the partition key except for interval partitioning as of 11g. With interval partitioning, you no longer need to set MAXVALUE, and Oracle will create new partitions for you.
Hash Partitioning

*Hash partitioning* is generally used when you are unsure where to put the breakpoints as you would in range partitioning. Hash partitioning breaks up data into the number of partitions specified based on the hash of the partition key specified. To get an even distribution, you should always specify a power of 2 ($2^n$) as the number of hash partitions. Hash partitioning only supports local indexes and range- or hash-partitioned global indexes. You can specify the names of the index and table partition, and you can later add or reduce the number of partitions if you find you have too many or too few. The following example shows a table with four hash partitions that is built on the partitioning key ACCT_NO and distributed across four tablespaces:

```sql
create table cust_sales_hash (  
  acct_no number(5),
  cust_name char(30),
  sale_day integer not null,
  sale_mth integer not null,
  sale_yr integer not null,
partition by hash (acct_no)
partitions 4
store in (users1, users2, users3, users4);
```

**TIP**

*When you don’t know how to break up a table, but you know that it needs to be partitioned and spread out, use hash partitioning.*

Composite Partitioning

Sometimes a table is so large and accessed so frequently that you need a much better way to “slice and dice it.” *Composite partitioning* combines range and hash partitioning. You use range partitioning to allow partition elimination and then hash the partitions further to distribute I/O. Composite partitioning supports local indexes and range- or hash-partitioned global indexes. The following is an example of composite partitioning that could lead to incredible job security due to its nonintuitive complexity:
This example builds partitions based on the range of values listed for the ORDERDATE column and puts them into partitions Q1, Q2, Q3, and Q4. It then subpartitions each of these range partitions into eight subpartitions based on a hash of the PRODUCTID column.

Here is an example of a hash-partitioned global index created on this table:

```
CREATE INDEX orders_acct_global_ix
ON orders (acct_no, ordid)
GLOBAL PARTITION BY HASH (acct_no)
partitions 4;
```

In 12cR2, composite partitioning may use interval partitioning as a subpartitioning strategy. In other words, MAXVALUE is not needed because the future subpartitions will automatically be built as data is added that is outside the current ranges.

**List Partitioning**

Oracle added list partitioning for the DBA or developer who really knows his or her data well. List partitioning allows you to assign the individual column values associated with each of the partitions. Several restrictions on list partitioning are displayed after the following code listing.

```
create table dept_part
(deptno number(2),
dname varchar2(14),
loc varchar2(13))
partition by list (dname)
(partition d1_east values ('BOSTON', 'NEW YORK', 'KANSAS CITY'),
 partition d2_west values ('SAN FRANCISCO', 'LOS ANGELES'),
 partition d3_south values ('ATLANTA', 'DALLAS'),
 partition d4_north values ('CHICAGO', 'DETROIT'));
```

Restrictions on list partitioning are as follows:
You can specify only one partitioning key in the column list, and it cannot be a LOB column. If the partitioning key is an object-type column, you can partition on only one attribute of the column type.

Each partition value in the VALUES clause must be unique among all partitions of the table.

If you specify the literal NULL for a partition value in the VALUES clause, then to access data in that partition in subsequent queries, you must use an IS NULL condition in the WHERE clause, rather than a comparison condition.

You cannot list partition an index-organized table.

The string comprising the list of values for each partition can be up to 4K.

The total number of partition values for all partitions cannot exceed 64K–1.

**TIP**

In 12cR2, you can also have the database automatically create a separate partition for each distinct partition key value (auto-list partitioning).

### Partitioned Indexes (Local)

Different types of partitioned indexes are covered in Chapter 2. The most common type is a local partitioned index, which is where the index is partitioned on the same columns, same number of partitions and bounds as the corresponding table:

```sql
create table dept
  (ddeptno number(2),
   dept_name varchar2(30))
partition by range (ddeptno)
(partition d1 values less than (10) tablespace dept1,
 partition d2 values less than (20) tablespace dept2,
 partition d3 values less than (maxvalue) tablespace dept3);
create index dept_idx on dept(ddeptno) local;
```

### Partial Indexes

Although partitioned tables have been providing management and performance improvements for quite some time, partitioned tables typically are very large tables and therefore have very large
indexes as well. In Oracle 12c, the introduction of partial indexes enables you to create an index and apply it to only specific partitions of the table, reducing the size of the index and only indexing partitions that get frequent use. The partial index can apply to both local and global indexes. To utilize this capability, we specify with the partition of a table if the partitioned is to be indexed using the INDEXING clause (INDEXING ON/INDEXING OFF). For example:

```sql
CREATE TABLE orders partial_idx (
    order_id NUMBER(12),
    order_date DATE CONSTRAINT order_date_nn NOT NULL,
    order_mode VARCHAR2(8),
    customer_id NUMBER(6) CONSTRAINT order_customer_id_nn NOT NULL,
    order_status NUMBER(2),
    order_total NUMBER(8,2),
    sales_rep_id NUMBER(6),
    promotion_id NUMBER(6),
    CONSTRAINT order_mode lov CHECK (order_mode in ('direct', 'online')),
    CONSTRAINT order_total_min CHECK (order_total >= 0)
INDEXING OFF
PARTITION BY RANGE (ORDER_DATE)
(PARTITION ord_p1 VALUES LESS THAN (TO_DATE('01 MAR-1999', 'DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p2 VALUES LESS THAN (TO_DATE('01 JUL-1999', 'DD-MON-YYYY'))
INDEXING OFF,
PARTITION ord_p3 VALUES LESS THAN (TO_DATE('01 OCT 1999', 'DD-MON-YYYY'))
INDEXING ON,
PARTITION ord_p4 VALUES LESS THAN (TO_DATE('01 MAR-2000', 'DD-MON YYYY'))
INDEXING ON,
PARTITION ord_p5 VALUES LESS THAN (TO_DATE('01 MAR-2010', 'DD-MON-YYYY')));
```

Then, we create the index and indicate if it is a partial index with the PARTIAL INDEX clause. For example, on a global index:

```sql
CREATE INDEX ORDERS_GI1 ON orders_partial_idx (PROMOTION_ID) GLOBAL INDEXING PARTIAL;
```

And here's an example on a local index:

```sql
CREATE INDEX ORDERS_GI2 ON orders_partial_idx (PROMOTION_ID) GLOBAL INDEXING PARTIAL;
```

Other partitioning new features in 12cR2 include the capability to split and merge partitions online; convert nonpartitioned tables to partitioned tables online; create multiple-column list partitions; use list partitioning as a subpartitioning strategy for composite partitioned tables; and
create read-only partitions.

Reference Partitioning

As of 11gR2, Oracle has added reference partitioning where a child table derives its partitioning information from the parent table, and the relationship is defined based on existing primary key (PK)/foreign key (FK) relationships between the parent and child. The partitioning key is resolved through an existing parent-child relationship, enforced by enabled and active primary key and foreign key constraints. Tables with a parent-child relationship can be logically equipartitioned by inheriting the partitioning key from the parent table without duplicating the key columns. The logical dependency also automatically cascades partition maintenance operations, thus making application development easier and less error-prone.

For example, consider the simple case of the ORDERS (parent) and LINEITEMS (child) tables, which are joined based on the PK/FK relationship on the ORDER_ID column in both tables. The ORDERS table also has an ORDER_DATE column, which is used to partition and prune the ORDERS table (there is range partitioning on the ORDER_DATE). The LINEITEMS table does not have any such column (so it’s not duplicated), and, therefore, there’s not an easy way to partition this table, and it can’t take advantage of partition pruning or partition-wide joins based on the ORDER_DATE column.

With reference partitioning, however, the ORDERS table is range-partitioned on ORDER_DATE, for a month at a time, and the LINEITEMS table also now automatically has one partition for each partition of the parent table (given that a reference partition is created using the PARTITION BY REFERENCE clause). The partitioning key is inherited through the PK/FK relationship. Please see the Oracle VLDB (Very Large Database) and Partitioning Guide for more information.

TIP

Reference partitioning is tailor-made for the partitioning of OLTP systems and those systems that tend to be far more normalized than the rest.

Partition-wise Joins

Oracle also allows a query against two partitioned tables to join on only the needed partitions. Instead of joining many rows to many rows, you can now perform partition elimination on each table and then join the results. To join on partitions, the tables must be equipartitioned tables, which means

- Tables are partitioned using the same partition key.
- Tables must be partitioned with the same partition breakpoints.

System Partitions

System partitions are used to break data into many smaller partitions, but not grouped into any
particular groupings other than whatever you decide. System partitions are great to use when you are inserting large amounts of data and want to break it into smaller pieces, but using the same table. You decide exactly what data goes where. Yes, this is as powerful and as dangerous as it sounds; things go exactly where you want them! You can’t forget to specify the partition or you will get an “ORA-14701: Partition-extended name or bind variable must be used for DMLs on tables partitioned by System method.”

System partitions have the following restrictions:

- Cannot be used with index-organized tables
- Cannot play a part in composite partitioning
- Cannot split
- Cannot be used with CREATE TABLE AS SELECT…
- Cannot be used with INSERT INTO table AS...

The basic syntax is

```sql
CREATE TABLE ...PARTITION BY SYSTEM PARTITIONS n
```

where n is 1 to 1024K–1.

The following is an example:

```sql
CREATE TABLE DEPT
  (DEPTNO NUMBER(2),
   DEPT_NAME VARCHAR2(30))
PARTITION BY SYSTEM
  (PARTITION D1,
   PARTITION D2,
   PARTITION D3);

INSERT INTO DEPT PARTITION (D1) VALUES (1, 'DEPT 1');
INSERT INTO DEPT PARTITION (D1) VALUES (22, 'DEPT 22');
INSERT INTO DEPT PARTITION (D1) VALUES (10, 'DEPT 10');
INSERT INTO DEPT PARTITION (D2) VALUES (15, 'DEPT 15');
INSERT INTO DEPT PARTITION (D3) VALUES (7, 'DEPT 7');
```

The PARTITION clause is optional for UPDATEs and DELETEs, but more efficient if you can use it (be very careful to ensure that what you are doing is what you want to do).

---

Global Index Maintenance: Drop and Truncate
Partition Operations

- With Database 12c, when you drop or truncate a partition, the global indexes are no longer invalid and managed automatically.
- Table partitions can be moved online:
  ```sql
  alter table dept move partition d1 tablespace data2 online;
  ```
- MERGE/SPLIT partitions are now online operations (12cR2).
- Nonpartitioned tables can be changed to partitioned tables online (12cR2).
- In 12cR2, Automatic Data Optimization (ADO, covered in the discussion of the Heat Map earlier in this chapter) is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics.

Other Partitioning Options

This section covers some of the many options that you can use when managing partitions. You will see that many of these options that are available for operations on tables are also available for partitions:

- **MODIFY PARTITION** `partition_name` Modifies the real physical attributes of a table partition. You can specify any of the following as new physical attributes for the partition: LOGGING, PCTFREE, PCTUSED, INITRANS, and STORAGE (note MAXTRANS is deprecated and defaults to 255 concurrent update transactions for a given data block, if there is enough available space in the block).
- **RENAME PARTITION** `partition_name` TO `new_partition_name` Renames table partition `PARTITION_NAME` to `NEW_PARTITION_NAME`.
- **MOVE PARTITION** `partition_name` Moves a table partition to another segment. You can move partition data to another tablespace, recluster data to reduce fragmentation, or change a create-time physical attribute:
  ```sql
  alter table dept move partition d3 tablespace dept4 nologging;
  ```
  In this example, the D3 partition with all corresponding data is moved from the DEPT3 tablespace, where it originally resided, to the DEPT4 tablespace; NOLOGGING disables redo generation during the MOVE operation and is not the same as the LOGGING or NOLOGGING attribute of the partition or table.

**TIP**

*When moving a partition, use the NOLOGGING option (if possible) for speed.*
**ADD PARTITION** `new_partition_name VALUES LESS THAN (value_list)` Adds a new partition to the “high” end of a partitioned table. You can specify any of the following as new physical attributes for the partition: LOGGING, PCTFREE, PCTUSED, INITRANS, and STORAGE. The VALUES clause specifies the upper bound for the new partition. The VALUE_LIST is a comma-separated, ordered list of literal values corresponding to partition key values. The VALUE_LIST must contain values that are greater than the partition bound for the highest existing partition in the table.

**EXCHANGE PARTITION** This powerful option allows you to convert a partition or subpartition into a nonpartitioned table or convert a nonpartitioned table into a partition. This option is very useful if you are archiving old range partitions and want to export them as stand-alone tables before you drop them. Also, it can be useful for quickly loading incremental data into an already-existing partitioned table.

**DROP PARTITION** `partition_name` Removes a partition and the data in that partition from a partitioned table:

```
alter table dept drop partition d3;
```

**TIP**

Dropping a table partition causes its local index (but not the other local partition indexes) to be dropped and a global index (one that exists on the entire table) to be unavailable (unless you’re willing to rebuild the indexes afterward). Don’t use global indexes if you plan to drop table partitions.

**TRUNCATE PARTITION** `partition_name` Removes all rows from a partition in a table. The example that follows shows the truncation of the D1 partition. For each partition or subpartition truncated, Oracle Database also truncates corresponding local index partitions and subpartitions. If those index partitions or subpartitions are marked UNUSABLE, then the database truncates them and resets the UNUSABLE marker to VALID.

```
alter table dept truncate partition d1;
```

**SPLIT PARTITION** `partition_name_old` Creates two new partitions, each with a new segment, new physical attributes, and new initial extents. The segment associated with the old partition is discarded. The example that follows shows splitting the D1 partition into a D1A partition and D1B partition at DEPTNO=5. Note that you must also rebuild the indexes after this operation.
Alter table dept split partition d1 at (5) into
(partition d1a tablespace dept1,
partition d1b tablespace dept2);

<table>
<thead>
<tr>
<th>SEGMENT_NAME</th>
<th>PARTITION_NAME</th>
<th>SEGMENT_TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT</td>
<td>D1A</td>
<td>TABLE PARTITION</td>
</tr>
<tr>
<td>DEPT</td>
<td>D1B</td>
<td>TABLE PARTITION</td>
</tr>
<tr>
<td>DEPT</td>
<td>D2</td>
<td>TABLE PARTITION</td>
</tr>
</tbody>
</table>

Alter index dept_idx rebuild partition d1a;
Alter index dept_idx rebuild partition d1b;

**MERGE PARTITIONS** *partition_list* **INTO PARTITION** *new_name* Takes two partitions and combines them into one partition. The next example shows merging the D1A and D1B partition back into the partition named D1. Note that you must also rebuild the indexes after this operation.

Alter table dept merge partitions d1a, d1b
into partition d1;

<table>
<thead>
<tr>
<th>SEGMENT_NAME</th>
<th>PARTITION_NAME</th>
<th>SEGMENT_TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT</td>
<td>D1</td>
<td>TABLE PARTITION</td>
</tr>
<tr>
<td>DEPT</td>
<td>D2</td>
<td>TABLE PARTITION</td>
</tr>
</tbody>
</table>

Alter index dept_idx rebuild partition d1;

The following bullet points are no longer commands, but options you can use with the partition maintenance commands (*ALTER TABLE PARTITION name MODIFY* or the *ALTER INDEX)*:

- **UNUSABLE LOCAL INDEXES** Marks all the local index partitions associated with the specified partition as unusable.

- **REBUILD UNUSABLE LOCAL INDEXES** Rebuilds the unusable local index partitions associated with the named partition.

- **ALTER INDEX .. MODIFY PARTITION .. UNUSABLE** Marks the index or index partition(s) as unusable. An unusable index must be rebuilt or dropped and re-created before it can be used. While one partition is marked unusable, the other partitions of the index are still valid, and you can execute statements that require the index if the statements do not access the unusable partition. You can also split or rename the unusable partition before rebuilding it.

- **ALTER INDEX .. REBUILD PARTITION** Rebuilds one partition of an index. You can also use this option to move an index partition to another tablespace or to change a create-time physical attribute.

---

Index Partitioning
Partitioned indexes have the same advantages as partitioned tables. Accessing smaller pieces instead of one index on the entire table increases performance when properly executed. There are local and global indexes, and prefixed or nonprefixed indexes. A **local index** has been partitioned; each piece is a local index. A **global index** is just a regular nonpartitioned index. A **prefixed index** is when the leftmost part of the index is the partition key, whereas a **nonprefixed index** can be costly to access because the partition key is not indexed. If a partition of a table with a global index is dropped, then the corresponding global index is invalidated. If a partition of a table with a local prefixed index is dropped, then the local index is also dropped.

The initialization parameter SKIP_UNUSABLE_INDEXES allows the user to disable error reporting of indexes and index partitions marked unusable. If you do not want the database to choose a new execution plan to avoid using unusable segments, you should set this parameter to FALSE (the default value is TRUE).

The following is an example of a local prefixed partitioned index (the most common type). The index name is DEPT_INDEX, and the index is on the DEPTNO column of the DEPT table. The index is split into three pieces (D1, D2, and D3) that are located in three tablespaces (DEPT1, DEPT2, and DEPT3) that are striped differently from the location of the corresponding table data. This ensures that accessing information from a table partition and its corresponding index partition will result in accessing two physical disk drives instead of one—given that DEPT1–DEPT3 are tablespaces that correspond to datafiles on different physical disks.

```sql
create index dept_index on dept (deptno)
  local
  (partition d1 tablesapce dept2,
   partition d2 tablesapce dept3,
   partition d3 tablesapce dept1);

Index Created.
```

You can get the information regarding partitioned indexes by accessing DBA_INDEXES:

```sql
select index_name, partition_name, tablesapce_name
from dba_ind_partitions
where index_name = 'DEPT_INDEX'
order by partition_name;

<table>
<thead>
<tr>
<th>INDEX_NAME</th>
<th>PARTITION_NAME</th>
<th>TABLESPACE_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEPT_INDEX</td>
<td>D1</td>
<td>DEPT2</td>
</tr>
<tr>
<td>DEPT_INDEX</td>
<td>D2</td>
<td>DEPT3</td>
</tr>
<tr>
<td>DEPT_INDEX</td>
<td>D3</td>
<td>DEPT1</td>
</tr>
</tbody>
</table>
```
Indexes that are partitioned (local indexes) should also be prefixed, meaning the partitioning key is the leading edge of the index.

Exporting Partitions

Partitions can be effortlessly exported. If the data in your table is segmented carefully, it is possible to keep all new information in a single partition to export. This is only true for certain datasets that use some sort of increasing column value for the partition key. For example, if you partition by date, all new data goes into the latest partition. However, if your data is partitioned by username, or some other generic identifier, then this is not always true. By using a partition key of increasing values, you could potentially eliminate the need to export data from partitions that have not changed and have been previously exported. By using the EXPORT command and giving the owner.table.partition_name for the table to be exported, only the partition is exported:

```
expdp user/pass file=tab.dmp tables=(owner.table:partition name)
```

Here’s a simple example using the DEPT table:

```
expdp scott/tiger file=dept.d1.dmp tables=(dept:d1) directory=dpump dir
```

If you are archiving old data, consider exchanging the partition for a table name that is more verbose before exporting it. This way, you could import just that table back for reference later and potentially avoid even having to return it to the partitioned table.

Eliminating Fragmentation (Only If Needed—Careful!)

Fragmentation can hamper space management operations in the database, but it is a long-enduring myth that overall the number of extents in a segment always impacts performance against the database. It is an equally long-enduring myth that the number of extents never impacts performance. Bitmap indexes with many noncontiguous extents spanning multiple datafiles can cause a big performance problem. Generally, locally managed tablespaces can minimize most extent-related issues. The need for repeated reorganizations should be a thing of the past for most (but not all) DBAs, if you have set up your storage properly. Fortunately, if you do still need to deal with the occasional reorganization, you now have several ways to perform this activity while minimizing downtime.
To avoid performance issues with extent management, you can do the following:

- Use locally managed uniform-extent tablespaces when you know how big a segment will grow or the rate at which it will grow.
- Use extent sizes that are multiples of the database block size.
- Move tables to tablespaces with an appropriate extent size when they grow too large.
- Avoid row chaining by using Automatic Segment Space Management (ASSM, discussed a bit later).

I recommend that you regularly monitor your database to find segments that are growing to extreme numbers of extents (over a thousand) and then manage those segments appropriately:

```
select  segment_name, segment_type, extents, bytes
from    dba_segments a, dba_tablespaces b
where   a.extents > 1000;
```

<table>
<thead>
<tr>
<th>SEGMENT_NAME</th>
<th>SEGMENT_TYPE</th>
<th>EXTENTS</th>
<th>BYTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDER</td>
<td>TABLE</td>
<td>2200</td>
<td>220000000</td>
</tr>
<tr>
<td>ORDER_IDX1</td>
<td>INDEX</td>
<td>1200</td>
<td>120000000</td>
</tr>
<tr>
<td>CUSTOMER</td>
<td>TABLE</td>
<td>7000</td>
<td>70000000</td>
</tr>
</tbody>
</table>

**TIP**

Query DBA_SEGMENTS on a regular basis to ensure that objects are not building up too many extents (when not using ASM). Catching problems early is the key to avoiding performance issues later (there are times when it’s better just to leave things as they are, particularly when there isn’t an issue). The goal is to place objects correctly in tablespaces with uniform extent sizes that are appropriate for the expected growth of the objects.

---

Using the Correct Extent Size

When data is read from a table, it is either accessed by a ROWID operation via an index or by a full table scan (except for index-organized tables). In most cases, access by ROWID is the preferred method. The ROWID method allows the database to determine the exact block that a record resides in and, therefore, bypasses any extent allocation information in the segment. The short answer is that ROWID operations do not care how many extents are in the segment. Database block sizes generally range from 4K to 32K. So, regardless of the number of extents in a segment, a full table scan always performs the same number of reads as long as the extent size is a multiple of the database block size.

Do you still need to worry about extent counts if you are using extents that are multiples of the
block size? Yes you do, but you aren’t as driven by it as you used to be. Think of it this way, the more extents you have, the more you have to manage, even if it is managed via faster methods. Therefore, my rule of thumb is if you have a segment growing over 4096 extents (assuming you are using locally managed tablespaces), consider moving it to a tablespace where the extent size is more appropriate for the size of the segment. If you have a 15G table, using a 200M extent size is probably more efficient than using a 1M extent size. For the purposes of loading data alone, you will save backend processing time because the database does not have to allocate as many extents during the load process.

Avoiding Chaining by Setting PCTFREE Correctly

When a row is created in a table, the data is written to a block and is given a ROWID. The ROWID identifies the data’s location on disk. If a row is updated, the changes are written to the same location on disk. The ROWID for the row does not change. Row chaining can occur when there isn’t enough room in the data blocks to store a single row or the most recent changes made to a row. A chained row is one that exists in multiple blocks instead of a single block. Accessing multiple blocks for the same row can be costly in terms of performance. To see if you have chaining problems, run the utlchain.sql script that Oracle provides to create the CHAINED_ROWS table. The utlchain.sql file comes with Oracle and is in the /rdbms/admin subdirectory of your ORACLE_HOME. You can also use Enterprise Manager or look for “Fetch By Continued Row” in STATSPACK or AWR Report to detect chained rows. You should check for chaining on a weekly basis and fix any problems immediately. To analyze the amount of chaining in a table (CUSTOMER in this example), run the following query:

```
ANALYZE TABLE CUSTOMER
LIST CHAINED ROWS;
```

Then, run the following query accessing the CHAINED_ROWS table to check the CUSTOMER table for chaining:

```
select HEAD_ROWID
from    CHAINED_ROWS
where   TABLE_NAME = 'CUSTOMER';
```

If no rows are returned, then you don’t have a chaining problem. If there is a chaining problem, then the query will return the HEAD_ROWID for all chained rows. You can also use SELECT COUNT(*) against the CHAINED_ROWS table to find the number of chained rows. In V$SYSSTAT, “table fetch continued row” is an indicator of chained rows as well.

To avoid row chaining, set PCTFREE (the amount of space reserved in a block for updates) correctly (don’t set this when using ASSM, discussed next). This parameter is set when the table is
created. The default value is set to 10 (10 percent free for updates), but this needs to be much higher in a table where there is a large frequency of update activity to rows in the table.

Incidentally, if you have a table where update activity will be very low to nonexistent, you can set the PCTFREE to a slightly lower value to ensure more rows will fit into the block and, therefore, conserve space in your table.

**TIP**

Find chaining problems by accessing the CHAINED_ROWS table. Avoid chaining problems by correctly setting PCTFREE or choosing the correct size for your database.

**& Using Automatic Segment Space Management (ASSM)**

Automatic Segment Space Management in locally managed tablespaces is an alternative to using free lists. This system of managing free space in segments utilizes bitmaps to track the amount of free space in blocks that is available for inserting rows. Because free lists are no longer used when ASSM is enabled, the overall time and resources needed by the database are greatly minimized.

In the latest version of the database, Oracle has further expanded the feature set of ASSM and provided a new clause to the ALTER TABLE and ALTER INDEXES statements. The SHRINK SPACE clause essentially coalesces the free space in the segment, releasing unused space so the segment can be smaller. This improves the performance of queries on this segment, and it is much easier to implement than to reduce a segment size through EXPORT/IMPORT or MOVE/RENAME operations. Refer to the documentation on this feature for restrictions and limitations.

ASSM should improve overall performance of block management within segments, but there is a circumstance where the architecture of using a free space bitmap for the block usage can slow performance. Full table scans of small tables (< 1000 rows) in an ASSM-enabled tablespace will actually require more buffer gets than a non-ASSM tablespace. Therefore, if you have your tablespaces organized by segment size, ASSM should probably be used only on those tablespaces with medium to large segments.

ASSM has the potential to make a dramatic improvement to block management performance, but do your research, as there are several bugs scattered across different versions of the database that can affect you in specific situations. Before implementing ASSM on your system, be sure to research the types of segments you will have in your tablespace and check for issues related to operations against those types of segments for your version of the database. Most of these bugs have patches that can be applied to resolve the issues.
TIP
Improve performance and segment management by using ASSM, or use separate tablespaces for smaller segments.

Increasing the Log File Size and LOG_CHECKPOINT_INTERVAL for Speed

If you want to speed up large numbers of INSERTs, UPDATEs, and DELETEs, increase the sizes of your log files and make sure they are on the fastest disk. Previously, you could also increase the LOG_CHECKPOINT_INTERVAL if it was set such that it would checkpoint prior to a log switch, and this currently defaults to zero (which means switching based on the redo log being full). The LOG_CHECKPOINT_INTERVAL determines the length of time between checkpoints. Therefore, any recovery that involves applying the online redo logs is affected—meaning complete database recovery or instance recovery. Increasing the size of your log files can increase the time needed for media recovery.

Oracle relies on online redo log files to record transactions. Each time a transaction takes place in the database, an entry is added to the online redo log file. If you increase the size allocated for the redo log files, you can increase performance by decreasing the overall number of required log switches and checkpoints. Uncommitted transactions generate redo entries, too, because they generate undo records and these undo records are also written to the redo logs. You can watch the logs spin during a large batch transaction. But keep the following characteristics in mind when you make modifications to the size of your log files:

- A log file must be online and available while the database is up or the database will halt (one of the few things that stops the database immediately).
- Online redo log files are recycled and offline redo log files are written to archived log files automatically (if archiving is activated).
- Minimum is two online redo log files. Online redo log file multiplexing (additional copies) is recommended to provide redundancy in case an online redo log file is lost.
- The number of initial log files and their sizes are determined automatically when the database is created.
- Archive logging can be turned on and off by restarting the database in MOUNT mode and then using the ALTER DATABASE command.
- Checkpoints occur when committed transactions in redo logs get written to the database. Checkpoints also update the datafile headers to set the checkpoint SCN, which is used during the rolling back phase of recovery. If the current SCN for the database at the time of failure was 234578, and the datafiles have a checkpoint SCN of 234500, then only the changes in the redo logs from 234500 to 234578 need to be rolled back. Checkpoints are basically consistency markers for the database—a way of saying everything is in sync at this point.
Determining If Redo Log File Size Is a Problem

Two potential problems are possible that should be addressed. The first concerns batch jobs that do not have enough total redo space to complete or are so fast that the online redo logs wrap (cycle through all the logs and start writing to the first one again) before they are archived to the offline redo logs. Because an online redo log cannot be overwritten until it is archived (when archiving is enabled), DML and DDL activity has to wait until an online log becomes available. By listing the online redo logs with their last update date and time at the operating system level, you can determine how often they are switching. You can also query V$LOG_HISTORY for the last 100 log switches. If you increase the size of the online redo logs, it may provide the space for large batch jobs doing large INSERT, UPDATE, and DELETE transactions. A better solution may be to increase the number of online redo logs so the additional space is provided while also having a frequent log switch (smaller but more online redo logs).

The second potential problem concerns long-running jobs that are spending a large amount of time switching online redo logs. Long-running jobs are often much faster when the entire job fits into a single online redo log. For the online transaction processing (OLTP) type of environment, smaller online redo logs are usually better. My rule of thumb is for online redo logs to switch every half hour (not counting the long-running batch jobs that shorten this time). By monitoring the date and time of the online redo logs at the operating system level (or querying V$LOG_HISTORY), you can determine whether to increase the size or number of online redo logs to reach an optimum switching interval.

Here is a query that shows you the time between log switches. It can be handy in determining if you have a problem:

```sql
select b.recid, to_char(b.first_time,'dd-mon-yy hh:mi:ss') start_time, a.recid, to_char(a.first_time,'dd-mon-yy hh:mi:ss') end_time, round(((a.first_time-b.first_time)*23)*60,2) minutes
from v$log_history a, v$log_history b
where a.recid = b.recid + 1
order by a.first_time asc
```

Determining the Size of Your Log Files and Checkpoint Interval

You can determine the size of your online redo log files by checking the size at the operating system level or querying the V$LOG and V$LOGFILE views. Displaying information about redo logs is shown in the query listed here:
The query output shows two groups of redo logs. Each group has two redo log files in it (one primary file and one multiplexed file). The data in /disk1/log1a.ora and in /disk2/log1b.ora is exactly the same (multiplexing redo log files is for availability and recoverability purposes).

**TIP**  
*Increase the size of your log files to increase the rate at which large INSERTs, DELETEs, and UPDATEs (DMLs) are processed.*

### Other Helpful Redo Log Commands

You can add additional redo logs by using the `ALTER DATABASE ADD LOGFILE` command to create larger redo logs and then to drop the smaller ones.

To multiplex online redo log files (creating a mirrored copy), use this command to add a log file to an existing group:

```sql
alter database add logfile member '/disk2/log1b.ora' to group 1;
alter database add logfile member '/disk2/log2b.ora' to group 2;
```

To drop an online redo log member, use this command:

```sql
alter database drop logfile member '/disk2/log2b.ora';
```

To add a new online redo log group, use this command:

```sql
alter database add logfile group 3 ('/disk1/log3a.ora') size 10M;
```
To drop an entire online redo log group (all copies), use this command:

```
ALTER DATABASE DROP LOGFILE GROUP 1;
```

**NOTE**
You cannot drop a redo log file group if doing so would cause the redo thread to contain less than two redo log file groups. You cannot also drop the redo log file group if it contains the current online redo log (ORA-01623). In this case, you need to switch log groups first and then you can drop the redo log group.

To switch log files (change current redo log group to next redo log group):

```
ALTER SYSTEM SWITCH LOGFILE;
```

**TIP**
Put the redo logs on the fastest disk (or SSD or flash) if you plan to write a lot of information. Try to use the outer edge of the disk (the fastest part on many disk types) for the redo logs. Better yet, there is an ASM feature that does this: The Intelligent Data Placement feature enables you to specify disk regions on Oracle ASM disks to ensure that frequently accessed data is placed on the outermost (hot) tracks, which provide higher performance.

**Additional Redo Log Instance Parameters**
These further instance parameters can have an effect on the performance of your online redo log files:

- **LOG_ARCHIVE_DUPLEX_DEST** Directory location with archive prefix (arch). This is a location to write an additional copy of archive logs (as redo logs are filled and are archived in ARCHIVELOG mode only). If you have the space, this safety net can save you if archiving errors occur. For Oracle Enterprise Edition (EE) databases, this parameter is deprecated in favor of the LOG_ARCHIVE_DEST_n parameters. If Oracle EE is not installed or it is installed but you have not specified any LOG_ARCHIVE_DEST_n parameters, this parameter is valid.

- **LOG_ARCHIVE_MIN_SUCCEED_DEST** Can be set to 1 to 10 if you are using LOG_ARCHIVE_DEST_n, or to values of 1 or 2 if you are using LOG_ARCHIVE_DEST and LOG_ARCHIVE_DUPLEX_DEST. This is the minimum number of successful archives
written for a redo log. If you set it to 2, then you have two mandatory archiving destinations, similar to setting LOG_ARCHIVE_DEST1 and LOG_ARCHIVE_DEST2 and mandatory archive sites. If you set any LOG_ARCHIVE_DEST_n parameter where \( n > 3 \), then those sites are treated as optional archive sites. If you set LOG_ARCHIVE_MIN_SUCCEED_DEST to 1, then the LOG_ARCHIVE_DUPLICATE_DEST or LOG_ARCHIVE_DEST_n \( (n > 1) \) sites are optional best-effort archive sites, not mandatory sites.

- **DB_WRITER_PROCESSES** This is the number of database writers to write data from the SGA to disk when one database writer isn’t enough.

- **DBWR_IO_SLAVES** If you can’t use multiple processes (or if you don’t have asynchronous I/O and want to emulate it), then you can use DBWR_IO_SLAVES to distribute the load of the ARCH and LGWR processes over multiple I/O slaves. This can’t be used if DB_WRITER_PROCESSES > 1.

## Storing Multiple Control Files on Different Disks and Controllers

Control files store information regarding startup, shutdown, and archiving. Because your system is useless without at least one good control file, you should store three copies of the control files on separate disks and controllers (if possible). If you do happen to remove all the control files while the database is open, you can use the ALTER DATABASE BACKUP CONTROLFILE command to generate a new one. If the database is closed and the control file is missing, you can use the CREATE CONTROLFILE statement to re-create the control file. However, re-creating the control file from scratch is a lot of work and prone to error. And lots of valuable, possibly critical, information is lost (for example, the most recent backup information for RMAN backups).

To view current control files, run the following query:

```sql
select name, value
from v$parameter
where name = 'control_files';
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>control_files</td>
<td>/disk1/ora10/ctl1.cra, /disk2/ora10/ctl2.cra, /disk3/ora10/ctl3.cra</td>
</tr>
</tbody>
</table>

Another suggestion is to create a text copy of the control file at regular intervals, or at least after any database architectural change (at the file or tablespace level). This helps if you lose all copies and have to re-create the control file from scratch.

## Other Disk I/O Precautions and Tips

Here are a few further miscellaneous notes pertaining to disk I/O:
If you can afford it and you need the speed, put everything on SSD (flash) or Exadata. At a minimum, try to put redo logs on SSD and, if possible, UNDO and TEMP.

- Heavy batch processing may need much larger UNDO, REDO, and TEMP tablespace sizes.
- Heavy DML (INSERT, UPDATE, and DELETE) processing may need much larger UNDO, REDO, and TEMP tablespace sizes.
- Heavy user access to large tables will usually require more CPU and memory.
- Poorly tuned systems will require more CPU and memory and larger temporary tablespace sizes.

A greater number of well-balanced disks and controllers will always increase performance (by reducing I/O contention).

- If you increase disk capacity, you can speed backup and recovery time by keeping a copy of the backup on disk instead of tape.
- If you can afford it, Exadata, EMC, and/or solid state or flash disk solutions are some of the absolute best ways to improve Oracle I/O performance.

Versions 10g and 11g required ASM and database instances to be on the same server. With new features of 12c ASM, this tightly coupled configuration for ASM and database instance has been loosened, and this provides for greater flexibility in managing ASM instances in RAC environments and remote ASM. Oracle also provides the new 12c Flex Clusters for RAC, the ability to rebalance hot spots, and fast sync and repairs.

Issues to Consider in the Planning Stages
If you’re planning a new system or an upgrade, here are some things you’ll want to consider:

- What is the maximum possible disk capacity for the hardware?
- What disk sizes are available?
- What will be the initial size of the database?
- What will be the future size of the database and what is the rate of growth?
- Will there be a RAID (striping) level for database files or the OS? Can I use ASM?
- What recovery methods will be employed?
- What archiving methods will be used to store historical information?
- How often will report output be kept on the system?
- What development space will be needed?
- What software will be installed, and how much space will it need to function efficiently?
- What system utilities will be installed, and how much space will they need to function efficiently?
What data transfer methods are going to be employed?

- Is ASM installed? Learn and plan for it if it is.
- What are the batch processing requirements, and will there be ad hoc user queries?
- How will the data be accessed that may cause potential hot spots?

Finally, it’s worth mentioning the product Oracle Orion here. Oracle Orion is a tool for predicting the performance of an Oracle database without having to install Oracle or create a database. Unlike other I/O calibration tools, Oracle Orion is expressly designed for simulating Oracle database I/O workloads using the same I/O software stack as Oracle. Orion can also simulate the effect of striping performed by Oracle Automatic Storage Management.

**TIP**

*When you are in the system planning stage, ensure that you find out all of the information related to the current and future use of the system. Don’t just think about the Oracle database needs—investigate the other software and applications that affect the performance of your Oracle database.*

**Tips Review**

- One of the best features of 12c is pluggable databases. It offers the ability to consolidate hundreds of databases into a single container database (CDB) with hundreds of pluggable databases (PDBs).
- Two of the best features of 12cR2 are the ability to flashback pluggable databases (PDBs) and the ability to build a subset standby with only some PDBs. In 12cR2, you can also set partitions and subpartitions to be read-only.
- Redo and archive log files are defined as fine-grained, whereas datafiles are coarse.
- Try to avoid splitting a logical device in a disk array into more than one filesystem. Splitting may seem to give you flexibility, but it can also increase the number of datafile locations you have to manage.
- Use disk arrays to improve performance and protect your data against disk failure. Choose the proper RAID level and technology solutions that enable you to maintain the availability your organization needs. Don’t just go “good enough,” because you will regret it at 2 a.m. when you lose a disk. ASM is a great option with striping and mirroring capabilities.
- Separate key Oracle datafiles in *traditional* filesystems to ensure that disk contention is not a bottleneck. By separating tables and indexes of often-joined tables, you can ensure that even the worst of table joins do not result in disk contention. In Enterprise Manager (Cloud Control), Oracle makes it easy to move data to a hotter or colder region of a disk.
Query V$FILESTAT and V$DATAFILE to see how effectively datafiles have been balanced. Note that temporary tablespaces are monitored using V$TEMPFILE and V$TEMPSTAT.

To have the largest Oracle 12c database possible, 8 exabytes, you must use 128T datafiles (and must also use bigfile tablespaces and a 32K block size).

Although ASM does not provide multipathing capabilities, it does leverage multipathing tools, as long as the path or device produced by the multipathing tool returns a successful return code from an FSTAT system call. My Oracle Support Note 294869.1 provides more details on ASM and multipathing.

To ensure that ASM is using the multipath device names and not the regular device, set the ASM_DISKSTRING parameter to look for the multipath device names. For example, if you are using EMC PowerPath, set the disk string to ‘/dev/emcpower*’. The only exception is when you are using Linux and the disk string is set to ‘ORCL:*’. In such cases, you would configure ASMLIB to give preference to saved multipath devices.

To minimize disk I/O on a single large table, you can break the table into multiple partitions that reside in tablespaces on different physical disks.

Tables can be easily partitioned for individual pieces to be accessed and/or manipulated; you can still access the entire table of a partitioned table. Accessing the tables DBA_TABLES, DBA_PART_TABLE, and DBA_SEGMENTS provides additional information concerning tables that have been partitioned.

You can also partition tables using multiple columns as the criteria. You must specify MAXVALUE for all columns that are part of the partition key except for interval partitioning as of 11g. In 12cR2, you can have interval partitions as part of composite partitions using the intervals as a subpartitioning strategy.

When you don’t know how to break up a table, but you know that it needs to be partitioned and spread out, use hash partitioning.

In 12cR2, you can have multiple columns for list partitioning.

In 12cR2, you can also have the database automatically create a separate partition for each distinct partition key value (auto-list partitioning).

Reference partitioning is tailor-made for the partitioning of OLTP systems and those systems that tend to be far more normalized than the rest.

Use the NOLOGGING option when rebuilding a problem table to avoid generating large amounts of redo.

CAUTION
When you create a table or index as NOLOGGING, the database does not generate redo log records for the operation. Thus, you cannot recover objects created with NOLOGGING, even if you are running in ARCHIVELOG mode. If you cannot afford to lose tables or indexes created with
NOLOGGING, then make a backup after the unrecoverable table or index is created. But, in 12cR2, on Oracle Data Guard for Data Warehouses, we now have NOLOGGING operations on the primary that can be tracked. Originally, blocks on the standby would be marked unrecoverable when NOLOGGING was used on the primary. With the new tracking, Data Guard can track the blocks for loads with NOLOGGING and, using RMAN, recover the blocks using the new RMAN command RECOVER DATABASE NOLOGGING.

- Dropping a table partition causes its local index (but not the other local partition indexes) to be dropped and a global index (one that exists on the entire table) to be unavailable (unless you’re willing to rebuild the indexes afterward). Don’t use global indexes if you plan to drop table partitions.

- Indexes that are partitioned (local indexes) should also be prefixed, meaning the partitioning key is the leading edge of the index.

- If you are archiving old data, consider exchanging the partition for a table name that is more verbose before exporting it. This way, you could import just that table back for reference later and potentially avoid even having to return it to the partitioned table.

- Query DBA_SEGMENTS on a regular basis to ensure that objects are not building up too many extents (when not using ASM). Catching problems early is the key to avoiding performance issues later (there are times when it’s better just to leave things as they are, particularly when there isn’t an issue). The goal is to place objects correctly in tablespaces with uniform extent sizes that are appropriate for the expected growth of the objects.

- Find chaining problems by accessing the CHAINED_ROWS table. Avoid chaining problems by correctly setting PCTFREE or choosing the correct size for your database.

- Improve performance and segment management by using ASSM, or use separate tablespaces for smaller segments.

- Increase the size of your log files to increase the rate at which large INSERTs, DELETEs, and UPDATEs (DMLs) are processed.

- Put the redo logs on the fastest disks (SSD or flash) if you plan to write a lot of information. Try to use the outer edge of the disk (the fastest part on many disk types) for the redo logs. Better yet, there is an ASM feature that does this: The Intelligent Data Placement feature enables you to specify disk regions on Oracle ASM disks to ensure that frequently accessed data is placed on the outermost (hot) tracks, which provide higher performance.

- Increase the size of online redo logs if log switches are occurring less than every half hour during normal business conditions (excluding infrequent large batch jobs). Increase the number of online redo logs if you are wrapping during large batch jobs.

- When you are in the system planning stage, ensure that you find out all of the information related to the current and future use of the system. Don’t just think about the Oracle database needs—investigate the other software and applications that impact performance of your Oracle database.
References

*Oracle Database Concepts* (Oracle Corporation).

*Oracle Database Administrator’s Guide* (Oracle Corporation).

*Oracle Database Reference* (Oracle Corporation).

*Oracle Database VLDB and Partitioning Guide* (Oracle Corporation).


Many thanks to Joe Matthew, who did the 12c update to this chapter. Also, thanks to Sri Avantsa, who did most of the updates for the 11g version, and to Bill Callahan, who did the previous update of this chapter. Thanks to Nitin Vengurlekar, who contributed a large amount of ASM knowledge to this chapter originally for 11g.
The Oracle initialization files (SPFILE or a PFILE such as initSID.ora) determine many Oracle operating system environment attributes, such as memory allocated for data, memory allocated for statements, resources allocated for I/O, and other crucial performance-related parameters. Each version of Oracle has added to the total number of initialization parameters, and Oracle 12c is no exception, having added many new parameters, especially related to the In-Memory Database. Oracle 12c Release 2 now has 4649 initialization parameters (412 documented and 4237 hidden). Note that these numbers will vary slightly on different patch releases and different operating systems.

As you might expect, an entire book could be written on how to set and tune each parameter; this book focuses on the key parameters that affect database performance. Consider reading or referencing Appendix A after this chapter, as it contains a list of all documented initialization parameters, obsolete and deprecated parameters, my Top 25 (many covered in this chapter), my Top 20 not-to-forget parameters (things like AUDIT_TRAIL for auditing and CELL_OFFLOAD_PROCESSING for smart scans in Exadata), my Top 13 undocumented parameters (many for recovery and corruption), my bonus Top 10 undocumented new parameters (such as the Exadata parameter _KCFIS_STORAGEIDX_DISABLED to turn off storage indexes for tuning/testing), and lastly, a section containing recommendations from the Oracle Applications Development team for 12c.

The key to an optimized Oracle database is often the architecture of the system and the parameters that set the environment for the database. Setting key initialization parameters (MEMORY_TARGET, MEMORY_MAX_TARGET, SGA_MAX_SIZE, PGA_AGGREGATE_TARGET, PGA_AGGREGATE_LIMIT, DB_CACHE_SIZE, SHARED_POOL_SIZE, and INMEMORY_SIZE) can be the difference between subsecond queries and queries that take several minutes (new 12c parameters are bolded). The MEMORY_TARGET parameter can replace some of the key parameters that are covered in this chapter (although you often need to still set minimums for some parameters to ensure Oracle allocates enough memory for them, especially DB_CACHE_SIZE and SHARED_POOL_SIZE). This chapter focuses on the crucial initialization parameters, but also lists the Top 25 initialization parameters near the end of the chapter. The chapter concludes with a look at the always growing typical server configurations for various database sizes.

This chapter contains the following tips and techniques designed to achieve the greatest performance gain with the least effort by focusing on the parameters that yield the biggest impact:
When upgrading to 12c
- Using SEC_CASE_SENSITIVE_LOGON and case-sensitive passwords
- Crucial memory initialization parameters for performance
- Setting the pluggable database (PDB) level using resource plan directives: MEMORY_LIMIT and MEMORY_MINIMUM (12cR2)
- Using Database 12c (12.1.0.2 and above) In-Memory Database
- Modifying the initialization parameter file without a restart
- Working with the SPFILE and creating a readable PFILE (init.ora)
- Viewing the initialization parameters via Enterprise Manager Cloud Control
- Tuning the DB_CACHE_SIZE
- Tuning the SHARED_POOL_SIZE
- Checking library cache and dictionary cache
- Querying the X$KSMSP table to get another picture of SHARED_POOL_SIZE
- Using multiple buffer pools
- Tuning the PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT (12c)
- User, session, and system memory use
- Working with the OPTIMIZER_MODE parameter
- Two important Exadata initialization parameters
- The top 25 performance-related initialization parameters to consider
- Typical server setups with different size databases
- Oracle Applications recommendations (more in Appendix A)

When Upgrading to Oracle Database 12c

When upgrading to Oracle Database 12c, you need to consider many parameters that will apply to your unique system. Please check Appendix A for any parameters that are obsolete (i.e., removed) or deprecated (i.e., may be removed in the future and use is discouraged, although still okay to use for backward compatibility). We will cover a few parameters that are both important and common for most systems. The Database Upgrade Assistant (DBUA) is extremely helpful and shows that Oracle truly wants to assist you in the upgrade process. The DBUA uses pre-upgrade scripts that check the following before the upgrade:

- Invalid user accounts or roles
- Invalid data types or invalid objects
- Desupported character sets
Statistics gathering (recommended, but not checked by DBUA)
Adequate resources (UNDO/ROLLBACK segments, tablespaces, and free disk space)
Missing SQL scripts needed for the upgrade
Listener running (if Oracle Enterprise Manager Cloud Control upgrade or configuration is requested)
Oracle Database software linked with the Database Vault option (if Database Vault is enabled, disable it before upgrade)

Next, consider some key parameters related to the In-Memory (IM) Database, which include:
INMEMORY_SIZE, INMEMORY_QUERY, INMEMORY_MAX_POPULATE_SERVERS,
INMEMORY_FORCE, INMEMORY_CLAUSE_DEFAULT, INMEMORY_VIRTUAL_COLUMNS,
and INMEMORY_TRICKLE_REPOPULATE_SERVERS_PERCENT. To turn on the In-Memory Database (In-Memory column store), set the following:

```
INMEMORY_SIZE=1520M
INMEMORY_QUERY_ENABLED=TRUE
SGA_TARGET  =25G
```

The INMEMORY_SIZE enables the In-Memory Database when it is set to any value (so ensure you are licensed before you do this). Also note that SGA_TARGET and MEMORY_TARGET will probably need to be increased by the amount of INMEMORY_SIZE since the value of INMEMORY_SIZE is included in the amount you set for the SGA_TARGET and therefore the MEMORY_SIZE. The “In-Memory Database (INMEMORY_SIZE)” section of this chapter covers this subject in detail.

There are also new parameters related to Adaptive Query Optimization (covered in detail in Chapter 8). The main parameters new in 12c are OPTIMIZER_ADAPTIVE_FEATURES and OPTIMIZER_ADAPTIVE_REPORTING_ONLY. All the parameters that can change the behavior of Adaptive Query Optimization are listed here (and a couple of extra ones below that; the defaults are listed):

```
OPTIMIZER_ADAPTIVE_FEATURES =TRUE
OPTIMIZER_ADAPTIVE_REPORTING_ONLY=False
OPTIMIZER_DYNAMIC_SAMPLING=2
OPTIMIZER_MODE=ALL_ROWS
OPTIMIZER_FEATURES_ENABLE=12.2.0.1
OPTIMIZER_INMEMORY_AWARE=TRUE
OPTIMIZER_USE_INVISIBLE_INDEXES=False
```

By default, the OPTIMIZER_ADAPTIVE_FEATURES parameter is set to TRUE to enable adaptive plans, automatic re-optimization, SQL plan directives, and adaptive distribution. Adaptive
plans are those that allow execution plans to automatically alter things like the join method (I’ve seen this work well) or the parallel query distribution on the first run. The OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter can be set to TRUE (FALSE is the default) to first test which queries are going to adapt before the optimizer actually uses the adapted plan. This might be helpful when first upgrading from an earlier version of Oracle, to avoid any unexpected behavior.

**Using SEC_CASE_SENSITIVE_LOGON**

Be aware that passwords are case sensitive. This is controlled by an initialization parameter introduced in 11g, SEC_CASE_SENSITIVE_LOGON. The default is TRUE, which makes passwords case sensitive by default. Set this to FALSE to disable this feature. You can also lock an account if a user fails to enter the correct password a specified number of times, using the SEC_MAX_FAILED_LOGIN_ATTEMPTS parameter (the default is 10). Based on your security needs, you may consider changing this value.

Once locked, the DBA must issue the following command to unlock an account:

```sql
SQL> ALTER USER username ACCOUNT UNLOCK;
```

**Crucial Memory Initialization Parameters for Performance**

Although tuning specific queries individually can lead to performance gains, the system will still be slow if the parameters for the initialization file are not set correctly, because the initialization file plays such an integral role in the overall performance of an Oracle database. While you can spend time setting all the initialization parameters, there are a few main parameters that need to be set correctly to realize significant performance gains:

- MEMORY_TARGET
- MEMORY_MAX_TARGET
- SGA_TARGET
- SGA_MAX_SIZE
- PGA_AGGREGATE_TARGET
- PGA_AGGREGATE_LIMIT
- DB_CACHE_SIZE
- SHARED_POOL_SIZE
- INMEMORY_SIZE

The MEMORY_TARGET parameter and optionally the parameter MEMORY_MAX_TARGET
will enable Automatic Memory Management (AMM) for all shared memory, including the Program Global Area (PGA), shared pool, and database buffer cache. This will set a defined amount of memory and allow Oracle to control the memory automatically and adjust the defined memory pool between the areas based on system needs (AMM is described in more detail in My Oracle Support Note 443746.1 as well as later in this chapter). In 10g, SGA_TARGET and SGA_MAX_SIZE were introduced as Automatic Shared Memory Management (ASMM) (My Oracle Support Note 295626.1 describes this in detail), which is essentially Automatic Memory Management minus the automatic management of the PGA included. The Oracle Applications Development team recommends using SGA_TARGET and SGA_MAX_SIZE for both 10g and 11g in 11i Apps (My Oracle Support Note 216205.1) and for 11g in Release 12 Apps (My Oracle Support Note 396009.1). I’ve included the Oracle Applications Development team’s recommendations at the end of this chapter.

The MEMORY_TARGET parameter enables you to set memory allocated to Oracle with one easy parameter (although you’ll shortly see that setting some minimums for other values is recommended). MEMORY_TARGET is used by Automatic Memory Management to set other memory settings, such as the memory allocated to both the PGA and SGA (System Global Area) combined. Setting this parameter enables Automatic Memory Management, but you can also set minimum values for key parameters. MEMORY_TARGET is used for everything that SGA_TARGET covers (including the INMEMORY_SIZE if used), but also now includes the PGA (especially important since this covers PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT, an important area). Key parameters such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, LARGE_POOL_SIZE, and JAVA_POOL_SIZE are all set automatically when MEMORY_TARGET is set. Setting minimum values for important initialization parameters in your system is also a very good idea. The MEMORY_MAX_TARGET parameter is optional and is the maximum memory allocated for Oracle and the maximum value allowed for MEMORY_TARGET.

In Oracle9i, you saw the beginning of Oracle’s Automated Memory Management with the SGA_MAX_SIZE (no more setting buffers, just DB_CACHE_SIZE and granule size: _KSMG_GRANULE_SIZE).

In Oracle 10g, the SGA_TARGET parameter was introduced (still recommended by Oracle Applications even in 11g). In the 10g edition of this book, however, it was recommended that you still set minimums for the key memory areas such as the Database Cache (DB_CACHE_SIZE) and shared pool (SHARED_POOL_SIZE). MEMORY_TARGET now combines the SGA and PGA into one setting, making life easy, especially for smaller, less complex systems, and it is still recommended when using automatic memory management of any kind to set minimums for each of the memory areas as described in this chapter. Some parameters are automatically sized (this chapter details the use of many of these parameters in the coming pages). Also note that MEMORY_TARGET (Automatic Memory Management) manages and includes SGA_TARGET and PGA_AGGREGATE_LIMIT, so it should be as big as the sum of the two of these. It is one level above Automatic Shared Memory Management (SGA_TARGET) and Automatic PGA Memory Management (PGA_AGGREGATE_TARGET). This manages many of the memory settings for the SGA that all used to be set individually (and still can be, and in some environments still should be). Setting this individual parameter is covered in later sections in this chapter.

These parameters are automatically sized when you use MEMORY_TARGET or SGA_TARGET (unless you set minimums), but setting minimums for each of the memory areas separately (as described in this chapter) is still recommended when using AMM of any kind:
These are manually sized SGA components that also use MEMORY_TARGET:

<table>
<thead>
<tr>
<th>Component</th>
<th>Initialization Parameter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer cache</td>
<td>DB_CACHE_SIZE (usually set minimum value also)</td>
</tr>
<tr>
<td>Shared pool</td>
<td>SHARED_POOL_SIZE (usually set minimum value)</td>
</tr>
<tr>
<td>Large pool</td>
<td>LARGE_POOL_SIZE (usually set minimum value)</td>
</tr>
<tr>
<td>Java pool</td>
<td>JAVA_POOL_SIZE (usually set minimum value)</td>
</tr>
<tr>
<td>Streams pool</td>
<td>STREAMS_POOL_SIZE</td>
</tr>
</tbody>
</table>

As stated earlier, the PGA is now managed by MEMORY_TARGET as well. This includes the PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT parameters. You should also set a minimum for PGA_AGGREGATE_TARGET, and a maximum, as of 12c, for PGA_AGGREGATE_LIMIT. To move from the SGA_TARGET to MEMORY_TARGET, set the MEMORY_TARGET and MEMORY_MAX_TARGET. To determine what value to use, run the following query and ensure that you add the values for SGA_TARGET and PGA_AGGREGATE_TARGET to estimate MEMORY_TARGET (the following outputs are limited to key values):
The following query can be used to find the current settings of the key initialization parameters on your database (if SGA_TARGET is set to a non-zero value, then some of these parameters are set to zero, which means Oracle sets it). For this example, I manually set the shared pool:

```sql
SQL> show parameter target

NAME                      TYPE       VALUE
----------------------------------------------
memory_max_target          big integer 0
memory_target              big integer 0
pga_aggregate_target       big integer 110M
sga_target                 big integer 250M

ALTER SYSTEM SET MEMORY_MAX_TARGET=360M SCOPE=SPFILE;
(ALTER SYSTEM SET MEMORY_TARGET=360M SCOPE=SPFILE;
ALTER SYSTEM SET SGA_TARGET=0; (or set a minimum)
ALTER SYSTEM SET PGA_AGGREGATE_TARGET=0; (or set a minimum)
(shutdown/startup)

SQL> show parameter target

NAME                      TYPE       VALUE
----------------------------------------------
memory_max_target          big integer 360M
memory_target              big integer 360M
pga_aggregate_target       big integer 0
sga_target                 big integer 0

ALTER SYSTEM SET SGA_TARGET=200M;
ALTER SYSTEM SET PGA_AGGREGATE_TARGET=100M;
(you can do this with DB_CACHE_SIZE and SHARED_POOL_SIZE as needed)

SQL> show parameter target

NAME                      TYPE       VALUE
----------------------------------------------
memory_max_target          big integer 360M
memory_target              big integer 360M
pga_aggregate_target       big integer 100M
sga_target                 big integer 200M
```
The MEMORY_TARGET approach and move to simplicity, especially for beginners and those who manage many databases, is excellent and should simplify and minimize management going forward for many environments.

### PDB Level: MEMORY_LIMIT and MEMORY_MINIMUM

In addition to the new MEMORY_TARGET initialization parameter to set all of memory for the Oracle SGA and PGA, there are PDB-specific parameters to ensure a minimum amount and a maximum setting. Those parameters set at the PDB level using resource plan directions are:

- **MEMORY_LIMIT** Limits the PDB to this percentage of PGA+SGA
- **MEMORY_MINIMUM** Guarantees the PDB this percentage of PGA+SGA

You’ll also see in the next section that there is both an INMEMORY_SIZE that you can set at the CDB level and then also INMEMORY_SIZE that you can set at the PDB level as well.

### In-Memory Database (INMEMORY_SIZE)

Introduced in Oracle Database version 12.1.0.2, the In-Memory Database is by far the best new feature for improving database performance (especially data warehouse performance). This capability is perfect for some types of workloads and helpful for others, but best of all, it does not require any application changes to make use of it.

Online transaction processing (OLTP) and data warehouse applications are common in most enterprises, and many systems dramatically blur the lines between what is OLTP and what is data warehousing—increasingly more OLTP systems are including reporting and data warehouse components. The Oracle Database now has a buffer cache for OLTP and all the DML activity you might do, while also having the in-memory cache to improve performance in data warehousing operations that stays consistent even with the other OLTP cache changes (similar to how tables/indexes stay consistent with each other). This is the typical mixed workload that is becoming more common, and the In-Memory Database just made the mixed workload performance skyrocket.

The In-Memory feature is made possible through a unique dual format that maintains an Oracle
row-based format for OLTP and a pure in-memory columnar format for query and analytical processing. This feature maintains both the row and columnar formats at the same time without any awareness from the application, therefore maintaining full compatibility back to the applications and allowing use of this feature without having to change a single line of code in your applications. It is also fully compatible with all existing Oracle Database features and options and therefore can be used with all features such as Real Application Clusters (RAC), partitioning, compression, pluggable databases, etc.

The In-Memory Database option is an In-Memory column store that is an addition to the database SGA called the in-memory area. Don’t be concerned, though, because this does not “double” memory requirements for the database; in fact, it is estimated that only 20 percent overhead is expected to make full use of this feature with a huge impact. This feature maintains the buffer cache as it normally would in a row-format-based store, which is most efficient for DML activity. At the same time, it will maintain an additional memory area for the columnar-based format, which is most effective for query and analytical activities (storing specified columns of compressed data for quick sums, averages, etc.). Not all tables should be part of the in-memory area, and it should be populated only with the columns of tables that are most critical to overall analytics performance. When you combine the in-memory area with the buffer cache in memory (the SGA), and then you add flash for everything else (what Google, Facebook, and Amazon do), you realize huge performance improvements.

The In-Memory Database option is turned on by setting the INMEMORY_SIZE to a non-zero value (must be set to at least 100M). Keep in mind this is a fixed memory size and is not managed automatically by an LRU (least recently used) algorithm. Once you are out of space, you are out until you remove something. Also remember that this memory comes out of the SGA settings, therefore, you will probably want to increase your SGA to accommodate it by increasing SGA_TARGET and MEMORY_TARGET by the amount of INMEMORY_SIZE depending on which your database is using. Also, the use of the In-Memory column store is controlled by the INMEMORY_QUERY parameter, which is enabled by default, meaning that the optimizer will use the IM for queries. If INMEMORY_QUERY is disabled at the system or session level, then the optimizer will not direct queries to use the IM. The in-memory use can be turned off dynamically by setting the IN_MEMORY_QUERY to DISABLED; for example:

```
ALTER SESSION SET INMEMORY QUERY=DISABLE;  (stop using IM)
```
The following example shows how to turn on the In-Memory Database (in-memory store):

```
inmemory_size=1520M
inmemory_query-enabled
sga_target=25G
```

Other key initialization parameter for setting up the In-Memory Database are

- **INMEMORY_MAX_POPULATE_SERVERS** Number of workers used to populate the IM Column Store. The default is 0.5xCPU_COUNT. Lowering it slows down repopulation.
- **INMEMORY_FORCE** If set to OFF, the IM will not be populated no matter what the object settings are. The default is DEFAULT, which allows normal population.
- **INMEMORY_CLAUSE_DEFAULT** Set defaults to be different. For example, to change the default compression:

  ```
  ALTER SYSTEM SET INMEMORY_CLAUSE INMEMORY PRIORITY HIGH;
  ```

- **INMEMORY_TRICKLE_REPOPULATE_SERVERS_PERCENT** The maximum percentage of time a worker (process) can participate in trickle repopulation (wakes up every 2 minutes). The default is 1 percent. It can also be set to 0 to disable trickle repopulation. *Trickle repopulation* refers to repopulating the In-Memory column store with change blocks from the SGA. Note that when a query is run against a given column in the In-Memory column store, any changed blocks from the SGA are moved at that time (your data is always “up to date” when queried).
In 12cR2, you can now dynamically resize the INMEMORY_SIZE while the system is running, provided you have the memory available in SGA_TARGET (and MEMORY_TARGET). In-memory is also supported with pluggable databases, but there are some things to keep in mind. All PDBs use and share a single memory area defined in the container database (CDB) level. You can define the INMEMORY_SIZE in each PDB, but it comes out of the INMEMORY_SIZE defined in the CDB; therefore, the sum of all PDBs’ used area cannot exceed the INMEMORY_SIZE defined at the container level. That said, you can oversubscribe the amount in the CDB. For instance, if you had three PDBs, each with an INMEMORY_SIZE=3M, and the CDB had an INMEMORY_SIZE=8M (which is allowed), the total that can fit is only 8M even though the sum of the PDBs is 9M. The first 8M will get the space, with each PDB having a maximum of 3M (one PDB may only get 2M). This provides some flexibility.

The In-Memory column store for RAC is defined on a per-instance basis. In a RAC environment, each instance has its own INMEMORY_SIZE defined for that instance. This means that each RAC instance can have a different INMEMORY_SIZE defined. However, it is recommended that the INMEMORY_SIZE remain consistent across all nodes—after all, the objects that will be placed are database level, not instance level. Different data can exist in the IM for each of the instances and large tables can span different instances across nodes in the cluster, and this is done by default (essentially it’s like having the combined memory of all the instances for the in-memory store). The distribution can be changed and you can set DUPLICATE across the cluster so that even the IM is fault tolerant. In Exadata only, you can set DUPLICATE ALL so that each in-memory store is an exact duplicate on each node in the cluster, which provides complete fault tolerance and continuous performance if a failure occurs in the In-Memory column store.

The following listings show how to duplicate:

```
ALTER TABLE emp INMEMORY DISTIBUTE BY PARTITION;
ALTER TABLE emp INMEMORY DUPLICATE;
```

(Duplicate to second node in-memory)

```
ALTER TABLE emp INMEMORY DUPLICATE ALL;
```

** Duplicate copies on all nodes (ignored if not engineered systems; i.e., Exadata)

Why have an IM columnar store? Because transactions run faster in row format and analytics run faster in columnar format. For analytics, the columnar In-Memory is better and faster because it only accesses the column data needed (and in compressed format—smaller/faster). In the buffer cache, typically you only see 10 to 20 percent of the table or table partition data, whereas in the IM, 100 percent of the table column(s) or table partition(s) is in memory.

To place an object in the new In-Memory column store, the INMEMORY attribute is set. Setting the attribute can happen as a default, at the tablespace level, or for a whole table. You can also set it for a single column(s) of a table or even for partition(s) of a table. There are so many options that I will simply give you some examples:
Tablespace  alter tablespace users default INMEMORY;
Table  alter table mytable INMEMORY;
Column  alter table mytable INMEMORY NO INMEMORY (prod_id);
Partition  alter table mytable modify partition mytable_part1 NO INMEMORY;

Once we place a table object into memory, we can see when our queries use in-memory by looking at the execution/EXPLAIN PLAN, as shown in this example:

```
select eno
from emp
order by eno;
EMPNO
----
7389
7390
...
```

The IM has hints that you can use in your SQL as well to force the optimizer to utilize the In-Memory column store:

- /*+ INMEMORY( table ) */ Put a table into the IM area
- /*+ NO_INMEMORY( table ) */ Take a table out of the IM area
- /*+ INMEMORY_PRUNING( table ) */ Control the use of the IM storage index
- /*+ NO_INMEMORY_PRUNING( table ) */ Control the use of the IM storage index
- /*+ PX_JOIN_FILTER( table ) */ Force the use of a Bloom filter for a join if the optimizer doesn’t
- /*+ NO_PX_JOIN_FILTER( table ) */ Force the non-use of a Bloom filter for a join if the optimizer doesn’t

The IM has the option for objects to be populated immediately on database startup or when the
Object is first read/queried. This is controlled by the PRIORITY keyword. This allows you to immediately populate the in-memory area on database startup for some objects and help save the performance hit on first-time read. It also allows you to assign the importance level of the objects that get into the in-memory store. This is all controlled via priority levels. There are five priority levels that control the loading of objects into the in-memory area:

- **CRITICAL** Object is populated immediately after the database is opened
- **HIGH** Object is populated after all CRITICAL objects have been populated, if space remains available in the IM column store
- **MEDIUM** Object is populated after all CRITICAL and HIGH objects have been populated, if space remains available in the IM column store
- **LOW** Object is populated after all CRITICAL, HIGH, and MEDIUM objects have been populated, if space remains available in the IM column store
- **NONE** Objects only populated after they are scanned for the first time (default), if space is available in the IM column store

Setting the priority determines how and when/if the objects are loaded into the IM store and in which order. For example, to set `mytable` into the IM store at database startup and have it be one of the first loaded, I would set the priority to CRITICAL:

```sql
alter table mytable INMEMORY PRIORITY CRITICAL;
```

The in-memory area also has compression, which is critical because it allows more data to be stored in-memory and uses less physical memory doing it. In 12c Release 2, Automatic Data Optimization (ADO, covered in Chapter 3) is extended to manage the In-Memory column store moving objects like tables and partitions in and out of memory based on the Heat Map statistics. There are several in-memory compression options:

- **NO MEMCOMPRESS** Data is populated without any compression
- **MEMCOMPRESS FOR DML** Minimal compression optimized for DML performance
- **MEMCOMPRESS FOR QUERY LOW** Optimized for query performance (default)
- **MEMCOMPRESS FOR QUERY HIGH** Optimized for query performance as well as space saving
- **MEMCOMPRESS FOR CAPACITY LOW** Balanced with a greater bias toward space saving
- **MEMCOMPRESS FOR CAPACITY HIGH** Optimized for space saving

To see the table:
By default, in-memory compression is FOR QUERY LOW, which provides the best performance while still getting some benefits from compression to improve the in-memory area utilization. The amount of compression experienced can vary anywhere from 2x–20x and is based on data type, compression type, and the data within the table.

The following example shows how we can apply different compression levels and in-memory all in the same table. This example specifies to not use in-memory for a large LOB column (c4), but to compress the table for in-memory at QUERY HIGH and to use CAPACITY HIGH for column c2:

```
CREATE TABLE mytable
  ( c1 NUMBER,
    c2 NUMBER,
    c3 VARCHAR2(10),
    c4 CLOB )
INMEMORY MEMCOMPRESS FOR QUERY HIGH
NO INMEMORY(c4)
INMEMORY MEMCOMPRESS FOR CAPACITY HIGH(c2);
```

Performance benefits for in-memory do not just stop at the In-Memory column store memory area; they also extend to In-Memory storage indexes created and maintained by Oracle. These are created for columns in the In-Memory column store, which allows data pruning from the SQL WHERE clause directly upon reading, saving rows returned to the optimizer for filtering. Oracle leverages SIMD speed developed in the gaming industry (think Volibear and *League of Legends*, the game that is played online by over 27M people daily). The SIMD (single instruction, multiple data) vector processing allows a single CPU instruction to evaluate multiple data points using a vector register and vector comparing all values in one CPU cycle (over 100× faster). Also, in-memory joins take advantage of Bloom filters to transform a join and improve the overall performance during the scan of larger tables. In 12cR2, the join group (column joined between two tables) is also compressed so that decompression is not needed when tables are joined (a very important advantage of R2). Also in R12cR2 is the ability to have In-Memory virtual columns, and Active Data Guard can now use the In-Memory column store while open in read-only mode. You can use In-Memory Expressions with the DBMS_INMEMORY_ADMIN package to capture hot expressions in the IM using the DBMS_INMEMORY_ADMIN.IME_CAPTURE_EXPRESSION. You can also use this package using the DBMS_INMEMORY_ADMIN.FASTSTART_ENABLE procedure to save data in the IM to a FastStart area (the specified tablespace, also see V$INMEMORY_FASTSTART_AREA) which can
be used to repopulate the IM on database restarts (in the original priority order). See the *Oracle Database In-Memory Guide* for additional information. Lastly, updates to internal dictionary objects have been made to accommodate the In-Memory Database capability:

- `V$IMSEGMENTS, V$IM_USER_SEGMENTS, V$IM_COLUMN_LEVEL, USER_TABLES, and V$KEY_VECTOR`
- `USER_TABLES` (inmemory, inmemory_priority, inmemory_compression, inmemory_distribute, inmemory_duplicate)

**TIP**

Setting `INMEMORY_SIZE` can lead to unbelievably fast analytics, but only set this parameter when properly licensed for this option.

**Changing the Initialization Parameters Without a Restart**

With each version of Oracle, you can alter more and more parameters without needing to restart the database, greatly reducing the need for scheduled downtime to implement system tuning changes.

As an example, this command changes the `SHARED_POOL_SIZE` to 128M while the database is running:

```
SQL> ALTER SYSTEM SET SHARED_POOL_SIZE = 128M;
```

In addition to being able to change parameters dynamically, you can now use a server parameter file (SPFILE) to store dynamic changes persistently to the instance parameters. Prior to Oracle 9i, any dynamic changes were lost when the database was restarted unless the parameters were added to the initialization parameter file manually. As of Oracle 9i, and continuing through Oracle 12c Release 2, dynamic changes can be stored in an SPFILE. The default order of precedence when an instance is started is to read parameter files in the following order:

1. `spfile<SID>.ora`
2. `spfile.ora`
3. `init<SID>.ora`

Parameters can be dynamically modified at a system-wide or session-specific scope. In addition, parameters can be changed in memory only or persistently across restarts via an SPFILE. In the first example, I change the `SHARED_POOL_SIZE` and also write it to the SPFILE. Note that you can use K (kilobytes), M (megabytes), and G (gigabytes), but not T (terabytes), P (petabytes), or E (exabytes)
yet (even though in 64-bit, an Oracle database can be 8E and you can directly address 16E of memory). Also, note that 1G = 1024*1024*1024 = 1,073,741,824 bytes.

```
SQL> ALTER SYSTEM SET SHARED_POOL_SIZE = 128M SCOPE=SPFILE;
```

In the second example, I write SHARED_POOL_SIZE to both the SPFILE (for future restarts) and the MEMORY (for the current SGA):

```
SQL> ALTER SYSTEM SET SHARED_POOL_SIZE = 1G SCOPE BOTH;
SQL> SHOW PARAMETER SHARED_POOL_SIZE

NAME                        TYPE       VALUE
-----------------------------------------------------------------
shared pool size             big integer 1G
```

I can also create a PFILE from the SPFILE (since the SPFILE is nonreadable):

```
SQL> CREATE PFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\INITORCL.ORA'
FROM SPFILE;
```

Or, as shown here, it checks the default location and writes it to the default location:

```
SQL> CREATE PFILE FROM SPFILE;
```

If my SPFILE is deleted for some reason (don’t ever do this), I can also re-create the SPFILE from the PFILE (if I’ve created one), as shown here, or from MEMORY:

```
SQL> CREATE SPFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\SPFILEORCL.ORA'
FROM PFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\INITORCL.ORA';
SQL> CREATE SPFILE='C:\APP\USER\PRODUCT\11.2.0\DBHOME_2\DATABASE\SPFILEORCL.ORA' FROM MEMORY;
```

When you look at PFILE’s output, other than the parameters I’ve physically set, it has limited information. It also has all of the settings for key memory parameters that have been set for me since I only set MEMORY_TARGET. Consider what happens if I run this:
If you use the ALTER SYSTEM commands to write to the SPFILE only, and then on startup realize you have set them incorrectly, the database will not start, and you cannot use an ALTER SYSTEM command to fix the problem. You can, however, create a PFILE from the SPFILE, modify the PFILE, and then use that to start the database. Afterward you need to create the SPFILE again and restart the database with the SPFILE.

Here is a listing of the INITORCL.ORA file (note that my MEMORY_TARGET was 6.56G and INMEMORY_SIZE=0):

```sql
orcl.__data_transfer_cache_size=0
orcl.__db_cache_size=2315255808
orcl.__inmemory_ext_roarea=0
orcl.__inmemory_ext_rwarea=0
orcl.__java_pool_size=16777216
orcl.__large_pool_size=33554432
orcl.__pga_aggregate_target=2339241888
orcl.__sga_target=4479516672
orcl.__shared_io_pool_size=973078528
orcl.__shared_pool_size=1073741824
orcl.__streams_pool_size=16777216
*compatiblc='12.2.0.0.0'
*db_block_size=8192
*db_domain=''
*db_name='orcl'
*log_buffer=4931584# log buffer update
*max_dump_file_size='UNLIMITED'
*memory_max_target=6871318528
*memory_target=6871318528
*optimizer_dynamic_sampling=2
*optimizer_mode='ALL_ROWS'
*shared_pool_size=1073741824
*undo_tablespace='UNDERTBS1'
... (rows deleted for size before and after this point) ...
```

You can get a better listing by dumping the MEMORY to a PFILE so you can see everything set:
SQL> CREATE PFILE='/home/oracle/init memory1.ora' FROM MEMORY;

This shows every parameter set for the database instance (whether you set them or Oracle did):

# Oracle init.ora parameter file generated by instance orcl on 06/18/2016 16:07:34
__data_transfer_cache_size=0
db_cache_size=2208M
__inmemory ext roacco=0
__inmemory ext roarea=0
__java_pool_size=16M
__large_pool_size=32M
__oracle_base='/u01/app/oracle' # ORACLE_BASE set from environment
pga_aggregate_target=2288M
sga_target=4272M
__shared_io_pool_size=928M
__shared_pool_size=1G
__streams_pool_size=16M
adaptive_window_consolidator_enabled=TRUE
aggregation_optimization_settings=0
always_antijoin='CHOOSE'
always_semi_join='CHOOSE'
and_pruning_enabled=TRUE
b_tree_bitmap_plans=TRUE
bloom_filter_enabled=TRUE
bloom_filter_ratio=35
bloom_folding_enabled=TRUE
TIP

If you can’t figure out why your system isn’t using the value in your init.ora file, an SPFILE is probably overriding it. And, don’t forget, you can also use a hint to override parameters at the query level.

Finally, in a Real Application Clusters (RAC/Grid) environment, parameters can be changed for a single instance or for all clustered database instances in a cluster.

There are two key fields in the V$PARAMETER view (which shows the parameter in effect for the session; V$SYSTEM_PARAMETER shows the parameters in effect for the entire instance):

- **ISSES_MODIFIABLE** Indicates if a user with the ALTER SESSION privilege can modify this initialization parameter for his or her session.
- **ISSYS_MODIFIABLE** Indicates if someone with ALTER SYSTEM privilege can modify this particular parameter.

The following query illustrates a list of initialization parameters that can be set without shutting down and restarting the database. This query displays the initialization parameters that can be modified with an ALTER SYSTEM or ALTER SESSION command (partial result displayed):
The result of the query (partial listing only) is all of the initialization parameters that may be modified:

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>ISDEFAULT</th>
<th>ISSES</th>
<th>ISSYS_MOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>sq$_ln_processes</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>archive_log_target</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_diskgroups</td>
<td></td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_diskstring</td>
<td></td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_power_limit</td>
<td>1</td>
<td>TRUE</td>
<td>TRUE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_preferred_read_failure_groups</td>
<td></td>
<td>TRUE</td>
<td>TRUE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>audit_file_dest</td>
<td>C:\APP\USER\ADMIN\ORCL\ADUMP</td>
<td>FALSE</td>
<td>FALSE</td>
<td>DEFERRED</td>
</tr>
<tr>
<td>background_dump_dest</td>
<td>c:\appl\user\diag\pdbms\orcl\trace</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>backup_tape_io_pluggable</td>
<td>FALSE</td>
<td>TRUE</td>
<td>FALSE</td>
<td>DEFERRED</td>
</tr>
</tbody>
</table>

Be careful granting the ALTER SESSION privilege to users, as knowledgeable developers can set individual parameters that positively affect their session at the expense of others on the system. A user could run the following command with the ALTER SESSION privilege:

```
SQL> ALTER SESSION SET SORT AREA SIZE=1000000000;
```

**TIP**

Changing initialization parameters dynamically is a powerful feature for both developers and DBAs. Consequently, a user with the ALTER SESSION privilege is capable of irresponsibly allocating 100M+ for the SORT_AREA_SIZE for a given session, if it is not restricted.

**Modifying an Initialization Parameter at the PDB Level**

You can gain some insight into which initialization parameters are modifiable at the pluggable database (PDB) level (or just the CDB level) by using the following query (PDBs are covered in detail in Chapter 3):
Among the 150 initialization parameters that are modifiable in 12cR2, keys ones include CURSOR_SHARING, OPEN_CURSORS, RESULT_CACHE_MODE, SORT_AREA_SIZE, DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, and INMEMORY_SIZE. One of the key initialization parameters that is not modifiable is MEMORY_TARGET.

**Insight into the Initialization Parameters from Oracle Utilities**

You can gain some insight into how Oracle balances some of these SGA parameters by crawling through the utility upgrade information and other scripts Oracle has published as guidelines. An interesting find is listed here, showing various size caches for different versions of Oracle, as well as 32- vs. 64-bit that Oracle (I added 12c based on the EBS notes later in this chapter) included in the scripts as minimum values (given you have the memory). These guidelines can be nice, but I think the DB_CACHE_SIZE is a bit too low for all of these. There are some great examples at the end of this chapter as well.
Viewing the Initialization Parameters with Enterprise Manager

You can also use Enterprise Manager to view the initialization parameter settings by going to the Database home page, selecting the server, and then selecting Initialization Parameters under the Database Configuration heading. The section of Enterprise Manager displayed in Figure 4-2 shows the initialization parameters. It shows the current settings for the parameters and also shows if the parameters can be modified (dynamic=•) without shutting down the database. Oracle Enterprise Manager is covered in detail in Chapter 5.
Increasing Performance by Tuning the
DB_CACHE_SIZE

Long-time users of Oracle and readers of prior editions of this book will notice that some familiar parameters have not been mentioned. In 10g, parameters such as DB_BLOCK_BUFFERS were deprecated (a parameter _DB_BLOCK_BUFFERS was set behind the scenes for backward compatibility). In later Oracle versions, DB_BLOCK_BUFFERS is back, but set to 0 (default), which means it’s not used unless you set it (use DB_CACHE_SIZE instead). While many of the familiar parameters from prior versions of Oracle are still valid, using them may disable many features, including Automatic Memory Management (AMM).
The DB_CACHE_SIZE is the initial memory allocated to the main data cache or the memory used for the data itself. This parameter doesn’t need to be set if you set MEMORY_TARGET or SGA_TARGET, but it is a good idea to set a value for this as a minimum setting. Your goal should always be getting toward a memory-resident database or at least getting all data that will be queried in memory. After MEMORY_TARGET (or SGA_TARGET) and MEMORY_MAX_TARGET, DB_CACHE_SIZE is the first parameter to look at in the initialization parameter file because it’s the most crucial parameter in Oracle for retrieving data. If the DB_CACHE_SIZE is set too low, Oracle won’t have enough memory to operate efficiently and the system may run poorly, no matter what else you do to it. If DB_CACHE_SIZE is too high, your system may begin to swap and may come to a halt.

DB_CACHE_SIZE makes up the area of the SGA that is used for storing and processing data in memory initially and for subsequent queries to access. (If the In-Memory columnar store is used, some of the DB_CACHE_SIZE may be used less, as described earlier in this chapter.) As users request information, data is put into memory. If the DB_CACHE_SIZE parameter is set too low, then the least recently used (LRU) data is flushed from memory. If the flushed data is recalled with a query, it must be reread from disk (consuming I/O and CPU resources).

Retrieving data from memory can be over 10,000 times faster than retrieving it from disk (depending on the speed of memory, flash used, and disk device speed, which may or may not have memory caching on the disk). Even if you take into consideration disk caching (memory on disk) and Oracle inefficiencies, retrieving data from memory is still about 100 times faster than reading data from the fastest disks or flash. Therefore, the higher the frequency that records are found in memory (without being retrieved from disk), the faster the overall system performance (usually at least 100+ times faster for well-tuned queries). Having enough memory allocated to store data in memory depends on the value used for DB_CACHE_SIZE.

TIP

Retrieving data from physical memory is generally substantially faster than retrieving it from disk, so make sure the SGA and PGA are large enough. One Oracle study showed Oracle memory access as averaging about 100 times faster than disk access. However, this takes into account disk-caching advances and flash, which you may or may not have on your system. The same study also showed an individual case where Oracle memory access was well over 10,000 times faster than disk (which was hard for me to believe), but it shows how important it is to measure this on your own unique system.

MEMORY_TARGET, SGA_TARGET (if used), and DB_CACHE_SIZE (if a minimum is set) are the key parameters to use when tuning the data cache hit ratio. The data cache hit ratio is the percentage of the data block accesses that occur without requiring a physical read from disk. While several situations can artificially inflate or deflate the data cache hit ratio, this ratio is a key indicator of system efficiency.

You can use the following query to view the data cache hit ratio (the first output is one with a lot of full table scans, the second a simple index scan):
While every application has exceptions, a data cache hit ratio of 95 percent or greater should be achievable for a well-tuned transactional application with the appropriate amount of memory. Because there is such a performance difference between some disk devices and memory access, improving the data cache hit ratio from 90 to 95 percent can nearly double system performance when reading disk devices that are extremely slow. Improving the cache hit ratio from 90 to 98 percent could yield nearly a 500 percent improvement where disks are extremely slow and under the right (or should I say wrong) architectural setup. However, with the advent of more flash cache on storage servers, this continues to be something you have to look at in depth to understand what is appropriate for your particular hardware and application load profile (what’s running through the system on a regular basis). If the load profile stays the same, but the hit ratio radically changes, you should investigate why it happened immediately (don’t wait for system users to complain). In the first output just shown, I was aware of many full table scans that were not an issue, so the low hit ratio was not an issue.

Poor joins and poor indexing can also yield very high hit ratios due to reading many index blocks, so make sure your hit ratio isn’t high for a reason other than a well-tuned system. An unusually high hit ratio may indicate the introduction of code that is poorly indexed or includes join issues. If the hit ratio goes much higher (bad query that might have over-indexing or poor use of indexes in joins) or much lower than normal (someone may have dropped an index or altered it to be invisible), you should investigate why it happened immediately (don’t wait for system users to complain).

### TIP

Hit ratios are useful to experienced DBAs but can be misleading or of little use to inexperienced DBAs. The best use of hit ratios is still to compare them over time (a barometer) to help alert you
to a substantial change to a system on a given day. While some people have deprecated hit ratios from their tuning arsenal, they are usually tool vendors who don’t see the value of tracking hit ratios over time because their tools are point-in-time or reactive-based tuning solutions. Hit ratios should never be your only tool, but they should definitely be one of many proactive tools in your arsenal (especially with the advent of the invisible index).

Oracle continues to downplay the importance of hit ratios by reducing the discussions on using hit ratios for tuning, but also continues to include them as barometers. Oracle is beginning to focus on analyzing system performance in terms of work done (CPU or service time) versus time spent waiting for work (wait time). Areas where hit ratios are still the primary tuning method are library cache and dictionary cache. See Chapter 14 on the AWR Report for more information on balancing the entire tuning arsenal, including hit ratios.

Using V$DB_CACHE_ADVICE in Tuning

DB CACHE SIZE

V$DB_CACHE_ADVICE is a view to assist in tuning DB_CACHE_SIZE. The view can be queried directly, and the data in the view is used by the Oracle kernel (or database engine) to make automatic cache management decisions.

Here is a query to view the effect of changing DB_CACHE_SIZE on the data cache hit ratio:

```
select name, size_for_estimate, size_factor, estd_physical_read_factor
from v$sql_cache_advice;
```

Reading these simple results from this very small SGA, you see the following:

- The current cache size in this example was small at 24M (SIZE_FACTOR = 1).
- You can decrease the cache size to be 16M and maintain the current cache hit ratio, since the PHYSICAL_READ_FACTOR remains at 1 up to a decrease to 16M.

Although this view provides an estimate of the effect of changing the cache size on the cache hit ratio, test any changes to validate that the results are as forecasted. Oracle Enterprise Manager provides a graphical view of the data in V$DB_CACHE_ADVICE. (Enterprise Manager is covered in Chapter 5.) To populate V$DB_CACHE_ADVICE, you have to enable the Dynamic Buffer Cache
Advisory feature, and it is not recommended to have this feature enabled on production systems all the time.

Using hit ratios to tune is not a good idea (nobody I know has ever said this), but using them as a barometer when things change is helpful to the great DBA who uses quick indicators to find potential trouble spots. Tool vendors and others hate these easy methods to see warning signs, because they would rather do it for you or charge you for a product you don’t need. The hit ratio for the data cache is usually greater than 95 percent for most transactional systems. The best use for a hit ratio, however, is to study your system over time to see major changes that should warrant further investigation. Usually, if your hit ratio is less than 95 percent, you may need to increase the value of DB_CACHE_SIZE. In some instances, you can increase performance substantially by increasing the hit ratio from 95 to 98 percent—especially if the last 5 percent of the hits going to disk are the main lag on the system or the disk cache gets flooded (full with cached data).

Although hit ratios less than 95 percent could be a sign that your DB_CACHE_SIZE is set too low or that you have poor indexing, hit ratio numbers can be distorted and this should be taken into account while tuning (note that Exadata works differently and is covered in Chapter 11). Hit ratio distortion and non-DB_CACHE_SIZE issues include the following:

- Recursive calls
- Missing or suppressed indexes
- Data sitting in memory
- UNDO/ROLLBACK segments
- Multiple logical reads
- Physical reads causing the system to use CPU

*Monitoring the V$SQLAREA View to Find Bad Queries*

When issues occur, locate bad queries by monitoring the V$SQLAREA view or using Enterprise Manager. Once you isolate the queries that are causing performance hits, tune the queries or modify how the information is stored to solve the problem. Using the Performance page of Enterprise Manager Grid Control or Database Control, a DBA can generate a report of the Top Activity for his or her system. The Top Activity section of Enterprise Manager Database Control (see Figure 4-3) displays a list of the worst SQL statements in the current cache based on Activity and also the Top Sessions by Activity. The graph at the top of Figure 4-3 shows increasing performance issues. The graphs on the left and right show the problem SQL (left) and users (right). The DBA can then click the problem SQL to begin the process of analyzing and tuning the SQL statement. Chapter 5 discusses the benefits of Oracle Enterprise Manager in detail and how to tune the SQL statements using Enterprise Manager. Also note that Database Control is installed with the Oracle Database software. Grid Control is a separate product.
FIGURE 4-3. Use Oracle Enterprise Manager Database Control to find problem queries.

TIP
Use Enterprise Manager Cloud Control or Database Control to find problem queries.

When an Index Is Suppressed
Consider the following query, where the CUSTOMER table is indexed on the unique CUSTNO column. It is not optimal to have this index suppressed by using the NVL (Null Value) because it results in a poor hit ratio.

```
select custno, name
from customer
where nvl(custno, 0) = 5789;
```

Db block gets: 1
Consistent gets: 194
Physical reads: 194
Hit ratio = 1 - (194 / (194+1)) = 1 - 194/195 = 0.0514, or 5.14%

If you are looking at this in Enterprise Manager, you’ll see an index missing on a query that is
being executed at the current time. Focus on the query that is causing this problem and fix the query. The query can be found by accessing the V$SQLAREA view, as shown in Chapter 8. You could build a function-based index (see Chapter 2) to solve this problem as well. For Exadata, this might be fine if all of the data is in the Flash Cache on a cell or if the query brings back fewer blocks of data based on features like the Smart Scan or Storage Index (more in Chapter 11).

TIP
A low hit ratio for a query could be an indication of a missing or suppressed index.

Well-Indexed Queries
Consider the following query, where the CUSTOMER table is indexed on the unique CUSTNO column. In this situation, it is optimal to utilize the CUSTNO index because it results in an excellent hit ratio.

```
select custno, name
from customer
where custno = 5789;
```

Db block gets: 0
Consistent gets: 192
Physical reads: 0
Hit ratio = 100%

If you are looking at this in Enterprise Manager, there is usually an index on the query that is being executed or the table could be cached in memory.

Bad Queries Executing a Second Time
When a full table scan is completed for the second time and the data is still in memory, you may see a good hit ratio even though the system is trying to run a bad query:

```
Db block gets: 1
Consistent gets: 105
Physical reads: 1
Hit ratio = 99% (A very high/usually good hit ratio)
```

If you are looking at this in Enterprise Manager, it appears that there is an index on the query being executed when, in fact, the data is in memory from the last time it was executed. The result is that you are “hogging up” a lot of memory even though it appears that an indexed search is being performed.
Since 10g, you can flush the buffer cache to clear it (similar to flushing the shared pool if you are familiar with that). You can also do this for an individual PDB. It is generally not intended for production use, but rather for system testing purposes. This can help with your tuning needs or as a Band-Aid if you have “free buffer” waits (there are better ways to fix free buffer waits, such as writing more often or increasing the `DB_CACHE_SIZE`). Note that any Oracle I/O not done in the SGA counts as a physical I/O. If your system has O/S caching or disk caching, the actual I/O that shows up as physical may indeed be a memory read outside of Oracle.

To flush the buffer cache, perform the following:

```
SQL> ALTER SYSTEM FLUSH BUFFER_CACHE;
```

**TIP**
Bad (slow) queries show in the `V$SQLAREA` view or `V$SESSION_LONGOPS` view (under certain conditions) with poor hit ratios the first time they are executed. You can also use Enterprise Manager to see statistical information. Make sure you tune them at that time. The second time that they execute, they may not show a poor hit ratio. Flushing the buffer cache for testing can help you get accurate results.

**Other Distortions**
You should consider several other hit ratio distortions:

- **Oracle Developer distortion** Systems that use Oracle Developer tools, JDeveloper (screens), or Application Express (APEX) to retrieve single rows of data frequently use the same information over and over. This reuse by some users of the system will drive up the hit ratio. Other users on the system may not be experiencing hit ratios that are as good as these users, yet the overall system hit ratio may look very good. The DBA must take into consideration that these users may be boosting the hit ratio to an artificially high level.

- **UNDO/ROLLBACK segment distortion** Because the header block of the UNDO/ROLLBACK segment is usually cached, the activity to the UNDO/ROLLBACK segment gives a falsely high hit ratio impact when truly there is no significant impact on the hit ratio.

- **Index distortion** An index range scan results in multiple logical reads on a very small number of blocks. I’ve seen hit ratios as high as 86 percent be recorded when none of the blocks are cached prior to the query executing. Make sure you monitor the hit ratio of individual, poorly tuned queries in addition to monitoring the big picture (overall hit ratio). You can also check bad indexes by making them invisible (see Chapter 2 for more information).

- **I/O distortion** Physical reads that appear to be causing heavy disk I/O may be actually causing you to be CPU bound. In tests, the same amount of CPU was used for 89 logical reads as was
used to process 11 physical reads. The result is that the physical reads are CPU costly because of buffer management. Fix the queries causing the disk I/O problems and you will usually free up a large amount of CPU as well. Performance degradation can be exponentially downward spiraling, but the good news is that when you begin to fix your system, it is often an exponentially upward-spiraling event. It’s probably the main reason why some people live to tune; tuning can be exhilarating.

Setting DB_BLOCK_SIZE to Reflect the Size of Your Data Reads

The DB_BLOCK_SIZE is the size of the default data block size when the database is created. Since Oracle 10g Release 2, each tablespace can have a different block size, thus making block size selection a less critical selection before the database is created. That said, a separate cache memory allocation must be made for each different database block size. But it is still very important to choose wisely. Although you can have different block-size tablespaces, this is not truly a performance feature, as the nondefault buffer caches are not optimized for performance. You still want to put the bulk of your data in the default buffer cache. You must rebuild the database if you want to increase the DB_BLOCK_SIZE. The block size for data warehouses is often 32K (you want many rows to be read at a time) and OLTP systems are often 8K. Most experts recommend an 8K block size.

The data block cache for the default block size is set using the DB_CACHE_SIZE initialization parameter. Cache is allocated for other database block sizes by using the DB_nK_CACHE_SIZE, where n is the block size in K. The larger the DB_BLOCK_SIZE, the more that can fit inside a single block and the more efficiently large amounts of data can be retrieved. A small DB_BLOCK_SIZE actually lets you retrieve single records faster and saves space in memory. In addition, a smaller block size can improve transactional concurrency and reduce log file generation rates. As a rule of thumb, a data warehouse should use the maximum block size available for your platform (either 16K or 32K) as long as no bugs exist for the given block size (check My Oracle Support to make sure), whereas a transaction-processing system should use an 8K block size. Rarely is a block size smaller than 8K beneficial, but I’ve used a 2K block size for a stock exchange application and I’ve seen a 4K block size in benchmarks. If you have an extremely high transaction rate system or very limited system memory, you might consider a block size smaller than 8K.

Full table scans are limited to the maximum I/O of the box (usually 64K, but as high as 1M on many systems). Most systems support 1M I/O rates now. You can up the amount of data read into memory in a single I/O by increasing the DB_BLOCK_SIZE to 8K or 16K. You can also increase the DBFILE_MULTIBLOCK_READ_COUNT to a maximum value of (max I/O size)/DB_BLOCK_SIZE.

Environments that run many single queries to retrieve data could use a smaller block size, but “hot spots” in those systems will still benefit from using a larger block size. Sites that need to read large amounts of data in a single I/O read should increase the DB_FILE_MULTIBLOCK_READ_COUNT. This may not be necessary with a parameter set, by default, to be much larger in 12c. My default for DB_FILE_MULTIBLOCK_READ_COUNT was 128, but check your system for variations to the default. The default value Oracle uses corresponds to the maximum I/O size that can be efficiently performed and is platform-dependent (according to Oracle docs). Setting the DB_FILE_MULTIBLOCK_READ_COUNT higher is especially important for data warehouses that
retrieve lots of records. If the use of DB_FILE_MULTIBLOCK_READ_COUNT starts to cause many full table scans (since the optimizer now decides it can perform full table scans much faster and decides to do more of them), then set OPTIMIZER_INDEX_COST_ADJ between 1 and 10 (I usually use 10) to force index use more frequently.

**TIP**

The database must be rebuilt if you increase the DB_BLOCK_SIZE. Increasing the DB_FILE_MULTIBLOCK_READ_COUNT allows more block reads in a single I/O, giving a benefit similar to a larger block size.

### Setting SGA_MAX_SIZE to 25 to 50 Percent of the Size Allocated to Main Memory

If you use it, the general rule of thumb is to start with an SGA_MAX_SIZE parameter of 20 to 25 percent of the size allocated to your main memory. A large number of users (300+) or a small amount of available memory may force you to make this 15 to 20 percent of physical memory. A small number of users (less than 100) or a large amount of physical memory may allow you to make this 30 to 50 percent of physical memory. If you set the SGA_MAX_SIZE less than 1G, then the _KSM_GRANULE_SIZE is 4M. If the SGA_MAX_SIZE is greater than 1G and less than 8G, then the _KSM_GRANULE_SIZE is 16M; from there, up to 16G is 32M, up to 32G is 64M, up to 64G is 128M, up to 128G is 256M, and if your SGA_MAX_SIZE is greater than 256G, then the _KSM_GRANULE_SIZE is 512M. This granule size determines the multiples for other initialization parameters. A granule size of 4M means that certain initialization parameters are rounded up to the nearest 4M. Therefore, if I set SGA_MAX_SIZE to 64M and DB_CACHE_SIZE to 9M, then the DB_CACHE_SIZE is rounded to 12M (since the granule size is 4M). If I set SGA_MAX_SIZE to 2000M and DB_CACHE_SIZE to 9M, then the DB_CACHE_SIZE is rounded to 16M (since the granule size is 16M). The V$SGA_DYNAMIC_COMPONENTS view allows you to see the sizes used for each SGA component (such as shared pool, buffer caches, etc.) and the granule size used.

**TIP**

The SGA_MAX_SIZE determines the granule size for other parameters. An SGA_MAX_SIZE < 1G means a 4M granule size, whereas an SGA_MAX_SIZE >= 256G means a 512M granule size. Some benchmarks have the granule size as high as 256M.

### Tuning the SHARED_POOL_SIZE for Optimal Performance
Sizing the SHARED_POOL_SIZE correctly makes sharing identical SQL statements possible. Getting the statement parsed is your first priority. If the query never makes it into memory, it can never request the data to be accessed; that’s where the SHARED_POOL_SIZE comes in. SHARED_POOL_SIZE specifies the memory allocated in the SGA for data dictionary caching and shared SQL statements.

The data dictionary cache is very important because that’s where the data dictionary components are buffered. Oracle references the data dictionary several times when a SQL statement is processed. Therefore, the more information (database and application schema and structure) that’s stored in memory, the less information that has to be retrieved from disk. While the dictionary cache is part of the shared pool, Oracle also caches SQL statements and their corresponding execution plans in the library cache portion of the shared pool (see the next section for how the shared SQL area works).

The data dictionary cache portion of the shared pool operates in a manner similar to the DB_CACHE_SIZE when caching information. For the best performance, it would be great if the entire Oracle data dictionary could be cached in memory. Unfortunately, this generally is not feasible, so Oracle uses a least recently used (LRU) algorithm for deciding what gets to stay in the cache.

Lastly, the Result Cache is part of the shared pool (allocated from the shared pool, but a separate area) as well, if you use it. Query function results and query fragments can be cached in memory for future executions. Choose calculations that frequently run over and over again. You should also choose data that does not frequently change. To use the Result Cache, set the RESULT_CACHE_SIZE=amount and the RESULT_CACHE_MODE=force parameters (set to force to automatically use it). The Result Cache takes its memory from the shared pool. You can use DBMS_RESULT_CACHE.FLUSH to clear the Result Cache. Note that anything cached is not passed between RAC/Grid nodes in 11gR1 (stays local to each instance), but data from the Result Cache is transferred over the interconnect to other RAC instances starting in 11gR2. Each Result Cache is local to each instance, as is the buffer cache, but can be shared over the interconnect since 11gR2. There is no global Result Cache. Please check the documentation for other restrictions and rules.

Using Stored Procedures for Optimal Use of the Shared SQL Area

Each time a SQL statement is executed, the statement is searched for in the shared SQL area and, if found, used for execution. This saves parsing time and improves overall performance. Therefore, to ensure optimal use of the shared SQL area, use stored procedures as much as possible since the SQL parsed is exactly the same every time and, therefore, shared. However, keep in mind that the only time the SQL statement being executed can use a statement already in the shared SQL area is if the statements are identical (meaning they have the same content exactly—the same case, the same number of spaces, etc.). If the statements are not identical, the new statement is parsed, executed, and placed in the shared SQL area (exceptions to this are possible when the initialization parameter CURSOR_SHARING has been set to SIMILAR or FORCE).

In the following example, the statements are identical in execution, but the word from causes Oracle to treat the two statements as if they were different, thus not reusing the original cursor that was located in the shared SQL area:
TIP

SQL must be written exactly the same to be reused. Case differences and any other differences will cause a reparse of the statement.

In the following example, I am using different values for ENAME, which is causing multiple statements to be parsed:

```
declare
    temp VARCHAR2(10);
begin
    select ename into temp
    from rich
    where ename = 'SMITH';
    select ename into temp
    from rich
    where ename = 'JONES';
end;
```

A query of V$SQLAREA shows that two statements were parsed even though they were very close to the same thing. Note, however, that PL/SQL converted each SQL statement to uppercase and trimmed spaces and carriage returns (which is a benefit of using PL/SQL):

```
select sql_text
from v$sqlarea
where sql_text like 'SELECT ENAME\%';
```

In the following example, there is a problem with third-party applications that do not use bind variables (they do this to keep the code “vanilla” or capable of working on many different databases without modification). The problem with this code is that the developer has created many statements that fill the shared pool and these statements can’t be shared (since they’re slightly different). You can build a smaller shared pool so there is less room for cached cursors and thus fewer cursors to search
through to find a match (this is the Band-Aid inexperienced DBAs use). If the following is your output from V$SQLAREA, you may benefit from lowering the SHARED_POOL_SIZE, but using CURSOR_SHARING is a better choice.

Setting CURSOR_SHARING=force and the query to V$SQLAREA will change to the one listed next because Oracle builds a statement internally that can be shared by all of the preceding statements. Now the shared pool is not inundated with all of these statements, but only one simple statement that can be shared by all users:

```
select empno from rich778 where empno =:SYS_B_0
```

Setting the SHARED_POOL_SIZE High Enough to Fully Use the DB_CACHE_SIZE

If the SHARED_POOL_SIZE is set too low, then you will not get the full advantage of your DB_CACHE_SIZE (since statements that can’t be parsed can’t be executed). The queries that can be performed against the Oracle V$ views to determine the data dictionary cache hit ratio and the shared SQL statement usage are listed in the sections that follow. These will help you determine if increasing the SHARED_POOL_SIZE will improve performance.

The SHARED_POOL_SIZE parameter is specified in bytes. The default value for the SHARED_POOL_SIZE parameter varies per system but is generally lower than necessary for large production applications.

Keeping the Data Dictionary Cache Objects Cached

The data dictionary cache is a key area to tune because the dictionary is accessed so frequently, especially by Oracle. At startup, the data dictionary cache contains no data. But as more data is read
into cache, the likelihood of cache misses decreases. For this reason, monitoring the data dictionary cache should be done only after the system has been up for a while and stabilized. If the dictionary cache hit ratio is less than 95 percent, then you’ll probably need to increase the size of the SHARED_POOL_SIZE parameter in the initialization parameter file. Implementing locally managed tablespaces (LMT) can also help your dictionary cache (see My Oracle Support Note 166474.1, “Can We Tune the Row Cache?”). However, keep in mind that the shared pool also includes the library cache (SQL statements), and Oracle decides how much of the distribution is for the library cache versus the row cache.

Use the following query against the Oracle V$ view to determine the data dictionary cache hit ratio:

```
select  ((1 - (Sum(GetMisses) / (Sum(GetHits) + Sum(GetMisses)))) * 100) "Hit Rate"
from     V$RowCache
where    Gets + GetMisses <> 0;
```

**TIP**

Measure hit ratios for the row cache (data dictionary cache) of the shared pool with the V$ROWCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios will be around 85 percent.

Using Individual Row Cache Parameters to Diagnose Shared Pool Use

To diagnose a problem with the shared pool or overuse of the shared pool, use a modified query to the V$ROWCACHE view. This shows how each individual parameter makes up the data dictionary cache, also referred to as the row cache (partial listing):
This query places an asterisk (*) for any query that has misses greater than 10 percent. It does this by using the CASE expression to limit the miss ratio to the tenth digit and then analyzes that digit for any value greater than 0 (which would indicate a hit ratio of 10 percent or higher). A 0.1 miss or higher returns an *. Explanations of each of the columns are provided in the next section.

### Keeping the Library Cache Reload Ratio at 0 and the Hit Ratio Above 95 Percent

For optimal performance, you’ll want to keep the library cache reload ratio \([\text{sum(reloads)} / \text{sum(pins)}]\) at zero and the library cache hit ratio greater than 95 percent. If the reload ratio is not zero, then statements are being “aged out” that are later needed and brought back into memory. If the reload ratio is zero (0), it means items in the library cache were never aged or invalidated. If the reload ratio is greater than 1 percent, the \text{SHARED\_POOL\_SIZE} parameter should probably be increased. Likewise, if the library cache hit ratio comes in less than 95 percent, then the

```sql
column parameter format a20 heading 'Data Dictionary Area'
column gets format 999,999,999 heading 'Total\_Requests'
column getmisses format 999,999,999 heading 'Misses'
column modifications format 999,999,999 heading 'Mods'
column flushes format 999,999,999 heading 'Flushes'
column getmiss_ratio format 9.99 heading 'Miss\_Ratio'

set pagesize 55

title 'Shared Pool Row Cache Usage'

select parameter, gets, getmisses, modifications, flushes, 
    (getmisses / decode(gets,0,1,gets)) getmiss ratio, 
    (case when (getmisses / decode(gets,0,1,gets)) > .1 then '*' else ' ' end) " " 
from v$rowcache
where Gets + GetMisses <> 0;
```

<table>
<thead>
<tr>
<th>Data Dictionary Area</th>
<th>Total Requests</th>
<th>Misses</th>
<th>Mods</th>
<th>Flushes</th>
<th>Miss Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>cc_segments</td>
<td>637</td>
<td>184</td>
<td>0</td>
<td>0</td>
<td>0.29 *</td>
</tr>
<tr>
<td>cc_tablespaces</td>
<td>18</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0.17 *</td>
</tr>
<tr>
<td>cc_users</td>
<td>126</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0.20 *</td>
</tr>
<tr>
<td>cc_rollback_segments</td>
<td>235</td>
<td>21</td>
<td>31</td>
<td>30</td>
<td>0.03 *</td>
</tr>
<tr>
<td>cc_objects</td>
<td>728</td>
<td>157</td>
<td>55</td>
<td>0</td>
<td>0.23 *</td>
</tr>
<tr>
<td>cc_global_oids</td>
<td>16</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0.33 *</td>
</tr>
<tr>
<td>cc_object_ids</td>
<td>672</td>
<td>164</td>
<td>55</td>
<td>0</td>
<td>0.24 *</td>
</tr>
<tr>
<td>cc_sequences</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.00 *</td>
</tr>
<tr>
<td>cc_usernames</td>
<td>193</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0.05</td>
</tr>
<tr>
<td>cc_histogram_cols</td>
<td>24</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>1.00 *</td>
</tr>
<tr>
<td>cc_profiles</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1.00 *</td>
</tr>
<tr>
<td>cc_user_grants</td>
<td>24</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0.63 *</td>
</tr>
</tbody>
</table>
SHARED_POOL_SIZE parameter may need to be increased. Also, if you are using ASMM, the SGA_TARGET includes both auto-tuned and manual parameters. When you decide to raise a parameter specifically (such as SHARED_POOL_SIZE), it influences the auto-tuned part. (Other parameters are affected; see My Oracle Support Notes 443746.1 and 295626.1, “How to Use Automatic Shared Memory (AMM) in 12c.”)

You can monitor the library cache in a couple of ways. The first method is to execute the STATSPACK report (STATSPACK is covered in detail in Chapter 14). The second is to use the V$LIBRARYCACHE view.

The following query uses the V$LIBRARYCACHE view to examine the reload ratio in the library cache:

```sql
select Sum(Pins) "Hits",
       Sum(Reloads) "Misses",
       ((Sum(Reloads) / Sum(Pins)) * 100)"Reload %"
from V$LibraryCache;
```

<table>
<thead>
<tr>
<th>Hits</th>
<th>Misses</th>
<th>Reload %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1032669</td>
<td>441</td>
<td>0.042704874</td>
</tr>
</tbody>
</table>

This next query uses the V$LIBRARYCACHE view to examine the library cache’s hit ratio in detail:

```sql
select Sum(Pins) "Hits",
       Sum(Reloads) "Misses",
       Sum(Pins) / (Sum(Pins) + Sum(Reloads)) "Hit Ratio"
from V$LibraryCache;
```

<table>
<thead>
<tr>
<th>Hits</th>
<th>Misses</th>
<th>Hit Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1033760</td>
<td>441</td>
<td>0.999573584</td>
</tr>
</tbody>
</table>

This hit ratio is excellent (greater than 99 percent) and does not require any increase in the SHARED_POOL_SIZE parameter.

Using Individual Library Cache Parameters to Diagnose Shared Pool Use

Using a modified query on the same table, you can see how each individual parameter makes up the library cache. This may help diagnose a problem or reveal overuse of the shared pool.
Use the following list to help interpret the contents of the V$LIBRARYCACHE view:

- **namespace** The object type stored in the library cache. The values SQL AREA, TABLE/PROCEDURE, BODY, and TRIGGER show the key types.
- **gets** Shows the number of times an item in the library cache was requested.
- **gethits** Shows the number of times a requested item was already in the library cache.
- **gethitratio** Shows the ratio of gethits to gets.
- **pins** Shows the number of times an item in the library cache was executed.
- **pinhits** Shows the number of times an item was executed when that item was already in the
Keeping the Pin Hit Ratio for Library Cache Items Close to 100 Percent

The pin hit ratio for all library cache items—\( \frac{\text{pinhits}}{\text{pins}} \)—should be close to 1 (or a 100 percent hit ratio). A pin hit ratio of 100 percent means that every time the system needs to execute something, it is already allocated and valid in the library cache. Although you will always experience some misses the first time a request is made, misses can be reduced by writing identical SQL statements.

**TIP**

Measure hit ratios for the library cache of the shared pool with the \textit{V$LIBRARYCACHE} view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios are around 85 percent.

Keeping the Miss Ratio Less Than 15 Percent

The miss ratio for data dictionary cache \( \frac{\text{getmisses}}{\text{gets}} \) should be less than 10 to 15 percent. A miss ratio of zero (0) means that every time the system went into the data dictionary cache, it found what it was looking for and did not have to retrieve the information from disk. If the miss ratio \( \frac{\text{getmisses}}{\text{gets}} \) is greater than 10–15 percent, the initialization \texttt{SHARED_POOL_SIZE} parameter should be increased.

Using Available Memory to Determine If the \texttt{SHARED_POOL_SIZE} Is Set Correctly

Here’s the main question that people usually want answered: “Is there any memory left in the shared pool?” To find out how fast memory in the shared pool is being depleted (made noncontiguous or in use) and also what percent is unused (and still contiguous), run the following query after starting the database and running production queries for a short period of time (for example, after the first hour of the day):
If you have plenty of contiguous free memory (greater than 2M), after running most of the queries in your production system (you’ll have to determine how long this takes), then you do not need to increase the SHARED_POOL_SIZE parameter. I have never seen this parameter go all the way to zero (Oracle saves a portion for emergency operations via the SHARED_POOL_RESERVED_SIZE parameter).

TIP
The V$SGASTAT view shows how fast the memory in the shared pool is being depleted. Remember it is only a rough estimate. It shows you any memory that has never been used combined with any piece of memory that has been reused. Free memory will go up and down as the day goes on, depending on how the pieces are fragmented.

Using the X$KSMSP Table to Get a Detailed Look at the Shared Pool

You can query the X$KSMSP table to get the total breakdown for the shared pool. This table will show the amount of memory that is free, memory that is freeable, and memory that is retained for large statements that won’t fit into the current shared pool. Consider the following query for a more accurate picture of the shared pool. Refer to Chapter 13 (the X$ tables) for an in-depth look at this query and how it is adjusted as Oracle is started and as the system begins to access shared pool memory.
Oracle does not state anywhere what the values for status in the X$KSMSP table indicate (KSMSP stands for Kernel Service layer Memory management SGA HEAP; I always remember it as Kernel Shared Memory Shared Pool instead). In the following table, I offer the following possible descriptions based on the behavior of these values as researched in Chapter 13. In Chapter 5, I also show how to graph these results in Enterprise Manager.

<table>
<thead>
<tr>
<th>Bytes</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>238,032,888</td>
<td>freeabl</td>
</tr>
<tr>
<td>128,346,176</td>
<td>recr</td>
</tr>
<tr>
<td>3,456</td>
<td>R-freea</td>
</tr>
<tr>
<td>124,551,032</td>
<td>perm</td>
</tr>
<tr>
<td>29,387,280</td>
<td>R-free</td>
</tr>
<tr>
<td>16,771,472</td>
<td>R-perm</td>
</tr>
<tr>
<td>66,884,304</td>
<td>free</td>
</tr>
</tbody>
</table>

7 rows selected.

Oracle does not state anywhere what the values for status in the X$KSMSP table indicate (KSMSP stands for Kernel Service layer Memory management SGA HEAP; I always remember it as Kernel Shared Memory Shared Pool instead). In the following table, I offer the following possible descriptions based on the behavior of these values as researched in Chapter 13. In Chapter 5, I also show how to graph these results in Enterprise Manager.

<table>
<thead>
<tr>
<th>Status</th>
<th>Possible Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>This is the amount of contiguous free memory available.</td>
</tr>
<tr>
<td>Freeabl</td>
<td>Freeable but not flushable shared memory currently in use.</td>
</tr>
<tr>
<td>Perm</td>
<td>I have read that this status is permanently allocated and non freeable memory, but in testing it, I find that it behaves as free memory not yet moved to the free area for use.</td>
</tr>
<tr>
<td>Recr</td>
<td>Allocated memory that is flushable when the shared pool is low on memory.</td>
</tr>
<tr>
<td>R-free</td>
<td>This is SHARED_POOL_RESERVED_SIZE (default 5 percent of shared pool).</td>
</tr>
<tr>
<td>R-freea</td>
<td>This is probably reserved memory that is freeable but not flushable.</td>
</tr>
<tr>
<td>R-rect</td>
<td>Re-creatable chunks of memory in the reserved pool.</td>
</tr>
<tr>
<td>R-perm</td>
<td>Permanent chunks of memory in the reserved pool.</td>
</tr>
</tbody>
</table>

**TIP**

The general rule of thumb (exact sizing depends on your unique systems) is to make the `SHARED_POOL_SIZE` parameter around 50–150+ percent of the size of your `DB_CACHE_SIZE`. In a system that makes use of a large amount of stored procedures or Oracle supplied packages, but has limited physical memory, this parameter could make up as much as 150+ percent of the size of `DB_CACHE_SIZE`. In a system that uses no stored procedures, but has a large amount of physical memory to allocate to `DB_CACHE_SIZE`, this parameter may be 10–20 percent of the size of `DB_CACHE_SIZE`. I have worked on larger systems where the `DB_CACHE_SIZE` was set as high as tens of gigabytes. I'm sure that hundreds of gigabytes to terabyte SGAs already exist (see examples at the end of this chapter). Petabyte databases are currently starting to make their entry. Note that in a shared server configuration (previously known as MTS), items from the PGA are allocated from the shared pool rather than the session process space.
Points to Remember About Cache Size

Here are some further notes about setting your cache and share pool sizes:

- If the dictionary cache hit ratio is low (less than 95 percent), then consider investigating and increasing SHARED_POOL_SIZE.
- If the library cache reload ratio is high (>1 percent), then consider investigating and increasing SHARED_POOL_SIZE.
- Size the data cache and shared pool appropriately for your systems in terms of workload requirements.

Waits Related to Initialization Parameters

Setting initialization parameters incorrectly often results in various types of performance issues that show up as general “waits” or “latch waits” in a STATSPACK report. In Chapter 14, I cover every type of wait and latch issue related to this. The following tables identify some waits and latch waits and their potential fixes.

<table>
<thead>
<tr>
<th>Wait Problem</th>
<th>Potential Fix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free buffer</td>
<td>Increase the DB_CACHE_SIZE; shorten the checkpoint; tune the code.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>Segment header; add freelists or freelist groups or use ASSM.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>Data block: separate hot data; use reverse key indexes; small block sizes.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>Data block: increase initrans and/or maxtrans.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>UNDO header: use automatic undo management.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>UNDO block: commit more; use automatic undo management.</td>
</tr>
<tr>
<td>Latch free</td>
<td>Investigate the detail (listing in next table of this chapter for fixes).</td>
</tr>
<tr>
<td>Log buffer space</td>
<td>Increase the log buffer; use faster disks for the redo logs.</td>
</tr>
<tr>
<td>Scattered read</td>
<td>Indicates many full table scans; tune the code; cache small tables.</td>
</tr>
<tr>
<td>Sequential read</td>
<td>Indicates many index reads; tune the code (especially joins).</td>
</tr>
<tr>
<td>Write complete waits</td>
<td>Adds database writers; checkpoint more often; buffer cache too small.</td>
</tr>
</tbody>
</table>

Some latch problems have often been bug related in the past, so make sure you check My Oracle Support for issues related to latches. Any of the latches that have a hit ratio less than 99 percent should be investigated.
Using Oracle Multiple Buffer Pools

There are pools for the allocation of memory. These pools relate to the DB_CACHE_SIZE and SHARED_POOL_SIZE. Each of these parameters, which were all-inclusive of the memory they allocate, now has additional options for memory allocation within each memory pool. I will cover the two separately.

Pools Related to DB_CACHE_SIZE and Allocating Memory for Data

In this section, I will focus on the Oracle pools that are used to store the actual data in memory. The initialization parameters DB_CACHE_SIZE, DB_KEEP_CACHE_SIZE, and DB_RECYCLE_CACHE_SIZE are the determining factors for memory used to store data. DB_CACHE_SIZE refers to the total size in bytes of the main buffer cache (or memory for data) in the SGA. Two additional buffer pools are DB_KEEP_CACHE_SIZE and DB_RECYCLE_CACHE_SIZE. These additional two pools serve the same purpose as the main buffer cache (DB_CACHE_SIZE), with the exception that the algorithm to maintain the pool is different for all three available pools. Note that the BUFFER_POOL_KEEP, DB_BLOCK_BUFFERS, and BUFFER_POOL_RECYCLE parameters have been deprecated and should no longer be used. Unlike BUFFER_POOL_KEEP and BUFFER_POOL_RECYCLE,
DB_KEEP_CACHE_SIZE and DB_RECYCLE_CACHE_SIZE are not subtracted from DB_CACHE_SIZE; they are allocated in addition to DB_CACHE_SIZE.

The main buffer cache (defined by DB_CACHE_SIZE) maintains the LRU (least recently used) list and flushes the oldest buffers in the list. While all three pools utilize the LRU replacement policy, the goal for the main buffer cache is to fit most data being used in memory.

The keep pool (defined by DB_KEEP_CACHE_SIZE) is hopefully never flushed; it is intended for buffers that you want to be “pinned” indefinitely (buffers that are very important and need to stay in memory). Use the keep pool for small tables (that fit in their entirety in this pool) that are frequently accessed and need to be in memory at all times.

The recycle pool (defined by DB_RECYCLE_CACHE_SIZE) is a pool from which you expect the data to be regularly flushed because too much data is being accessed to stay in memory. Use the recycle pool for large, less important data that is usually accessed only once in a long while (ad hoc user tables for inexperienced users are often put here).

The following examples give a quick look at how information is allocated to the various buffer pools. Remember, if no pool is specified, then the buffers in the main pool are used.

1. Create a table that will be stored in the keep pool upon being accessed:
   ```
   CREATE TABLE state_list (state_abbrev VARCHAR2(2), state_desc VARCHAR2(25))
   STORAGE (BUFFER POOL KEEP);
   ```

2. Alter the table to the recycle pool:
   ```
   ALTER TABLE state_list STORAGE (BUFFER POOL RECYCLE);
   ```

3. Alter the table back to the keep pool:
   ```
   ALTER TABLE state_list STORAGE (BUFFER POOL KEEP);
   ```

4. Find the disk and memory reads in the keep pool:
   ```
   SELECT physical_reads "Disk Reads",
          db_block_gets + consistent_gets "Memory Reads"
   FROM v$buffer_pool_statistics
   WHERE name = 'KEEP';
   ```

Modifying the LRU Algorithm

In this section, I’m going to go over the deep edge for experts only. Skip this section if you’ve used Oracle for only a decade or less. There are five undocumented initialization parameters (defaults are in parentheses) that you can use to alter the LRU algorithm for greater efficiency when you really have studied and understand your system buffer usage well:

- **_DB_PERCENT_HOT_DEFAULT (50)** The percent of buffers in the hot region
- **_DB_AGING_TOUCH_TIME (3)** Seconds that must pass to increment touch count again
- **_DB_AGING_HOT_CRITERIA (2)** Threshold to move a buffer to the MRU end (hot end) of LRU chain
- **_DB_AGING_STAY_COUNT (0)** Touch count reset to this when moved to MRU end
- **_DB_AGING_COOL_COUNT (1)**: Touch count reset to this when moved to LRU end
- **_DB_AGING_FREEZE_CR (FALSE)**: Make CR (consistent read) buffers always too cold to keep in cache

By decreasing the value of the first of these parameters, you allow buffers to remain longer; increasing the values causes a flush sooner. Setting the second parameter lower gives higher value to buffers that are executed a lot in a short period of time. The third, fourth, and fifth parameters all relate to how quickly to move things from the hot end to the cold end and how long they stay on each end.

### Pools Related to SHARED_POOL_SIZE and Allocating Memory for Statements

In this section, I focus on the pools that are used to store the actual statements in memory. Unlike the pools related to the data, the LARGE_POOL_SIZE is allocated outside the memory allocated for SHARED_POOL_SIZE, but it is still part of the SGA.

The LARGE_POOL_SIZE is a pool of memory used for the same operations as the shared pool. Oracle defines this as the size set aside for large allocations of the shared pool. You’ll have to do your own testing to ensure where the allocations are coming from in your system and version of Oracle. The minimum setting is 300K, but the setting must also be as big as _LARGE_POOL_MIN_ALLOC, which is the minimum size of shared pool memory requested that will force an allocation in the LARGE_POOL_SIZE memory. Unlike the shared pool, the large pool does not have an LRU list. Oracle does not attempt to age memory out of the large pool.

You can view your pool settings by querying the V$PARAMETER view:

```sql
SELECT name, value, isdefault, isshared modifiable, issys modifiable
FROM v$parameter
WHERE name like '%pool%'
AND isdeprecated <> 'TRUE'
ORDER BY 1;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>ISDEFAULT</th>
<th>ISSRS</th>
<th>ISSYS_MOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>java_pool_size</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>large_pool_size</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>olap_page_pool_size</td>
<td>0</td>
<td>TRUE</td>
<td>TRUE</td>
<td>DEFERRED</td>
</tr>
<tr>
<td>shared_pool_reserved_size</td>
<td>53687091</td>
<td>TRUE</td>
<td>FALSE</td>
<td>FALSE</td>
</tr>
<tr>
<td>shared_pool_size</td>
<td>1073741824</td>
<td>FALSE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>streams_pool_size</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
</tbody>
</table>

6 rows selected.
TIP

The additional buffer pools (memory for data) available in Oracle are initially set to zero. You should not need to set them initially, but you may need to for your unique system.

Tuning PGA_AGGREGATE_TARGET and PGA_AGGREGATE_LIMIT

The PGA_AGGREGATE_TARGET, now included as part of MEMORY_TARGET, specifies the total amount of session PGA memory that Oracle will attempt to allocate across all sessions. Oracle will allocate what it feels is appropriate based on MEMORY_TARGET, but you should set a minimum value based on what you’ve seen in prior versions. My Oracle Support Note 223730.1 describes Automatic PGA_AGGREGATE_TARGET Management quite well.

PGA_AGGREGATE_TARGET was introduced in Oracle9i and should be used in place of the *_SIZE parameters such as SORT_AREA_SIZE, although a local session may still want to set a local SORT_AREA_SIZE for some local short-term operation. Also, since Oracle9i, the PGA_AGGREGATE_TARGET parameter does not automatically configure ALL *_SIZE parameters. For example, both the LARGE_POOL_SIZE and JAVA_POOL_SIZE parameters are not affected by PGA_AGGREGATE_TARGET. The advantage of using PGA_AGGREGATE_TARGET is the ability to cap the total user session memory to minimize OS paging.

When PGA_AGGREGATE_TARGET is set, WORKAREA_SIZE_POLICY must be set to AUTO. Like the V$DB_CACHE_ADVICE view, the V$PGA_TARGET_ADVICE (Oracle 9.2 and later versions) and V$PGA_TARGET_ADVICE_HISTOGRAM views exist to assist in tuning the PGA_AGGREGATE_TARGET. Oracle Enterprise Manager provides graphical representations of these views.

The PGA_AGGREGATE_TARGET should be set to attempt to keep the ESTD_PGA_CACHE_HIT_PERCENTAGE greater than 95 percent. By setting this appropriately, more data will be sorted in memory that may have been sorted on disk.

The next query returns the minimum value for the PGA_AGGREGATE_TARGET that is projected to yield a 95 percent or greater cache hit ratio:

```sql
select min(pga_target_for_estimate)  
from v$pga_target_advice  
where estd_pga_cache_hit_percentage > 95;
```

```
MIN(PGA_TARGET_FOR_ESTIMATE)  
-----------------------------  
299892736
```

Since the PGA_AGGREGATE_TARGET would get too high in 11g, Oracle created an additional parameter. In 12c, there is a new 12c initialization parameter called PGA_AGGREGATE_LIMIT.
The PGA makes up part of the MEMORY_TARGET. Set the parameter as follows:

```sql
ALTER SYSTEM SET PGA_AGGREGATE_TARGET=1024M;
ALTER SYSTEM SET PGA_AGGREGATE_LIMIT=2048M;
```

**Modifying the Size of Your SGA to Avoid Paging and Swapping**

Before you increase the size of your SGA, you must understand the effects on the physical memory of your system. If you increase parameters that use more memory than what is available on your system, then serious performance degradation may occur. When your system processes jobs, if it doesn’t have enough memory, it starts paging or swapping to complete the active task.

When *paging* occurs, information that is *not currently* being used is moved from memory to disk. This allows memory to be used by a process that *currently* needs it. If paging happens a lot, the system will experience decreases in performance, causing processes to take longer to run.

When *swapping* occurs, an *active* process is moved from memory to disk temporarily so that another *active* process that also desires memory can run. Swapping is based on system cycle time. If swapping happens a lot, your system is dead. Depending on the amount of memory available, an SGA that is too large can cause swapping.

**Understanding the Oracle Optimizer**

The Oracle optimizer was built to make your tuning life easier by choosing better paths for your poorly written queries. Rule-based optimization (now obsolete and unsupported) was built on a set of rules for how Oracle processes statements. Oracle 10g Release 2 only supported the use of the cost-based optimizer; the rule-based optimizer was no longer supported. Since Oracle 10g Release 2, Oracle has automatic statistics gathering turned on to aid the effectiveness of the cost-based optimizer. In Oracle, many features are only available when using cost-based optimization. The cost-based optimizer now has two modes of operation: normal mode and tuning mode. Normal mode should be used in production and test environments; tuning mode can be used in development environments to aid developers and DBAs in testing specific SQL code.

**How Optimization Looks at the Data**

Rule-based optimization is *Oracle-centric*, whereas cost-based optimization is *data-centric*. The optimizer mode under which the database operates is set via the initialization parameter OPTIMIZER_MODE. The possible optimizer modes are as follows:

- **ALL_ROWS** Gets all rows faster (generally forces index suppression). This is good for untuned, high-volume batch systems. This is the default.
FIRST_ROWS Gets the first row faster (generally forces index use). This is good for untuned systems that process lots of single transactions.

FIRST_ROWS (1|10|100|1000) Gets the first \( n \) rows faster. This is good for applications that routinely display partial results to users such as paging data to a user in a web application.

CHOOSE Now obsolete and unsupported but still allowed. Uses cost-based optimization for all analyzed tables. This is a good mode for well-built and well-tuned systems (for advanced users). This option is not documented for 12cR2 but is still usable.

RULE Now obsolete and unsupported but still allowed. Always uses rule-based optimization. If you are still using this, you need to start using cost-based optimization, as rule-based optimization is no longer supported under Oracle 10g Release 2 and higher. This option is not documented for 12cR2 but is still usable.

The default optimizer mode for 12cR2 is ALL_ROWS. Also, cost-based optimization is used even if the tables are not analyzed. Although RULE/CHOOSE are definitely desupported and obsolete and people are often scolded for even talking about using rule-based optimization, I was able to set the mode to RULE in 12cR2. Consider the following error I received when I set OPTIMIZER_MODE to a mode that doesn’t exist (SUPER_FAST):

```
SQL> alter system set optimizer_mode=super_fast
ERROR: ORA-00996: invalid value SUPER_FAST for parameter optimizer_mode, must be from among first_rows_1000, first_rows_100, first_rows_10, first_rows_1, first_rows, all_rows, choose, rule
```

NOTE
The optimizer in Oracle 12c Release 2 uses cost-based optimization regardless of whether the tables have been analyzed or not.

TIP
In Oracle 12c Release 2, the main OPTIMIZER_MODEs to use are ALL_ROWS (the default) and FIRST_ROWS.

Creating Enough Dispatchers
When using Shared Server, some of the things you need to watch for are high busy rates for the
existing dispatcher processes and increases in wait times for response queues of existing dispatcher processes. If the wait time increases, as the application runs under normal use, you may wish to add more dispatcher processes, especially if the processes are busy more than 50 percent of the time.

Use the following statement to determine the busy rate:

```sql
select Network,
     ((Sum(Busy) / (Sum(Busy) + Sum(Idle)))) * 100 "% Busy Rate"
from V$Dispatcher
group by Network;
```

<table>
<thead>
<tr>
<th>NETWORK</th>
<th>% Busy Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP1</td>
<td>0</td>
</tr>
<tr>
<td>TCP2</td>
<td>0</td>
</tr>
</tbody>
</table>

Use the following statement to check for responses to user processes that are waiting in a queue to be sent to the user:

```sql
select Network Protocol,
     Decode (Sum(Totalq), 0, 'No Responses',
             Sum(Wait) / Sum(Totalq) || ' hundredths of a second')
     "Average Wait Time Per Response"
from V$Queue Q, V$Dispatcher D
where Q.Type = 'DISPATCHER'
and Q.Paddr = D.Paddr
group by Network;
```

<table>
<thead>
<tr>
<th>PROTOCOL</th>
<th>Average Wait Time Per Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP1</td>
<td>0 hundredths of a second</td>
</tr>
<tr>
<td>TCP2</td>
<td>1 hundredths of a second</td>
</tr>
</tbody>
</table>

Use the following statement to check the requests from user processes that are waiting in a queue to be sent to the user:

```sql
select Decode (Sum(Totalq), 0, 'Number of Requests',
              Sum(Wait) / Sum(Totalq) || ' hundredths of a second')
     "Average Wait Time Per Request"
from V$Queue
where Type = 'COMMON';
```

**Average Wait Time Per Request**

12 hundredths of a second
Have Enough Open Cursors (OPEN_CURSORS)

If you don’t have enough open cursors, then you will receive errors to that effect. The key is to stay ahead of your system by increasing the OPEN_CURSORS initialization parameter before you run out of open cursors.

Don’t Let Your DDL Statements Fail (DDL_LOCK_TIMEOUT)

DDL statements (CREATE/ALTER/DROP) require exclusive locks and thus sometimes fail due to bad timing when they conflict with other statements that lock the table. The parameter DDL_LOCK_TIMEOUT specifies the amount of time (in seconds) the DDL statement will wait for the lock before timing out and failing. The default value is 0; the max value is 100,000 (27.77 hours). The following example shows setting the value to 1 hour or 3600 seconds.

```sql
SQL> alter session set DDL_LOCK_TIMEOUT = 3600;
Session altered.
```

Two Important Exadata Initialization Parameters (Exadata Only)

Oracle has two very important parameters to use to test major features of Exadata. The first is CELL_OFFLOAD_PROCESSING, which relates to Smart Scans (cell scans). The default value is TRUE, which means that Smart Scans are turned on for Exadata (if you are using it). You can set this value to FALSE to turn off Smart Scans and check other features or compare speeds with and without this feature.

The second parameter is undocumented and should only be used with the consent of Oracle Support and also only for testing purposes. The second is _KCFIS_STORAGEIDX_DISABLED, which is used to disable storage indexes. This tells Oracle not to use storage index optimization on storage cells if set to TRUE. The default is FALSE. Another undocumented parameter (again check with Oracle Support) is also related to how the Smart Scan works and uses Bloom filters. The parameter _BLOOM_FILTER_ENABLED is set to TRUE by default. With Exadata, Bloom filters are used for join filtering with Smart Scans. _BLOOM_PRUNING_ENABLED also has a default of TRUE. Set these parameters to FALSE to disable them. See Chapter 11 for additional information.

Top 25 Initialization Parameters

The following list is my list of the top 25 most important initialization parameters, in order of importance. Your top 25 may vary somewhat from my top 25 because everyone has a unique business,
unique applications, and unique experiences.

1. **MEMORY_TARGET** This is the initialization parameter setting for all of the memory allocated to *both* the PGA and SGA combined (new in 11g). Setting MEMORY_TARGET enables Automatic Memory Management, so Oracle allocates memory for you based on system needs, but you can also set minimum values for key parameters. MEMORY_TARGET is used for everything that SGA_TARGET was used for but now additionally includes the PGA (especially important as MEMORY_TARGET now includes the important area PGA_AGGREGATE_TARGET). Important parameters such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, LARGE_POOL_SIZE, and JAVA_POOL_SIZE are all set automatically when you set MEMORY_TARGET. Setting minimum values for important initialization parameters in your system is also a very good idea.

2. **MEMORY_MAX_TARGET** This is the maximum memory allocated for Oracle and the maximum value to which MEMORY_TARGET can be set.

3. **DB_CACHE_SIZE** Initial memory allocated to data cache or memory used for data itself. This parameter doesn’t need to be set if you set MEMORY_TARGET or SGA_TARGET, but setting a value for this as a minimum setting is a good idea. Your goal should always be toward a memory-resident database or at least toward getting all data that will be queried in memory.

4. **SHARED_POOL_SIZE** Memory allocated for the data dictionary and for SQL and PL/SQL statements. The query itself is put in memory here. This parameter doesn’t need to be set if you set MEMORY_TARGET, but setting a value for this as a minimum is a good idea. Note that SAP recommends setting this to 400M. Also note that the Result Cache gets its memory from the shared pool and is set with the RESULT_CACHE_SIZE and RESULT_CACHE_MODE (FORCE/AUTO/MANUAL) initialization parameters. Lastly, an important note since 11g is that this parameter now includes some SGA overhead (12M worth) that it previously did not in version 10g. Set this 12M higher than you did in 10g!

5. **INMEMORY_SIZE** The In-Memory column store resides in this area, which is separate from the buffer cache used to store data in memory. Tables, tablespaces, partitions, and other objects can have single columns stored in this memory area in a compressed fashion. This allows for much faster analytics (like summing an individual column). Oracle builds indexes to make this even faster based on ranges of values. This is new in 12c.

6. **SGA_TARGET** If you use Oracle’s Automatic Shared Memory Management, this parameter is used to determine the size of your data cache, shared pool, large pool, and Java pool automatically (see Chapter 1 for more information). Setting this to 0 disables it. This parameter doesn’t need to be set if you set MEMORY_TARGET, but you may want to set a value for this as a minimum setting for the SGA if you’ve calibrated it in previous versions. The SHARED_POOL_SIZE, LARGE_POOL_SIZE, JAVA_POOL_SIZE, and DB_CACHE_SIZE are all set automatically based on this parameter (or MEMORY_TARGET if used). INMEMORY_SIZE is also included in this number.

7. **PGA_AGGREGATE_TARGET** and **PGA_AGGREGATE_LIMIT** The _TARGET is a soft memory cap for the total of all users’ PGAs. This parameter doesn’t need to be set if you set MEMORY_TARGET, but setting a value as a minimum setting is a good idea. Note that SAP
specifies to set this to 20 percent of available memory for OLTP and 40 percent for OLAP. The _LIMIT sets the upper limit that is allowed (the hard memory cap).

8. **SGA_MAX_SIZE** Maximum memory that SGA_TARGET can be set to. This parameter doesn’t need to be set if you set MEMORY_TARGET, but you may want to set a value if you use SGA_TARGET.

9. **OPTIMIZER_MODE** FIRST_ROWS, FIRST_ROWS_\(n\), or ALL_ROWS. Although RULE/CHOOSE are definitely desupported and obsolete and people are often scolded for even talking about using rule-based optimization, I was able to set the mode to RULE. Consider the following error I received when I set OPTIMIZER_MODE to a mode that doesn’t exist (SUPER_FAST):

```sql
SQL> alter system set optimizer_mode=super_fast
ERROR:
ORA-00096: invalid value SUPER_FAST for parameter optimizer_mode, must be from among first rows 1000, first row 100, first row 10, first row 1, first rows, all rows, choose, rule
```

10. **SEC_MAX_FAILED_LOGIN_ATTEMPTS** If the user fails to enter the correct password after this many tries (new as of 11g) the server process drops the connection and the server process is terminated. The default is 3 (consider increasing this value for less secure systems). A similar parameter in my top 25 list in the prior edition included **SEC_CASE_SENSITIVE_LOGON**, which was new as of 11g, but is deprecated as of 12.1. Be careful if you’re still using this parameter in 11g (fix case issues with passwords by ensuring passwords can be lower, upper, or mixed case before you upgrade to 12c!).

11. **CURSOR_SHARING** Converts literal SQL to SQL with bind variables, reducing parse overhead. The default is EXACT. Consider setting it to FORCE after research.

12. **OPTIMIZER_USE_INVISIBLE_INDEXES** The default is FALSE to ensure invisible indexes are not used by default (new in 11g). Set this parameter to TRUE to use all of the indexes and to check which ones might have been set incorrectly to be invisible; this could be a helpful tuning exercise, or it could also bring the system to halt, so only use it in development.

13. **OPTIMIZER_USE_PENDING_STATISTICS** The default is FALSE to ensure pending statistics are not used, whereas setting this to TRUE enables all pending statistics to be used (new in 11g).

14. **OPTIMIZER_INDEX_COST_ADJ** Coarse adjustment between the cost of an index scan and the cost of a full table scan. Set between 1 and 10 to force index use more frequently. Setting this parameter to a value between 1 and 10 pretty much guarantees index use, however, even when not appropriate, so be careful because it is highly dependent on the index design and implementation being correct. Please note that if you are using Applications 11i, setting OPTIMIZER_INDEX_COST_ADJ to any value other than the default (100) is not supported (see My Oracle Support Note 169935.1). I’ve seen a benchmark where this was set to 200. Also, see bug 4483286. SAP suggests that you not set it for OLAP, but set it to 20 for OLTP.

15. **DB_FILE_MULTIBLOCK_READ_COUNT** For full table scans to perform I/O more efficiently, this parameter reads the given number of blocks in a single I/O. The default value is 12812cR2, but it is usually noted not to change this from the default.

16. **LOG_BUFFER** Server processes making changes to data blocks in the buffer cache generate
redo data into the log buffer. SAP says to use the default, whereas Oracle Applications sets it to 10M. I’ve seen benchmarks with it set over 100M.

17. **DB_KEEP_CACHE_SIZE** Memory allocated to the keep pool or an additional data cache that you can set up outside the buffer cache for very important data that you don’t want pushed out of the cache.

18. **DB_RECYCLE_CACHE_SIZE** Memory allocated to a recycle pool or an additional data cache that you can set up outside the buffer cache and in addition to the keep pool described in item 17. Usually, DBAs set this up for ad hoc user query data with poorly written queries.

19. **OPTIMIZER_USE_SQL_PLAN_BASELINES** The default is TRUE, which means Oracle uses these baselines if they exist (new in 11g). Note that Stored Outlines are deprecated (discouraged but they still work) in 11g, as they are replaced with SQL Plan Baselines.

20. **OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES** The default is FALSE, which means that Oracle does not capture them by default, but if you create some, it will use them as stated in the previous parameter (new in 11g).

21. **LARGE_POOL_SIZE** Total bytes in the large pool allocation for large PL/SQL and a few other Oracle options less frequently used.

22. **STATISTICS_LEVEL** Used to enable advisory information and optionally keep additional OS statistics to refine optimizer decisions. TYPICAL is the default.

23. **JAVA_POOL_SIZE** Memory allocated to the JVM for Java stored procedures.

24. **JAVA_MAX_SESSIONSPACE_SIZE** Upper limit on memory that is used to keep track of the user session state of Java classes.

25. **OPEN_CURSORS** Specifies the size of the private area used to hold (open) user statements. If you get an “ORA-01000: maximum open cursors exceeded,” you may need to increase this parameter, but make sure you are closing cursors that you no longer need. Prior to 9.2.0.5, these open cursors were also cached and, at times, caused issues (ORA-4031) if OPEN_CURSORS was set too high. As of 9.2.0.5, SESSION_CACHED_CURSORS now controls the setting of the PL/SQL cursor cache. Do not set the parameter SESSION_CACHED_CURSORS as high as you set OPEN_CURSORS, or you may experience ORA-4031 or ORA-7445 errors. SAP recommends setting this to 2000; Oracle Applications has OPEN_CURSORS at 600 and SESSION_CACHED_CURSORS at 500.

**TIP**

Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.

**Initialization Parameters over the Years**
Oracle has moved from a time when there were over four times as many documented parameters as undocumented in Oracle 6, to the undocumented parameters exceeding the documented in Oracle 8i, to four times as many undocumented as documented parameters in Oracle 10g, to six times more in 11g. In 12c, the increase is less on documented, but substantially more on the undocumented side. Clearly, Oracle has migrated to a place where experts have more dials to set in 12c (undocumented), but the number of dials to set for the standard database setup (documented parameters) is not increasing as much and is becoming standardized. The following table charts the changing numbers of documented and undocumented parameters:

<table>
<thead>
<tr>
<th>Version</th>
<th>Documented</th>
<th>Undocumented</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>111</td>
<td>19</td>
<td>130</td>
</tr>
<tr>
<td>7</td>
<td>117</td>
<td>68</td>
<td>185 (+42% vs. V6)</td>
</tr>
<tr>
<td>8.0</td>
<td>193</td>
<td>119</td>
<td>312</td>
</tr>
<tr>
<td>8.1</td>
<td>203</td>
<td>301</td>
<td>504 (+62% vs. V7)</td>
</tr>
<tr>
<td>9.0</td>
<td>251</td>
<td>436</td>
<td>687</td>
</tr>
<tr>
<td>9.2</td>
<td>257</td>
<td>540</td>
<td>797 (+58% vs. 8i)</td>
</tr>
<tr>
<td>10.2</td>
<td>257 (+0%)</td>
<td>1124 (+108%)</td>
<td>1381 (+73% vs. 9i)</td>
</tr>
<tr>
<td>11.2</td>
<td>341 (+33%)</td>
<td>2053 (+83%)</td>
<td>2394 (+73% vs. 10g)</td>
</tr>
<tr>
<td>12.2</td>
<td>412 (+21%)</td>
<td>4237 (+106%)</td>
<td>4649 (+94% vs. 11g)</td>
</tr>
</tbody>
</table>

Finding Undocumented Initialization Parameters

Querying the table X$KSPPI shows you documented as well as undocumented initialization parameters. The query may only be done as user SYS, so be careful. See Chapter 13 for a complete look at the X$ tables. My top 13 undocumented initialization parameters are listed in Appendix A. Appendix C gives a complete listing as of the writing of this book of the X$ tables.
The following is a brief description of the columns in the X$KSPPPI and X$KSPPCV tables:

- **KSPPINM** Parameter name
- **KSPPSTVL** Current value for the parameter
- **KSPPSTDF** Default value for the parameter

A partial output listing of the initialization parameters is shown here:

<table>
<thead>
<tr>
<th>KSPPINM</th>
<th>KSPPSTVL</th>
<th>KSPPSTDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>write_connection</td>
<td>3</td>
<td>TRUE</td>
</tr>
<tr>
<td>_yield_check_interval</td>
<td>1000000</td>
<td>TRUE</td>
</tr>
<tr>
<td>active_instance_count</td>
<td>1</td>
<td>TRUE</td>
</tr>
<tr>
<td>ag_tn_processes</td>
<td>1</td>
<td>FALSE</td>
</tr>
<tr>
<td>archive_lag_target</td>
<td>0</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

**TIP**

*Using undocumented initialization parameters can cause corruption. Never use these if you are not an expert and you are not directed by Oracle Support!* Ensure that you work with Oracle Support before setting these parameters.

**Understanding the Typical Server**

There’s nothing typical about most unique systems. The key to understanding Oracle is to understand its dynamic nature. Oracle continues to have many attributes of previous versions while also leading the way by implementing the future of distributed database and object-oriented programming. Experience from earlier versions of Oracle always benefits the DBA in future versions of Oracle. Here are some of the future changes to consider as you build your system:

- With pluggable databases (PDBs) and the public cloud, Oracle can be consolidated and maintained at a single point. (Many databases with fewer DBAs managing the system looks like the corporate future.)
- Database maintenance is becoming more visual (all point-and-click maintenance as in Enterprise Manager). The V$ views are still your lowest-performance-cost access method, but Enterprise Manager is easier to use for more complex inquiries that may require multiple V$ views to get the same result.
- Hardware and CPUs continue to get faster, eliminating the CPU as a bottleneck. (I/O
Object-oriented and Agile development is crucial to rapid system development.

Graphics, big data, and image storage is leading to databases that are soon to become increasingly larger. Also, the fact that disk space and flash are getting less expensive has made businesses more willing to keep historical data.

While Oracle has excelled in the software market, no hardware maker has kept up over the past decade. With the advent of Exadata, Oracle is getting us to exabyte databases faster than anticipated.

### Modeling a Typical Server

This section contains very rough estimates designed as setup guidelines. However, it is important to emphasize that these are only guidelines and that the reality is that every system is different and must be tuned to meet that system’s demands. (CPU speed depends on the type of processor, e.g., RISC or SPARC vs. Intel.) The following table does not include guidelines for Oracle Applications. Oracle Applications tends to have unique issues that are addressed by Oracle in the application documentation and on My Oracle Support.

<table>
<thead>
<tr>
<th>Database Size</th>
<th>Up to 25G</th>
<th>100–200G</th>
<th>500–3000G</th>
<th>10T–100T*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of users</td>
<td>100</td>
<td>200</td>
<td>500–2000</td>
<td>5000–20,000</td>
</tr>
<tr>
<td>Number of CPU cores</td>
<td>4–8</td>
<td>8–16</td>
<td>16–64+</td>
<td>128–360</td>
</tr>
<tr>
<td>System memory</td>
<td>8G</td>
<td>16G</td>
<td>32–512G+</td>
<td>2T</td>
</tr>
<tr>
<td>SGA_MAX_SIZE*</td>
<td>2G</td>
<td>4G</td>
<td>8G–200G</td>
<td>500–700G</td>
</tr>
<tr>
<td>PGA_AGGREGATE_LIMIT*</td>
<td>512M</td>
<td>1G</td>
<td>2G–50G</td>
<td>50–100G</td>
</tr>
<tr>
<td>INMEMORY_SIZE</td>
<td>1G</td>
<td>2G</td>
<td>4G–50G</td>
<td>50–200G</td>
</tr>
<tr>
<td>Total disk capacity</td>
<td>100G</td>
<td>500–1000G</td>
<td>1–3T</td>
<td>100T</td>
</tr>
<tr>
<td>Percentage of query</td>
<td>75 percent</td>
<td>75 percent</td>
<td>75 percent</td>
<td>90 percent</td>
</tr>
<tr>
<td>Percentage of DML</td>
<td>25 percent</td>
<td>25 percent</td>
<td>25 percent</td>
<td>10 percent</td>
</tr>
<tr>
<td>Number of redo logs</td>
<td>4–8</td>
<td>6–10</td>
<td>6–12</td>
<td>2–12</td>
</tr>
<tr>
<td>multiplexed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The following variables can be reason to deviate from the typical server configuration:

- Heavy DML processing may require much larger ROLLBACK/UNDO, REDO, and TEMP tablespace sizes. Exadata best practice is a 32G logfile; you don’t need as many at this size!
- Poorly tuned systems require more CPU and memory.
- A greater number of disks, cache on disks, and controllers always increase performance by reducing I/O contention.
- An increase in the disk capacity can speed backup and recovery time by going to disk and not tape. Faster tape speeds lower backup and recovery times as well. Oracle’s purchase of Sun also netted them StorageTek.
- Using all flash changes everything. Leading-edge companies often have all flash!

---

Sizing the Oracle Applications Database

The Oracle Applications Development team wrote a note on My Oracle Support (Note 216205.1 for 11i and 396009.1 for Release 12) that shows the initialization parameters that should be used (or not used) with various versions of Oracle Applications. I always review the settings that the Oracle Applications Development team recommends, as they often are dealing with large systems and they’ve learned some nice tricks. The common database parameters suggested are listed in Appendix A and version-specific parameters follow that listing (note that many comments were removed for brevity; see the actual My Oracle Support note for full detail). For a given Oracle E-Business Suite (EBS) instance, always make sure that the init.ora parameters are set according to the My Oracle Support note.
Support document “Database Initialization Parameters for Oracle E-Business Suite Release 12” (Doc ID 396009.1). An EBS database instance has to adhere to these recommendations since they went through rigorous testing inside Oracle Labs’ systems simulating various EBS data patterns/modules... etc. Of course, Oracle wrote the code for EBS and developed it, so they know better than anybody else how the application code would behave at certain points in time. The following table gives an example of how to size the memory of an EBS database.

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Development or Test Instance</th>
<th>11–100 Users</th>
<th>101–500 Users</th>
<th>501–1000 Users</th>
<th>1001–2000 Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes</td>
<td>200</td>
<td>200</td>
<td>800</td>
<td>1200</td>
<td>2500</td>
</tr>
<tr>
<td>Sessions</td>
<td>400</td>
<td>400</td>
<td>1600</td>
<td>2400</td>
<td>5000</td>
</tr>
<tr>
<td>SGA_TARGET</td>
<td>1G</td>
<td>1G</td>
<td>2G</td>
<td>3G</td>
<td>14G</td>
</tr>
<tr>
<td>SHARED_POOL_SIZE (csp)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1800M</td>
<td>3000M</td>
</tr>
<tr>
<td>SHARED_POOL_RESERVE_SIZE (csp)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>180M</td>
<td>300M</td>
</tr>
<tr>
<td>SHARED_POOL_SIZE (no csp)</td>
<td>400M</td>
<td>600M</td>
<td>800M</td>
<td>1000M</td>
<td>2000M</td>
</tr>
<tr>
<td>SHARED_POOL_RESERVE_SIZE (no csp)</td>
<td>40M</td>
<td>60M</td>
<td>80M</td>
<td>100M</td>
<td>100M</td>
</tr>
<tr>
<td>PGA_AGGREGATE_TARGET</td>
<td>1G</td>
<td>2G</td>
<td>4G</td>
<td>10G</td>
<td>20G</td>
</tr>
<tr>
<td>Total Memory Required</td>
<td>~2 G</td>
<td>~3 G</td>
<td>~6 G</td>
<td>~13 G</td>
<td>~34 G</td>
</tr>
</tbody>
</table>

The range of user counts provided in the table refers to active Oracle Applications users, not total or named users. For example, if you plan to support a maximum of 500 active Oracle Applications users, then you should use the sizing per the range 101–500 users. The parameter values provided in this document reflect a development/test instance configuration, and you should adjust the relevant parameters according to the Applications user counts (refer to the table).

On the other hand, EBS does allow all sorts of customizations to use the underlying Database features. So, any number of partitioning can be done for huge tables for a better performance with the approval of Oracle Support. The only caveat with having many customizations is to keep a tab on them for maintenance, patching, and future upgrades.

Let’s assume that as part of the problem identification process, we have determined that the Auto Invoice Import concurrent program is running slower than normal. We have also eliminated user login issues (people are able to successfully log in to the EBS home page from multiple sites) and have verified other concurrent programs are finishing on time. That narrowed down the problem to a single concurrent request. By having the concurrent request ID, we can tie that to a specific database session...
ID (SID) and serial number by running the following query (or by using any of the traditional methods like OEM, AWR, ASH reports, V$ views, etc.):

```
Set linesize 150
Set Pages 1000
Set head on
```
Column Manager Format A10
Column Request Format 999999
Column Program Format A40
Column User_Name Format A10
Column Started Format A18
Column Status Format A6
Column Phase Format A6

Prompt
prompt Request Information
prompt ----------------------
prompt ;

Select /*+ RULE */
    --Concurrent_Queue_Name Manager,
Request_Id Request, User_Name,
    --, Run_A lone_Flag,
Substr(User.Concurrent.Program.Name,1,40) Program,
    To_Char(Actual_Start_Date,'DD-MON-YY HH24:MI:SS') Started
    ,Decode(Fcr.Status_Code,'R','Normal',Fcr.Status_Code) Status
    ,Decode(Fcr.Phase_Code,'R','Normal',Fcr.Phase_Code) Phase
from Fnd_Concurrent_Queue Fcq, Fnd_Concurrent_Requests Fcr,
    Fnd_Concurrent_Programs Fcp, Fnd_User Fu, Fnd_Concurrent_Processes Fpro
where
    Phase_Code = 'R' And
    Fcr.Controlling_Manager = Fcp.Concurrent_Process_Id
    And
    (Fcq.Concurrent_Queue_Id = Fpro.Concurrent_Queue_Id
    And
    Fcq.Application_Id = Fpro.Concurrent_Process_Id)
    And
    (Fcr.Concurrent_Program_Id = Fcp.Concurrent_Program_Id
    And
    Fcr.Program_Application_Id = Fcp.Application_Id)
    And
    Fcr.RequestedBy = User_Id
    And
    Fcr.Request_Id = '&&Request_Id'
;

Column Full_Name Format A40
Prompt
Prompt Full name of the User running the program
Prompt -------------------------------
Prompt

Select /*+ RULE */
    Substr(Emp.Full_name,1,50) Full_Name
from Fnd_User Fu, Hr_Employees Emp
where Fu.Employee_Id = Emp.Employee_Id (+)
    and Fu.user_id =
        ( select requested_by
            from Fnd_concurrent_Requests
            where request_id = '&&Request_Id' )
;
prompt
prompt Oracle (v$session) information for this request ;
Prompt --------------------------------------------------
prompt ;
select a.sid Sid, a.serial# SerialNo, substr(a.username,1,10) UserName,
       substr(a.program,1,30) Program,
       substr(a.osuser,1,10) OSUser, b.pidOSProcess, a.status Status, a.type Type,
b.background Background,
to_char(a.logon_time,'DD-MON-YY HH24:MI:SS') LogonTime
from v$session a, v$process b
where a.paddr = b.addr and
b.spid = (select ORACLE_PROCESS_ID
from find_concurrent_requests
where request_id = '&&Request_id')
;

Prompt
Prompt Oracle Process Id and Application Process Id for this given request
Prompt -------------------------------------------------------------

Prompt

Column ORACLE_PROCESS_ID Format A30
Column APPLICATION_PROCESS_ID Format A30
select substr(ORACLE_PROCESS_ID,1,30) ORACLE_PROCESS_ID, substr(OS_PROCESS_ID,1,30) APPLICATION_PROCESS_ID
from find_concurrent_requests
where request_id = '&&Request_id'
;

prompt
prompt Oracle SQL run by this request currently is ;
Prompt --------------------------------------------
prompt ;
select a.sql_text
from v$sql_text_with_newlines a, v$session b
where a.address = b.sql_address and
a.hash_value = b.sql_hash_value and
b.sid = (select a.sid
from v$session a
where a.paddr = b.addr and
b.spid = (select ORACLE_PROCESS_ID
from find_concurrent_requests
where request_id = '&&Request_id'))
;

prompt
prompt Oracle SQL run by other requests currently is ;
Prompt ---------------------------------------------
prompt ;
select a.sql_text
from v$sql_text_with_newlines a, v$session b
where a.address = b.sql_address and
a.hash_value = b.sql_hash_value and
b.spid = (select spid
from find_concurrent_requests
where request_id = '&&Request_id')
;

prompt
prompt Application Process Id and Oracle Process Id for this given request
Prompt ---------------------------------------------------------------

Prompt

Column APPLICATION_PROCESS_ID Format A30
Column ORACLE_PROCESS_ID Format A30
select substr(APPLICATION_PROCESS_ID,1,30) APPLICATION_PROCESS_ID, substr(ORACLE_PROCESS_ID,1,30) ORACLE_PROCESS_ID
from find_concurrent_requests
where request_id = '&&Request_id'
;

prompt
prompt Application SQL run by this request currently is ;
Prompt -----------------------------------------------
prompt ;
select a.sql_text
from v$sql_text_with_newlines a, v$session b
where a.address = b.sql_address and
a.hash_value = b.sql_hash_value and
b.spid = (select spid
from find_concurrent_requests
where request_id = '&&Request_id')
;

prompt
prompt Application SQL run by other requests currently is ;
Prompt ---------------------------------------------
prompt ;
select a.sql_text
from v$sql_text_with_newlines a, v$session b
where a.address = b.sql_address and
a.hash_value = b.sql_hash_value and
b.spid = (select spid
from find_concurrent_requests
where request_id = '&&Request_id')
;
Once a specific database session is identified, we can drill down further by collecting a runtime \texttt{EXPLAIN PLAN} and looking at various wait events that are associated with a particular SQL query that’s being executed in the database. We can also run the SQLT tracing/diagnostic tools as described in the My Oracle Support Note “All About the SQLT Diagnostic Tool” (Doc ID 215187.1). After identifying and looking at the SQL Plans and and the raw tkprof/trace files, we can go through all the tables/indexes that are in question and verify when the database statistics were last collected for these tables/indexes that are involved in the query. For all the seeded queries, do a general search on the short name of the program at the MOS website. You might be running into an already known issue and there could be a performance fix patch available. If not, open up a service request (SR) with Oracle Support asking for a code fix. In most cases, Oracle Support will have you collect most of the diagnostic data discussed here and upload the raw tkprof/trace files to the SR.

For custom DML statements/complex select queries, EBS does allow you to create custom indexes, histograms, etc. We can also use the SQL Performance Analyzer or SQL Plan Management features to make certain we have good plans as “Accepted” and “Fixed” plans, so that the optimizer will always choose those plans irrespective of what the optimizer engine says about the current data, as long as there were no DDL changes in the underlying objects of a query. This can be done using Oracle Enterprise Manager (OEM) or SQL*Plus commands. Please refer to the SQL Plan Management chapter (Chapter 8) in this book for more detailed information.

For more generic, database-wide slow response times, we can make use of all of the tips and techniques discussed in the other chapters of this book and troubleshoot further. For example, running the AWR report during a problem window, running an ASH report, or running an ADDM report for a specific problem window will all help narrow down the problem. Please refer to Chapter 14 for further information on AWR, ASH, ADDM, and OEM monitoring.

At a high level, make sure that the Gather Schema Stats concurrent program is scheduled to run at a frequent interval. Schedule this program to run once a week for all the schemas with a 20 percent or 30 percent estimate, and leave all the other parameters to their defaults for stable performance in the database. Module-specific or tables/indexes-specific versions of this program can be run depending on the need and just after any major custom concurrent program, data load programs, or DML statements that might skew the data pattern in the database.

Run daily reports to find the object lists based on the \texttt{last_modified} time stamp and created columns from DBA_OBJECTS for the last 24 hours. The idea is to identify any objects at the database level that were created/modified and are being accounted/reconciled against the internal change request system. Often, unaccounted, unapproved, and untested code changes prove to harm the stability of the production systems. Run a daily report to identify the list of users and responsibilities for which the debug/trace profile options are turned on. Turn them off if they are no longer needed. Ideally, the production environment should not have any trace or debugs enabled unless a specific issue is being worked on. Unnecessary trace/debugs would put pressure and overhead on the database.
Look for orphaned M$LOG tables with a large number of rows in the database. If the volume keeps growing over a period of time, then it is an indication of an orphaned materialized view (MV). Materialized views are based on a trigger logic and, depending on the complete or full refresh and the way in which the MVs are maintained (or not maintained), the M$LOG table would tend to grow. In a normal scenario during a complete or fast refresh or at the end of the refresh, the underlying M$LOG table would get deleted in the source for the already updated rows in the target. When this process is broken, the trigger on the source table is on and it will make the M$LOG grow exponentially, using large amounts of database low-level resources such as enqueues and latches. This could put enormous overhead on the database and eventually on the applications. Additional Oracle Applications notes are at the end of Appendix A.

**Tips Review**

- The key initialization parameters in Oracle are MEMORY_TARGET, MEMORY_MAX_TARGET, SGA_TARGET, SGA_MAX_SIZE, PGA_AGGREGATE_TARGET, PGA_AGGREGATE_LIMIT, DB_CACHE_SIZE, SHARED_POOL_SIZE, and INMEMORY_SIZE. If you use ASMM, then SGA_TARGET is also a key initialization parameter.

- Setting INMEMORY_SIZE can lead to unbelievably fast analytics, but only set this parameter when properly licensed for this option. Active Data Guard can also use the In-Memory column store, and there are also In-Memory virtual columns allowed.

- If you use the ALTER SYSTEM commands to write to the SPFILE only, and then on startup realize you have set them incorrectly, the database will not start, and you cannot use an ALTER SYSTEM command to fix the problem. You can, however, create a PFILE from the SPFILE, modify the PFILE, and then use that to start the database. Afterward you need to create the SPFILE again and restart the database with the SPFILE.

- If you can’t figure out why your system isn’t using the value in your init.ora file, you probably have an SPFILE overriding it. And don’t forget, you can also use a hint to override parameters at the query level in 12c. Different PDBs (pluggable databases) can have some parameters set at the PDB level.

- Changing initialization parameters dynamically is a powerful feature for both developers and DBAs. Consequently, a user with the ALTER SESSION privilege is capable of irresponsibly allocating 100M+ for the SORT_AREA_SIZE for a given session, if it is not restricted.

- Retrieving data from physical memory is generally substantially faster than retrieving it from disk, so make sure the SGA and PGA are large enough. One Oracle study showed Oracle memory access as averaging about 100 times faster than disk access. However, this takes into account disk-caching advances and flash, which you may or may not have on your system. The same study also showed an individual case where Oracle memory access was well over 10,000 times faster than disk (which was hard for me to believe), but it shows how important it is to measure this on your own unique system.
Poor joins and poor indexing also yield very high hit ratios, so make sure your hit ratio isn’t high for a reason other than a well-tuned system. An unusually high hit ratio may indicate the introduction of code that is poorly indexed or includes join issues.

Hit ratios are useful to experienced DBAs but can be misleading or of little use to inexperienced DBAs. The best use of hit ratios is still to compare them over time (a barometer) to help alert you to a substantial change to a system on a given day. While some people have deprecated hit ratios from their tuning arsenal, they are usually tool vendors who don’t see the value of tracking hit ratios over time because their tools are point-in-time or reactive-based tuning solutions. Hit ratios should never be your only tool, but they should definitely be one of many proactive tools in your arsenal (especially with the advent of the invisible index).

In Oracle 12c Release 2, use Enterprise Manager Cloud Control to find problem queries.

A low hit ratio for a query could be an indication of a missing, invisible, or suppressed index.

Bad (slow) queries show in V$SQLAREA or V$SESSION_LONGOPS (under certain conditions) views with poor hit ratios the first time they are executed. You can also use Enterprise Manager to see statistical information. Make sure you tune them at that time. The second time that they execute, they may not show a poor hit ratio (may be in memory). Flushing the buffer cache for testing can help you get accurate results.

The database must be rebuilt if you change the DB_BLOCK_SIZE. Increasing the DB_FILE_MULTIBLOCK_READ_COUNT allows more block reads in a single I/O, giving a benefit similar to a larger block size. In 12c, the default is 128, so it may not need to be changed.

The SGA_MAX_SIZE determines the granule size for other parameters. An SGA_MAX_SIZE < 1G means a 4M granule size, whereas an SGA_MAX_SIZE >= 256G means a 512M granule size. Some benchmarks have the granule size as high as 256M.

SQL must be written exactly the same to be reused. Case differences and any other differences will cause a reparse of the statement unless you use CURSOR_SHARING.

Measure hit ratios for the row cache (data dictionary cache) of the shared pool with the V$ROWCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios will be around 85 percent.

Measure hit ratios for the library cache of the shared pool with the V$LIBRARYCACHE view. A hit ratio of greater than 95 percent should be achieved. However, when the database is initially started, hit ratios are around 85 percent.

The V$SGASTAT view shows how fast the memory in the shared pool is being depleted. Remember that it is only a rough estimate. It shows you any memory that has never been used combined with any piece of memory that has been reused. Free memory will go up and down as the day goes on, depending on how the pieces are fragmented.

The general rule of thumb (exact sizing depends on your unique systems) is to make the SHARED_POOL_SIZE parameter 50–150+ percent of the size of your DB_CACHE_SIZE. In a system that makes use of a large amount of stored procedures or Oracle supplied packages,
but has limited physical memory, this parameter could make up as much as 150+ percent of the size of `DB_CACHE_SIZE`. In a system that uses no stored procedures, but has a large amount of physical memory to allocate to `DB_CACHE_SIZE`, this parameter may be 10–20 percent of the size of `DB_CACHE_SIZE`. I have worked on larger systems where the `DB_CACHE_SIZE` was set as high as 10s of Gigs. I’m sure that 100s of Gigs to Terabyte SGAs already exist. Petabyte databases are currently starting to make their entry. Note that in a shared server configuration (previously known as MTS), items from the PGA are allocated from the shared pool rather than the session process space.

- The additional buffer pools (memory for data) available in Oracle are initially set to zero. You should not need to set them initially, but you may need to for your unique system.
- The optimizer in Oracle 12c Release 2 uses cost-based optimization regardless of whether the tables have been analyzed or not. `CHOOSE` and `RULE` are obsolete and unsupported settings for `OPTIMIZER_MODE`, yet they are still allowed; `ALL_ROWS` is the default.
- There is no `OPTIMIZER_MODE` called `COST` (a misconception). If you are using Oracle Database 9i Release 2 or an earlier version and are not sure what optimizer mode to use, then use `CHOOSE` or `FIRST_ROWS` and analyze all tables. As the data in a table changes, tables need to be reanalyzed at regular intervals. In Oracle 12c Release 2, the main `OPTIMIZER_MODEs` to use are `ALL_ROWS` and `FIRST_ROWS` (`ALL_ROWS` is the default).
- Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.
- Using undocumented initialization parameters can cause corruption. Never use these if you are not an expert and you are not directed by Oracle Support! Ensure that you work with Oracle Support before setting these parameters.

**References**


*Oracle Installation Guide* (Oracle Corporation).

Oracle My Oracle Support Notes: 216205.1, 396009.1, 295626.1, 443746.1, 223730.1.

*Performance Tuning Guide* (Oracle Corporation).

Craig Shallahamer, “All About Oracle’s Touch-Count Data Block Buffer Algorithm” (OraPub, excellent!).


Thanks to Mike Messina, who did the primary update for the chapter to 12c, and Palani Kasi, who provided the Oracle Applications section update at the end. Thanks to Randy Swanson, who did the update for this chapter in the 9i version of the book (where were you this time around?). Thanks to Lucas Niemiec for finding the scripts that show Oracle’s installation settings. Thanks to Binu Joy, who provided some great installation notes and SAP parameters for this chapter and Appendix A.
Oracle Enterprise Manager Cloud Control finally matches or exceeds the market’s answer to monitoring and tuning the Oracle database. Oracle has usually been behind the market with okay-to-good products over the years. No longer is this the case; Oracle has stepped up to the plate and delivered one of the best products ever (including support for Exadata and the cloud). This chapter provides a quick tour of why Oracle Enterprise Manager Cloud Control (called both OEM or EM) is now at the next level. The tour neither explores the entire product nor teaches you how to use all of the features (that would take an entire book). Rather, this chapter exposes you to some of the tools and tuning features that you will find helpful in your tuning endeavors. With Oracle’s focus on the grid since Oracle 10g and continuing into 11g, many screenshots show multiple instances so you can see either a single-instance or multi-instance cluster with the product. The grid of servers can now be in the cloud or on-premises and also can be RAC or non-RAC (especially with 12c sharding). With multitenant databases in 12c, OEM also shows all pluggable databases (PDBs) with drill-down screens. OEM is an excellent tuning tool for all levels of DBAs and is especially valuable as you head into the growing decade of the cloud.

One way to ensure great performance for your system is to monitor your system for potential performance issues before they become major problems. One vehicle that provides a graphical user interface (GUI) for tuning is OEM, along with related performance-tuning add-on products (which are an added cost). The OEM product suite continues to change over time, but this particular version has taken a giant leap forward with its support for both on-premises and cloud databases. With the statistics from the Automatic Workload Repository (AWR), this tool is now tremendously powerful. AWR snapshots are taken every hour by default, and once the AWR snapshot is taken, the Automatic Database Diagnostic Monitor (ADDM) analysis occurs immediately (STATISTICS_LEVEL must be set to TYPICAL or ALL) via the MMON background process. The results of ADDM are also stored in the AWR and accessible via OEM. All of these streamline managing both on-premises and cloud databases.

In addition to monitoring, spectacular screens will show you where a problem is occurring, down to the “latch wait” or “global cache cr transfer wait.” The tools for running the AWR Report (covered in detail in Chapter 14) are included, as are tools to change the spfile.ora or init.ora file. The tools for monitoring a group of servers are equally spectacular (yes, they are that good). Screens showing performance on every instance and piece of hardware (each in a different color) allow you to click the graph to branch to an individual instance or look at a particular piece of hardware. You
can delve into performance at the database, host, application server, network, or disk (ASM or non-ASM) level. Of all the Oracle products I have seen hit a home run over time, this one hit a grand slam with the Oracle OEM Cloud Control release.

Oracle Enterprise Manager standard applications include a central management console and additional packs, and many products (like Diagnostics Pack) have an additional cost (please check with Oracle for any price implications for different modules/packs). Accessing the AWR requires the Diagnostics Pack, and running SQL Tuning Sets requires the Tuning Pack. You can use ADDM to see what Oracle advises after an hour of gathering statistics to AWR. You can use the SQL Tuning Advisor for tuning a specific SQL statement or set of statements (you can also run this from the Top Activity screen). Use the SQL Performance Analyzer to tune statements in a Guided Workflow, which shows the before and after tuning results for a set of SQL statements. You can compare an Oracle version’s effect on SQL statements; for instance, you can compare a tuning set from one version to another, and you can even look at the before and after comparison of initialization parameter changes. Finally, you can even perform an Exadata simulation and run an AWR Report or Active Session History (ASH, or mini-AWR) report from OEM.

The following tips are covered in this chapter:

- Enterprise Manager basics and accessing OEM via Oracle Cloud Services
- Monitoring policies and alerts
- Monitoring the database
- Evaluating potential changes with SQL Performance Analyzer
- Tuning the Oracle database using OEM’s ADDM
- Monitoring and tuning via the OEM menus
- Viewing the Oracle topology
- Monitoring and tuning the hosts
- Monitoring and tuning application servers and web applications (using APM)
- Viewing and scheduling jobs
- Accessing available reports, including the ASH and AWR Reports
- Real Application Testing (Database Replay)

**Oracle Enterprise Manager Basics and Accessing OEM via Oracle Cloud**

Once OEM is installed, the login screen (shown in Figure 5-1) is displayed. Depending on how security is set up, you may need to enter the username, password, or database information at login screens, depending on which screens are accessed within the product. Once installed, you can log in, but if you don’t, you will need the remember this URL (I suggest bookmarking this URL).
Shortly after logging in to OEM, you will be in the main screen showing enterprise-level architecture and actions. Figure 5-2 shows the Enterprise tab with options for monitoring, reporting, configuring, as well as provisioning and patching. The Inventory and Usage information on the right side of the screen shows different servers in the architecture. With this version of OEM, you can monitor systems that are both on-premises and in the cloud. Shortly, we’ll go into the Enterprise Summary choice on the Enterprise menu to do some performance tuning on some of the databases there, but first let’s look at some of the basics included in the product.

If you set up the cloud separately, you can either use the main version of OEM to monitor the cloud
service directly, or you can use a cloud-only OEM Express version that comes with the cloud service. Figure 5-3 shows the menu from which to access the 12c OEM Console from a cloud service (rolta1 in this example) and gives a feel for how the OEM Express screen looks. Oracle Cloud My Services has a pull-down list from your cloud service that allows you to open the OEM Express console. All of the OEM screens in the cloud are the same or similar to those on-premises (although OEM Express is a cloud-only lighter version). The rest of the examples in the chapter will show the OEM screens from on-premises (see Chapter 11 for more on the Oracle Cloud).

![Oracle Cloud My Services pull-down menu to open the OEM Express Console](image)

As shown in Figure 5-2, some of the available setup options on the Enterprise menu include Monitoring, Configuration, Provisioning and Patching, and access to various tools and other configuration items. For example, if you choose Enterprise | Monitoring | Blackouts, you’ll see the screen shown in Figure 5-4. Blackouts are periods of time that allow the system to suspend monitoring for the performance of maintenance activities. This eliminates the skewing of the data during normal operating hours. Even though statistics gathering is suspended, the period is still recorded to ensure too many blackouts aren’t scheduled by a DBA.
After familiarizing themselves with OEM, DBAs should set up the preferences that are deemed best for the environment being monitored. At any time while using the product, you can click Setup (the setup options tab is located at the upper-right hand of the Figure 5-2 screen) to see all the preference options, as displayed in Figure 5-5 (in this case I chose the Provisioning and Patching option from the Setup tab). Several preferences should be set, including the e-mail addresses for sending various alerts or messages as well as notification rules. You can even change the tabs to be exactly what seems most intuitive for the environment. It is best to stay within the Oracle standard configuration, however, so another DBA can easily follow what’s been done. Spend some time investigating all of the nice links from the Setup tab.

One of the best parts of OEM is the great online help that is provided (Figure 5-6). No matter where you are, you can always access the Help option from the drop-down menu of your username.
You can then search for either a very general area like “monitoring database performance” or something very specific like “setting e-mail address.” Substantial help is included in the product on how to tune the various areas of Oracle at the host, database, application server, ASM, OS, or network levels. Also, an interesting feature is the Oracle Database 2 Day series of books that are incorporated into the OEM help. You can browse through 2 Day DBA within OEM, for example. The key is to take advantage of these resources and learn something every time you access OEM.

**FIGURE 5-6. Enterprise Manager Online Help window**

**TIP**

*In Oracle Enterprise Manager 12c, the online help is spectacular. Learn something every day by reading or searching for topics in the new Enterprise Manager Online Help window.*

**Starting with All Targets and Other Groupings**

The Enterprise Summary is the first option displayed after logging into OEM and clicking the
Enterprise tab pull-down in Figure 5-2. The Enterprise Summary window is then displayed with five panes: Overview, Patch Recommendations, Inventory and Usage, Compliance Summary, and Least Compliant Targets. Figure 5-7 shows that the Overview pane is open to the All Targets view with 273 targets being currently monitored. In the Status section, green indicates targets are up, red indicates targets are down, yellow indicates targets with an unknown status, and black indicates targets under blackout. The Overview pane also reports incidents, problems, and jobs. The Inventory and Usage pane shows all hosts that are being monitored. By viewing these two panes, you will immediately know whether instances are up or down, the status of jobs that were executed, and the ability to drill deeper to get the details of given server or database instance or cluster database. This window is the one that I want to see first thing in the morning so I know that everything being monitored is up and running efficiently. It also has a Patch Recommendations section to make you aware of available patches, and Compliance Summary and Least Compliant Targets sections to identify security policy violations and targets that need special attention. With OEM 12c, a nice feature is the ability to group common areas together. For instance, you can group all databases together into a group called PROD_DB so the group can be monitored together to see if they are all running. The same can be done for development databases (call them DEV_DB). A DBA usually configures things so the PROD_DB group is more proactive in sending alerts, pages, or e-mails than the DEV_DB group.
While I used OEM 12c as the main focus of this chapter, I also include coverage of new products such as Application Performance Monitoring (APM). OEM 13c, while recently available, doesn’t support Linux prior to Release 6, and the overall screens and flow are very similar to those in 12c (I stuck with what most people will be using to support both 12c and 11g as well as various releases of Linux; you must use a 12.1.0.2+ repository with OEM 13c). For reference, I’ve included a comparable OEM 13c Enterprise Summary screenshot in Figure 5-8.

We’ll look at a few other options from this screen later, such as Hosts and Job Activity, but I want to focus on performance tuning first. For performance-related issues, you can click the value next to Targets Monitored (upper-left side of Figure 5-7) and then click Database Instance under the Databases tab. We’ll choose to monitor the PRODDB (Container Database) as displayed in Figure 5-9. You can see in the Performance pane that we have three container databases: PROD, PDB$SEED, and CDB$ROOT. You can also see the main Performance tab pull-down menu with many options we will investigate in the coming sections including: Top Activity, SQL Performance Analyzer, Real-Time ADDM, Access Advisor, Optimizer Statistics, AWR, and ASH Analytics. The menu can also take you to the Database Replay (covered near the end of this chapter).
Monitoring and Tuning Using the OEM Performance Menu

You’ll find several tabs under the Database Instance Server or Cluster Database (depending on which one you select). Clicking the Performance menu will show a list of helpful options shown in Figure 5-9. In this section, I want to focus on those menu items that are most beneficial to quick performance improvements. The most important when the system is in serious trouble is the Top Activity screen. The Top Activity will show the SQL and Users waiting the most and overall system performance. When the system is less busy, you might want to look into the SQL Performance Analyzer and tuning queries with ADDM and Tuning SQL Tuning Sets.

Performance Tab: Top Activity

The Top Activity Screen quickly shows how the system is running overall, where problems exist, and what specific problems need to be fixed. Clicking Top Activity in the pull-down menu in Figure 5-9 will bring up the Top Activity screen displayed in Figure 5-10. The waits are shown in various colors and also listed to the right of the graph. You can also go directly to a Wait Activity by clicking the item you want to see in more detail. Also note that the Top Activity screen option is listed at the bottom of most performance-related screens in OEM. When systems have serious issues, I spend a lot of time on the Top Activity screen. Figure 5-10 shows a Top Activity screen with some serious performance spikes, especially between 11:40 and 11:47 AM. You can move (click and drag) the shaded rectangle on the graph to the area that you would like to focus in on (you can look back in time to what happened before an issue occurred as well as after an issue happens). In the lower part of the screen you will see the associated Top SQL statements (on the lower left) and the associated Top Sessions (on the lower right). If you scroll down, you can instantly see the cost of each SQL statement.
and how the statement adds up to the graph in the shaded rectangle area. You can instantly check the boxes next to all of the Top SQL statements that you would like the Tuning Advisor to tune for you (or at least make suggestions).

![Top Activity screen](image)

**FIGURE 5-10. Top Activity screen**

---

**Performance Tab: SQL | SQL Performance Analyzer**

Clicking SQL Performance Analyzer Home in the pull-down menu in Figure 5-9 under Performance | SQL will bring up the SPA screen displayed in Figure 5-11. The SQL Performance Analyzer (SPA) gives a variety of options for tuning Oracle. You can use a Guided Workflow, even comparing different releases for a SQL Tuning Set. You can compare the effect of changing an initialization parameter, and you can even perform an Exadata simulation. Although I can’t show all of the steps for each of these tasks, I’ll try to show a few of the key screens here.
Clicking the Guided Workflow option brings up a step-by-step way to compare two different SQL Tuning Sets (Figure 5-12). This allows you to make changes to an environment, tune the SQL statements, or test another change.

After completing all of the Guided Workflow steps, the SQL Performance Analyzer shows the output comparing the SQL Tuning Sets before and after changes. Figure 5-13 shows the before and
Instead of choosing the Guided Workflow option in the SPA, this time let’s choose the Upgrade from 10.2 or higher releases option (see Figure 5-10) to compare upgrades from 10.2 or 11g to 12c. Figure 5-14 shows one of the screens that appear for this comparison. You need to fill in the Task Name, SQL Tuning Set, and two Database Link fields for a successful test.
Once I complete the steps for the comparison, the SPA displays a detailed comparison similar to the output shown in Figure 5-16.

In OEM 12c there is the ability to simulate Exadata. Clicking the Exadata Simulation option in the SPA (see Figure 5-10) displays the Exadata Simulation screen (Figure 5-15).
Once I enter all of the information and run the associated jobs for the Exadata Simulation, the SPA displays a comparison of my current system to Exadata to see if it would be beneficial (Figure 5-16). For my test, I tried something easy to see if even the most simple queries would show I needed Exadata (when, in fact, I didn’t). Fortunately, the SPA indeed showed that Exadata would *not* be beneficial, as all statements were unchanged—to which I give Oracle credit (I thought surely they would try to talk me into Exadata!).

**Performance Tab: Real-Time ADDM**

Clicking Real-Time ADDM in the pull-down menu in Figure 5-9 under Performance | Real-Time ADDM will bring up the Real-Time ADDM Results screen displayed in Figure 5-17. There are also other screens that you can click a button to get Real-Time ADDM as well. This shows performance based on the last time ADDM was generated.

As stated earlier, Oracle gathers stats every hour on the hour for the AWR and runs an ADDM report directly after that. However, if a problem occurs after the hour (perhaps at 3:01 PM as you see in Figure 5-17), the ADDM report that ran at 3 pm doesn’t reveal the problem, and perhaps you really don’t want to wait until 4 pm if the problem is severe. The answer is the ability to Run ADDM now. You can start the Real-Time ADDM now by clicking Start. After the ADDM is complete, you’ll see the screen in Figure 5-18 under the Progress tab showing it with a status of Finished.
You can also run an ADDM Report (addmrpt.sql) in SQL*Plus to see these findings. In an effort to increase performance, the ADDM analyzes a number of different database-related problems, including:

- Memory-related issues such as shared pool latch contention, log buffer issues, or database buffer cache–related problems
- CPU bottlenecks
- Disk I/O performance issues
- Database configuration problems
- Space-related issues, such as tablespaces running out of space
- Application and SQL tuning issues such as excessive parsing and excessive locking
- RAC-related issues such as global cache interconnect issues, lock manager issues, global resource contention issues, and any other globally significant issues

**TIP**
*Use the SQL Tuning Advisor only to tune SQL statements, not conditions such as row locks.*

By clicking the Findings tab, the Findings for ADDM are displayed. This screen displays the finding(s)/problem(s) as well as offering action(s) needed for fixing the problem or related SQL. In the example in Figure 5-19, the issue has to do with SQL statements consuming significant database
You can schedule the SQL Tuning Advisor (note that this is part of the SQL Tuning Pack) to investigate the SQL in greater detail and get recommend changes in the problem SQL. Choosing Performance in Figure 5-9, and clicking | SQL | SQL Tuning Advisor opens the SQL Tuning Advisor, ready to tune any SQL in question and offer suggestions. In Figure 5-20, the recommendations for the subpar SQL statements for a given SQL Tuning Set are identified by check marks. The worst SQL (SQL ID = 9rk22atf5ng4p) seems like it will benefit from implementing an index.
By selecting the radio button corresponding to the worst SQL text and then clicking View Recommendations, you can see the SQL and the recommendations to enhance the SQL (Figure 5-21). Implementing the index should help by 95.89 percent according to the recommendations. You can also click the link in the rightmost column to compare the Explain Plans to see what is being changed and what the benefit will be.
The Explain Plans comparison shows that the order of table access has been changed as well as some of the joining methods. Creating the index would not require the SQL to perform full table scans, as seen in Figure 5-22.

![Explain Plans comparison](image)

**Figure 5-22. Explain Plans comparison**

**TIP**

*Compare Explain Plans is a great SQL Tuning Advisor tool built into OEM.*

In Figure 5-23, it is evident from the Top Activity screen that the now-tuned SQL statement is no longer causing the negative impact (performance spike) that was previously felt earlier in the day (refer to Figure 5-17). The entire system is now running much better, with fewer users waiting in the queue.
Within the Tuning Pack, you will find a product called SQL Access Advisor (SAA). SAA can be used for tuning the entire workload (not just high-load SQL statements). Choose the option available from the Performance menu (Figure 5-9). To access the screen, choose Performance | SQL | Access Advisor, shown in Figure 5-24. SAA gives recommendations on how to improve performance of a workload through indexes (bitmap, b-Tree, functional, and concatenated), materialized views/logs, and a combination of these. SAA considers the cost of DML in terms of index maintenance and storage when it recommends additional access structure. SAA can also be used during the development phase to figure out what access structures are required before production deployment. You can use SQL Tuning Sets as input to SAA. Please check the Oracle documentation for additional information.
Another option available from the Performance menu (Figure 5-9) is access to the Optimizer Statistics Console screen, shown in Figure 5-25. To access the screen, choose Performance | SQL | Optimizer Statistics. Keeping statistics up to date for dynamic tables can be a chore (worse if done for static tables too—don’t do that). The Optimizer Statistics Console can help in this endeavor. Many different gathering options for optimizer statistics can be specified from this screen, as well as the scheduling and managing of specific jobs.
You can access the Automatic Workload Repository (AWR) by choosing Performance | AWR | AWR Administration. The Automatic Workload Repository screen includes information on all snapshots and collection levels. (See Chapter 14 for more on AWR and how snapshots work.) In the example in Figure 5-26, there are 372 snapshots with a retention of 15 days and an interval of 60 minutes.
By clicking the Edit button, you can change the interval or retention period on the Edit Settings screen, shown in Figure 5-27. You can also edit the collection level.
In Figure 5-26 you can also click the Run Compare Periods Report button and then enter any specific snapshot to begin and end with to generate some basic snapshot details, as shown in Figure 5-28 (like a very mini-Statspack).

![AWR Run Compare Periods Report](image)

**FIGURE 5-28. AWR Run Compare Periods Report**

Alternatively, you can run and display the full AWR Report by clicking the Run AWR Report button (covered in detail in Chapter 14—see that chapter for full display sections). Once you have completed the Begin Snapshot and End Snapshot fields, click the Generate Report button to generate the report shown in Figure 5-29.
You can access the Active Session History (ASH) Analytics by choosing Performance | ASH Analytics (Figure 5-30). The best report, in my humble opinion, is the Automatic Workload Repository (AWR) Report (covered above). The next best report is a mini-AWR report (as I call it) or the Active Session History Report (ASH Report) found in the reporting sections of OEM. It shows in a very quick way the key sections found in a Statspack or AWR Report. In 12c, you now have near real-time ASH information from that report with ASH Analytics (Figure 5-30).
Some of the information in the ASH Report includes various Top Events and Load Profile, as in a Statspack or AWR Report. While the details of this report are beyond the scope of this chapter, please refer to Chapter 14 for tuning wait events and detailed information on the AWR Report, which includes much of the same information that will help in understanding the ASH Report.

**TIP**
The Active Session History (ASH) Analytics is a new and simple way to find and diagnose performance problems quickly.

### Monitoring and Tuning Using the OEM Administration Menu

You’ll find several tabs under the Database Instance Server or Cluster Database (depending on which one you select). Clicking the Administration menu will show a list of helpful options (Initialization Parameters, In-Memory Central, Storage, Resource Manager, and more). The scope of these options is well beyond this chapter, but you can get an idea from the screen shown in Figure 5-31 that some wonderful built-in tools are available to help the DBA work more effectively and efficiently. A couple of these frequently used options are described in this section.
FIGURE 5-31. The Administration menu

Database Administration Tab: Storage | Tablespaces

Choosing Administration | Storage | Tablespaces displays the Tablespace screen, shown in Figure 5-32. This screen lists all of the tablespace for this database, including information on allocated and used space, the type of tablespace, extent management, and segment management.
By clicking a specific tablespace (USERS in this example), the View Tablespace screen in Figure 5-33 is displayed. This screen includes additional information, including the actual datafile(s) underlying the tablespace. Also notice all the available pull-down menu actions. Some of these are very powerful and huge time-savers.

Choosing Show Tablespace Contents from the Actions pull-down menu displays the screen shown in Figure 5-34. This shows all of the segments that are contained in the given tablespace and is an excellent way to view objects that correspond to a heavily accessed tablespace.
Something more difficult to discover is the Extent Map. Clicking the arrow (>) next to Extent Map (shown at the bottom of Figure 5-34) expands the Show Tablespace Contents screen to display a very cool Extent Map, an example of which is shown in Figure 5-35. The Extent Map provides a graphical view of all tablespaces, datafiles, segments, total data blocks, free data blocks, and percentage of free blocks available in the tablespace’s current storage allocation. The tool gives you the option of displaying all segments for a tablespace or all segments for a datafile. The Extent Map also provides additional information for each segment, including average free space per block, chained rows, and the last date that the object was analyzed.
The Extent Map, which displays the information in a tablesapce block by block in a graphical manner, is a super-cool feature that’s hard to discover in OEM.

Database Administration Tab: In-Memory Central and Initialization Parameters

The Administration menu is useful for getting to many areas that are easier to change using OEM instead of SQL. Items such as In-Memory Central (if you are using the In-Memory feature) and Initialization Parameters (shown at the container database level) are included under the Administration menu (Figure 5-36).
Database Administration Tab: All Initialization Parameters

Choose Administration | Initialization Parameters to open the screen shown in Figure 5-37. You can view and change the current initialization parameters from this screen. You can also group the parameters by category or sort out the dynamic parameters. Other databases and/or instances can be checked for any current values or recent changes.

Clicking the SPFile tab displays the contents (see more information in Chapter 4) if the SPFILE is being used. Figure 5-38 shows an example of viewing the initialization parameters from the SPFILE; it also shows the location.
Another option available from the Administration menu is Resource Manager, which enables you to monitor and tune using consumer groups. After choosing Administration | Resource Manager, click the highlighted Consumer Groups link to display the Consumer Groups screen, as shown in Figure 5-39. A system that includes users in AR (Accounts Receivable), CRM (Customer Relationship Management), and BI (Business Intelligence) can be better visualized when services are set up for each of them (now it’s easy to see who is using all of the resources). In Figure 5-39, you see a Consumer Group BATCH_GROUP as the first listing.
FIGURE 5-39. Consumer Groups screen

TIP
If you take the time to set up services, you can use the Top Consumers screen to see quickly which business areas are consuming the most resources.

Monitoring and Tuning Using the OEM Database or Cluster Database Menu

The Oracle Database menu, shown in Figure 5-40, also has several administration options, notably Logs (for accessing associated alert log and trace files, viewing alert log errors, and archiving and purging alert logs), Provisioning, and Cloning.
Database Tab: Job Activity

Scheduler Central contains all scheduled tasks. It also includes links for the Oracle Scheduler, Jobs, and Automated Maintenance tasks. Choosing Oracle Database | Job Activity opens the Job Activity screen, in which the job activity and all jobs are listed (Figure 5-41). It shows the time that each job will execute, as well as the target system on which the job will execute. There is also information about the owner, status, and job type.
Cluster Database Tab: Configuration|Database Topology

The Configuration Topology screen (as shown in Figure 5-42) shows the topology for a 12c cluster database. Notice that details are shown on the right part of the screen. (Clicking the database from the graph would show details about the database, clicking the Listener from the graph would show details about the listener, etc.) Something nice is the information about the node, which pops up when the mouse rolls over one of the pictures in the graph.

Monitoring the Hosts

While the Top SQL is usually the problem, digging into other areas of the infrastructure can quickly reveal issues. Choosing Targets (Figure 5-7) | Hosts displays all of the hosts out there. In the example shown in Figure 5-43, five hosts are listed.
Clicking just one of the hosts (HQORADB02) displays all of the detailed information about that host. This includes the IP address, the OS, the number of CPUs, the amount of memory, and the available disk space. It also shows any Alerts or Policy violations as it did at the database or instance level. Figure 5-44 shows that the host is currently up.
By clicking the Host tab, hovering over the Monitoring tab from the drop-down menu, and then clicking the Status History button, the complete availability of this host is displayed over a period of time. In Figure 5-45, the host shown has been down 0 percent of the time.

Monitoring the Application Servers and Web Applications

While database and host monitoring was crucial to the performance of client/server systems in the 1990s, the Internet and web applications have driven performance issues at the application-server level over the last decade. Finding issues at the application-server level (usually where the actual code is running) is critical to good performance. OEM offers several ways to monitor all application servers. The main way is by choosing it from the Targets in Figure 5-7 as we did for Hosts. The application server name as well as CPU and memory usage is displayed. As at the database and host levels, alerts and policy violations are also listed. One of the nicest aspects of OEM is that you can monitor a piece of the infrastructure or investigate a specific program that is causing performance issues.

In this section, viewing the web application itself will be discussed. Choosing Targets | Web Applications displays all of the information about a given web application. OEM shows whether the application is up or down, how long it’s been up, its availability, related topology, alerts, and a variety of performance information. OEM also tests the performance of a given web application by
allowing beacons to run at various times to measure its performance. These beacons are representative queries of what a user may be doing on a regular basis. Now the DBA knows when an application is slow because he or she will also be running a query that is similar to the user’s query on a regular basis.

Oracle Cloud has added an even better tool for monitoring web applications and specific customer web pages. When you are running Oracle Cloud Services, you can look at the application performance in much more detail using the new Application Performance Monitoring (APM) tool. Figure 5-46 shows the topology of a RideShare application with response times for different tiers, including the AppServer and Database tiers.

![Application Performance Monitoring tool application server monitoring](image)

**FIGURE 5-46. Application Performance Monitoring tool application server monitoring**

You can also click a specific application being used by customers and see the breakdown of time spent loading the page, page views in less than a minute, errors, and other details (Figure 5-47). Thank you to Oracle for providing Figures 5-47 and 5-48 of this new product (late 2016).
You can use Enterprise Manager to monitor web servers and web applications. In Oracle Cloud 12c, Oracle provides a new tool for DevOps called Application Performance Monitoring (APM) to help monitor customer web pages in much greater detail.

**Real Application Testing (Database Replay)**

Real Application Testing, which captures the database workload on one system (usually your current system) and replays it later on a different system (your future system), is a great tool. It is under the Performance tab | Database Replay in Figure 5-9. This is helpful for testing upgrades to 12c—capture
an 11g or 10g workload and then test it against 12c. I recommend taking a full Oracle class on this to understand it fully. The Database Replay option is shown in Figure 5-48.

Here are the steps in brief:

1. Capture the workload on a database.
2. Prepare the test database.
3. Prepare for replay.
4. Replay the workload on the test database.
5. Compare your results.

You can compare your results using a few different options. You can run a Synchronized Replay that replays everything with exact concurrency and commits with minimal data divergence. You can also perform an Unsynchronized Replay, which replays without the same concurrency or commits. Also, data divergence can be large depending on the load test performed. A report is created based on Data Divergence, Error Divergence, and Performance Divergence. The detail for the Capture task is shown in Figure 5-49.

---

**Summary**

A great way to test how your system will perform on new hardware or with a new version of Oracle is to use Oracle’s Real Application Testing (Database Replay).
With OEM, DBAs are able to manage more databases and also manage systems more effectively using this versatile tool, which now extends into cloud computing, grid computing, and Exadata. This comprehensive knowledge of system health and performance also enables businesses to plan and trend out usage for future growth. Enterprise Manager is the most powerful Oracle utility available. It’s not just for beginners; the better you are, the better this tool is. Keep in mind that OEM 13c is now available (shown in Figure 5-8), but it doesn’t support Linux prior to Release 6 and requires use of a 12.1.0.2+ repository, which is why the functionally similar OEM 12c was the main focus of this chapter.

**Tips Review**

- In Oracle Enterprise Manager 12c, the online help is spectacular. Learn something every day by reading or searching for topics in the new Enterprise Manager Online Help button window.
- Use the SQL Tuning Advisor only to tune SQL statements, not conditions such as row locks.
- Compare Explain Plan is a great SQL Tuning Advisor tool built into OEM.
- The Extent Map, which displays the information in a tablespace block by block in a graphical manner, is a super-cool feature that’s hard to discover in OEM.
- If you take the time to set up Services, you can use the Top Consumers screen to see quickly which business areas are consuming the most resources.
- You can use Enterprise Manager to monitor web servers and web applications. In Oracle Cloud 12c, Oracle provides a new tool for DevOps called Application Performance Monitoring (APM) to help monitor customer web pages in much greater detail.
- The Active Session History (ASH) report is a new and simple report that you can use to find and diagnose performance problems quickly.
- A great way to test how your system will perform on new hardware or with a new version of Oracle is to use Oracle’s Real Application Testing (Database Replay).

**References**

*Oracle Enterprise Manager Cloud Control Documentation* (Oracle Corporation).
*Using Oracle Application Performance Monitoring Cloud Service* (Oracle Corporation).
*Using Clusterware Administration and Deployment Guide* (Oracle Corporation).
Rich Niemiec, “Tuning the Oracle Grid” (Oracle Open World).
Oracle Learning Library
*Tuning Pack 2.0* (Oracle White Paper).

Thanks to Asad Mohammed, who did most of the update for the chapter to 12c. Thanks to Steve Lemme for the screenshots for APM. Thanks to Anil Khilani, Prabhaker Gongloor (GP), Valerie K. Kane, and David LeRoy of Oracle, who contributed a couple of the screenshots and a bit of the
verbiage to this chapter previously. I want to also thank Ken Morse of Oracle, who contributed the majority of the screenshots and verbiage in the first tuning book on SQL Analyze, Oracle Expert, and Tuning Pack 2.0. Ken was a tremendous help in completing this chapter the first time around, while Valerie and David were instrumental the second time around.
Finding and fixing problem queries has a lot to do with using the tools that are available. Different tools need to be used for different situations. The tools covered in this chapter are Oracle’s provided utilities: SQL TRACE, TKPROF, EXPLAIN PLAN, DBMS_XPLAN, and STORED OUTLINES (previously used, and to convert to what is now used: SQL Plan Baselines/plan stability). These tools were enhanced, including the addition of the DBMS_MONITOR and DBMS_SESSION packages and TRCSESS, in 10g. The SQL tracing options have been centralized and extended using the DBMS_MONITOR package. Starting with Oracle 11g, SQL PLAN MANAGEMENT (SPM) has been added. STORED OUTLINES still work but are deprecated (discouraged) and will probably be gone for good in a future release. With 12c, Adaptive SQL Plan Management has been added.

The tips covered in this chapter include the following:

- Simple steps for using SQL TRACE/TKPROF
- Exploring sections of the SQL TRACE output
- Tracing a more complex query and what to look for to help performance
- Using DBMS_MONITOR
- Using TRCSESS
- Using EXPLAIN PLAN
- Reading EXPLAIN PLAN—top to bottom or bottom to top?
- Using DBMS_XPLAN (a much better way)
- Tracing in developer tools
- Important columns in the PLAN_TABLE table
- Tracing for errors and the undocumented initialization parameters
- Using SQL PLAN MANAGEMENT (SPM)
- Converting from STORED OUTLINES to SQL PLAN MANAGEMENT
Using adaptive plans and SPM, a 12c new feature
Using Adaptive SQL Plan Management, a 12c new feature

The Oracle SQL TRACE Utility
You use the Oracle SQL TRACE utility to measure timing statistics for a given query, a batch process, and an entire system. SQL TRACE is deprecated (discouraged and on the way out) in 11g, but it still works and is still used by many developers. It has been replaced with DBMS_MONITOR and DBMS_SESSION. I’m keeping this section because so many people still use SQL TRACE, but please start using the newer packages. SQL TRACE is a thorough method for finding potential bottlenecks on the system. SQL TRACE has the following functionality:

- SQL TRACE runs the query and generates statistics about an Oracle query (or series of queries) that is executed.
- SQL TRACE helps developers analyze every section of a query.

Generally, the Oracle SQL TRACE utility records all database activity (particularly queries) in a trace file. This trace file is very hard to read and should be changed into a readable format using the TKPROF utility (as described in the following section).

Simple Steps for SQL TRACE with a Simple Query
The steps for setting up and running Oracle’s SQL TRACE utility are listed here:

1. Set the following init.ora parameters (SPFILE users will need to use the ALTER SYSTEM command to change these parameters):

   ```
   TIMED_STATISTICS = TRUE
   MAX_DUMP_FILE_SIZE = unlimited
   ```

   The TIMED_STATISTICS parameter allows tracing to occur on the system. The MAX_DUMP_FILE_SIZE specifies the maximum file size in “minimum physical block size at device level” blocks. This is the largest size that the file will grow to; any further data to be recorded will be ignored, will not be written to the trace file, and might be missed. Both of these parameters may also be set via an ALTER SYSTEM command (for the entire system) and take effect when the next user logs in, but they will not affect those currently logged in to the system. You may also set the TIMED_STATISTICS and MAX_DUMP_FILE_SIZE parameters at the session level using the ALTER SESSION command (for an individual session). The output will be stored in the USER_DUMP_DEST (for Oracle 10.2 and earlier systems). After 11.1, the DIAGNOSTIC_DEST parameter is used instead, and its value is set automatically by Oracle. To determine the location of the files, run the following script:
NOTE
In addition to VALUE, you can also specify the instance (INST_ID) and container ID (CON_ID) for pluggable databases.

```sql
select value
from v$diag_info
where name = 'Diag Trace';
```

VALUE
-----------------------------------
/u01/app/oracle/diag/orcl/orcl/trace

The value returned is the path of the trace file.

2. Enable SQL TRACE for a SQL*Plus session (this starts tracing for an individual session):

```sql
alter session set SQL_TRACE true;
```

There are actually several different ways of starting and stopping trace sessions, which will be discussed later in this chapter.

3. Run the query to be traced:

```sql
select table_name, owner, initial_extent, uniqueness
from ind2
where owner || '' = 'SCOTT'; -- Note: An index on "OWNER" is suppressed
```

4. Disable SQL TRACE for the SQL*Plus session:

```sql
alter session set SQL_TRACE false;
```

You do not actually have to stop the trace to examine the trace file, but it is a good idea. After running SQL TRACE, your output filename will look something like the following (the process ID is usually included in the trace filename):

`orcl_ora_19554.trc`

TIP
Setting TIMED_STATISTICS = TRUE in the initialization file enables the collection of time statistics.

Finding the generated trace file may be the trickiest part of this whole process. The generated file should be named for the process ID of the trace session and include that number in the filename. Looking for the date and time of the file makes it easy to find if you are the only one tracing something. In the previous example, 19554 is the process ID of the session being traced. The trace filenames may vary between `ora%` and `ora_%`, depending on the operating system on which the trace was performed, and the file should appear in the location specified by running the script listed in Step 1. Another way of finding the file is to put a marker inside the file output (such as issuing a query like `SELECT 'Rich1' FROM DUAL;`), and then use a file search utility like `grep` in Linux or Windows.
Search to find the text and the file that contains it.

You can use the following query, running from the same session, to obtain the number included in the trace filename (assuming you can access the V$ views):

```sql
select spid, s.sid, s.serial#, p.username, p.program
from v$process p, v$session s
where p.addr = s.paddr
and s.sid = (select sid from v$mystat where rownum=1);
```

**NOTE**

Don’t forget to grant SELECT on V_$PROCESS, V_$SESSION, and V_$MYPSTAT to the user if not already granted.

Run TKPROF at the operating system prompt to convert the trace file into a readable format. The following command creates the file `rich2.prf` in the current directory from the `ora_19554.trc` trace file and also logs in to the database as system/manager to get the EXPLAIN PLAN output:

```
tkprof orcl ora_19554.trc rich2.prf explain-system/manager
```

The TKPROF utility translates the TRACE file generated by the SQL TRACE facility to a readable format. You can run TKPROF against a TRACE file that you have previously created, or you can run it while the program that is creating the TRACE file is still running. Table 6-1 lists options for TKPROF.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>tracefile</td>
<td>This is the name of the SQL TRACE file containing the statistics by SQL_TRACE.</td>
</tr>
<tr>
<td>output_file</td>
<td>This is the name of the file where TKPROF writes its output.</td>
</tr>
<tr>
<td>print = number</td>
<td>This is the number of statements to include in the output. If this statement is not included, TKPROF lists all statements in the output.</td>
</tr>
<tr>
<td>explain = username/password</td>
<td>Run the EXPLAIN PLAN on the user's SQL statements in the TRACE file. This option creates a PLAN_TABLE of its own, so the user needs to have privileges to create the table and space in which to create it. When TKPROF is finished, this table is dropped. Ensure that you use the username/password of the user who parsed the cursor (ran the query) to ensure the EXPLAIN PLAN output is for the correct user. See Metalink Note 199081.1 for more information. In 12c, there is also the option pdb:trace=username/password.</td>
</tr>
<tr>
<td>insert = filename</td>
<td>This option creates a script to create a table and store the TRACE file statistics for each SQL statement traced.</td>
</tr>
<tr>
<td>record = filename</td>
<td>This option produces a file of all the user's SQL statements.</td>
</tr>
<tr>
<td>sys = yes</td>
<td>no</td>
</tr>
<tr>
<td>sort = parameters</td>
<td>A tremendous number of sorting options are available. My favorites are FCHCPU (CPU time of fetch), FCHDSK (disk reads for fetch), FCHCU and FCHQRY (memory reads for fetch), FCHROW (number of rows fetched), EXEDSK (disk reads during execute), EXECU and EXFQRY (memory reads during execute), EXEROW (rows processed during execute), EXECPUS (execute CPU time), PRSCPU (parse CPU), and PRSCNT (times parsed).</td>
</tr>
<tr>
<td>waits = yes</td>
<td>no</td>
</tr>
<tr>
<td>aggregate = yes</td>
<td>no</td>
</tr>
<tr>
<td>table = schema.table</td>
<td>The table into which TKPROF temporarily puts execution plans before writing them to the output file.</td>
</tr>
</tbody>
</table>
TABLE 6-1. Command-Line Options for TKPROF

The syntax for TKPROF is as follows:

\[
\text{tkprof tracefile output_file [sort = parameters] [print=number]} \\
[\text{explain=username/password}] [\text{waits=yes|no}] \\
[\text{aggregate=yes|no}] [\text{insert=filename}] [\text{sys=yes|no}] [\text{table=table.schema.table}] \\
[\text{record=filename}] [\text{width=number}]
\]

The following are some quick examples using the options described in Table 6-1.

Run TKPROF and list only the top five CPU (fetch + execute + parse) results:

```
\text{tkprof orcl_ora_19554 rich3 explain=system/manager sort=\{FCHCPU, EXECPU, PRSCPU\} print=5}
```

Run TKPROF and omit all recursive statements:

```
\text{tkprof orcl ora 19554 rich4 explain=system/manager sys=no}
```

Run TKPROF and create a file that shows your TRACE session:

```
\text{tkprof orcl ora 19554 traces rich6.prf explain=system/manager record=record1.sql}
```

TIP

The TKPROF utility puts traced output into a readable format. Without running TKPROF, reading the output of a TRACE would be difficult. By specifying `explain = username/password` (as shown in the accompanying examples), you are able to get the EXPLAIN execution path, in addition to the execution statistics of the query.

TIP

Run TKPROF from the command line without any parameter to get a list of all the parameters.
Now let’s run a quick example and see the output:

```sql
alter session set sql_trace true;
select table_name, owner, initial_extent, uniqueness
from ind2
where owner || '' = 'SCOTT';
alter session set sql_trace false;
```

Here’s the output:

```
select TABLE_NAME, OWNER, INITIAL_EXTENT, UNIQUENESS
from ind2
where OWNER = 'SCOTT';
```

<table>
<thead>
<tr>
<th></th>
<th>count</th>
<th>cpu</th>
<th>elapsed</th>
<th>disk</th>
<th>query</th>
<th>current</th>
<th>rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parse:</td>
<td>1</td>
<td>1.00</td>
<td>2.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Execute:</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Fetch:</td>
<td>2</td>
<td>69.00</td>
<td>113.00</td>
<td>142</td>
<td>430</td>
<td>0</td>
<td>36</td>
</tr>
</tbody>
</table>

Here is the execution plan (no index used):

```
TABLE ACCESS (FULL) OF 'IND2'
```

The preceding output shows 142 disk reads (physical reads) and 430 total reads (query + current). The number of memory reads is the total reads less the disk reads, or 288 memory reads (430 – 142). Having such a high number of disk reads compared to query reads is certainly a potential problem unless you are running a data warehouse or queries that often do require full table scans. The execution path shows a full table scan, confirming that you may have a potential problem.

**TIP**

A traced query with a large number of physical reads may indicate a missing index. The DISK column indicates the physical reads (usually when an index is not used), and the QUERY column added to the current column is the total number of block reads (the physical reads are included in this number). A query with a large number of query reads and a low number of disk reads may indicate the use of an index, but if the query reads are overly high, it could indicate a bad index or bad join order of tables. A query with a large number of current reads usually indicates a large DML (UPDATE, INSERT, DELETE) query.

The next listing shows what happens when you rerun the query (after restarting the system) to be
traced, but now using an index on the OWNER column:

```
select table_name, owner, initial_extent, uniqueness
from ind2
where owner = 'SCOTT'; (The index on "OWNER" is not suppressed)
```

The following listing shows the output of the file rich2.prf. Often you’ll see zero (0) disk reads for queries that have frequently accessed data. The first time a query is run, there will always be disk reads.

```
select table_name, owner, initial_extent, uniqueness
from ind2
where owner = 'SCOTT';
```

<table>
<thead>
<tr>
<th></th>
<th>count</th>
<th>cpu</th>
<th>elapsed</th>
<th>disk</th>
<th>query</th>
<th>current</th>
<th>rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parse</td>
<td>2</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Execute</td>
<td>2</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fetch</td>
<td>4</td>
<td>6.00</td>
<td>6.00</td>
<td>0</td>
<td>148</td>
<td>0</td>
<td>72</td>
</tr>
</tbody>
</table>

Note that the number of total reads went from 430 to 148 by using an index. The following listing (abbreviated) shows the execution plan (index used):

```
TABLE ACCESS (BY ROWID) OF 'IND2'
INDEX (RANGE SCAN) OF 'IND2_1' (NON-UNIQUE)
```

The Sections of a TRACE Output

The TRACE utility has multiple sections, including the SQL statement, statistics, information, and EXPLAIN PLAN. Each of these is discussed in the following text sections.

The SQL Statement

The first section of a TKPROF statement (yes, still works in 12.2) is the SQL statement. This statement will be exactly the same as the executed statement. If any hints or comments were in the statement, they are retained in this output. This can be helpful when you are reviewing the output from multiple sessions. If you find a statement that is causing problems, you can search for the exact statement. Remember, some of the statements from Oracle Forms are generated dynamically, so parts of the query (particularly WHERE clause predicates) may be displayed as bind variables (:1) and not actual text.
The Statistics Section

The statistics section contains all the statistics for this SQL statement and all the recursive SQL statements generated to satisfy this statement. This section has eight columns, the first being the type of call to the database. There are three types of calls: Parse, Execute, and Fetch. Each call type generates a separate line of statistics. The Parse is where the SQL statement itself is put into memory (library cache of the shared pool), or it can also reuse an exact cursor. The Execute is where the statement is actually executed, and the Fetch is where the data is retrieved. The other seven columns are the statistics for each type of call. Table 6-2 explains each column and its definition.

<table>
<thead>
<tr>
<th>Column</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>COUNT</td>
<td>The number of times this type of call was made.</td>
</tr>
<tr>
<td>CPU</td>
<td>The total CPU time for all of the calls of this type for this statement.</td>
</tr>
<tr>
<td>ELAPSED</td>
<td>The total elapsed time for this call.</td>
</tr>
<tr>
<td>DISK</td>
<td>The total number of data blocks retrieved from disk to satisfy this call.</td>
</tr>
<tr>
<td>QUERY</td>
<td>The total number of data buffers retrieved from memory for this type of call.</td>
</tr>
<tr>
<td>CURRENT</td>
<td>The total number of data buffers retrieved from memory for this type of call.</td>
</tr>
<tr>
<td>ROWS</td>
<td>The total number of rows processed by this statement.</td>
</tr>
</tbody>
</table>

TABLE 6-2. Statistics for Each Type of Call

The Information Section

The information section contains information about the number of library cache misses from parse and execute calls. If the number of misses is high, you may have a problem with the size of the shared pool. You should check the hit ratio and the reload rate of the library cache. This section also shows the username of the last user to parse this statement. You’ll also find information about the current optimizer mode setting.

The Row Source Operation Section
The row source operation section lists the number of rows cross-referenced with the operation that used the rows.

TIP
The trace file is a point-in-time picture of what happened on the system at the time that the trace was run (includes the row source operation). In contrast, the EXPLAIN PLAN (detailed next) is generated when the TKPROF listing is created, which could be some time later. The row source operation listing is generated as part of the trace file and can be used to see if the database objects have changed since the trace was performed.

The EXPLAIN PLAN (Execution Plan)
I find this section of the TKPROF output to be the most useful. The first column of this section is the number of rows processed by each line of the execution plan. Here, you are able to see how slow a statement is. If the total number of rows in the Fetch statistics is low compared to the number of rows being processed by each line of the EXPLAIN PLAN, you may want to review the statement. This plan is generated when you use the EXPLAIN OPTION of the TKPROF command and is the plan that would be generated if the SQL was executed at the time that the TKPROF command was run. If you want the plan that was generated at the time that SQL was originally run, then use the row source operation plan command.

It is also possible that only one line of the execution plan is processing a large number of rows compared to the rest of the statement. This situation can be caused by full table scans or the use of a bad index.

Table 6-3 lists some of the problems to look for in the TKPROF output.
Digging into the TKPROF Output

When you compare the TKPROF output to the actual object’s physical characteristics, you start to see how Oracle really works. Consider a CUSTOMER table with over 100,000 records contained in over 1000 blocks. By querying DBA_TABLES and DBA_EXTENTS, you can see the blocks that are both allocated (1536) and being used (1382), as shown in the following listing:

```sql
select sum(blocks)
from dba_segments
where segment_name = 'CUSTOMER';
```

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>The parsing numbers are high.</td>
<td>The SHARED_POOL_SIZE may need to be increased or use bind variables more.</td>
</tr>
<tr>
<td>The disk reads are very high.</td>
<td>Indexes are not being used or may not exist.</td>
</tr>
<tr>
<td>The query and/or current (memory reads) are very high.</td>
<td>Indexes may be on columns with low cardinality (columns where an individual value generally makes up a large percentage of the table; like a YES/NO field). Removing/suppressing the index or using histograms or a bitmap index may increase performance. A poor join order of tables or bad order in a concatenated index may also cause this.</td>
</tr>
<tr>
<td>The parse elapse time is high.</td>
<td>There may be a problem with the number of open cursors.</td>
</tr>
<tr>
<td>The number of rows processed by a row in the EXPLAIN PLAN is high</td>
<td>This could be a sign of an index with a poor distribution of distinct keys (unique values for a column). This could also be a sign of a poorly written SQL statement.</td>
</tr>
<tr>
<td>compared to the other rows.</td>
<td>This indicates the statement had to be reloaded. You may need to increase the SHARED_POOL_SIZE in the init.ora file or do a better job of sharing SQL by using bind variables.</td>
</tr>
<tr>
<td>The number of misses in the library cache during parse is greater than 1.</td>
<td></td>
</tr>
</tbody>
</table>
If you look at the TKPROF output of a query that counts all records in the CUSTOMER table (shown in the next listing), you see that it performs a full table scan because this is the first access after a startup. Also note that the number of blocks accessed (mostly physical disk access) is slightly higher than the total number of blocks in the physical table (seen in the previous queries). All but 4 of the 1387 query blocks read are disk reads. (Disk reads are a subset of the query, which is the sum of disk and memory reads in consistent mode.)

If you run this query a second time (shown in the following listing), a big change occurs. Looking at the TKPROF output of a query that counts all records in the CUSTOMER table, this time you see that it still performs a full table scan, but now there are many fewer disk reads because most of the blocks needed are already cached in memory. Most of the 1387 query blocks read are memory reads. (Only 121 are disk reads.)
**TIP**

*Full table scans are one of the first things Oracle pushes out of memory (becoming least recently used as soon as you run them) because they are so inefficient, generally using a lot of memory.*

---

**Using DBMS_MONITOR**

In a multitier environment with connection pooling or a shared server, a session can span multiple processes and even multiple instances. DBMS_MONITOR is a built-in package introduced in Oracle 10g that allows any user’s session to be traced from client machine to middle tier to the backend database. This makes it easier to identify the specific user who is creating a large workload. DBMS_MONITOR replaces trace tools such as DBMS_SUPPORT. The DBA role is required to use DBMS_MONITOR.

End-to-end application tracing can be based on the following:

- **Session** Based on session ID (SID) and serial number on the local instance.
- **Client identifier** Allows trace to be set across multiple sessions. Specifies the end user based on the logon ID. Set this using the DBMS_SESSION.SET_IDENTIFIER procedure.
- **Instance** Specifies a given instance based on the instance name.
- **Service name** Specifies a group of related applications. Set using the DBMS_SERVICE.CREATE_SERVICE procedure (which creates a DB service).
- **Module name** Set by developers in their application code using procedure
DBMS_APPLICATION_INFO.SET_MODULE. This name is used to represent the module or code being executed.

- **Action name** Set by developers in their application code using procedure DBMS_APPLICATION_INFO.SET_ACTION. This name is used to represent the action being performed by the module.

End-to-end application tracing can generate the following details:

- **Waits** If TRUE, then wait information is written to the trace file.
- **Binds** If TRUE, then bind information is written to the trace file.
- **Instance name** The name of the instance being traced if this parameter is set.
- **Plan stat** (new in 11g) Frequency that row source statistics are written to trace file (possible values include NEVER, FIRST_EXECUTION [default], or ALL_EXECUTIONS).

Service name, module name, and action name are associated hierarchically; you can’t specify an action name without specifying the module name and the service name, but you can specify only the service name, or only the service name and module name.

Oracle 11g introduced an important parameter called *plan stat*. If you want to guarantee that a row source plan is present in the trace file for each SQL statement, then use a value of ALL_EXECUTIONS for the parameter.

**TIP**

*Using a value of ALL_EXECUTIONS for the PLAN_STAT ensures that information regarding the execution plans is always contained in the trace file.*

### Setting Trace Based on Session ID and Serial Number

To set the trace based on session ID and serial number, first determine the SID and serial number of the session you want to trace:
To enable the trace using DBMS_MONITOR:

```
select sid, serial#, username
from v$session;
```

<table>
<thead>
<tr>
<th>SID</th>
<th>SERIAL#</th>
<th>USERNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>156</td>
<td>3588</td>
<td>SCOTT</td>
</tr>
<tr>
<td>142</td>
<td>1054</td>
<td>SYS</td>
</tr>
</tbody>
</table>

To enable the trace using DBMS_MONITOR:

```
SQL> exec dbms_monitor.session trace enable(156, 3588, TRUE, FALSE);
```

The third parameter is for waits (default is TRUE), and the fourth parameter is for bind variables (default is FALSE).

To turn off the trace:

```
SQL> exec dbms_monitor.session trace disable(156, 3588);
```

To trace the current session, set the SID and SERIAL# to NULL:

```
SQL> exec dbms_monitor.session trace enable(null,null);
```

(or exit the session).

## Setting Trace Based on Client Identifier

To set the trace based on a client identifier as the user, first set the identifier for the current session by running the following:

```
SQL> exec dbms_session.set_identifier('bryan id');
```

To verify the client identifier:
Now you can set the trace for this client identifier:

```
SQL> exec dbms_monitor.client_id_trace_enable('bryan id', wait=>true, binds=>false);
```

The second parameter is for waits (default is TRUE), and the third parameter is for bind variables (default is FALSE). The benefit of using CLIENT_ID traces is that tracing is enabled for all instances and is persistent across restarts. Whatever shared process or session ID the client with the identifier `bryan id` uses, this user’s activities will be written to one or more trace files. For a multitenant environment, the connection between the end client and database is nonstatic; that is, the end client makes a request and can be routed to different database sessions from the middle tier. In older versions, you had no way to keep track of clients across many database sessions, whereas now you can use end-to-end tracing to get the CLIENT_IDENTIFIER attribute. This column can also be found in V$SESSION.

To disable this client identifier trace:

```
SQL> exec dbms_monitor.client_id_trace_disable('bryan id');
```

### Setting Trace for the Service Name/Module Name/Action Name

In order to use the action name, you must include the module name and the service name. In order to use the module name, the service name must be present. Tracing is enabled for a given combination of service name, module name, and action name globally for a database unless an instance name is specified for a procedure. The service name is determined by the connect string used to connect to a service.

An Oracle database is represented to clients as a service; that is, the database performs work on behalf of clients. A database can have one or more services associated with it. For example, you could have one database with two different services for web clients: book.us.acme.com for clients making book purchases and soft.us.acme.com for clients making software purchases. In this example, the database name is SALES.ACME.COM, so the name isn’t even based on the database name. The service name is specified by the SERVICE_NAMES parameter in the initialization parameter file. A
default service name is created automatically for the database with the same name as the global
database name, a name comprising the database name (DB_NAME parameter) and the domain name
(DB_DOMAIN parameter).

To enable tracing for a service name (assuming the service ebk2 has been created):

```
SQL> exec dbms_monitor.serv_mod_act_trace_enable(service_name=>'ebk2');
```

This traces all sessions that connect to the database using a service with the name of ebk2.

To enable tracing for a combination of service, module, and action:

```
SQL> exec dbms_monitor.serv_mod_act_trace_enable(service_name=>'ebk2', module_name=>'salary update', action_name=>'Insert item');
```

To disable tracing in the preceding code, use the procedure
SERV_MOD_ACT_TRACE_DISABLE, as shown here:

```
SQL> exec dbms_monitor.serv_mod_act_trace_disable(service_name=>'ebk2', module_name=>'salary update', action_name=>'Insert item');
```

To trace for the entire database or instance (not recommended):

```
SQL> execute DBMS_MONITOR.DATABASE_TRACE_ENABLE(waits => TRUE, hints => FALSE, instance_name => 'ebk1');
```

**TIP**

*When using DBMS_MONITOR, disable tracing when you are done; otherwise, every session that meets the criteria specified will be traced.*

---

**Enabled Tracing Views**

DBA_ENABLED_TRACES and DBA_ENABLED_AGGREGATIONS are the views to look at to see what enabled tracing and statistics gathering is in place. You can use these views to make sure all the tracing options have been disabled. The following example shows the output from the DBA_ENABLED_TRACES view:
The TRCSESS utility allows trace data to be selectively extracted from multiple trace files and saved into a single trace file based on criteria such as session ID or module name. This command-line utility is especially useful in connection pooling and shared server configurations, where each user request could end up in a separate trace file. TRCSESS lets you obtain consolidated trace information pertaining to a single user session.

This consolidated trace file can be created according to several criteria:

- Session ID
- Client ID
- Service name
- Action name
- Module name

The command syntax for TRCSESS is as follows:

```
trcsess [output] [session=] [clientid=] [service=] [action=] [module=] [trace file names]
```

**output** = output destination default being standard output.

**session** = The SID and Serial# of the session to be traced, in the format SID.Serial#.

**clientid** = clientid to be traced.

**service** = service to be traced.

**action** = action to be traced.

**module** = module to be traced.

**trace file names** = list of trace file names, separated by spaces, which need to be searched by the trcsess command. If no files are listed, then all the files in the current directory will be searched. The wild card character, *, may be used in the file names.
Example 1
This is from one of the examples in the earlier section “Using DBMS_MONITOR,” where SERVICE_NAME = EBK2, MODULE= SALARY_UPDATE, and ACTION = INSERT_ITEM. Go to the DIAGNOSTIC_DEST directory or ADR_HOME, the location is `<DIAGNOSTIC_DEST dir>/rdbms/DB_NAME/SID/trace, and run the following command:

```
trcsexx output combo.trc service "ebk2" module "salary update" action "insert item"
```

This searches all the trace files that meet the preceding criteria and creates a consolidated trace file named combo.trc.

Now TKPROF can be run against combo.trc:

```
tkprof combo.trc output=combo_report sort=fchela
```

Example 2
Set the client ID:

```
SQL> exec dbms_session.set_identifier('ebk3');
```

Enable tracing for the client ID:

```
SQL> execute dbms_monitor.client_id_trace enable ('ebk3');
```

Trace by this client ID, and then issue this command (from the directory as before):

```
trcsexx output=combo2.trc clientid=ebk3 *.trc
```

TRCSESS checks all the trace files for the specified client ID. Now TKPROF can be run against combo2.trc (the combined trace file).

Example 3
In the first case, all the trace files in the current directory are used as input, and a single trace file (combo3.trc) is created, with all session=17.1988 trace information. (Note that 17.1988 is the <SID>.<Serial#>.)
In the second case, only the two trace files listed are used as input and a single trace file (combo4.trc) is created, with all session=17.1988 trace information from the two trace files listed.

**Using EXPLAIN PLAN Alone**

The EXPLAIN PLAN command allows developers to view the query execution plan that the Oracle optimizer uses to execute a SQL statement. This command is very helpful in improving the performance of SQL statements because it does not actually execute the SQL statement—it only outlines the plan and inserts this execution plan in an Oracle table. Prior to using the EXPLAIN PLAN command, a file called utlxplan.sql (located in the same directory as catalog.sql, typically ORACLE_HOME/rdbms/admin) must be executed under the Oracle account that will be executing the EXPLAIN PLAN command.

The script creates a table called PLAN_TABLE that the EXPLAIN PLAN command uses to insert the query execution plan in the form of records. This table can then be queried and viewed to determine if the SQL statement needs to be modified to force a different execution plan. Oracle supplies queries to use against the PLAN_TABLE table, too: utlxpls.sql and utlxplp.sql. Either will work, but utlxplp.sql is geared toward parallel queries. An EXPLAIN PLAN example is shown next (executed in SQL*Plus).

**Q. Why use EXPLAIN without TRACE?**

A. The statement is *not* executed; it only shows what will happen if the statement is executed.

**Q. When do you use EXPLAIN without TRACE?**

A. When the query will take an exceptionally long time to run.

The procedures for running TRACE vs. EXPLAIN are demonstrated here:

```
1
TABLE ACCESS
BY ROWID
ON CUSTOMER

2
INDEX
RANGE SCAN
ON IX_CUST_PHONE
```
1. Find the script; it is usually in the ORACLE_HOME/rdbms/admin directory:
   utlxplan.sql

2. Execute the script utlxplan.sql in SQL*Plus:
   @utlxplan (run this as the user who will be running the EXPLAIN plan)
   This script creates the PLAN_TABLE for the user executing the script. You can create your own PLAN_TABLE, but use Oracle’s syntax—or else!

3. Run EXPLAIN PLAN for the query to be optimized (the SQL statement is placed after the FOR clause of the EXPLAIN PLAN statement):
   
   ```sql
   explain plan for
   select       CUSTOMER_NUMBER
   from         CUSTOMER
   where        CUSTOMER_NUMBER = 111;
   Explained.
   ```

4. Optionally, you can also run EXPLAIN PLAN for the query to be optimized using a tag for the statement:
   
   ```sql
   explain plan
   set statement_id = 'CUSTOMER' for
   select       CUSTOMER_NUMBER
   from         CUSTOMER
   where        CUSTOMER_NUMBER = 111;
   ```

   **TIP**
   Use the SET STATEMENT_ID = ‘your_identifier’ when the PLAN_TABLE will be populated by many different developers. I rarely use the SET STATEMENT_ID statement. Instead, I explain a query, look at the output, and then delete from the PLAN_TABLE table. I continue to do this (making changes to the query) until I see an execution plan that I think is favorable. I then run the query to see if performance has improved. If multiple developers/DBAs are using the same PLAN_TABLE, the SET STATEMENT_ID (case sensitive) is essential to identifying a statement.

5. Select the output from the PLAN_TABLE:
   
   ```sql
   select operation, options, object_name, id, parent_id
   from     plan table
   where    statement id = 'CUSTOMER';
   ```

<table>
<thead>
<tr>
<th>Operation</th>
<th>Options</th>
<th>Object Name</th>
<th>ID</th>
<th>Parent</th>
</tr>
</thead>
<tbody>
<tr>
<td>select statement</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Table Access</td>
<td>By ROWID</td>
<td>Customer</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Range Scan</td>
<td>CUST IDX</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>
TIP
Use EXPLAIN instead of TRACE so you don’t have to wait for the query to run. EXPLAIN shows the path of a query without actually running the query. Use TRACE only for multiquery batch jobs to find out which of the many queries in the batch job are slow.

TIP
You can use the utlxpls.sql and utlxplp.sql queries provided by Oracle to query the plan table without having to write your own query and without having to format the output.

An Additional EXPLAIN Example for a Simple Query
This section walks you through a simple process of running a query and then checking the EXPLAIN PLAN for the information about how the query will be processed.

1. Run the query with the EXPLAIN syntax embedded prior to the query:

```
explain plan
set statement_id = 'query 1' for
select customer_number, name
from customer
where customer_number = '111';
```

2. Retrieve the output of EXPLAIN by querying the PLAN_TABLE.

To retrieve the information for viewing, you must execute a SQL statement. Two scripts provided in the Oracle documentation are displayed in Steps 2 and 3, along with the results of each based on the previous EXPLAIN PLAN command. Note that this example varies from the last example. The CUSTOMER_NUMBER column is an indexed number field, which, in the second example, is suppressed because of a datatype mismatch (111 is in quotes, forcing a TO_CHAR operation). In the first example, I treated the CUSTOMER_NUMBER column correctly as a number field (111 is not in quotes). At times, the optimizer is smart enough not to do this to you, but when you use Pro*C or other similar coding, the optimizer may not be able to translate this for you.

```
select operation, options, object_name, id, parent_id
from plan_table
where statement_id = 'query 1'
order by id;
```

<table>
<thead>
<tr>
<th>Operation</th>
<th>Options</th>
<th>Object_Name</th>
<th>TD</th>
<th>Parent TD</th>
</tr>
</thead>
<tbody>
<tr>
<td>select Statement</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Table Access</td>
<td>Full</td>
<td>Customer Information</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Alternatively, you could just run the utlxpls.sql script.

3. Retrieve more intuitive and easy-to-read output for EXPLAIN:

```sql
select lpad('', 2*(level-1)) || operation || ' ' || options || ' ' || decode(id, 0, 'Cost = ', ' '| 'position) "Query Plan"
from plan_table
start with id = 0
and statement_id = 'query 1'
connect by prior id = parent id
and statement_id = 'query 1';
```

Here is the output:

```
Query Plan
select statement       Cost=220
 Table Access Full Customer
```

EXPLAIN PLAN—Read It Top to Bottom or Bottom to Top?

Whether you should read from top to bottom or bottom to top depends on how you write the query that retrieves the information from the PLAN_TABLE table. This is probably why many people disagree about which way to read the result. (All methods may be correct.) The following listing shows the order of execution based on the query that retrieves the information. In this example, the output is read top to bottom, with one caveat: you must read it from the innermost to the outermost. This listing shows a method that should clear up any questions:
delete from plan_table;
explain plan:
set statement_id = 'SQL1' for
select to_char(sysdate, 'MM/DD/YY HH:MI AM'), to_char(trunc((sysdate - 4 - 1), 'day') + 1), 'DD-MON-YY')
from bk, ee
where bk_shift_date <= to_char(trunc((sysdate - 4), 'DD-MON-YY'))
and bk_empno = ee_empno()
order by cc_job_group, bk_empno, bk_shift_date
/
select LPad(' ', 2*(Lvcl-1)) || Lvcl || '.' || Nvl(Position,0)|| ' ' ||
   Operation || ' ' || OPTIONS || ' ' || Object_Name || ' ' || Object_Type || ' ' ||
   Decode(id, 0, Statement_Id || ' Cost = ' || Position) || cost ||
   ' ' || Object_Node "Query Plan"
from plan_table
start with id = 0 And statement_id = 'SQL1'
connect by prior id = parent_id
and statement_id = 'SQL1'
/
Query Plan
1.0 SELECT STATEMENT SQL1 Cost =
2.1 SORT ORDER BY (7th)
3.1 FILTER (6th)
4.1 NESTED LOOPS OUTER (5th)
  5.1 TABLE ACCESS BY ROWID BK (2nd)
    6.1 INDEX RANGE SCAN BK 06 NON-UNIQUE (1st)
  5.2 TABLE ACCESS BY ROWID EE (4th)
    6.2 INDEX UNIQUE SCAN I EE 01 UNIQUE (3rd)

Reading the EXPLAIN PLAN

Using the previous EXPLAIN PLAN, I will elucidate the steps. The numbers in the left column in Table 6-4 identify each step. They are listed in the order in which they are executed.
### Setting AUTOTRACE ON

There is also an easier method available for generating an EXPLAIN PLAN and statistics about the performance of a query with SQL*Plus. The main difference between AUTOTRACE and EXPLAIN PLAN is that AUTOTRACE actually executes the query (in the way TRACE does) and automatically queries the plan table, whereas EXPLAIN PLAN does neither. The AUTOTRACE command generates similar information, as shown in the next listing. To use AUTOTRACE, the user must possess the PLUSTRACE role (by running `plustrce.sql`, which is usually located in the `ORACLE_HOME/sqlplus/admin` directory).

```sql
SET AUTOTRACE ON
select count(last_name)
from emp
where name = 'branches';
```
The AUTOTRACE option provides an EXPLAIN PLAN and statistics for a query. AUTOTRACE provides many of the TRACE and TKPROF statistics such as disk reads (physical reads) and total reads (consistent reads + db block gets).

TIP
If the error "Unable to verify plan table format or existence" occurs when enabling AUTOTRACE, you must create a plan table using the utlxplan.sql script.
CAUTION

AUTOTRACE may fail when querying system views because the user may not have permission to view underlying objects.

Table 6-5 shows other AUTOTRACE options.

<table>
<thead>
<tr>
<th>Option</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>SET AUTOT ON</td>
<td>Turn on AUTOTRACE (short way)</td>
</tr>
<tr>
<td>SET AUTOT OFF</td>
<td>Turns off AUTOTRACE (short way)</td>
</tr>
<tr>
<td>SET AUTOT ON EXP</td>
<td>Shows only the EXPLAIN PLAN</td>
</tr>
<tr>
<td>SET AUTOTRACE ON STAT</td>
<td>Shows only the statistics</td>
</tr>
<tr>
<td>SET AUTOTRACE TRACE</td>
<td>Does not show the output of the query</td>
</tr>
</tbody>
</table>

TABLE 6-5. AUTOTRACE Options

EXPLAIN PLAN When Using Partitions

Table partitions yield different outputs for their EXPLAIN PLANs (as shown in the following listing). Here, I’ve created a table with three partitions and a partitioned index. Broadly speaking, partitions are tables stored in multiple places in the database. For more information on partitioning tables, refer to Chapter 3.
I now generate an EXPLAIN PLAN that forces a full table scan to access the first two partitions:

```
create table dept1
(deptno number(2),
 dept_name varchar2(30))
partition by range(deptno)
(partition d1 values less than (10),
 partition d2 values less than (20),
 partition d3 values less than (maxvalue));
```

```
insert into dept1 values (1, 'DEPT 1');
insert into dept1 values (7, 'DEPT 7');
insert into dept1 values (10, 'DEPT 10');
insert into dept1 values (15, 'DEPT 15');
insert into dept1 values (22, 'DEPT 22');
```

```
create index dept_index
on dept1 (deptno)
local
(partition d1,
 partition d2 ,
 partition d3 );
```

I now generate an EXPLAIN PLAN that forces a full table scan to access the first two partitions:

```
explain plan for
select dept_name
from dept1
where deptno || '' = 1
or deptno || '' = 15;
```

When selecting from the plan table, you must select the additional columns PARTITION_START (starting partition) and PARTITION_STOP (ending partition). For a full table scan, all partitions will be accessed:

```
select operation, options, id, object_name, partition_start, partition_stop
from plan table;
```

The output (for the full table scan) is shown here:

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>ID</th>
<th>OBJECT_NAME</th>
<th>PARTITION_START</th>
<th>PARTITION_STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARTITION</td>
<td>CONCATENATED</td>
<td>0</td>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>PARTITION RANGE: RANGE</td>
<td>PARTITION</td>
<td>0</td>
<td>DEPT</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
The preceding example shows that a full table scan on the DEPT1 table is performed. All three partitions are scanned. The starting partition is 1, and the ending partition is 3.

Next, an EXPLAIN PLAN is generated in the following listing for an index range scan of partition 2 only (ensure that you delete from the plan table to clear it):

```
explain plan for select dept_name
from dept1
where deptno = 15;
Explained.
```

Now I generate an EXPLAIN PLAN for an index range scan accessing only the second partition:

```
select operation, options, id, object_name, partition_start, partition_stop
from plan_table;
```

The output (for the index range scan) is shown here:

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>ID</th>
<th>OBJECT_NAME</th>
<th>PARTITION_START</th>
<th>PARTITION_STOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARTITION RANGE</td>
<td>SINGLE</td>
<td>1</td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>TABLE ACCESS BY LOCAL INDEX PREDICTION</td>
<td>RANGE SCAN</td>
<td>2</td>
<td>DEPT1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>INDEX</td>
<td></td>
<td>3</td>
<td>DEPT INDEX</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

This output shows that the only partition of the table or index that is accessed is the second partition. This is because the value for DEPTNO = 15 is within the second partition of the DEPT1 table. The DEPTNO column is also indexed, and this value is also within the second partition of the index.

**TIP**

Partitions can also be viewed by the EXPLAIN PLAN by accessing the columns PARTITION_START and PARTITION_STOP in the PLAN_TABLE table.

**Finding High Disk and/or Memory Reads Without Using TRACE**

Is there another method for retrieving problem disk and memory read information without tracing everything? Yes! By using V$SQLAREA, you can find the problem queries on your system. This next listing shows how to find the problem queries. In this query, you are searching for queries where the
disk reads are greater than 10,000 (missing or suppressed index potentials). If your system is much larger, you may need to set this number higher.

```sql
select disk_reads, sql_text
from v$sglarea
where disk_reads > 10000
order by disk_reads desc;
```

<table>
<thead>
<tr>
<th>DISK READS</th>
<th>SQL TEXT</th>
</tr>
</thead>
</table>
| 12987      | select order#, columns, types from orders
|            | where substr(orderid, 1, 2) = 1 |
| 11131      | select custid, city from customer
|            | where city = 'CHICAGO' |

This output suggests that there are two problem queries causing heavy disk reads. The first has the index on ORDERID suppressed by the SUBSTR function; the second shows that there is a missing index on CITY.

In the query in the following listing, you are searching for queries where the memory reads are greater than 200,000 (over-indexed query potentials). If your system is much larger, you may need to set this number higher.

```sql
select buffer_gets, sql_text
from v$sglarea
where buffer_gets > 200000
order by buffer_gets desc;
```

<table>
<thead>
<tr>
<th>BUFFER GETS</th>
<th>SQL TEXT</th>
</tr>
</thead>
</table>
| 300219      | select order#, cust_no, from orders
|            | where division = '1' |

The output suggests that one problem query is causing substantially heavy memory reads (300,219 blocks of data read into memory). The index on DIVISION appears to have a cardinality of 1 because this table has only a single division. What’s happening here is that the entire index is being read and then the entire table is being read. The index should be suppressed for this statement to improve performance (and perhaps should be removed permanently if additional divisions will not be added).

**TIP**

Accessing the V$SQLAREA table can give statistics that are often found when tracing a query. See **Chapter 12** for additional information on accessing V$SQLAREA.
Tracing/Explaining Problem Queries in Developer Products

Although you can issue the ALTER SESSION SET SQL_TRACE TRUE command on the SQL*Plus command line to TRACE SQL statements, doing this is tough when it comes to using developer products. One drawback to this option is that you are not able to trace a form or report; you need to cut the code out of the form or report and run it from SQL*Plus. This process can be very time-consuming if you do not know which statements you need to trace.

There is another way to create a trace of the execution of a form. If you are using Forms (versions 6i, 10g, and 11g), you can include statistics = yes on the command line. This way, you are able to trace individual forms. Later versions of Oracle Forms and Oracle Reports (all part of Fusion Middleware) allow tracing from inside a form or report. Please refer to the Forms and/or Reports (Fusion Middleware) documentation for an explanation of how to use these options. Oracle Applications often has a menu item to do this as well. You could also use DBMS_MONITOR to trace these products. Lastly, some methods for tracing PL/SQL programs are available: DBMS_PROFILER, DBMS_TRACE, and DBMS_HPROF.

TIP
You can also use TRACE within the Fusion Middleware (Developer) products. You simply need to set statistics = yes on the command line for some products, or you may embed the tracing within an actual trigger to turn tracing on and off.

Important Columns in the PLAN_TABLE Table

The descriptions for some of the more important columns available in the PLAN_TABLE table are as follows:

- **STATEMENT_ID** The value of the option STATEMENT_ID parameter specified in the EXPLAIN PLAN statement.
- **TIMESTAMP** The date and time when the EXPLAIN PLAN statement was issued.
- **REMARKS** Any comment (up to 80 bytes) you wish to associate with each step of the EXPLAIN PLAN. If you need to add or change a remark on any row of the PLAN_TABLE table, use the UPDATE statement to modify the rows of the PLAN_TABLE table.
- **OPERATION** The name of the internal operation performed in this step. In the first row generated for a statement, the column contains one of four values: DELETE, INSERT, SELECT, or UPDATE, depending on the type of statement.
- **OPTIONS** A variation on the operation described in the OPERATION column. See Chapter 7.
TIP
The OPERATION and OPTIONS columns of the PLAN_TABLE are the most important columns for tuning a query. The OPERATION column shows the actual operation performed (including type of join), and the OPTIONS column tells you when a full table scan is being performed (that may need an index).

- **OBJECT_NODE** The name of the database link used to reference the object (a table name or view name). For local queries using the parallel query option, this column describes the order in which output from operations is consumed.
- **OBJECT_OWNER** The name of the user who owns the schema containing the table or index.
- **OBJECT_NAME** The name of the table or index.
- **OBJECT_INSTANCE** A number corresponding to the ordinal position of the object as it appears in the original statement. The numbering proceeds from left to right, outer to inner, with respect to the original statement text. Note that view expansion results in unpredictable numbers.
- **OBJECT_TYPE** A modifier that provides descriptive information about the object, for example, NON-UNIQUE for indexes.
- **OPTIMIZER** The current optimizer mode.
- **ID** A number assigned to each step in the execution plan.
- **PARENT_ID** The ID of the next execution step that operates on the output of the ID step.

TIP
The PARENT_ID column is very important because it shows the dependencies of two steps in an EXPLAIN PLAN. If a step in the EXPLAIN PLAN has a PARENT_ID, it implies that this statement must run prior to the PARENT_ID that is specified.

- **POSITION** The order of processing for steps that all have the same PARENT_ID.
- **OTHER** Other information that is specific to the execution step that a user may find helpful.
- **OTHER_TAG** The contents of the OTHER column.
- **COST** The cost of the operation as estimated by the optimizer’s cost-based approach. The value of this column does not have any particular unit of measurement; it is merely a weight value used to compare costs of execution plans.
CARDINALITY The cost-based approach’s estimate of the number of rows accessed by the operation.

BYTES The cost-based approach’s estimate of the number of bytes accessed by the operation.

OTHER_XML This column can be queried to find out extra information that the optimizer used to determine the execution plan.

TIP
The BYTES column is extremely important when evaluating how to tune a query. When an index is used and the number of bytes is great, it implies that doing a full table scan would perhaps be more efficient (i.e., reading the index and data is more costly than just reading the data in a full table scan). Also, the number of bytes helps you determine which table should be accessed first in the query (driving table) because one table may limit the number of bytes needed from another. See Chapter 9 for tips on choosing the driving table.

TIP
Remember that both the COST and BYTES values in a query are estimates; it is quite possible for a version of a query with a higher estimated cost or bytes to run faster than another with a lower value.

Using DBMS_XPLAN

DBMS_XPLAN is one of the most common and best ways to query the execution plan of a query quickly. It automatically queries the last plan in PLAN_TABLE when you use the DBMS_XPLAN.DISPLAY procedure. There are a couple of other options as well to display it in different ways, but most people like it because it’s a quick way to see the last execution plan as they are tuning a query. It will also give additional information after the execution plan. It will highlight filter versus join conditions and let you know if the plan table is current. It will also display a warning message if an old version of the plan table is being used. Keep in mind that OPERATION column text truncation might be a problem if you don’t set the LINESIZE as shown in the following example. The DBMS_XPLAN package has the following table functions:

DISPLAY Display the last query plan

DISPLAY_CURSOR Display contents and execution plan of any loaded cursor (can specify SQL_ID)

DISPLAY_AWR Display contents and execution plan of stored SQL statement in AWR
DISPLAY_SQLSET  Display contents and execution plan of statements in a SQL Tuning Set

The following is a DBMS_XPLAN example (run this after you run an EXPLAIN PLAN on a query):

```
SET LINESIZE 130
SET PAGESIZE 0

select * from table (dbms_xplan.display);
```

```
PLAN_TABLE_OUTPUT

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost</th>
<th>Start</th>
<th>Stop</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>UPDATE STATEMENT</td>
<td>.JOURNAL_LINE</td>
<td>328</td>
<td>2296</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>UPDATE</td>
<td>.JOURNAL_LINE</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>PARTITION RANGE ALL</td>
<td>.JOURNAL_LINE</td>
<td>328</td>
<td>2296</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
```

Note: cpu costing is off, 'PLAN_TABLE' is old version
11 rows selected.

There is an additional procedure to display the plan stored in AWR (AWR is covered in Chapter 14) or in a Tuning Set (more on this in Chapter 8). The following are queries to look at SQL Plan Baselines (covered in Chapter 8) and a quick query to display a cursor (query V$SQL or other V$ views to get the cursor; Chapter 12 covers V$ views):

```
DBMS_XPLAN_DISPLAY_SQL_PLAN_BASELINE
| sql_handle IN VARCHAR2  := NULL, |
| plan_name IN VARCHAR2 := NULL, |
| format IN VARCHAR2 := 'TYPICAL' <'BASIC'/ALL'> |
RETurn dbms_xplan type table;

select * from table (dbms_xplan.display cursor('ahvccymgw92jw'));
```

There are many options for different levels of statistics, specific child numbers of a cursor, and the ability to use your own plan table. Please check the Oracle docs for additional information. A few more quick examples are listed here:

```
select * from table (dbms_xplan.display (null, null, 'basic'));
select * from table (dbms_xplan.display (null, null, 'typical'));
select * from table (dbms_xplan.display (null, null, 'all'));
```
Initialization Parameters for Undocumented TRACE

One area that the experts can investigate is the X$KSPPI table. A brief listing for undocumented TRACE parameters in init.ora is shown here (see Appendix A for additional information). Note that Oracle does not support use of undocumented features of the product.

```
select x$kppinn "Parameter Name", kspstvl "Value", kspptstdf "Default"
from x$ksppi x, x$ksspnev y
where x.indx = y.indx
and x$kppinn like '/ %trace% escape '/'
```

TIP
The X$KSPPI table can be accessed only by the SYS user. See Chapter 13 for tips on accessing the X$ tables and using some of these parameters. Do not use any undocumented parameters without consulting My Oracle Support. Also, the layout and column names of these views have been known to change between Oracle releases.

Tracing Errors Within Oracle for More Information

This section explains the use of one of the undocumented features of TRACE. Before using undocumented initialization parameters, please contact My Oracle Support. To TRACE errors for a session, you can set an event in the initialization parameters file (see Chapter 13 for more information). You can also trace sessions for errors by running the query shown next (used to TRACE a 4031 error). These queries build a TRACE file in your USER_DUMP_DEST that will contain a dump of the full error text.

Use the following command to trace sessions for errors:

```
alter session set events='4031 trace name errorstack level 4';
```

TIP
Tracing queries can help performance, but using the TRACE facility built into the undocumented TRACE init.ora parameters (discussed previously) can give you great insight into solving errors within Oracle.
Tracing by Enabling Events

Trace sessions can also be initiated by using this command:

```sql
SQL> Alter session set events '10046 trace name context forever, level 1';
Session altered.
```

The value of the level (1 in the previous command) can be 1 (regular trace), 4 (trace bind variables), 8 (trace wait states), or 12 (regular trace, plus bind variables and wait states). Information about bind variables and wait states can then appear in the trace file but will be ignored by TKPROF when formatting the report. The trace file output for the previous command looks like this:

```
SELECT SYSDATE FROM DUAL WHERE SYSDATE IN ( :d1 )
END OF BODY
```

To turn event tracing off, use the following command:

```sql
SQL> Alter session set events '10046 trace name context off';
Session altered.
```

Oracle 11g introduced a new syntax for setting events that makes it easier to trace processes without knowing the SID or SERIAL# (see My Oracle Support Note 813737.1 for additional information). You can now use the following command instead:

```sql
alter system set events 'sql trace {process : ospid = 2345} level=12';
```

Using Stored Outlines

Oracle8i introduced a facility called STORED OUTLINES that allows a query to use a predetermined execution plan every time that query is run, no matter where the query is run from. While the use of STORED OUTLINES was deprecated (discouraged) in 11g, they are still used and thus covered here briefly (sections following this will cover converting STORED OUTLINES to SQL Plan Management and SQL Plan Baselines). People sometimes speak of the STORED OUTLINES as storing an
execution plan, but this is not really what happens. Instead, Oracle stores a series of hints—
instructions to the database to execute a query in a precise way—to duplicate the execution plan as
saved during a recording session.

Oracle can replicate execution plans for queries using STORED OUTLINES through a process
similar to using the EXPLAIN PLAN functionality in SQL*Plus. First, you set up the STORED
OUTLINE session by telling Oracle to save outlines for queries you are about to run using the ALTER
SESSION command. Next, you execute the query for which you want the outline stored. (You
generally do this on a session-only basis so as not to affect other users.) Finally, if the execution plan
is acceptable, you can save it to the database so it can be used by everyone everywhere. STORED
OUTLINES have been largely replaced by SPM (SQL Plan Management).

**Dropping Stored Outlines**

How do you get rid of STORED OUTLINES when you don’t want them anymore or when they impact
performance negatively? Use the DROP UNUSED procedure in the DBMS_OUTLN package.

To drop all unused outlines:

```sql
execute dbms_outln.drop_unused
```

To remove outlines that have been used, first apply the DBMS_OUTLN.CLEAR_USED
procedure, which accepts an outline name (available from the USER_OUTLINES view) and can be
run against only one outline at a time. You could write a short PL/SQL program to clear outlines en
masse.

To determine whether an outline is actually being used, examine the USED column in
USER_OUTLINES. You can also query the OUTLINE_CATEGORY column in the V$SQL view to
see things that are still in the cache.

```sql
SELECT OUTLINE_CATEGORY, OUTLINE_SID
FROM V$SQL
WHERE SQL_TEXT = 'portion of query%'
```

**Using SQL Plan Management (SPM) and SPM Example**

SQL Plan Management has been added to help preserve the performance of SQL statements by only
allowing execution plans that improve the performance of the statement being executed. SPM is
similar to, yet different from, STORED OUTLINES. Like STORED OUTLINES, SPM’s goal is to
stabilize the execution plan of a SQL statement. STORED OUTLINES freeze an execution plan for a
SQL statement, whereas SPM allows a new execution plan to be selected as long as it improves the
performance of the SQL statement. Some of the reasons that you would need SPM include:
- New version of Oracle (new optimizer version—use capture/replay to test effect)
- Changes to optimizer statistics or data changes
- Schema, application, or metadata changes (use SQL Advisor to get suggestions)
- System settings changes (use SQL Replay to find what works)
- SQL Profile (statistics—data skews and correlated columns) creation

**TIP**

*STORED OUTLINES* freeze an execution plan whereas *SPM* allows a new execution plan as long as the plan improves the performance of the SQL statement. If both a stored outline and an SPM plan exist for a SQL statement, the stored outline takes precedence.

---

## SPM Terms

The following are terms related to the SMB hierarchy.

- **Main components of SPM:**
  - **Plan capture** Creation of the SQL Plan Baseline that stores accepted execution plans.
  - **Plan selection** Any new execution plans for an accepted statement are initially stored as unaccepted plans in the SQL Plan Baseline.
  - **Plan evolution** Evaluation of all unaccepted plans and only plans which increase performance by a certain threshold are changed to accepted and used.

- **SQL Management Base (SMB)** SQL Plan History and SQL Plan Baseline are located within the SMB. The SMB is located in the SYSAUX tablespace and also contains SQL profiles.

- **SQL Plan History** A subset of SMB that includes both *accepted* and *not accepted* plans generated for a SQL statement.

- **SQL Plan Baseline** A subset of SQL Plan History that includes only the set of accepted plans generated for a SQL statement.

- **Flags** Used to indicate the status of an execution plan in the SMB:
  - **Enabled** The default value for an execution plan in Plan History or Plan Baseline is ENABLED.
  - **Accepted** The plan needs to be accepted before it can be considered to be used.
  - **Fixed** The plan takes precedence over other execution plans.
  - **Reproduced** Automatically set to YES when the CBO (Cost-Based Optimizer) is able to
Adaptive (new in 12c) The plan has been determined to be an adaptive plan and not accepted; once the plan is accepted, the adaptive flag will be set to NO.

The illustration on the next page shows a target chart of how this hierarchy looks.

The following are terms related to the status of plans:

- **Accepted plan** A plan must be both ENABLED and ACCEPTED in order to be considered by the optimizer.

- **Enabled plan** The default value for an execution plan in Plan History or Plan Baseline is ENABLED. A plan must be both ENABLED and ACCEPTED to be considered by the optimizer.

- **Fixed plan** This execution plan gets priority over other plans for a SQL statement unless there are other FIXED plans, in which case the FIXED plan with the best performance is selected.

Some other terms associated with SPM include

- **AUTOPURGE** A plan is automatically purged from Plan History if it has not been used for 53 weeks (based on the LAST_EXECUTED date in DBA_SQL_PLAN_BASELINES). This date can be modified using the DBMS_SPM.CONFIGURE package.

- **OPTIMIZER_USE_SQL_PLAN_BASELINES** The database parameter that determines if
OPTIMIZER_CAPTURE_PLAN_BASELINES Any SQL statements executed while this parameter is set to TRUE are added to the Plan Baseline (but not necessarily ACCEPTED). The default is FALSE.

DBA_SQL_PLAN_BASELINES A view for gathering information about Plan Baselines that have been created.

TIP
A SQL Plan Baseline must be both ENABLED and ACCEPTED to be considered by the optimizer.

Using SPM

SPM is enabled and SQL statements are stored in the SQL Management Base using the following method:

1. Set the OPTIMIZER_CAPTURE_PLAN_BASELINES parameter to TRUE at the system or session level.
2. Use the SQL Tuning Set (see Chapter 29 of the Oracle Database 12c SQL Tuning Guide for details).
3. Extract the statement from the shared pool using the DBMS_SPM.LOAD_PLANS_FROM_CURSOR_CACHE function (see the Oracle Database 12c SQL Tuning Guide, Chapter 29, for details).

Note that only repeatable SQL statements (that is, statements that have been parsed or executed more than once) are considered by SPM.

SPM is helpful for

- Database upgrades
- System and/or data changes
- Deployment of new application modules

SPM Example

Here is an example of how SPM works:

1. Turn capture on and run the SQL statement more than once so SPM can determine if the statement is repeatable, and then turn capture off:
2. Query DBA_SQL_PLAN_BASELINES to determine the status of the SQL statement in SPM:

```
select plan_name, sql_handle, enabled, accepted, fixed, module, sql_text
from dba_sql_plan_baselines;
```

<table>
<thead>
<tr>
<th>PLAN_NAME</th>
<th>SQL_HANDLE</th>
<th>ENABLED</th>
<th>ACCEPTED</th>
<th>FIXED</th>
<th>MODULE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQL_PLAN_19f32b4c3279c279d5260ad3</td>
<td>SQL*Plus</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>SQL*Plus</td>
</tr>
</tbody>
</table>

Note that ENABLED is YES, ACCEPTED is YES, and FIXED is NO. Also note the module that was used to add this plan (SQL*Plus).

3. Now make a change to the environment (index added) and run the SQL statement again:

```
create index ellen on emp(job);
alter session set optimizer_capture_sql_plan_baselines=true;
select /* ebk1 */ from emp where job='PRESIDENT';
select /* ebk1 */ from emp where job='PRESIDENT';
alter session set optimizer_capture_sql_plan_baselines=false;
```

4. Query DBA_SQL_PLAN_BASELINES to determine the status of the SQL statement in SPM:

```
select plan_name, sql_handle, enabled, accepted, fixed, module, sql_text
from dba_sql_plan_baselines;
```

<table>
<thead>
<tr>
<th>PLAN_NAME</th>
<th>SQL_HANDLE</th>
<th>ENABLED</th>
<th>ACCEPTED</th>
<th>FIXED</th>
<th>MODULE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQL_PLAN_19f32b4c3279c279d5260ad3</td>
<td>SQL*Plus</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>SQL*Plus</td>
</tr>
<tr>
<td>SQL_PLAN_19f32b4c3279c279d5260ad3</td>
<td>SQL*Plus</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>SQL*Plus</td>
</tr>
</tbody>
</table>

Note that another PLAN NAME was added (with the same SQL_HANDLE) that has an ACCEPTED value of NO, which means the optimizer will not consider this plan.

Now I’m going to set OPTIMIZER_USE_SQL_PLAN_BASELINE to FALSE and allow the optimizer to choose a plan (not necessarily in the Plan Baseline). Then I will set the OPTIMIZER_USE_SQL_PLAN_BASELINE to TRUE and force the optimizer to choose only an accepted plan in the Plan Baseline.
Using DBMS_XPLAN tells you what actually happened versus an EXPLAIN PLAN, which tells you what’s intended (by comparing the two, you can see if something changed from what execution plan was intended/started and what execution plan was eventually used/ended with). Note that in the first case, the optimizer chooses a plan that makes use of the index, but, in the second case, it did not because that plan was not an ACCEPTED plan.

The next step is to evolve a SQL plan to allow a plan with an ACCEPTED status of NO to be changed to YES if the plan performs better than plans that already have an ACCEPTED value of YES:
report clob;
BEGIN
report := DBMS_SPM.EVOLVE_SQL_PLAN_BASELINE(
    sql_handle => 'SYS_SQL_1ba5c312d5260ad3');
DBMS_OUTPUT.PUT_LINE(report);
END;
/

Here is the output:
Note that the plan, which was previously not ACCEPTED, is now ACCEPTED:
Now when I run the SQL statement with OPTIMIZER_USE_SQL_PLAN_BASELINE set to TRUE, this newly ACCEPTED plan is chosen because it performs better than other ACCEPTED plans for this SQL statement:

```sql
alter system set optimizer_use_sql_plan_baselines=true;

explain plan for
select /* ebkl */ * from emp where job='PRESIDENT';
select * from table(dbms_xplan.display(null,null,'basic'));

PLAN_TABLE_OUTPUT
Plan hash value: 3484773680

<table>
<thead>
<tr>
<th>id</th>
<th>Operation</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>TABLE ACCESS BY INDEX ROWID</td>
<td>EMP</td>
</tr>
<tr>
<td>2</td>
<td>INDEX RANGE SCAN</td>
<td>ELLEN</td>
</tr>
</tbody>
</table>
```

Using Fixed SQL Plan Baselines

Fixed plans (if present) are used instead of any other plans in the Plan Baseline for a SQL statement. If more than one Fixed plan exists for a SQL statement, then the Fixed plan with the best performance is used. Here is an example of how to set a plan to FIXED:
Dropping a Plan

Here is an example of how to drop a plan using the SQL_HANDLE:

```sql
DECLARE
  l_plan_dropped pls_integer;
BEGIN
  l_plan_dropped := DBMS_SPM.drop_sql_plan_baseline
    (sql_handle => 'SYS_SQL_976227df3c76f615', plan_name => NULL);
END;
/

set serveroutput on
declare
  l_plan_dropped pls_integer;
begin
  l_plan_dropped := DBMS_SPM.drop_sql_plan_baseline
    (sql_handle => 'SYS_SQL_976227df3c76f615', plan_name => NULL);
end;
/
```

Converting from Stored Outlines to SQL Plan Management

Now I will walk you through an example of how to convert a SQL statement from using STORED OUTLINES to using SQL Plan Management.

To create a stored outline:

```
DECLARE
  l_plan_dropped pls_integer;
BEGIN
  l_plan_dropped := DBMS_SPM.drop_sql_plan_baseline
    (sql_handle => 'SYS_SQL_976227df3c76f615', plan_name => NULL);
END;
/
```
To use the stored outline:

```
alter session set query_rewrite_enabled = true;
alter session set create_stored_outlines = true;
create or replace outline key outline on select /* ebk2 */ from emp where job = 'PRESIDENT';
Session altered.
Session altered.
Outline created
```

The following shows the status of the stored outline:

```
select *
from  user_outlines;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>CATEGORY</th>
<th>USED</th>
<th>TIMESTAMP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VERSION</th>
<th>SQL_TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SIGNATURE</th>
<th>COMPATIBLE</th>
<th>ENABLED</th>
<th>FORMAT</th>
<th>MIGRATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that the MIGRATED status field shows it to be NOT-MIGRATED and the USED status field shows it to be USED.

To migrate this stored outline to a Plan Baseline:
To migrate all stored outlines:

```sql
DECLARE
  uw_outlines CLOB;
BEGIN
  uw_outlines := dbms_spm.migrate_stored_outline('ALL');
END;
/
```

To retrieve the status of the stored outline and the plan outline after the migration:

```sql
select * from user_outlines;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>CATEGORY</th>
<th>USED</th>
<th>TIMESTAMP</th>
<th>VERSION</th>
<th>SQL_TEXT</th>
<th>SIGNATURE</th>
<th>COMPATIBLE</th>
<th>ENABLED</th>
<th>FORMAT</th>
<th>MIGRATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Note that ACCEPTED is set to YES for the PLAN OUTLINE and MIGRATED is set to MIGRATED for STORED OUTLINE. Because the status of the STORED OUTLINE is MIGRATED, the optimizer will not look at the STORED OUTLINE when determining which plan to use.

To drop the migrated stored outline:

```
DECLARE
    drp_outline PLS_INTEGER;
BEGIN
    drp_outline := DBMS_SPM.DROP_MIGRATED_STORED_OUTLINE();
END;
/
```

This drops all migrated stored outlines.

---

Adaptive Plans (12c New Feature) and SPM

The concept of an adaptive plan is that the execution of a statement can start with one execution plan (say, for instance, a join using nested loops) and switch to another (join using a Hash Join) during execution without rerunning based on what it’s seeing (statistics-wise) while it’s running. Statistic collectors are set at critical points during the plan execution to see if the actual execution is varying greatly from what was expected originally, based on the statistics. This allows Oracle to compare actual row counts (during the execution) with estimates (prior to execution that were used). If the difference in the comparison crosses certain thresholds, Oracle will switch to a better execution plan.
during execution. If automatic plan capture is enabled and the SQL statement is identified as an adaptive plan, only the plan that is executed will be captured in the baseline if a plan for the SQL statement does not already exist in the baseline. If a plan already exists in the baseline, then the new plan will be marked as ADAPTIVE and that plan will be checked during the evolve process (either the automatic or manual evolve process—see the next section for an example). Oracle also ensures the next execution of this statement will use the new execution plan.

Adaptive SQL Plan Management

There have been changes in 12c to the process of evolving SQL Plan Baselines. SYS_AUTO_SPM_EVOLVE_TASK is a new automatic evolve task that runs in the default maintenance window (normally starting at 22:00 M–F and 6:00 Sat–Sun). The task is used to rank all unaccepted plans and run the evolve process on those plans. Unaccepted plans whose performance is better than the existing accept plan(s) by a defined amount are “evolved” to an ACCEPTED status. In addition to this automatic evolve process, there is also a manual evolve process.

Settings for the task SYS_AUTO_SPM_EVOLVE_TASK are listed next. DBMS_SPM.set_evolve_task_parameter can be used to change parameters.

```
col parameter_name format a30
col parameter_value format a45

select parameter_name, parameter_value
from  dba_advisor_parameters
where  task_name = 'SYS AUTO SPM EVOLVE TASK'
and    parameter_value != 'UNUSED'
order by parameter_name
/
```

<table>
<thead>
<tr>
<th>PARAMETER NAME</th>
<th>PARAMETER VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCEPT PLANS</td>
<td>TRUE</td>
</tr>
<tr>
<td>ALTERNATE PLAN Baseline</td>
<td>EXISTING</td>
</tr>
<tr>
<td>ALTERNATE PLAN LIMIT</td>
<td>0</td>
</tr>
<tr>
<td>ALTERNATE_PLAN_SOURCE</td>
<td>CURSOR_CACHE+AUTOMATIC_WORKLOAD_REPOSITORY</td>
</tr>
<tr>
<td>DAYS_TO_EXPIRE</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT EXECUTION TYPE</td>
<td>SPM EVOLVE</td>
</tr>
<tr>
<td>EXECUTION DAYS TO EXPIRE</td>
<td>30</td>
</tr>
<tr>
<td>JOURNALING</td>
<td>INFORMATION</td>
</tr>
<tr>
<td>MODE</td>
<td>COMPREHENSIVE</td>
</tr>
<tr>
<td>TARGET_OBJECTS</td>
<td>1</td>
</tr>
<tr>
<td>TIME_LIMIT</td>
<td>3600</td>
</tr>
<tr>
<td>SPM_VERIFY</td>
<td>TRUE</td>
</tr>
</tbody>
</table>

Evolving SQL Plan Baseline Manually Using an Example
Here is the initial setup: Table EBKM_TAB has 10,000 rows with no indexes. The OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES = TRUE and OPTIMIZER_USE_SQL_PLAN_BASELINES = TRUE. The following SQL statement will be executed several times in this test:

```
select *
from   ebkm_tab
where  emp_id = 500;
```

Following is the initial run of the SQL statement:

```
select *
from   ebkm_tab
where  emp_id = 500;
```

**Execution Plan**

Plan hash value: 618037802

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>25</td>
<td>14</td>
<td>(0)</td>
</tr>
<tr>
<td>*</td>
<td>TABLE ACCESS FULL</td>
<td>EBKM_TAB</td>
<td>1</td>
<td>25</td>
<td>14</td>
<td>(0)</td>
</tr>
</tbody>
</table>

Another execution is needed so that the SQL is added to the SQL Plan Baseline:
Now an index is added to the EMP_ID column of the EBKM_TAB table and stats are computed:

```
create index ebkm_tab_idx on ebkm_tab(emp_id);
Index created.
EXECUTE DBMS_STATS.GATHER_SCHEMA_STATS(ownname -> 'KEVIN');
PL/SQL procedure successfully completed.
```

Rerun the original SQL statement:

```
select *
from   ebkm_tab
where  emp_id = 500;
```
A second SQL_HANDLE has been added for the SQL statement but with ACCEPTED = NO:

```
select plan_name, sql_handle, enabled, accepted, fixed, adaptive, sql_text
from dba_sql_plan_baselines
where creator='KEVIN'
and sql_text like '%ebkn_t%';
```

The first step in manually evolving the statement is the CREATE_EVOLVE_TASK:
Use the TASK_NAME in the following EXECUTE_EVOLVE_TASK:

```sql
SQL> SET SERVEROUTPUT ON
SQL> DECLARE
    2 l_return VARCHAR2(32767);
    3 BEGIN
    4 l_return := DBMS_SPM.create_evolve_task(sql_handle => 'SQL_1dbf17892fe02b98');
    5 DBMS_OUTPUT.put_line('Task Name: ' || l_return);
    6 END;
    7 /
Task Name: TASK 1992
```

Use TASK_NAME and EXECUTION_NAME in the following REPORT_EVOLVE_TASK:

```sql
SQL> SET SERVEROUTPUT ON
SQL> DECLARE
    2 l_return VARCHAR2(32767);
    3 BEGIN
    4 l_return := DBMS_SPM.execute_evolve_task(task_name => 'TASK_1992');
    5 DBMS_OUTPUT.put_line('Execution Name: ' || l_return);
    6 END;
    7 /
Execution Name: EXEC 2142
```
SQL> SELECT DBMS_SPM_report.evolve_task(task_name => 'TASK_1992', execution_name => 'EXEC_2142') AS output  
   2 FROM dual;

OUTPUT

GENERAL INFORMATION SECTION

Task Information:

<table>
<thead>
<tr>
<th>Task Name</th>
<th>TASK_1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Owner</td>
<td>KEVIN</td>
</tr>
<tr>
<td>Execution Name</td>
<td>EXEC_2142</td>
</tr>
<tr>
<td>Execution Type</td>
<td>SPM EVOLVE</td>
</tr>
<tr>
<td>Scope</td>
<td>COMPREHENSIVE</td>
</tr>
<tr>
<td>Status</td>
<td>COMPLETED</td>
</tr>
<tr>
<td>Started</td>
<td>06/05/2016 07:12:50</td>
</tr>
<tr>
<td>Finished</td>
<td>06/05/2016 07:12:59</td>
</tr>
<tr>
<td>Last Updated</td>
<td>06/05/2016 07:12:59</td>
</tr>
<tr>
<td>Global Time Limit</td>
<td>2147483646</td>
</tr>
<tr>
<td>Per-Plan Time Limit</td>
<td>UNUSED</td>
</tr>
<tr>
<td>Number of Errors</td>
<td>0</td>
</tr>
</tbody>
</table>

SUMMARY SECTION

Number of plans processed : 1
Number of findings      : 1
Number of recommendations: 1
Number of errors        : 0

DETAILS SECTION

Object ID : 2
Test Plan Name    : SQL_PLAN_1vgsrj4ry3awzd2487c70
Base Plan Name    : SQL_PLAN_1vgsrj4ry3awzd4fe1fc32
SQL Handle        : SQL_1dbf17892fe02b99
Parsing Schema    : KEVIN
Test Plan Creator : KEVIN
SQL Text          : select * from chkm_tab where cmp id = 500
Execution Statistics:

<table>
<thead>
<tr>
<th></th>
<th>Base Plan</th>
<th>Test Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elapsed Time (s)</td>
<td>.0000028</td>
<td>.0000003</td>
</tr>
<tr>
<td>CPU Time (s)</td>
<td>.0000033</td>
<td>0</td>
</tr>
<tr>
<td>Buffer Gets</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Optimizer Cost</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Disk Reads</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Direct Writes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rows Processed</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Executions</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

FINDINGS SECTION

Findings {1}:

1. The plan was verified in 0.09200 seconds. It passed the benefit criterion because its verified performance was 18.01110 times better than that of the baseline plan.

Recommendation:

Consider accepting the plan. Execute
dbms_spn.accept_sql_plan_baseline(task_name => 'TASK_1992', object_id => 2,
task_owner => 'XEVIN');

EXPLAIN PLANS SECTION

Baseline Plan

<table>
<thead>
<tr>
<th>Plan Id</th>
<th>203</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plan Hash Value</td>
<td>1340210226</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>25</td>
<td>14</td>
<td>00:00:01</td>
</tr>
<tr>
<td>*1</td>
<td>TABLE ACCESS FULL</td>
<td>EBKM_TAB</td>
<td>1</td>
<td>25</td>
<td>14</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

Predicate Information (identified by operation id):

* 1 - filter("EMP ID"=500)
The unaccepted plan has met the performance improvement criteria and can be changed to an accepted plan:
The new accepted plan is now being used:

```sql
SELECT * FROM emp WHERE emp_id = 503;
```

**Execution Plan**

Plan hash value: 13220998e9

<table>
<thead>
<tr>
<th>TID</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytest</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>1</td>
<td>TABLE ACCESS BY INDEX ROWID</td>
<td>EMPM_TAB</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>INDEX RANGE SCAN</td>
<td>EMPM_TAB_IDX</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Setting TIMED_STATISTICS = TRUE in the init.ora will enable the collection of time statistics. The initialization parameter SQL_TRACE has been deprecated (may go away in the future).

The TKPROF utility converts traced output into a readable format. Without running TKPROF, reading the output of a TRACE would be difficult. By specifying `explain = username/password`, you can get the EXPLAIN execution path, in addition to the execution statistics for the query. There is also an option for a PDB (pluggable database) in R12.

Run TKPROF from the command line without any parameter for a list of all the parameters.

A traced query with a large number of physical reads may indicate a missing index.

The trace file is a point-in-time picture of what happened on the system at the time that the trace was run (includes the row source operation). In contrast, the EXPLAIN PLAN is generated when the TKPROF listing is created, which could be some time later. The row source operation listing is generated as part of the trace file and can be used to see if the database objects have changed since the TRACE was performed.

Full table scans are one of the first things Oracle pushes out of memory (becoming least recently used as soon as you run them) because they are so inefficient, generally using a lot of memory.

Using a value of ALL_EXECUTIONS for the PLAN_STAT ensures that information regarding the execution plan is always contained in the trace file.

When using DBMS_MONITOR, disable tracing when you are done; otherwise, every session that meets the criteria specified will be traced.

Use the SET STATEMENT_ID = 'your_identifier' when the PLAN_TABLE will be populated by many different developers. I rarely use the SET STATEMENT_ID statement. Instead, I explain a query, look at the output, and then delete from the PLAN_TABLE table. I continue to do this (making changes to the query) until I see an execution plan that I think is favorable. I then run the query to see if performance has improved. If multiple developers/DBAs are using the same PLAN_TABLE, the SET STATEMENT_ID (case sensitive) is essential to identifying a statement.

Use EXPLAIN instead of TRACE so you don’t have to wait for the query to run. EXPLAIN shows the path of a query without actually running the query. Use TRACE only for multiquery batch jobs to find out which of the many queries in the batch job are slow.

You can use the utlxpls.sql and utlxplp.sql queries provided by Oracle to query the PLAN_TABLE table without having to write your own query and format the output.

Whether the EXPLAIN PLAN is read from top to bottom or from bottom to top depends entirely on the query used to select information from the PLAN_TABLE. Both methods of reading the query may be correct, given that the query selecting the information is correctly structured.
If the error “Unable to verify plan table format or existence” occurs when enabling AUTOTRACE, you must create a PLAN_TABLE using utlxplan.sql.

AUTOTRACE may fail when querying system views because the user may not have permission to view underlying objects.

Partitions can also be viewed by the EXPLAIN PLAN by accessing the columns PARTITION_START and PARTITION_STOP in the PLAN_TABLE table.

Accessing the V$SQLAREA table can give statistics that are often found when tracing a query.

You can also use TRACE within the Fusion Middleware (Developer) products. You simply need to set statistics = yes on the command line for some products, or you may embed the tracing within an actual trigger to turn tracing on and off.

The OPERATION and OPTIONS columns of the PLAN_TABLE are the most important columns for tuning a query. The OPERATION column shows the actual operation performed (including type of join), and the OPTIONS column tells you when a full table scan is being performed (that may need an index).

The PARENT_ID column is very important because it shows the dependencies of two steps in an EXPLAIN PLAN. If a step in the EXPLAIN PLAN has a PARENT_ID, it implies that this statement must run prior to the PARENT_ID that is specified.

The BYTES column is extremely important when evaluating how to tune a query. When an index is used and the number of bytes is great, it implies that doing a full table scan would perhaps be more efficient (i.e., reading the index and data is more costly than just reading the data in a full table scan). Also, the number of bytes helps you determine which table should be accessed first in the query (driving table) because one table may limit the number of bytes needed from another.

Both the COST and BYTES values in a query are estimates; it is quite possible for a version of a query with a higher estimated cost or bytes to run faster than another with a lower value.

The X$KSPPI table can be accessed only by the SYS user. See Chapter 13 for tips on accessing the X$ tables and using some of these parameters. Do not use any undocumented parameters without consulting My Oracle Support. Note that the layout and column names of these views have been known to change between Oracle releases.

Tracing queries can help performance, but using the TRACE facility built into the undocumented TRACE init.ora parameters can give you great insight into solving errors within Oracle.

STORED OUTLINES freeze an execution plan whereas SQL Plan Management allows a new execution plan as long as the plan improves the performance of the SQL statement. If both a stored outline and an SPM plan exist for a SQL statement, the stored outline takes precedence.

A SQL Plan Baseline must be both ENABLED and ACCEPTED to be considered by the optimizer.

An adaptive plan is one in which the execution of a statement can start with one execution plan (a join using nested loops) and switch to another (join using a Hash Join) during execution.
without rerunning based on what it’s seeing (statistics-wise) while it’s running. Statistic collectors are set at critical points during the plan execution to see if the actual execution is varying greatly from what was expected originally, based on the statistics. If the difference in the comparison crosses certain thresholds, Oracle will switch to a better execution plan during execution. Comparing EXPLAIN PLAN (execution at start) to DBMS_XPLAN (final plan at completion), you can see the before/after plans.

References

My Oracle Support (Metalink) Notes: 293661.1, 13737.1, 726802.1.

Oracle Database 12c SQL Tuning Guide (Oracle Corporation).

Many thanks to Warren Bakker for upgrading this chapter to Oracle 12c, 11g, and 10g. Thanks to Mark Riedel for previously upgrading this chapter to Oracle9i, and to Dave Hathway, Greg Pucka, and Roger Behm for their original contributions to this chapter.
Although the cost-based optimizer is incredibly accurate in choosing the correct optimization path and use of indexes for thousands of queries on your system, it is not perfect (even with 12c Adaptive Query Optimization). To this end, Oracle provides hints that you can specify for a given query to override the optimizer, hopefully achieving better performance for a given query. This chapter focuses on the basic syntax and use of hints. The chapters following this one (Chapters 8 and 9) have more complex examples, using various hints covered in this chapter.

Because every system is diverse, the most useful hints for your system may not be the same ones that I have found to be best. Common to most systems is the use of the FULL, INDEX, ORDERED, and LEADING hints. A system with the parallel option may use the PARALLEL hint most often. In 12c, some of the best hints are those related to the In-Memory (IM) column store (INMEMORY and NO_INMEMORY hints), those related to pluggable databases (CONTAINERS hint), and those related to Adaptive Query Optimization (ADAPTIVE_PLAN and AUTO_REOPTIMIZE hints). Lastly, I do cover the hint that’s not an optimizer hint (WITH_PLSQL). Other hints that were introduced in 11g that you might not be using yet include RESULT_CACHE, MONITOR, and NO_MONITOR. Several formerly supported hints were removed from the Oracle Database SQL Language Reference (these were deprecated/discouraged/unsupported): RULE, the anti-join hints (HASH_AJ, NL_AJ, MERGE_AJ), the semi-join hints (HASH_SJ, NL_SJ, MERGE_SJ), ROWID, and AND_EQUAL.

Tips covered in this chapter include the following:

- The top hints used, the available hints and groupings, and specifying multiple hints
- When using an alias, the necessity to use the alias, not the table name, in the hint
- Using the FIRST_ROWS hint generally to force the use of indexes
- Using the ALL_ROWS hint generally to force a full table scan
- Using the FULL hint to perform a full table scan
- Using the INDEX hint to affect the use of an index
- Using the NO_INDEX hint to disallow a specified index from being used
- Using the INDEX_ASC hint to use an index ordered in ascending order
- Using the INDEX_DESC hint to use an index ordered in descending order
Using the INDEX_JOIN hint to allow the merging of indexes on a single table
- Using the INDEX_COMBINE hint to access multiple bitmap indexes
- Performing fast full scans with the INDEX_FFS hint
- Using the ORDERED hint to specify the driving order of tables
- Using the LEADING hint to specify just the first driving table
- Using the NO_EXPAND hint to avoid OR expansion
- Using queries involving multiple locations and the DRIVING_SITE hint
- Using the USE_MERGE, USE_NL, and USE_HASH hints to change how tables are joined internally
- Processing subqueries earlier with PUSH_SUBQ
- Using the parallel query option and PARALLEL and NO_PARALLEL
- Using APPEND and NOAPPEND for faster data inserts
- Caching and pinning a table into memory with the CACHE hint in the buffer cache
- Using the NOCACHE hint
- Caching table data with the RESULT_CACHE in the shared pool
- Overriding the CURSOR_SHARING setting with the CURSOR_SHARING_EXACT hint
- Using the INMEMORY and NO_INMEMORY hints (only 12.1.0.2+)
- Using the USE_INVISIBLE_INDEXES hint (12c)
- Using the CONTAINERS hint (12c)
- Using the WITH_PLSQL hint (12c)
- Miscellaneous hints and notes from 12c and other versions

Top Hints Used
I did an informal survey at TUSC to see which hints both DBAs and developers use in their day-to-day tuning. I asked them to give me only the top three that they used. The results were not surprising to me, but if you’ve never used hints, this is quite helpful in determining where to start. Here is the list of TUSC’s top hints, in the order in which they are used (I personally use INDEX, ORDERED, PARALLEL, LEADING, FULL, APPEND, and NO_INDEX the most):

1. INDEX
2. ORDERED
3. PARALLEL
4. FIRST_ROWS
5. FULL
6. LEADING
7. USE_NL
8. APPEND
9. USE_HASH
10. RESULT_CACHE

NOTE
The top three in this list are also the top three that I’ve used the most since hints were introduced. I’ve frequently used all of these in my tuning, so they are a great place to start.

The Top Hints list will probably be expanded to add these five new hints by 12cR2:

1. INMEMORY/NO_INMEMORY
2. USE_INVISIBLE_INDEXES
3. CONTAINERS
4. AUTO_REOPTIMIZE/ADAPTIVE_PLAN
5. WITH_PLSQL

Use Hints Sparingly

Hints fall into two primary categories: usage directives and compiler directives. **Usage directives** are those that can be set using initialization parameters in addition to the statement level (i.e., FIRST_ROWS, ALL_ROWS). If you have an OLTP database, setting the optimizer (at the instance level) from ALL_ROWS to FIRST_ROWS immediately focuses the optimizer on returning the first few rows faster (best response time for most OLTP applications). Setting the optimizer (at the instance level) to ALL_ROWS immediately focuses the optimizer on returning all rows faster (best throughput for all rows, which may be preferred for batch operations or data warehouses). The hints you give the optimizer influence its choices for join operations and the order of operations. In both database cases (OLTP and data warehouse), the goal is to solve performance issues system-wide instead of needing to tune individual queries.

When there are queries inside a data warehouse that behave more like OLTP queries or vice versa, you may need to use hints for those specific statements. As you begin to use hints, you may find yourself tuning the same type of problem over and over, an indication that you have improper instance-level settings or improper database structures (missing indexes or I/O contention, for example) that are impacting performance. Tuning the symptoms (using **compiler directives** in the short term) leads you to the pattern that can be fixed for the long term. Then you will hopefully be able to apply a usage directive to fix the problem system-wide. Try to use hints with this in mind and you’ll use them only rarely.
Hints are best used sparingly. Hints are called “hints” and not “commands” for a reason: the cost-based optimizer may reject the instruction if it decides that the query will perform better without implementing the hint. Furthermore, hints can perform unpredictably when used with other hints, upgrading the database, applying patches, or changing database initialization/session parameters. Hints can provide valuable functionality, but you should only use them when other ways of achieving the same goals do not work.

Fix the Design First

In a three-table join, depending on the column order of the index on the intersection table, the query usually accesses the tables in a particular order. By correctly indexing the intersection table and the joined columns of the other tables, you will eliminate many of your performance problems before they happen. If you are using an ORDERED or LEADING hint over and over for joins, review the indexes on the joined tables to help you change how the optimizer is looking at the problem. Rewriting SQL statements so they correctly use indexes will also solve many of your problems, eliminating the need for a hint. Putting a function on an indexed column may suppress the index and cause the tables to drive differently (be read in a different order). Use hints when you have exhausted the other avenues for tuning a query. If you find that you are using the same hint for the same problem over and over, you almost certainly have a problem that can be fixed system-wide instead. Always try to unlock the system problem inside each query-level issue. This also helps you avoid the pain caused by hints working differently when you upgrade to a new version.

For example, consider a typical three-table join between STUDENT, CLASS, and STUDENT_CLASS tables. The STUDENT table contains one row for each student, the CLASS table contains one row for each CLASS, and the STUDENT_CLASS table is the intersection table, as multiple students attend multiple classes. The primary keys for the tables may look like this:

STUDENT primary key STUDENT_ID
CLASS primary key CLASS_ID
STUDENT_CLASS concatenated primary key of (CLASS_ID, STUDENT_ID)

When the primary keys are defined in this manner, Oracle automatically creates indexes to support them. The intersection table, STUDENT_CLASS, has a concatenated index on two columns, CLASS_ID and STUDENT_ID, with CLASS_ID as the leading column. Is this the best column order for all of the application's queries? Unless you can forecast all of the queries that will join these tables, you should create a second index on the STUDENT_CLASS table’s primary key columns:

STUDENT_CLASS secondary index on (STUDENT_ID, CLASS_ID)

When processing a join of these three tables, the optimizer can now choose to begin at either the STUDENT or CLASS table and will have an available index on STUDENT_CLASS that will support its needs. You may find that the secondary index is rarely used—but it is there when it is needed to support application users and their related business processes. By designing the indexing structures to support multiple access paths, you give the optimizer the tools it needs to choose the best execution path without resorting to a hint.
Available Hints and Groupings

The available hints vary according to the version of the database installed. While this chapter focuses on frequently used hints, many hints that are not covered in detail may give great performance gains for someone with a particular system. Hint functionality and syntax is listed in the Oracle documentation in the *Oracle Database SQL Language Reference*.

Hints are separated into the different categories described in the following sections according to which type of operation is being modified by the hint. Each hint is discussed in detail, including syntax and examples, in the sections that follow. The view V$SQL_HINT lists the available hints, the version in which they became available, and the hint class (such as ACCESS, CACHE, etc.).

### Execution Path

Hints modify the execution path when an optimizer processes a particular statement. The instance-level parameter OPTIMIZER_MODE can be used to modify all statements in the database to follow a specific execution path, but a hint to a different execution path overrides anything that is specified in the instance parameter file. If a SQL statement has a hint specifying an optimization approach and goal, then the optimizer should use the specified approach regardless of the presence or absence of statistics, the value of the OPTIMIZER_MODE initialization parameter, and the OPTIMIZER_MODE parameter of the ALTER SESSION statement. Oracle also notes this in its documentation: If these statistics have not been gathered, or if the statistics are no longer representative of the data stored within the database, then the cost-based optimizer does not have sufficient information to generate the best plan.

Hints that change the execution path include the following:

- **ALL_ROWS**
- **FIRST_ROWS(n)**

### Access Methods

The hints that are grouped into access methods allow the coder to vary the way the data is accessed. This group of hints is most frequently used, especially the INDEX hint. The INDEX hint provides direction as to whether and how indexes are used, and how the corresponding indexes will be merged to get the final answer.

The access method hints are listed here and described later in this chapter:

- **FULL**
- **INDEX, INDEX_ASC, INDEX_DESC**
- **NO_INDEX, NO_INDEX_FFS, NO_INDEX_SS**
- **INDEX_COMBINE**
Query Transformation Hints

Query transformation hints are especially helpful in a data warehouse if you are familiar with using fact and dimension tables. The FACT hint can designate a given table to be the FACT or driving table for a query. The NO_FACT hint does the opposite. The STAR_TRANSFORMATION hint is used to access the fact table efficiently when joining multiple tables. The NO_STAR_TRANSFORMATION hint instructs the optimizer *not* to perform a star query transformation when you have a schema whose structure appears to be that of a data warehouse but isn’t actually. Persuading the cost-based optimizer to use star plans is assisted by using bitmap indexes instead of b-tree indexes.

Some of the query transformations have nothing to do with star queries. Many transformations take place behind the scenes without using hints at all, but hints are available to help this process along. MERGE requests index values (not table values) as the primary data source; REWRITE rewrites a query to access a materialized view instead of source tables; and UNNEST works with subqueries to restructure the query to use a table join. Use NO_QUERY_TRANSFORMATION to avoid query transformations.

The query transformation hints are:

- FACT, NO_FACT
- MERGE, NO_MERGE
- USE_CONCAT, NO_EXPAND
- NO_QUERY_TRANSFORMATION
- REWRITE, NO_REWRITE
- STAR_TRANSFORMATION, NO_STAR_TRANSFORMATION
- UNNEST, NO_UNNEST

Join Operations

The join operations group of hints controls how joined tables merge data together. A join operation may direct the optimizer to choose the best path for retrieving all rows for a query (*throughput*) or for retrieving the first row (*response time*).

Two hints are available to influence join order directly. LEADING specifies a table to start with for the join order to use, whereas ORDERED tells the optimizer to join the tables based on their order in the FROM clause, using the first table listed as the driving table (*accessed first*).

Hints available to direct the use of join operations include...
Parallel Execution

The parallel execution group of hints applies to databases using the parallel option (only available with Oracle Enterprise Edition). These hints override the table specification for the degree of parallelism.

The parallel execution hints are

- PARALLEL, NO_PARALLEL
- PARALLEL_INDEX, NO_PARALLEL_INDEX

Other Hints

Other hints are not easily grouped into categories. The APPEND and NOAPPEND hints can be used without the parallel option, but they are frequently used with it. The cache grouping pertains to the hints that will put items as most recently used (CACHE) or least recently used (NOCACHE).

Like APPEND and CACHE, the following hints are available to influence the ways in which the optimizer processes the table accesses:

- APPEND, NOAPPEND
- CACHE, NOCACHE
- CURSOR_SHARING_EXACT
- DRIVING_SITE
- DYNAMIC_SAMPLING
- MODEL_MIN_ANALYSIS
- PUSH_PRED, NO_PUSH_PRED
- PUSH_SUBQ, NO_PUSH_SUBQ
- QB_NAME
- OPT_PARAM
- RESULT_CACHE, NO_RESULT_CACHE
Specifying a Hint

If you incorrectly specify a hint in any way, it becomes a comment and is ignored. No error is issued because the botched hint becomes a comment (unless the comment structure itself is incorrect). Be very careful to get the hint syntax exactly correct. The best way to ensure that a hint has been correctly specified is to run an EXPLAIN PLAN (or DBMS_XPLAN), or set AUTOTRACE to ON in SQL*Plus to see if the hint was used; check to see if the execution plan is producing the expected results if the hint should affect the plan. Some hints are overridden by the optimizer despite the fact that a hint is primarily for influencing decisions made by the Oracle optimizer. The basic hint syntax (in this example, it is for a FULL hint) is shown here. Note that the difference in these two formats is that the first uses multiline comment delimiters and the second uses inline comment delimiters. If you use the inline comment delimiter, then anything that comes after it (like column names) is ignored. You must continue the query on the next line.

```sql
select /*+ FULL(table) */ column1, ...
```

or

```sql
select --+FULL(table)
column1, ...
```

The (TABLE) in the preceding code snippet is the table name on which to perform a full table scan, or the alias for the table if you specified an alias in the FROM clause, as shown here:

```sql
select /*+ FULL(employees) */ employee_id, last_name, department_id
from employees
where department_id = 1;
```

In this example, even if you have an index on the DEPARTMENT_ID column, a full table scan should be performed. The hint is not required to be uppercase. If using block comments with hints, be careful not to try to comment out the hinted text later with an enclosing block comment. The database ignores the second start block comment marker (it will be commented), uses the first closing block comment marker (from the hint) to close the initial block comments, and raises a syntax error when the second, unmatched block comment terminator is found.

```sql
select /* FULL(employees) */ employee_id, last_name, department_id
from employees
where department_id = 1;
```

In this query, if there were an index on the DEPARTMENT_ID column, the index would be used
because the hint is missing the plus sign (+) and becomes a comment.

When a hint accepts multiple arguments, spaces or commas may separate arguments:

```sql
SELECT /*+ index(employees emp emp id pk emp job ix) */ ... 
```

or

```sql
SELECT /*+ index(employees, emp emp id pk, emp job ix) */ ... 
```

**TIP**

Incorrect hint syntax leads to the hint being interpreted as a comment. If an additional hint is specified correctly, it will be used.

By default, hints only affect the code block in which they appear. If you hint the access of the EMPLOYEES table in a query that is part of a UNION operation, the other queries within the UNION are not affected by your hint. If you want all of the unioned queries to use the same hint, you need to specify the hint in each of the queries. This also applies to views, subqueries, and subquery factoring (the WITH clause).

You can specify the query block name in hints to specify the query block to which the hint applies. Thus, in an outer query, you can specify a hint that applies to a subquery. The hint syntax for the `QUERY_BLOCK` argument is in the form

```sql
@query_block
```

where `QUERY_BLOCK` is a user-specified or system-generated identifier. Use the QB_NAME hint to specify the name for the query block. If you are using system-generated hints, you can view the query block names via the EXPLAIN PLAN for the query (an example is given later in this chapter).

**Specifying Multiple Hints**

You can use more than one hint at a time, although this may cause some or all of the hints to be ignored. Separate hints with spaces, as shown here:

```sql
SELECT /*+ FULL(table) CACHE(table), */ column1, ...
```
The (TABLE) in this code snippet is the table name to perform the full scan and cache on:

```sql
select /*+ FULL(employees) CACHE(employees)*/
  employee_id, last_name, department_ID
from employees
where department id = 1;
```

**TIP**

Multiple hints are separated with a space. Specifying multiple hints that conflict with each other causes the query to use none of the conflicting hints.

**When Using an Alias, Hint the Alias, Not the Table**

When you use aliases on a given table that you want to use in a hint, you must specify the alias and not the table name in the hint. If you specify the table name in the hint when an alias is used, the hint is not used.

```sql
select /*+ FULL(table) */ column1,...
```

The (TABLE) in this code snippet has to be replaced with the alias that follows since the query uses an alias. If an alias is used, the alias must be used in the hint or the hint will not work:

```sql
select /*- FULL(A) */ employee id, last name, department id
from employees A
where department id = 1;
```

**TIP**

If an alias is used, the alias must be used in the hint or the hint will not work.

**The Hints**

The hints discussed here are available as of Oracle Database 12c Release 1 as well as being available in Oracle Database 12c Release 2. Consult the Oracle documentation for more information.
As of 11g and continuing into 12c, Oracle Database automatically maintains optimizer statistics if it is enabled. The database automatically collects optimizer statistics for tables with absent or stale statistics. If fresh statistics are required for a table, then the database collects them both for the table and associated indexes. The automatic optimizer statistics collection runs as part of AutoTask and is enabled by default to run in all predefined maintenance windows (which means, once daily). Automatic optimizer statistics collection relies on the modification monitoring feature. This monitoring is enabled by default when STATISTICS_LEVEL is set to TYPICAL or ALL. Monitoring tracks the approximate number of INSERTs, UPDATEs, and DELETEs for that table and whether the table has been truncated since the last time statistics were gathered. If a monitored table has been modified more than 10 percent, then these statistics are considered stale and gathered again. You use the DBMS_STATS package to manage the statistics manually. Adaptive Query Optimization (discussed in Chapter 8 in detail) improves the Oracle optimizer.

The Oracle Demo Sample HR Schema

I used the sample Oracle demo HR schema to produce the examples that follow. In some cases, I created additional objects to facilitate working with some of the hints where they were not created with the sample schema.

```
create bitmap index employees first name bmp on employees(first name);
create bitmap index employees commission bmp on employees(commission pct);
```
inner table. The inner table shortens the result set that is joined back to the outside table in the query, and specifying access paths overrides this hint.

You may also specify the number of rows (as in the second example that follows) that you want FIRST_ROWS to optimize getting (the default is one). Note that this is specified in powers of 10 up to 1000. Using FIRST_ROWS \( (n) \) is totally based on costs and is sensitive to the value of \( n \). With small values of \( n \), the optimizer tends to generate plans that consist of nested loops joins with index lookups. With large values of \( n \), the optimizer tends to generate plans that consist of hash joins and full table scans (behaving more like ALL_ROWS).

**Syntax**

```sql
select /*+ FIRST_ROWS(n) */ column1, ...
```

**Example**

```sql
select /*= FIRST_ROWS */ employee_id, last_name, department_id
from employees
where department_id = 1;
```

**Example**

```sql
select /*+ FIRST_ROWS(10) */ employee_id, last_name, department_id
from employees
where department_id = 1;
```

**TIP**

The FIRST_ROWS hint causes the optimizer to choose a path that retrieves the first row (or a specified number of rows) of a query fastest, at the cost of retrieving multiple rows slower. The FIRST_ROWS hint may be set as the default for the entire database by setting `OPTIMIZER_MODE = FIRST_ROWS` in the system parameter file; query-level hints will override the default setting for a given query. You can also set the optimizer to FIRST_ROWS_n (see Chapter 4 for additional information).
The ALL_ROWS Hint

The ALL_ROWS (*best throughput*) hint directs a query to optimize a query on the basis of retrieving all of the rows the fastest. This approach is especially helpful when users of the system are in a heavy batch report environment and running reports that retrieve a lot of rows. This would be a poor choice for a heavy transaction processing environment where users are trying to view a single record on a screen. The ALL_ROWS hint may suppress the use of indexes that under normal circumstances would have been used. Specifying access path hints overrides the use of this hint.

Syntax

```sql
select /*+ ALL_ROWS */ column1, ...
```

Example

```sql
select /*= ALL_ROWS */ employee id, last name, department id
from employees
where department id = 1;
```

TIP

*The ALL_ROWS hint causes the optimizer to choose a path that retrieves all the rows of a query fastest, at the cost of retrieving one single row slower. The ALL_ROWS hint may be set as the default for the entire database by setting OPTIMIZER_MODE = ALL_ROWS (the default) in the system parameter file; query-level hints will override the default setting for a given query.*

The FULL Hint

The FULL hint directs a query to override the optimizer and perform a full table scan on the specified table in the hint. The FULL hint has different functionality based on the query that you are tuning. You can use it to force a full table scan when a large portion of the table is being queried. The cost of retrieving the index *and* the rows may be greater than just retrieving the entire table. The FULL hint may also cause an unexpected result. Causing a full table scan may cause tables to be accessed in a different order, because a different driving table is used. This may lead to better performance, leading one to believe that the full table scan was the key benefit, when changing the order of the driving table was the real cause of the improved performance.
Syntax

```sql
select /*+ FULL([query block] table) */ column1,...
```

Here, *(TABLE)* is the table name to perform the full scan on. If an alias is used, the alias *must* be used in the hint or it will *not* work.

Note that you should only specify the table name in the hint, not the schema name.

Example

```sql
select /*+ FULL(employees) */ employee_id, last_name, department_id
from employees
where department_id = 1;
```

The FULL hint in this example would be particularly helpful if the only department in the company was one (1). Going to an index on DEPARTMENT_ID and the EMPLOYEES table would be slower than simply performing a full table scan on the EMPLOYEES table.

The FULL hint is also a necessary part of using some of the other hints. The CACHE hint can cache a table in memory only when the full table is accessed. Some of the hints in the parallel grouping also necessitate the use of a full table scan. I cover each of these hints later in this chapter.

TIP

*The FULL hint performs a full table scan on the table that is specified, not all tables in the query. The FULL hint may also lead to better performance, which is attributable to causing a change in the driving table of the query and not to the actual full table scan.*

If multiple tables have the same name in the same query, assign aliases to them in the FROM clause and then reference the aliases in the hints.

The INDEX Hint

The INDEX hint is frequently used to request one or more indexes to be used for a given query. Oracle generally chooses the correct index or indexes with the optimizer, but when the optimizer chooses the wrong index or no index at all, this hint is excellent. You may also use multiple indexes with this hint, and Oracle will choose one or more of the indexes specified based on the best plan. If you only specify one index, the optimizer considers only the specified index.
Syntax

Example

In the preceding example, the EMP_EMP_ID_PK index on the EMPLOYEES table is used.

Example

In the second example, Oracle may use the EMP_DEPARTMENT_IX index or the EMP_EMP_ID_PK index or a merge of both of them. I've given these choices to the optimizer to decipher the best choice. It would have been best, however, to only specify the index on the EMPLOYEE_ID column (EMP_EMP_ID_PK) if this were the most restrictive statement (usually much more restrictive than the department).

TIP

The INDEX hint causes the optimizer to choose the index specified in the hint. Multiple indexes for a single table can be specified, but it is usually better to specify only the most restrictive index on a given query (and, that way, avoid the merging of each index's result). If multiple indexes are specified, Oracle chooses which (one or more) to use, so be careful or your hint could potentially be overridden.

Example
In this example, no index is specified. Oracle now weighs all of the possible indexes that are available and chooses one or more to be used. Since I have not specified a particular index, but I have specified the INDEX hint, the optimizer should *not* do a full table scan.

**TIP**

The INDEX hint, without a specified index, should not consider a full table scan, even though no indexes have been specified. The optimizer will choose the best index or indexes for the query.

As of Oracle Database 10g, you can specify column names as part of the INDEX hint. The columns can be prefixed with the table names (not table aliases). Each column listed in the hint must be a physical column in the table, not an expression or calculated column.

**Syntax**

```sql
select /*+ INDEX (query_block) [table.]column1 [table2.column2...] */ column1, ...
```

**Example**

```sql
select /*+ INDEX (employees.department_id) */ employee_id, last_name
from employees
where department_id = 1;
```

**The NO_INDEX Hint**

The NO_INDEX hint disallows the optimizer from using a specified index. This is a great hint for tuning queries with multiple indexes. Although you may not know which of multiple indexes to drive the query with, you might know which ones that you *don’t* want the optimizer to use (NO_INDEX). You may also want to disallow an index for many queries prior to dropping an index or, as of Oracle
11g, make invisible an index that you don’t think is necessary.

**Syntax**

```sql
SELECT /*+ NO_INDEX([@query block] table_index1 [,index2...]) */ column, ...
FROM employees
WHERE employee_id = 7782
AND department_id = 1;
```

**Example**

In this example, the specified index on the EMPLOYEES table should not be used. If the NO_INDEX hint is used and no index is specified, a full table scan is performed. If the NO_INDEX and a conflicting hint (such as INDEX) are specified for the same index, then both hints are ignored (as in the example that follows).

**Example**

```sql
SELECT /*+ NO_INDEX(employees emp_department_ix)
       INDEX(employees emp_department_ix) */
     last_name, department_id
FROM employees
WHERE department_id = 1
AND last_name = 'SMITH';
```

**TIP**
The NO_INDEX hint must be in the tuning expert’s toolkit. It is used to remove an index from consideration by the optimizer, so you may evaluate the need for the index prior to dropping it or so you can evaluate other indexes. Be careful not to conflict with other index hints. The NO_INDEX hint is one of my personal favorites when I want to drop an index and check which index (if any) will be used instead of the one that I plan to drop.
The INDEX_JOIN Hint

The INDEX_JOIN hint merges separate indexes from a single table together so only the indexes need to be accessed. This approach saves a trip back to the table.

Syntax

```sql
SELECT /*+ INDEX JOIN([@query block] table index1 [,index2...]) */ column, ...
```

Example

```sql
SELECT /*+ INDEX JOIN(employees emp_emp_id_pk emp_department_ix) */
employee_id, last_name
FROM employees
WHERE employee_id = 7750
AND department_id = 1;
```

In this query, the optimizer should merge both specified indexes and not need to access the table. All information needed is contained in these two indexes when they are merged. For a more detailed example, see Chapter 8.

TIP

Not only does the INDEX_JOIN hint allow you to access only indexes on a table, which is a scan of fewer total blocks, but also it can be five times faster (in some of my tests) than using an index and scanning the table by ROWID.

The INDEX_COMBINE Hint

The INDEX_COMBINE hint is used to specify multiple bitmap indexes when you want the optimizer to use all indexes that you specify. You can also use the INDEX_COMBINE hint to specify single indexes (this is preferred over using the INDEX hint for bitmaps). For b-tree indexes, use the INDEX hint instead of this one. The INDEX_COMBINE hint is similar to the INDEX_JOIN hint but is used for bitmap indexes.
The INDEX_COMBINE hint causes the optimizer to merge multiple bitmap indexes for a single table instead of choosing which one is better (as with the INDEX hint).

**The INDEX_ASC Hint**

The INDEX_ASC hint currently does exactly the same thing as the INDEX hint. Since indexes are already scanned in ascending order, this does nothing more than the current INDEX hint. So what is it good for? Oracle does not guarantee that indexes will be scanned in ascending order in the future, but this hint does guarantee that an index will be scanned in ascending order.
In this example, the specified index should be used.

**TIP**
The INDEX_ASC hint does exactly what the INDEX hint does because indexes are already scanned in ascending order. INDEX_ASC guarantees this to be true, however, as Oracle may change this default in the future. Descending indexes are actually sorted in descending order. Oracle treats descending indexes as function-based indexes. The columns marked DESC are sorted in descending order.

The **INDEX_DESC** Hint

The INDEX_DESC hint causes indexes to be scanned in descending order (of their indexed value or order), which is the opposite of the INDEX and INDEX_ASC hints. This hint is overridden when the query has multiple tables because the index needs to be used in the normal ascending order to be joined to the other table in the query. Some restrictions for this include that it does not work for bitmap indexes or for descending indexes (because it causes the index to be scanned in ascending order), and it does not work across partitioned index boundaries but performs a descending index scan of each partition. The execution plan should list “INDEX RANGE SCAN DESCENDING” for an operation when this hint is adopted, and the data might come back in reverse order (though the only way to be certain of sorting is to use an ORDER BY clause).

**Syntax**

```sql
select /*+ INDEX DESC [@query block] table index1 [, index2 ...] */ column1, ...
```

**Example**

```sql
select /*+ INDEX_DESC(employees emp.department_ix) */
      department_id, employee_id, last_name
from employees
where department_id <= 30;
```
TIP
The INDEX_DESC hint processes an index in descending order of how it was built. This hint should not be used if more than one table exists in the query.

The INDEX_FFS Hint

The INDEX_FFS hint indicates a fast full scan of the index should be performed. That is, all values in the index will be read without sorting. INDEX_FFS accesses only the index and not the corresponding table. The fast full scan of the index is used only if all of the information that the query needs to retrieve is in the index. This hint can give great performance gains, especially when the table has a large number of columns. Beware, at times a fast full scan of an index is the wrong path for the optimizer to take (look for it in the EXPLAIN PLAN as a potential issue).

Syntax

```sql
select /*+ [query block]  INDEX_FFS(table index) */ column1, ...
```

Example

```sql
select /*- INDEX_FFS (employees emp_name_ix) */ first_name, last_name
from employees
where last_name = 'SMITH';
```

The INDEX_FFS hint is used only if the index contains all the columns in the SELECT list. The NO_INDEX_FFS hint has the same syntax, but this hint tells the optimizer not to perform fast full index scans of the specified indexes. You must specify both the table and index in both of these hints.

TIP
The INDEX_FFS hint processes only the index and does not take the result and access the table. All columns that are used and retrieved by the query must be contained in the index.
The ORDERED Hint

The ORDERED hint directs tables to be accessed in a particular order, based on the order of the tables in the FROM clause of the query, which is often referred to as the driving order for a query. Generally, the last table in the FROM clause is the driving table in queries (this is version dependent); however, using the ORDERED hint causes the first table in the FROM clause to be the driver (and each table in order). The ORDERED hint also guarantees the driving order. When the ORDERED hint is not used, Oracle may internally switch the driving table, when you compare how tables are listed in the FROM clause (EXPLAIN PLAN can show how tables are accessed). The complexity of possibilities when this hint is used is so great that much of the next chapter is focused on this subject (please see Chapter 8 for more information regarding tuning joins). This chapter briefly covers this hint, mainly for syntactical purposes.

Syntax

```
select  /*+ ORDERED */ column1, ...
```

Example

```
select  /*+ ORDERED */ employee_id, last_name,
        d.department_id
from    employees e, departments d
where   e.department_id = d.department_id
        and d.department_id = 10
        and e.employee_id = 7747;
```

If both tables (EMPLOYEES and DEPARTMENTS) have been analyzed and there are no indexes on either table, the EMPLOYEES table should be accessed first and the DEPARTMENTS table is accessed second. There are many possible variations (covered in the next two chapters) that cause this to work differently (especially based on the join).

Example
In this example for a three-table join, EMPLOYEES should be joined first to DEPARTMENTS (second as listed in the FROM clause), and then the result set joined to JOBS. There are many possible join-order variations (covered in the next chapter) that could cause this to work differently, but generally, when the ORDERED hint is used, if accepted, the join order should be as specified.

TIP
The ORDERED hint is one of the most powerful hints available. It processes the tables of the query in the sequential order in which they are listed in the FROM clause. There are many variations that cause this to work differently. The version of Oracle, the existence of indexes on the tables, and which tables have been analyzed can all cause this to work differently. However, when a multiple join is slow and you don't know what to do, this is one of the first hints you should try!

The LEADING Hint
As the complexity of queries becomes greater, figuring out the order of all of the tables using the ORDERED hint becomes more difficult. You can often figure out which table should be accessed first (driving table), but you may not know which table to access after that one. The LEADING hint allows you to specify one table to drive the query; the optimizer figures out which table to use after that. If you specify more than one table with this hint, it is ignored. The ORDERED hint overrides the LEADING hint.

Syntax

```sql
select /*+ LEADING([@query block] table [table]...) */ column1, ...
```

Example
As stated in the discussion of the ORDERED hint, the process by which a leading table is selected is complex. In this example, the EMPLOYEES table would probably be chosen as the driving table as it is the intersection table. The LEADING hint allows you to specify another table (I chose DEPARTMENTS as the driving table) to be the first table accessed in the query. Be sure you have properly configured the indexes to support the join order you specify.

**TIP**
The LEADING hint works similarly to the ORDERED hint. The LEADING hint is used to specify a single table to drive a query while allowing the optimizer to figure out the rest.

## The NO_EXPAND Hint

The NO_EXPAND hint is used to keep the optimizer from “going off the deep end” when evaluating IN lists that are combined with an OR. It disallows the optimizer from using OR expansion, which refers to converting a query to apply OR conditions to execute as separate subqueries whose results are merged with UNION ALL instead of applying OR conditions as a filter. Without the NO_EXPAND hint, the optimizer may create a very long execution plan or use an INLIST ITERATOR access method. To use OR expansion, use the USE_CONCAT hint.

### Syntax

```
select /*+ NO_EXPAND [@query block] */ column1, ...
```

### Example
I have used the NO_EXPAND hint and was able to increase performance to almost 50 times faster than without the hint. For simple queries, there may not be much difference in the EXPLAIN PLAN with or without the hint. However, when using a query that joins the EMPLOYEES and DEPARTMENTS tables and selects at least one column from each table, you can see a big difference in the EXPLAIN PLAN. In 12cR2, the optimizer uses the UNION ALL operator to perform OR expansion, where previously the optimizer used the CONCATENATION operator. It’s yet to be seen if this will correct some of the issues.

**TIP**

The NO_EXPAND hint prevents the optimizer from using OR expansion and is used when the query becomes substantially more complex as a result of the expansion.

### The DRIVING_SITE Hint

The DRIVING_SITE hint is for processing distributed queries in the designated database. The table specified in the hint should determine the driving site that will be used to process the actual join.

**Syntax**

```sql
select /*+ DRIVING_SITE ([@query block] table) */ column1, ...
```

**Example**

```sql
select /*+ DRIVING_SITE (deptremote) */ employee_id, last_name
from employees, departmentoratusc deptremote
where employees.department_id = deptremote.deptno
and deptremote.department_id = 10
and employee_id = 7747;
```

Oracle normally retrieves the rows from the remote site and joins them at the local site if this hint is not specified. Because the EMPLOYEE_ID = 7747 limits the result set, I would rather pass the
small number of rows from the EMPLOYEES table to the remote site instead of pulling an entire DEPARTMENTS table department back to my local site to process to minimize the overhead of data transfer.

A similar benefit may be achieved by limiting the rows that are retrieved from a remote site by creating a view locally for the remote table (if you can have a limiting WHERE clause in the view that still retrieves the desired data). The local view should include the WHERE clause that will be used, so the view will limit the rows returned from the remote database before they are sent back to the local database. I have personally tuned queries from hours to seconds using this method of creating a remote view versus using the DRIVING_SITE hint.

When using the DRIVING_SITE hint, the location is not specified in the hint (just the table name). However, if an alias is used, the alias has to be used instead of the table name in the hint.

**TIP**
The DRIVING_SITE hint is extremely powerful, as it will potentially limit the amount of information that will be processed over your network. The table specified with the DRIVING_SITE hint is the location where the join will be processed. Using views for remote tables can also lead to better performance by limiting the number of rows passed from the remote site before the records are sent to the local site.

**The USE_MERGE Hint**
The USE_MERGE hint is a hint that tells the optimizer to use a MERGE JOIN operation when performing a join. A MERGE JOIN operation may be useful when queries perform set operations on large numbers of rows, perhaps on non-equijoin conditions.

Assume you are joining two tables together. In a MERGE JOIN, the row set returned from each table is sorted and then merged to form the final result set. Because each result is sorted and then merged together, this action is most effective when retrieving all rows from a given query. If you want the first row faster instead, then USE_NL might be a better hint (to force a nested loops join).

In the following illustration, the EMPLOYEES and DEPARTMENTS tables are joined, and that result set is then joined to the JOBS table via a MERGE JOIN operation.
Syntax

```sql
select        /* USE_MERGE([@query block] table [table]) */ column, ...
```

where the first table should be accessed by a merge join. The second table specification is optional, and, if unspecified, the optimizer decides what to join the first table to.

Example

```sql
select       /* use_merge(j) */ employee_id, last_name,
        d.department_id, j.job_title
from         departments d, employees e, jobs j
where        e.department_id = d.department_id
and           d.department_id = 10
and           e.employee_id = 7747
and           c.job_id = j.job_id;
```

The USE_MERGE hint in this query causes the JOBS table to be joined in a sort-merge join to the returned row source resulting from the join of the EMPLOYEES and DEPARTMENTS tables. The rows are sorted and then merged together to find the final result. The NO_USE_MERGE hint uses the same syntax but instructs the optimizer to not use merge joins when selecting execution paths for a query. The optimizer will instead favor other join methods such as hash joins and nested loops joins. See Chapter 9 for a more detailed discussion of joins.

TIP

In a join of three or more tables, the USE_MERGE hint causes the table(s) specified in the hint to be sort-merge joined with the resulting row set from a join of the other tables in the join.

The USE_NL Hint

The USE_NL (use nested loops) hint is usually the fastest way to return a single row (in terms of response time); it may be slower at returning all the rows. This hint causes a statement to be processed using nested loops, which takes the first matching row from one table based on the result from another table. This is the opposite of a merge join, which retrieves rows that match the conditions from each table and then merges them together.
Syntax

where table1 should be the first table read (usually the smaller of the two tables by blocks) and table2 the inner or lookup table. Reversing the order of the tables might persuade the cost-based optimizer to read the tables in the suggested order; if not, try the LEADING or ORDERED hints to specify the order of the tables, which can affect performance. If only one table is specified in the hint, use a nested loops access method with the optimizer, choosing the table listed in the hint to be the inner or lookup table.

Example

The USE_NL hint directs the optimizer to take the resulting rows returned from the EMPLOYEES table and process them with the matching rows from the DEPARTMENTS table (the specified nested loop table). The first row that matches from the DEPARTMENTS table can be returned to the user immediately (as in a web-based application), as opposed to waiting until all matching rows are found. The ORDERED hint specifies that the EMPLOYEES table should be processed first. Note that there is a difference between using this query with or without the ORDERED hint as well.

TIP

The USE_NL hint usually provides the best response time (first row comes back faster) for smaller result sets, whereas the USE_MERGE hint usually provides the best throughput when the USE_HASH hint can’t be used.

The NO_USE_NL hint uses the same syntax but instructs the optimizer not to use nested loops joins. A related hint, USE_NL_WITH_INDEX, takes two parameters—the name of the inner or lookup table for the join along with the name of the index to use when performing the join.
The USE_HASH Hint

The USE_HASH (use hash join) hint is usually the fastest way to join many rows together from multiple tables if you have adequate memory for this operation. The USE_HASH <hint or method> is similar to the nested loops where one result of one table is looped through the result from the joined table. The difference is that the second table (the lookup table) is put into memory and should usually be the smaller table. You must have a large enough HASH_AREA_SIZE or PGA_AGGREGATE_LIMIT (see Chapter 4) for this to work properly; otherwise, the operation will occur on disk (which slows things down).

NOTE

Don’t confuse USE_HASH with HASH, which is used with hash clusters—physical data structures that store master and detail rows together in the same databases as already joined.

Syntax

```
SELECT /*+ USE_HASH ([#query block] Table1 [, Table2, ...]) */ i, ...
```

Example

```
SELECT /*+ use hash(d) */ employee id, last name,
       d.department_id
FROM    employees e, departments d
WHERE   e.department id = d.department id;
```

The USE_HASH hint directs the optimizer to take the rows returned from the EMPLOYEES table and process them with the matching rows from the DEPARTMENTS table (the specified hash table), which are hashed into memory. The first row that matches from the DEPARTMENTS table can be returned to the user immediately, as opposed to waiting until all matching rows are found. There are cases in which the optimizer overrides this hint, and environmental settings greatly affect the optimizer’s decision to use hash joins. In the preceding query, if you added the condition “AND D.DEPARTMENT_ID=1”, the optimizer would override the USE_HASH hint and do the more efficient nested loops join (since the DEPARTMENTS table has been narrowed down by this condition) or use a merge join.

The NO_USE_HASH hint has a similar syntax but instructs the optimizer to not use hash joins when selecting execution paths for a query. The optimizer should instead use other join methods such as nested loops or merge joins. You often need to add the ORDERED hint in addition to table join
hints to drive things the way you want them.

**TIP**

The USE_HASH hint usually provides the best response time for larger result sets.

SWAP_JOIN_INPUTS is an undocumented hint (there are My Oracle Support articles about it) used to persuade the cost-based optimizer to use the specified table as the lookup hash table. Even though it is undocumented, it is listed in the V$SQL_HINT view.

**Syntax**

```
Select  /*+ SWAP_JOIN_INPUTS(table1) */ ... 
```

The QB_NAME Hint

The QB_NAME hint is used to assign a name to a query block within a statement. You can then assign a hint elsewhere in the statement that references the query block. For example, if you have a query that contains a subquery, you can assign a query block name to the subquery and then provide the hint at the outermost query level. If two or more query blocks are given the same QB_NAME value, the optimizer ignores the hints. You can also use the query block names when looking at execution plans to decide to which part of the query a particular operation belongs. This hint in 12cR2 is used in the CONTAINERS hint (described later in the chapter) to push hints to pluggable databases (PDBs).

If you have a complex query, with subqueries in the EXPLAIN PLAN, it appears that the optimizer generates a default name for these query blocks, such as emp@sel$4. By using the QB_NAME hint, you can specify the name instead (use a name that means something to you). This option is very helpful when trying to tune extremely complex queries that contain more than one subquery.

**Syntax**

```
Select  /*+ QB_NAME(query block) */ column1... 
```

Example
Even though the FULL hint is specified in the outer query (main query), it should affect the subquery because you used the query block specified in the inner query (subquery).

The PUSH_SUBQ Hint

The PUSH_SUBQ hint can lead to dramatic performance gains (an increase of more than 100 times in terms of performance) when used in the appropriate situation. The best situation in which to use this hint is when the subquery returns a relatively small number of rows (quickly); those rows can then be used to substantially limit the rows in the outer query. PUSH_SUBQ causes the subquery to be evaluated at the earliest possible time. This hint cannot be used when the query uses a merge join and cannot be used with remote tables. Moving the subquery to be part of the main query (when possible) can lead to the same gains when the tables are driven in the correct order (accessing the former subquery table first).

Syntax

```
select  /*+ PUSH_SUBQ [@query block] */ column, ...
```

Example

```
select  /*+ cardinality(e,1000000) push_subq */
e.department_id,
e.employee_id,
m.last_name  as manager_last_name,
max(e.salary) as max salary
```
This query processes the subquery to be used by the outer query at its earliest possible time. I used the undocumented CARDINALITY hint to simulate a large dataset because it was impossible to get PUSH_SUBQ to do anything with the small amount of rows I had. CARDINALITY tells the optimizer to use the indicated number as the expected number of rows in a data source instead of data dictionary statistics or defaults.

**TIP**
The PUSH_SUBQ hint can improve performance greatly when the subquery returns only a few rows very fast, and those rows can be used to limit the rows returned in the outer query.

---

### The PARALLEL Hint

The PARALLEL hint tells the optimizer to break a query into pieces (the *degree of parallelism*) and process each piece with a different process simultaneously. The degree of parallelism is applied to each parallelizable operation of a SQL statement. A query that requires a sort operation causes the number of processes used to be double the degree specified, as both the table accesses and the sorts are parallelized. A query coordinator process is also invoked to split and put the results together, so if you set the degree of parallelism for a query to four, it may use four processes for the query plus four *more* processes for the sorting, plus one *more* process for the breaking up and putting together of the four pieces, or nine (9) total processes.

PARALLEL can be applied to the INSERT, UPDATE, and DELETE portions of a statement (you have to commit immediately after if you use this) as well as to SELECT commands. You should create tables with the PARALLEL clause when you plan to use this option (which should make using the hint unnecessary, although the degree of parallelism can be changed with the hint). See Chapter 11 for a detailed look at all of the requirements and rules associated with this powerful option.

**Syntax**
The degree is the number of pieces (processes) into which the query is broken.

Example

```sql
select /*+ PARALLEL (employees) */ employee_id, hire_date
from employees
order by hire_date;
```

This statement does not specify a degree of parallelism. The default degree of parallelism is dictated by the table definition when the table was created or the system default is used.

Example

```sql
select /*+ PARALLEL (employees,4) */ employee_id, hire_date
from employees
order by hire date;
```

This statement specifies a degree of parallelism of 4. Per previous discussion, as many as nine query servers may be allocated or created to satisfy this query. If you have multiple tables and you specify the PARALLEL hint with a numeric value, that is the degree of parallelism used for all the tables in the query, overriding the parallel setting at the table level. If you specify a table name (as in the previous example), then the PARALLEL hint applies to only that table; any other tables accessed by the query use the table’s parallelism setting.

**TIP**

Using the PARALLEL hint enables the use of parallel operations. If the degree is not specified with the hint, the default degree specified during table creation is used.

The NO_PARALLEL Hint

If a table is created with a parallel degree set, the table should automatically be queried in parallel and should use that degree for all full table scan queries. You may, however, also “turn off” the use of parallel operations in any one given query on a table that has been specified to use parallel operations by using the NO_PARALLEL hint. The NO_PARALLEL hint results in a query with a
degree of one (1).

**NOTE**
The NO_PARALLEL hint used to be NOPARALLEL before Oracle standardized the naming.

**Syntax**

```sql
select /*+ NO PARALLEL ([@query block]table) */ ... 
```

**Example**

```sql
select /*+ NO_PARALLEL(employees) */ employee_id, hire_date
from employees
order by hire date;
```

**TIP**
Using the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.

**The PARALLEL_INDEX Hint**

The PARALLEL_INDEX hint asks the optimizer to parallelize index scans (full, range, or fast full) for b-tree indexes. Oracle documentation suggests that PARALLEL_INDEX works with partitioned indexes, but I found that it worked with nonpartitioned indexes too. Essentially PARALLEL_INDEX is a PARALLEL hint for index reads and, like the PARALLEL hint, specifying the degree of parallelism is optional.

**Syntax**

```sql
/*/+ PARALLEL_INDEX([@query block] table index [degree]) */
```
Example

```sql
select /*+ PARALLEL_INDEX(employees emp_emp_id_pk) */ count(*)
from employees;
```

NO_PARALLEL_INDEX (formerly NOPARALLEL_INDEX) is used to avoid parallel index reads.

Syntax

```sql
/*+ NO PARALLEL_INDEX([@query block] table index) */
```

The APPEND Hint

The APPEND hint can improve the performance of INSERTs (at times dramatically), but with a potential cost in terms of physical database space. The APPEND hint does not check to see if there is space within currently used blocks for INSERTs but instead appends the data into new blocks. You might potentially waste space, but you will gain speed. If you never delete rows from a table, you should definitely consider the APPEND hint.

If an INSERT is parallelized using the PARALLEL hint, then APPEND is used by default. You can use the NOAPPEND hint (next section) to override this behavior. Also note that before you can use this example, you must first enable parallel DML.

Syntax

```sql
insert /*+ APPEND */ ...
```

Example

```sql
insert /*+ APPEND */ into sales_hist
    select *
    from sales
    where cust_id = 8890;
```

There are a couple of things to consider when using the APPEND hint. First, remember that APPEND ignores existing free space, so you can waste a lot of disk space when using this option.
Second, APPEND does not work with single-row inserts using a VALUES clause; it only works with INSERTS whose data comes from subqueries. Finally, a COMMIT should follow an INSERT using APPEND to avoid an error when querying back newly inserted data.

**TIP**

The APPEND hint inserts values into a table without checking the free space in the currently used blocks, instead appending the data into new blocks. Great performance is often the end result at the cost of physical disk space (and well worth it).

### The NOAPPEND Hint

The NOAPPEND hint overrides the default for the PARALLEL inserts (the default, of course, is APPEND). The NOAPPEND hint turns off the direct-path INSERT option.

**Syntax**

```sql
insert  /*+ NOAPPEND */  ...
```

**Example**

```sql
insert  /*+ NOAPPEND */
into job_history (employee_id, start_date, end_date, job_id, department_id)
select employee_id, hire_date, to_date('12/31/2099', 'mm/dd/yyyy'),
       job_id, department_id
from employees e
where not exists(
    select 0
    from  job_history jh
    where jh.employee_id = e.employee_id);
```

**TIP**

The NOAPPEND hint overrides a PARALLEL hint, which normally uses the APPEND hint by default.
The CACHE Hint

The CACHE hint causes a full table scan to be cached (pinned) into memory (into the buffer cache), so future queries accessing the same table find it in memory instead of going to disk. This creates one potentially huge problem. If the table is very large, then it takes up an enormous amount of memory (data block buffer cache space in particular). For small lookup tables, however, this is an excellent option. Tables can be created with the CACHE option to be cached the first time they are accessed.

Syntax

```sql
select /*+ CACHE([@query_block] table) */ column1, ...
```

Example

```sql
select /*+ FULL(departments) CACHE(departments) */ department_id, location_id
from departments;
```

The entire DEPARTMENTS table is now cached in memory and is marked as a most recently used (MRU) object.

TIP

The CACHE hint should be used with small lookup tables that are often accessed by users. This ensures the table remains in memory.

The NOCACHE Hint

The NOCACHE hint causes a table that is specified to be CACHED at the database level to not get cached when you access it and is usually used to override an existing table specification.

Syntax

```sql
select /*+ NOCACHE(table) */ column1, ...
```
Example

```sql
alter table departments cache;

select /*+ NOCACHE(departments) */ department_id, location_id
from departments;
```

In this example, the table should not be cached despite the ALTER statement and is put on the least recently used (LRU) list.

TIP

The `NOCACHE` hint should be used to prevent caching a table specified with the `CACHE` option—basically, when you want to access the table but you don’t want to cache it.

The RESULT_CACHE Hint

As of 11g (and now in 12c), Oracle provides a new, separate shared memory pool to store query results. This Result Cache is allocated directly from the shared pool but is maintained separately. Queries executed often may experience better performance when using the new pool through the `RESULT_CACHE` hint. Setting the `RESULT_CACHE_MODE` initialization parameter to `FORCE` stores all results in the new cache for every query executed (this may not be desirable), but the `NO_RESULT_CACHE` hint can be used to override this behavior. The difference between `RESULT_CACHE` and `CACHE` is where the data is stored. `NO_RESULT_CACHE` requests that data not be cached in the shared pool (it still can be cached in the buffer cache).

The `RESULT_CACHE` hint should work with individual parts of a query (query blocks) as well as entire result sets. The `RESULT_CACHE` operation appears in an execution plan as `RESULT_CACHE` with a system-generated temporary table name when the hint is used or when the query results are retrieved from the Result Cache (best used with `SUM`, `MAX`, `MIN`, etc.).

Syntax

```sql
select /*+ RESULT_CACHE */ column1 ...```

Example
The RESULT_CACHE hint caches query results in the shared pool; the NO_RESULT_CACHE hint is used when you don’t want to cache data in the shared pool (it still can be cached in the buffer cache).

The CURSOR_SHARING_EXACT Hint

The CURSOR_SHARING_EXACT hint is used to ensure that literals in SQL statements are not replaced with bind variables. This hint can be used to correct any minor issues when you don’t want to use cursor sharing even though the instance-level CURSOR_SHARING parameter is set to either FORCE or SIMILAR (but note that SIMILAR is deprecated and its use should be avoided).

Syntax

```sql
select /*+ CURSOR_SHARING_EXACT */ column1, ...
```

Example

```sql
select /*+ CURSOR_SHARING_EXACT */ employee_id, last_name
from employees
where employee_id = 123;
```

In this example, Oracle will not be able to reuse a current statement in the shared pool unless it is exactly like this one (including white space and the 123 literal). It should not create a bind variable. Additional examples related to cursor sharing are in Chapter 4.
The CURSOR_SHARING_EXACT hint overrides the system parameter file setting of CURSOR_SHARING to either FORCE or SIMILAR.

The INMEMORY and NO_INMEMORY and Other IM Hints

One of the biggest changes in 12c (12.1.0.2+) is the addition of the In-Memory (IM) column store (covered in detail in Chapter 4). Included in this release are several hints to help drive a query. The main ones are the INMEMORY and NO_INMEMORY hints.

INMEMORY (table_name) and NO_INMEMORY(table_name)

A quick example (drives the query to use INMEMORY):

```sql
select /*+ INMEMORY(emp) */ ename, deptno
from emp;
```

The INMEMORY_PRUNING hint (and NO_INMEMORY_PRUNING) controls the use of the IM storage index (which scans the CUs, or compression units). You can use it and then also check if a storage index (automatically built by Oracle in the IM) was used to further prune the result. Note the following example first selects values from the EMP table, and then runs the query used to check for storage index pruning in the V$STATNAME and V$MYSTAT view:

```sql
select /*+ (INMEMORY_PRUNING(emp) */ ename, deptno
from emp
WHERE empid = '4444';
```

```sql
select name, value, sysdate
from v$statname a, v$mystat b
where name = 'IM scan CUs pruned' and a.statistic - b.statistic;
{If "no rows selected" then storage indexes are not being leveraged}
```

The IM option has several hints that you can use in your SQL as well to force the optimizer to utilize the In-Memory column store. The following are used most often:

- /*+ INMEMORY(table) */ (place a table into the In-Memory column store)
- /*+ NO_INMEMORY(table) */ (remove a table from the In-Memory column store)
- /*+ INMEMORY_PRUNING(table) */ (control the use of the IM storage index)
- /*+ NO_INMEMORY_PRUNING(table) */ (control the use of the IM storage index)
/*+ PX_JOIN_FILTER(table) */ (force Bloom filter for a join if optimizer doesn’t)
/*+ NO_PX_JOIN_FILTER(table) */ (force non-use of Bloom filter for a join if optimizer doesn’t)
/*+ VECTOR_TRANSFORM */ (force use of VECTOR GROUP BY—not in docs!)

TIP

In 12c (12.1.0.2+) the addition of the In-Memory (IM) column store brought us several hints. The INMEMORY hint (also, NO_INMEMORY) can be used to help drive a query to use (or not use) the In-Memory column store.

👍 The USE_INVISIBLE_INDEXES Hint

You can create or alter an index to be invisible. In 11g, when you set an index to invisible, it required an exclusive lock that not many people noticed (since it was always fast if you weren’t doing a lot of DML). In 12c, the lock is not needed anymore (truly performed online). The following query shows the creation of a new invisible index on the DEPTNO column of the EMP table and subsequent query where the index is not seen/used, and finally using the hint to force it:

```sql
create index dept_inv_idx on dept_rich(deptno) invisible;
Index created.

select count(*)
from   dept_rich
where  deptno = 30; (doesn't see the index)
COUNT(*)
----------
812
```

You can still force the use of the index if you use a hint, in 12cR2, with a
USE_INVISIBLE_INDEXES hint—or by setting the initialization parameter (see Chapter 4) OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE:

```sql
SELECT /* USE_INVISIBLE_INDEXES */ COUNT(*)
FROM dept_rich
WHERE deptno = 30;  /* forces the index with hint */
```

```
TIP
You can still force the use of an invisible index in 12cR2 with the USE_INVISIBLE_INDEXES hint.
```

The CONTAINERS Hint

With the advent of pluggable databases (PDBs) in 12c (see Chapter 3), there are hints that help you do more, even across PDBs. The ability to aggregate data across multiple PDBs using the CONTAINERS hint, as a common user (like SYSTEM) in the CDB, is helpful. The CONTAINERS hint causes the SQL to be recursively executed in each PDB. You can even pass hints to those PDBs as well with the `hint_string`. Basic syntax example:

```sql
SELECT /*+ CONTAINERS(DEFAULT_PDB_HINT=hint_string */ ... FROM CONTAINERS(object)...
```
TIP

With pluggable databases (PDBs) in 12c, you can aggregate data across multiple PDBs, while in the CDB, using the CONTAINERS hint. The CONTAINERS hint causes the SQL to be recursively executed in each PDB.

The WITH_PLSQL Hint

Lastly, the hint that’s not an optimizer hint: WITH_PLSQL. If a query containing the PL/SQL declaration section is not the top-level query, the top-level query must include the WITH_PLSQL hint (if not included, you will receive an ORA-32034 error). It can be a SELECT or DML (both will fail under these conditions). The WITH_PLSQL hint allows the statement to compile and run as expected, but it is not an optimizer hint, just a hint. Basic syntax example:

```
UPDATE /*+ WITH_PLSQL */ ... 
SELECT /*+ WITH_PLSQL */ * from (WITH FUNCTION...)
```

TIP

In 12c, if a query containing the PL/SQL declaration section is not the top-level query, the top-level query must include the WITH_PLSQL hint, but it is not an optimizer hint.

Some Miscellaneous Hints and Notes

This section lists “the best of the rest” of the hints that are available. Each hint is listed with a brief explanation. Please see the Oracle documentation if you want to use one of them.

- **DYNAMIC_SAMPLING** The DYNAMIC_SAMPLING hint is set from 0 to 10. The higher the number is set, the more effort the compiler puts into dynamic sampling. It generates statistics at run time for use in a query.

- **INDEX_SS** The INDEX_SS hint instructs the optimizer to use the skip-scan option for an index on the specified table. A skip-scan is when Oracle skips the first column of a concatenated index and uses the rest of the index. This hint works well with a two-part concatenated index, where you often use both parts but infrequently need only the second part (at times you don’t have any condition for the first part). You need to specify both the table and the index.

- **INDEX_SS_ASC** The INDEX_SS_ASC hint is the same as the INDEX_SS hint, but this could change in a future version of Oracle.
INDEX_SS_DESC The INDEX_SS_DESC hint uses the same syntax as the INDEX_SS hint but instructs the optimizer to scan the index skip-scan in descending order.

MODEL_MIN_ANALYSIS The MODEL_MIN_ANALYSIS hint instructs the optimizer to omit some compile-time optimizations of spreadsheet rules. This hint can reduce the compilation time required during spreadsheet analysis and is used with SQL modeling queries (queries using the MODEL clause).

MONITOR The MONITOR hint turns index monitoring on for short queries. For MONITOR to work, the initialization/session parameter CONTROL_MANAGEMENT_PACK_ACCESS must be set to “DIAGNOSTIC+TUNING”. NO_MONITOR turns off index monitoring, even for long-running queries. Monitoring refers to entries logged in the V$SQL_MONITOR and V$SQL_PLAN_MONITOR tables during query execution.

NATIVE_FULL_OUTER_JOIN When the full outer join condition between two tables is an equijoin, Oracle Database automatically uses a native execution method based on a hash join. This hint instructs the optimizer to consider using the hash full–outer join execution method, when it might not normally do so. If you specify NO_NATIVE_FULL_OUTER_JOIN, then the full outer join is executed as a union of the left outer join and an antijoin.

NOLOGGING There is no “NOLOGGING” hint to turn off archive logging for a DML statement although developers sometimes think there is. You can, however, ALTER TABLE EMP NOLOGGING and then do an INSERT /*+ APPEND */ into the EMP table to bypass the redo if the database is in ARCHIVELOG mode (careful, as this has major recovery implications—back up after this). If the database is in NOARCHIVELOG mode (not recommended), any direct load operations, such as the INSERT /*+ APPEND */ , are not recoverable. NOLOGGING works with many DDL commands, such as for creating tables, creating indexes, and rebuilding indexes (careful, as this also has major recovery implications; back up after and don’t leave tables and indexes in NOLOGGING mode).

OPT_PARAM This hint allows you to modify the parameter setting in effect for the duration of the query. This only works with session parameters that can be changed! Remember to put parameter names in single quotes.

PUSH_PRED This hint causes WHERE clause conditions to be pushed into a query view to exclude rows as soon as possible in the select process. NO_PUSH_PRED reverses this activity.

REWRITE_OR_ERROR The REWRITE_OR_ERROR hint in a query produces the following error if the query did not rewrite for queries against materialized views (this happens when there are no suitable materialized views for query rewrite to use):

ORA-30393: a query block in the statement did not rewrite

Support My Oracle Support Note 1215173.1 discusses this hint.

USE_NL_WITH_INDEX The USE_NL hint instructs the optimizer to use a nested loops join with the specified table as the nondriving table (or as the inner table that is looped through with the result of the driving table). The USE_NL_WITH_INDEX hint allows you to also specify the index that is used during access. However, the optimizer must be able to use that
index with at least one join.

- **GATHER_OPTIMIZER_STATISTICS** The use of `GATHER_OPTIMIZER_STATISTICS` (and `NO_GATHER_OPTIMIZER_STATISTICS`) is now allowed in 12c during bulk loads. `CREATE TABLE` should be ... AS SELECT and `INSERT INTO... SELECT`. There is also an undocumented parameter that can force things as well (`_OPTIMIZER_GATHER_STATS_ON_LOAD`)

- **USE_CUBE** Use a cube join for the query in 12c (also, `NO_USE_CUBE`). You need to ensure the initialization parameter `_OPTIMIZER_CUBE_JOIN_ENABLED=true` (for the system or session). Also, `CUBE_AJ` and `CUBE_SJ` are available.

- **AUTO_REOPTIMIZE** The optimizer changes execution plan on future executions of the query (also, `NO_AUTO_REOPTIMIZE`) starting in 12c.

- **ADAPTIVE_PLAN** Use an adaptive plan (also, `NO_ADAPTIVE_PLAN` hints) starting in 12c when `_OPTIMIZER_ADAPTIVE_PLANS=false`.

## Undocumented Hints

The *Oracle Database SQL Language Reference* contains seldom-used hints that I have not mentioned. Other hints are mentioned in the Oracle documentation but not the SQL guide. These hints are generally found in sources such as the *Oracle Database Data Warehousing Guide* or performance tuning manuals but without a formal write-up of their syntax and functionality. Some hints exist but are not mentioned anywhere in the documentation (as mentioned previously, V$SQL_HINT gives you a complete list of all hints). A few undocumented hints like `SWAP_JOIN_INPUTS` are included in My Oracle Support articles describing their syntax and functionality, but most are a complete mystery. Distinguishing between undocumented hints and mere comments included in the hint comment structure can be difficult. What might appear to be an undocumented hint may actually be nothing more than a comment that uses the same comment delimiters (`/* */`) as hints, but without the “+” sign.

You should not use undocumented hints unless directed to by Oracle Support. Undocumented features tend to be unsupported.

The RULE hint is deprecated, undocumented, and is unsupported in 12c (and 11gR2), even though it was supported in previous versions of the database. The RULE optimizer mode was officially desupported in Oracle 10.1. My Oracle Support (Doc ID 189702.1) has a good write-up on this change, and also contains links and tips for migrating to the cost-based optimizer. Even the *Performance Tuning Guide* for Oracle 10.1 release says, “The CHOOSE and RULE optimizer hints are no longer supported. The functionalities of those hints still exist but will be removed in a future release.” I believe these hints are currently only retained to support upgrades from older systems (such as 9i). However, as Oracle9i moves into complete obsolescence, the RULE-related parameter settings and hints will most likely be removed from the software. Prepare now!

RULE invokes the *rule-based optimizer*, an older way of determining an execution path for a query based on a set of rules. The rule-based optimizer is generally less efficient than the cost-based optimizer but can be useful under some rare conditions, generally where no valid statistics for query
objects exist:

- CAST conversions of collections to temporary tables
- TABLE function temporary table conversions (pipelined functions)
- When joining views (including views of views and inline views)
- When joining many tables together (more than three, very rarely) and the cost-based optimizer becomes overwhelmed and chooses a suboptimal path (and takes a while to do it)
- Queries against system tables where the cost-based optimizer is not making optimal choices

It has been suggested that the undocumented CARDINALITY hint (which allows override of the cardinality statistic) can overcome some of these limitations, but CARDINALITY requires an estimate of the number of rows beforehand and table cardinality is only a part of what the cost-based optimizer uses to determine an execution path.

Because the RULE hint is unsupported (according to the 12c, 11g, and 10g documentation), only use it with extreme caution, if at all. The RULE hint should probably only be used when migrating queries written for the rule-based optimizer to the cost-based optimizer.

### Using Hints with Views

Although hints can be hard-coded into views, doing so is generally a bad idea because it is impossible to know how a view will be used (selected standalone, joined to other tables or views, or even used by other views). It is better to push a hint into a view when needed in a query rather than permanently embed a hint in a view through a global hint.

To use a global hint, use the view name followed by a period followed by the name of the affected table designation, as used inside the view (table name or alias).

#### Example

```sql
select /*+ USE_HASH(v.emp) */ count(*)
from emp_details_view v
where employee_id = 100;
```

When using global hints, you need to know the usage of tables and aliases in the target view. In this example, the EMP_DETAILS_VIEW uses the alias d for DEPARTMENTS, so that designator must be used in the global hint. The underlying table name is EMP.

### Notes on Hints and Stored Outlines (or SQL Plan
Baselines)

SQL Plan Baselines or stored outlines, which still work, but are deprecated/discouraged in 11g, are covered in Chapter 6, but a note here is relevant for the discussion on hints. Migrating from stored outlines to SQL Plan Baselines is also covered in Chapter 6. STORED OUTLINES or baselines allow a query to use a predetermined execution plan every time that query is run, no matter where the query is run from. People sometimes speak of the STORED OUTLINES as storing an execution plan, but this is not really what happens. Instead, Oracle stores a series of hints to duplicate the execution plan as saved during a recording session. If you want to query the hints for a STORED OUTLINE, you can use the following query to USER_OUTLINE_HINTS:

Example

```
select hint
from user_outline_hints
where name = 'your_outline_name';
```

The very same considerations regarding using hints apply to stored outlines: unpredictable behavior when upgrading, applying patches, or changing initialization/session parameters. Also, if the query structure changes in any way, the stored outline may stop working.

Why Isn’t My Hint Working?

Often a hint won’t behave like you want it to. Sometimes the optimizer overrides the hint, but usually people have a problem related to one of the following:

- The hint syntax is incorrect.
- The table(s) is not analyzed or the statistics are not current.
- There is a conflict with another hint.
- The hint requires a system parameter to be set for it to work.
- The table name was aliased in the query, but you used the table name, not the alias, in the hint.
- The hint requires a different version of Oracle than you have.
- You don’t understand the correct application for the hint.
- You haven’t slept lately—for many of the reasons cited here.
- There is a software bug.

Hints at a Glance
The following table lists many hints discussed in this chapter (and a couple of others) and how the hint is used.
Hint
FIRST_ROWS
ALL_ROWS
FULL
INDEX
NO_INDEX
INDEX_JOIN
INDEX_ASC
INDEX_DESC
INDEX_COMBINE
INDEX_FFS
ORDERED
LEADING
INMEMORY
NO_INMEMORY
CONTAINERS
NO_EXPAND
STAR_TRANSFORMATION
DRIVING_SITE
USE_MERGE
USE_HASH
USE_NL
PUSH_SUBQ
PARALLEL
NO_PARALLEL
PARALLEL_INDEX
NO_PARALLEL_INDEX
APPEND
NOAPPEND
CACHE
NOCACHE
RESULT_CACHE
NO_RESULT_CACHE
CURSOR_SHARING_EXACT
QB_NAME
Use
Generally force the use of indexes
Generally force a full table scan
Force a full table scan
Force the use of an index
Disallow a specified index from being used
Allow the merging of indexes on a single table
Use an index ordered in ascending order
Use an index ordered in descending order
Access multiple bitmap indexes
Perform a fast full index scan
Specify the driving order of tables
Specify just the first driving table
Allow the query to use the In-Memory column store
Disallow the query to use the In-Memory column store
Aggregate data from PDBs while in the main CDB
Help eliminate OR expansion
Force a star query transform
Process data by driving it from a particular database
Change how tables are joined internally to merge joining
Change how tables are joined internally to hash joining
Change how tables are joined internally to nested loops
Force the subquery to process earlier
Cause full table scan queries to break a query into pieces and process each piece with a different process
Turn off use of parallel operations for one given query
Perform index scan in parallel
Does not perform index scan in parallel
Append data into new blocks
Check for free space within current blocks before using new ones
Cause a full table scan to be pinned into memory
Cause a table that is specified to be cached at database level to not get cached when you access it
Cache data in the shared memory pool
Cause data not to be cached in the shared memory pool
Override the CURSOR_SHARING setting
Assign a name to a query block
Tips Review

- Incorrect hint syntax leads to the hint being interpreted as a comment. If an additional hint is specified correctly, it will be used.

- Multiple hints are separated with a space. Specifying multiple hints that conflict with each other causes the query to use *none* of the conflicting hints.

- If an alias is used, the alias *must* be used in the hint or it will *not* work.

- The **FIRST_ROWS** hint causes the optimizer to choose a path that retrieves the first row (or a specified number of rows) of a query the fastest, at the cost of retrieving multiple rows more slowly. The **FIRST_ROWS** hint may be set as the default for the entire database by setting `OPTIMIZER_MODE = FIRST_ROWS` in the system parameter file; query-level hints will override the default setting for a given query. You can also set the optimizer to **FIRST_ROWS_n**.

- The **ALL_ROWS** hint causes the optimizer to choose a path that retrieves all the rows of a query the fastest, at the cost of retrieving one single row more slowly. The **ALL_ROWS** hint may be set as the default for the entire database by setting `OPTIMIZER_MODE = ALL_ROWS` (the default) in the system parameter file; query-level hints will override the default setting for a given query.

- The **FULL** hint performs a full table scan on the table that is specified, not all tables in the query. The **FULL** hint may also lead to better performance, which is attributable to causing a change in the driving table of the query and *not* to the actual full table scan.

- The **INDEX** hint causes the optimizer to choose the index specified in the hint. Multiple indexes for a single table can be specified, but it is usually better to specify only the most restrictive index on a given query (and, that way, avoid the merging of each index’s result). If multiple indexes are specified, Oracle chooses which (one or more) to use, *so be careful* or your hint could potentially be overridden.

- The **INDEX** hint, without a specified index, should not consider a full table scan, even though no indexes have been specified. The optimizer will choose the best index or indexes for the query.

- The **NO_INDEX** hint must be in the tuning expert’s toolkit. It is used to remove an index from consideration by the optimizer, so you may evaluate the need for the index prior to dropping it or so you can evaluate other indexes. Be careful not to conflict with other index hints. The **NO_INDEX** is one of my personal favorites when I want to drop an index and check which index (if any) will be used instead of the one that I plan to drop.

- Not only does the **INDEX_JOIN** hint allow you to access only indexes on a table, which is a scan of fewer total blocks, but also it can be five times faster (in some of my tests) than using an index and scanning the table by ROWID.

- The **INDEX_COMBINE** hint causes the optimizer to merge multiple bitmap indexes for a single table instead of choosing which one is better (as with the **INDEX** hint).
The INDEX_ASC hint does exactly what the INDEX hint does because indexes are already scanned in ascending order. INDEX_ASC guarantees this to be true, however, as Oracle may change this default in the future. Descending indexes are actually sorted in descending order. Oracle treats descending indexes as function-based indexes. The columns marked DESC are sorted in descending order.

The INDEX_DESC hint processes an index in descending order of how it was built. This hint should not be used if more than one table exists in the query.

The INDEX_FFS hint processes only the index and does not take the result and access the table. All columns that are used and retrieved by the query must be contained in the index.

The ORDERED hint is one of the most powerful hints available. It processes the tables of the query in the sequential order in which they are listed in the FROM clause. There are many variations that cause this hint to work differently. The version of Oracle, the existence of indexes on the tables, and which tables have been analyzed can all cause this to work differently. However, when a multiple join is slow and you don’t know what to do, this is one of the first hints you should try!

The LEADING hint works similarly to the ORDERED hint. The LEADING hint is used to specify a single table to drive a query while allowing the optimizer to figure out the rest.

The NO_EXPAND hint prevents the optimizer from using OR expansion and is used when the query becomes substantially more complex as a result of the expansion.

The DRIVING_SITE hint is extremely powerful, as it will potentially limit the amount of information that will be processed over your network. The table specified with the DRIVING_SITE hint is the location where the join will be processed. Using views for remote tables can also lead to better performance by limiting the number of rows passed from the remote site before the records are sent to the local site.

In a join of three or more tables, the USE_MERGE hint causes the table(s) specified in the hint to be sort-merge joined with the resulting row set from a join of the other tables in the join.

The USE_NL hint usually provides the best response time (first row comes back faster) for smaller result sets, whereas the USE_MERGE hint usually provides the best throughput when the USE_HASH hint can’t be used.

The USE_HASH hint usually provides the best response time for larger result sets.

The PUSH_SUBQ hint can improve performance greatly when the subquery returns only a few rows very fast, and those rows can be used to limit the rows returned in the outer query.

Using the PARALLEL hint enables the use of parallel operations. If the degree is not specified with the hint, the default degree specified during table creation is used.

Using the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.

The APPEND hint inserts values into a table without checking the free space in the currently used blocks, instead appending the data into new blocks. Great performance is often the end result at the cost of physical disk space (and well worth it).
The NOAPPEND hint overrides a PARALLEL hint, which normally uses the APPEND hint by default.

The CACHE hint should be used with small lookup tables that are often accessed by users. This ensures that the table remains in memory.

The NOCACHE hint should be used to prevent caching a table specified with the CACHE option—basically, when you want to access the table but you don’t want to cache it.

The RESULT_CACHE hint caches query results in the shared pool; the NO_RESULT_CACHE hint is used when you don’t want to cache data in the shared pool (it still can be cached in the buffer cache).

The CURSOR_SHARING_EXACT hint overrides the system parameter file setting of CURSOR_SHARING to either FORCE or SIMILAR.

In 12c (12.1.0.2+) the addition of the In-Memory (IM) column store brought us several hints. The INMEMORY hint (also, NO_INMEMORY) can be used to help drive a query to use (or not use) the In-Memory column store.

In 12c (12.1.0.2+) the INMEMORY_PRUNING hint controls the use of the IM storage index. You can check to see if a storage index was used to further prune the result by checking V$STATNAME and V$MYSTAT views.

You can still force the use of an invisible index in 12cR2 with the USE_INVISIBLE_INDEXES hint.

With pluggable databases (PDBs) in 12c, you can aggregate data across multiple PDBs, while in the CDB, using the CONTAINERS hint. The CONTAINERS hint causes the SQL to be recursively executed in each PDB.

In 12c, if a query containing the PL/SQL declaration section is not the top-level query, the top-level query must include the WITH_PLSQL hint, but it is not an optimizer hint.

References
Oracle Database SQL Language Reference (Oracle Corporation).

Many thanks to Mark Riedel for upgrading this chapter to Oracle 11g! Lucas Niemiec also did some research on a few of the hints and My Oracle Support notes listed.
This chapter focuses on specific queries that you may encounter and some general information for tuning those specific queries, but it has also been updated to include some great information on Oracle 12c Adaptive Query Optimization, on Oracle’s Automatic SQL Tuning, and some queries to access Oracle’s Automatic Workload Repository (AWR). Examples of query tuning are spread throughout this book as well as instructions on making them more effective in terms of your system’s architecture. This chapter centers on some of the most common queries that can be tuned on most systems. A query can display several variations in behavior, depending on system architecture, the data distribution in the tables, what tool or application is accessing the database, the specific version of Oracle Database, and a variety of other exceptions to the rules. Your results will vary; use your own testing to come up with the most favorable performance. The goal in this chapter is to show you many of the issues to watch for and how to fix them.

This chapter uses strictly cost-based examples for timings (except where noted). No other queries were performed at the time of the tests performed for this chapter. I also flush the buffer cache and shared pool to retest things. Many hints are also used throughout this chapter. For a detailed look at hints and the syntax and structure of hints, please refer to Chapter 7. Multiple table and complex queries are the focus of the next chapter and are not covered here.

Please note that this is not an all-inclusive chapter. Many other queries are covered throughout the book, which need to be investigated when trying to increase performance for a given query. Some of the most dramatic include using the parallel features of Oracle Database (Chapter 11), using partitioned tables and indexes (Chapter 2), and using PL/SQL to improve performance (Chapter 10). Note the benefits of using EXPLAIN and TRACE for queries (Chapter 6). Oracle Database 12c provide the AWR and Automatic Database Diagnostic Monitor (ADDM). The Oracle Enterprise Manager Cloud Control views of these new features are shown in Chapter 5. Tips covered in this chapter include the following:

- Which queries do I tune? Querying the V$SQLAREA and V$SQL views
- Some useful 12c views for locating resource-intensive sessions and queries
- When should I use an index?
- What if I forget the index?
- Creating and checking an index
What if I create a bad index?
Exercising caution when dropping an index
Using invisible indexes
Function-based indexes and virtual columns
Increasing performance by indexing the SELECT and WHERE columns
Using the Fast Full Scan feature to guarantee success
Making queries “magically” faster
Caching a table into memory
Using the Result Cache
Choosing between multiple indexes on a table (use the most selective)
Indexes that can get suppressed
Tuning OR clauses
Using the EXISTS clause and the nested subquery
That table is a view!
SQL and the Grand Unified Theory
Tuning changes in Oracle Database 12c
12c Adaptive Query Optimization
Automatic SQL Tuning and the SQL Tuning Advisor
Using the SQL Performance Analyzer (SPA)

Which Queries Do I Tune? Querying V$SQLAREA and V$SQL Views

V$SQLAREA and V$SQL are great views that you can query to find the worst-performing SQL statements that need to be optimized. The value in the DISK_READS column signifies the volume of disk reads that are being performed on the system. This, combined with the executions (DISK_READS/EXECUTIONS), returns the SQL statements that have the most disk hits per statement execution. Any statement that makes the top of this list is most likely a problem query that needs to be tuned. The AWR Report or Statspack Report also lists the resource-intensive queries; see Chapter 14 for detailed information.

Selecting from the V$SQLAREA View to Find the Worst Queries
The following query can be used to find the worst queries in your database. This query alone is worth the price of this book if you’ve not heard of V$SQLAREA yet.

```sql
select b.user_name, a.disk_reads reads, a.executions exec, a.disk_reads / decode(a.executions, 0, 1, a.executions) rds_exec_ratio, a.sql_text statement
from v$sqlarea a, dba_users b
where a.parsing_user_id = b.user_id
and a.disk_reads > 100000
order by a.disk_reads desc;
```

<table>
<thead>
<tr>
<th>USERNAME</th>
<th>READS</th>
<th>EXEC</th>
<th>RDS_EXEC_RATIO</th>
<th>STATEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHOC1</td>
<td>7281934</td>
<td>1</td>
<td>7281934</td>
<td>select custno, ordno from cust, orders</td>
</tr>
<tr>
<td>ADHOC5</td>
<td>4230044</td>
<td>4</td>
<td>1057511</td>
<td>select ordno from orders where trunc(ordno) = 721305</td>
</tr>
<tr>
<td>ADHOC1</td>
<td>801716</td>
<td>2</td>
<td>400858</td>
<td>select custno, ordno from cust where substr(custno,1,6) = '314159'</td>
</tr>
</tbody>
</table>

The DISK_READS column in the preceding statement can be replaced with the BUFFER_GETS column to provide information on SQL statements requiring the largest amount of memory.

Now consider the output in a second example where there is a count of a billion-row table (EMP3) and a count of what was originally a 130M-row table (EMP2), where all of the rows in EMP2, except the first 15 rows inserted, were deleted. Note that Oracle counts all the way up to the high water mark (HWM) of EMP2 (it read over 800,000, 8K blocks even though all of the data was only in 1 block). This listing would have told you something is wrong with the query on EMP2 that needs to be addressed, given that it only has 15 rows in it (analyzing the table will not improve this).

```sql
select count(*) from emp3
select count(*) from emp2
```

For this issue, if the EMP2 table was completely empty, you could simply truncate the table to fix it. Since the table still has 15 rows, you have a few options; which option you choose depends on your unique situation. I can

- EXPORT/TRUNCATE/IMPORT; CREATE TABLE emp2b AS SELECT * FROM emp2 (CTAS) and then DROP and RENAME (I have to worry about indexes/related objects, etc.)
Do an “ALTER TABLE emp2 MOVE TABLESPACE new1” and rebuild the indexes.

If it has a primary key, use DBMS_REDEFINITION.CAN_REDEF_TABLE to verify that the table can be redefined online.

Please check the Oracle documentation for syntax/advantages/disadvantages and stipulations (not all are listed here) for each of these options, so you can apply the best option to your situation (each of these options has major downsides, including users not being able to access the table and related objects getting dropped depending on which you use, so be careful). Once I reorganize the table, the next `COUNT(*)` only reads 1 block instead of 800,065 blocks (it was well worth fixing the problem). Note in the query, I change “emp2” to “emP2” so I can find that cursor in the cache.

```
alter table emp2 move;  -- You can specify a tablespace

select count(*)
from emP2;
```

```
select b.username, a.disk_reads/decode(a.executions, 0, 1, a.executions) rds_exec_ratio,
a.sql_text Statement
from v$sqlarea a, dba_users b
where a.parsing_user_id = b.user_id
and a.sql_text like '%emP2%'
order by a.disk_reads desc;
```

<table>
<thead>
<tr>
<th>USERNAME</th>
<th>READS</th>
<th>EXEC</th>
<th>RDS_EXEC_RATIO</th>
<th>STATEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCOTT</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>select count(*) from emP2</td>
</tr>
</tbody>
</table>

You can also shrink space in a table, index-organized table, index, partition, subpartition, materialized view, or materialized view log. You do this using the ALTER TABLE, ALTER INDEX, ALTER MATERIALIZED VIEW, or ALTER MATERIALIZED VIEW LOG statement with the SHRINK SPACE clause. See the Oracle Administrators Guide for additional information. Lastly, if you want to use the “ALTER TABLE table MOVE TABLESPACE tablespace_name” command, consider using the same size tablespace (or smaller if appropriate) to move things “back and forth” so as not to waste space.

**TIP**

*Query V$SQLAREA to find your problem queries that need to be tuned.*
Selecting from the V$SQL View to Find the Worst Queries

Querying V$SQL allows you to see the shared SQL area statements individually versus grouped together (as V$SQLAREA does). Here is a faster query to get the top statements from V$SQL (this query can also access V$SQLAREA by only changing the view name):

```sql
SELECT *
FROM (SELECT address,
         RANK() OVER (ORDER BY buffer_gets DESC) AS rank_bufgets,
         TO_CHAR(100 * ratio_to_report(buffer_gets) OVER (), '999.99') pct_bufgets
      FROM v$sql)
WHERE rank_bufgets < 11;
```

Here is the output:

<table>
<thead>
<tr>
<th>ADDRESS</th>
<th>RANK_BUFGETS</th>
<th>PCT_BUF</th>
</tr>
</thead>
<tbody>
<tr>
<td>131B7914</td>
<td>1</td>
<td>66.35</td>
</tr>
<tr>
<td>131ADA6C</td>
<td>2</td>
<td>24.57</td>
</tr>
<tr>
<td>131BC16C</td>
<td>3</td>
<td>1.97</td>
</tr>
<tr>
<td>1321B9B54</td>
<td>4</td>
<td>.90</td>
</tr>
<tr>
<td>1329F20</td>
<td>5</td>
<td>.71</td>
</tr>
<tr>
<td>132C7374</td>
<td>5</td>
<td>.71</td>
</tr>
<tr>
<td>132E6B04</td>
<td>7</td>
<td>.52</td>
</tr>
<tr>
<td>132A26DC</td>
<td>8</td>
<td>.48</td>
</tr>
<tr>
<td>131F42A3</td>
<td>9</td>
<td>.48</td>
</tr>
<tr>
<td>13258C14</td>
<td>10</td>
<td>.48</td>
</tr>
</tbody>
</table>

You can alternatively select SQL_TEXT instead of ADDRESS if you want to see the SQL:

```sql
COL SQL_TEXT FOR A50
SELECT *
FROM (SELECT sql_text,
         RANK() OVER (ORDER BY buffer_gets DESC) AS rank_bufgets,
         TO_CHAR(100 * ratio_to_report(buffer_gets) OVER (), '999.99') pct_bufgets
      FROM v$sql)
WHERE rank_bufgets < 11;
```

TIP

You can also query V$SQL to find your problem queries that need to be tuned.
Oracle 12c Views for Locating Resource-Intensive Sessions and Queries

Oracle 12c provides many views, giving you access to a wealth of information from the OS (operating system) and the Automatic Workload Repository (AWR). The AWR provides metric-based information, which is useful for monitoring and diagnosing performance issues. Metrics are a set of statistics for certain system attributes as defined by Oracle. Essentially, they are context-defined statistics that are collated into historical information within the AWR.

Accessing the AWR and ADDM information via Enterprise Manager is covered in Chapter 5 as well as in the Oracle documentation. In this section, I am only looking at pulling some specific information out of these views using SQL to locate queries that may need tuning. Please check your licensing to ensure which products are an added cost (this can vary by version!). You must have the Oracle Diagnostics Pack license to use AWR and ADDM (including accessing their underlying tables, such as the DBA_HIST tables). Statspack was still free the last time I checked, but check Oracle licensing on any product you use to be sure. You can also check the DBA_FEATURE_USAGE_STATISTICS table.

Selecting from V$SESSMETRIC to Find Current Resource-Intensive Sessions

The following query shows the sessions that are heaviest in physical reads, CPU usage, or logical reads over a defined interval (15 seconds, by default). You may want to adjust the thresholds as appropriate for your environment.

```
sellect TO_CHAR(m.end_time,'DD MON YYYY HH24:MI:SS') c_dttm,
    m.intsize_nsec/100 ints, -- interval size in sec
    o.userid,          
    m.session_id,      
    m.session_serial_num, 
    ROUND(m.cpu) cpu100, -- CPU usage 100th nec
```
Viewing Available AWR Snapshots

The next few queries access AWR snapshot information (including the next section).

Query the DBA_HIST_SNAPSHOT view to find more information about specific AWR snapshots:

```sql
select snap_id,
       TO_CHAR(begin_interval_time,'DD-MON-YYYY HH24:MI:SS') b_dttm,
       TO_CHAR(end_interval_time,'DD-MON-YYYY HH24:MI:SS') e_dttm
from dba_hist_snapshot
where begin_interval_time > TRUNC(SYSDATE);
```

<table>
<thead>
<tr>
<th>SNAP_ID</th>
<th>B_DTTM</th>
<th>E_DTTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>503</td>
<td>25 MAY 2011 00:00:35</td>
<td>25 MAY 2011 01:00:48</td>
</tr>
<tr>
<td>504</td>
<td>25-MAY-2011 01:00:48</td>
<td>25-MAY-2011 02:00:00</td>
</tr>
<tr>
<td>505</td>
<td>25-MAY-2011 02:00:00</td>
<td>25-MAY-2011 03:00:13</td>
</tr>
<tr>
<td>506</td>
<td>25-MAY-2011 03:18:38</td>
<td>25-MAY-2011 04:00:54</td>
</tr>
<tr>
<td>507</td>
<td>25 MAY 2011 04:00:54</td>
<td>25 MAY 2011 05:00:07</td>
</tr>
</tbody>
</table>
Selecting from the DBA_HIST_SQLSTAT View to Find the Worst Queries

SQL statements that have exceeded predefined thresholds are kept in the AWR for a predefined time (seven days, by default). You can query the DBA_HIST_SQLSTAT view to find the worst queries. The following is the equivalent statement to the V$SQLAREA query earlier in this chapter.

```
select snap_id, disk_reads_delta reads_delta,
       executions_delta exec_delta,
       disk_reads_delta /decode (executions_delta, 0, 1, executions_delta) rds_exec_ratio,
       sql_id
from dba_hist_sqlstat
where disk_reads_delta > 100000
order by disk_reads_delta desc;
```

Note that in the output, the same SQL_ID appears in three different AWR snapshots. (In this case, it was executed during the first one and is still running.) You could also choose to filter on other criteria, including cumulative or delta values for DISK_READS, BUFFER_GETS, ROWS_PROCESSED, CPU_TIME, ELAPSED_TIME, IOWAIT, CLWAIT (cluster wait), and so on. Run a DESC command of the view DBA_HIST_SQLSTAT to get a full list of its columns. This listing shows different SQL_IDs at the top of the list.

<table>
<thead>
<tr>
<th>SNAP ID</th>
<th>READS DELTA</th>
<th>EXEC DELTA</th>
<th>RDS EXEC RATIO</th>
<th>SQL ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>9743276</td>
<td>0</td>
<td>9743276</td>
<td>03ay719wdrnqz1</td>
</tr>
<tr>
<td>39</td>
<td>9566692</td>
<td>0</td>
<td>9566692</td>
<td>03ay719wdrnqz1</td>
</tr>
<tr>
<td>37</td>
<td>7725091</td>
<td>1</td>
<td>7725091</td>
<td>03ay719wdrnqzl</td>
</tr>
</tbody>
</table>

When Should I Use an Index?

In Oracle version 5, many DBAs called the indexing rule the 80/20 Rule; you needed to use an index if less than 20 percent of the rows were being returned by a query. In version 7, this number was reduced to about 7 percent on average, and in versions 8i and 9i, the number was closer to 4 percent. In versions 10g and 11g, Oracle is better at retrieving the entire table, so the value continues to be in the 5 percent or less range, although it depends not only on the number of rows but also on how the blocks are distributed (see Chapter 2 for additional information).
Figure 8-1 shows when an index should generally be used (in V5 and V6 for rule-based optimization and in V7, V8i, V9i, V10g, V11g, or V12c for cost-based optimization). However, based on the distribution of data, parallel queries or partitioning can be used and other factors need to be considered. In Chapter 9, you will see how to make this graph for your own queries using mathematical models. If the table has fewer than 1000 records (small tables), then the graph is also different. For small tables, Oracle’s cost-based optimizer generally uses the index when only less than 1 percent of the table is queried. This graph shows you the progress in versions of Oracle (these are hardware dependent). The lower the percentage of rows returned, the more likely you would use an index. This graph shows the speed of a full table scan becoming faster. Because of the many variables starting with Oracle9i, the percentage could continue to decrease as the trend shows happening from V5 to V8i, or it could increase slightly, depending on how you architect the database. In Oracle9i, Oracle 10g, Oracle 11g, or 12c, you create where the graph goes. Hardware like Exadata and Exalogic enhancements can further alter this graph (where percentage could decrease to less than 1 percent); your choice may depend on how the data and indexes are architected, how the data is distributed within the blocks, and how it is accessed.

**FIGURE 8-1. When to generally use an index based on the percentage of rows returned by a query**

**TIP**

When a small number of rows ("small" is version and hardware dependent, but almost always less than 5 percent, and even less than 1 percent at times) are returned to meet a condition in a query, you generally want to use an index on that condition (column), given that the small number of rows also returns a small number of individual blocks (usually the case).
Selecting Query Text from the
DBA_HIST_SQLTEXT View

The query text for the offending queries shown in the previous two examples can be obtained from the DBA_HIST_SQLTEXT view with the following query:

```sql
select command_type, sql_text
from dba_hist_sqltext
where sql_id = '03ay719wdmgz1';
```

<table>
<thead>
<tr>
<th>COMMAND_TYPE</th>
<th>SQL_TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>select count(1) from t2, t2</td>
</tr>
</tbody>
</table>

```sql
select command_type, sql_text
from dba_hist_sqltext
where sql_id = 'f6c6qfq28rtkv';
```

<table>
<thead>
<tr>
<th>COMMAND_TYPE</th>
<th>SQL_TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>select count(*) from emp3</td>
</tr>
</tbody>
</table>

Selecting Query EXPLAIN PLAN from the
DBA_HIST_SQL_PLAN View

The EXPLAIN PLAN for the offending SQL is also captured. You may view information about the execution plan through the DBA_HIST_SQL_PLAN view. If you want to display the EXPLAIN PLAN, the simplest way is to use the DBMS_XPLAN package with a statement such as this one:
As you can see, this particular query is a Cartesian join, which is normally not a valid table join (certainly not a good idea as it joins every row of one table with every row of another table) and can lead to the massive resource consumption. This query was used to show how to take advantage of some of the new functionality for identifying and collecting information about poorly performing SQL. Here is the output for the query that was used earlier that queries the EMP3 table, which is over 1 billion rows (still fast at 5 minutes, even though it’s 1B rows):

```
SELECT *
FROM table(DBMS_XPLAN.DISPLAY_AWR('03ay719wdsnqz1'))
```

**PLAN_TABLE_OUTPUT**

```
SQL_ID 03ay719wdsnqz1

SELECT count(*) FROM t2, t2

Plan hash value: 1163428054

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>10G(100)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MERGE JOIN CARTESIAN</td>
<td>6810G</td>
<td>1G (2)</td>
<td>999:59:59</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>INDEX FAST FULL SCAN</td>
<td>T2_I1</td>
<td>2609K</td>
<td>3996 (2)</td>
<td>00:00:48</td>
</tr>
<tr>
<td>4</td>
<td>BUFFER SORT</td>
<td></td>
<td>2609K</td>
<td>10G (2)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>INDEX FAST FULL SCAN</td>
<td>T2_I1</td>
<td>2609K</td>
<td>3994 (2)</td>
<td>00:00:48</td>
</tr>
</tbody>
</table>
```

As you can see, this particular query is a Cartesian join, which is normally not a valid table join (certainly not a good idea as it joins every row of one table with every row of another table) and can lead to the massive resource consumption. This query was used to show how to take advantage of some of the new functionality for identifying and collecting information about poorly performing SQL. Here is the output for the query that was used earlier that queries the EMP3 table, which is over 1 billion rows (still fast at 5 minutes, even though it’s 1B rows):

```
SELECT *
FROM table(DBMS_XPLAN.DISPLAY_AWR('f6c6gqg28rtkv'))
```

**PLAN_TABLE_OUTPUT**

```
SQL_ID f6c6gqg28rtkv

SELECT count(*) FROM emp3

Plan hash value: 1396384608

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TABLE ACCESS FULL</td>
<td>EMP3</td>
<td>1006M</td>
<td>1605K (1)</td>
<td>05:21:10</td>
</tr>
</tbody>
</table>
```
What If I Forget the Index?

Although it seems obvious that columns, which are generally restrictive, require indexes, this requirement is not always such common knowledge among users or managers. I once went to a consulting job where their database was suffering from incredibly poor performance. When I asked for a list of tables and indexes, they replied, “We have a list of tables, but we haven’t figured out what indexes are yet and if we should use them or not—do you think you can help our performance?” My first thought was, “Wow, can I ever—my dream tuning job.” My second thought was that I had been training experts too long and had forgotten that not everyone is as far along in their performance education. While basic index principles and structure are covered in Chapter 2, this section will focus on query-related issues surrounding indexes.

Even if you have built indexes correctly for most columns needing them, you may miss a crucial column here and there. If you forget to put an index on a restrictive column, then the speed of those queries will not be optimized. Consider the following example where the percent of rows returned by any given CUST_ID is less than 1 percent (there are about 25M rows on the SALES2 table and about 25K of them are CUST_ID=22340). Under these circumstances, an index on the CUST_ID column should normally be implemented. The next query does not have an index on CUST_ID:

```sql
select count(*)
from sales2
where cust_id = 22340;
```

```
COUNT(*)

25750
```

Elapsed: 00:00:08.47 (0.47 seconds)

**Execution Plan**

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>(1)</td>
<td>00:06:32</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TABLE ACCESS FULL</td>
<td>SALES2</td>
<td>24M</td>
<td>32639</td>
<td>00:06:32</td>
</tr>
</tbody>
</table>

119260 consistent gets (memory reads)
119258 physical reads (disk reads)
1,000 times more blocks read than using an index (we’ll see this in a moment)

Not only is the query extremely slow, but it also uses a tremendous amount of memory and CPU to perform the query. This results in an impatient user and a frustrating wait for other users due to the
lack of system resources. (Sound familiar?)

Creating an Index

To accelerate the query in the last example, I build an index on the CUST_ID column. The storage clause must be based on the size of the table and the column. The table is over 25 million rows (the space for the index is about 461M). Specifying Automatic Segment Space Management for the underlying tablespace allows Oracle to manage segment space automatically for best performance. I could also perform an ALTER SESSION SET SORT_AREA_SIZE = 500000000 (if I had the necessary OS memory) and the index creation would be much faster.

```
create index sales2_idx1 on sales2(cust_id)
tablespace rich;
Index Created.
```

Invisible Index

Oracle has a feature called invisible indexes. An invisible index is invisible to the optimizer by default. Using this feature, you can test a new index without affecting the execution plans of the existing SQL statements or you can test the effect of dropping an index without actually dropping it (the index continues to be maintained even though it is not seen by the optimizer; this ensures if you make it visible again, it’s up to date). Note that Chapter 2 has additional information and queries related to invisible indexes.

You can create an invisible index or you can alter an existing index to make it invisible. To enable the optimizer to use all invisible indexes (not a good idea usually), set the new initialization parameter called OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE. This parameter is set to FALSE by default. You can run this CREATE instead of the one in the previous section:

```
create index sales2_idx1 on sales2(cust_id)
tablespace rich
storage (initial 400M next 10M pctincrease 0) invisible;
Index Created
```

Checking the Index on a Table
Before creating indexes, check for current indexes that exist on that table to ensure there are no conflicts.

Once you have created the index, verify that it exists by querying the DBA_IND_COLUMNS view:

```sql
select table_name, index_name, column_name, column_position
from dba_ind_columns
where table_name = 'SALES2'
and table_owner = 'SH'
order by index_name, column_position;
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NAME</th>
<th>COLUMN_NAME</th>
<th>COLUMN_POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>SALES2</td>
<td>SALES2_IDX1</td>
<td>CUST_ID</td>
<td>1</td>
</tr>
</tbody>
</table>

The TABLE_NAME is the table that is being indexed; the INDEX_NAME is the name of the index; the COLUMN_NAME is the column being indexed; and the COLUMN_POSITION is the order of the columns in a multipart index. Because our index involves only one column, the COLUMN_POSITION is 1 (CUST_ID is the first and only column in the index).

Query USER_INDEXES to verify the visibility of the index:

```sql
select index_name, visibility
from user_indexes
where index_name = 'SALES2_IDX1';
```

<table>
<thead>
<tr>
<th>INDEX_NAME</th>
<th>VISIBILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SALES2_IDX1</td>
<td>VISIBLE</td>
</tr>
</tbody>
</table>

Is the Column Properly Indexed?

Rerun the same query now that the CUST_ID column is properly indexed. The query is dramatically faster, and more important, it no longer “floods” the system with a tremendous amount of data to the SGA (it has a much lower number of block reads) and subsequently reduces the physical I/O as well. Originally, this query took around 120,000 physical reads. Now it only takes about 60 physical reads (1000× less) and over 800× faster. Even though the query itself runs in seconds, this time difference can be a big deal if the query runs many times.
TIP
The first tip concerning slow queries is that you'll have a lot of them if you don't index restrictive columns (return a small percentage of the table). Building indexes on restrictive columns is the first step toward better system performance.

What If I Create a Bad Index?
In the query to the PRODUCT table, I have a COMPANY_NO column. Since this company's expansion has not occurred, all rows in the table have a COMPANY_NO = 1. What if I am a beginner and I have heard that indexes are good and have decided to index the COMPANY_NO column? Consider the following example which selects only certain columns from the PLAN_TABLE after executing the query.

The cost-based optimizer will analyze the index as bad and suppress it. The table must be reanalyzed after the index (depending on the statistics level) is created for the cost-based optimizer to make an informed choice. The index created on COMPANY_NO is correctly suppressed by Oracle internally (since it would access the entire table and index).
Indexes can also be suppressed when they cause poorer performance by using the FULL hint:

```sql
select /*= FULL('PRODUCT') */ product_id, qty
from   product
where  company_no = 1;
```

Elapsed time: 405 seconds (all records are retrieved via a full table scan)

```
<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>FULL</td>
<td>PRODUCT</td>
</tr>
</tbody>
</table>
```

41,562 physical reads (disk reads)
Next, consider a similar example on a faster server with a 25M-row table where I am summing all rows together. Oracle *is* once again smart enough to do a full table scan since I am summing the *entire* table. A full table scan only scans the table, but if I force an index (as in the second example), it has to read many more blocks (almost 50 percent more), scanning both the table and the index (resulting in a query that is almost four times slower).

```sql
select sum(prod_id) 
from sales 
where cust_id=1;
```

```
SUM(PROD_ID)
-----------
1338666817
```

Elapsed: 00:00:08.58

**Execution Plan**

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>7</td>
<td>33009</td>
<td>20:06:37</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* 2</td>
<td>TABLE ACCESS FULL</td>
<td>SALES3</td>
<td>24M</td>
<td>165M</td>
<td>33009</td>
<td>20:06:37</td>
</tr>
</tbody>
</table>

"Statistics"

```
119665  consistent gets
119660  physical reads
```

Now let’s try scanning the index and then go to the table (bad idea):
TIP

Bad indexes (indexing the wrong columns) can cause as much trouble as forgetting to use indexes on the correct columns. While Oracle’s cost-based optimizer generally suppresses poor indexes, problems can still develop when a bad index is used at the same time as a good index. The cost of each index for INSERTs and DELETEs must also be considered when adding many indexes.

Exercising Caution When Dropping an Index

Some people’s first reaction when they find a query that is using a poor index is to drop the index. Suppressing the index should be your first reaction, however, and investigating the impact of the index on other queries should be the next action. Unless your query was the only one being performed against the given table, changing/dropping an index might be a detrimental solution (perhaps it’s only used during month-end or year-end reporting). The invisible index feature can be used to determine the effect of dropping an index without actually dropping it (Chapter 2 covers the indexes in detail as well using the invisible index to create multiple types of indexes on the same column at the same time in 12c). Issue the following command against the index that needs to be dropped:

```sql
alter index sales2_idx1 invisible;
```
An invisible index is an index that continues to be maintained, but is ignored by the optimizer unless you explicitly set it back to being visible or turn all invisible indexes on by setting the OPTIMIZER_USE_INVISIBLE_INDEXES to TRUE (careful). This way you can test the effect of dropping a particular index. If you want to reverse it, all you need to do is

```
alter index sales2 idx visible;
```

The next section investigates indexing columns that are both in the SELECT and WHERE clauses of the query.

**Indexing the Columns Used in the SELECT and WHERE**

The preceding section described how dropping an index can hurt performance for a query. Consider the following query where the index was created to help. I built a million-row EMPLOYEES table from the famous SCOTT.EMP table. This query does not have indexed columns:

```sql
select ename
from employees
where deptno = 10;
```

Elapsed time: 55 seconds (a full table scan is performed)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>FULL</td>
<td>EMPLOYEES</td>
</tr>
</tbody>
</table>

First, I place an index on the DEPTNO column to try to improve performance:
This situation is now worse since almost all values for DEPTNO were equal to 10 (we read the entire index and almost the entire table, which takes longer than just reading the entire table). In this query, only the ENAME is selected. If this is a crucial query on the system, choose to index both the SELECT and the WHERE columns. By doing this, you create a concatenated index:

```
Drop index dept_idx1;
Create index emp_idx1 on employees (deptno, ename)
Tablespace test1
Storage (initial 20M next 5M pctincrease 0);
```

The query is now tremendously faster:

```
select ename
from employees
where deptno = 10;
```

Elapsed time: Less than 1 second (the index on deptno AND ename is used)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDEX</td>
<td>RANGE SCAN</td>
<td>EMP IDX1</td>
</tr>
</tbody>
</table>

The table itself did not have to be accessed (only read the entire index), which increases the speed of the query. Indexing both the column in the SELECT clause and the column in the WHERE clause allows the query to only access the index.

Consider the following 25M-row SALES3 table (created from SALES2). I have a two-part single
index on the CUST_ID and PROD_ID columns. Oracle only needs to access the index (no table access), since all needed information is contained in the index (60K reads instead of the 160K you saw earlier).

```
select sum(prod_id)
from sales3
where cust_id = 1;
```

```
SUM(PROD_ID)
-----------
1399649817
```

Elapsed: 00:00:05.4

**Execution Plan**

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>7</td>
<td>16690</td>
<td>00:03:21</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>INDEX FAST FULL SCAN</td>
<td>SALES2_IDX_MULTI</td>
<td>24M</td>
<td>165M</td>
<td>16690</td>
<td>00:03:21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistics:</th>
</tr>
</thead>
<tbody>
<tr>
<td>60574   consistent gets</td>
</tr>
<tr>
<td>60556   physical reads</td>
</tr>
</tbody>
</table>

**TIP**

For crucial queries on your system, consider concatenated indexes on the columns contained in both the SELECT and the WHERE clauses so only the index is accessed.

**Using the Fast Full Scan**

The preceding section demonstrated that if I index both the SELECT and the WHERE columns, the query is much faster. Oracle does not guarantee that only the index will be used under these circumstances. However, there is a hint that guarantees (under most circumstances) that only the index will be used. The INDEX_FFS hint is a fast full scan of the index. This hint accesses only the index and not the corresponding table. Consider a query from a table with 100M rows with the index on CUST_ID called SALES2_IDX.

First, you check the number of blocks read for a full table scan and then a fast full index scan:
Now let's try to select using a full index scan instead:

```sql
select /*+ index_ffs (sales2 sales2_idx) */ count(*)
from sales2;

COUNT(*)
----------
100153887

Elapsed: 00:24:06.07
```

Execution Plan

Plan hash value: 2862189843

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>32761</td>
<td>01:06:32</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TABLE ACCESS FULL</td>
<td>SALES2</td>
<td>24M</td>
<td>32761</td>
<td>01:06:32</td>
</tr>
</tbody>
</table>

Statistics

820038 consistent gets
481141 physical reads
The query with the INDEX_FFS hint now only accesses the index. Instead of scanning over 800K blocks (of which 400K were physical reads), you only scan around 300K blocks (of which 210K are physical reads). Also note, sometimes your queries scan the entire index (as this one did), which is often not as good as if you have a limiting condition, so be careful; using an index search is much better than a full index scan when possible. Oracle often scans the index versus scanning the table for a count(*), by default, in 12c. Running either of these queries a second time (see next section) does not get rid of the physical scans since the query retrieves enough data to fill half of the number of blocks as in the total buffer cache (it is pushed out of the cache quickly since it is not a short table; see Chapter 14 for additional details).

TIP
The INDEX_FFS hint processes only the index and does not access the table. All columns that are used and retrieved by the query must be contained in the index.

Making the Query “Magically” Faster
Consider the following query from the last example in which the user adds a hint called “RICHS_SECRET_HINT.” The user overheard a conversation about this hint at a recent user group and believes this hint (buried deep in the X$ tables) is the hidden secret to tuning. First, the query is run and no index can be used (a large EMPLOYEES table with over 14M rows):
There is *no* index that can be used on this query. A full table scan is performed. The user now adds Rich’s secret hint to the query:

```
select /*+ richs_secret_hint */ ename, job
from employees
where deptno = 10
and ename = 'ADAMS';
```

Elapsed time: under 1 second (one record is retrieved in this query)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td>FULL</td>
<td>EMPLOYEES</td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The hint worked and the query is “magically” faster, although a full table scan was still performed in the second query. Actually, the data is now stored in memory and querying the data from memory is now much faster than going to disk for the data—so much for the magic! By effectively using the 12c Result Cache, you can *magically* make things faster as well. See the “Using the Result Cache” section later in this chapter.

**TIP**

*When running a query multiple times in succession, it becomes faster because you have now cached the data in memory (although full table scans are aged out of memory quicker than indexed scans). At times, people are tricked into believing that they have made a query faster, when in actuality they are accessing data stored in memory. Flushing the buffer cache or restarting the test system can help you get accurate tuning results for comparisons. The next time a user calls and says a query was too slow, just say: Really? Try running it again.*

**Caching a Table in Memory**
While it is disappointing that there is no “secret hint” for tuning (ORDERED and LEADING are the hints closest to magic), you can use the previous section to learn from, and then you can use this knowledge to your advantage. In the previous section, the query ran faster the second time because it was cached in memory. What if the tables used most often were cached in memory all the time? Well, the first problem is that if you cannot cache every table in memory, you must focus on the smaller and more often used tables to be cached. You can also use multiple buffer pools as discussed in Chapter 4. The following query is run against an unindexed CUSTOMER table to return one of the rows:

```
select prod_id, cust_id
from sales
where cust_id=999999999
and prod_id is not null;
```

<table>
<thead>
<tr>
<th>PROD ID</th>
<th>CUST ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>999999999</td>
</tr>
</tbody>
</table>

Elapsed: 00:00:00.84

Execution Plan

Plan hash value: 7815903877

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>50</td>
<td>1300</td>
<td>1241</td>
<td>00:00:15</td>
</tr>
<tr>
<td>* 1</td>
<td>TABLE ACCESS FULL</td>
<td>SALES</td>
<td>50</td>
<td>1300</td>
<td>1241</td>
<td>00:00:15</td>
</tr>
</tbody>
</table>

The database is then stopped and restarted so as to not influence the timing statistics (you can also perform an ALTER SYSTEM FLUSH BUFFER_Cache, but only do this on a test system). The table is altered to cache the records:

```
alter table sales cache;
```

Table altered.

Query the unindexed, but now cached, SALES table and it still takes 0.84 seconds. The table has been altered to be cached, but the data is not in memory yet. Every subsequent query will now be faster (after the first one). I query the unindexed (but now cached) SALES table to return one of the rows in 0.04 seconds, or 21 times faster (this increase in speed could add up fast if this query is run thousands of times):
The query is faster because the table is now cached in memory; in fact, all queries to this table are now fast regardless of the condition used. A cached table is "pinned" into memory and placed at the "most recently used" end of the cache; it is pushed out of memory only after other full table scans to tables that are not cached are pushed out. Running a query multiple times places the data in memory so subsequent queries are faster—only caching a table ensures that the data is not later pushed out of memory. Oracle caches frequently used data, by default, as you access things over and over.

**TIP**
Caching an often-used but relatively small table into memory ensures that the data is not pushed out of memory by other data. Be careful, however—cached tables can alter the execution path normally chosen by the optimizer, leading to an unexpected execution order for the query (for instance, affecting the driving table in nested loop joins).

**Using the Result Cache**
The Result Cache lets you cache SQL results in an area of the SGA to improve performance.

The following RESULT_CACHE hint caches the results on execution:

```sql
select /*+ result_cache */ SUM(sal)
from scott.emp
where deptno=20;
```
When a query with RESULT_CACHE hint is run, Oracle will see if the results of the query have already been executed, computed, and cached, and, if so, retrieve the data from the cache instead of querying the data blocks and computing the results again. Take the following important points into consideration before using this feature:

- The Result Cache feature is useful only for SQL queries that are executed frequently.
- The underlying data doesn’t change very often. When the data changes, the result set is removed from the cache.

If you are executing the same queries over and over, using the RESULT_CACHE hint often makes subsequent queries run faster. Chapters 1 and 4 contain additional information on this.

TIP

*If you are executing the same queries over and over (especially grouping or calculation functions), using the RESULT_CACHE hint often makes subsequent queries run faster (at times very much faster).*

### Choosing Among Multiple Indexes (Use the Most Selective)

Having multiple indexes on a table can cause problems when you execute a query where the choices include using more than one of the indexes. The optimizer almost always chooses correctly. Consider the following example where the percent of rows returned by any given PRODUCT_ID is less than 1 percent where the data is equally distributed between the blocks. Under these circumstances, place an index on the PRODUCT_ID column. The following query has a single index on PRODUCT_ID:

```sql
select product_id, qty
from product
where company no = 1
and product_id = 167;
```

1 second (one record is retrieved; the index on product_id is used)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>BY ROKID</td>
<td>PRODUCT</td>
</tr>
<tr>
<td>INDEX</td>
<td>RANGE SCAN</td>
<td>PROD_IDX</td>
</tr>
</tbody>
</table>

10% consistent gets (memory reads)
1 physical reads (disk reads)
Now create an additional index on the COMPANY_NO column. In this example, all of the records have a COMPANY_NO = 1, an extremely poor index. Rerun the query with both indexes (one on PRODUCT_ID and one on COMPANY_NO) existing on the table:

```
select product_id, qty
from product
where company_no = 1
and product_id = 167;
```

Elapsed time: 725 seconds (one record is returned; a full table scan is performed)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>FULL</td>
<td>PRODUCT</td>
</tr>
</tbody>
</table>

4,625,725 consistent gets (memory reads)
80,513 physical reads (disk reads)

Oracle has chosen not to use either of the two indexes (perhaps because of a multiblock initialization parameter or some other "exception to the rule"), and the query performed a full table scan. Depending on the statistical data stored and version of Oracle used, I have seen this same query use the right index, the wrong index, no index at all, or a merge of both indexes. The correct choice is to force the use of the correct index. The correct index is the most restrictive. Rewrite the query to force the use of the most restrictive index, as follows, or better yet, fix the real initialization parameter issue (the less hints that you use, the better—especially when you upgrade to the next version of Oracle).

To rewrite the query to force the use of the most restrictive index:

```
select /*+ index(product prod_idxl) */ product_id, qty
from product
where company_no = 1
and product_id = 167;
```

Elapsed time: 1 second (one record is retrieved)

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>BY ROWID</td>
<td>PRODUCT</td>
</tr>
<tr>
<td>INDEX</td>
<td>RANGE SCAN</td>
<td>PROD_IDX1</td>
</tr>
</tbody>
</table>

107 consistent gets (memory reads)
1 physical reads (disk reads)
TIP
When multiple indexes on a single table can be used for a query, use the most restrictive index when you need to override an optimizer choice. While Oracle’s cost-based optimizer generally forces the use of the most restrictive index, variations will occur, depending on the version of Oracle used, the structure of the query, and the initialization parameters that you may use. Fix the larger issue (get rid of bad indexes) if you see this as a trend.

TIP
Bitmap indexes usually behave differently because they are usually much smaller. See Chapter 2 for more information on the differences between bitmap indexes and other indexes.

The Index Merge
Oracle’s index merge feature allows you to merge two separate indexes and use the result of the indexes instead of going to the table from one of the indexes. Consider, for instructional purposes only, the following example (if you use a rule-based hint, which Oracle does not support, but uses internally at times, Oracle includes a note in the EXPLAIN PLAN that specifically suggests you use the cost-based optimizer). Also note that OPTIMIZER_MODE set to CHOOSE is not supported either, so use either ALL_ROWS or FIRST_ROWS instead.

The following statistics are based on 1,000,000 records. The table is 210M.
In the first query, I test the speed of using just one of the indexes and then going back to the table (under certain scenarios, Oracle tunes this with an AND-EQUAL operation to access data from the indexes). I then use the INDEX_JOIN hint to force the merge of two separate indexes and use the result of the indexes instead of going back to the table. When the indexes are both small compared to the size of the table, this can lead to better performance. On a faster system, the second query takes only 0.06 seconds, so your mileage will vary.

Now, let's consider a query to the 25M-row SALES3 table on a faster server with separate indexes on the CUST_ID and PROD_ID columns. Using an index merge of the two indexes yields a very slow response time and many blocks read (over 200K physical reads):
If I drop the two indexes on SALES3 and replace them with a two-part single index on the CUST_ID and PROD_ID columns, performance improves greatly—over ten times faster. Another benefit is the reduction of physical block reads from over 200K to only 60K.
Indexes That *Can* Get Suppressed

Building the perfect system with all of the correctly indexed columns does not guarantee successful system performance. With the prevalence in business of bright-eyed ad hoc query users comes a variety of tuning challenges. One of the most common is the suppression of perfectly good indexes. A modification of the column side of a WHERE clause often results in that index being suppressed (unless function-based indexes are utilized or the super-smart optimizer figures out a better path). Alternative methods for writing the same query do exist that do not modify the indexed column. A couple of those examples are listed next. Oracle *does* use the indexes in many cases, internally fixing the suppression (they continue to get better at this from version to version), especially when an index search or a full index scan can be run instead of a full table scan. If you use 3GL code or code within applications, the results vary, so I continue to show these areas that are a problem with certain tools or applications for you to consider when you run into that full table scan that you didn’t expect.

A math function is performed on the column:

```sql
select product_id, qty
from product
where product_id+12 = 166;

Elapsed time: 405 second

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>FULL</td>
<td>PRODUCT</td>
</tr>
</tbody>
</table>
```

The math function is performed on the other side of the clause (Oracle often fixes this internally):

```sql
select product_id, qty
from product
where product_id = 154;

Elapsed time: 1 second

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>OPTIONS</th>
<th>OBJECT NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>BY ROWID PRODUCT</td>
<td></td>
</tr>
<tr>
<td>INDEX</td>
<td>RANGE SCAN PROD_IDX1</td>
<td></td>
</tr>
</tbody>
</table>
```

A function is performed on the column:
As I stated previously, Oracle is often smart enough to figure out the issue and still use the index. The following query shows that the index is scanned with no table access despite the attempt to suppress the index (adding zero (0) or using a NULL Value (NVL) gave the same result). In the following case, everything needed is in the index. Oracle figures out the substring function on the leading edge of the index but is still able to use only the index despite needing both columns from the index (versus using the index to access back to the table).

```
select product_id, qty
from product
where substr(product_id, 1, 1) = '1';
Elapsed time: 405 second

OPERATION          OPTIONS    OBJECT NAME
------------------- ---------- ------------
SELECT STATEMENT   ----------   -----------
TABLE ACCESS       FULL       PRODUCT

The function is rewritten so the column is not altered (a LIKE or function-based index would fix this):

```

```
select product_id, qty
from product
where product_id like '1%';
Elapsed time: 1 second

OPERATION          OPTIONS    OBJECT NAME
------------------- ---------- ------------
SELECT STATEMENT   ----------   -----------
TABLE ACCESS       BY ROWID   PRODUCT
INDEX              RANGE SCAN PROD_IDX1
```
At times, modifying the column side of the query can result in the index being suppressed unless a function-based index is used. Oracle may also fix this issue during parsing. The more complex the query, the less likely Oracle will fix it.

Function-Based Indexes

One of the largest problems with indexes, as seen in the previous section, is that indexes are often suppressed by developers and ad hoc users. Developers using functions often suppress indexes. There is a way to combat this problem. Function-based indexes allow you to create an index based on a function or expression. The value of the function or expression is specified by the person creating the index and is stored in the index. Function-based indexes can involve multiple columns, arithmetic expressions, or maybe a PL/SQL function or C callout.

The following example shows how to create a function-based index:

```sql
CREATE INDEX emp_idx ON emp (UPPER(ename));
```

An index that uses the UPPER function has been created on the ENAME column. The following example queries the EMP table using the function-based index:
The function-based index (EMP_IDX) can be used for this query. For large tables where the condition retrieves a small amount of records, the query yields substantial performance gains over a full table scan. See Chapter 2 for additional details and examples.

The following initialization parameters must be set (subject to change with each version) to use function-based indexes (the optimization mode must be cost-based as well). When a function-based index is not working, this is often the problem.

TIP
Function-based indexes can lead to dramatic performance gains when used to create indexes on functions often used on selective columns in the WHERE clause.

To check the details for function-based indexes on a table, you may use a query similar to this:

```sql
select table_name, index_name, column_expression
from dba_ind_expressions
where table_name = 'SALES2'
and table_owner = 'SH'
order by index_name, column_position;
```

**Virtual Columns**

A helpful feature introduced in Oracle 11g is the *virtual column*, a column that allows you to define a function on other column(s) in the same table. Here is an example of creating a table with a virtual column:

```sql
select ename, job, deptno
from emp
where upper(ename) = 'ELLISON';
```
An important point to remember is that indexes defined against virtual columns are equivalent to function-based indexes.

The “Curious” OR

The optimizer often has problems when the OR clause is used. The best way to think of the OR clause is as multiple queries that are then merged. Consider the following example where there is a single primary key on PK_COL1, PK_COL2, and PK_COL3. Prior to Oracle 9i, Oracle Database performed this query in the following way:

```sql
select *
from table_test
where pk_col1 = 'A'
and pk_col2 in ('B', 'C')
and pk_col3 = 'D';
```

2 Table Access By Rowid TABLE_TEST
1 Index Range Scan TAB_PK

NOTE
PK_COL2 and PK_COL3 were not used for index access.

Since Oracle9i, Oracle has improved how the optimizer handles this query (internally performing an OR expansion). In 12c, the optimizer uses the full primary key and concatenates the results (as shown next), which is much faster than using only part of the primary key (as in the preceding access path). Even though the access path for the preceding query looks better because there are fewer lines, don’t be tricked; fewer lines in the EXPLAIN PLAN doesn’t mean a more efficient query.
To get this desired result prior to 9i, you would have needed to break up the query as shown here (I show this since often making a query longer can make it faster, as it’s processed differently):

```sql
select *
from   table_test
where (pk_col1 = 'A'
and   pk_col2 = 'B'
and   pk_col3 = 'D')
or (pk_col1 = 'A'
and   pk_col2 = 'C'
and   pk_col3 = 'D');
```

TIP

Oracle has improved the way that it performs the OR clause. The NO_EXPAND hint can still be helpful, as it prevents the optimizer from using OR expansion, as described in Chapter 7.

Using the EXISTS Function and the Nested Subquery

Another helpful tip to remember is to use the EXISTS function instead of the IN function in most circumstances. The EXISTS function checks to find a single matching row to return the result in a subquery. Because the IN function retrieves and checks all rows, it is slower. Oracle has also improved the optimizer so it often performs this optimization for you as well. Consider the following example, where the IN function leads to very poor performance. This query is faster only if the ITEMS table is extremely small.
In this query, the entire ITEMS table is retrieved.

This query is faster when the condition PRODUCT_ID = 167 substantially limits the outside query:

```sql
SELECT product_id, qty
FROM product a
WHERE product_id = 167
AND exists
    (SELECT 'x'
     FROM items b
     WHERE b.item_no = a.item_no);
```

Elapsed time: 2 seconds (The items table query search is limited to 3 rows)

In this query, only the records retrieved in the outer query (from the PRODUCT table) are checked against the ITEMS table. This query can be substantially faster than the first query if the ITEM_NO in the ITEMS table is indexed or if the ITEMS table is very large, yet the items are limited by the condition PRODUCT_ID = 167 in the outer query.
TIP

Using the nested subquery with an EXISTS clause may make queries dramatically faster, depending on the data being retrieved from each part of the query. Oracle 12c often makes this translation internally, saving you time and giving you performance gains!

That Table Is Actually a View!

Views can hide the complexity of SQL but they can also add to the complexity of optimization. When looking at a SELECT statement, unless you have instituted some kind of naming convention for views, you cannot tell if an object is a table or a view from the SELECT statement alone. You must examine the object in the database to tell the difference. Views can join multiple tables. Be careful about joining views or using a view designed for one purpose for a different purpose, or you may pay a heavy performance price. Ensure that all tables involved in the view are actually required by your query. Also keep in mind that different types of triggers can also hide performance issues behind a simple query. Good developer documentation can save a lot of time in finding performance issues in complex code.

SQL and Grand Unified Theory

Many physicists have searched for a single theory that explains all aspects of how the universe works. Many theories postulated have worked well in certain circumstances and break down in others. This is fine for theoretical physics, but it can spell disaster in a database. When writing SQL, one should not attempt to write the “Grand Unified SQL” statement that will do all tasks, depending on the arguments passed to it. This typically results in suboptimal performance for most tasks performed by the statement (or you feel the effect during the next upgrade). It is better to write separate, highly efficient statements for each task that needs to be performed.

Tuning Changes in Oracle Database 12c

The general SQL tuning principles remain the same in 11g and 12c, but some significant cost-based optimizer changes should be noted:

- The RULE (and CHOOSE) OPTIMIZER_MODE has been deprecated and desupported in both 11g and 12c. (The only way to get rule-based behavior is by using the RULE hint in a query, which is not supported either.) In general, using the RULE hint is not recommended, but for individual queries that need it, it is there. Consult with My Oracle Support before using the RULE hint. See Chapter 4 for more information on initialization parameters. OPTIMIZER_MODE values include ALL_ROWS, FIRST_ROWS, and FIRST_ROWS_n.

- In 12c, the cost-based optimizer has two modes:
  - In NORMAL mode, the cost-based optimizer considers a very small subset of possible
execution plans to determine which one to choose. The number of plans considered is far smaller than in past versions of the database in order to keep the time to generate the execution plan within strict limits. SQL profiles (statistical information) can be used to influence which plans are considered.

The TUNING mode of the cost-based optimizer can be used to perform more detailed analysis of SQL statements and make recommendations for actions to be taken and for auxiliary statistics to be accepted into a SQL profile for later use when running under NORMAL mode. TUNING mode is also known as the Automatic Tuning Optimizer mode, and the optimizer can take several minutes for a single statement (good for testing). See the Oracle Database Performance Tuning Guide Automatic SQL Tuning (Chapter 17 in the 11.2 docs). Oracle states that the NORMAL mode should provide an acceptable execution path for most SQL statements. SQL statements that do not perform well in NORMAL mode may be tuned in TUNING mode for later use in NORMAL mode. This should provide a better performance balance for queries that have defined SQL profiles, with the majority of the optimizer work for complex queries being performed in TUNING mode once, rather than repeatedly, each time the SQL statement is parsed.

In Oracle 12c, the optimizer has been greatly improved by introducing the Adaptive Query Optimization feature. This new feature allows the optimizer to “change its mind” during the first run of an execution plan, and then discover additional information to further fine-tune the plan going forward. In other words, the optimizer can now make runtime adjustments during the execution of the plan. Figure 8-2 shows all the components that make up Adaptive Query Optimization. Adaptive plans can change the join method or the parallel distribution method at execution time. Adaptive statistics can be gathered at execution time and then stored for future use. I’ll go over each one of these components in detail in the next two subsections.

---

**FIGURE 8-2. Adaptive Query Optimization**
Adaptive plans help the optimizer make the final plan choice on the first execution of a SQL statement. Let’s review how the optimizer creates the default execution plan, as shown in Figure 8-3.

After a SQL statement is parsed, the query is first sent to a query transformer, which tries to rewrite the SQL to be more efficient. After the query is transformed, it is sent to an estimator, which computes estimated costs of CPU and I/O by using default statistics. All of that information is then sent to the plan generator, which creates multiple plans using different data access paths and join methods. Only the plan with the lowest cost is chosen. After that, the default plan is sent to a row source generator, which creates all the steps and their associated default costs for actual execution.

In Oracle 12c, the optimizer now instruments the default plan with statistics collector. So at runtime, the optimizer reads and buffers a small number of rows in each step, and compares the actual statistics with the default plan estimates. If they are significantly different, the step is adapted to use the better plan to avoid poor performance. Currently the only steps that can change in a default plan are join method operations and parallel query distribution.

There are two new initialization parameters that control the adaptive features, OPTIMIZER_ADAPTIVE_FEATURES and OPTIMIZER_ADAPTIVE_REPORTING_ONLY. All of the parameters that can change the behavior of adaptive optimization are listed here:
By default, the OPTIMIZER_ADAPTIVE_FEATURES parameter is set to TRUE so execution plans can automatically change the join method operations (I've seen this work well) or the parallel query distribution on the first run. The OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter can be set to TRUE to first test which queries are going to adapt before the optimizer actually uses the adapted plan. This might be helpful when first upgrading from an earlier version of Oracle to avoid any unexpected behavior. By default, the REPORTING_ONLY option is set to FALSE. Both parameters can be set at system or session levels. You can also set the OPTIMIZER_FEATURES_ENABLE parameter to something less than 12.1.0.1 in order to turn this feature off. However, I recommend using the REPORTING_ONLY parameter to control this feature as it's less intrusive. Finally, the OPTIMIZER_DYNAMIC_SAMPLING parameter has a new level that helps control dynamic statistics, which I'll talk about later in this section.

To identify whether a SQL statement is using an adaptive plan, we need to look at a new column in the V$SQL table called IS_RESOLVED_ADAPTIVE_PLAN. If the value of this column is Y, then the plan has been adapted and is the final plan. If the column value is N, then the plan is adaptable but the final plan has not yet been chosen. The N value is rarely seen, as the final plan is chosen on the first run. If the column is null, then the plan is not adaptable. Another new column in V$SQL is called IS_REOPTIMIZABLE. This column is used to tell the optimizer to look for a better plan on the next execution. We will discuss this column in more detail when looking at adaptive statistics.

The following query can be used to quickly identify which SQL statements are using adaptive plans:

```sql
SELECT sql_id, child_number, plan_hash_value,
       is_resolved_adaptive_plan, is_reoptimizable,
       substr(sql_text, 1, 130) sql_text
FROM v$sql
WHERE is_resolved_adaptive_plan = 'Y'
ORDER BY sql_id, child_number;
```

In my examples, I've used the 'OE' sample schema and the following SQL statement to demonstrate how Adaptive Query Optimization works:
Figure 8-4 shows that the query for a customer’s order shipped status has been adapted. Notice that on the very first execution, Child Number 0 has changed from the default plan to an adapted plan. In fact, all of the child cursors have adaptive plans, identified by the ‘Y’ in the IS_RESOLVED_ADAPTIVE (IRAP) column. Also, notice that Child Number 0 has a value of ‘R’ in the IS_REOPTIMIZABLE (IR) column. The ‘R’ value is used to tell the optimizer that the OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter is set to TRUE. The optimizer won’t use this plan, but you can see what the plan would be if the Adaptive Query Optimization features were enabled. After changing the REPORTING_ONLY parameter to FALSE, we can see that Child Number 1 has a value of ‘Y’ in the IS_REOPTIMIZABLE column. After the first execution, the optimizer compares default cardinality estimates with the actual number of rows for each operation. If the estimates are significantly different, the child is marked with a ‘Y’ so the plan won’t be used again. When the IS_RESOVED_ADAPTIVE column equals ‘Y’, the optimizer performs a hard parse on the next execution (Child Number 2), so it can use the newly gathered statistics to find a better plan. Finally, Child Number 3 has been successfully reoptimized and no more changes are currently required. The IS_REOPTIMIZABLE column is set to ‘N’ on the final plan.

```sql
SELECT c.cust_first_name, c.cust_last_name, o.order_date,
       o.order_status, o.order_modc,
       i.line_item_id, p.product_Description,
       i.unit_price * i.quantitytotal_price,
       quantityquantity_ordered, ip.total_on_hand
FROM orders o, order_items i, customers c, products p,
     (SELECT product_id, sum(quantity_on_hand) total_on_hand
      FROM inventories
      GROUP BY product_id) ip
WHERE i.order_id = o.order_id
AND c.customer_id = o.customer_id
AND p.product_id = i.product_id
AND c.cust_last_name = :B1 AND O.order_status = 0
AND o.order_date between
to_timestamp(:BEG_DATE) and to_timestamp(:END_DATE);
```

**FIGURE 8-4.** Query is resolved adaptive and is reoptimizable.
To find more information about why child cursors can’t be shared and why plans change, we can query the V$SQL/shared_CURSOR table. This table contains 70 columns of mismatches or differences between the child cursors. Each column identifies a specific reason why the cursor cannot be shared with a ‘Y’ value. Viewing this table can be difficult because of all the Y and N columns. The following SQL statement can be used to report the results in a more readable format for a particular SQL_ID:

```
DECLARE c NUMBER;
col_cnt NUMBER;
col_rec DBMS_SQL.DESC_TAB;
col_value VARCHAR2(4000);
ret_val NUMBER;
BEGIN
  c := DBMS_SQL.OPEN_CURSOR;
  DBMS_SQL.PARSE(c,'SELECT q.sql_text, s.*
FROM V$SQL_SHARED_CURSOR s, V$SQL q
WHERE s.sql_id = q.sql_id
AND s.child_number = q.child_number
AND q.sql_id = '&1'' DBMS_SQL.NATIVE);
  DBMS_SQL.DESCRIBE_COLUMNS(c, col_cnt, col_rec);
  FOR idx IN 1 .. col_cnt LOOP
    DBMS_SQL.DEFINE_COLUMN(c, idx, col_value, 1000);
  END LOOP;
  ret_val := DBMS_SQL.EXECUTE(c);
  WHILE (DBMS_SQL.FETCH_ROWS(c) > 0) LOOP
    FOR idx IN 1 .. col_cnt LOOP
      DBMS_SQL.COLUMN_VALUE(c, idx, col_value);
      IF col_rec(idx).col_name in ('SQL_ID', 'ADDRESS', 'CHID_ADDRESS', 'CHILD_NUMBER', 'SQL_TEXT', 'REASON')
      THEN
        DBMS_OUTPUT.PUT_LINE(RPAD(col_rec(idx).col_name, 30) || ' = ' || col_value);
      ELSIF col_value = 'Y' THEN
        DBMS_OUTPUT.PUT_LINE(RPAD(col_rec(idx).col_name, 30) || ' = ' || col_value);
      END IF;
    END LOOP;
  END LOOP;
  DBMS_SQL.CLOSE_CURSOR(c);
END;
```

Figure 8-5 displays the results of the preceding V$SQL/shared_CURSOR query for our customer order query. Notice the ‘Y’ column names under each child number as the REASON for the change.
To view adaptive plans, there are two new format parameter values for the DBMS_XPLAN.DISPLAY_CURSOR function. The +ADAPTIVE format parameter will show all active and inactive steps of a plan. The +REPORT format parameter can be used when the OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter is set to TRUE to see how the plan would be adapted if the optimizer were running Adaptive Query Optimization. Figure 8-6 shows an example of setting the REPORTING_ONLY parameter to TRUE at session level. Then, using the +ADAPTIVE and +REPORT format parameters on the DISPLAY_CURSOR function, we can view what changes would occur if the optimizer were in non-reporting mode. Since we asked for the ‘+adaptive’ format, the inactive steps are also listed and marked with a hyphen. Basically, the STATISTICS COLLECTOR and HASH JOIN steps have been marked inactive. Also, notice in the “Note” section that “adaptive plans are enabled for reporting mode only” and the new plan without the inactive steps is listed again.
The +REPORT parameter also shows any reoptimization changes or improvements on statistics. In Figure 8-6, the default estimated rows for the INVENTORY table were at 1112. This is probably the reason for the optimizer choosing the hash join method. However, the actual statistics sampled during the execution shows that only 28 rows from the INVENTORY table will be returned, so the optimizer switched to using the nested loops join method instead, which should be substantially better (see Figure 8-7).
The optimizer is able to change the join method, such as changing a nested loops join to a hash join, on the fly at runtime. The only exception to this rule is when the initial join step is a sort merge join, as there will be no adaptation. This is probably due to the overhead of the sort, as the sampling would be too costly.

EXPLAIN PLAN can still be used with the DBMS_XPLAN.DISPLAY function to show estimated plans. However, you should always check the OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter value, as it may be displaying the adaptive plan when it’s actually in reporting-only mode. It’s important to know that when viewing adaptive plans in either the V$SQL_PLAN table or Oracle Enterprise Manager, all the steps, both active and inactive, will be shown without distinguishing which steps were actually used. You can, however, tell if the plan has been adapted by looking at the OTHER_XML column in V$SQL_PLAN. If the plan is adaptive, the OTHER_XML column will have an XML tag of <info type="adaptive_plan">yes</info>. The best way to see the actual plan is to use the DBMS_XPLAN.DISPLAY_CURSOR function with the +ADAPTIVE format parameter.

The other way a plan can adapt is when a SQL statement is resolved by using a parallel query. The optimizer tries to evenly distribute the number of rows across the number of processes that is has to work with. Historically, the optimizer would look at the number of rows and degree of parallelism (DOP) and then decide how to distribute the data. This often caused problems when there were only a few parallel processes trying to distribute a large number of rows. Also, any data skew could cause unequal distribution and performance issues. In 12c, a new Hybrid Hash distribution technique tries to fix those issues. Basically, the optimizer chooses the distribution method at execution time by inserting statistic collectors in front of the parallel processes on the producer side of the operation.
The optimizer will choose the Hybrid Hash distribution method if rows are greater than the threshold or it will choose the Broadcast distribution method if rows are less than the threshold. The threshold is defined as $2 \times \text{DOP}$.

Figure 8-8 shows an example of how the Hybrid Hash distribution works. A hybrid hash does not decide the final data distribution until execution time. The optimizer collects statistics in front of the parallel server processes to check the threshold. Notice that I included a hint so the DOP for our customer query is set to 20. So my threshold is $2 \times 20 = 40$.

![Image](image.png)

**FIGURE 8-8. Hybrid Hash, a new parallel distribution method**

The optimizer chose to use the Hybrid Hash distribution method on the INVENTORIES table because the rows accessed were well over my threshold of 40. Likewise, it chose the Broadcast distribution method when accessing ORDERS and ORDER_ITEMS because they had rows below the threshold.

### Adaptive Statistics

The other piece to the Adaptive Query Optimizer is adaptive statistics (refer to Figure 8-2 shown earlier). I’ve already presented some examples of the optimizer using them, but I’ll dive further into all the different aspects of adaptive statistics, including dynamic statistics, automatic reoptimization, and SQL plan directives.
Dynamic Statistics

Dynamic sampling is not a new feature in 12c. However, the name has been changed to dynamic statistics because you can instruct the optimizer to automatically decide when to use dynamic statistics for any SQL statement. Historically, if statistics were missing, the optimizer would first sample a few random blocks to get more information. In 12c, you can set the initialization parameter OPTIMIZER_DYNAMIC_SAMPLING to a new level, 11. This new level, which can be set either at system or session level, will allow the optimizer to decide whether to use dynamic statistics even if there are base table statistics. The optimizer considers the base table statistics, the complexity of the statement, and the total execution time in order to decide whether to use dynamic statistics or not. This feature could be really useful if your data is rapidly growing and changing at such a pace that statistics get stale very quickly. Figure 8-9 shows a good example of why you would want to use dynamic statistics.

In the example in the upper portion of Figure 8-9, the SELECT statement shows the number of rows returned will be over 1 million. My EXPLAIN PLAN shows that the default plan estimated a
little over 101K rows will be returned. This is almost ten times off what is really going to be returned from the table. The bottom of the figure shows how to set the dynamic sampling to level 11. Notice now the optimizer has better statistics at 898K and the sampling level is set to AUTO. It is important to know that parse time will take longer when you have dynamic sampling set to AUTO or level 11. However, the results are often persisted in cache as dynamic statistics or as a SQL plan directive that can be used for other “like” or similar queries. We’ll get into more detail on SQL plan directives in a few pages.

**Automatic Reoptimization**

I briefly discussed automatic reoptimization in the context of adaptive plans. However, automatic reoptimization differs from adaptive plans in that reoptimization changes the plan after the first execution, not during it. The optimizer uses the information gathered during the execution and compares it with the default estimates. If they differ significantly, then the plan will be reoptimized on the next run. Sometimes, the optimizer will store the new information gathered as a ‘SQL plan directive’ so other similar queries can benefit from the information. Or it will store an OPT_ESTIMATE hint in V$SQL_REOPTIMIZATION_HINTS for future reference. The optimizer can reoptimize a query several times by using statistics feedback or performance feedback to change the plan.

**Statistics Feedback**

Statistics feedback is used when estimated cardinalities are wrong. This can be due to missing or inaccurate statistics or complex predicates, or if there are multiple (and/or) filter predicates on a table. Also, the optimizer will use statistics feedback if the predicates contain complex operations for which the optimizer can’t compute any estimates. Figure 8-10 shows an example of how statistics feedback works. For this example, the DBMS_XPLAN format parameter ALLSTATS LAST is used in conjunction with the GATHER_PLAN_STATISTICS hint to show the estimated rows versus the actual rows returned in each step.
In this example, notice how far off the default estimates are. In step 6 alone, the estimated number of rows read is 1042K, when in reality only 57,350 rows are needed. The optimizer realizes this discrepancy and uses statistics feedback to further optimize it.

**Performance Feedback** Performance feedback is another part of reoptimization that deals with parallel queries. The initialization parameter PARALLEL_DEGREE_POLICY needs to be set to ADAPTIVE before the optimizer will use this feature. On the first execution, the optimizer decides whether to execute the statement in parallel and then decides the degree of parallelism (DOP) based on estimates. After the first run, the optimizer compares the DOP chosen with the DOP based on the actual execution. If they differ significantly, the statement will be marked for reparse and the actual performance statistics (e.g., CPU time) will be stored as feedback for subsequent executions. Basically, the optimizer looks at the CPU time it took and compares that with the value of the parameter PARALLEL_MIN_TIME_THRESHOLD. If the PARALLEL_DEGREE_POLICY parameter is not set to ADAPTIVE, statistics feedback can still be used to change the DOP. Figure 8-11 shows an example of performance feedback. Notice that the notes section shows that it computed the degree of parallelism.
As mentioned earlier, automatic reoptimization sometimes stores additional discovered statistics so the optimizer can use that extra information for other queries. It stores them in two new tables, DBA_SQL_PLAN_DIRECTIVES and DBA_SQL_PLAN_DIR_OBJECTS. The tables contain additional instructions for missing column group statistics (i.e., extended statistics) or data skew in join columns. Column group statistics are used for related columns, such as the CITY, STATE, and ZIP columns in a CUSTOMER table, for example. The optimizer can make much more intelligent choices if it knows only a few column combinations can occur. A SQL plan directive will direct the optimizer to gather dynamic statistics for better cardinality estimates and, hopefully, a better plan.
Other queries that contain the same query expression can also benefit from the SQL plan directive. In my example, a SQL plan directive on the CUSTOMER table for CITY, STATE, and ZIP would direct the optimizer to gather dynamic statistics on every SQL statement that references those columns in the WHERE clause. It’s important to note that the directive will be used until there is a supported column group statistic or histogram created with DBMS_STATS. If the optimizer finds significant data skew within the combination of columns, it will automatically create the column group statistic or histogram.

However, I think it’s important to keep an eye on the number of directives you have in your database, as they can give clues to problems with current statistics-gathering methods. The following query can be used to view all the directives under the example schema of ‘OE’:

```
SELECT TO_CHAR(d.directive_id) dir_id,
       o.owner, o.object_name, o.subobject_namecol_namcol_name,
       o.object_type, d.type, d.state, d.reason
FROM dba_sql_plan_directives d, dba_sql_plan_dir_objects o
WHERE ddirective_id = o.directive_id
AND o.owner IN ('OE', 'O1') ORDER BY 1, 2, 3, 4, 5;
```

The SQL plan directive 7222552036492658097 in Figure 8-12 has identified a join cardinality misestimate for the CUSTOMERS, ORDERS, and ORDER_ITEMS tables. The optimizer will use dynamic statistics when these three tables are joined. The next directive, 8043841522631655845, has identified a column group of CUSTOMER_ID, CUST_FIRST_NAME, and CUST_LAST_NAME. We could create extended statistics for this column group using DBMS_STATS so this directive is no longer needed.

The database manages SQL plan directives in a shared pool and periodically writes them (every 15 minutes) to the SYSAUX tablespace. If a directive is not used for 53 weeks, it is deleted from the tables by default. A new system package, DBMS_SPD, can be used to manually manage SQL plan directives. Please note that you can’t manually create directives; you can only alter, drop, change settings, or stage them for moving to other databases. There is also a command to flush the directives out of the SGA. This can be especially useful when testing.

Following is an example of dropping all directives for the example schema OE. The PL/SQL loops through all the directives in the two tables and runs the DBMS_SPD.DROP_SQL_PLAN_DIRECTIVE procedure.
Oracle 12c Changes in Statistics Gathering and Two New Histograms

In Oracle 12c, basic statistics are now gathered during index CREATE TABLE AS (CTAS) and INSERT AS SELECT (IAS) operations. During these operations, the optimizer has to read the data anyway, so it might as well capture the statistics at the same time. Statistics are also gathered for global temporary tables at the session level to improve costing information.

In addition, there are two new types of histograms, Top-Frequency and Hybrid. In previous versions, there were only two types of histograms: Frequency, where the number of distinct values (NDVs) had to be less than or equal to 254, and Height Balanced, where NDVs were greater than 254. These histograms didn’t work very well if you had some values that were more popular than others. The Top-Frequency histogram fixes this if you have greater than 254 NDVs but only a few of these values take up most of the rows. Top-Frequency will ignore the unpopular values and store only the popular values in the histogram. Figure 8-13 shows that the table, LOCATIONS, has a Top-Frequency histogram on the COUNTRY_ID column.
On further inspection, we can see that there are 305 distinct values for COUNTRY_ID, but many of them are unpopular. Therefore, the Top-Frequency histogram can fit the popular values into 254 buckets and ignore the 51 rows that statistically won’t make a difference. Notice that by selecting the COUNTRY_ID values from the LOCATION table that are not in the histogram, we can see that value 351 is being ignored.

The Hybrid histogram is similar to the Height Balanced histogram (which is deprecated in 12c) in that it deals with NDVs that are far greater than 254 buckets. In the Height Balanced histogram, endpoints often crossed buckets, especially if you had a mix of popular values and unpopular values. This often led to many different distinct values in one bucket, which rendered the histogram ineffective. The new Hybrid histogram (see Figure 8-14) stores the frequency of the endpoints instead of letting the endpoints run over into multiple buckets. It can get more endpoints into the buckets, thus giving the optimizer more information about the data skew.
Figure 8-14 shows an example of a Hybrid histogram on the CUST_LAST_NAME column with 1000 distinct values stored in 254 buckets. Notice that ENDPOINT_REPEAT_COUNT contains the number of rows containing the same last name.

It’s important to note that the new histograms will only be created if you use DBMS_STATS.GATHER_*_STATS with AUTO_SAMPLE_SIZE (the default) turned on.

Oracle 12c Changes in SQL Plan Management

SQL Plan Management (SPM) was introduced to help stop performance regression caused by bad plan changes. Basically it involves using baselines to compare any new plan against the existing baseline to make sure that only new plans that perform better (1.5 times greater) can be used. The only change in 12c is there is now a nightly task called SYS_AUTO_SPM_EVOLVE_TASK that will automatically run against nonaccepted plans and decide whether to evolve them or not. The DBA can then view a report of the automatic changes via a new function in DBMS_SPM called REPORT_AUTO_EVOLVE_TASK. Please note that the old way of evolving plans has been deprecated...although it’s still listed in the package and still works.

The following example shows the new way to manually evolve a plan using tasks. The CREATE_EVOLVE_TASK function takes the SQL_HANDLE in DBA_SQL_PLAN_BASELINES and creates a task name. The EXECUTE_EVOLVE_TASK function then evaluates the new plan and
the IMPLEMENT_EVOLVE_TASK function marks it as accepted or not. Notice that I forced this plan to be accepted. The optimizer doesn’t automatically evolve plans where the performance isn’t 1.5 times greater than the existing baseline. I found that some plans, while not meeting this criteria, can and do improve performance, so careful consideration should be given when forcing a plan to be accepted.

```sql
var task varchar2(1000);
var evolve varchar2(100);
varimple varchar2(1000);
varrptclob;
exec :task := DBMS_SPM.CREATE_EVOLVE_TASK(sql_handle =>'&sql_handle');
exec :evolve := DBMS_SPM.EXECUTE_EVOLVE_TASK(task_name=>:task);
exec :imple := DBMS_SPM.IMPLEMENT_EVOLVE_TASK
(task_name=>:task, FORCE=>true);
exec :rpt := DBMS_SPM.REPORT_EVOLVE_TASK
(task_name =>:task, type =>'TEXT', execution name =>:evolve);
print
```

The REPORT_EVOLVE_TASK function lists information about the evolution and whether it passed or failed in accepting the plan as a new baseline. In Figure 8-15, we can see the values of the bind variables and review its findings and recommendations. Since I forced this plan to be accepted, the recommendation already happened.
To turn off the nightly automated task to automatically evolve and accept new baselines, you can run the following commands:

```sql
SELECT parameter_name, parameter_value
FROM dba_advisor_parameters
WHERE task_name = 'SYSAUTO_SPM_EVOLVE_TASK'
AND parameter_name = 'ACCEPT_PLANS';
execdba_spm.set_evolve_task_parameter ('SYSAUTO_SPM_EVOLVE_TASK', 'ACCEPT_PLANS', 'false');
```

**Oracle Automatic SQL Tuning**
Oracle introduced the SQL Tuning Advisor to help DBAs and developers improve the performance of
SQL statements (note that you must purchase the Diagnostics Pack). A component of the SQL Tuning Advisor is the Automatic SQL Tuning Adviser, which includes statistics analysis, SQL profiling, access path analysis, and SQL structure analysis. The SQL Tuning Advisor uses input from the ADDM, from resource-intensive SQL statements captured by the AWR, from the cursor cache, or from SQL Tuning Sets. Oracle has extended the SQL Tuning Advisor by adding additional features such as SQL Replay (also a cost option), Automatic SQL Tuning, SQL Statistics Management, and SQL Plan Management.

Since this chapter is focused on query tuning, I’ll describe how to pass specific SQL to the SQL Tuning Advisor in the form of a SQL Tuning Set, and then I’ll cover the Automatic SQL Tuning Advisor and SQL Performance Analysis (SQL Replay). The Oracle recommended interface for the SQL Tuning Advisor is Oracle Enterprise Manager (see Chapter 5), but you can use the Application Programming Interfaces (APIs) via the command line in SQL*Plus. I cover the command-line session so you can better understand the analysis procedure for a single query. This section is only a small glance into the functionality of the SQL Tuning Advisor. You also have the capability to create SQL Tuning Sets and SQL profiles and to transport SQL Tuning Sets from one database to another.

Ensuring the Tuning User Has Access to the APIs

The following privileges needed to access the API should be restricted to authorized users in a production environment (with proper licensing). The privileges are granted by SYS. The ADMINISTER SQL TUNING SET privilege allows a user to access only his or her own tuning sets.

```
GRANT ADMINISTER SQL TUNING SET to &TUNING_USER;  -- or
GRANT ADMINISTER ANY SQL TUNING SET to &TUNING_USER;
GRANT ADVISOR to &TUNING_USER;
GRANT CREATE ANY SQL PROFILE to &TUNING_USER;
GRANT ALTER ANY SQL PROFILE to &TUNING_USER;
GRANT DROP ANY SQL PROFILE to &TUNING_USER;
```

Creating the Tuning Task

If you want to tune a single SQL statement, for example,

```
select COUNT(*)
from t2
where UPPER(owner) = 'RIC';
```

you must first create a tuning task using the DBMS_SQLTUNE package:
Making Sure the Task Can Be Seen in the Advisor Log

To see the task, query the USER_ADVISOR log:

```
select task_name
from user_advisor_log;
```

<table>
<thead>
<tr>
<th>TASK_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>first_tuning_task13</td>
</tr>
</tbody>
</table>

Executing the SQL Tuning Task

To execute the tuning task, you use the DBMS_SQLTUNE package, as shown here:

```sql
DECLARE
  tuning_task_name VARCHAR2(30);
  tuning_sqltext CLOB;
BEGIN
  tuning_sqltext := 'SELECT COUNT(*) ' ||
    'FROM t2 ' ||
    'WHERE UPPER(owner) = :owner';
  tuning_task_name := DBMS_SQLTUNE.CREATE_TUNING_TASK(
    sql_text => tuning_sqltext,
    bind_list => sql binds('anydata.ConvertVarchar2(100)'),
    user_name => 'RIC',
    scope => 'COMPREHENSIVE',
    time_limit => 60,
    task_name => 'first_tuning_task13',
    description => 'Tune T2 count');
END;
/```
Checking Status of the Tuning Task

To see the specific tuning task, query the USER_ADVISOR log:

```sql
select status
from user_advisor_tasks
where task_name = 'first_tuning_task13';
```

<table>
<thead>
<tr>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPLETED</td>
</tr>
</tbody>
</table>

Displaying the SQL Tuning Advisor Report

To see the SQL Tuning Advisor Report, you also use the DBMS_SQLTUNE package:

```sql
SET LONG 8000
SET LONGCHUNKSIZE 8000
SET LINESIZE 100
SET PAGESIZE 100
select dbms_sqltune.report_tuning_task('first_tuning_task13')
from dual;
```

Reviewing the Report Output

The report output shown next is lengthy, but it essentially recommends creating a function-based index on the OWNER column of table T2. Had the SQL Tuning Advisor recommended the use of a SQL profile, this could have been accepted by using the DBMS_SQLTUNE.ACCEPT_SQL_PROFILE package.
GENERAL INFORMATION SECTION

Tuning Task Name : first_tuning_task13
Tuning Task Owner : RIC
Workload Type : Single SQL Statement
Scope : COMPREHENSIVE
Time Limit (seconds) : 60
Completion Status : COMPLETED
Started at : 11/20/2010 20:49:56
Completed at : 11/20/2010 20:49:56
Number of Index Findings : 1
Number of SQL Restructure Findings : 1

FINDINGS SECTION (2 findings)

1. Index Finding (see explain plans section below)

The execution plan of this statement can be improved by creating one or more indices.

Recommendation (estimated benefit: 100%)

Consider running the Access Advisor to improve the physical schema design or creating the recommended index.
create index RIC.IDX$$_00CP0001 on RIC.T2(UPPER('OWNER'));

Rationale
Creating the recommended indexes significantly improves the execution plan of this statement. However, it might be preferable to run "Access Advisor" using a representative SQL workload as opposed to a single statement. This will allow Oracle to get comprehensive index recommendations which takes into account index maintenance overhead and additional space consumption.

2- Restructure SQL finding (see plan 1 in explain plans section)

The predicate UPPER("T2"."OWNER")='RIC' used at line ID 2 of the execution plan contains an expression on indexed column "OWNER". This expression prevents the optimizer from selecting indices on table "RIC"."T2".

Recommendation

- Rewrite the predicate into an equivalent form to take advantage of indices. Alternatively, create a function-based index on the expression.

Rationale

The optimizer is unable to use an index if the predicate is an inequality condition or if there is an expression or an implicit data type conversion on the indexed column.

EXPLAIN PLANS SECTION

1- Original

Plan hash value: 1374435053

Predicate Information (identified by operation id):

2 - filter(UPPER("OWNER")='RIC')
Tuning SQL Statements Automatically Using SQL Tuning Advisor

Oracle’s Automatic SQL Tuning Advisor analyzes Automatic Workload Repository data to find high-load SQL statements that have been executed repeatedly. Oracle then uses the SQL Tuning Advisor to tune those statements, creates SQL profiles, if needed, and tests them thoroughly. If the advisor thinks implementing the SQL profile is beneficial, it automatically implements those profiles. No intervention is needed. The Automatic SQL Tuning Advisor runs during the normal maintenance window. The DBA can then run reports against those recommendations and validate those SQL profiles.

Enabling Automatic SQL Tuning Advisor

The following procedure is used to enable the Automatic SQL Tuning Advisor:

```sql
BEGIN
  DBMS_AUTO_TASK_ADMIN.ENABLE(client_name => 'sql tuning advisor', operation => NULL, window_name => NULL);
END;
/```

Configuring Automatic SQL Tuning Advisor

To query what is currently set for the Automatic SQL Tuning Advisor, run the following query:
Now change SQL_PROFILE parameters as follows:

```sql
select parameter_name, parameter_value
from dba_advisor_parameters
where task_name = 'SYS_AUTO_SQL_TUNING_TASK'
and parameter_name IN ('ACCEPT_SQL_PROFILES',
                         'MAX_SQL_PROFILES_PER_EXEC',
                         'MAX_AUTO_SQL_PROFILES');
```

<table>
<thead>
<tr>
<th>PARAMETER_NAME</th>
<th>PARAMETER_VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCEPT SQL_PROFILES</td>
<td>FALSE</td>
</tr>
<tr>
<td>MAX_SQL_PROFILES_PER_EXEC</td>
<td>20</td>
</tr>
<tr>
<td>MAX_AUTO_SQL_PROFILES</td>
<td>10000</td>
</tr>
</tbody>
</table>

The next step is to force the execution of the task so you see the results immediately:

```sql
EXEC dbms_sqltune.execute_tuning_task(task_name => 'SYS_AUTO_SQL_TUNING_TASK');
```

---

Viewing Automatic SQL Tuning Results

The following procedure reports the most recent run of the Automatic SQL Tuning Advisor:
Print :p_report prints the report and recommendation:

<table>
<thead>
<tr>
<th>Tuning Task Name</th>
<th>: SYS AUTO SQL TUNING TASK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning Task Owner</td>
<td>: SYS</td>
</tr>
<tr>
<td>Workload Type</td>
<td>: Automatic High-Load SQL Workload</td>
</tr>
<tr>
<td>Execution Count</td>
<td>: 14</td>
</tr>
<tr>
<td>Current Execution</td>
<td>: EXRC 1259</td>
</tr>
<tr>
<td>Execution Type</td>
<td>: TUNE SQL</td>
</tr>
</tbody>
</table>
**Global SQL Tuning Result Statistics**

- **Number of SQLs Analyzed**: 3
- **Number of SQLs in the Report**: 3
- **Number of SQLs with Findings**: 3
- **Number of SQLs with Statistic Findings**: 3

**SQLs with Findings Ordered by Maximum (Profile/Index) Benefit, Object ID**

<table>
<thead>
<tr>
<th>object ID</th>
<th>SQL ID</th>
<th>statistics</th>
<th>profile (benefit)</th>
<th>index (benefit)</th>
<th>restructure</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>4q8yn4bngw19s</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>lvzwdtr0ywagd</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>5sp4ugqba4ma8</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Objects with Missing/Stale Statistics (ordered by schema, object, type)**

<table>
<thead>
<tr>
<th>Schema Name</th>
<th>Object Name</th>
<th>Type</th>
<th>State</th>
<th>Cascade</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS</td>
<td>OBJECT_TAB</td>
<td>TABLE</td>
<td>MISSING</td>
<td>KO</td>
</tr>
</tbody>
</table>

**DETAILS SECTION**

**Statements with Results Ordered by Maximum (Profile/Index) Benefit, Object ID**

- **Object ID**: 42
- **Schema Name**: SYS
- **SQL ID**: 4q8yn4bngw19s
- **SQL Text**: `insert into object_tab select * from object_tab`

**FINDINGS SECTION (1 finding)**

1. **Statistics Finding**

   Table "SYS"."OBJECT_TAB" was not analyzed.

   **Recommendation**
   - Consider collecting optimizer statistics for this table.
executedbms_stats.gather_table_stats(ownname => 'SYS', tabname => 'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE, method_opt => 'FOR ALL COLUMNS SIZE AUTO');

Rationales

The optimizer requires up-to-date statistics for the table in order to select a good execution plan.

EXPLAIN PLANS SECTION

1- Original

Plan hash value: 622661728

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost ($CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>INSERT STATEMENT</td>
<td></td>
<td>4674K</td>
<td>419M</td>
<td>7687 (1)</td>
<td>00:01:33</td>
</tr>
<tr>
<td>1</td>
<td>LOAD TABLE CONVENTIONAL</td>
<td>OBJECT_TAB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TABLE ACCESS FULL</td>
<td>OBJECT_TAB</td>
<td>4674K</td>
<td>419M</td>
<td>7687 (1)</td>
<td>00:01:33</td>
</tr>
</tbody>
</table>

Object ID : 43
Schema Name: SYS
SQL ID : fvwdr3sywagd
SQL Text : select count(*) from object_tab where UPPER(owner) = 'SYS'

FINDINGS SECTION (1 finding)

1- Statistics Finding

Table "SYS","OBJECT_TAB" was not analyzed.

Recommendation

- Consider collecting optimizer statistics for this table.
executedbms_stats.gather_table_stats(ownname => 'SYS', tabname => 'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE, method_opt => 'FOR ALL COLUMNS SIZE AUTO');

Rationales

The optimizer requires up-to-date statistics for the table in order to select a good execution plan.

EXPLAIN PLANS SECTION

1- Original

Plan hash value: 2592630531
Predicate Information (identified by operation id):

2 - filter(UPPER("OWNER")='SYS')

Object ID : 44
Schema Name: SYS
SQL ID : 5sp4ugqbs4ms6
SQL Text : select count(*) from object_tab where UPPER(owner)='SCOTT'

FINDINGS SECTION (1 finding)

1- Statistics Finding

Table "SYS"."OBJECT_TAB" was not analyzed.

Recommendation

- Consider collecting optimizer statistics for this table.
  executedms_stats.gather_table_stats(ownname => 'SYS', tabname => 'OBJECT_TAB', estimate percent => DBMS_STATS.AUTO_SAMPLE_SIZE,
  method_opt => 'FOR ALL COLUMNS SIZE AUTO');

Rationale

The optimizer requires up-to-date statistics for the table in order to select a good execution plan.

EXPLAIN PLANS SECTION

1- Original

Plan hash value: 2592930531

Predicate Information (identified by operation id):

2 - filter(UPPER("OWNER")='SCOTT')
Check the Recommendation sections. The SQL Tuning Advisor has recommended that you collect statistics. Just by running the following statement, you would improve the performance of the problem SQL listed in the SQL Tuning Advisor report:

```sql
execute dbms_stats.gather_table_stats(ownername => 'SYS', tabname => - 'OBJECT_TAB', estimate_percent => DBMS_STATS.AUTO_SAMPLE_SIZE, - method opt => 'FOR ALL COLUMNS SIZE AUTO');
```

**Using SQL Performance Analyzer (SPA)**

The concept of SQL Tuning Sets and the SQL Tuning Advisor were introduced in 10g. Oracle makes use of SQL Tuning Sets with the SQL Performance Analyzer, often referred to as SPA. The SPA compares the performance of specific SQL statements defined in a particular SQL Tuning Set, before and after a database change. The database change could be a major upgrade, an initialization parameter change, or simply an index or statistics collection change. Chapter 5 covers how to do this in Enterprise Manager. Because this chapter focuses on SQL tuning, this section looks at what the SQL Performance Analyzer can do with queries before and after creating an index. In Chapter 9, I cover more uses for the SPA, especially in database and application upgrades, as well as Real Application Testing and Database Replay. The SPA is a part of Real Application Testing and is not available in the database by default. The use of the SPA and Database Replay requires the Oracle Real Application Testing licensing.

**Step 1: Set Up the Testing Environment**

For this test, a table is created called OBJECT_TAB, and the table is populated to simulate a decent workload:

```sql
create table object_tab as
select *
from dba_objects;

insert into object_tab
select *
from object_tab;
commit;
```

The OBJECT_TAB table does not have any indexes; statistics are collected (as displayed here):
Next, the shared pool is flushed to clear out SQL statements in memory to get a new workload:

```
alter system flush shared_pool;
```

**Step 2: Execute the Queries**

Execute the following testing queries:

```
select count(*)
from object_tab
where object_id=100;

select count(*)
from object_tab
where object_id<100;

select count(*)
from object_tab
where object_id=1000;

select count(*)
from object_tab
where object_id<=1000;
```

Later you’ll create an index for the OBJECT_ID column and compare the performance of the SQL statement before and after the index is created.

**Step 3: Create a SQL Tuning Set**

Creating a SQL Tuning Set is done by collecting many SQL statements that you would like to tune into one set. Create a SQL Tuning Set with the following command:

```
execDBMS SQLTUNE.create sqlset(sqlset name=>'sql replay test');
```

**Step 4: Load the SQL Tuning Set**

The following procedure loads the Tuning Set by obtaining SQL statements from the CURSOR_CACHE that query the OBJECT_TAB table:
Step 5: Query from the SQL Tuning Set

Run the following query:

```sql
DECLARE
    l_cursor DBMS_SQLTUNE.sqlset_cursor;
BEGIN
    OPEN l_cursor FOR
    SELECT VALUE(a)
    FROM TABLE(DBMS_SQLTUNE.select_cursor_cache(
        basic_filter => 'sql text LIKE ''%object tab%'' and parsing schema name = ''SYS''',
        attribute_list => 'ALL')
    ) a;
    DBMS_SQLTUNE.load_sqlset(sqlset_name => 'sql replay test', populate_cursor => l_cursor);
END;
/
```

**Step 6: Print from the SQL Tuning Set**

Print from the SQL Tuning Set and note the TASK ID (record it somewhere for later use):

```sql
VARIABLE v_task VARCHAR2 (64);
EXEC :v_task := DBMS_SQLPA.create_analysis_task(sqlset_name=>'sql_replay_test');
print :v_task
v TASK
TASK 832
```

**Step 7: Execute Before Analysis Task**

Execute the contents of the Tuning Set before the database change to gather performance information:
Step 8: Make the Necessary Changes
Add an index that you already know you need to improve performance of the queries in the Tuning Set (and regather statistics):

```sql
create index object_tab_index_id on object_tab(object_id);
exec dbms_stats.gather_table_stats(USER,'OBJECT_TAB',cascade=>TRUE);
```

Step 9: Execute after Create Index Analysis Task

Step 10: Execute Compare Analysis Task
Step 11: Print the Final Analysis

SET LONG 100000000
SET PAGESIZE 0
SET LINESIZE 200
SET LONGCHUNKSIZE 200
SET TRIMSPool ON
spool /tmp/report.txt

SELECT DBMS_SQLPA.report_analysis_task('TASK_832')
from dual;

spool off

Report Output

General Information

Task Information:

<table>
<thead>
<tr>
<th>Task Name</th>
<th>TASK_832</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task Owner</td>
<td>SYS</td>
</tr>
<tr>
<td>Description</td>
<td></td>
</tr>
</tbody>
</table>

Workload Information:

<table>
<thead>
<tr>
<th>SQL Tuning Set Name</th>
<th>sql replay test</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQL Tuning Set Owner</td>
<td>SYS</td>
</tr>
<tr>
<td>Total SQL Statement Count</td>
<td>7</td>
</tr>
</tbody>
</table>

Execution Information:

<table>
<thead>
<tr>
<th>Execution Name</th>
<th>EXEC_847</th>
</tr>
</thead>
<tbody>
<tr>
<td>Started</td>
<td>02/04/2010 15:57:00</td>
</tr>
<tr>
<td>Execution Type</td>
<td>COMPARE PERFORMANCE</td>
</tr>
<tr>
<td>Last Updated</td>
<td>02/04/2010 15:57:00</td>
</tr>
<tr>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>Global Time Limit</td>
<td>UNLIMITED</td>
</tr>
</tbody>
</table>
Scope : COMPREHENSIVE
Per-SQL Time Limit : UNUSED
Status : COMPLETED
Number of Errors : 0
Number of Unsupported SQL : 1

Analysis Information:

Before Change Execution:

<table>
<thead>
<tr>
<th>Execution Name</th>
<th>before_change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Execution Type</td>
<td>TEST EXECUTE</td>
</tr>
<tr>
<td>Scope</td>
<td>COMPREHENSIVE</td>
</tr>
<tr>
<td>Status</td>
<td>COMPLETED</td>
</tr>
<tr>
<td>Started</td>
<td>02/04/2010 15:50:38</td>
</tr>
<tr>
<td>Last Updated</td>
<td>02/04/2010 15:51:41</td>
</tr>
<tr>
<td>Global Time Limit</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>Per-SQL Time Limit</td>
<td>UNUSED</td>
</tr>
<tr>
<td>Number of Errors</td>
<td>0</td>
</tr>
</tbody>
</table>

After Change Execution:

<table>
<thead>
<tr>
<th>Execution Name</th>
<th>after_change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Execution Type</td>
<td>TEST EXECUTE</td>
</tr>
<tr>
<td>Scope</td>
<td>COMPREHENSIVE</td>
</tr>
<tr>
<td>Status</td>
<td>COMPLETED</td>
</tr>
<tr>
<td>Started</td>
<td>02/04/2010 15:56:13</td>
</tr>
<tr>
<td>Last Updated</td>
<td>02/04/2010 15:56:15</td>
</tr>
<tr>
<td>Global Time Limit</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>Per-SQL Time Limit</td>
<td>UNUSED</td>
</tr>
<tr>
<td>Number of Errors</td>
<td>0</td>
</tr>
</tbody>
</table>

Comparison Metric: ELAPSED TIME

Workload Impact Threshold: 1%

SQL Impact Threshold: 1%

Report Summary

Projected Workload Change Impact:

<table>
<thead>
<tr>
<th>Overall Impact</th>
<th>99.59%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvement Impact</td>
<td>99.59%</td>
</tr>
<tr>
<td>Regression Impact</td>
<td>0%</td>
</tr>
</tbody>
</table>

SQL Statement Count

<table>
<thead>
<tr>
<th>SQL Category</th>
<th>SQL Count</th>
<th>Plan Change Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Improved</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Unchanged</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Unsupported</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Wow! Overall impact is a positive 99.59 percent! Having viewed the queries, this makes sense. The query accessed a 1.1-million row table, yet only 16 rows satisfied the OBJECT_ID = 100 condition. By adding an index on the OBJECT_ID column, performance is drastically improved!

Tips Review

- In 12c, Oracle introduced Adaptive Query Optimization. Now Oracle can change execution plans on the fly from, say, a hash join to a nested loops join based on the dynamic statistics it is collecting as it is executing. It can also use the better execution plan for future executions as well using automatic reoptimization. You can also tune and direct future executions using SQL plan directives.

- Query V$SQLAREA and V$SQL to find problem queries that need to be tuned.

- You can also query V$SQL to find your problem queries that need to be tuned.

- When a small number of rows ("small" is version and hardware dependent, but almost always less than 5 percent and even less than 1 percent at times) are returned to meet a condition in a query, you generally want to use an index on that condition (column), given that the small number of rows also returns a small number of individual blocks (usually the case).

- The first tip concerning slow queries is that you will have a lot of them if you don’t index restrictive columns (return a small percentage of the table). Building indexes on restrictive columns is the first step toward better system performance.

- Bad indexes (indexing the wrong columns) can cause as much trouble as forgetting to use indexes on the correct columns. While Oracle’s cost-based optimizer generally suppresses poor indexes, problems can still develop when a bad index is used at the same time as a good index. The cost of each index for INSERTs and DELETEs must also be considered when adding many indexes.

- For crucial queries on your system, consider concatenated indexes on the columns contained in both the SELECT and the WHERE clauses so only the index is accessed.

- The INDEX_FFS hint processes only the index and does not access the table. All columns that
are used and retrieved by the query must be contained in the index.

When running a query multiple times in succession, it becomes faster because you have now cached the data in memory (although full table scans are aged out of memory quicker than indexed scans). At times, people are tricked into believing that they have actually made a query faster, when in actuality they are accessing data stored in memory. Flushing the buffer cache or restarting the test system can help you get accurate tuning results for comparisons. The next time a user calls and says a query was too slow, just say: Really? Try running it again.

Caching an often-used but relatively small table into memory ensures that the data is not pushed out of memory by other data. Be careful, however—cached tables can alter the execution path normally chosen by the optimizer, leading to an unexpected execution order for the query (for instance, affecting the driving table in nested loop joins).

If you are executing the same queries over and over (especially grouping or calculation functions), using the RESULT_CACHE hint often makes subsequent queries run faster (at times very much faster).

When multiple indexes on a single table can be used for a query, use the most restrictive index when you need to override an optimizer choice. While Oracle’s cost-based optimizer generally forces the use of the most restrictive index, variations will occur, depending on the version of Oracle used, the structure of the query structure, and the initialization parameters that you may use. Fix the larger issue (get rid of bad indexes) if you see this as a trend.

Bitmap indexes usually behave differently because they are usually much smaller. See Chapter 2 for more information on the differences between bitmap indexes and other indexes.

At times, modifying the column side of the query can result in the index being suppressed unless a function-based index is used. Oracle may also fix this issue during parsing. The more complex the query, the less likely Oracle will fix it.

Function-based indexes can lead to dramatic performance gains when used to create indexes on functions often used on selective columns in the WHERE clause.

Oracle has improved the way that it performs the OR clause. The NO_EXPAND hint can still be helpful, as it prevents the optimizer from using OR expansion, as described in Chapter 7.

Using the nested subquery with an EXISTS clause may make queries dramatically faster, depending on the data being retrieved from each part of the query. Oracle 12c often makes this translation internally, saving you time and giving you performance gains!

In 12c, adaptive plans help the optimizer make the final plan choice on the first execution of a SQL statement. It accomplishes this by instrumenting the default execution plan with statistic collectors that will be used during execution or on future executions.

The 12c optimizer might change the execution plan during the execution phase if the SQL is long running and the statistic collector exceeds the threshold it expects. This is known as dynamic statistics and the execution plan could change from a nested loops to a hash join based on the new statistics collected while the query is running.

Most importantly, ensure that you are correctly licensed. Many tuning packs are an extra cost.
Check DBA_FEATURE_USAGE_TABLE to confirm which features you are using.

References

*Oracle Database Performance Tuning Guide 12c Release 2 (12.2)* (Oracle Corporation).
Deb Dudek, *DBA Tips, or a Job Is a Terrible Thing to Waste* (TUSC).
*Query Optimization in Oracle9i, An Oracle Whitepaper* (Oracle Corporation).

Janis Griffin did the great 12c update and additions to this chapter. In the prior edition, Rama Balaji added several new sections and helped with the update for 11g. Thanks to Connor McDonald for his feedback on V$SQLAREA. Rob Christensen contributed the major portion of a previous update to this chapter.
Table Joins and Other Advanced Tuning
(Advanced DBA and Developer)

With Oracle Database 11g and available in 12c, Oracle introduced a new option called Real Application Testing. Real Application Testing allows you to capture a complete database workload on one database and replay it on another database. You can replay the exact workload and you even have the option to synchronize workload timing. This tool is very valuable for load testing on a new application release, database patch, or database upgrade. If you need to tune a specific object or set of queries, 12c also offers the SQL Performance Analyzer (SPA). This tool provides the ability to examine a SQL workload on a database, record a portion of it based on what you want collected/tested, and then take that workload and examine it in another environment. The new environment can include any database changes (including initialization parameter changes), hardware changes, or environment changes. SPA not only offers a powerful new way to examine the potential impact of change with more predictable results, but also allows the targeting of a specific change while measuring its potential impact.

This chapter was originally the most painful to write due to the complexities of Oracle joins and block level tuning. I’ve included many examples from Oracle and other products over the years to show different possible tuning patterns and how to solve future patterns. This chapter includes a section that shows how to link tuning to mathematical equations so that you can develop your own tuning theory and compare results for your unique system. This chapter is not strictly 12c related; rather, it is focused on advanced query tuning concepts, showing the evolution of the Oracle database. Oracle is growing much faster and is truly more of a platform than a database these days.

The driving table or the first table accessed in a query is an important aspect of superior performance. Using the Enterprise Manager Cloud Control Tuning Pack and Automatic Workload Repository (AWR) statistics, Oracle can do a lot to help you tune things (see Chapter 5 for more information). If the optimizer has designated the wrong table as the driving table in a query, the optimizer’s choice can be the difference between hours and seconds. Usually, the cost-based optimizer chooses the correct table, but your indexing on tables affects how this works. If you need to change the driving table using a hint on the same table over and over, this symptom often indicates an indexing plan that still needs work. When you have to tune multiple tables using hints, tuning increasing numbers of tables gets progressively harder. With only two or three tables, it’s easy enough to use an ORDERED hint (guaranteeing the order of the tables) and then to try variations of the table order until you achieve the fastest outcome. However, a ten-table join has 3,628,800 possible combinations, which makes trying all these combinations slightly time-consuming. Using a LEADING
hint (you specify the first or leading table to drive the query with) simplifies this chore, but it is still far more daunting than building the correct indexing scheme in the first place.

One of the greatest challenges of this book was trying to put driving tables into a helpful format for readers, using the EXPLAIN PLAN, AUTOTRACE, and TKPROF. The optimizer’s complexity and all the potential paths for joining and optimizing a query can be mind-boggling. Suppressing a single index in a query can affect the driving table, how Oracle joins tables in a query, and how Oracle uses or suppresses other indexes. This chapter focuses on helping you make better decisions when choosing a driving table. Although I have a good understanding of how Oracle performs these complexities, putting that understanding into words was the challenging task for the first half of this chapter. The challenge for the second half was relating performance tuning to mathematical equations.

The tips covered in this chapter include the following:

- Real Application Testing
- Database Replay
- SQL Performance Analyzer
- Join methods
- Table join initialization parameters
- A two-table join: equal-sized tables (cost-based)
- A two-table INDEXED join: equal-sized tables (cost-based)
- Forcing a specific join method
- Eliminating join records (candidate rows) in multitable joins
- A two-table join between a large table and a small table
- Three table joins: not as much fun (cost-based)
- Bitmap join indexes
- Third-party product tuning
- Tuning distributed queries
- When you have everything tuned
- Miscellaneous tuning snippets
- Tuning at the block level (advanced)
- Tuning using Simple Mathematical Techniques

**Database Replay (capture/replay)**

Database Replay (often referred to as Real Application Testing or capture/replay) is used to capture a database workload on one system and replay it later on a different system and is very useful when comparing two different systems or different versions of Oracle. You can perform Real Application Testing in text mode (covered in this section only as an overview—use the Oracle documentation as
To perform Real Application Testing, the basic steps are as follows:

1. Capture workload on a database, from 10gR2 or higher.
2. Restore the database on a test system to the SCN when capture begins.
3. Perform the upgrade and make changes to the test system as needed.
4. Preprocess the captured workload if it is not preprocessed.
5. Configure the test system for replay.
6. Replay the workload on the test system (can be synchronized or unsynchronized).
7. Create a report that shows Data, Error, and Performance divergences.

Database Replay is used to replay a workload in a manner that you would like to test. You can have a replay that executes exactly as it was captured or use other Oracle options to replay it in a different manner. Database Replay can be used in command-line mode or through Oracle Enterprise Manager.

## Set Up Source Database for Database Replay

**Capture**

As stated earlier, you can utilize database releases prior to 11g for capturing a workload for replay on a 12c database (as early as 10gR2). First, however, some setup is required (see the Oracle notes on this that come with the product).

## Prepare to Capture Workload

You need to prepare the source database where you will be capturing the workload for replay.

To create a directory location where the workload capture file can be written:

```bash
mkdir dbcapture
```

To create a directory within the source database where the workload will be captured:

```sql
CREATE DIRECTORY dbcapture AS 'c:\oracle\dbcapture';
```
Capture the Workload

Prior to executing the workload, you need to initiate the capture.

1. Start the capture process:
   
   ```sql
   SQL> exec dbms_workload_capture.start_capture('NRML ACTIVITY', 'DDBCAPTURE');
   ```

2. Run the workload.

3. When complete, or when you have captured the desired workload, stop the capture process:
   
   ```sql
   SQL> exec dbms_workload_capture.finish_capture();
   ```

4. Execute a report on the capture:
   
   ```sql
   -- Capture Report
   DECLARE
   cap_id NUMBER;
   cap_rpt CLOB;
   buffer VARCHAR2(32767);
   buffer_size CONSTANT BINARY_INTEGER := 32767;
   amount BINARY_INTEGER;
   offset NUMBER(38);
   file_handle UTL_FILE.FILETYPE;
   directory_name CONSTANT VARCHAR2(80) := 'DDBCAPTURE';
   v_filename CONSTANT VARCHAR2(80) := 'Capture.html';
   ```
Prepare the Workload for Replay

The following steps show how to prepare the workload for replay:

1. Create a directory location for the captured workload to be placed in for processing and replay on both the processing database and the replay database if the processing and replay databases are different. Best practice is to process the workload on the same database that will execute the replay.

c:\oracle> mkdir replay
2. Copy the captured workload files to another directory if on the same host as the database where the workload was captured or to the destination system location to be processed:
   
   ```
   copy c:\oracle\dbcapture\* c:\oracle\Replay
   ```

3. Create a directory in the Oracle database that will process the captured workload:
   
   ```
   SQL> create directory REPLAY as 'c:\oracle\replay';
   ```

### Process the Workload for Replay

This process is resource-intensive. It should, therefore, be done on a nonproduction system. If you capture the workload on your production system, move the capture files to a test or development system to prepare them for replay.

Process the captured workload:

```sql
SQL> exec dbms_workload_replay.process_capture ('REPLAY');
```

The process creates the following files in the REPLAY directory (and a few others) during the processing of the captured workload (you may also have a subdirectory, which you would need to add to any of the directory locations):

- wcr_login.pp
- WCR_SCN_ORDER.EXTB
- WCR_SEQ_DATA.EXTB
- WCR_CONN_DATA.EXTB
- wcr_process.wmd

### Prepare to Replay the Workload

Next, you need to prepare the replay database. In the following steps, you prepare the replay database. Keep in mind this is version/system dependent, and there may be variations needed for your system.

1. Go to the database where the replay will be executed if different from the database that processed the workload. If the replay database is the same as the database that processed the workload, skip to Step 3; otherwise, proceed to Step 2.

2. If you have not done so already, go to the “Prepare the Workload for Replay” section, earlier in this chapter, and execute the steps on the database that will replay the workload.

3. Initialize the replay:
Prepare for workload replay:

```sql
SQL> exec dbms_workload_replay.initialize_replay ('TEST_REPLAY','REPLAY');
```

5. Calibrate the workload to determine the number of workload replay clients. At the command line, change to the REPLAY directory and calibrate:

```bash
cd c:/oracle\replay
C:\oracle\replay> wrc mode=calibrate
```

---

**Execute the Workload Replay**

Now that the workload has been captured and processed, the workload is ready to be replayed. I suggest using Oracle Enterprise Manager Cloud Control if possible. Follow these steps to execute the workload on the new system:

1. Note the number of workload replay clients indicated in the previous section that you need to execute the processed workload.
2. Open a window for each workload replay client that you will need, as these will each be separate executions. As indicated in the previous step, you only need one client.
3. From the command line, execute the `replay` command with the `wrc` utility for the number of workload replay clients needed, with one command in each window:

```bash
C:\oracle\proccapture> wrc system/xxxxx@orcl12c replaydir=c:\oracle\replay
```

4. Repeat for each of the replay clients needed.

5. AWR information will be available for the time period in which the workload replay was executed. Oracle recommends that the executed workload replay cover at least one complete snap period to provide the most useful data. You can take a snapshot prior to beginning and immediately after the workload execution (this is optional):

```sql
SQL> execute DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT ();
```

6. From another window, log in to the database where the workload replay will be executed and start the workload replay process. An indication that the workload has been started will appear:

```sql
SQL> exec dbms_workload_replay.start_replay ;
```

PL/SQL procedure successfully completed.

7. Monitor the workload replay until it is completed.

8. Once the workload replay is complete, take another AWR snapshot (optional):

```sql
SQL> execute DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT ();
```

9. Execute workload replay report extraction, and evaluate the results from the report:

```sql
SQL> execute DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT ();
```
10. Go to the directory used in the script, C:\oracle\replay, and view the Replay.html file.
SQL Performance Analyzer

The SQL Performance Analyzer (SPA) is a great tool for measuring and reporting on performance before and after instituting a change. The SPA uses the DBMS_SQLTUNE package to accomplish its analysis. In Chapter 8, you learned how to use the SPA for a simple tuning issue in which the SPA recommended an index that improved performance by over 99 percent. But the SPA is much broader. This tool is one of the most powerful ways to answer some of the most common performance questions:

- What will be the impact of removing this index?
- What will be the impact of adding an index to this table?
- What will be the impact of changing an index from a b-tree to a bitmap?
- What will be the impact of reorganizing and ordering this table?
- What will be the impact of partitioning this table?
- What will be the impact of changing a table to an index-organized table?
- What will be the impact of regathering the cost-based optimizer stats?
- What will be the impact of updating the database patch level?
- What will be the impact of upgrading the database to the next version?
- What will be the impact of changing this database initialization parameter?
- What will happen if I change the database from using file systems to ASM?

Create a SQL Tuning Set

To make a comparison using the SPA, the first step is to create a SQL Tuning Set. The first execution of the SQL Tuning Set is the one to use as a baseline; use the second to make the comparison. Create a SQL Tuning Set (as shown here) prior to making any changes, and then create a second Tuning Set after you’ve made the changes. You can also do this in Enterprise Manager (see Chapter 5 for additional information).
Create an Analysis Task

After creating a SQL Tuning Set with the SQL workload execution, you create an analysis task:

```
dbms_sqlpa.create_analysis_task(sqlset_name => 'my_sts',
                                 task_name => 'my_spa_task',
                                 description => 'test index changes');
```

Execute Analysis Task

After creating the analysis task, you need to execute the task for a baseline tuning set. After executing the analysis task, you can make your changes for comparison against the baseline. This requires creating a second SQL Tuning Set, a second analysis task, and then executing that task. Then you can generate a comparison.

Pre-change:
Now you have two SQL Tuning Sets and are ready to generate a comparison.
To generate a comparison:

```sql
dbms_sqlpa.execute_analysis_task(
    task_name => 'my_spa_task',
    execution_type => 'test execute',
    execution_name => 'after index change');
```

```sql
-- Script: spa_compare.sql
-- Executes a SQL Tuning Set Comparison and then outputs a report from SPA

spool SPA_COMPARE_REPORT.out

-- Get the whole report for the single statement case.
SELECT DBMS_SQLPA.REPORT_ANALYSIS_TASK('my_spa_task') FROM dual;

-- Show me the summary for the std case.
SELECT DBMS_SQLPA.REPORT_ANALYSIS_TASK('my_spa_task', 'TEXT', 'TYPICAL', 'SUMMARY') FROM dual;

-- Show me the findings for the statement. I'm interested in.
SELECT DBMS_SQLPA.REPORT_ANALYSIS_TASK('my_spa_task', 'TEXT', 'TYPICAL', 'FINDINGS', 5) FROM dual;
spool off
```

📌 Query SQL Performance Analyzer Advisor Tasks

You can show the Advisor tasks using the DBA_ADVISOR_TASKS view or
USER_ADVISOR_TASKS view:

```
SELECT owner, task_name, status
FROM dba_advisor_tasks
WHERE owner <> 'SYS';
```

<table>
<thead>
<tr>
<th>OWNER</th>
<th>TASK_NAME</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCOTT</td>
<td>TASK_1949</td>
<td>COMPLETED</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1950</td>
<td>COMPLETED</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1948</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1943</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1946</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_2700</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1945</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1923</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1944</td>
<td>INITIAL</td>
</tr>
<tr>
<td>SCOTT</td>
<td>TASK_1947</td>
<td>INITIAL</td>
</tr>
</tbody>
</table>

**Cancel an Executing SQL Performance Analyzer Analysis Task**

If a SQL Performance Analyzer analysis task is in the process of executing, you can cancel it manually at any time. You may need to do this for tasks you wish to interrupt due to resource issues, database performance impact issues, and so on.

**Syntax**

```
DBMS_SQLPA.CANCEL ANALYSIS TASK ('my spa task') ;
```

**Remove SQL Performance Analyzer Analysis Task**

After you have utilized the information from the SQL Performance Analyzer analysis, you may no longer need the analysis task. To clear space and remove unused or unneeded analysis tasks, it is best to drop them. Oracle provides a procedure within the DBMS_SQLPA package to remove an analysis task.

**Syntax**

```
DBMS_SQLPA.DROP ANALYSIS TASK ('my spa task') ;
```
Before you can drop a SQL Tuning Set, you must remove all references to the SQL Tuning Set, including SPA analysis tasks as well as SQL Tuning Advisor tasks. You can determine references to SQL Tuning Sets via the DBA_SQLSET_REFERENCES view. Having the reference ID is critical to being able to inactivate a SQL set reference.

### Example

```sql
SQL> exec DBMS_SQLPA.DROP_ANALYSIS_TASK ('my_spa_task') ;

PL/SQL procedure successfully completed
```

### Determine Active SQL Tuning Sets

#### Remove SQL Tuning Set

After you have finished the SQL Performance Analyzer analysis, to conserve space and remove unneeded results from SQL Performance Analyzer activities, you may want to remove SQL Tuning Sets. You can only remove inactive SQL Tuning Sets. To remove an active SQL Tuning Set, you have to first remove the SPA analysis tasks that reference the SQL Tuning Set. After removing all analysis tasks, you must remove the SQL Tuning Set references; otherwise, an ORA-13757 error will result indicating the SQL Tuning Set is still active.

### Remove SQL Tuning Set Reference
Drop SQL Tuning Set

Ensure all references to the SQL Tuning Set being dropped have first been removed, and then you can drop the SQL Tuning Set itself.

**Syntax**

```sql
DBMS_SQLTUNE.DROP_SQLSET ('<tuning set name>');
```

**Example (references have not been removed)**

```sql
SQL> exec DBMS_SQLTUNE.DROP_SQLSET ('STS SPA 1');
BEGIN DBMS_SQLTUNE.DROP_SQLSET ('STS SPA 1'); END;
ERROR at line 1:
ORA-13757: "SQL Tuning Set" "STS SPA 1" owned by user "SCOTT" is active.
ORA-06512: at "SYS.DBMS_SQLTUNE_INTERNAL", line 8597
ORA 06512: at "SYS.DBMS_SQLTUNE", line 3015
ORA 06512: at line 1
```

**Example (references have been removed):**

```sql
SQL> exec DBMS_SQLTUNE.DROP_SQLSET ('STS SPA 1');
PL/SQL procedure successfully completed.
```
Join Methods
Since the days of Oracle 6, the optimizer has used three primary ways to join row sources together: the NESTED LOOPS join, the SORT-MERGE join, and the CLUSTER join. (There is also the favorite of the ad hoc query user—the Cartesian join.) Oracle 7.3 introduced the HASH join, and Oracle8i introduced the INDEX join, making for a total of five primary join methods. Each method has a unique set of features and limitations. Before you attack a potential join issue, you need to know the answers to the following questions:

- Which table will drive the query (first table accessed), and when will other tables be accessed given the path that is chosen for the query? What are the alternate driving paths?
- What are the Oracle join possibilities (described in this section)? Remember, each join possibility for Oracle can yield different results, depending on the join order, the selectivity of indexes, and the available memory for sorting and/or hashing.
- Which indexes are available, and what is the selectivity of the indexes? The selectivity of an index not only can cause the optimizer to use or suppress an index, but can also change the way the query drives and may determine the use or suppression of other indexes in the query.
- Which hints provide alternate paths, and which hints suppress or force an index to be used? These hints change the driving order of the tables, and they change how Oracle performs the join and which indexes it uses or suppresses.
- Which version of Oracle are you using? Your choices vary, depending on the version and release of Oracle you are using. The optimizer also works differently, depending on the version.

NESTED LOOPS Joins
Suppose somebody gave you a telephone book and a list of 20 names to look up, and then asked you to write down each person’s name and corresponding telephone number. You would probably go down the list of names, looking up each one in the telephone book one at a time. This task would be pretty easy because the telephone book is alphabetized by name. Moreover, somebody looking over your shoulder could begin calling the first few numbers you write down while you are still looking up the rest. This scene describes a NESTED LOOPS join.

In a NESTED LOOPS join, Oracle reads the first row from the first row source and then checks the second row source for matches. All matches are then placed in the result set and Oracle goes on to the next row from the first row source. This continues until all rows in the first row source have been processed. The first row source is often called the outer or driving table, whereas the second row source is called the inner table. Using a NESTED LOOPS join is one of the fastest methods of receiving the first records back from a join.

NESTED LOOPS joins are ideal when the driving row source (the records you are looking for) is small and the joined columns of the inner row source are uniquely indexed or have a highly selective nonunique index. NESTED LOOPS joins have an advantage over other join methods in that they can
quickly retrieve the first few rows of the result set without having to wait for the entire result set to be determined. This situation is ideal for query screens where an end user can read the first few records retrieved while the rest are being fetched. NESTED LOOPS joins are also flexible in that any two-row sources can always be joined by NESTED LOOPS—regardless of join condition and schema definition.

However, NESTED LOOPS joins can be very inefficient if the inner row source (second table accessed) does not have an index on the joined columns or if the index is not highly selective. If the driving row source (the records retrieved from the driving table) is quite large, other join methods may be more efficient.

Figure 9-1 illustrates the method of executing the query shown next where the DEPT table is accessed first and the result is then looped through the EMP table with a NESTED LOOPS join. The type of join performed can be forced with a hint and will vary due to different variables on your system.

```sql
select /*+ ordered */ ename, dept.deptno
from dept, emp
where dept.deptno = emp.deptno;
```
SORT-MERGE Joins

Suppose two salespeople attend a conference and each collects over 100 business cards from potential new customers. They now each have a pile of cards in random order, and they want to see how many cards are duplicated in both piles. The salespeople alphabetize their piles, and then they call off names one at a time. Because both piles of cards have been sorted, it becomes much easier to find the names that appear in both piles. This example describes a SORT-MERGE join.

In a SORT-MERGE join, Oracle sorts the first row source by its join columns, sorts the second row source by its join columns, and then merges the sorted row sources together. As matches are found, they are put into the result set.

SORT-MERGE joins can be effective when lack of data selectivity or useful indexes renders a NESTED LOOPS join inefficient, or when both of the row sources are quite large (greater than 5 percent of the blocks accessed). Also, SORT-MERGE joins can be used only for inequalities, whereas HASH joins can be used only for equijoins (WHERE D.deptno = E.deptno, as opposed to WHERE D.deptno >= E.deptno). SORT-MERGE joins require temporary segments for sorting (if SORT_AREA_SIZE or the automatic memory parameters like MEMORY_TARGET are set too small). This can lead to extra memory utilization and/or extra disk I/O in the temporary tablespace.

Figure 9-2 illustrates the method of executing the query shown next when a SORT-MERGE join is performed.

---

**FIGURE 9-2. SORT-MERGE join**
A CLUSTER join is really just a special case of the NESTED LOOPS join that is not used very often. If the two row sources being joined are actually tables that are part of a cluster, and if the join is an equijoin between the cluster keys of the two tables, then Oracle can use a CLUSTER join. In this case, Oracle reads each row from the first row source and finds all matches in the second row source by using the CLUSTER index.

CLUSTER joins are extremely efficient because the joining rows in the two row sources will actually be located in the same physical data block. However, clusters carry certain caveats of their own, and you cannot have a CLUSTER join without a cluster. Therefore, CLUSTER joins are not very commonly used.

HASH joins are the usual choice of the Oracle optimizer when the memory is set up to accommodate them. In a HASH join, Oracle accesses one table (usually the smaller of the joined results) and builds a hash table on the join key in memory. It then scans the other table in the join (usually the larger one) and probes the hash table for matches to it. Oracle uses a HASH join efficiently only if the parameter PGA_AGGREGATE_TARGET is set to a large enough value. If MEMORY_TARGET is used, the PGA_AGGREGATE_TARGET is included in the MEMORY_TARGET, but you may still want to set a minimum (see Chapter 4 for additional information). If you set the SGA_TARGET, you must set the PGA_AGGREGATE_TARGET as the SGA_TARGET does not include the PGA (unless you use MEMORY_TARGET as just described). The HASH join is similar to a NESTED LOOPS join in the sense that there is a nested loop that occurs—Oracle first builds a hash table to facilitate the operation and then loops through the hash table. When using an ORDERED hint, the first table in the FROM clause is the table used to build the hash table.

HASH joins can be effective when the lack of a useful index renders NESTED LOOPS joins inefficient. The HASH join might be faster than a SORT-MERGE join, in this case, because only one row source needs to be sorted, and it could possibly be faster than a NESTED LOOPS join because probing a hash table in memory can be faster than traversing a b-tree index. As with SORT-MERGE joins and CLUSTER joins, HASH joins work only on equijoins. As with SORT-MERGE joins, HASH joins use memory resources and can drive up I/O in the temporary tablespace if the sort memory is not sufficient (which can cause this join method to be extremely slow). Finally, HASH joins are available only when cost-based optimization is used (which should be 100 percent of the time for your application running on Oracle 11g).

Figure 9-3 illustrates the method of executing the query shown in the listing that follows when a HASH join is used.

```sql
SELECT /*+ ordered */ ename, dept.deptno
FROM emp, dept
WHERE dept.deptno = emp.deptno;
```
Figure 9-3. HASH Join

1. Builds a hash table for EMP table in memory

<table>
<thead>
<tr>
<th>ENAME</th>
<th>DEPTNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>GALLOWY</td>
<td>10</td>
</tr>
<tr>
<td>DULLEY</td>
<td>20</td>
</tr>
<tr>
<td>REITER</td>
<td>30</td>
</tr>
<tr>
<td>TAYLOR</td>
<td>20</td>
</tr>
<tr>
<td>HATHAWAY</td>
<td>20</td>
</tr>
<tr>
<td>PREVATT</td>
<td>30</td>
</tr>
</tbody>
</table>

1 Record Returned

<table>
<thead>
<tr>
<th>ENAME</th>
<th>DEPTNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>GALLOWAY</td>
<td>10</td>
</tr>
</tbody>
</table>

The loop would continue until each of the DEPTNOs in the DEPT table have been checked against those in the EMP table. The subsequent loop results are (for DEPTNOs 20, 30, 40):

The second loop:
3 Records Returned

<table>
<thead>
<tr>
<th>ENAME</th>
<th>DEPTNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>DULLEY</td>
<td>20</td>
</tr>
<tr>
<td>TAYLOR</td>
<td>20</td>
</tr>
<tr>
<td>HATHAWAY</td>
<td>20</td>
</tr>
</tbody>
</table>

The third loop:
2 Records Returned

<table>
<thead>
<tr>
<th>ENAME</th>
<th>DEPTNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>REITER</td>
<td>30</td>
</tr>
<tr>
<td>PREVATT</td>
<td>30</td>
</tr>
</tbody>
</table>

The fourth loop:
No Records Returned

```
select /*+ ordered */ ename, dept.deptno
from emp, dept
where dept.deptno = emp.deptno;
```

INDEX-MERGE Joins
Prior to Oracle8i, you always had to access the table unless the index contained all of the information required. As of Oracle8i, if a set of indexes exists that contains all of the information required by the query, then the optimizer can choose to generate a sequence of HASH joins between the indexes. Each of the indexes is accessed using a range scan or fast full scan, depending on the conditions available in the WHERE clause. This method is extremely efficient when a table has a large number of columns but you want to access only a limited number of those columns. The more limiting the conditions in the WHERE clause, the faster the execution of the query. The optimizer evaluates this as an option when looking for the optimal path of execution.

You must create indexes on the appropriate columns (those that will satisfy the entire query) to ensure that the optimizer has the INDEX-MERGE join as an available choice. This task usually involves adding indexes on columns that may not be indexed or on columns that were not indexed together previously. The advantage of INDEX-MERGE joins over fast full scans is that fast full scans have a single index satisfying the entire query. INDEX-MERGE joins have multiple indexes satisfying the entire query.

Two indexes (one on ENAME and one on DEPTNO) have been created prior to the execution of the corresponding query in this next listing. The query does not need to access the table! Figure 9-4 shows this INDEX-MERGE join in graphical format.

![INDEX-MERGE Join Diagram](image)

**FIGURE 9-4. An INDEX MERGE join of EMP_IDX1 and EMP_IDX2**
To show the improved efficiency, consider this example that uses the TEST2 table. The TEST2 table has 1 million rows and is 210M in size. First, you create the indexes:

```sql
create index doby on test2 (doby);
create index state on test2 (state);
create index dobmsy on test2 (state, doby);
```

Neither DOBY nor STATE is very limiting when queried individually; consequently, the first indication is to execute a full table scan, as shown in this listing:

```sql
select /*+ FULL(test2) */ state, doby
from test2
where doby = 1972
and state = 'MA';
```

**SELECT STATEMENT**
**TABLE ACCESS (FULL) OF 'TEST2'**

*Elapsed time: 12.6 seconds*

Using a single index on DOBY is slower than the full table scan:

```sql
select /*+ index(test2 doby) */ state, doby
from test2
where doby = 1972
and state = 'MA';
```

**SELECT STATEMENT**
**TABLE ACCESS (BY INDEX ROWID) OF 'TEST2'**
**INDEX (RANGE SCAN) OF 'DOBY' (NON-UNIQUE)**

*Elapsed time: 13.45 seconds*

Using a single index on STATE is also slower than a full table scan:
However, using an INDEX-MERGE join of DOBY and STATE is quicker than a full table scan because the table does not need to be accessed, as in this listing:

```sql
select /*+ index(test2 state) */ state, doby
from test2
where doby = 1972
and state = 'MA';
```

SELECT STATEMENT
TABLE ACCESS (BY INDEX ROWID) OF 'TEST2'
INDEX (RANGE SCAN) OF 'STATE' (NON-UNIQUE)

Elapsed time: 23.50 seconds

However, using an INDEX-MERGE join of DOBY and STATE is quicker than a full table scan because the table does not need to be accessed, as in this listing:

```sql
select /*+ index_join(test2 doby state) */ state, doby
from test2
where doby = 1972
and state = 'MA';
```

SELECT STATEMENT
VIEW OF 'index$_join$_001'
HASH JOIN
INDEX (RANGE SCAN) OF 'DOBY' (NON-UNIQUE)
INDEX (RANGE SCAN) OF 'STATE' (NON-UNIQUE)

Elapsed time: 4.76 seconds

However, the INDEX_FFS (if a single index on all needed columns exists) is still the most efficient method, as shown here:

```sql
select /*+ index_ffs(test2 dobmsy) */ state, doby
from test2
where doby = 1972
and state = 'MA';
```

SELECT STATEMENT
INDEX (FAST FULL SCAN) OF 'DOBMSY' (NON-UNIQUE)

Elapsed time: 3.6 seconds

Although fast full scan is the most efficient option in this case, the INDEX join accommodates more situations. Also, an INDEX_FFS is often a problem as it scans through many index blocks and shows up as a severe amount of 'db file sequential read' waits (so try to tune it by using a better index or having a more selective query so it doesn’t need to scan the whole index). Your
mileage will vary; this example is only to show how to tune. Which solution is best will be clearer on your unique system after detailed testing.

Table Join Initialization Parameters
Performance of SORT-MERGE joins and HASH joins is strongly impacted by certain initialization parameters. Join performance can be crippled if certain parameters are not set properly.

SORT-MERGE and HASH Join Parameters
The initialization parameter `DB_FILE_MULTIBLOCK_READ_COUNT` specifies how many blocks Oracle should read at a time from disk when performing a scattered read such as a full table scan. In 11g, my default was 128 (128 * 8192 = 1048576, or 1M; but this is platform dependent and 1M for most platforms), which should be more than sufficient. Because SORT-MERGE joins often involve full table scans, setting this parameter correctly reduces overhead when scanning large tables.

The initialization parameter `PGA_AGGREGATE_TARGET` (this can be part of the memory allocated with `MEMORY_TARGET`, if used, as described earlier) specifies how much memory can be used for sorting, which has a strong impact on performance of all sorts. Because SORT-MERGE joins require sorting of both row sources, the amount of memory allocated for sorting can greatly impact SORT-MERGE join performance. If an entire sort cannot be completed in the amount of memory specified, then a temporary segment in the temporary tablespace is allocated. In this case, the sort is performed in memory one part at a time, and partial results are stored on disk in the temporary segment. If memory allocated for sorting is set very small, then excessive disk I/O is required to perform even the smallest of sorts. If it is set too high, then the operating system may run out of physical memory and resort to swapping. The same is true for HASH joins. If the HASH table can’t be built because of insufficient memory, a HASH join could be excessively slow using disk I/O instead.

Table 9-1 provides a quick view of the primary join types.
TABLE 9-1. Primary Join Methods

<table>
<thead>
<tr>
<th>Category</th>
<th>NESTED LOOPS Join</th>
<th>SORT-MERGE Join</th>
<th>HASH Join</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimizer hint</td>
<td>USE_NL</td>
<td>USE_MERGE</td>
<td>USE_HASH</td>
</tr>
<tr>
<td>When you can use it</td>
<td>Any join.</td>
<td>Any join.</td>
<td>Equi joins only.</td>
</tr>
<tr>
<td>Resource concerns</td>
<td>CPU, disk I/O.</td>
<td>Memory, temporary segments.</td>
<td>Memory, temporary segments.</td>
</tr>
<tr>
<td>Features</td>
<td>Efficient with highly selective indexes and restrictive searches. Used to return the first row of a result quickly.</td>
<td>Better than NESTED LOOPS when an index is missing or the search criteria are not very selective. Can work with limited memory.</td>
<td>Better than NESTED LOOPS when an index is missing or the search criteria are not very selective. It is usually faster than a SORT-MERGE.</td>
</tr>
<tr>
<td>Drawbacks</td>
<td>Very inefficient when indexes are missing or if the index criteria are not limiting.</td>
<td>Requires a sort on both tables. It is built for best optimal throughput and does not return the first row until all rows are found.</td>
<td>Can require a large amount of memory for the hash table to be built. Does not return the first rows quickly. Can be extremely slow if it must do the operation on disk.</td>
</tr>
</tbody>
</table>

A Two-Table Join: Equal-Sized Tables (Cost-Based)

Consider the following tables (they have been analyzed) that will be used for this example:

<table>
<thead>
<tr>
<th>Table</th>
<th>Rows</th>
<th>Indexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMALL1</td>
<td>10000</td>
<td>No Indexes</td>
</tr>
<tr>
<td>SMALL2</td>
<td>10000</td>
<td>No Indexes</td>
</tr>
</tbody>
</table>

This section of examples is important as you learn more about how the cost-based optimizer works, with all conditions being equal in a join (same size tables/no indexes).

Example 1

Neither table has an index and there aren’t any other noteworthy conditions on the tables. Oracle uses a HASH join if the initialization parameters have been set up to allow a HASH join; otherwise, it uses a SORT-MERGE join. In this example, both tables are equal, so the first one in the FROM clause
is used and Oracle uses a HASH join:

```sql
select small1.col1, small2.col2
from small1, small2
where small1.col1 = small2.col2;
```

**Join Method: HASH Join (If Hash Initialization Parameters Are Set Up)** The SMALL1 table is accessed first and used to build a hash table. Oracle accesses the SMALL1 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL2 and probes the hash table for matches to SMALL2.

---

<table>
<thead>
<tr>
<th>To</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>0</td>
<td>38 (55)</td>
<td>00:00:02</td>
</tr>
<tr>
<td></td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>0</td>
<td>38 (55)</td>
<td>00:00:02</td>
</tr>
<tr>
<td>2</td>
<td>HASH JOIN</td>
<td>SMALL1</td>
<td>6701K</td>
<td>98M</td>
<td>89 (&gt;5)</td>
<td>00:00:02</td>
</tr>
<tr>
<td>3</td>
<td>TABLE ACCESS FULL</td>
<td>SMALL2</td>
<td>10000</td>
<td>10000</td>
<td>23 (0)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>4</td>
<td>TABLE ACCESS FULL</td>
<td>SMALL1</td>
<td>10000</td>
<td>10000</td>
<td>23 (0)</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

**Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up)** Although SMALL1 would normally be the driving table (because it is first in the FROM clause and this example uses cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL1 table is accessed first for this operation (an EXPLAIN or AUTOTRACE shows this).

Now change the order of the tables in the FROM clause. The SMALL2 table is listed first and is also accessed first as the driving table. A HASH join is performed. A full table scan is needed on both tables, and the order in the FROM clause has no impact on the driving table, as shown here:

```sql
select small1.col1, small2.col2
from small2, small1
where small1.col1 = small2.col2;
```

**Join Method: HASH Join (If Hash Initialization Parameters Are Set Up)** The SMALL2 table is accessed first and used to build a hash table. Oracle accesses the SMALL2 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL1 and probes the hash table for matches to SMALL1.
Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL2 would normally be the driving table (because it is first in the FROM clause and using cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL2 table is accessed first for this operation (an EXPLAIN or AUTOTRACE will show this).

Example 1 Outcomes
If you have set up the initialization parameters for hashing, Oracle builds a hash table from the join values of the first table (accessed first), and then it probes that table for values from the second table. Forcing a USE_MERGE hint always causes the first table to be accessed first in my testing regardless of the order in the FROM clause.

Finally, if neither table is analyzed in Example 1, Oracle accesses what it believes to be the smallest table first (very important point here). Before I ran the ANALYZE, it listed SMALL2 as slightly less than 10,000 rows, and it always accessed it first regardless of the order in the FROM clause. Once I ran an ANALYZE on both tables, they both were listed at 10,000 rows, and the first table listed in the FROM clause was always accessed first as the driving table.

Example 2
Neither table has an index, and you will use the ORDERED hint, as in this listing:

```sql
select /*+ ORDERED */ small1.col1, small2.col1
from small1, small2
where small1.col1 = small2.col1;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 table is accessed first and used to build a hash table. Oracle accesses the SMALL1 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL2 and probes the hash table for matches to SMALL2.
Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL1 would normally be the driving table (because it is first in the FROM clause and using cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL1 table is accessed first for this operation (an EXPLAIN or AUTOTRACE will show this).

Now change the order of the tables in the FROM clause:

```
select /*+ ORDERED */ small1.col1, small2.col1
from small2, small1
where small1.col1 = small2.col1;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL2 table is accessed first and used to build a hash table. Oracle accesses the SMALL2 table and builds a hash table on the join key (COL1) in memory. It then scans SMALL1 and probes the hash table for matches to SMALL1.

Join Method: SORT-MERGE Join (If Hash Initialization Parameters Are Not Set Up) Although SMALL2 would normally be the driving table (because it is first in the FROM clause and using cost-based optimization), a SORT-MERGE join forces the sorting of each of the tables before they are merged together (because there are no indexes). A full table scan is needed on both tables, and the order in the FROM clause has no impact, but the SMALL2 table is accessed first for this operation (an EXPLAIN or AUTOTRACE will show this).
Example 2 Outcomes

If hash initialization parameters are set up, Oracle builds a hash table from the join values of the first table listed and then probes that hash table for values from the second table listed. If hash initialization parameters are not set up, the first table in the FROM clause in cost-based optimization is accessed first and is the driving table when an ORDERED hint is used; but in a SORT-MERGE join, this has no impact because each table must be sorted and then all tables must be merged together.

TIP
Using cost-based optimization, the first table in the FROM clause is the driving table when the ORDERED hint is used. This overrides the optimizer from choosing the driving table. If a SORT-MERGE join is used, then the order of the tables has no impact because neither will drive the query (although the first listed table is accessed first for the operation and is the driving table). Knowing which table is generally the driving table when using an ORDERED hint in small joins can help you solve larger table join issues and also help you find indexing problems.

TIP
When hash initialization parameters are set up, the optimizer uses HASH joins in lieu of SORT-MERGE joins. With HASH joins, the first table is used to build a hash table (in memory if available), and the second table in the FROM clause then probes for corresponding hash table matches. The first table in the FROM clause (using the ORDERED hint) is the first table accessed in a HASH join.

A Two-Table INDEXED Join: Equal-Sized Tables (Cost-Based)

To get a better understanding of the driving table and how Oracle processes a query, an example where all conditions are equal in both tables is instructive. Although the queries in this section look strange because I am trying to keep all conditions equal, they are helpful in understanding the way joins work. Consider the following tables (they have been analyzed) that will be used for this example:

| SMALL1  | 10000 rows | Index on COL1 |
| SMALL2  | 10000 rows | Index on COL1 |
NOTE
This section of examples is important as you learn how the cost-based optimizer works using indexes. Although the query in this section wouldn’t normally be written, it shows how the driving table works with a two-table join, all conditions being equal. In other words, it is only for instructional purposes.

Example 1
Both tables have an index on the COL1 column, as in this example:

```sql
select small1.col1, small2.col1
from small1, small2
where small1.col1 = small2.col1
and small1.col1 = 77
and small2.col1 = 77;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 index is the query’s driving statement (since the SMALL1 table is the first table listed in the FROM clause). The SMALL1 index is accessed first and used to build a hash table. Oracle accesses the SMALL1 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL2 index and probes the hash table for matches to SMALL2. Also note, switching the order of the predicates in the two AND clauses does not change anything.

Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up) The SMALL1 index (since the SMALL1 table is the first table listed in the FROM clause) is the query’s driving statement. Oracle retrieves the records from the index on SMALL1 and then takes each record and checks for matches in the SMALL2 index. A NESTED LOOPS join is faster when the source rows from the SMALL1 table are a small set and there is a reasonably selective index on the SMALL2 joining column (brief EXPLAIN PLAN listed here).
Now change the order of the tables in the FROM clause:

```
select small1.col1, small2.col1
from small2, small1
where small1.col1 = small2.col1
and small1.col1 = 77
and small2.col1 = 77;
```

**Join Method: HASH Join (If Hash Initialization Parameters Are Set Up)** The SMALL2 index (since the SMALL2 table is the first table listed in the FROM clause) is the query’s driving statement. The SMALL2 index is accessed first and used to build a hash table. Oracle accesses the SMALL2 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL1 index and probes the hash table for matches to SMALL1. Also note, switching the order of the predicates in the two AND clauses does not change anything.

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>00:00:01</td>
</tr>
<tr>
<td>2</td>
<td>HASH JOIN</td>
<td>small2_idx</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>00:00:01</td>
</tr>
<tr>
<td>3</td>
<td>INDEX RANGE SCAN</td>
<td>small2_idx</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>00:00:01</td>
</tr>
<tr>
<td>4</td>
<td>INDEX RANGE SCAN</td>
<td>small1_idx</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

**Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up)** The SMALL2 index (since the SMALL2 table is the first table in the FROM clause) is the query’s driving statement. Oracle retrieves the records from the index on SMALL2 and then takes each record and checks for matches in the SMALL1 index. A NESTED LOOPS join is faster when the source rows from the SMALL2 table are a small set and there is a reasonably selective index on the SMALL1 joining column (brief EXPLAIN PLAN listed here).

**Example 1 Outcomes**
All conditions being equal, the index from the first table is accessed first (the first table in the FROM clause) in cost-based optimization and is the driving table. The index is used on the join condition for the second table. In Example 1, Oracle uses a HASH join to join the queries, but a NESTED LOOPS join or SORT-MERGE join is also possible, depending on other factors in the table and index.

Example 2
Both tables have an index on the COL1 column, and I use the ORDERED hint, as shown here:

```sql
select /*+ ORDERED */ small1.col1, small2.col1
from small1, small2
where small1.col1 = small2.col1
and small1.col1 = 77
and small2.col1 = 77;
```

Join Method: HASH Join (If Hash Initialization Parameters Are Set Up) The SMALL1 index (since the SMALL1 table is the first table listed in the FROM clause) is the query’s driving statement. The SMALL1 index is accessed first and used to build a hash table. Oracle accesses the SMALL1 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL2 index and probes the hash table for matches to SMALL2. Also note, switching the order of the predicates in the two AND clauses does not change anything.

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>6</td>
<td>5 (20)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*2</td>
<td>HASH JOIN</td>
<td></td>
<td>29630</td>
<td>173K</td>
<td>5 (20)</td>
<td>00:00:01</td>
</tr>
<tr>
<td>3</td>
<td>INDEX RANGE SCAN SMALL1 IDX</td>
<td>667</td>
<td>20K</td>
<td>2 (0)</td>
<td>00:00:01</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>INDEX RANGE SCAN SMALL2 IDX</td>
<td>667</td>
<td>20K</td>
<td>2 (0)</td>
<td>00:00:01</td>
<td></td>
</tr>
</tbody>
</table>

Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up) The SMALL1 index (since the SMALL1 table is the first table listed in the FROM clause) is the query’s driving statement. Oracle retrieves the records from the index on SMALL1 and then takes each record and checks for matches in the SMALL2 index. A NESTED LOOPS join is faster when the source rows from the SMALL1 table are a small set and there is a reasonably selective index on the SMALL2 joining column (brief EXPLAIN PLAN listed next).
Now change the order of the tables in the FROM clause:

```
select /*+ ORDERED */ small1.col1, small2.col1
from small2, small1
where small1.col1 = small2.col1
and small1.col1 = 77
and small2.col1 = 77;
```

**Join Method: HASH Join (If Hash Initialization Parameters Are Set Up)** The SMALL2 index (since the SMALL2 table is the first table listed in the FROM clause) is the query’s driving statement. The SMALL2 index is accessed first and used to build a hash table. Oracle accesses the SMALL2 index and builds a hash table on the join key (COL1) in memory. It then scans the SMALL1 index and probes the hash table for matches to SMALL1. Also note, switching the order of the predicates in the two AND clauses does *not* change anything.

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost (%CPU)</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>00:00:01</td>
</tr>
<tr>
<td>1</td>
<td>SORT AGGREGATE</td>
<td></td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*2</td>
<td>HASH JOIN</td>
<td>29630 173K</td>
<td>5</td>
<td>(20)</td>
<td>00:00:01</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>INDEX RANGE SCAN</td>
<td>SMALL2 IDX</td>
<td>667</td>
<td>2021</td>
<td>2</td>
<td>00:00:01</td>
</tr>
<tr>
<td>4</td>
<td>INDEX RANGE SCAN</td>
<td>SMALL1 IDX</td>
<td>667</td>
<td>2021</td>
<td>2</td>
<td>00:00:01</td>
</tr>
</tbody>
</table>

**Join Method: NESTED LOOPS Join (If Hash Initialization Parameters Are Not Set Up)** The SMALL2 index (since the SMALL2 table is the first table in the FROM clause) is the query’s driving statement. Oracle retrieves the records from the index on SMALL2 and then takes each record and checks for matches in the SMALL1 index. A NESTED LOOPS join is faster when the source rows from the SMALL2 table are a small set and there is a reasonably selective index on the SMALL1 joining column (brief EXPLAIN PLAN listed here).

**Example 2 Outcomes**

All conditions being equal, the index from the first table is accessed first (the *first* table listed in the FROM clause) in cost-based optimization using a HASH or NESTED LOOPS join and is the driving statement with or without the ORDERED hint. Only the ORDERED hint guarantees the order in which all the tables are accessed. The index is used on the join condition for the second table.
**TIP**

Using cost-based optimization and a NESTED LOOPS join as the means of joining, the first table in the FROM clause is the driving table (all other conditions being equal), but only the ORDERED hint guarantees this. In NESTED LOOPS joins, choosing a driving table that is the smaller result set (not always the smaller table) makes fewer loops through the other result set (from the nondriving table) and usually results in the best performance.

---

**Forcing a Specific Join Method**

When choosing an execution plan for a query involving joins, the Oracle optimizer considers all possible join methods and table orders. The optimizer does its best to evaluate the merits of each option and to choose the optimal execution plan, but sometimes the optimizer does not choose the best solution because of poor indexing strategies.

In these situations, you can use the USE_NL, USE_MERGE, and USE_HASH hints to request a specific join method, and you can use the ORDERED hint to request a specific join order for all tables (or use LEADING to use the first table in the FROM clause as the driving table and leave the order of the remaining tables for Oracle to figure out). The optimizer does its best to observe the wishes of these hints, but if you ask for something impossible (such as a SORT-MERGE join on an antijoin), the optimizer ignores the hint.

When tuning SQL that uses joins, you should run benchmark comparisons between different join methods and table execution order. For example, if a report joins two tables that form a master-detail relationship and the proper primary-key and foreign-key indexes are in place, the optimizer will probably choose to use a NESTED LOOPS join. However, if you know that this particular report joins all of the master records to all of the detail records, you might think it’s faster to use a SORT-MERGE join or HASH join instead. Run a benchmark to ensure that you have the best solution.

In the following three listings, the first listing shows an example query and its TKPROF output, the second listing shows the same query with a USE_MERGE hint, and the third listing shows it with a USE_HASH hint. In this example, the indexes were built so that a full table scan must be executed on the PURCHASE_ORDER_LINES table. (Using an index would have been the better choice but not as instructive.) You can see that in this situation the HASH join reduced CPU time by almost 40 percent and logical I/Os by about 98 percent. The goal is not to demonstrate how to tune this type of query, but how to use different types of joining.

---

**Forcing a NESTED LOOPS Join**

The PURCHASE_ORDER_LINES table is the driving table. Each record (one at a time) is taken from the PURCHASE_ORDER_LINES table, and for each one, you loop through for matches in the PURCHASE_ORDERS table. This is slow because the driving table list is large. (PURCHASE_ORDER_LINES has a large number of rows.)
Forcing a SORT-MERGE Join

For the SORT-MERGE case, Oracle sorts both tables and then merges the result. This method is still not an efficient way to perform the query.

Forcing a HASH join

The HASH join has proven to be the most efficient because it puts the PURCHASE_ORDERS table into a hash table and then scans to retrieve the corresponding records from PURCHASE_ORDER_LINES. If you cannot get the correct access order, you can use the SWAP_JOIN_INPUTS hint as well.
Oracle chose to do a NESTED LOOPS join in 10g and a HASH join in 11g. In 12c, it does a HASH join. NESTED LOOPS is not the most efficient way of joining in this case, but if you don’t set the memory parameters appropriately, Oracle might choose NESTED LOOPS over a HASH Join. For this query, by using the USE_HASH hint, you can cut CPU time by almost 40 percent and logical I/Os by about 98 percent. Although the CPU reduction is impressive, the reduction in logical I/Os (memory reads) is saving SGA memory for other users. Sometimes when you are retrieving a large amount of data, access using a full table scan is the most efficient method. In 11g, Oracle uses the HASH join method frequently, provided the initialization parameters related to it are set appropriately.

TIP
To change the method that Oracle uses to join multiple tables, use the USE_MERGE, USE_NL, and USE_HASH hints. Multiple tables may need to be specified for the hint to work, and the driving order is usually from first to last in the FROM clause.

Eliminating Join Records (Candidate Rows) in Multitable Joins
Suppose you have a list of 1000 residents of your town along with each resident’s street address, and you are asked to prepare an alphabetized list of residents who have the newspaper delivered to their home. (Only 50 get the newspaper.) You could first alphabetize the list of 1000 names (all residents in the town) and then look up each street address in the list of 50 residents who get the newspaper. (Sort the 1000 and then find the 50.) A faster method would be to look up each street address of those who get the newspaper first, and then get the names of the residents at that street and do the alphabetization last. (Find the 50 who get the newspaper from the list of 1000 and then sort the 50 matches.) Either way, you need to look at the 1000 street addresses. However, these lookups will
eliminate many names from the list, and the sorting will be faster when you have a list of only 50 to sort.

You can apply the same concept when writing SQL table joins together. The Oracle optimizer is pretty smart about choosing the most efficient order in which to perform tasks, but how a query is written can constrain the options available to the optimizer.

The query in this next listing leaves the optimizer no choice but to read all of Acme’s invoice lines (the large table/the intersection table), when, in fact, only the unpaid invoices (the small table) are of interest:

```sql
select v.vendor_num, i.invoice_num, sum (l.amount) 
from vendors v, invoices i, invoice_lines l 
where v.vendor_name = 'ACME' 
and l.vendor_num = v.vendor_num 
and i.vendor_num = l.vendor_num 
and i.invoice_num = l.invoice_num 
and i.paid = 'N' 
group by v.vendor_num, i.invoice_num 
order by i.invoice_num;
```

You could rewrite this query, as shown here:

```sql
select v.vendor_num, i.invoice_num, sum (l.amount) 
from vendors v, invoices i, invoice_lines l 
where v.vendor_name = 'ACME' 
and i.vendor_num = v.vendor_num 
and i.paid = 'N' 
and l.vendor_num = i.vendor_num 
and l.invoice_num = i.invoice_num 
group by v.vendor_num, i.invoice_num 
order by i.invoice_num;
```

In the rewritten query in this listing, the optimizer eliminates all of the paid invoices (the new intersection table) before joining to the INVOICE_LINES table. If most of the invoices in the database have already been paid, then the rewritten query is significantly faster. (The schema design in this example is dubious and is used only for illustrative purposes.)

**TIP**

In a three-table join, the driving table is the intersection table or the table that has a join condition to each of the other two tables in the join. Try to use the most limiting table as the driving table (or intersection table) so your result set from the join of the first two tables is small.
A Two-Table Join Between a Large and Small Table

Consider the following tables that will be used for this example:

```
PRODUCT  70 thousand rows  Index on PRODUCT_ID
PRODUCT LINES  4 million rows  Index on PRODUCT_ID
```

This section uses only cost-based optimization. This section of examples is important because it looks at a situation often encountered. It involves a two-table join between a small (business small) table and a large table. The subsequent conditions (beyond the join itself) are on the column that you are joining. At times, the index on this column in the subsequent condition is suppressed. Unfortunately, this situation leads to seven possible situations, based on various conditions. This section covers three of the main situations, and the results are summarized at the end.

Example 1

Neither table can use an index (they are suppressed), and there are no other conditions, as shown in this example:

```
SELECT product.name, product_lines.qty
FROM product, product_lines
WHERE product.product_id || '' = product_lines.product_id || '';
```

**EXPLAIN PLAN Output**

```
SELECT STATEMENT
  HASH JOIN
    TABLE ACCESS FULL OF 'PRODUCT'
    TABLE ACCESS FULL OF 'PRODUCT_LINES'
```

The order of the tables in the FROM clause can be reversed, as shown here:

```
SELECT product.name, product_lines.qty
FROM product_lines, product
WHERE product.product_id || '' = product_lines.product_id || '';
```
Example 1 Outcome

All conditions being equal, the first table in the FROM clause in cost-based optimization is the driving table (first accessed). Because these tables are different sizes, however, Oracle chooses the smaller table to be the driving table regardless of the order in the FROM clause. The PRODUCT table is used to build a hash table on the join key (PRODUCT_ID), and then the PRODUCT_LINES table is scanned, probing the hash table for join key matches.

TIP

Using cost-based optimization, when a large table and a small table are joined, the smaller table is the driving table (accessed first), and the smaller table is used to build a hash table in memory on the join key. The larger table is scanned and then probes the hash table for matches to the join key. Also note that if there is not enough memory for the hash, the operation can become extremely slow because the hash table may be split into multiple partitions that could be paged to disk. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table, and it will be the one used to build the hash table.

Example 2

A subsequent clause allows the large table to use the PRODUCT_ID index:

```sql
SELECT product.name, product_lines.qty
FROM product, product_lines
WHERE product.product_id = product_lines.product_id
AND product_lines.product_id = 4488;
```

EXPLAIN PLAN Output
The order of the tables in the FROM clause can be reversed, as shown here:

```
SELECT product.name, product_lines.qty
FROM product_lines, product
WHERE product.product_id = product_lines.product_id
AND product_lines.product_id = 4488;
```

**EXPLAIN PLAN Output**

```
SELECT STATEMENT
MERGE JOIN
 TABLE ACCESS BY INDEX ROWID PRODUCT
 INDEX RANGE SCAN PRODUCT_ID1
 BUFFER SORT
 TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
 INDEX RANGE SCAN PRODUCT1
```

**Example 2 Outcomes**

When a subsequent condition on PRODUCT_ID on the large table exists, the larger table is always the driving table regardless of the order in the FROM clause. The order of the tables in the FROM clause does not alter the order in which Oracle performs this join unless an ORDERED hint is used. In Example 2, a SORT-MERGE join is executed. For this example, a HASH join is also possible.

**TIP**

Using cost-based optimization, when a large and small table are joined, the larger table is the driving table if an index can be used on the large table. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table.

**Example 3**

A subsequent clause, shown in the following listing, allows the small table to use the PRODUCT_ID
The large table still drives the query after getting this condition (on PRODUCT_ID) passed to it by the join. Oracle is smart enough to figure out that PRODUCT_ID exists in both tables and it is more efficient to limit the PRODUCT_LINES table. In the upcoming section “Three-Table Joins: Not as Much Fun,” Oracle’s excellent internal processing to improve queries will become more evident.

```
select product.name, product_lines.qty
from product, product_lines
where product.product_id = product_lines.product_id
and product.product_id = 4488;
```

**EXPLAIN PLAN Output**

```
SELECT STATEMENT
MERGE JOIN
  TABLE ACCESS BY INDEX ROWID PRODUCT
  INDEX RANGE SCAN PRODUCT_ID1
  BUFFER SORT
  TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
  INDEX RANGE SCAN PRODUCT1
```

The order of the tables in the FROM clause can be reversed, as shown here:

```
select product.name, product_lines.qty
from product_lines, product
where product.product_id = product_lines.product_id
and product.product_id = 4488;
```

**EXPLAIN PLAN Output**

```
SELECT STATEMENT
MERGE JOIN
  TABLE ACCESS BY INDEX ROWID PRODUCT
  INDEX RANGE SCAN PRODUCT_ID1
  BUFFER SORT
  TABLE ACCESS BY INDEX ROWID PRODUCT_LINES
  INDEX RANGE SCAN PRODUCT1
```

**Example 3 Outcomes**
When a subsequent condition on PRODUCT_ID on the small table exists, the larger table gets this condition passed to it via the join and is still the driving table. The order of the tables in the FROM clause does not alter the procedure unless an ORDERED hint is used. For this example, a HASH join is also possible.

Summary
The examples in this section demonstrate the value of some of the optimizer’s behavior. The optimizer almost always chooses how to drive a query correctly, but sometimes it must be corrected for a given query. It chooses the right path in most situations.

Three-Table Joins: Not as Much Fun
In a three-table join, Oracle joins two of the tables and joins the result with the third table.

When the query in the following listing is executed, the EMP, DEPT, and ORDERS tables are joined together, as illustrated in Figure 9-5.

```
select /*+ ORDERED */ ENAME, DEPT.DEPTNO, ITEMNO
from EMP, DEPT, ORDERS
where emp.deptno = dept.deptno
and emp.empno = orders.empno;
```

Which table is the driving table in a query? People often give different answers, depending on the query that accesses the PLAN_TABLE. This query would drive with the EMP table accessed first, the DEPT table accessed second, and the ORDERS table accessed third (there are always exceptions to the rule).

This next listing shows a query that has only one possible way to be accessed (the subqueries must be accessed first) and a query to the PLAN_TABLE that will be used for the remainder of this
The following listing is a quick and simple EXPLAIN PLAN query (given the PLAN_TABLE is empty). Throughout this chapter, I show many of these, but I also show the output using AUTOTRACE (SET AUTOTRACE ON) and TIMING (SET TIMING ON).

```sql
explain plan for
select cust_last_name, cust_first_name
from customers
where customer_id =
(select customer_id
from order_lines
where quantity = 1
and product_id =
(select p.product_id
from product_information p
where p.product_id = 807
and product_description = 'test'))

The following listing is a quick and simple EXPLAIN PLAN query (given the PLAN_TABLE is empty). Throughout this chapter, I show many of these, but I also show the output using AUTOTRACE (SET AUTOTRACE ON) and TIMING (SET TIMING ON).

```sql
select lpad(' ',2*level) || operation oper, options, object_name
from plan_table
connect by prior id = parent_id
start with id = 1
order by id;

EXPLAIN PLAN Output
Next, you can see abbreviated EXPLAIN PLAN output. (Additional EXPLAIN PLAN information can be found in Chapter 6.)

<table>
<thead>
<tr>
<th>OPER</th>
<th>OPTIONS</th>
<th>OBJECT_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE ACCESS</td>
<td></td>
<td>CUSTOMERS</td>
</tr>
<tr>
<td>INDEX</td>
<td>BY INDEX ROWID</td>
<td>customers_idx1</td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td></td>
<td>ORDER_LINES</td>
</tr>
<tr>
<td>INDEX</td>
<td>RANGE SCAN</td>
<td>order_lines_idx1</td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td>BY INDEX ROWID</td>
<td>PRODUCT_INFORMATION</td>
</tr>
<tr>
<td>INDEX</td>
<td>RANGE SCAN</td>
<td>product_info_idx1</td>
</tr>
</tbody>
</table>

The order of access is PRODUCT_INFORMATION, ORDER_LINES, and CUSTOMERS. The innermost subquery (to the PRODUCT_INFORMATION table) must execute first so it can return the PRODUCT_ID to be used in the ORDER_LINES table (accessed second), which returns the
CUSTOMER_ID that the CUSTOMERS table (accessed third) needs.

TIP
To ensure that you are reading your EXPLAIN PLAN correctly, run a query in which you are sure of the driving table (with nested subqueries).

One exception to the previous subquery is shown here:

```sql
explain plan for
select cust_last_name, cust_first_name
from customers
where customer_id =
  (select customer_id
   from order_lines o
   where o.product_id = 807
   and quantity = 1
   and o.product_id =
     (select p.product_id
      from product_information p
      where p.product_id = 807
      and product_description = 'test'));
```

EXPLAIN PLAN Output

<table>
<thead>
<tr>
<th>OPER</th>
<th>OPTIONS</th>
<th>OBJECT_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE ACCESS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDEX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FILTER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TABLE ACCESS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDEX</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The expected order of table access is based on the order in the FROM clause: PRODUCT_INFORMATION, ORDER_LINES, and CUSTOMERS. The actual order of access is ORDER_LINES, PRODUCT_INFORMATION, and CUSTOMERS. The ORDER_LINES query takes the PRODUCT_ID from the subquery to the PRODUCT_INFORMATION table and executes first (Oracle is very efficient).
Bitmap Join Indexes

Oracle changes the boundaries of relational database design and implementation with the addition of new indexing features. The bitmap join index allows you to build a single index across the joined columns of two tables. The ROWIDs from one table are stored along with the matching values from the other table. This feature is an incredible performance gold mine, as was the case of the function-based index, and it is as powerful as the designer, developer, or DBA who implements it. This section focuses on the bitmap join index.

Bitmap Indexes

To fully appreciate where a bitmap join index is helpful, it is important to understand a bitmap index. Bitmap indexes are most helpful in a data warehouse environment because they are generally great (fast) when you are only selecting data. A bitmap index is smaller than a b-tree index because it stores only the ROWID and a series of bits. In a bitmap index, if a bit is set, it means that a row in the corresponding ROWID (also stored) contains a key value. For example, consider the EMP table with two new columns indicating gender and marital status:

<table>
<thead>
<tr>
<th>EMPNO</th>
<th>GENDER (M/F)</th>
<th>MARRIED (Y/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>1002</td>
<td>F</td>
<td>Y</td>
</tr>
<tr>
<td>1003</td>
<td>F</td>
<td>N</td>
</tr>
<tr>
<td>1004</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>1005</td>
<td>M</td>
<td>Y</td>
</tr>
</tbody>
</table>

The bitmaps stored may be the following (the actual storage depends on the algorithm used internally, which is more complex than this example): 

<table>
<thead>
<tr>
<th>EMPNO=</th>
<th>GENDER=F</th>
<th>MARRIED=Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>1001</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1002</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1003</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1004</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1005</td>
<td>()</td>
<td>1</td>
</tr>
</tbody>
</table>

As you can tell from the preceding example, finding all of the females by searching for the gender bit set to a ‘1’ in the example would be easy. You can similarly find all of those who are married or even quickly find a combination of gender and marital status. Oracle stores ranges of rows for each bitmap as well, which is why bitmaps don’t do well when you update the bitmap-indexed column (as
you can lock an entire range of rows).

You should use b-tree indexes when columns are unique or near-unique; you should at least consider bitmap indexes in all other cases. Although you generally would not use a b-tree index when retrieving 40 percent of the rows in a table, using a bitmap index generally makes this task faster than doing a full table scan. Using an index in this situation is seemingly in violation of the 80/20 or 95/5 rules, which are generally to use an index when retrieving 5–20 percent or less of the data and to do a full table scan when retrieving more. Bitmap indexes are smaller and work differently than b-tree indexes, however. You can use bitmap indexes even when retrieving a large percentage (20–80 percent) of a table. You can also use bitmaps to retrieve conditions based on NULLs (because NULLs are also indexed), and can be used for not-equal conditions for the same reason. The best way to find out is to test!

**Bitmap Index Caveats**

Bitmap indexes do not perform well in a heavy DML (UPDATE, INSERT, DELETE) environment and generally are not used in certain areas of an OLTP environment. There is a heavy cost if you are doing a lot of DML, so be very careful with this. Applying NOT NULL constraints and fixed-length columns allows bitmaps to use less storage, so a good designer is once again worth his or her weight in gold. Use the INDEX_COMBINE hint instead of the INDEX hint or AND_EQUAL hint for bitmap indexes. Like b-tree indexes, bitmap indexes should be rebuilt (ALTER INDEX … REBUILD) if there is a lot of DML activity. Bitmaps are very good for multicolumn read-only indexes that together make a reasonably selective value but separately do not. These columns when indexed together, if often used together in a WHERE clause, are a good choice for a bitmap.

---

**Bitmap Join Index**

In a typical business relational database, you are often joining the same two or three tables over and over. The bitmap join index can give you substantial gains when properly applied to many of these circumstances. In a bitmap join index, the ROWIDs from one table are stored along with the indexed column from the joined table. The bitmap join index in Oracle is a lot like building a single index across two tables. You must build a primary key or unique constraint on one of the tables. When you are looking for information from just the columns in the index or a count, then you will be able to access the single join index. Let’s look at a very simple example to learn how to use it. Then I’ll show you how to apply it to multiple columns and multiple tables.

**Example 1**

Let’s create two sample tables from our friendly EMP and DEPT tables, as shown in this listing:
You must then add a unique constraint (or have a primary key) to the DEPT1 table to use this type of index. You can then create the bitmap index on the EMP1 table that includes the columns of both tables.

```sql
alter table dept1
add constraint dept_constr1 unique (deptno);
Table altered.
```

```sql
create bitmap index empdept_idx
on emp1(dept1.deptno)
from emp1, dept1
where emp1.deptno = dept1.deptno;
Index created.
```

You are now storing the ROWID to the DEPT1 table in the bitmap index that maps to the DEPTNO column in the EMP1 table. To test how well this works, you can perform a simple `count(*)` of the intersection rows between the two tables (you would generally have additional limiting conditions), forcing the use of the bitmap index with an INDEX hint:

```sql
select /*+ index(emp1 empdept_idx) */ count(*)
from emp1, dept1
where emp1.deptno = dept1.deptno;
```

```
COUNT(*)
--------
14
```

Elapsed: 00:00:00.01

Execution Plan (Explain plan)

```
0  SELECT STATEMENT
1   0  SORT (AGGREGATE)
2   1  BITMAP CONVERSION (COUNT)
3   2  BITMAP INDEX (FULL SCAN) OF 'EMPDEPT IDX'
```

You can see from the preceding EXPLAIN PLAN output that the bitmap index was used; alternatively, you could use `SET AUTOTRACE ON` while in SQL*Plus to get the following output:
Although this simplistic example shows how to count an index (instead of the table) and applies some benefits of the bitmap join index, the next section explores better uses of the bitmap join index by manipulating columns outside the join in the index.

Best Uses for the Bitmap Join Index

Example 1 in the previous section shows a basic use of the bitmap join index, focusing on just the joined columns. The next three sections show targeted areas where you may discover better uses for bitmap join indexes.

Bitmap Join Indexes on Columns Other Than the Join

Consider this example where the EMP1 and DEPT1 tables are once again joined on the DEPTNO column. In this example, you want to index the LOC column instead of the join column. This allows you to select the LOCATION column from the DEPT1 table by directly accessing only the index and the EMP1 table. Remember, the join condition must be on the primary key or unique column. The example in the following listing assumes that the unique constraint on DEPT1.DEPTNO from the example in the earlier listing (where I added a unique constraint to the DEPT1 table) exists.

Create bitmap index emp_dept_location
on emp1 (dept1.loc)
from emp1, dept1
where emp1.deptno = dept1.deptno;

The query shown next can now use the bitmap join index appropriately:
Bitmap Join Indexes on Multiple Columns
Consider an example where you want an index on multiple columns. The syntax is still the same, but now you include multiple columns in the index. The next example assumes that the unique constraint on DEPT1.DEPTNO from the example in the earlier listing (where I added a unique constraint to the DEPT1 table) exists.

Create bitmap index on multiple columns:
```
create bitmap index emp_dept_location_deptname
on emp1 (dept1.loc, dept1.dname)
from emp1, dept1
where emp1.deptno = dept1.deptno;
```

The query in the following listing is able to use the bitmap join index appropriately:
```
select emp1.empno, emp1.ename, dept1.loc
from emp1, dept1
where emp1.deptno = dept1.deptno;
```

Bitmap Join Indexes on Multiple Tables
As you become more familiar with using the bitmap join index, you will be able to solve complex business problems that involve multiple tables. The following example shows how to apply the bitmap join index to multiple tables. The syntax is still the same, but it has now been expanded to include multiple columns in the index and multiple tables being joined for the index. The example shown next assumes that the unique constraint on DEPT1.DEPTNO from the example in the earlier listing (where I added a unique constraint to the DEPT1 table) exists and, additionally, that it exists on SALES1.EMPNO (creation not shown).

Create bitmap index on multiple tables:
```
create bitmap index emp_dept_location_ms
on emp1 (dept1.loc, sales1.marital_status)
from emp1, dept1, sales1
where emp1.deptno = dept1.deptno
and emp1.empno = sales1.empno;
```

The query in this next listing is now able to use the bitmap join index appropriately:
```
select emp1.empno, emp1.ename, dept1.loc, dept1.dname
from emp1, dept1
where emp1.deptno = dept1.deptno;
```
Bitmap Join Index Caveats

Because the result of the join is stored, only one table can be updated concurrently by different transactions, and parallel DML is supported only on the fact table. Parallel DML on the dimension table marks the index as unusable. No table can appear twice in the join, and you can’t create a bitmap join index on an index-organized table (IOT) or a temporary table.

Another Nice Use for the Bitmap Join Index

A nice tuning trick when you are counting rows is to try to count the index instead of the table. Consider the following large-table example used for counting. These tables each contain roughly 2 million rows, so that you can see the possible impact on a larger scale. The new tables, EMP5 and EMP6, each have 2 million rows with EMPNO indexes on them.

To add the constraint and run a join without the bitmap index:

```sql
alter table emp5
    add constraint emp5 constr unique (empno);

select count(*)
from emp5, emp6
where emp5.empno = emp6.empno;
```

```
COUNT(*)

2005007
Elapsed: 00:01:07.18
```

Execution Plan

```
0  SELECT STATEMENT
1    0  SORT (AGGREGATE)
2    1  NESTED LOOPS
3    2  TABLE ACCESS (FULL) OF 'EMP6'
4    2  INDEX (RANGE SCAN) OF 'EMP5I_EMPNO' (NON UNIQUE)
```

Statistics

```
6026820  consistent gets
7760  physical reads
```
There is an index on the EMP5 table, but there is no correlation or index back to the EMP6 table because the index on EMP6 contains only EMPNO as the second part of a concatenated index. The result is a relatively slow query.

If you make EMPNO the only part or the leading part of the concatenated index, you solve this problem. Use the new bitmap join index, as shown here:

```sql
CREATE BITMAP INDEX emp5_j6 ON emp6(emp5.empno)
FROM emp5, emp6
WHERE emp5.empno = emp6.empno;
Index created.
```

Elapsed: 00:02:29.91

```sql
SELECT /*+ index(emp6 emp5_j6) */ COUNT(*)
FROM emp5, emp6
WHERE emp5.empno = emp6.empno;
```

<table>
<thead>
<tr>
<th>COUNT(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005227</td>
</tr>
</tbody>
</table>

Elapsed: 00:00:00.87

Execution Plan

```
0 SELECT STATEMENT
  0 0 SORT (AGGREGATE)
  2 1 BITMAP CONVERSION (COUNT)
  3 2 BITMAP INDEX (FULL SCAN) OF 'EMP5 J6'
```

Performing a count of the bitmap join index makes this very fast. I chose this example for a reason. The real problem with the original slow query was not that it took a minute to execute, but that it performed over 6 million memory block reads and over 7000 disk block reads. You may not receive any wait events, but you have a poorly written query that will cause problems when you have volumes of users on the system. Take a step up to expert level by finding queries with large memory and disk reads and start doing proactive tuning now so you don’t get to wait states and need to tune things reactively. Using a bitmap join index is one way to improve performance.
Third-Party Product Tuning

Sometimes, you are at the mercy of a third-party product. Although you cannot modify the code, you can often modify the use of indexes. The following three examples are from a third-party financial product.

Example 1

This query took 22 minutes to run. By providing a hint (using SQL Plan Management) to use a more efficient index, I reduced the query execution time to 15 seconds.

This next listing shows the query before the hint was added:

update PS_COMBO_DATA_TBL
set   EFFDT_FROM = TO_DATE ('1990-01-01', 'YYYY-MM-DD'),
      EFFDT_TO = TO_DATE ('2099-01-01', 'YYYY-MM-DD')
where  SETID = 'RRD'
       and PROCESS_GROUP = 'GROUP1'
       and COMBINATION = 'ACCT/NCLOC'
       and VALID_CODE = 'V'
       and EFFDT_OPEN = 'Y'
       and EXISTS
       (select 'X'
        from   PS_JRNL_LN
        where  BUSINESS_UNIT = '00003'
        and PROCESS_INSTANCE = 0000085176
        and JRNL_LINE_STATUS = '3'
        and ACCOUNT = PS_COMBO_DATA_TBL.ACCOUNT
        and PRODUCT = PS_COMBO_DATA_TBL.PRODUCT );

Now, here’s the query after the index hint was added:
Example 2

The query in the next listing was taking 33 minutes to run. By creating a concatenated index on the PS_GROUP_CONTROL table (columns: DEPOSIT_BU, DEPOSIT_ID, PAYMENT_SEQ_NUM), I reduced the query execution time to 30 seconds, as shown here:

```sql
update PS_COMBO_DATA_TBL
set EFFDT_FROM = TO_DATE ('1990-01-01', 'YYYY-MM-DD'),
     EFFDT_TO = TO_DATE ('2099-01-01', 'YYYY-MM-DD')
where SETID = 'RRD'
and PROCESS_GROUP = 'GROUP1'
and COMBINATION = 'ACCT/NOLOC'
and VALU_CODE = 'V'
and EFFDT_OPEN = 'Y'
and EXISTS
(select /*+ INDEX(PS_JRNL_LN PSGJRNL_LN) */ 'X'
    from PS JRNL_LN
    where RUSTNESS_UNIT = '00003'
    and PROCESS_INSTANCE = 0000085176
    and JRNL_LINE_STATUS = '3'
    and ACCOUNT = PS_COMBO_DATA_TBL.ACCOUNT
    and PRODUCT = PS_COMBO_DATA_TBL.PRODUCT );
```

```sql
select C.BUSINESS_UNIT, C.CUST_ID, C.ITEM,
    C.ENTRY_TYPE, C.ENTRY_REASON, C.ENTRY_AMT,
    C.ENTRY_CURRENCY, C.ENTRY_AMT_BASE,
    C.CURRENCY_CD, C.POSTED_FLAG, D.PAYMENT_SEQ_NUM
from PS_PENDING_ITEM C,
     PS_GROUP_CONTROL D
where D.DEPOSIT_BU = :1
and D.DEPOSIT_ID = :2
and D.PAYMENT_SEQ_NUM = :3
and D.GROUP_BU = C.GROUP_BU
and D.GROUP_ID = C.GROUP_ID
order by D.PAYMENT_SEQ_NUM;
```

Here is the EXPLAIN PLAN before the index was added:
And here's the EXPLAIN PLAN after the index was added:

```
Execution Plan
SELECT STATEMENT
  SORT ORDER BY
    NESTED LOOPS
      ANALYZED TABLE ACCESS FULL PS_GROUP_CONTROL
      ANALYZED TABLE ACCESS BY ROWID PS PENDING ITEM
      ANALYZED INDEX RANGE SCAN PS PENDING ITEM
```

Example 3

The query shown next was taking 20 minutes to run and was reduced to 30 seconds. To achieve this, I created a concatenated unique index on the PS_CUST_OPTION table (columns: CUST_ID, EFFDT) instead of the current index, which is only on CUST_ID. This forces Oracle to use a concatenated unique index rather than a single-column index, as shown here:

```
Execution Plan
SELECT STATEMENT
  SORT ORDER BY
    NESTED LOOPS
      ANALYZED TABLE ACCESS BY ROWID PS GROUP CONTROL
        INDEX RANGE SCAN PSAGROUP_CONTROL
      ANALYZED TABLE ACCESS BY ROWID PS PENDING ITEM
      ANALYZED INDEX RANGE SCAN PS PENDING ITEM
```
Here's the EXPLAIN PLAN before the index was added:

```
INSERT INTO PS_PP_CUST_TMP (PROCESS_INSTANCE, DEPOSIT_BU, DEPOSIT_ID, PAYMENT_SEQ_NUM, CUST_ID, PAYMENT_AMT, PAYMENT_DT, PP_METHOD, SETID, SUBCUST_QUAL1, SUBCUST_QUAL2, PP_HOLD, PP_NET_SW, PAYMENT_CURRENCY)
from PS_CUST_OPTION O, PS_CUSTOMER C, PS_ITEM I, PS_SET_CNTRL_REC S, PS_PAYMENT_ID_ITEM X, PS_PP_PAYMENT_TMP P
where P.PROCESS_INSTANCE = 95298
and S.SETCNTRLVALUE = I.BUSINESS_UNIT
and I.CUST_ID = C.CUST_ID
and I.ITEM_STATUS = 'O'
and (X.REF_VALUE = I.DOCUMENT
or SUBSTR (X.REF_VALUE, 3, 7) = SUBSTR (I.DOCUMENT, 4, 7))
and S.RECNAME = 'CUSTOMER'
and S.SETID = C.SETID
and O.SETID = C.REMIT_FROM_SETID
and O.CUST_ID = C.REMIT_FROM_CUST_ID
and O.EFFDT =
(select MAX (X.EFFDT)
from PS_CUST_OPTION X
where X.SETID = O.SETID
and X.CUST_ID = O.CUST_ID
and X.EFF_STATUS = 'A'
and X.EFFDT <= P.PAYMENT_DT)
and O.PP_METHOD <> ' '
and P.DEPOSIT_BU = X.DEPOSIT_BU
and P.DEPOSIT_ID = X.DEPOSIT_ID
and P.PAYMENT_SEQ_NUM = X.PAYMENT_SEQ_NUM
and X.REF_QUALIFIER_CODE = 'D';
```
Here's the EXPLAIN PLAN after the index was added:
TIP
You may not be able to modify actual code for some third-party products, but you can often add, force, or suppress indexes (using SQL Plan Management) to improve performance.

Tuning Distributed Queries

When improperly written, distributed queries can sometimes be disastrous and lead to poor performance. In particular, a NESTED LOOPS join between two row sources on separate nodes of a distributed database can be very slow because Oracle moves all the data to the local machine (depending on how the query is written). The following listing shows a simple distributed query and its execution plan. This query is slow because, for each row retrieved from the CUSTOMERS table, a separate query is dispatched to the remote node to retrieve records from the BOOKINGS table. This results in many small network packets moving between the two database nodes, and the network latency and overhead degrade performance.

```sql
select customer_id, customer_name, class_code
from customers cust
where exists
  (select 1
   from bookings@book bkg
   where bkg.customer_id = cust.customer_id
   and bkg.status = 'OPEN')
order by customer_name;
```

The following is the TKPROF output (note that TKPROF still works in 11g and is located in $ORACLE_HOME/bin):

```
<table>
<thead>
<tr>
<th>Call</th>
<th>count</th>
<th>cpu</th>
<th>elapsed</th>
<th>disk</th>
<th>query</th>
<th>current</th>
<th>rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paran</td>
<td>1</td>
<td>0.00</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Execute</td>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fetch</td>
<td>156</td>
<td>0.41</td>
<td>11.85</td>
<td>0</td>
<td>476</td>
<td>2</td>
<td>155</td>
</tr>
<tr>
<td>Total</td>
<td>158</td>
<td>0.41</td>
<td>11.86</td>
<td>0</td>
<td>476</td>
<td>2</td>
<td>155</td>
</tr>
</tbody>
</table>
```

Rows Execution Plan
0 SELECT STATEMENT GOAL: CHOOSE
155 SORT (ORDER BY)
467 FILTER
The query in the preceding listing can be rewritten in a form that causes less network traffic. In the next listing, one query is sent to the remote node to determine all customers with open bookings. The output is the same, but performance is greatly improved. Both versions of the query use roughly the same CPU time and logical I/Os on the local node, but the elapsed time is about 97 percent better here. This gain is attributable to reduced network overhead.

```
select customer_id, customer_name, class_code
from customers
where customer_id in
 (select customer_id
  from bookings@book
  where status = 'OPEN' )
order by customer_name;
```

Here is the TKPROF output:

```
Call    count  cpu    elapsed  disk  query  current  rows
Parse   1       0.00  0.01    0.00  0      0        0
Execute 1       0.00  0.02    0.00  0      0        0
Fetch   156     0.07  0.27    0.00  467    0       153
total  158     0.07  0.28    0.00  467    0       153

Rows: Execution Plan
0     SELECT STATEMENT GOAL: CHOOSE
  156   SORT (ORDER BY)
  156   NESTED LOOPS
  156   VIEW
  1003  SORT (UNIQUE)
  1003  REMOTE [BOOK.WORLD]
        SELECT "CUSTOMER_ID","STATUS" FROM "BOOKINGS" BOOKINGS WHERE "STATUS"='open'
  116   TABLE ACCESS GOAL: ANALYZED (FULL) OF 'CUSTOMERS'
  156   INDEX GOAL: ANALYZED (UNIQUE SCAN) OF 'SYS_C002103'

(UNIQUE)
```

When distributed queries cannot be avoided, use IN clauses, set operators such as UNION and MINUS, and use everything else you can to reduce the network traffic between nodes of the database. Views that limit the records in a table can also improve performance by reducing what is sent from the remote client to the local client.
TIP
When distributed queries cannot be avoided, use IN clauses, set operators such as UNION and MINUS, and use everything else you can to reduce the network traffic between database nodes. Queries written in a manner that causes looping between distributed nodes (distributed databases) can be extremely slow.

When You Have Everything Tuned
If you have successfully tuned all of your queries, then you can start working on those that go to the data dictionary views. Is it possible to get tuning tips or techniques from looking at data dictionary queries and how they are structured? The answer is yes! You can see them in the SQL_TRACE output. The next example shows that even Oracle’s own views have some highly complex joining schemes (note that this process has one less step than 10g required, and it still takes a fraction of a second and only 37 memory reads):

```sql
select * 
from  dba_ind_columns 
where  table_name = 'PRODUCT_LINES';
```

The execution plan output is as follows:
The issues covered in this section will help the advanced DBA. I’ll discuss external tables, consider the “Snapshot Too Old” issue along with how to set the event to dump every wait, and explore what’s really going on by performing block dumps.

**External Tables**

External tables allow you to access data that is not inside the database. Relational databases took off in the 1980s because of the ability to access data through relational tables. This was the first move away from mainframes and legacy systems that stored information in flat files or some facsimile of that. Oracle 11g continues the next paradigm in relational database technology. External tables extend the relational model beyond the database. Now you have a means by which to access all of the legacy data. You have a way to access all of that information dumped into flat files (perhaps, via third-party products).

One of the most costly parts of the extract, transform, load (ETL) process used for data warehousing and business intelligence is loading data into temporary tables so it can be used with

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>NESTED LOOPS OUTER</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>TABLE ACCESS BY INDEX ROWID</td>
<td>COL$</td>
</tr>
<tr>
<td>* 3</td>
<td>INDEX UNIQUE SCAN</td>
<td>I_COL3</td>
</tr>
<tr>
<td>* 4</td>
<td>TABLE ACCESS CLUSTER</td>
<td>ATTRCOL$</td>
</tr>
<tr>
<td>5</td>
<td>NESTED LOOPS</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>NESTED LOOPS</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>NESTED LOOPS OUTER</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>NESTED LOOPS</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>NESTED LOOPS</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>NESTED LOOPS</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>NESTED LOOPS</td>
<td></td>
</tr>
<tr>
<td>* 12</td>
<td>INDEX SKIP SCAN</td>
<td>I_OBJ2</td>
</tr>
<tr>
<td>13</td>
<td>TABLE ACCESS CLUSTER</td>
<td>ICOL$</td>
</tr>
<tr>
<td>* 14</td>
<td>INDEX UNIQUE SCAN</td>
<td>I_OBJ#</td>
</tr>
<tr>
<td>15</td>
<td>TABLE ACCESS BY INDEX ROWID</td>
<td>OBJ$</td>
</tr>
<tr>
<td>* 16</td>
<td>INDEX RANGE SCAN</td>
<td>I_OBJ1</td>
</tr>
<tr>
<td>* 17</td>
<td>TABLE ACCESS BY INDEX ROWID</td>
<td>IND$</td>
</tr>
<tr>
<td>* 18</td>
<td>INDEX UNIQUE SCAN</td>
<td>I_IND1</td>
</tr>
<tr>
<td>* 19</td>
<td>TABLE ACCESS CLUSTER</td>
<td>COL$</td>
</tr>
<tr>
<td>* 20</td>
<td>TABLE ACCESS CLUSTER</td>
<td>ATTRCOL$</td>
</tr>
<tr>
<td>21</td>
<td>TABLE ACCESS CLUSTER</td>
<td>USER$</td>
</tr>
<tr>
<td>* 22</td>
<td>INDEX UNIQUE SCAN</td>
<td>I_USER#</td>
</tr>
<tr>
<td>23</td>
<td>TABLE ACCESS CLUSTER</td>
<td>USER$</td>
</tr>
<tr>
<td>* 24</td>
<td>INDEX UNIQUE SCAN</td>
<td>I_USER#</td>
</tr>
</tbody>
</table>
other tables already in the database. Although external tables were introduced primarily to assist in the ETL process, Pandora’s box cannot be closed. I have seen a plethora of uses for external tables, and I believe it’s just the beginning. If Java and XML were minor aspects integrated into the relational model, the use of external tables brings the entire machine into the database and forever changes the rules of engagement.

This simple example shows you exactly how to use external tables. First, you need a flat file of data to access for the examples. You do this by simply spooling some data from our familiar friend, the EMP table:

```sql
set head off
set verify off
set feedback off
set pages 0
spool emp4.dat

select empno||','||ename ||','|| job||','||deptno||','
from scott.emp;

spool off
set head on
set verify on
set feedback on
set pages 26
```

The following is partial output of the `emp4.dat` file:

```
7369,SMITH,CLERK,20,
7499,ALLEN,SALESMAN,30,
7521,WARD,SALESMAN,30,
7566,JONES,MANAGER,20,
7654,MARTIN,SALESMAN,30,
```

Then you need to create a directory from within SQL*Plus so Oracle knows where to find your external tables:

```
SQL> create directory rich_new as '/u01/home/oracle/rich';
Directory created.
```

You then create the actual table definition that will reference the flat file that resides externally. Note that even if you successfully create the table, access to the external table may not necessarily result in a successful query. If the data is not stored in a way that matches the column definition of
your table, you will get an error when you select the actual data. An example of the CREATE TABLE command is shown here:

```
create table emp_external4
  (empno char(4), ename char(10), job char(9), deptno char(2))
organization external
  (type oracle_loader
    default directory rich_new
    access parameters
    (records delimited by newline
     fields terminated by ','
     (empno, ename, job, deptno))
  location ('emp4.dat'))
reject limit unlimited;
```

SQL> desc emp_external4
Name                                      Null? Type
----------------------------------------------------
EMPNO                                    CHAR(4)
ENAME                                    CHAR(10)
JOB                                      CHAR(9)
DEPTNO                                    CHAR(2)

```
select *
from emp_external4;
```

<table>
<thead>
<tr>
<th>EMPNO</th>
<th>ENAME</th>
<th>JOB</th>
<th>DEPTNO</th>
</tr>
</thead>
<tbody>
<tr>
<td>7369</td>
<td>SMITH</td>
<td>CLERK</td>
<td>20</td>
</tr>
<tr>
<td>7499</td>
<td>ALLEN</td>
<td>SALESMAN</td>
<td>30</td>
</tr>
<tr>
<td>7521</td>
<td>WARD</td>
<td>SALESMAN</td>
<td>30</td>
</tr>
</tbody>
</table>
...  

There is currently no support for DML (INSERT, UPDATE, DELETE) commands, but you can always do this outside the database because the data is in a flat file. By using shell scripting, as shown next, you can certainly replicate those commands. Although you can’t create an index currently, external tables are pleasantly and surprisingly fast.
To count records, you can either use the Unix command or do it within the database. Either way, you have a means to work with data in flat files that are not within the database. This next listing is the `wc` (word count) command with the `-1` option, which indicates to count the lines. This is a simple Unix command for counting records in a flat file. I created a file with 200,020 rows for the next more intensive test.

```bash
$ wc -l cmp4.dat
 200020  200020  4400400  cmp4.dat
$ ls -l cmp4.dat
-rwxr-xr-x 1 oracle oinstall 4400400 Aug 9 06:31 cmp4.dat
```

You can also count the records in the flat file using SQL, since you’ve now built an external table. The command shown next takes less than one second to return its result:

```sql
select count(*)
from emp_external4;
```

```
COUNT(*)
---------
  200020
```

Elapsed: 00:00:00.63

Once you know you can count records in less than one second, you press on to look for specific information. Can you count selective pieces of data that fast? Yes. The code in the next listing looks for specific employee numbers (EMPNO) from the flat file, which is now referenced via an external table. The result is returned once again in less than one second.

```sql
select count(*), EMPNO
from emp_external4
where EMPNO = 12345;
```

```
COUNT(*)   EMPNO
---------   ------
  200020  12345
```

Elapsed: 00:00:00.63
Once you know you can scan through 200,000 records in less than one second (on a single-processor machine in my case), you want to see how fast you can scan through millions of records. The example shown next builds a second table and joins it with the first so you can test scanning through 4 million rows. The result is less than 3 seconds to scan through this massive amount of data using only modest hardware.

```
create table emp_external5
(empno char(4), ename char(10), job char(9), deptno char(2))
organization external

location ('emp5.dat');
```

Now you join the two 200,000-row tables to create a join that merges the 20 rows in the first result set with the 20 rows of the second table, as shown next. This results in a join accessing 4 million rows with a result set of 400 rows. The result is an answer in less than 3 seconds.

```
select a.empno, b.job, a.job
from emp_external4 a, emp_external5 b
where a.empno = b.empno
and a.empno = 7900
and b.empno = 7900;
```

400 rows selected.
Elapsed: 00:00:02.46

Here is the execution plan for the previous join:

```
Execution Plan

0  SELECT STATEMENT
1 0  SORT AGGREGATE
2 1  HASH JOIN
3 2  EXTERNAL TABLE ACCESS (FULL) OF 'EMP_EXTERNALS5'
4 3  EXTERNAL TABLE ACCESS (FULL) OF 'EMP_EXTERNAL4'
```
You can also use hints with external tables, and you can join external tables with regular tables. You can parallelize the operation, and you can even insert the data from the external table directly into the database at any time. The possibilities are endless. External tables are not simply a serious advantage of using Oracle; they are one of the greatest benefits to relational technology in the past decade. They give you the window into the data that is not in your database. They allow you to access those legacy systems that have data stored in a multitude of flat files. They provide you the path to consolidate those legacy systems by moving step-by-step into the future.

Consider the quick use for an external table to read the alert file shown in the following listing. The original script for this was written by Dave Moore and passed to me by Howard Horowitz. The following is an alteration of those scripts:

```
SQL> Create directory alert1 as 'c:\app\user\diag\rdbms\orcl\orcl\trace';
Directory created.
SQL> Create table alert_log (text varchar2(200))
Organization EXTERNAL
(Type oracle_loader
Default directory alert1
Access parameters
(Records delimited by newline
Badfile 'rich1.bad'
Logfile 'rich1.log'
)location ('alert ora.log'))
Reject limit unlimited;
Table created.

select *
from alert_log
where rownum < 25;
```

Sun Mar 06 16:45:43 2011
Starting ORACLE instance (normal)

Oracle Database 11g Enterprise Edition Release 11.2.0.1.0 - 64bit Production
With the Partitioning, OLAP, Data Mining and Real Application Testing options.
Using parameter settings in client-side pfile
C:\APP\USER\CPS10COLLOGS\DBCA\ORCL\INITORCLTEMP.ORA on machine USER-PC
System parameters with non-default values:
  processes            = 150
  memory_target        = 6560M
{partial listing only of selected data}
External tables are one of the best Oracle inventions in many versions. Your innovative mind will drive you to new heights using external tables. But be careful: data residing outside the database is not subject to the same Oracle backups and security as data inside the database.

Snapshot Too Old: Developer Coding Issue

Oracle holds undo information in case you need to roll back a transaction and also to keep a read-consistent version of data. Long-running queries may need the read-consistent versions of the data in UNDO segments because they may not be at the same System Change Number (SCN) as the ones currently in memory. (They may have been changed since the start of the query.) If the UNDO segment holding the original data is overwritten, the user receives the dreaded Snapshot Too Old error. With advances in Oracle 11g, this error is, indeed, not rare (using automatic undo management), but there is another, more frequent occurrence of the error in the later versions of Oracle.

In their infinite wisdom, developers find wonderful ways to update information that they are querying within the same piece of code causing this problem. They are the ones both querying and updating and causing the Snapshot Too Old error to occur. One flawed developer method is known as the Fetch Across Commit. In this method, the developer first selects a large number of rows from a table into a cursor and then fetches the rows to use for an update to the table, committing after a select number (say, every 1000 records) based on a counter. What happens is that the cursor needs a read-consistent image of the table, yet the developer is committing 1000 records within the same code to the table. The result is a Snapshot Too Old error.

TIP

In addition to the more typical reasons, when developers modify the data as it is being selected, fetching across commits, the Snapshot Too Old error can occur. To fix this problem, close and reopen the cursor causing the issue.

Set Event to Dump Every Wait

In Chapter 14, you will learn about two excellent tuning tools that Oracle offers: Statspack and AWR. These are great tools for showing everything in a single report for you to analyze. But what if you have a burning issue and you directly need to dump exactly what the system is doing so you can see every wait on the system? If the compilation of all waits in the V$ views is not enough to solve problems and you need to see the waits in real time, the answer is the very dangerous “Set Event 10046 at the system level.” You can also do this at the session level (see Chapter 13 for additional settings beyond this section).

This event dumps every single wait that occurs so you can search through and see exactly what’s causing the problem. You should use this strategy only as a last resort, and you should rarely use it.
You need a lot of disk space to use it when you have a lot of waits.

When you’re ready to dump the problem, here’s how to turn it on:

```
Alter system set events '10046 trace name context forever, level 12';
System altered.
```

**NOTE**

You are also often required to increase the max size of dump files to get all the info you need within the single trace file.

The following listing shows what you’ll get (in your DIAGNOSTIC_DEST):

```
Trace file c:\app\user\diag\dbms\ora1\ora1\trace\ora1 ora 11.2.0.1.0 - 64bit. Production
With the Partitioning, GIAP, Data Mining and Real Application
--------------
PARSING BY CURSOR #1 len=61 dep=0 aid=84 sid=3 lid=84 dbr=95022705835 br=2699451087
ud='211b1a2d' sqlid='8y7yruilyk656g'
select count(*)
from small1 a, small b
where a.empno=b.empno
END OF STMT
PARS #9:c=0,e=1414,p=0,cx=0,cpu=0,ms=1,ex=0,dep=0,og=1,plh=1041396182,tim=95022706834
EXEC #9:c=0,e=23,p=0,cx=0,cpu=0,ms=0,ex=0,dep=0,og=1,plh=1041396182,tim=95022706929
WAIT #9: nam='SQL*Net message to client' ela- 3 driver id-1111630976 #bytes-1 p3=0
... [PARTIAL LISTING - SELECTED LINKS ONLY]
```

Although this output shows some irrelevant waits that come up when you quickly turn this on and off, when you have a real problem, the waits will be clear. You are looking for a section with something like the following, which shows a latch free issue. (See Chapter 14 for steps on how to resolve this issue.) When you don’t know what you’re waiting for, this gives you a slightly more “at the street” level understanding of exactly what’s going on than the V$ views do:
When you have a nice dump of the problem, here’s how you turn it off:

```
ALTER system set events '10046 trace name context off';
```

System altered.

**CAUTION**

*Using the event 10046 at the system level can give a real-time dump of waits. Be careful because you can use a lot of space very quickly on a very busy system. Only an expert who has the help of Oracle Support should use this method.*

### 14 Hours to 30 Seconds with the EXISTS Operator

Although the Oracle optimizer is very good at ensuring a query is efficient, you can change a multitable join into a query with a subquery using the EXISTS operator. You can only do this if the table to put into the subquery doesn’t have anything being selected from it in the SELECT statement. In this example, the goal is to pull one row back to use for test data in a test system:
--query with table join
explain plan for
SELECT MEMBER_NO
, CONTRACT
, DEP
, SBSB_CK
, SBSB_ID
, GRGR_ID
, MBME_BIRTH_DT
, x.MEME_CK
, MEME_REL
, MEME_SFX
, MEME_LAST_NAME
, MBME_FIRST_NAME
, to_timestamp('06/01/2006','mm/dd/yyyy')
, 'PHASE 3'
, CREATE_WHO
, CREATE_DT
, UPDATE_WHO
, UPDATE_DT FROM PROD_PH.XREF_MEME x

, PROD.CMC_MEPE_PRCS_ELIG
WHERE x.meme_ck = e.meme_ck
and rownum = 1;

--Star query plan with B-TREE indexes!
You can see from this example that using EXISTS instead of joining the tables can be very beneficial. Thanks to Mark Riedel of TUSC for sending, as he puts it, “the TUSC patented EXISTS statement.” We first discovered this around 1990.
Tuning at the Block Level (Advanced)

Although block tuning is covered briefly in Chapter 14, here I cover it in a bit more depth. An internal table called the buffer hash table (X$BH) holds block headers. There is a hash chain to which blocks are linked that are protected by a CBC latch (cache buffers chains latch). This hash chain links to the actual address located in memory (the memory set up with DB_CACHE_SIZE, which is the cache used for data). For a given block in Oracle, only one version of a block is CURRENT, and no more than six other CR versions of the block (as of 11g) exist. Thus, only seven versions of a given block (maximum) are in memory at a time (forming a hash chain of six), although different blocks can be hashed to the same chain (depending on the hashing algorithm). When you perform a DML transaction—INSERT, UPDATE, or DELETE—you always need the CURRENT version of a block. In some versions of Oracle 8, you had to set _DB_BLOCK_HASH_BUCKETS to a prime number to keep the dba blocks evenly balanced in the hash buckets (more information on this in Chapter 14) and to avoid a long hash chain arising from the way the hash was calculated. If you didn’t set this to a prime number, you could get a very long hash chain (as many blocks were hashed to the same chain), and then get major CBC latch waits (CBC latches are used in 10g, 11g and 12c, although not under all conditions). The hashing algorithm changed and will not need to be prime in 12c (so don’t change it).

Also note that Oracle has something called in-memory undo (IMU), which can give you some hard-to-understand results when you are viewing information at the block level. If you are familiar with IMU, which was new as of 10g, you will find that blocks don’t show up as dirty when you query X$BH and they have been dirtied. This is because updates are made inside the actual block, as opposed to in the UNDO block, before images are taken. I discovered that this happens only for certain retention settings, though. There is a parameter, _IN_MEMORY_UNDO=TRUE, in the initialization file that is set to FALSE for some TPC benchmarks. Other parameters include _IMU_POOLS and _DB_WRITER_FLUSH_IMU. If you access the block trying to update a different row in the block, the IMU is flushed to the UNDO block, and the block shows as dirty (in my tests anyway, although I was told this depends on what the UNDO retention is set to). IMU writes the UNDO and REDO to memory instead of to disk (which is what the _IMU_POOLS parameter is for). IMU transactions always have room reserved in the current log file for writing out their REDO. They also acquire an interested transaction list (ITL) in the block header (discussed in the next section) and reserve space in the UNDO segment. Several sections of IMU statistics are displayed in the AWR Report or the Statspack Report.

When you are querying a block for the first time, you always use the CURRENT version. If the block is being used, you will build a clone of the block called a CONSISTENT READ (CR) version by applying any UNDO needed to the CURRENT version of the block to get it to a point in time that makes it useful to you (perhaps you need a version of the block before the DML was performed and not committed by another user). This complex and Oracle-patented process may include reading the ITL (which is populated when someone does a DML [Data Manipulation Language] on a block), mapping the record to the UNDO HEADER, or directly to the UNDO BLOCK, and then applying the UNDO to get the correct CR version that you need. So let’s take a look at how this happens:

- User 1 updates a record in block 777 (User 1 has not committed).
- User 2 queries the same block and sees that the lock byte is set for a row being queried.
- User 2 goes to the ITL portion of the block and gets the transaction ID (XID).
The XID maps to the UNDO block, which holds the information before the update was performed.

A clone of the block is made (call it block 778).

The UNDO information is applied to the block, rolling it back to where it used to be.

Block 777 is a CURRENT block.

Block 778 is a CONSISTENT READ block before the User 1 update occurred.

If another user wants to do a query before the commit, that user can also read the CR version.

Also note that REDO goes forward; UNDO goes back. Yes, the UNDO (ROLLBACK) information is applied to the block, but this has the effect of undoing the most recent changes to the block, including setting the SCN for the block to a past time, not a future time. This is why they are called ROLLBACK segments.

Note especially the fact that the block is not rolled back to what it was, but it is rolled forward to what it used to be. While the result is the same, how Oracle performs this operation is critical to understanding how Oracle works. Oracle blocks are always moving forward in time (this is why the REDO works—it’s always applying things forward sequentially). There are also links to all blocks for the least recently used (LRU) and least recently used-write (LRU-W) to help make buffer replacement and writing much faster. This information is also maintained in the buffer headers.

If nothing has been advanced enough for you so far, this section is worth the price of the book and should keep you busy for the next decade tuning your system to perfection (if you’d like). Oracle often has perplexing new features: either I can’t seem to get them working or there’s simply a bug in the program that I am unaware of. How do you find out if a problem is yours or Oracle’s? Dump the blocks one at a time.

Consider the intense example in the listing that follows. Find the table/index block information that you want to dump, as shown here:

```sql
SELECT FILE_ID, BLOCK_ID, BLOCKS FROM DBA_EXTENTS
WHERE SEGMENT_NAME = 'EMP'
AND OWNER = 'SCOTT';
```

<table>
<thead>
<tr>
<th>FILE_ID</th>
<th>BLOCK_ID</th>
<th>BLOCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50465</td>
<td>3</td>
</tr>
</tbody>
</table>

Dump the table/index block information, as demonstrated here:
The ALTER SYSTEM command selects and then dumps the data blocks for the EMP table owned by SCOTT to a trace file for the current user session in the DIAGNOSTIC_DEST directory, much like TKPROF. The information that is dumped is very cryptic, but it can be helpful for tuning purposes.

The information in the listing that follows compares portions of the block dumps of two different bitmap join indexes. One is on the DEPTNO column, where the tables are also being joined by DEPTNO. The other is on the LOCATION column, where the table is being joined by DEPTNO. By comparing index information, you can see that the LOCATION column was included in the stored part of the index, even though the query was going back to the table to retrieve the LOCATION column in the query. The problem was an Oracle bug that you would discover only by performing this dump (partially shown in this next listing; only the first record is displayed for each).

The best use for dumping blocks is to see how Oracle really works (unless data encryption is enabled, making it unhelpful). Get ready for a long night if you plan to use this tip; I spent a weekend playing with this the first time I used it.

**TIP**

_Dumping data blocks can be a valuable tool to understand how Oracle works and to investigate_
problem-tuning areas. Only a tuning expert should use block dumps, and even an expert should use the help of Oracle Support. Oracle does not publish the structure of block dumps, so they can change at any time.

Now let’s look at an example to show you how to interpret some of the output that you get from a block dump as well as some other helpful queries that you can do when you do the deep dive into block dumps.

This query will give you the block number for every record of a table:

```sql
select rowid, empno,
    dbms_rowid.rowid_relative into rowno,
    dbms_rowid.rowid_block_number(rowid) into blockno,
    dbms_rowid.rowid_row_number(rowid) into rowno, rownum table_rownum,
    rpad(to_char(dbms_rowid.rowid_row_number(rowid), '000000000') || ':', 30, '.') || '
    to_char(dbms_rowid.rowid_row_number(rowid), '0000') || '
    to_char(dbms_rowid.rowid_relative into rowid, '0000') }, 18) myrowid
from emp;
```

<table>
<thead>
<tr>
<th>ROWID</th>
<th>EMPNO</th>
<th>ETHNO</th>
<th>BLOCKNO</th>
<th>ROWNO</th>
<th>TABLE ROWNUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MYROWID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAAAAAAAAAAAAAAABBBBBBBBBBBBBBB</td>
<td>7369</td>
<td>5</td>
<td>56586</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>AAAAAAAAAAAAAAAABBBBBBBBBBBBBBB</td>
<td>7499</td>
<td>5</td>
<td>56586</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>AAAAAAAAAAAAAAAABBBBBBBBBBBBBBB</td>
<td>7528</td>
<td>5</td>
<td>56586</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>partial listing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Most of the information found in block dumps can be found in the data dictionary or can be accessed using a built-in package such as DBMS_SPACE. In certain scenarios, however, knowing how to read a block dump might benefit you; for instance, it may help you determine exactly why a transaction is blocked. You will probably use other tools prior to dumping a block, utllockt.sql, for instance, or Enterprise Manager, but if you want to see exactly what is holding a lock on a row in a block, and how many rows are blocked, the block dump output can be quite useful. You may also want to look at row chaining, look at the space utilization in the block for each row, or simply look at the block because a block is corrupted and you want to take a closer look at it. Sometimes, looking at what is stored in a corrupted block can help you figure out where the corruption originated—for example, text that comes from a third-party tool or a block for which large chunks were changed to all zeros (disk repair utilities).

Key Sections of a Block Dump

Sections to note within the block dump include the block ITL, the flag section, and the block data
The Block ITL Section in a Block Dump

One of the key sections of a block dump is the interested transaction list (ITL). The ITL section shown next appears in the early part of the dump. This one shows two ITL slots (two is the minimum number of ITL slots for both tables and indexes—if you don’t believe what you read, you can dump it yourself to make sure). The XID is the transaction ID. The UBA is the Undo Block Address. I’ll discuss the Flag in a moment. The Lock shows the number of records locked (four records are locked in the first ITL slot because I deleted four rows for this example), and the SCN/FSC is either the SCN for committed information (Flag is a C) or FSC (Free Space Credit), which is the amount of bytes that will be recovered within the block if the transaction is committed. This number is a hexadecimal number. For this example, it is 9d, which is 157 bytes recovered if the transaction to delete four records is committed; the transaction could also be rolled back.

Here is another block dump example of an ITL section where three updates were being done on the EMP1 table, DEPTNO column: one user updating all records with DEPTNO=10 (6 records), one user updating all records with DEPTNO=20 (4 records), and a third user updating all records with DEPTNO=30 (5 records).

The Flag Section

The flag section is a bit complex. It tells you what state the transaction is in (CBUT):
The Block Dump Data Section

The next block dump shows the data section. This is the first part (the header section) of the block dump data section.

```
---    The transaction is active, or it is committed pending block cleanout.
C---   The transaction has been committed and the row locks have been cleaned out.
-B--   The Undo Block Address contains undo for this block.
--U--  The transaction is committed (the SCN is the upper bound), but block cleanout has not occurred (a fast commit).
---T   This transaction was still active when the SCN for block cleanout was recorded.
C-U-   The block was cleaned by delayed block cleanout, and the undo segment information has been overwritten. The SCN will show the lowest SCN that could be re-created by the undo segment.
```

Following is the description of this header information:

```
tab 0, row 13, @0x1b0b
tl: 39 fb: --H-FL-- lb: 0x0  cc: 8
```

The data part of the block dump data section starts with the line col0, as is shown in the block dump that follows:

```
col 0: [ 3 ]  c2 50 23
col 1: [ 6 ]  4d 49 4c 4c 45 52
col 2: [ 5 ]  43 4c 45 52 4b
col 3: [ 3 ]  c2 4e 53
col 4: [ 7 ]  77 b6 01 17 01 01 01
```
The following example shows how to interpret the output from the block dump data section for the first column (col0), which is the EMPNO column:

```
col 0: [ 3] c2 50 23
```

Hex to Decimal: Col0 = EMPNO = 7934
50 (Hex) = 80 (Decimal) - 1 = 79
23 (Hex) = 35 (Decimal) - 1 = 34
c2: Number in the thousands (c2 is exponent)

The following example shows how to interpret the dump output from the block dump data section for the second column (col1), which is ENAME:

```
col 1: [ 6] 4d 49 4c 4c 45 52
```

Hex to Character: Col1 = ENAME = MILLER
4d (Hex) = M [Character] [= 77 (decimal)]
49 (Hex) = I [Character]
4c (Hex) = L [Character]
4c (Hex) = L [Character]
45 (Hex) = E [Character]
52 (Hex) = R [Character]

Also note that the hex values correspond to the character mapping tables (which depend on the National Language Support [NLS] settings for your database). For example, if you search “ASCII code character” on Google, you can view a table of hex/decimal ASCII codes, in which 4d/77 corresponds to M.

This example from the dump output from the block dump data shows the HIREDATE column, which is a DATE field:

```
col 4: [ 7] 77 b6 01 17 01 01 01
```

Hex to Decimal: Col4 = HIREDATE = 23-Jan-82
77 (Hex) = 119 (Decimal) - 100 - 19 <century>
b6 (Hex) = 182 (Decimal) - 100 = 82 <year>
01 (Hex) = 1 (Decimal) <month>
17 (Hex) = 23 (Decimal) <day>
01 01 01 (Hex) = This is the Hour, Minute, Second
(The Default time is 00:00:00)
You may want to select the hex data from the table. The following example uses `SELECT dump()` and gets the `ENAME` from the hex:

```sql
select dump(ename,16), ename
from emp1
where dump(ename,16) like '34d,49,4c,4c,45,52';
```

<table>
<thead>
<tr>
<th>Typ-1 len-6: 4d,49,4c,4c,45,52</th>
<th>ENAME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MLI.RE</td>
</tr>
</tbody>
</table>

Let’s query a new block (56650) from EMP1 and watch the EMP1 buffer header change (so far it’s clean—the dirty bit is N—and consists of only one copy [or record], and it’s the current version, with state=1):

```sql
select lrba_seq, state, dbafile, dblaclk, tch, flag, hscn_bas, cr_scn_bas,
decode(bitand(flag,1), 0, 'N', 'Y') dirty, /* dirty bit */
decode(bitand(flag,16), 0, 'N', 'Y') temp, /* temporary bit */
decode(bitand(flag,1516), 0, 'N', 'Y') ping, /* ping (to shared or null) bit */
dedecode(bitand(flag,16384), 0, 'N', 'Y') stale, /* stale bit */
dedecode(bitand(flag,65536), 0, 'N', 'Y') direct, /* direct access bit */
deencode(bitand(flag,1048576), 0, 'N', 'Y') new /* new bit */
from x$dbh
where dblaclk = 56650
order by dblaclk;
```

<table>
<thead>
<tr>
<th>LRBA_SEQ</th>
<th>STATZ</th>
<th>DGRAFT</th>
<th>DABFIL</th>
<th>DBLAFLK</th>
<th>TCH</th>
<th>FLAG</th>
<th>HSCN BAS</th>
<th>CR_SCN BAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>56650</td>
<td>0</td>
<td>35659776</td>
<td>4291957295</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Watch the EMP1 buffer header when you delete a row:

```sql
delete from emp1
where comm = 0;
```

1 row deleted.

Let’s query the block (56650) and watch the EMP1 buffer header. There are now two copies (or records): one copy is the current version (state=1), and one is a clone (CR, state=3).
Note that V$TRANSACTION now has the record (created when transactions have UNDO):

The column names in the output have these meanings:

- **USN** is the Undo Segment Number (ROLLBACK segment ID).
- **SLOT** is the slot number in the ROLLBACK segment’s transaction table.
- **SQN** is the sequence number for the transaction.
- **USN+SLOT+SQN** are the three values that uniquely identify a transaction XID.
- **UBLK** is the block for the last UNDO entry (it tells you how many UNDO blocks there are).
- **UREC** is the record number of the block (it shows how many table and index entries the transaction has inserted, updated, or deleted).

If you are doing an INSERT or DELETE, then you will see that UREC is set to (number of indexes...
for this table) + (how many rows you insert/delete). If you UPDATE a column, then UREC will be set to (number of indexes that his column belongs to) * 2 + (number of updated rows). If the column belongs to no index, then the UREC is set to the number of rows that were updated. If UBLK and UREC decrease each time you query, then the transaction is rolling back. When UREC reaches zero, the rollback is finished.

If you dump the block at this time, you see the locked record in the first row of the ITL section:

Now let’s do an INSERT in four other sessions to get XSBH up to six versions of the block. There are now six copies: one copy is the current version (state-1) and five are clones (CR, state-3).

Can you get more than six versions of a block? Probably, but this is unsupported. In the following listing, I’ve selected the maximum-allowed CR buffers per data block address (dba):
Now consider an example in 11g where I am updating/selecting multiple times in a block to get the maximum number of CR versions of a block:

```
select a.kspinnm, b.kspstvl, b.kspstdf, a.kspddeac
from xskappi a, xskappcov b
where a.indx = b.indx
and subst((keppinnm,1,1) = ')
and keppinnm llike 'select'
order by keppinn;
```

```
db block max cr dbu 6 TRUE Maximum Allowed Number of CR buffers per dbu
```

Now I am going to run the 11g command to flush the buffer cache:

```
select lrba_seq, state, dbarfil, dbablk, tch, flag, hscn_bas,cr_scn_bas,
       decode(bitand(flag,1), 0, 'N', 'Y') dirty, /* Dirty bit */
       decode(bitand(flag,16), 0, 'N', 'Y') temp, /* temporary bit */
       decode(bitand(flag,1536),0,'N','Y') ping, /* ping (to shared or null) bit */
       decode(bitand(flag,65536),0,'N','Y') stale, /* stale bit */
       decode(bitand(flag,1048576),0,'N','Y') direct, /* direct access bit */
       decode(bitand(flag,1048576),0,'N','Y') new /* new bit */
from x3hh
where dbablk = 56650
order by dbablk;
```

```
LRBA_SEQ STATE DBARFIL DBABLK TCH FLAG HSCN_BAS
-------- ------ ------- ------ ------ -------- 
        5 1410707  1      524288   0
  23105852 N N N N N N
        5 1410707  1      524288   0
  23105815 N N N N N N
        5 1410707  1      524288   0
  23105727 N N N N N N
        5 1410707  1      524288   0
  23105710 N N N N N N
        5 1410707  1      524288   0
  23105677 N N N N N N
        5 1410707  1      524288   0
  23105674 N N N N N N
        5 1410707  4 35651593 23105710
  4051 Y N N N N
```

7 rows selected.

Now I am going to run the 11g command to flush the buffer cache:
Now I'll rerun all of my SELECTs/UPDATEs to refill the cache to see the result. The result is that I get five CR versions and one CURRENT version of the block, but the original seven buffered blocks that I had are now reset to mostly zeros. Oracle has populated all new records in X$BH and zeroed out the original ones after the buffer cache flush (5 CR and 1 CURRENT + 7 other zeroed out).

<table>
<thead>
<tr>
<th>LRBA_SEQ</th>
<th>STATE</th>
<th>DBARFIL</th>
<th>DBABLK</th>
<th>TCH</th>
<th>FLAG</th>
<th>HSCN_BAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR SCN BAS</td>
<td>D T P S D N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>---------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23106121 N N N N N N N</td>
<td>3</td>
<td>10</td>
<td>1410707</td>
<td>1</td>
<td>524288</td>
<td>0</td>
</tr>
<tr>
<td>23106120 N N N N N N N</td>
<td>3</td>
<td>10</td>
<td>1410707</td>
<td>1</td>
<td>524288</td>
<td>0</td>
</tr>
<tr>
<td>23106119 N N N N N N N</td>
<td>3</td>
<td>10</td>
<td>1410707</td>
<td>1</td>
<td>524288</td>
<td>0</td>
</tr>
<tr>
<td>23106118 N N N N N N N</td>
<td>3</td>
<td>10</td>
<td>1410707</td>
<td>1</td>
<td>524288</td>
<td>0</td>
</tr>
<tr>
<td>23106116 N N N N N N N</td>
<td>3</td>
<td>10</td>
<td>1410707</td>
<td>1</td>
<td>524288</td>
<td>0</td>
</tr>
<tr>
<td>23106115 N N N N N N N</td>
<td>3</td>
<td>10</td>
<td>1410707</td>
<td>1</td>
<td>524288</td>
<td>0</td>
</tr>
<tr>
<td>4051 N Y N N N N N</td>
<td>1</td>
<td>10</td>
<td>1410707</td>
<td>2</td>
<td>33554433</td>
<td>23106121</td>
</tr>
<tr>
<td>0 N N N N N N N</td>
<td></td>
<td>10</td>
<td>1410707</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 N N N N N N N</td>
<td></td>
<td>10</td>
<td>1410707</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 N N N N N N N</td>
<td></td>
<td>10</td>
<td>1410707</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 N N N N N N N</td>
<td></td>
<td>10</td>
<td>1410707</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 N N N N N N N</td>
<td></td>
<td>10</td>
<td>1410707</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 N N N N N N N</td>
<td></td>
<td>10</td>
<td>1410707</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

13 rows selected.

This listing still has room for one more active CR block. The listing gives a good feeling for how Oracle handles the buffer cache flush. Testing things at the block level can help you to understand new functionality but shouldn’t be used every day. Block tuning should be primarily used in a test system for often-run code that needs detailed attention.

A deeper dive into block tuning is beyond the scope of this book. However, some of the queries
I've presented in this section will allow you to investigate what is going on at the block level in the very rare case that you need to see it. The best reason to perform block dumps is to see what’s going on inside of Oracle. In the next section, you get a brief look at the block level of bitmap indexes and a few other types.

# A Brief Look at an Index Block Dump

Now let’s take a quick look at some index block dumps. First let’s look at a bitmap index. Each of the indexed rows consists of five lines:

<table>
<thead>
<tr>
<th>col</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Indexed value (length in hex).</td>
</tr>
<tr>
<td>1</td>
<td>ROWID for the first occurrence of the indexed value.</td>
</tr>
<tr>
<td>2</td>
<td>ROWID for the last occurrence of the indexed value.</td>
</tr>
<tr>
<td>3</td>
<td>Actual bitmap which will have 1 where value occurred in range between first and last rowid, otherwise 0 in swap byte notification, first byte usually cx where x in (8, ..., f). When all slots for cf filled, new segment starts.</td>
</tr>
</tbody>
</table>

Consider the following bitmap index block dump:

```plaintext
row#0[8010] flag: ---D-, lock: 2
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 07
col 3; len 1; (1):  00

row#1[7989] flag: ---D-, lock: 2
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 07
col 3; len 2; (2):  c8 03

row#2[7968] flag: ------, lock: 2
col 0; len 1; (1):  31
col 1; len 6; (6):  02 40 2d 60 00 00
col 2; len 6; (6):  02 40 2d 60 00 07
col 3; len 2; (2):  c8 07
```

If you insert 64 rows (0–63) and then take a block dump (note the 3f in col 2),
then you insert one more row (0–64), you get the following (note the 40 in col 2):

row#0[8007] flag: -----, lock: 0
col 0; len 1; (1): 31
col 1; len 6; (6): 02 40 2d 60 00 00
col 2; len 6; (6): 02 40 2d 60 00 40
col 3; len 9; (9): cf ff ff ff ff ff ff ff

An index value exists in a block with ROWID=02 40 2d 60 00 40 (40(hex) => 64(decimal)). The previous end ROWID was 3f (3*16+15 = 63). When the index is updated, you must have enough space to accommodate growth; if you don’t, a split occurs. Not just that, a lock is placed on the entry in the leaf index—but this entry can span over multiple blocks. As a side effect, for the duration of a lock, no other transaction can update the blocks in the affected block range. Bitmap indexes are used for a column with just a few different values, so on bigger tables each bitmap likely covers quite a few blocks. A lock placed on those blocks can have disastrous effects on other transactions, which is why bitmap indexes are almost always used for query-only data or mostly static data.

Now let’s see how the block dump of a reverse key index looks. Note that a reverse key index will be marked with the value NORMAL/REV in dba_indexes (index_type). You can see in the following example that the hex values in col 1 are reversed.

Regular index entry:

Row 0:[8008] flag: -----, lock: 0
col 0; len 2; (2): c1 02
col 1; len 7; (7): 78 69 0c 19 03 27 10
col 2; len 6; (6): 02 40 2e 70 00 00

Reverse key:

Row 0:[8007] flag: -----, lock: 0
col 0; len 2; (2): 02 c1
col 1; len 7; (7): 10 27 03 19 0c 69 78
col 2; len 6; (6): 02 40 2e 70 00 00

Finally, let’s take a quick look at how a regular index (ascending) differs from a descending index when you do an index block dump.

A regular index:
A descending index:

You can see from all of these examples that the block dump can give you insight into new features as well as details about internal data structures and indexes in Oracle. Use the block dump sparingly and generally on a test system, however.

Tuning Using Simple Mathematical Techniques

This section discusses some simple but effective mathematical techniques you can use to significantly improve the performance of some Oracle SQL–based systems. These techniques can leverage the effectiveness of Oracle performance diagnostic tools and uncover hidden performance problems that can be overlooked by other methods. Using these techniques also helps you make performance predictions at higher loads.

NOTE

Joe A. Holmes provided the material for this section. I am extremely grateful for his contribution because I believe it ties all the chapters of this book together.

The methodology called Simple Mathematical Techniques involves isolating and testing the SQL
process in question under ideal conditions, graphing the results of rows processed versus time, deriving equations using simple methods (without regression), predicting performance, and interpreting and applying performance patterns directly to tuning SQL code.

Traditional Mathematical Analysis

First of all, do not be intimidated by this section. You will be able to understand this, and the information provided will help you predict response times for your queries as the tables grow.

Traditional mathematical methods are very useful for analyzing performance. These may include graphing performance metrics on an x-y coordinate axis to obtain a picture of what a process is really doing and applying Least Squares Regression or Polynomial Interpolation to derive equations for predicting performance at higher loads. Computer science academics and specialists use these techniques extensively for performance analysis, which is laden with problems. First, textbook notation and explanations are often very complex and difficult to understand. Most math textbooks I have encountered that treat approximation and interpolation, for example, are steeped in theory rather than providing clear and practical examples.

Second, little or no information is available on how to apply this kind of analysis directly to tuning SQL code. This is probably because SQL analysis requires more specific interpretations to be useful rather than something broader or more general.

Seven-Step Methodology

The following are seven steps in the methodology. Note that deriving performance equations and interpreting patterns are discussed in more detail in the sections that follow.

1. Isolate the SQL code in question.
   The SQL code in question is isolated from surrounding system code and placed in a SQL*Plus or PL/SQL script that can be run independently to duplicate the production process.

2. Run tests under ideal conditions.
   In this context, “ideal” is defined as one SQL process running on a dedicated machine with hardware-processing power fixed and executed under high-volume data.

3. Graph performance observations on an x-y coordinate axis.
   From tests, the number of rows processed (x) versus time (y) for each SQL statement within a process is graphed on an x-y coordinate axis. This is referred to as a row-time metric. Ideally, the optimizer is, for the most part, more mechanical and less random, creating a more clearly defined and predictable trendline. The basic line shape can provide clues to the cause of underlying performance problems.

4. Use simple equation determination.
   Once points are plotted on a graph, you assume that what appears straight is a linear function
and what appears curved upward is a quadratic function. Other shapes may appear, but they are beyond the scope of this section. From these observations, you can use either a simple two-point linear or three-point quadratic method to determine the equations. You can perform both methods easily by hand or with a basic calculator. You can also use spreadsheets like Microsoft Excel with graphing and trendline (regression) capabilities. Each separate SQL statement is graphed and analyzed individually.

5. Predict performance.

You can use derived equations to predict performance at much higher loads than are practical to test. Because the accuracy of the predictions may decrease as the predicted load increases, it is suggested that you make only ballpark predictions.

It may be advantageous to calculate two performance lines: the first as a lower bound if the performance line is truly linear, and the second as an upper bound if the performance line might turn out to be a quadratic curve. The predicted value would, therefore, lie somewhere in between. Later, you may want to try a test to see how close your prediction was to the actual time. Also be aware that it is not as important whether a slow-running process is predicted to take 20 or 24 hours, but rather, whether it can be improved to, say, 1 hour.

6. Interpret performance patterns and experiment.

The shape of the performance lines and the nature of the equations can provide clues about the cause of underlying performance problems and support (or sometimes contradict) the interpretations of diagnostic tools. You can conduct experiments on SQL code based on pattern clues and the correction applied to production code. You can graph tests of an improved process again and compare the results with the original process.

7. Keep a record of results to build expertise.

To build up your expertise at using both these mathematical methods and your interpretation of Oracle diagnostic tools, keep a record of before and after performance graphs, the true cause of performance problems, and the effective solutions you found. Graphs provide hard evidence of performance problems that you can present in a clear visual form to management and end users.

Deriving Performance Equations

The following sections discuss two simple methods for equation determination based on simplified versions of Newton’s Divided Difference Interpolating Polynomial. You can use these methods if you assume that what appears as a straight line is linear and what appears as upward sloping is quadratic.

Simple Linear Equation Determination

The following is a simple two-point method for determining a linear best-performance line equation:

\[ y = a_0 + a_1x \]  
(This is the final equation to use for linear queries.)

\[ y = \text{the number of rows in the table} \]
Figure 9-6 shows points from an ideal test that appears linear. You visually select two points \((x_1, y_1)\) and \((x_2, y_2)\) that define a straight line of minimum slope, where slope: 

\[
a_1 = \frac{y_2 - y_1}{x_2 - x_1}.
\]

**A Simple Example** These equations look great, but let’s look at a real-life query (using a basic query to the EMP table). You must time the query on the basis of two different table sizes to get an equation for the line.

```sql
select ename, deptno
from emp
where deptno = 10;
```

For a very small system, consider the response for two tests:
1. When 1000 records were in the EMP table, this query took 2 seconds.
2. When 2000 records were in the EMP table, this query took 3 seconds.

Therefore, you know that
\[ y_1 = 2 \text{ (seconds)} \]
\[ x_1 = 1000 \text{ (records)} \]
\[ y_2 = 3 \text{ (seconds)} \]
\[ x_2 = 2000 \text{ (records)} \]

**Step 1** Find the slope of the line.

\[ a_1 = \frac{y_2 - y_1}{x_2 - x_1} \]
\[ a_1 = \frac{3 - 2}{2000 - 1000} \]
\[ a_1 = 0.001 \text{ (The slope of the line is 0.001.)} \]

**Step 2** Get the \( y \)-intercept.

\[ a_0 = y_1 - a_1 x_1 \]
\[ a_0 = 2 - (0.001)(1000) \]
\[ a_0 = 2 - 1 \]
\[ a_0 = 1 \text{ (The } y \text{-intercept is 1.)} \]

**Step 3** Now you can calculate response for any size EMP table.

You now have everything you need for this query, so you can figure out how long this query will take as the number of rows in the EMP table increases.

What will the response time be for 3000 rows?

\[ y = a_0 + a_1 x \text{ (The response time is } y \text{, and } x \text{ is the number of rows in the table.)} \]
\[ y = 1 + (0.001)(3000) \]
\[ y = 1 + 3 \]
\[ y = 4 \text{ seconds (The response time for this query in a 3000-row EMP table will be 4 seconds.)} \]

What will the response time be for 100,000 rows?

\[ y = a_0 + a_1 x \]
\[ y = 1 + (0.001)(100,000) \]
\[ y = 101 \text{ seconds (The response time for a 100,000-row EMP table will be 1 minute and 41 seconds.)} \]
Simple Quadratic Equation Determination

Unfortunately, many queries don’t behave linearly. Consequently, the preceding section doesn’t always help you. But never fear—a simple method for curved lines is next. Once again, do not be intimidated by this section. You will be able to understand this, and with this information, you will be able to predict query scaling (predict any response time for an increased number of rows). The following is a simple three-point method for determining a quadratic best-performance equation. This is the equation you will use:

\[ y = a_0 + a_1 x + a_2 x^2 \] (This is the final equation to use for nonlinear queries.)

- \( y \) = response time for a query
- \( x \) = number of rows
- \( a_0, a_1, a_2 \) = constants derived from the curve the query creates

**Figure 9-7** shows points from an ideal test.

---

You visually select three points, \((0, y_0), (x_1, y_1), \) and \((x_2, y_2)\), that appear to be of minimum slope on a quadratic-like curve. The midpoint between 0 and \(x_1\) is \(x_a\), and the midpoint between \(x_1\) and \(x_2\) is \(x_b\), such that

\[ x_a = (x_1 + 0)/2 \quad \text{and} \quad x_b = (x_2 + x_1)/2 \]
When joined, \((0, y_0)\) and \((x_1, y_1)\) form a secant (a straight line that connects two points on a curve) with slope \(S_a\), and \((x_1, y_1)\) and \((x_2, y_2)\) form a secant with slope \(S_b\). The x midpoints \((x_a, y_a)\) and \((x_b, y_b)\) lie on the desired curve with tangents having slopes \(S_a\) and \(S_b\), respectively. From the derivative of a quadratic equation, which gives the slope of the curve at the midpoints, you have

\[
S_a = \frac{y_1 - y_0}{x_1 - 0} = a_1 + 2a_2x_a
\]

\(S_a\) = slope of the lower part of the curve

\[
S_b = \frac{y_2 - y_1}{x_2 - x_1} = a_1 + 2a_2x_b
\]

\(S_b\) = slope of the upper part of the curve

Using Gauss elimination, you solve for the \(a_i\) coefficients, such that

\[
a_2 = \frac{(S_b - S_a)}{[2(x_b - x_a)]} = \frac{(S_b - S_a)}{x_2}
\]

\[
a_1 = S_a - 2a_2x_a = S_a - a_2x_1.
\]

\[
a_0 = y_0
\]

You’ll have to use these three equations to get \(a_0\), \(a_1\), and \(a_2\), and then you can use the final equation. These will be the constants in the equation that will give you the response time of a query as you vary the number of rows in the table.

---

**NOTE**

This method will not work in all cases. If any \(a_i\) coefficients are negative, the equation may dip below the X axis and something else must be used. Often, the origin or \(a_0 = y_0 = 0\) works best with this method.

---

**A Simple Example** All of these equations look great, but let’s look at a real-life query. You must time the query using two different table sizes to get an equation for the line. The ORDERS table has an index on ORDNO, but it is suppressed by the NVL function (causing the nonlinear response time). The real solution to this problem is to eliminate NULLs in the ORDERS table and remove the NVL function from the query. However, this example is for instructional purposes to generate a quadratic equation.

```sql
select ordno, total
from orders
where nvl(ordno, 0) = 7777;
```

For your system, consider the response of this query for two tests:

- When there were 100 records in the ORDERS table, this query took 5 seconds.
When there were 2000 records in the ORDERS table, this query took 1000 seconds.

You want to know how long this query will take when you have 10,000 rows in the ORDERS table. Therefore, you know that

\[ y_1 = 5 \text{ (seconds)} \]

\[ x_1 = 100 \text{ (records)} \]

\[ y_2 = 1000 \text{ (seconds)} \]

\[ x_2 = 2000 \text{ (records)} \]

\[ y_0 = 1 \text{ (second – estimate); this is the } y\text{-intercept} \]

You could calculate \( y_0 \) by using two points near the lower part of the curve (near 100 rows using the linear equations from the preceding section), but because the lower part of the curve is small (5 seconds for 100 rows), you can guesstimate this to be 1 second. (You should calculate it.)

**Step 1** Calculate \( S_a \) and \( S_b \).

\[ S_a = (y_1 - y_0)/(x_1 - 0) \]

\[ S_a = (5 - 1)/(100 - 0) \]

\[ S_a = 0.04 \text{ (The slope of the lower part of the curve is almost horizontal.)} \]

\[ S_b = (y_2 - y_1)/(x_2 - x_1) \]

\[ S_b = (1000 - 5)/(2000 - 100) \]

\[ S_b = 0.52 \text{ (The slope of the upper part of the curve is much higher than the lower part.)} \]

**Step 2** Calculate \( a_0 \), \( a_1 \), and \( a_2 \).

\[ a_2 = (S_b - S_a)/x_2 \]

\[ a_2 = (0.52 - 0.04)/2000 \]

\[ a_2 = 0.00024 \]

\[ a_1 = S_a - a_2x_1 \]

\[ a_1 = 0.04 - (0.00024)(100) \]

\[ a_1 = 0.016 \]

\[ a_0 = y_0 \]

\[ a_0 = 1 \text{ (The } y\text{-intercept is 1.)} \]

**Step 3** Create the equation to use as the table grows.
\[ y = a_0 + a_1 x + a_2 x^2 \]
\[ y = 1 + (0.016)x + (0.00024)x^2 \] (This is your equation to calculate future responses.)

**Step 4** Calculate the expected response for 10,000 rows.

\[ y = 1 + (0.016)x + (0.00024)x^2 \]
\[ y = 1 + (0.016)(10,000) + (0.00024)(10,000^2) \]
\[ y = 24,161 \] (The query will take 24,161 seconds, or just under seven hours; you have a problem.)

You’ll have to fix the NVL problem soon so the users don’t have to wait seven hours. But in reality, you have calculated only a couple of points, and this should be extended out further to get a better future estimate of performance.

**TIP**

Spreadsheets like Microsoft Excel are very useful tools for graphing performance metrics and automatically deriving trendline equations. For example, to create a graph using Excel, list the observed \((x,y)\) data in cells. Highlight the cells, and select Chart Wizard | XY (Scatter) | Chart Subtype. Select a Line subtype and click Next | Next | Finish to create the graph. To derive a trendline equation, click the graph line once, and select Chart | Add Trendline. On the Type tab, select Linear; Polynomial Order = 2 (for quadratic) or other model type. To show the trendline equation, on the Options tab, select Display Equation On Chart. Then click OK to complete the graph. The solution equation can be programmed back into the spreadsheet (depending on your spreadsheet version) and used to predict values at higher volumes.

**Pattern Interpretation**

Graphical performance patterns provide clues to underlying SQL problems and solutions, as seen in Figure 9-8. The ultimate goal in using these methods is to convert a steep linear or quadratic best-performance line to one that is both shallow and linear by optimizing the SQL process. This may involve experiments with indexes, temporary tables, optimizer hint commands, or other Oracle SQL performance tuning methods.
With pattern interpretation, performing your own application-specific SQL experiments to develop expertise at using these methods is important. Table 9-2 shows more specific interpretations—based on my personal experience—that provide a general idea of how you can apply what you observe directly to tuning SQL code. Assuming the scale is correct, pattern interpretation often provides a more accurate picture of what is actually happening to a process and may support or even contradict what a diagnostic tool tells you.
TABLE 9-2. Graphical Representations of Various Tuning Situations

<table>
<thead>
<tr>
<th>Pattern in Figure 9-8</th>
<th>Possible Problem</th>
<th>Possible Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Missing index on a query SELECTing values.</td>
<td>Create an index. Fix a suppressed index.</td>
</tr>
<tr>
<td>A</td>
<td>Over-indexed table suffering during DML statements.</td>
<td>Drop some of the indexes or index fewer columns (or smaller columns) for the current indexes.</td>
</tr>
<tr>
<td>B</td>
<td>No problem.</td>
<td>Don’t touch it!</td>
</tr>
<tr>
<td>C</td>
<td>Missing index on a query SELECTing values.</td>
<td>Create an index. Fix a suppressed index.</td>
</tr>
<tr>
<td>C</td>
<td>Over-indexed table suffering during an INSERT.</td>
<td>Drop some of the indexes or index fewer columns (or smaller columns) for the current indexes.</td>
</tr>
<tr>
<td>D</td>
<td>Doing a full table scan or using the ALL_ROWS hint when you shouldn’t be.</td>
<td>Try to do an indexed search. Try using the FIRST_ROWS hint to force the use of indexes.</td>
</tr>
<tr>
<td>E</td>
<td>The query was fine until some other limitation (such as disk I/O or memory) was encountered.</td>
<td>Find out which ceiling you hit caused this problem. Increasing the SGA may solve the problem, but this could be many things.</td>
</tr>
<tr>
<td>E₁</td>
<td>If the limitation in line E is corrected, processing should continue along a straight line.</td>
<td>Further tuning may improve the process to line B.</td>
</tr>
</tbody>
</table>

**General Linear and Quadratic Interpretations**

A shallow linear performance line usually indicates a relatively efficient process compared to something much steeper or curved. The slope $a_1$ indicates the rate $y$ increases for a given $x$. Scale is important because a shallow line on one scale can look steep on another, and vice versa. A large $a_0$ coefficient always indicates an inefficient process.

An upward-sloping (concave) quadratic curve almost always indicates a problem with the process because as more rows are added, the time to process each additional row increases. Coefficient $a_2$ affects the bowing of the curve. If it is very small, the equation may be more linear. However, even a very slight bowing may be an indicator of something more insidious under much higher volumes.

In rare cases, a quadratic curve might appear downward sloping (convex), indicating a process where as more rows are added, the time to process each additional one decreases (i.e., economies of scale). This is desirable and may occur at a threshold, where a full table scan is more efficient than...
Indexing

Missing indexes commonly cause poor SQL performance. In Figure 9-8, line A or C could result from a missing index, depending on code complexity and data volume. Proper indexing improves performance to line B. Over-indexing can be as bad as missing indexes. Line A or C could be a process that is forced to use an index, whereas a full table scan would improve the process to B. Inserting into an indexed table is always slower than into an index-free table. Line A or C could be from an INSERT into a heavily indexed table versus line B with no indexing.

Indexing Example This listing illustrates what can happen with indexing analysis. Suppose you have two tables, TABLE_A and TABLE_B, and there is a one-to-many relationship between them based on KEY_FIELD. There does not have to be a join between the two tables.

You want to perform the following update within a KEY_FIELD:

```sql
table a.total = table a.total + sum(table b.amount)
```

The SQL statement shown next will do this. Note that the EXISTS subquery must be used to prevent the NULLing out of any TABLE_A.TOTAL fields, where TABLE_A.KEY_FIELD does not match TOTAL_B.KEY_FIELD.

```sql
update table_a ta set ta.total = 
(select ta.total + sum(tb.amount) 
from table_b tb 
where tb.key_field = ta.key_field 
group by ta.total) 
where exists 
(select null 
from table_b tb2 
where tb2.key_field = ta.key_field);
```

If there is a unique index on the TABLE_A.KEY_FIELD and a nonunique index on
TABLE_B.KEY_FIELD, then the performance will be similar to line B in Figure 9-8. However, if there is no index on TABLE_B.KEY_FIELD or the cost-based optimizer decides to shut it off, a line will be generated similar to A or C. The reason is that the EXISTS subquery heavily depends on indexing.

I have seen cases where the number of rows in TABLE_A was small (< 2000), but the cost-based optimizer shut off the index on TABLE_B and reported a small EXPLAIN PLAN cost. This was regardless of the number of rows in TABLE_B (which was up to 800,000 rows). Actual tests showed a steep performance line that contradicted the EXPLAIN PLAN cost. This is an example of uncovering a problem that may have been overlooked by a diagnostic tool.

When the optimizer (cost-based) finds a query to retrieve less than 5–6 percent (based on the average distribution) of the data in a table, the optimizer generally drives the query with an index if one exists. Figure 9-9 shows how Oracle has evolved through the past years prior to Oracle9i. In Oracle 10g, the optimizer is very good at analyzing not only the number of rows, but also the distribution of data, and also knows if the query has been run previously. The first time a query is executed is different from the second time even if this was weeks ago. While the response time still depends on the percentage of blocks (better than looking at the percentage of rows) retrieved by the query, what kind of disks, cache for the disks, cache for the operating system, and previous queries change the upper part of the graph greatly (where you retrieve most of the table). Everything starts depending more on your hardware and access patterns. In 11g, this continues to improve, and in Exadata, you have a whole new paradigm with even greater efficiencies. I have left the following graph in Figure 9-9 in this version of the book to show where Oracle has been in the past (Chapter 8 shows a graph of where we are currently with 11g).

![Graph showing optimum percentage of rows for index for older versions of Oracle](image)

**FIGURE 9-9. Optimum percentage of rows for index for older versions of Oracle**

**Optimizer Execution Plan**

You can graph performance patterns to leverage available diagnostic tools. For example, you analyzed a slow and complex SQL statement that used views and ran high-volume data under the
Oracle cost-based optimizer. Results showed a very high performance line identical to $D$ in Figure 9-8. The Oracle EXPLAIN PLAN also showed an inefficient execution plan. Once an effective optimizer hint command was found (i.e., FIRST_ROWS) and added directly to the SQL statements that defined the views, performance improved dramatically to line $B$.

**Multiple Table Joins**

Complex *multiple-table join* statements often run poorly regardless of the conventional tuning used and may be similar to lines $A$ or $C$ in Figure 9-8. From past experience, rather than trying to tune only the statement with conventional techniques, a more effective solution is to decompose it into a series of simple SQL statements using temporary tables. The final result would be the same, but at much faster speed, represented by a composite line at $B$.

**Jackknifing**

*Jackknifing* is a pattern where a performance line starts off shallow but then veers steeply upward at a certain threshold point, similar to $E$ in Figure 9-8. Two linear equations may define the behavior; its cause could be anything from disk I/O or memory limitations to a switch in the optimizer execution plan due to changing data volumes. Possible solutions are to increase the system’s limitations, run fresh optimizer statistics, or break the statement into selection ranges. Proper tuning might either straighten out the line to $E_1$ or improve it further to line $B$.

**Riding the Quadratic Curve**

Often, a poorly performing SQL process is designed and tested on low-volume data, but in production under higher volumes, its true and degrading quadratic nature is revealed, as shown by curve $A$ in Figure 9-10. In this example, a process was created and tested up to $x_1$. Performance was believed to be close to line $B$, but once in production and when the volume was increased to $x_3$, the line really turned out to be curve $A$. 
If you cannot find a proper tuning solution, you can still improve a quadratic process of unknown cause by breaking the original statement into lower-volume selection ranges and riding the shallow part of the quadratic curve. Suppose in Figure 9-10, you break the process into three selection ranges: from [0 to \( x_0 \)] that rides the lower part of curve A, from \([x_1 \text{ to } x_2]\) that rides the lower part of curve \( A_1 \), and from \([x_2 \text{ to } x_3]\) that rides the lower part of curve \( A_2 \). The overall result is something closer to line \( B \) from [0 to \( x_3 \)] with \( y_2' \) taking a lot less time than the original \( y_2 \). Although this technique may not be the best solution, it could still solve the problem.

Instead of running everything all at once, breaking up the process using a SQL loop and commit mechanism can sometimes buy better overall performance for processes like UPDATEs and DELETEs that use ROLLBACK segments.

**Volatility Effects**

Running under ideal conditions and graphing the results makes it much easier to analyze the effects of outside traffic and its resulting volatility. For example, line \( A \) in Figure 9-11 is from an inefficient linear process run under ideal conditions. Suppose a controlled amount of traffic from another process is then run at the same time. It could be a large query, insert, update, or backup, etc. This second test moves line \( A \) by 100 percent to \( A_1 \). In other words, the process with added traffic on the system is twice as slow.
FIGURE 9-11. Example of volatility effects

Now suppose you optimize the original process. Under an ideal test of the new process, the best performance line shifts down to $B$. If you were to predict what would happen if you applied the same controlled traffic to the new process, you might predict a 100 percent shift to $B_2$.

However, since the slopes between $A$ and $B$ differ (with $A$ being much steeper than $B$), the 100 percent time increase from $B$ to $B_2$ would be much less than from $A$ to $A_1$. In fact, an actual traffic test on line $B$ might prove to be much less than even the predicted 100 percent due to the overall efficiency of the line $B$ process. In general, more efficient SQL processes are less susceptible to added traffic effects than less efficient processes.

Mathematical Techniques Conclusions

Simple Mathematical Techniques is an effective Oracle SQL performance analysis and tuning methodology that involves running tests under ideal conditions, graphing performance observations, and using simple linear and quadratic equation determination for predicting performance at higher loads. It also includes the interpretation of performance patterns that can be applied directly to tuning SQL code. You can build your own tuning tools using these methods.

The methodology acts as a catalyst by combining the use of some traditional mathematical analysis with Oracle diagnostic tools to aid in their interpretation and to leverage their effectiveness. It can also help you identify hidden problems that may be overlooked by other diagnostic methods by providing a broad picture of performance. The technique can also help you overcome performance-
tuning barriers such as inexperience with Oracle, lack of hard evidence, or difficulties with
diagnostic tool interpretation that may prevent effective performance tuning. You can also analyze
volatility effects from outside traffic. Graphs provide a visual picture of performance for presentation
to management and end users. And you can use spreadsheets such as Microsoft Excel with these
techniques for quick and easy performance analysis.

TIP
If you want an Oracle symphony as great as one of Beethoven’s, you must learn and know how to
apply mathematical techniques to your tuning efforts. You don’t have to learn everything that you
learned in college calculus; merely apply the simple equations in this chapter to tie everything in
this book together. Thank you, Joe Holmes, for doing the math for us!

Tips Review

■ Using cost-based optimization, the first table in the FROM clause is the driving table when the
ORDERED hint is used. This overrides the optimizer from choosing the driving table. If a
SORT-MERGE join is used, then the order of the tables has no impact because neither will
drive the query (although the first listed table is accessed first for the operation and is the
driving table). Knowing which table is generally the driving table when using an ORDERED
hint in small joins can help you solve larger table join issues and also help you find indexing
problems.

■ When hash initialization parameters are set up, the optimizer uses HASH joins in lieu of
SORT-MERGE joins. With HASH joins, the first table is used to build a hash table (in
memory if available), and the second table in the FROM clause then probes for corresponding
hash table matches. The first table in the FROM clause (using the ORDERED hint) is the first
table accessed in a HASH join.

■ Using cost-based optimization and a NESTED LOOPS join as the means of joining, the first
table in the FROM clause is the driving table (all other conditions being equal), but only the
ORDERED hint guarantees this. In NESTED LOOPS joins, choosing a driving table that is the
smaller result set (not always the smaller table) makes fewer loops through the other result set
(from the nondriving table) and usually results in the best performance.

■ To change the method that Oracle uses to join multiple tables, use the USE_MERGE, USE_NL,
and USE_HASH hints. Multiple tables may need to be specified for the hint to work, and the
driving order is usually from first to last in the FROM clause.

■ In a three-table join, the driving table is the intersection table or the table that has a join
condition to each of the other two tables in the join. Try to use the most limiting table as the
driving table (or intersection table) so your result set from the join of the first two tables is
small when you join it to the third table. Also, ensure that all join conditions on all tables are
indexed!
Using cost-based optimization, when a large table and a small table are joined, the smaller table is the driving table (accessed first), and the smaller table is used to build a hash table in memory on the join key. The larger table is scanned and then probes the hash table for matches to the join key. Also note that if there is not enough memory for the hash, the operation can become extremely slow because the hash table may be split into multiple partitions that could be paged to disk. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table, and it will be the one used to build the hash table.

Using cost-based optimization, when a large and small table are joined, the larger table is the driving table if an index can be used on the large table. If the ORDERED hint is specified, then the first table in the FROM clause is the driving table.

To ensure that you are reading your EXPLAIN PLAN correctly, run a query for which you are sure of the driving table (with nested subqueries).

You may not be able to modify actual code for some third-party products, but you can often add, force, or suppress indexes (using SQL Plan Management) to improve performance.

When distributed queries cannot be avoided, use IN clauses, set operators such as UNION and MINUS, and use everything else you can to reduce the network traffic between database nodes. Queries written in a manner that causes looping between distributed nodes (distributed databases) can be extremely slow.

In addition to the more typical reasons, when developers modify the data as it is being selected, fetching across commits, the Snapshot Too Old error can occur. To fix this problem, close and reopen the cursor causing the issue.

Dumping data blocks can be a valuable tool to understand how Oracle works and to investigate problem-tuning areas. Only a tuning expert should use block dumps, and even an expert should use the help of Oracle Support. Oracle does not publish the structure of block dumps, so they can change at any time.

If you want an Oracle symphony as great as one of Beethoven’s, you must learn and know how to apply mathematical techniques to your tuning efforts. You don’t have to learn everything that you learned in college calculus; merely apply the simple equations in this chapter to tie everything in this book together.

If you’ve read and understood this entire chapter, you’re probably among the top-tuning professionals and you will see the heights and joys that I’ve seen with tuning Oracle.

References

Mike Ault, “Advantages of Oracle9i Real Application Clusters” (TUSC, 2002).
Janet Bacon, “Reading a Block Dump” (TUSC).
*Block Level Reading Tool from Terlingua Software.*
S. Chapra and R. Canale, *Numerical Methods for Engineers; with Programming and Software*
Kevin Gilpin, Mark Bobak, and Jonathon Lewis, Metalink notes “EM Grid Control 10g” (otn.oracle.com, Oracle Corporation).
Guy Harrison, Oracle SQL High-Performance Tuning 2/e (Prentice Hall, 2000).
Scott Marin, The Machinations of Oracle (Terlingua Software).
Dave Moore, Oracle Professional, February 2002, Managing Oracle9i Real Application.
James Morle, Scaling Oracle8i (Addison-Wesley, 1999).
Rich Niemiec, “Oracle10g New Features” (TUSC Presentation).
Oracle11g Documentation (Oracle Corporation).
Real Application Cluster Documentation Set (technet.oracle.com).
Jay Rossiter, “Oracle Enterprise Manager 10g: Making the Grid a Reality” (Oracle Corporation).
Oracle 10g and Oracle9i documentation.
Craig Schallahamer, “All about Oracle’s Touch Count Algorithm” (orapub.com).
Roger Schrag, “Tuning Joins” (Database Specialists).
Randy Swanson, “Oracle10g New Features” (www.tusc.com).
The tips and techniques section of www.ioug.org.

Thanks to Mike Messina who added the Real Application Testing, Database Replay, and SQL Performance Analyzer sections. Special thanks to Francisco Javier Moreno, Guillermo L. Ospina Romero, and Rafael I. Larios Restrepo from the University Nacional in Medellín, Colombia (who contributed; Maurizio Bonomi of Italy (detailed join sections); Joe Holmes of Canada (for the “Tuning Using Simple Mathematical Techniques” section); Veljko Lavrnic (VL), Scott Martin, and Tirth (tink) for help and insight with the block tuning section; and Roger Schrag (basic join sections). Thanks to Joe Trezzo, Andy Mendelsohn, Sean McGuire, Mike Broulette, Judy Corley, Greg Pucka, Randy Swanson, Bob Taylor, and Mark Greenhalgh for their contributions to this chapter.
As with each release before it, Oracle Database 12c continues to elevate PL/SQL performance and functionality to new levels. This chapter focuses on helpful tips that are new with 12c (up to 12cR2) as well as tips that continue to be useful from older versions. Once you have great queries to monitor your system, you need to automate them. PL/SQL gives you the capability to do so while also providing some great packages and procedures that you can use for tuning. The PL/SQL engine processes all PL/SQL requests and passes the statements on to Oracle for execution. When PL/SQL is passed to Oracle, it is placed in Oracle’s System Global Area (SGA), more particularly in the shared pool. In Oracle, PL/SQL source code can be stored in the database in the form of procedures, functions, packages, and triggers. Once these objects are stored in the database in compiled format, they can be executed from any Oracle tool by any user who has been granted EXECUTE privilege on that object. Upon execution, the p-code (executable code) is loaded into the shared pool and executed by Oracle. A PL/SQL object remains in the shared pool until the object is aged out with a Least Recently Used (LRU) algorithm. If any process calls the object, it does not have to be reloaded into the SGA shared pool as long as it has not been aged out. Therefore, Oracle looks in the shared pool (which is very efficient) for the object prior to going to disk (which is not as efficient) to load the object. How well the SQL within the PL/SQL is tuned is probably the biggest factor driving performance, yet I will cover other tuning considerations in this chapter. The last portion of this chapter is dedicated to understanding and being able to locate the PL/SQL. Here are the tips covered in this chapter:

- Leverage the PL/SQL Function Result Cache to improve performance (improved in 12c)
- Define PL/SQL subprograms in a SQL statement (new in 12c)
- Reference sequences directly in PL/SQL expressions
- Identity Columns (new in 12c)
- Max size increase for VARCHAR2, NVARCHAR2, and RAW data types (new in 12c)
- Binding PL/SQL-only data types to SQL statements using DBMS_SQL (new in 12c)
- Use named parameters in SQL function calls
- Simplify loops with the CONTINUE statement
- Leverage compile-time warnings to catch programming mistakes
- Increase performance with native compilation (improved in 12c)
- Maximize performance with the optimizing compiler (improved in 12c)
- Use DBMS_APPLICATION_INFO for real-time monitoring
- Use a custom replacement of DBMS_APPLICATION_INFO for real-time monitoring in a RAC environment
- Log timing information in a database table
- Reduce PL/SQL program unit iterations and iteration time
- Use ROWID for iterative processing
- Standardize on data types, IF statement order, and PLS_INTEGER
- Reduce the calls to SYSDATE
- Reduce the use of the MOD function
- Improve shared pool use by pinning objects
- Identify the PL/SQL that needs to be pinned
- Use and modify DBMS_SHARED_POOL.SIZES
- Get detailed object information from DBA_OBJECT_SIZE
- Find invalid objects
- Find disabled triggers
- Use PL/SQL associative arrays for fast reference table lookups
- Find and tune the SQL when objects are used
- Consider the time component when working with Oracle’s DATE data type
- Use PL/SQL to tune PL/SQL
- Understand the implications of PL/SQL location
- Specify a rollback segment for a large cursor
- Use temporary database tables for increased performance
- Integrate a user-tracking mechanism to pinpoint execution location
- Limit the use of dynamic SQL
- Use pipelined table functions to build complex result sets
- Suppress debugging commands with conditional compilation
- Take advantage of the samples just for the beginners (beginners start here)
Performance (Improved in 12c)

Perhaps the best developer feature in Oracle Database 12c is the improved PL/SQL Function Result Cache. This feature provides a quick way to build a cache of function results that will be used automatically when a subsequent call to a function is made with the same parameter values. It essentially eliminates the hand-coded caches that you’ve had to build in the past using PL/SQL array structures. More importantly, the new Function Result Cache works at the instance level, not the session level as is the case with hand-coded mechanisms.

Let’s start the example with these tables:

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Rows</th>
<th>Column</th>
<th>Type</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>cities</td>
<td>1,111</td>
<td>city_id</td>
<td>number</td>
<td></td>
</tr>
<tr>
<td>cities</td>
<td></td>
<td>country_id</td>
<td>number</td>
<td></td>
</tr>
<tr>
<td>cities</td>
<td></td>
<td>city_name</td>
<td>varchar2</td>
<td>50</td>
</tr>
<tr>
<td>residents</td>
<td>1,000,000</td>
<td>resident_id</td>
<td>number</td>
<td></td>
</tr>
<tr>
<td>residents</td>
<td></td>
<td>resident_id</td>
<td>number</td>
<td></td>
</tr>
<tr>
<td>residents</td>
<td></td>
<td>first_name</td>
<td>varchar2</td>
<td>50</td>
</tr>
<tr>
<td>residents</td>
<td></td>
<td>last_name</td>
<td>varchar2</td>
<td>50</td>
</tr>
<tr>
<td>residents</td>
<td></td>
<td>salary</td>
<td>number</td>
<td></td>
</tr>
<tr>
<td>residents</td>
<td></td>
<td>city_id</td>
<td>number</td>
<td></td>
</tr>
</tbody>
</table>

There are a total of 398,124 USA residents with these totals in some key cities:

<table>
<thead>
<tr>
<th>City Name</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchorage</td>
<td>907</td>
</tr>
<tr>
<td>Baltimore</td>
<td>865</td>
</tr>
<tr>
<td>Chicago</td>
<td>869</td>
</tr>
<tr>
<td>Dallas</td>
<td>924</td>
</tr>
<tr>
<td>New York City</td>
<td>890</td>
</tr>
</tbody>
</table>
Next, you create a function that returns the average salary for a specified country:

```
CREATE OR REPLACE FUNCTION get_avg_sal (p_country_c IN VARCHAR2) RETURN NUMBER IS
  v_avg N NUMBER;
BEGIN
  SELECT TRUNC(AVG(r.salary), 2)
  INTO v_avg
  FROM residents r,
       countries c,
       cities t
  WHERE r.city_id = t.city_id
    AND r.country_id = c.country_id
    AND c.country_name = p_country_c;
  RETURN v_avg;
END get_avg_sal;
```

The baseline performance is obtained by executing the function several times to compute the average salary of residents in the USA:

```
SELECT get_avg_sal('USA') FROM dual;
```

```
GET_AVG_SAL('USA')
-------------------
515368.02
```

**Execution Times**

- 0.421 seconds
- 0.359 seconds
- 0.358 seconds
- 0.359 seconds
- 0.374 seconds

The initial execution, which incurs the overhead of parsing the statement, is ignored to yield an average execution time of 0.3625 seconds. Not a bad showing overall considering the RESIDENTS table contains 1 million records. However, let’s see how this seemingly fast performance can compound into poor performance when the function is utilized within a complex query. The task is to determine the number of Chicago residents who earn more than the average salary. Here are the results:
Clearly, the problem here is that the GET_AVG_SAL function is being executed 869 times, once for each resident who lives in Chicago. Realizing that the GET_AVG_SAL function can only return 65 different values (one for each country), one might be inclined to build a caching mechanism into the function call. You can implement a cache in a matter of seconds by simply adding the RESULT_CACHE keyword to the function definition:

```sql
CREATE OR REPLACE FUNCTION get_avg_sal (p_country_c in varchar2) return number
result cache is
v_avg_n number;
BEGIN
    select round(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities t,
    where r.city_id = t.city_id
    and t.country_id = c.country_id
    and c.country_name = p_country_c;
    return v_avg_n;
END get_avg_sal;
```

With the Result Cache enabled, the average execution time of the function has dropped to 0.0155 seconds, as shown here:

```sql
select get_avg_sal('USA') from dual;
```

```
515368.02
```

```
The complex Chicago query now completes in a blazing 0.749 seconds!

Let's take a closer look at what is happening within the function. First, the function is modified slightly to generate console output every time it executes:

```sql
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_id in varchar2) return number result_cache is
  v_avg_u number;
BEGIN
  dbms_output.put_line('Executing Function Body');
  select count(avg(r.salary), 2)
  into v_avg_u
  from residents r,
       countries c,
       cities t
  where r.city_id = t.city_id
  and r.country_id = c.country_id
  and c.country_name = p_country_id
  return v_avg_u;
END get_avg_sal;
```

Now let's run the complex Chicago query:

```sql
select count(*)
  from residents r,
       cities c,
       countries cr
where r.city_id = c.city_id
  and c.country_id = cr.country_id
  and cr.country_name = 'USA'
  and c.city_name = 'Chicago'
  and r.salary > get_avg_sal(cr.country_name);
```

```
COUNT(*)
---------
434
```

Executing Function Body

Executed in 1.591 seconds

The single "Executing Function Body" indicates that the function body was only executed a single time. When you re-execute the query,
the "Executing Function Body" text does not appear because the results are coming from the Result Cache. As an added benefit, the Result Cache is automatically leveraged by any session of the instance. In comparison, a manually coded cache would be session-specific (each session would maintain its own copy of the cache array and values). To test this, start a new SQL session and run the complex Chicago query:

```
select count(*)
  from residents r,
       cities  c,
       countries cr
where r.city_id    = c.city_id
  and c.country_id = cr.country_id
  and cr.country_name = 'USA'
  and c.city_name   = 'Chicago'
  and r.salary      > get_avg_sal(cr.country_name);
```

```
          COUNT(*)
-----------------
            434
```

Executed in 0.811 seconds

Clearly, the new database session is utilizing the cache that was populated in the original session for the `get_avg_sal('USA')` function call. If you alter the query to report on Dublin, Ireland, you will see that the function must be executed again to fill the cache with data for Ireland:
If you are wondering what happens to the cache when the underlying table data is changed, let’s take a look using a few SQL commands (run in a relaunched database):

```sql
select count(*)
  from residents r,
       cities c,
       countries cr
where r.city_id = c.city_id
  and c.country_id = cr.country_id
  and cr.country_name = 'Ireland'
  and c.city_name = 'Dublin'
  and r.salary > get_avg_sal(cr.country_name);
```

```
COUNT(*)
--------
431
```

**Executing Function Body**

**Executed in 1.872 seconds**

If you are wondering what happens to the cache when the underlying table data is changed, let’s take a look using a few SQL commands (run in a relaunched database):

```sql
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
515368.02
```
Clearly the cache is not aware of the underlying data manipulations and the result being returned is now incorrect. Oracle provides a utility package, DBMS_RESULT_CACHE, that you can leverage to force an immediate purging of the cache, as shown next. Purging, of course, allows the cache to be repopulated with the proper values, taking into account the sweeping salary change that was made. Note that EXECUTE privileges for the DBMS_RESULT_CACHE package are not provided by default.
The appropriate long-term solution is to alter the function definition to identify underlying dependencies that the cache needs to take into account. Do this with the RELIES_ON clause:

```sql
CREATE OR REPLACE FUNCTION get_avg_sal(p country c in varchar2)
return number result cache relies on (cities, residents) is
  v avg n number;
BEGIN
  dbms_output.put_line('Executing Function Body');
  select trunc(avg(r.salary), 2)
  into v avg n
  from residents r,
       countries c,
       cities t
  where r.city_id   = t.city_id
    and t.country_id = c.country_id
    and c.country_name = p.country_c;
  return v_avg_n;
END get_avg_sal;
```

The Result Cache now monitors changes to the CITIES and RESIDENTS tables and refreshes itself as needed. The CITIES table is listed as a dependency to track any reorganizations that may occur, such as a new city being added to a country. Let's see how this change impacts the results:
The cache now responds to changes in the underlying tables that the function relies on and refreshes itself as needed.

In addition to the DBMS_RESULT_CACHE package mentioned earlier, Oracle provides several performance views to monitor the Result Cache: V$RESULT_CACHE_STATISTICS, V$RESULT_CACHE_MEMORY, V$RESULT_CACHE_OBJECTS, and V$RESULT_CACHE_DEPENDENCY. From a developer perspective, the most useful of these views are V$RESULT_CACHE_STATISTICS and V$RESULT_CACHE_OBJECTS. The former provides a summary overview of the entire Result Cache, whereas the latter provides details for each object in the Result Cache.

The V$RESULT_CACHE_STATISTICS view always returns ten records providing summary information about the entire Result Cache. Here’s an example of the information returned by V$RESULT_CACHE_STATISTICS:
These name-value pairs are defined as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Size (Bytes)</td>
<td>Size of each memory block.</td>
</tr>
<tr>
<td>Block Count Maximum</td>
<td>Maximum number of memory blocks allowed.</td>
</tr>
<tr>
<td>Block Count Current</td>
<td>Number of memory blocks currently allocated.</td>
</tr>
<tr>
<td>Result Size Maximum (Blocks)</td>
<td>Maximum number of blocks allowed for a single result.</td>
</tr>
</tbody>
</table>
The STATUS column of V$RESULT_CACHE_STATISTICS indicates the viability of the data in the cache with values being limited to:

- **New**: Result is still under construction.
- **Published**: Result is available for use.
- **Bypass**: Result will be bypassed for use.
- **Expired**: Result has exceeded expiration time.
- **Invalid**: Result is no longer available for use.

The rows in the V$RESULT_CACHE_OBJECTS view with the value ‘Result’ for the TYPE column are of most interest as they allow you to review information such as hit rates. The view contains a “Published Result” record (TYPE = ‘Result’ and STATUS = ‘Published’) for each unique combination of function name and input parameters that is still valid in the cache. The V$RESULT_CACHE_OBJECTS view also contains “Invalid” records (STATUS = ‘Invalid’) that result when cache entries are invalidated, such as when a change in a RELIES_UPON object causes the cache to be refreshed. Based on the SQL that has been issued during this discussion, you can expect the view to have two published result records: one for the numerous calls to `get_avg_sal('USA')` and one for the calls to `get_avg_sal('Ireland')`. Here is a portion of the record for the USA call:
These columns are identified as follows:

<table>
<thead>
<tr>
<th>Column</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE</td>
<td>6</td>
</tr>
<tr>
<td>Status</td>
<td>Published</td>
</tr>
<tr>
<td>Bucket No</td>
<td>095</td>
</tr>
<tr>
<td>Hash</td>
<td>109888822551</td>
</tr>
<tr>
<td>Name</td>
<td>&quot;SCOTT&quot;.&quot;CT AVC SAL&quot;;8.&quot;CT2 AVC SAL&quot;#8440331613f0f5d3 #1</td>
</tr>
<tr>
<td>Namespace</td>
<td>PLSQL</td>
</tr>
<tr>
<td>Creation Timestamp</td>
<td>1/23/2009 9:58:57 AM</td>
</tr>
<tr>
<td>Creator UID</td>
<td>5512</td>
</tr>
<tr>
<td>Depend Count</td>
<td>3</td>
</tr>
<tr>
<td>Block Count</td>
<td>1</td>
</tr>
<tr>
<td>SCN</td>
<td></td>
</tr>
<tr>
<td>Column Count</td>
<td>1</td>
</tr>
<tr>
<td>Pin Count</td>
<td>0</td>
</tr>
<tr>
<td>Scan Count</td>
<td>4345</td>
</tr>
<tr>
<td>Row Count</td>
<td>1</td>
</tr>
<tr>
<td>Row Size Max</td>
<td>7</td>
</tr>
<tr>
<td>Row Size Min</td>
<td>7</td>
</tr>
<tr>
<td>Row Size Avg</td>
<td>7</td>
</tr>
<tr>
<td>Build Time</td>
<td>146</td>
</tr>
<tr>
<td>LRU Number</td>
<td>0</td>
</tr>
<tr>
<td>Invalidations</td>
<td>NULL</td>
</tr>
<tr>
<td>Object No</td>
<td>NULL</td>
</tr>
<tr>
<td>Space Overhead</td>
<td>274</td>
</tr>
<tr>
<td>Space Unused</td>
<td>743</td>
</tr>
<tr>
<td>Column Name</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ID</td>
<td>Identifier for the cache object (also the ID of the first block)</td>
</tr>
<tr>
<td>TYPE</td>
<td>Type of the cache object</td>
</tr>
<tr>
<td>STATUS</td>
<td>Status of the object</td>
</tr>
<tr>
<td>BUCKET_NO</td>
<td>Internal hash bucket for the object</td>
</tr>
<tr>
<td>HASH</td>
<td>Hash value for the object</td>
</tr>
<tr>
<td>NAME</td>
<td>Name (for example, SQL prefix or PL/SQL function name)</td>
</tr>
<tr>
<td>NAMESPACE</td>
<td>The type of cached result (SQL or PL/SQL)</td>
</tr>
<tr>
<td>CREATION_TIMESTAMP</td>
<td>Time when the object was created</td>
</tr>
<tr>
<td>CREATOR_UID</td>
<td>The ID of the user that created the result</td>
</tr>
<tr>
<td>DEPEND_COUNT</td>
<td>The number of dependencies for each result, or the number of dependents if the TYPE is a dependency</td>
</tr>
<tr>
<td>BLOCK_COUNT</td>
<td>Total number of blocks in the cached object</td>
</tr>
<tr>
<td>SCN</td>
<td>Either the build SCN for a result or the SCN at which a dependency was invalidated</td>
</tr>
<tr>
<td>COLUMN_COUNT</td>
<td>Number of columns in the cached result</td>
</tr>
<tr>
<td>PIN_COUNT</td>
<td>Number of active scans on this result</td>
</tr>
<tr>
<td>SCAN_COUNT</td>
<td>Total number of scans initiated on the cached result</td>
</tr>
<tr>
<td>ROW_COUNT</td>
<td>Total number of rows in the cached result</td>
</tr>
<tr>
<td>ROW_SIZE_MAX</td>
<td>Size of the largest row (in bytes)</td>
</tr>
<tr>
<td>ROW_SIZE_MIN</td>
<td>Size of the smallest row (in bytes)</td>
</tr>
<tr>
<td>ROW_SIZE_AVG</td>
<td>Average size of a row (in bytes)</td>
</tr>
<tr>
<td>BUILD_TIME</td>
<td>Amount of time (in hundredths of a second) it took to build the cached result</td>
</tr>
<tr>
<td>IRU_NUMBER</td>
<td>IRU list position (the smaller the value, the more recent the usage)</td>
</tr>
<tr>
<td>OBJECT_NO</td>
<td>The data dictionary object number for the dependency object</td>
</tr>
<tr>
<td>INVALIDATIONS</td>
<td>The number of times the dependency object has invalidated its dependent objects</td>
</tr>
<tr>
<td>SPACE_OVERHEAD</td>
<td>Overhead (in bytes) for the result</td>
</tr>
<tr>
<td>SPACE_UNUSED</td>
<td>Unused space (in bytes) for the result</td>
</tr>
</tbody>
</table>
In conclusion, the new PL/SQL Function Result Cache makes possible enormous performance gains with a minimum of development effort. It shouldn’t be used as a crutch for poorly written/designed functions but as another tool for creating highly efficient routines.

In 12c, we also can combine invoker rights (AUTHID CURRENT_USER) with the Function Result Cache (RESULT_CACHE). Our function will look like this now:

```sql
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_c IN VARCHAR2) RETURN NUMBER
AUTHID CURRENT USER
RESULT CACHE IS
    v_avg_n NUMBER;
BEGIN
    SELECT TRUNC(AVG(r.salary), 2)
    INTO v_avg_n
    FROM residents r,
         countries c,
         cities t
    WHERE r.city_id = t.city_id
    AND t.country_id = c.country_id
    AND c.country_name = p_country_c;
    RETURN v_avg_n;
END get_avg_sal;
```

With this declaration the Result Cache for an invoker rights function is logically partitioned by the name of the current user. Performance will be improved when executed by the same user invoking this function with exactly the same parameter.

**Define PL/SQL Subprograms in a SQL Statement (New in 12c)**

Release 12c presented two new features to increase query performance when a subprogram is called. We can now create a PL/SQL subprogram inline SELECT statement utilizing the WITH clause declaration. This function when created in the WITH clause subquery is only available for the current query and is not stored as an object in the database (similar to an inline view). Since this subprogram in the WITH clause will be called from the SELECT statement, only the function in the declaration can be used.

Let’s use the function from the previous example:
CREATE OR REPLACE FUNCTION get_avg_sal(p_country_c in varchar2)
return number is
    v_avg_n number;
BEGIN
    select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities t
    where r.city_id = t.city_id
        and t.country_id = c.country_id
        and c.country_name = p_country_c;
    return v_avg_n;
END get_avg_sal;

In 12c, if we don’t want to store this function in the database, and use it just in SELECT statements, we can use the WITH clause:

WITH FUNCTION get_avg_sal(p_country_c in varchar2)
return number result_cache relies_on(cities, residents) is
    v_avg_n number;
BEGIN
    select trunc(avg(r.salary), 2)
    into v_avg_n
    from residents r,
         countries c,
         cities t
    where r.city_id = t.city_id
        and t.country_id = c.country_id
        and c.country_name = p_country_c;
    return v_avg_n;
END;
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
------------------
515568.02

No switching from SQL to PL/SQL engines and vice versa, and no stored object with all needed grants, synonyms, and so on! In addition to performance gains for one execution, this new 12c feature is very helpful for queries written using read-only accounts. You don’t need to create functions’ privileges in the specialized reports if no reusability is required. The local WITH clause declaration takes precedence over the stand-alone function with the same name.

A second, related feature new in 12c is that a function can be created with the UDF pragma to inform the compiler that the function is always called in a SELECT statement. UDF stands for user-defined function. Since version 7, we have been able to create PL/SQL functions, store them in the
database, and call them from SQL or PL/SQL. The problem on the performance side is that this requires context switching from SQL and PL/SQL each time. With Oracle 12c we can use PRAGMA UDF as a compiler directive indicating that this function is used in the SQL statement.

Let’s take our function from the previous example and add this PRAGMA UDF:

```sql
FUNCTION get_avg_sal(p_country_c in varchar2) return number result_cache relies_on(cities, residents) is
PRAGMA UDF;
  v_avg_n number;
BEGIN
  select trunc(avg(r.salary), 2)
  into v_avg_n
  from residents r,
       countries c,
       cities t
  where r.city_id = t.city_id
       and t.country_id   = c.country_id
       and c.country_name = p_country_c;
  return v_avg_n;
END;
select get_avg_sal('USA') from dual;

GET_AVG_SAL('USA')
-----------------
515568.02
```

Let’s compare the performance of this new option to just calling the simple stored `GET_AVG_SAL` function, which we will set as 1× performance. When using the WITH option, performance is 3.7× faster, and with UDF pragma performance is 3.9× faster. As you can see, the performance gain is significant, but you need to remember a few of the drawbacks. A function utilizing the WITH clause is not stored in the database and cannot be reused. A function created with PRAGMA UDF can slow down performance if called directly from another PL/SQL program. So, use PRAGMA UDF in a function only when calling it from a SQL statement.

**Reference Sequences Directly in PL/SQL Expressions**

You can reference sequences directly in PL/SQL expressions without the archaic “select from dual” construct. The result is more streamlined code that is easier to read and maintain. Oracle also promises improved performance and scalability. Let’s start with a PL/SQL block written the “old fashioned” way with a “select from dual” construct being used to pull values from a sequence:
drop sequence my_seq;
create sequence my_seq 
minvalue 1 
start with 1 
increment by 1 
nocache;

DECLARE
  v_time_start_i integer;
  v_time_end_i  integer;
  v_value_i integer;
BEGIN
  v_time_start_i := dbms_utility.get_time;
  for i in 1..100000 loop
    select my_seq.nextval
    into v_value_i
    from dual;
  end loop;

  v_time_end_i := dbms_utility.get_time;
  dbms_output.put_line('Execution Time: ' ||
                        (v_time_end_i - v_time_start_i)/100 ||
                        ' seconds');
END;
/

This block executes in 61.47 seconds (averaged across three executions).
You can streamline the code by referencing the NEXTVAL and CURRVAL pseudocolumns directly within the PL/SQL code, as shown here:
The average execution time with this block is 61.90 seconds. While the ability to reference the sequence value directly in PL/SQL has simplified the code, a performance gain has not been realized. In fact, the performance has degraded slightly. To investigate further, the previous tests are repeated with sequences using various cache sizes. The results are summarized here.

So it would appear that the inline construct has a slight performance advantage, particularly when the sequences are defined with a cache. However, the advantage is so slight that I am reluctant to say definitively that the new construct is indeed faster. A second round of testing with the same parameters as before and the performance advantage now tips in favor of the “select from dual” construct.

<table>
<thead>
<tr>
<th>Cache Size</th>
<th>Select from Dual</th>
<th>Inline</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>61.47</td>
<td>61.90</td>
</tr>
<tr>
<td>20</td>
<td>6.76</td>
<td>6.72</td>
</tr>
<tr>
<td>500</td>
<td>3.94</td>
<td>3.89</td>
</tr>
</tbody>
</table>
Identity Columns (New in 12c)

You can utilize the ability to define an IDENTIFY clause against a table column defined using a numeric type, instead of code that creates and uses a sequence object (the Create Sequence privilege is required to create Identity Columns since they are in fact sequential values or sequences). When creating a table (or altering a column) with the 12c Identity Column, the following options are available: ALWAYS, BY DEFAULT, and ON NULL. ALWAYS forces the use of the identity. If an INSERT statement references the Identity Column (even to specify a NULL value), an error will be raised.

An example with ALWAYS looks like this:

```sql
drop table emps PURGE;
CREATE TABLE emps {   
    Emp_ID NUMBER GENERATED ALWAYS AS IDENTITY,
    First_Name VARCHAR2(55),
    Middle_Name VARCHAR2(30),
    Last_Name VARCHAR2(100));
SQL> INSERT INTO emps ('JOE', 'A', 'SMITH');
1 row created.

But any attempt to pass a value for the EMP_ID will result in an error:

```sql
SQL> INSERT INTO emps (Emp_ID, Last_Name) VALUES (2, 'SMITH');
ERROR at line 1:
ORA-32795: cannot insert into a generated always identity column
(passing NULL to the GENERATED ALWAYS column will result with the same error).
```

The BY DEFAULT clause allows you to use the identity if the column isn’t referenced in the INSERT statement, but if the column is referenced, the specified value will be used in place of the identity.

An example with BY DEFAULT looks like this:
The BY DEFAULT ON NULL clause allows the identity to be used if the Identity Column is referenced but a value of NULL is specified.

An example with BY DEFAULT ON NULL looks like this:

```sql
drop table emps PURGE;
CREATE TABLE emps (   Emp_ID NUMBER GENERATED BY DEFAULT ON NULL AS IDENTITY,
                     First_Name VARCHAR2(55),
                     Middle_Name VARCHAR2(30),
                     Last_Name VARCHAR2(100)
);
SQL> INSERT INTO emps (Emp_ID, LAST_NAME) VALUES (2, 'SMITH');
1 row created.

A couple of additional notes about Identity Columns:

- Identity Columns are always NOT NULL.
- [DBA|ALL|USER]_TAB_IDENTITY_COLS views show information about Identity Columns.
- The link between the table and the sequence is stored in the SYS.IDNSEQ$ table:
The following steps must be completed first to use this new extended data type:

1. Restart the database in upgrade mode (STARTUP UPGRADE).
2. Issue ALTER SYSTEM set max_string_size=extended.
3. Execute the utl32k.sql script from rdbms/admin as SYSDBA.
4. Restart the database in normal mode.

Now we can create this table with the extended character data type:
Allow Binding PL/SQL-Only Data Types to SQL Statements (New in 12c)

Oracle 12c now supports the binding of PL/SQL-only data types to anonymous blocks, PL/SQL function calls in SQL, the TABLE operator in SQL, and CALL statements like:

- BOOLEAN Type
- Record Types
- TABLE Operator
- Collections

Some of the most interesting uses of this feature are in dynamic SQL. Let’s take a look at an example with a Boolean type calling function, where annual salary will be increased or not increased based on the passed Boolean parameter:
Use Named Parameters in SQL Function Calls

When passing formal parameter values to PL/SQL subprograms, Oracle has always permitted position, named, and mixed notations. It is generally an accepted best practice to use the named notation, as it both increases code readability and offers a level of protection against changes to a subprogram’s signature. Unfortunately, in prior versions to 11g the named notation was not available when PL/SQL functions were called from within a SQL command. This limitation left PL/SQL function calls that were embedded in SQL statements vulnerable to undesired effects if the subroutine signatures were not changed in a very careful manner.

Let’s look at an example. First, I create a function that accepts a person’s first and last names and formats them into a single string using the format LastName, FirstName:

```sql
CREATE OR REPLACE FUNCTION emp_review (p_emp_id in NUMBER,
    p_review_date in DATE,
    p_full_increase in BOOLEAN)
RETURN VARCHAR2 IS
BEGIN
    IF p_boolean THEN
        UPDATE emp
        SET review_date = p_review_date,
            pay = pay * .3
        WHERE emp_id = p_emp_id;
        RETURN 'INCREASED';
    ELSE
        UPDATE emp
        SET review_date = p_review_date,
            WHERE emp_id = p_emp_id;
        RETURN 'NO INCREASE';
    END IF;
END;
/
SET SERVEROUTPUT ON
DECLARE
    v_sql VARCHAR2(32000); -- (note: utilizing increased allowable size)
    v_boolean BOOLEAN := TRUE;
    v_result VARCHAR2(30);
    v_date DATE;
BEGIN
    v_date := SYSDATE;
    v_sql := 'SELECT emp_review (:357, v_date, :v_boolean) INTO :1 result FROM dual';
    EXECUTE IMMEDIATE l_sql INTO l_result USING l_boolean;
    DBMS_OUTPUT.put_line('Review result = ' || l_result);
END;
/
Review_result = INCREASED

PL/SQL procedure successfully completed.
```
I'll now use this function to format a couple of fictitious records from an EMPLOYEES table. I start out by using the positional notation that was mandatory in 11g:

```sql
CREATE OR REPLACE FUNCTION format name(p first c in varchar2 default null,
  p last c in varchar2 default null)
  return varchar2 is
BEGIN
  return (p last || ', ' || p first || ');
END format name;
```

For comparison purposes, I’ll employ the same data using a PL/SQL block, as that method has always offered the use of named notation:

```sql
DECLARE
cursor v_emps_cur is
  select *
  from emps
  where emp id in (1, 7);
```
As expected, the results are identical to what was returned by the SQL statement. Now let’s fast-forward to a future enhancement in which the FORMAT_NAME function supports the middle name as well:

```
CREATE OR REPLACE FUNCTION format_name(p_first_c in varchar2 default null,
  p_middle_c in varchar2 default null,
  p_last_c in varchar2 default null)
return varchar2 is
BEGIN
  return(p_last_c || ' || p_first_c || ' || p_middle_c);
END format_name;
```

Note that the developer interjected the new middle name parameter between the existing parameters. Re-executing the SQL and PL/SQL extraction commands from before, you see that the former is returning incorrect results because of the positional notation:
You can now utilize the named notation with SQL to limit the impact of function signature changes, as shown here:

```sql
select t.*, 
    format_name(p_first_c => t.first_name, 
                 p_last_c => t.last_name) as name
from emps t
where emp_id in (1, 7);
```

TIP

*Named notation continues to be the preferred method for passing parameters to subroutines. You can now extend this best practice approach to SQL statements to yield consistency across the entire code base.*

**Simplify Loops with the CONTINUE Statement**

The CONTINUE statement is used to cycle a loop (and skip the remaining statements) without requiring a branch to the end or raising an exception. The CONTINUE statement has two forms:

```
CONTINUE;
```
CONTINUE WHEN boolean expression;

The first form executes unconditionally and the second form executes only when the Boolean expression is TRUE. The CONTINUE statement will not necessarily improve performance but it provides better structured coding techniques and helps to avoid the awkward GOTO statement.

The following example displays only numbers divisible by three from within a loop.

**Without CONTINUE statement:**

```sql
BEGIN
  for v_count_i in 1 .. 20 loop
    if mod(v_count_i, 3) != 0 then
      goto skip;
    end if;

    dbms_output.put_line('Value = ' || v_count_i);
    null;
  end loop;
END;
```

Results:
Value = 3
Value = 6
Value = 9
Value = 12
Value = 15
Value = 18

**With CONTINUE statement:**

```sql
BEGIN
  for v_count_i in 1 .. 20 loop
    if mod(v_count_i, 3) != 0 then
    goto skip;
    end if;

    dbms_output.put_line('Value = ' || v_count_i);
  end loop;
END;
```
With CONTINUE statement using WHEN clause:

BEGIN
  for v_count_i in 1 .. 20 loop
    if mod(v_count_i, 3) != 0 then
      continue;
    end if;
    dbms_output.put_line('Value = ' || v_count_i);
  end loop;
END;

Results:
Value = 3
Value = 6
Value = 9
Value = 12
Value = 15
Value = 18

With CONTINUE statement using WHEN clause:

BEGIN
  for v_count_i in 1 .. 20 loop
    continue when mod(v_count_i, 3) != 0;
    dbms_output.put_line('Value = ' || v_count_i);
  end loop;
END;

Results:
Value = 3
Value = 6
Value = 9
Value = 12
Value = 15
Value = 18

From a performance perspective, none of these three techniques has a distinctive advantage over the other two. Consider the following modified versions of the samples executed over a much larger number of iterations:
DECLARE
    v_total_count_i binary_integer := 0;
    v_div3_count_i binary_integer := 0;
BEGIN
    for v_count_i in 1 .. 10000000 loop
        v_total_count_i := v_total_count_i + 1;
        if mod(v_count_i, 3) != 0 then
            goto skip;
        end if;
        v_div3_count_i := v_div3_count_i + 1;
    end loop;
    dbms_output.put_line('Total Iterations: ' || v_total_count_i);
    dbms_output.put_line(' Divisible by 3: ' || v_div3_count_i);
END;
/

Total Iterations: 10000000
Divisible by 3: 3333333
PL/SQL procedure successfully completed
Executed in 10.343 seconds

DECLARE
    v_total_count_i binary_integer := 0;
    v_div3_count_i binary_integer := 0;
BEGIN
    for v_count_i in 1 .. 10000000 loop
        v_total_count_i := v_total_count_i + 1;
        if mod(v_count_i, 3) != 0 then
            continue;
        end if;
        v_div3_count_i := v_div3_count_i + 1;
    end loop;
    dbms_output.put_line('Total Iterations: ' || v_total_count_i);
    dbms_output.put_line(' Divisible by 3: ' || v_div3_count_i);
END;
/

Total Iterations: 10000000
Divisible by 3: 3333333
PL/SQL procedure successfully completed
Executed in 10.358 seconds
TIP
The new CONTINUE statement creates loop constructs that are more streamlined, but there are no performance gains to be realized at this time.

Leverage Compile-Time Warnings to Catch Programming Mistakes (Improved in 12c)

Since 10g, the PL/SQL compiler has had the capability to provide compile-time warnings regarding common programming mistakes. These warnings cover an assortment of issues that, if left unattended, may result in performance problems or logic errors. Before moving into the examples, note that the PL/SQL compiler does not issue compile-time warnings by default. This functionality is controlled by the Oracle Server parameter, PLSQL_WARNINGS. This parameter can be set specifically for a desired session by altering the session, as shown here:

```
alter session set plsql_warnings='ENABLE:ALL';
```

To ensure that compilation warnings are given consistently, however, it is recommended that the parameter be configured at the database level (consider setting this only for development or test
Consider the following sample procedure in which the developer has created an if-then condition that is unreachable during execution. The PL/SQL compiler issues a warning drawing the developer’s attention to the problem.

```sql
create or replace procedure warning_proc is
BEGIN
  if 1 - 2 then
    dbms_output.put_line('Inside If Statement');
  end if;
  dbms_output.put_line('After If Statement');
END warning_proc;
/

SP2-0604: Procedure created with compilation warnings
SQL> show errors
Errors for PROCEDURE WARNING_PROC:

LINE/COL ERROR
-------- ---------------
4/5 PLW-06002: Unreachable code
```

Since 11g, Oracle included additional deficiencies that the PL/SQL compiler can detect. Easily the most notable of these is PLW-06009, which detects the inappropriate use of the WHEN OTHERS exception handler. Consider the following example:
The developer has made a programming error that will cause the variable `v_ctr_n` to be overflowed on the last iteration of the loop. Normally, this error would not be a major concern because the overflow would trip a runtime exception that could be used to respond to and handle the overflow. However, the developer’s inappropriate use of the WHEN OTHERS exception handler effectively suppresses any such runtime exception, so the system reacts as if nothing has gone wrong. Indeed, if the procedure is executed, it seems to complete successfully:

```
SQL> exec warning_proc;
PL/SQL procedure successfully completed.
```

While there are a few legitimate cases in which WHEN OTHERS NULL might be useful, in general, it is an extremely bad programming habit that developers should avoid. Runtime exceptions that should be ignored should be isolated with an exception handler specific to that exception. The WHEN OTHERS handler, when employed, should propagate the exception (or raise a new one) to identify the failure condition to the calling subroutine. Tweaking the previous code in this manner yields the desired runtime results, as shown here:
create or replace procedure warning_proc is
  v_contr number(2);
begin
  for i in 1..100 loop
    v_contr := i;
  end loop;
exception
  when others then
    raise;
end warning_proc;
/

SQL> exec warning_proc;
BEGIN warning_proc; END;
*

ERROR at line 1:
ORA-06512: PL/SQL: numeric or value error: number precision too large
ORA-06512: at "TUSC_11G_BOOK.WARNING_PROC", line 9
ORA-06512: at line 1

TIP
Experienced and novice developers alike should leverage PL/SQL compile-time warnings to catch obscured programming problems before code deployment.

Increase Performance with Native Compilation

Native compilation is the process by which a stored PL/SQL program is compiled into native code that does not need to be interpreted at runtime. In comparison, code that is not natively compiled is stored in an intermediate form that must be interpreted at runtime.

The ability to compile PL/SQL code natively has been around since Oracle9i; however, the implementation has changed significantly starting with 11g. In 9i and 10g, the compiled program units were stored and executed externally as C programs. The compilation required an external C compiler and system configuration by a DBA. Starting with 11g and continuing with 12c, the database can handle the native compilation on its own and an external compiler is no longer needed. The natively compiled program units are stored within the databases in the system tablespace.

Because the natively compiled code does not need to be interpreted at runtime, the expectation is that it will execute faster. However, the native compilation only applies to the procedural code in a PL/SQL program unit, not any embedded SQL statements. As a result, the performance gains to be realized really depend upon how much procedural code exists in relation to SQL code. At a bare minimum, a natively compiled program unit that is SQL heavy should execute at least as fast as its non-natively compiled counterpart. As the volume of procedural code increases, the faster the natively compiled code should be.

To begin, let’s start with four stored procedures utilizing various amounts of procedural and SQL
code. The first procedure contains absolutely no SQL, whereas the rest contains increasing amounts of SQL intermixed with the PL/SQL.

create or replace function native_comp_1 return number as
  v_avg_n number := 0;
  v_total_n number := 0;
BEGIN
  for i in 1..1000000 loop
    v_total_n := v_total_n + i;
    v_avg_n   := v_total_n/i;
  end loop;
  return(v_avg_n);
END;

create or replace function native_comp_2 return number as
  cursor cl is
    select *
    from residents;
BEGIN
  for cl_rec in cl loop
    null;
  end loop;
  return(null);
END;

create or replace function native_comp_3 return number as
  v_salary_n number := 0;
  cursor cl is
    select salary
    from residents;
BEGIN
  for cl_rec in cl loop
    v_salary_n := v_salary_n + cl_rec.salary;
  end loop;
  return(v_salary_n);
END;
The default compilation mode (native or interpreted) can be set at the system level via the PLSQL_CODE_TYPE database initialization parameter. Alternatively, the mode can be changed at the session level using one of the following commands:

```
alter session set plsql_code_type=interpreted;
alter session set plsql_code_type=native;
```

The session/system needs to be altered prior to compiling a given program unit. Altering the compilation mode parameter does not impact program units that are already compiled in the database. To ascertain the compilation type from an existing program unit, query the PLSQL_CODE_TYPE column of the USER_PLSQL_OBJECT_SETTINGS dictionary table.

Here are the results when the test procedures are compiled in interpreted mode:
Here are the results when the test procedures are compiled natively:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Code Type</th>
<th>Iterations</th>
<th>Fastest</th>
<th>Slowest</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>native_comp_1</td>
<td>INTERPRETED</td>
<td>20</td>
<td>5.26</td>
<td>6.12</td>
<td>5.4465</td>
</tr>
<tr>
<td>native_comp_2</td>
<td>INTERPRETED</td>
<td>20</td>
<td>1.97</td>
<td>2.28</td>
<td>2.138</td>
</tr>
<tr>
<td>native_comp_3</td>
<td>INTERPRETED</td>
<td>20</td>
<td>1.17</td>
<td>1.48</td>
<td>1.3555</td>
</tr>
<tr>
<td>native_comp_4</td>
<td>INTERPRETED</td>
<td>20</td>
<td>2.81</td>
<td>3.21</td>
<td>2.8995</td>
</tr>
</tbody>
</table>

Native compilation provided increased performance across the board, particularly with the program units that contained more procedural logic in relation to SQL commands, as detailed in the table:

<table>
<thead>
<tr>
<th>Function</th>
<th>Interpreted</th>
<th>Native</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIVE_COMP_1</td>
<td>5.4465</td>
<td>4.846</td>
<td>11.02</td>
</tr>
<tr>
<td>NATIVE_COMP_2</td>
<td>2.138</td>
<td>2.0515</td>
<td>4.05</td>
</tr>
<tr>
<td>NATIVE_COMP_3</td>
<td>1.3555</td>
<td>1.2065</td>
<td>10.99</td>
</tr>
<tr>
<td>NATIVE_COMP_4</td>
<td>2.8995</td>
<td>2.582</td>
<td>10.64</td>
</tr>
</tbody>
</table>

With nothing to lose and everything to gain, setting the database default to native compilation would seem to make sense. Any performance degradation caused by it—and I have yet to come across any—should be handled on a one-off basis, shifting individual program units back to native interpretation as needed.

Maximize Performance with the Optimizing Compiler

With each release of the database, Oracle tweaks the PL/SQL compiler to yield faster performance. You’ve already seen how natively compiled PL/SQL code can execute faster than code that is interpreted and compiled. Now let’s take a look at what is possible when you give the compiler greater freedom to “tweak” your PL/SQL programs as it compiles them. Since 10g Oracle has given developers the ability to control the level of optimization that is applied via the PLSQL_OPTIMIZE_LEVEL parameter, which has the following valid values:
One of the specific optimizations triggered at Level 2 is subroutine inlining. Subroutine inlining is optimization that replaces modularized subroutines with copies of the subroutine. The intent is to eliminate the inherent overhead when calling modularized program units. The effects should be most dramatic when the subprogram is called repeatedly as part of a large-volume loop. The primary caveat is that subroutine inlining can only occur if the subroutine being called is within the same program unit as the caller.

When a stored program is installed/recompiled, the compiler optimization level defaults from the database configuration, which can be ascertained with the following query:

```sql
SELECT value
FROM v$parameter
WHERE name = 'plsql_optimize_level';
```

Alternatively, you can set a specific optimizer level by altering the current session:

```sql
ALTER SESSION SET plsql_optimize_level=X;
```

Remember, the optimizer level setting only comes into play at the next compilation. It does not impact compiled programs already in the database. Use the ALTER command to recompile any existing program units with the current optimizer setting.

So that you can see what the various optimizer levels bring to the table, I will demonstrate using some stored functions that are compiled at each of the levels and then executed. Note I’m using native compilation throughout this test. First up is a simple function that uses a basic FOR loop and a nested function to compute a running total of the numbers between 1 and 100 million. This procedure does not interact with any database tables.
CREATE OR REPLACE FUNCTION optcomp_1 return number is
  v_total_n number;
PROCEDURE update_total(p_curr_tot_n in out number,
  p_salary_n  in  number) is
BEGIN
  p_curr_tot_n := p_curr_tot_n + p_salary_n;
END update_total;
BEGIN
  v_total_n := 0;
  for i in 1..100000000 loop
    update_total(p_curr_tot_n => v_total_n,
      p_salary_n  => i);
  end loop;
  return(v_total_n);
END optcomp_1;

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Level</th>
<th>Iterations</th>
<th>Fastest</th>
<th>Slowest</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>optcomp_1</td>
<td>0</td>
<td>10</td>
<td>34.4</td>
<td>34.81</td>
<td>34.538</td>
</tr>
<tr>
<td>optcomp_1</td>
<td>1</td>
<td>10</td>
<td>27.14</td>
<td>27.52</td>
<td>27.333</td>
</tr>
<tr>
<td>optcomp_1</td>
<td>2</td>
<td>10</td>
<td>19.17</td>
<td>19.43</td>
<td>19.287</td>
</tr>
<tr>
<td>optcomp_1</td>
<td>3</td>
<td>10</td>
<td>11.53</td>
<td>11.67</td>
<td>11.614</td>
</tr>
</tbody>
</table>

Clearly, the performance increases with each optimizer level. Unfortunately, Oracle does not publish the exact optimizations that are being applied to the code at each level, but it is possible to get some insight, particularly with respect to subroutine inlining.

The technique calls for enabling all PL/SQL warnings prior to compilation:

```
alter session set plsql code type=native;
alter session set plsql_optimize_level=3;
alter session set plsql_warnings = 'enable:all';
```

```
alter function optcomp_1 compile;
```

```
SP2-0807: Function altered with compilation warnings
```

```
show errors;
```

```
Errors for FUNCTION TUSC_11G_BOOK.OPTCOMP_1:
```

```
LINE/COL ERROR
```

```
11/5   PLW-06005: inlining of call of procedure 'UPDATE_TOTAL' was done
3/3    PLW-06006: uncalled procedure "UPDATE TOTAL" is removed.
```

The compilation warnings confirm that subroutine inlining was performed and the original subroutine removed. At Levels 2 and 3, the optimizer is free to rearrange the code to replace the function call (to UPDATE_TOTAL) with a copy of the subroutine, thereby eliminating the overhead. The overhead is small (remember, we are dealing with 100 million loop iterations in this example),
but it does exist.

In the second example, the basic FOR loop is replaced with a cursor to the RESIDENTS table that I have been experimenting with. Recall that this table contains 1 million records. The cursor fetches the salary of each resident and then passes that to a nested subroutine that updates a running total variable:

```sql
CREATE OR REPLACE FUNCTION optcomp 2 return number is
  v_total_n number;
  cursor cl is
    select r.resident_id, r.salary
    from residents r;
  PROCEDURE update_total(p_curr_tot_n in out number, p_salary_n in number) is

  BEGIN
    p_curr_tot_n := p_curr_tot_n + p_salary_n;
  END update_total;
BEGIN
  v_total_n := 0;
  for cl_rec in cl loop
    update_total(p_curr_tot_n => v_total_n, p_salary_n => cl_rec.salary);
  end loop;
  return(v_total_n);
END optcomp_2;
```

These are the testing results:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Level</th>
<th>Iterations</th>
<th>Fastest</th>
<th>Slowest</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>optcomp_2</td>
<td>0</td>
<td>10</td>
<td>8.2</td>
<td>8.35</td>
<td>8.244</td>
</tr>
<tr>
<td>optcomp_2</td>
<td>1</td>
<td>10</td>
<td>7.86</td>
<td>7.92</td>
<td>7.878</td>
</tr>
<tr>
<td>optcomp_2</td>
<td>2</td>
<td>10</td>
<td>.08</td>
<td>1.33</td>
<td>.978</td>
</tr>
<tr>
<td>optcomp_2</td>
<td>3</td>
<td>10</td>
<td>.84</td>
<td>1.11</td>
<td>.952</td>
</tr>
</tbody>
</table>

As before, you can see that performance improves with each optimizer level, with a significant gain as you move beyond Level 1. Looking at the compiler warnings, you will see that the optimizer is inlining both the nested function call (UPDATE_TOTAL) and the cursor definition:
Moving on, the program is revised to no longer fetch the salary in the cursor. The UPDATE_TOTAL nested procedure now has the additional task of fetching the salary for each resident based upon the resident identifier:

```
CREATE OR REPLACE FUNCTION optcomp_3 return number is
    v_total_n number;
    cursor cl is
        select r.resident_id
        from residents r;
    PROCEDURE update_total(p_curr_tot_n in out number,
p_resident_n in number) is
        v_salary_n number;
    BEGIN
        select r.salary
        into v_salary_n
        from residents r
        where r.resident_id = p_resident_n;
p_curr_tot_n := p_curr_tot_n + v_salary_n;
    END update_total;
    BEGIN
        v_total_n := 0;
        for cl_rec in cl loop
            update_total(p_curr_tot_n => v_total_n,
p_resident_n => cl_rec.resident_id);
        end loop;
        return(v_total_n);
    END optcomp 3;
```

These are the testing results:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Level</th>
<th>Iterations</th>
<th>Fastest</th>
<th>Slowest</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>optcomp_3</td>
<td>0</td>
<td>10</td>
<td>34.7</td>
<td>38.19</td>
<td>35.068</td>
</tr>
<tr>
<td>optcomp_3</td>
<td>1</td>
<td>10</td>
<td>34.22</td>
<td>34.28</td>
<td>34.248</td>
</tr>
<tr>
<td>optcomp_3</td>
<td>2</td>
<td>10</td>
<td>24.84</td>
<td>24.89</td>
<td>24.872</td>
</tr>
<tr>
<td>optcomp_3</td>
<td>3</td>
<td>10</td>
<td>24.52</td>
<td>24.62</td>
<td>24.589</td>
</tr>
</tbody>
</table>
This less efficient design definitely takes longer to execute, but it still achieves a significant performance improvement once the optimizer reaches Level 2. You see almost no further improvement as you move to Level 3, however. The PL/SQL compilation warnings reveal that the cursor and the UPDATE_TOTAL procedure call are being inlined just as before. Optimizations or not, the limiting factor here is the 1 million individual queries being issued to perform piecemeal fetching of resident salaries.

The final iteration of the test program replaces the cursor loop with a basic FOR loop spanning the range 0 to 1 million. This is possible because the resident IDs are densely packed in this range.

```sql
CREATE OR REPLACE FUNCTION optcomp_4 return number is
  v_total_n number;
PROCEDURE update_total(p_curr_tot_n in out number,
                        p_resident_n in number) is
  v_salary_n number;
BEGIN
  select r.salary
  into v_salary_n
  from residents r
  where r.resident_id = p_resident_n;
  p_curr_tot_n := p_curr_tot_n + v_salary_n;
END update_total;
BEGIN
  v_total_n := 0;
  for i in 1..1000000 loop
    update_total(p_curr_tot_n => v_total_n,
                 p_resident_n => i);
  end loop;
  return(v_total_n);
END optcomp_4;
```

These are the testing results:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Level</th>
<th>Iterations</th>
<th>Fastest</th>
<th>Slowest</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>optcomp_4</td>
<td>0</td>
<td>10</td>
<td>25.08</td>
<td>25.11</td>
<td>25.098</td>
</tr>
<tr>
<td>optcomp_4</td>
<td>1</td>
<td>10</td>
<td>24.97</td>
<td>25</td>
<td>24.986</td>
</tr>
<tr>
<td>optcomp_4</td>
<td>2</td>
<td>10</td>
<td>24.29</td>
<td>24.58</td>
<td>24.422</td>
</tr>
<tr>
<td>optcomp_4</td>
<td>3</td>
<td>10</td>
<td>23.61</td>
<td>23.69</td>
<td>23.636</td>
</tr>
</tbody>
</table>

This program shows the least amount of improvement as the optimization level increases. As in the previous example, the real limitation here is the high volume of one-off queries that are being issued to retrieve each resident’s salary. Regardless, optimization Level 3 has once again turned in the best performance. The specific optimizations being reported by the compiler are shown here:
Let's investigate subprogram inlining a bit further. As noted earlier, inlining becomes possible at optimization Level 2. That doesn't mean that it will happen at Level 2, just that the optimizer will consider it. The optimizer could choose not to perform inlining based upon some analytical result. If inlining is going to be performed automatically by the optimizer, it would most likely occur at Level 3. Suppose automatic inlining were occurring and the impact was reduced performance. You could reduce the optimization level to prevent the inlining, but you may sacrifice other optimizations in the process. The preferred solution is to stop the inlining and nothing else. You can accomplish this with the INLINE pragma. The INLINE pragma provides a mechanism by which the developer can coerce or prevent inlining. In the case of coercion, it is nothing more than that—a suggestion that the optimizer perform inlining, but the optimizer has the final word. In the case of prevention, however, the optimizer must obey. To demonstrate, I slightly revised the OPTCOMP_1 function that I experimented with earlier to add an INLINE pragma to prevent the inlining of the UPDATE_TOTAL function:

```plsql
CREATE OR REPLACE FUNCTION optcomp 5 return number is
  v_total_n number;
  PROCEDURE update_total(p_curr_tot_n in out number, p_salary_n in number) is
    BEGIN
      p_curr_tot_n := p_curr_tot_n + p_salary_n;
    END update_total;
BEGIN
  v_total_n := 0;
  for i in 1..100000000 loop
    pragma inline(update_total, 'no');
    update_total (p_curr_tot_n => v_total_n, p_salary_n => i);
  end loop;
  return(v_total_n);
END optcomp 5;
```

These are the testing results:
The results are nearly identical to what you saw before, with the sole exception being the results at Level 3. Unlike before, there is almost no improvement as the level changes from 2 to 3. Earlier, Level 3 yielded a performance increase of 8 seconds over Level 2. Reviewing the PL/SQL warnings reveals that the inlining was blocked by the pragma directive:

```
LINE/COL ERROR
---------------------------------
12/5 PLW-06008: call of procedure 'UPDATE TOTAL' will not be inlined
```

Comparing these warnings to those from the analysis of OPTCOMP_1 reveals that the optimizer chose to perform inlining at Level 3 originally.

Clearly, the optimizer is capable of making notable improvements in PL/SQL performance. The test scenarios that I tried did not uncover any situations in which optimization Level 2 or 3 failed to increase performance, although it is always a possibility. It is probably best to leave the optimizer at Level 2, the default, but those wishing to squeeze out every last bit of performance may want to increase that to Level 3.

Use DBMS_APPLICATION_INFO for Real-Time Monitoring

The DBMS_APPLICATION_INFO package provides a powerful mechanism for communicating point-in-time information about execution in an environment. The following example illustrates this, as it enables a long-running PL/SQL program unit to provide information on the progress of the routine every 1000 records. The PL/SQL code segment updates the application information with the number of records processed and the elapsed time every 1000 records.

The following is an example illustrating the update of all employees’ salaries:
DECLARE
  CURSOR cur_employee IS
    SELECT employee_id, salary, ROWID
    FROM a_employees_test;
  lv_new_salary_num NUMBER;
  lv_count_num PLS INTEGER := 0;
  lv_start_time_num PLS_INTEGER;
BEGIN
  lv_start_time_num := DBMS_UTIL.GET_TIME;
  FOR cur_employee_rec IN cur_employee LOOP
    lv_count_num := lv_count_num + 1;
    -- Determination of salary increase
    lv_new_salary_num := cur_employee_rec.salary;
    UPDATE a_employees_test
    SET salary = lv_new_salary_num
    WHERE rowid = cur_employee_rec.ROWID;
    IF MOD(lv_count_num, 1) = 0 THEN
      DBMS_APPLICATION_INFO.SET_MODULE('Records Processed: ' ||
          lv_count_num, 'Elapsed: ' || (DBMS_UTIL.GET_TIME -
          lv_start_time_num)/100 || ' sec');
    END IF;
  END LOOP;
  COMMIT;
  DBMS_APPLICATION_INFO.SET_MODULE('Records Processed: ' ||
      lv_count_num, 'Elapsed: ' || (DBMS_UTIL.GET_TIME -
      lv_start_time_num)/100 || ' sec');
END;
/

To monitor the progress, query the V$SESSION view, as shown in the following example:

```
SELECT username, sid, serial#, module, action
FROM V$SESSION
WHERE username = 'SCOTT';
```

Please note that this query needs to be run in a separate session from the one executing the PL/SQL block.

The following is the output from the V$SESSION view, when queried three different times. The last output is when the PL/SQL program unit was completed.
Your response time will depend on how fast your system is and how well it is architected. The reason for the two records being returned for each query in the preceding output is that both the execution of the PL/SQL program unit to update employees’ salary and the SQL statement to monitor the progress via the V$SESSION view are executed under the SCOTT schema in two different SQL*Plus sessions. The preceding example illustrates a valuable technique to deploy in an environment and provides a real-time monitoring mechanism. It becomes easier to determine accurately how long a program has been running and to estimate how long a program has to complete.

If DBAs do not want users’ queries against the V$SESSION view to return information for all users, they can create a view based on the V$SESSION view that limits the retrieval to only the executing user’s session information. This can be accomplished by executing the commands as the SYS user. The following syntax creates the new view (the new view is named SESSION_LOG, but any name can be used). Including “USER” in the query that follows returns the name of the session user (the user who logged on) with the data type VARCHAR2:

```
CREATE VIEW session_log AS
SELECT *
FROM V$SESSION
WHERE username = USER;
```

The following syntax creates a public synonym:

```
CREATE PUBLIC SYNONYM session_log FOR session_log;
```

The following syntax grants SELECT permission to all users:

```
GRANT SELECT ON session_log TO PUBLIC;
```
Once the SESSION_LOG view is set up, as shown in the preceding statements, the preceding V$SESSION view query can be changed to SELECT from the SESSION_LOG view, as in the following query, to limit the output to only the user executing the query:

```
SELECT username, sid, serial#, module, action
FROM   session_log;
```

**TIP**

*Use the Oracle-supplied package DBMS_APPLICATION_INFO to log point-in-time information to the V$SESSION view to enable monitoring of long-running processes.*

---

**Log Timing Information in a Database Table**

Monitoring performance is an ongoing process. Many variables in an environment can change and affect performance over time; therefore, performance should be monitored continuously. Some of the variables include user growth, data growth, reporting growth, application modification/enhancement deployment, and additional load on the system from other applications. With this in mind, an Oracle system must be regularly monitored to ensure performance remains at, or above, an acceptable level. (Oracle ADDM does this for you as well.) One method for monitoring the system performance is to create a mechanism for logging timing statistics for certain aspects of an application. Batch programs are good candidates for this monitoring procedure. The monitoring procedure can be accomplished by inserting timing statistics into a database table. The following example provides the database table logging method by creating a database table and then integrating INSERT statements for the timing of the process into the table. Oracle’s own SQL monitoring starts when a SQL statement runs parallel or when it has consumed at least 5 seconds of CPU or I/O time in a single execution. You can monitor the statistics for SQL statement execution using many V$ views (especially V$SQL and V$SQL_MONITOR). See Chapter 12 for many great queries to the V$ views used for Oracle monitoring.

In this example, the important information to log in the database table is the program identifier (some unique method of identifying the program), the date and time the program is executed, and the elapsed time of the execution. One column has been added for this application, namely, the number of records updated. This additional column is important for this application to monitor the growth of employee records being processed. When creating a timing log table for your application, add columns to store additional important processing information that may affect your timing results. Create the following table to log the timing information:

```sql
CREATE TABLE timing_log (prog_id VARCHAR2(20), date_time DATE, elapsed_time NUMBER, records_updated NUMBER);
```
Once you have created the table, you can enhance PL/SQL program units to log the timing information into the PROCESS_TIMING_LOG table, as illustrated in the following program:

```sql
CREATE TABLE process_timing_log
(
    program_name VARCHAR2(30),
    execution_date DATE,
    records_processed NUMBER,
    elapsed_time_sec NUMBER)
;
```

Once you have created the table, you can enhance PL/SQL program units to log the timing information into the PROCESS_TIMING_LOG table, as illustrated in the following program:

```sql
CREATE OR REPLACE PROCEDURE update_salary AS
    CURSOR cur_employee IS
        SELECT employee_id, salary, ROWID
        FROM s_employee_test;
    lv_new_salary_num NUMBER;
    lv_count_num      PLS_INTEGER := 0;
    lv_start_time_num PLS_INTEGER;
    lv_total_time_num NUMBER;
BEGIN
    lv_start_time_num := DBMS.Utility.GET_TIME;
    FOR cur_employee_rec IN cur_employee LOOP
        lv_count_num := lv_count_num + 1;
        -- Determination of salary increase
        lv_new_salary_num := cur_employee_rec.salary;
        UPDATE s_employee_test
        SET salary     = lv_new_salary_num
        WHERE rowid = cur_employee_rec.ROWID;
    END LOOP;
    lv_total_time_num := (DBMS.Utility.GET_TIME -
        lv_start_time_num)/100;
    INSERT INTO process_timing_log
        (program_name, execution_date, records_processed,
         elapsed_time_sec)
    VALUES
        ('UPDATE_SALARY', SYSDATE, lv_count_num,
         lv_total_time_num);
    COMMIT;
END update_salary;
/
```

As shown in the preceding code segment, the timer is started at the beginning of the program unit and then stopped at the end of the program unit. The difference between the start and ending times is logged into the PROCESS_TIMING_LOG for each execution of the UPDATE_SALARY program. If the UPDATE_SALARY program unit is executed three times, as shown in the following syntax, then three timing records are inserted into the PROCESS_TIMING_LOG table:
The following script retrieves the information from the PROCESS_TIMING_LOG table:

```sql
SELECT program_name,
       TO_CHAR(execution_date,'MM/DD/YYYY HH24:MI:SS') execution_time,
       records_processed, elapsed_time_sec
FROM process_timing_log
ORDER BY 1,2;
```

This output shows one possible result. There is a difference in the elapsed time for the same program execution. If the difference increases over time, this may indicate a need to analyze the program unit further or the application to determine what caused the execution time increase. With logging mechanisms in place, the elapsed time can be monitored at any point in time because the timing information is being logged to a database table.

In the preceding example, the time logged was per program unit. If the program is complex and executed for an extended period of time, you may want to change the logging of timing statistics in the program. The INSERT into the PROCESS_TIMING_LOG table could be performed after a certain number of iterations or to log timing for certain functionality in a program unit.

**TIP**

Log (INSERT) execution timing information into a database table for long-running PL/SQL program units to integrate a proactive performance-monitoring mechanism into your system. The database table can be reviewed at any point in time to determine if performance has decreased over time.

Another method is to use the DBMS_PROFILER package to get timing statistics per line of PL/SQL code. See Metalink (My Oracle Support) article 104377.1, “Performance of New PL/SQL Features” for more information.

**TIP**
System load in terms of number of active sessions can have a large impact on the performance of program execution; therefore, modifying the database table logging method to include a column for the number of active sessions can be helpful. You can fill this column by adding one additional query to the program unit being executed to retrieve the count from the V$SESSION view.

**Reduce PL/SQL Program Unit Iterations and Iteration Time**

Any PL/SQL program unit involving looping logic is a strong candidate for performance improvements. Potential improvements for these types of programs can be accomplished in two ways. The first is to reduce the number of iterations by restructuring the logic to accomplish the same functional result. The second is to reduce the time per iteration. Either reduction often improves performance dramatically.

To bring this point into perspective, think of the following scenario: You need to process 9000 employee records in a PL/SQL routine, and to process each employee takes 2 seconds. This equates to 18,000 seconds, which equates to 5 hours. If the processing per employee is reduced to 1 second, the time to process the 9000 employees is reduced by 9000 seconds, or 2.5 hours … quite a difference!

The following example shows a minor restructuring of a PL/SQL program unit to illustrate reducing per-loop processing and overall processing. The program unit processes a loop 1,000,000 times. Each iteration adds to the incremental counter used to display a message each 100,000 iterations and adds to the total counter used to check for loop exiting. To view DBMS_OUTPUT, make sure you issue the SET SERVEROUTPUT ON command first.

```sql
CREATE OR REPLACE PACKAGE stop watch AS
  pv start time num PLS INTEGER;
  pv stop time num PLS INTEGER;
  pv_last_stop_time_num PLS_INTEGER;
  -- This procedure creates a starting point for the timer routine and
  -- is usually called once at the beginning of the PL/SQL program unit.
  PROCEDURE start_timer;

  -- This procedure retrieves a point in time and subtracts the current
  -- time from the start time to determine the elapsed time. The
  -- interval elapsed time is logged and displayed. This procedure is
  -- usually called repetitively for each iteration or a specified
  -- number of iterations.
  PROCEDURE stop_timer;
END stop watch;
/
```

The package has been created.
CREATE OR REPLACE PACKAGE BODY stop_watch AS
PROCEDURE start_timer AS
BEGIN
    pv_start_time_num := DBMS UTILITY.GET TIME;
    pv_last_stop_time_num := pv_start_time_num;
END start_timer;
PROCEDURE stop_timer AS
BEGIN
    pv_stop_time_num := DBMS UTILITY.GET_TIME;
    DBMS_OUTPUT.PUT_LINE('Total Time Elapsed: ' ||
                              TO_CHAR((pv_stop_time_num - pv_start_time_num)/100,
                              '999,999.99') || ' sec  Interval Time: ' ||
                              TO_CHAR((pv_stop_time_num - pv_last_stop_time_num)/100,
                              '999,999.99') || ' sec');
    pv_last_stop_time_num := pv_stop_time_num;
END stop_timer;
END;
/

The package body has been created.
By changing the program to only add to the LV_TOTAL_COUNTER_NUM variable each time the incremental counter reaches 100,000, overall execution time is reduced:
The DBMS_OUTPUT.PUT_LINE output for each batch of processed records was not included in the following output:

```
IF lv_counter_num >= 100000 THEN
  DBMS_OUTPUT.PUT_LINE('Processed 100,000 Records. Total ' ||
                        'Processed ' || lv_total_counter_num);
  lv_total_counter_num := lv_total_counter_num +
                        lv_counter_num;
  lv_counter_num := 0;
  EXIT WHEN lv_total_counter_num >= 100000;
END IF;
END LOOP;
stop_watch.stop_timer;
```

The DBMS_OUTPUT.PUT_LINE output for each batch of processed records was not included in the following output:

```
Total Time Elapsed:     .47  sec  Interval Time:     .47  sec
PL/SQL procedure successfully completed.
```

The preceding example illustrates the performance difference achieved by changing the iteration logic to reduce the timing per iteration. The example is basic and shows a 34 percent increase on 1 million iterations. Based on the restructuring and the iterations, this improvement can make a huge difference.

**TIP**

*When a PL/SQL program unit involves extensive looping or recursion, concentrate on reducing the execution time per iteration. The benefits add up fast, and it is easy to do the math to determine the overall improvement potential. Also review the looping or recursion for restructuring to reduce the number of iterations, while keeping the functionality. With the extreme flexibility of PL/SQL and SQL, a variety of ways typically exist to accomplish the same result. If a PL/SQL program unit is not performing optimally, sometimes you have to rewrite the logic another way.*

**Use ROWID for Iterative Processing**

The ROWID variable can improve PL/SQL programs that retrieve records from the database, perform manipulation on the column values, and then complete with an UPDATE to the retrieved record. When retrieving each record, the ROWID can be added to the selected column list. When updating each record, the ROWID can be used in the predicate clause. The ROWID is the fastest access path to a record in a table, even faster than a unique index reference.

The performance improvement of using the ROWID is illustrated in the following example. The
example retrieves each of the 25,000 employee records, calculates a new salary for each employee, and then updates the employees’ salary. The actual salary calculation is not shown in this example. The first PL/SQL code segment shows the timing results with the UPDATE using the EMPLOYEE_ID column, which has a unique index on the column:

```
DECLARE
    CURSOR cur_employee IS
        SELECT employee_id, salary
        FROM   s_employee test;
    lv_new_salary_num NUMBER;
BEGIN
    stop_watch.start_timer;
    FOR cur_employee_rec IN cur_employee LOOP
        -- Determination of salary increase
        lv_new_salary_num := cur_employee_rec.salary;
        UPDATE s_employee_test
        SET salary   = lv_new_salary_num
        WHERE employee id = cur employee_rec.employee id;
    END LOOP;
    COMMIT;
    stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Total Time Elapsed: 1.71 sec  Interval Time: 1.71 sec
PL/SQL procedure successfully completed.
```

```
Total Time Elapsed: 1.59 sec  Interval Time: 1.59 sec
PL/SQL procedure successfully completed.
```

In the following procedure, the same functionality is maintained while changing the UPDATE to perform the UPDATE based on the ROWID. This involves adding the ROWID in the SELECT statement and changing the UPDATE predicate clause.
The following output shows the timing of two executions of the preceding code segment:

<table>
<thead>
<tr>
<th>Total Time Elapsed:</th>
<th>1.45 sec</th>
<th>Interval Time:</th>
<th>1.45 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL/SQL procedure successfully completed.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Time Elapsed:</th>
<th>1.48 sec</th>
<th>Interval Time:</th>
<th>1.48 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL/SQL procedure successfully completed.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As evidenced from the timings, execution is faster using the ROWID. The first PL/SQL code segment UPDATE statement retrieves the result by using the index on EMPLOYEE_ID to get the ROWID and then goes to the table to search by ROWID. The second PL/SQL code segment UPDATE statement goes directly to the table to search by ROWID, thus eliminating the index search. The performance improvement increases when more records are involved and when the index used does not refer to a unique index.

TIP
Use the ROWID variable to enhance performance when SELECTing a record in a PL/SQL program unit and then manipulating the same record in the same PL/SQL program unit.

Standardize on Data Types, IF Statement Order, and PLS_INTEGER

Several minor programming modifications can be introduced into your standard PL/SQL development
that can improve performance. Three of these techniques are outlined in this section:

- Ensure the same data types in comparison operations.
- Order IF conditions based on the frequency of the condition.
- Use the PLS_INTEGER PL/SQL data type for integer operations.

Ensure the Same Data Types in Comparison Operations

When variables or constant values are compared, they should have the same data type definition. If the comparison does not involve the same data types, then Oracle implicitly converts one of the values, thus introducing undesired overhead. Any time values are compared in a condition, the values should be the same data type. You should use this standard when developing PL/SQL program units as it is good programming style.

The following procedure illustrates the cost of comparing different data types, namely, a numeric data type to a character value in the IF statement:

```sql
CREATE OR REPLACE PROCEDURE test if (p condition num NUMBER) AS
    lv_temp_num NUMBER := 0;
    lv_temp_cond_num NUMBER := p_condition_num;
BEGIN
    stop_watch.start_timer;
    FOR lv_count_num IN 1..100000 LOOP
        IF lv_temp_cond_num = '1' THEN
            lv temp_num := lv temp num + 1;
    ```
The following illustrates the execution of the TEST_IF procedure:

EXECUTE test_if(8)

The following output is the execution result of the TEST_IF procedure:

Total Time Elapsed:       .26 sec   Interval Time:       .26 sec
PL/SQL procedure successfully completed.

Unnecessary overhead is introduced with the different data types. If the procedure is changed to the same data type comparisons, the following execution is much faster:
CREATE OR REPLACE PROCEDURE test_if (p_condition_num NUMBER) AS
 lv_temp_num NUMBER := 0;
 lv_temp_cond_num NUMBER := p_condition_num;
BEGIN
  stop watch.start timer;
  FOR lv_count num IN 1..100000 LOOP
    IF lv_temp_cond_num - 1 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 2 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 3 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 4 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 5 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 6 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 7 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSE
      lv_temp_num := lv_temp_num + 1;
    END IF;
  END LOOP;
  stop watch.stop_timer;
END;
/

The following code listing illustrates the execution of the new TEST_IF procedure:

```
EXECUTE test_if(8)
```

Total Time Elapsed: .17 sec  Interval Time: .17 sec
PL/SQL procedure successfully completed.

As shown in the preceding examples, the execution is 23 percent faster. The improvement increases as the frequency of execution increases.

Therefore, in the final example, the comparison in the IF statement of LV_TEMP_COND_NUM to a 1,2,3, and so forth, is comparing a NUMBER to a PLS_INTEGER. Some internal Oracle conversion overhead is still taking place. To eliminate this overhead, the 1,2,3 … should be changed to 1.0, 2.0, 3.0 …. When I made this change to the final example, the timing was reduced to 0.16 seconds.
TIP
Ensure all conditional comparisons compare the same data types. Additionally, ensure the data types within the numeric family are comparing the same subtype.

Order IF Conditions Based on the Frequency of the Condition

The natural programming method when developing IF statements with multiple conditions is to order the conditional checks by some sequential order. This order is typically alphabetical or numerically sequenced to create a more readable segment of code, but it usually is not the most optimal order. Especially when using the ELSIF condition several times in an IF statement, the most frequently met condition should appear first, followed by the next most frequent match, and so forth.

In the preceding section, the execution of the procedure was always carried out by passing an 8, which meant every loop had to check all eight conditional operations of the IF logic to satisfy the condition. If you pass a 1, which is equivalent to saying the first condition satisfies all IF executions, you get a more optimized result, as shown in the following example:

```sql
EXECUTE test if(1)
```

Total Time Elapsed: 0.05 sec  Interval Time: 0.05 sec
PL/SQL procedure successfully completed.

The preceding output illustrates a performance improvement from the preceding section with the correct ordering of IF conditions. Therefore, take the extra step of analyzing IF condition order before coding them.

TIP
Ensure the string of PL/SQL IF conditions appear in the order of most frequently satisfied, not a numerical or alphanumerical sequential order.

Use the PLS_INTEGER PL/SQL Data Type for Integer Operations

The typical standard for declaring a numeric data type is to use the NUMBER data type. In PL/SQL release 2.2, Oracle introduced the PLS_INTEGER data type. This data type can be used in place of
any numeric family data type declaration, as long as the content of the variable is an integer and remains within the bounds of –2147483648 and +2147483647. Therefore, most counters and operations with integers can use this data type. The PLS_INTEGER involves fewer internal instructions to process, thus improving performance when using this numeric data type. The more references to this variable, the more improvement realized. Operations on NUMBER data types use library arithmetic, whereas operations on the data types PLS_INTEGER, BINARY_FLOAT, and BINARY_DOUBLE use hardware arithmetic. For local integer variables, use PLS_INTEGER. For variables that can never have the value NULL, do not need overflow checking, and are not used in performance-critical code, use SIMPLE_INTEGER (see the Oracle Database PL/SQL Language Reference for more types and additional information). Note also that if you assign a PLS_INTEGER variable to a NUMBER variable, then PL/SQL converts the PLS_INTEGER value to a NUMBER value (because the internal representations of the values differ). However, whenever possible, you should avoid these implicit conversions.

This improvement for PLS_INTEGER is illustrated in the following PL/SQL code segment. The code segment is the same example as used in the previous two sections, with the data type declarations being changed to PLS_INTEGER from NUMBER.

```sql
CREATE OR REPLACE PROCEDURE test_if (p_condition_num PLS_INTEGER) AS
  lv_temp_num        PLS_INTEGER := 0;
  lv_temp_cond_num   PLS_INTEGER := p_condition_num;
BEGIN
  stop_watch.start_timer;
  FOR lv_count_num IN 1..100000 LOOP
    IF lv_temp_cond_num = 1 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 2 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 3 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 4 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 5 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSIF lv_temp_cond_num = 6 THEN
      lv_temp_num := lv_temp_num + 1;
    ELSE
      lv_temp_num := lv_temp_num + 1;
    END IF;
  END LOOP;
  stop_watch.stop_timer;
END;
/```
The following illustrates the execution of the TEST_IF procedure:

```sql
EXECUTE test_if(1)
```

The following performance improvement is evident based on the execution results:

Total Time Elapsed:   .03 sec   Interval Time:    .03 sec
PL/SQL procedure successfully completed.

**TIP**

Use the PLS_INTEGER type when processing integers to improve performance. If a number with precision is assigned to a PLS_INTEGER variable, the value will be rounded to a whole number as if the ROUND function had been performed on the number.

**Reduce the Calls to SYSDATE**

The SYSDATE variable is a convenient method of retrieving the current date and time. Calls to SYSDATE involve some overhead; therefore, if this variable is needed to log the date of certain processing, the call to this variable should be made once at the start of the program rather than at each iteration. This technique of calling SYSDATE once at the start of the program assumes the date logging is desired at the point in time the program started.

The reduction of SYSDATE calls is illustrated in the following example. The example loops through 10,000 iterations, calling SYSDATE (only the date portion of the variable because the TRUNC function is used to truncate the time portion) every iteration.

```sql
DECLARE
  lv_current_date DATE;
BEGIN
  STOP_WATCH.START_TIMER;
  FOR lv_count_num IN 1..10000 LOOP
    lv_current_date := TRUNC(SYSDATE);
  END LOOP;
  STOP_WATCH.STOP_TIMER;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:
The following PL/SQL code segment has been modified to retrieve the SYSDATE only once, at the beginning of the program, and set to another variable each iteration:

```sql
DECLARE
  lv_current_date DATE := TRUNC(SYSDATE);
  lv_final_date DATE;
BEGIN
  stop_watch.start_timer;
  FOR lv_count_num IN 1..10000 LOOP
    lv_final_date := lv_current_date;
  END LOOP;
  stop_watch.stop_timer;
END;
/
```

The following output shows the timing of two executions of the preceding code segment:

```
Total Time Elapsed: .04 sec   Interval Time: .04 sec
PL/SQL procedure successfully completed.

Total Time Elapsed: .01 sec   Interval Time: .01 sec
PL/SQL procedure successfully completed.
```

As evident in the preceding example, overhead is associated with the SYSDATE call, and the number of calls to SYSDATE should be reduced, if possible.

**TIP**
Attempt to limit the calls to SYSDATE in iterative or recursive loops because overhead is associated with this variable. Set a PL/SQL date variable to SYSDATE in the declaration and reference the PL/SQL variable to eliminate the overhead.

**Reduce the Use of the MOD Function**
Certain PL/SQL functions are more costly to use than others. MOD is one function that has better overall performance when applied using additional PL/SQL logic. This is illustrated in the following example. MOD is a useful function, but if it is executed in an IF statement, as illustrated here, additional overhead is introduced.

BEGIN
    stop_watch.start_timer;
    FOR lv_count_num IN 1..10000 LOOP
        IF MOD(lv_count_num, 1000) = 0 THEN
            DBMS_OUTPUT.PUT_LINE('Hit 1000; Total: ' || lv_count_num);
        END IF;
    END LOOP;
    stop_watch.stop_timer;
END;
/

The following output shows the timing of two executions of the preceding code segment:

Hit 1000; Total: 1000
Hit 1000; Total: 2000
Hit 1000; Total: 3000
Hit 1000; Total: 4000
Hit 1000; Total: 5000
Hit 1000; Total: 6000
Hit 1000; Total: 7000
Hit 1000; Total: 8000
Hit 1000; Total: 9000
Hit 1000; Total: 10000
Total Time Elapsed: 0.04 sec  Interval Time: 0.04 sec
PL/SQL procedure successfully completed.

Total Time Elapsed: 0.04 sec  Interval Time: 0.04 sec

Here, I have modified the preceding PL/SQL code segment to eliminate use of the MOD function and perform the same check with additional PL/SQL logic:
As shown in the two preceding examples, the MOD function adds overhead. You can get better performance with PL/SQL IF statements.

```
DECLARE
  lv_count_inc_num PLS_INTEGER := 0;
BEGIN
  stop watch.start_timer;
  FOR lv_count_inc_num IN 1..10000 LOOP
    lv_count_inc_num := lv_count_inc_num + 1;
    IF lv_count_inc_num = 1000 THEN
      DBMS_OUTPUT.PUT_LINE('Hit 1000; Total: ' || lv_count_inc_num);
    end if;
    lv_count_inc_num := 0;
  END LOOP;
  stop watch.stop_timer;
END;
/

Hit 1000; Total: 1000
Hit 1000; Total: 2000
Hit 1000; Total: 3000
Hit 1000; Total: 4000
Hit 1000; Total: 5000
Hit 1000; Total: 6000
Hit 1000; Total: 7000
Hit 1000; Total: 8000
Hit 1000; Total: 9000
Hit 1000; Total: 10000

Total Time Elapsed: .01 sec   Interval Time: .01 sec
PL/SQL procedure successfully completed.

Total Time Elapsed: .00 sec   Interval Time: .00 sec
```

As shown in the two preceding examples, the MOD function adds overhead. You can get better performance with PL/SQL IF statements.

**Improve Shared Pool Use by Pinning PL/SQL Objects**

The SHARED_POOL_SIZE parameter sets the amount of shared pool allocated in the SGA (see Chapter 4 and Appendix A for a detailed look at SHARED_POOL_SIZE and closely related shared pool parameters). The shared pool stores all SQL statements and PL/SQL blocks executed in the Oracle database. Given the method by which Oracle manages the shared pool, as far as aging, the shared pool can become fragmented. In addition, since Oracle will not age any objects that are currently being processed by a session, you may get an Oracle error indicating that the shared pool does not have enough memory for a new object. The exact error message is “ORA-4031: unable to allocate XXX bytes of shared memory” (where XXX is the number of bytes Oracle is attempting to allocate). If you receive this error, it means you should increase the size of your SGA shared pool as soon as possible. The method to do this prior to Oracle9i was to modify the initialization parameter SHARED_POOL_SIZE and then shut down and start up the database. The quick, but costly, method of eliminating this error until the next database shutdown was to flush the SGA shared pool. You
accomplished this with the following command (only allowed if ALTER SYSTEM privilege is assigned to a user):

```
alter system flush shared_pool;
```

In Oracle9i, you could modify the SHARED_POOL_SIZE parameter without shutting down the database as long as you didn’t exceed the SGA_MAX_SIZE. This eliminated the need to do things that you had to do in previous versions. You still had to pin the large objects into the shared pool when the database had started and make sure the shared pool was large enough for all of these statements to be cached. Starting with 10g, Oracle uses Automatic Memory Management (AMM). In both 11g and 12c, you can set the MEMORY_TARGET (but you can also set a minimum for the SHARED_POOL_SIZE). Oracle internally manages the memory parameters for you and can be altered dynamically as long as you don’t exceed the value of MEMORY_MAX_TARGET (see Chapter 4 on setting initialization parameters).

---

*Pinning (Caching) PL/SQL Object Statements into Memory*

In the event that you cannot maintain a sufficient SHARED_POOL_SIZE to keep all statements in memory, keeping the most important objects cached (pinned) in memory may become necessary. The following example shows how to pin PL/SQL object statements (the procedure PROCESS_DATE is pinned in the example that follows) in memory using the DBMS_SHARED_POOL.KEEP procedure:

```
begin
  dbms_shared_pool.keep('process_date','p');
end;
/
```

or

```
execute sys.dbms_shared_pool.keep ('SYS.STANDARD');
```

By pinning an object in memory, the object will not be aged out or flushed until the next database shutdown. Also consider My Oracle Support Note 61760.1: DBMS_SHARED_POOL should be created as user SYS. No other user should own this package. Any user requiring access to the package should be granted EXECUTE privileges by SYS. If you create the package in the SYS schema, and run the sample code in a different schema, you need to
1. Grant the EXECUTE_CATALOG_ROLE role to the user running the example (i.e., TEST), and grant EXECUTE privilege on DBMS_SHARED_POOL to TEST.

2. Fully qualify the package, as in SYS.DBMS_SHARED_POOL.KEEP, because the dbmspool.sql script does not create a public synonym for this package.

**TIP**

Use the DBMS_SHARED_POOL.KEEP procedure to pin PL/SQL objects into the shared pool.

**NOTE**

To use this procedure prior to Oracle 10g, you had to first run the dbmspool.sql script. The prvtpool.plb script is automatically executed after dbmspool.sql runs. In 10g through 12c, the dbmspool.sql script is called by catpdbms.sql, and catpdbms.sql is called by catproc, so the procedure is already created.

### Pinning All Packages

To pin all packages in the shared pool, execute the following as the SYS user (this code comes from My Oracle Support):

```sql
declare
  own varchar2(100);
  nam varchar2(100);
  cursor pkgs is
    select owner, object_name
    from dba_objects
    where object_type = 'PACKAGE';
begin
  open pkgs;
  loop
    fetch pkgs into own, nam;
    exit when pkgs nós found;
    dbms_shared_pool.keep(owner || '.' || nam, 'P');
  end loop;
end;
/```
A more targeted approach, pinning only packages that need to be reloaded, would be better than pinning all packages, especially because most DBA interfaces since Oracle9i involve PL/SQL packages. At the very least, you should check to make sure you are not trying to pin invalid packages as well. Common packages that are shipped with Oracle (that should be kept) include STANDARD, DBMS_STANDARD, and DIUTIL.

**TIP**

Use the DBMS_SHARED_POOL.KEEP procedure in PL/SQL to pin all packages when the database is started (if memory/shared pool permits) and to avoid errors involving loading packages in the future.

### Identify PL/SQL Objects That Need to Be Pinned

Fragmentation causing several small pieces to be available in the shared pool, and not enough large contiguous pieces, is a common occurrence. The key to eliminating shared pool errors (as noted in the preceding section) is to understand which of the objects will be large enough to cause problems when you attempt to load them. Once you know the problem PL/SQL, you can then pin this code when the database has started (and the shared pool is completely contiguous). Doing this ensures that your large packages are already in the shared pool when they are called, instead of searching for a large contiguous piece of the shared pool (which may not be there later as the system is used). You can query the V$DB_OBJECT_CACHE view to determine PL/SQL that is both large and currently not marked “kept.” These are objects that may cause problems (due to their size and need for a large amount of contiguous memory) if they need to be reloaded at a later time. This query only shows the current statements in the cache. The example that follows searches for those objects requiring greater than 100K:

```sql
select name, sharable_mem
from v$db_object_cache
where sharable_mem > 100000
and type in ('PACKAGE', 'PACKAGE BODY', 'FUNCTION', 'PROCEDURE')
and kept = 'NO';
```

**TIP**

Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also large enough to cause problems potentially.
Use and Modify DBMS_SHARED_POOL.SIZES

An alternative and very precise indication of shared pool allocation can be viewed through the DBMS_SHARED_POOL.SIZES package procedure. This call accepts a MINIMUM SIZE parameter and displays all cursors and objects within the shared pool of a size greater than that provided. The following is the actual statement issued to retrieve this:

```sql
select to_char(sharable_mem / 1000, '999999') sz, decode
    (kept_versions, 0, '' , rpad('yes(' || to_char(kept_versions)
    || '))', 6) keeppd, rawtohex(address) || ',' || to_char
    (hash_value) name, substr(sql_text, 1, 1354) extra, 1 iscursor
from v$sqlarea
where sharable_mem > &min_ksize * 1000
union
select to_char(sharable_mem / 1000, '999999') sz, decode(kept,'yes', 'yes ','') keeped, owner || '.' || name || load(' ', length(owner) + length(name) ) ) || '(' || type || ')
    name, null extra, 0 iscursor
from v$dh_object_cache v
where sharable_mem > &min_ksize * 1000
order by 1 desc;
```

The preceding query can be placed into a procedure package, of your own construction, to display a formatted view of cursors and objects within the shared pool.

Find Large Objects

You can use the DBMS_SHARED_POOL.SIZES package procedure (DBMS_SHARED_POOL is the package and SIZES is the procedure within the package) to view the objects using shareable memory higher than a threshold that you set.

Execute the DBMS_SHARED_POOL.SIZES package as displayed next for a threshold of 100K (the output follows):
Get Detailed Object Information from DBA_OBJECT_SIZE

Query the DBA_OBJECT_SIZE view to show the memory used by a particular object along with much more detailed information concerning the object:

```sql
SET SERVEROUTPUT ON SIZE 10000;
BEGIN
SYS.DBMS_SHARED_POOL.GET_SIZES(100);
END;
/

SIZE(K) KEPT NAME SYS_STANDARD (PACKAGE)
118 YES DT.OWNER, DT.TABLE_NAME, DT.TABLESPACE_NAME,
109 DT.INITIAL_EXTENT, DT.NEXT_EXTENT, DT.NUM_ROWS,
DT.AVG_ROW_LEN,
SUM(DE.BYTES) PHY_SIZE
FROM DBA_TABLES DT, DBA_SEGMENTS DE
WHERE DT.OWNER = DE.OWNER
AND DT.TABLE_NAME = DE.SECTION_NAME
AND DT.TABLESPACE_NAME = DE.TABLESPACE_NAME
GROUP BY DT.OWNER, DT.TABLE_NAME, DT.TABLESPACE_NAME,
DT.INITIAL_EXTENT, DT.NEXT
(0R14559C, 3388846737) (CURSOR)
RDBA.RDBA_GENERATE_STATISTICS (PACKAGE)
PL/SQL procedure successfully completed.
```

Get Contiguous Space Currently in the Shared Pool
Why does the shared pool return errors when an object is loaded? The answer is that a large enough piece of the shared pool is not available to fit the piece of code. In the last section you learned how to find the size of the code that you have. You also saw in a previous section how to pin pieces of code into the shared pool. Now, let’s look at the query that will tell you which code, of the code that has made it into the shared pool, is very large and either should be pinned or should be investigated and shortened if possible.

The following query accesses an X$ table (see Chapter 13), and you must be the SYS user to access these tables:

```sql
select ksmchsiz, ksmchcom
from x$ksmsp
where ksmchsiz > 10000
and ksmchcom like '%$PL/SQL$';
```

This query shows that the packages that have been accessed are very large and should be pinned at the time that the database has started. If the last line of this query is eliminated, it will also show the large pieces of free memory (KSMCHCOM = ‘free memory’ and KSMCHCOM = ‘permanent memory’) that are still available (unfragmented) for future large pieces of code to be loaded. See Chapter 13 for more details on the X$ tables and example output.

**TIP**

Query X$KSMSP to find all large pieces of PL/SQL that have appeared in the shared pool. These are candidates for pinning when the database has started.

**Find Invalid Objects**

Developers often change a small section of PL/SQL code that fails to compile upon execution, forcing an application failure. A simple query, reviewed daily, helps you spot these failures before the end user does:

```sql
col "Owner" format a12
col "Object" format a20
col "OType" format a12
```
The preceding example displays any objects that are invalid, meaning they were never compiled successfully or changes in dependent objects have caused them to become invalid. If you have a procedure called PROCESS_DATE, for example, which was found to be invalid, you could manually recompile this procedure with the following command:

```sql
alter procedure PROCESS_DATE compile;
```

Once this command is executed and PROCESS_DATE passes the recompile, Oracle would change the procedure automatically from INVALID to VALID.

Another manual method that exists is to call the DBMSUTILITY.COMPILE_SCHEMA package procedure to recompile all stored procedures, functions, and packages for a given schema:

```sql
begin
  dbms_utility.compile_schema('USERA');
end;
/
```

**NOTE**

You could also run the `utlrp.sql` script to recompile all the invalid objects in the database. See the script for restrictions on running this script.

To find the state of all PL/SQL objects for your schema, execute the following:
TIP
You can recompile an entire schema (either all or just the invalid objects) with
DBMS_UTILITY.COMPILE_SCHEMA.

Find Disabled Triggers
In some respects, a disabled trigger is far more dangerous than an invalid object because it doesn’t fail—it just doesn’t execute! Disabled triggers can have severe consequences for applications, and consequently business processes, that depend on business logic stored within procedural code.

The following script identifies disabled triggers:

```
col "Owner/Table" format a30
col "Trigger Name" format a25
col "Event" format a15
col "Owner" format a10
select substr(owner,12) "Owner", trigger_name "Trigger Name",
    trigger_type "Type", triggering_event "Event",
    table_owner||'.'||table_name "Owner/Table"
from dba_triggers
where status <> 'ENABLED'
order by owner, trigger name;
```

If you modify the preceding query to check only the SYS schema and certain columns, as shown next, you get a list of disabled triggers that are provided by Oracle:
To find all triggers for your schema, execute the following code:

```sql
select trigger_name, STATUS, trigger_type, triggering_event, trigger_body
from user_triggers;
```

<table>
<thead>
<tr>
<th>Trigger Name</th>
<th>STATUS</th>
<th>Type</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>AURORA$SERVER$SHUTDOWN</td>
<td>DISABLED</td>
<td>BEFORE EVENT</td>
<td>SHUTDOWN</td>
</tr>
<tr>
<td>AURORA$SERVER$STARTUP</td>
<td>DISABLED</td>
<td>AFTER EVENT</td>
<td>STARTUP</td>
</tr>
<tr>
<td>NO_VM_CREATE</td>
<td>DISABLED</td>
<td>BEFORE EVENT</td>
<td>CREATE</td>
</tr>
<tr>
<td>NO_VM_DROP</td>
<td>DISABLED</td>
<td>BEFORE EVENT</td>
<td>DROP</td>
</tr>
<tr>
<td>SYS_LOGOFF</td>
<td>DISABLED</td>
<td>BEFORE EVENT</td>
<td>LOGOFF</td>
</tr>
<tr>
<td>SYS_LOGON</td>
<td>DISABLED</td>
<td>AFTER EVENT</td>
<td>LOGON</td>
</tr>
</tbody>
</table>

**TIP**

Query DBA_TRIGGERS (for system-wide objects) or USER_TRIGGERS (for your schema only) to find the state of triggers and avoid errors with disabled triggers. Disabled triggers can have fatal results for an application: they don’t fail; they just don’t execute.

**Use PL/SQL Associative Arrays for Fast Reference Table Lookups**

Programs that are designed to process data coming into a system usually incorporate numerous reference table lookups to validate and/or code the incoming data properly. When the reference tables
are searched, using a unique key that is a numerical data type, the query performance against the reference tables can be drastically improved by loading the reference tables into PL/SQL associative arrays (formerly known as index-by tables). Consider an incoming dataset that contains a single numerical column that must be translated to a coded string using a reference table. Here is a program to handle this task using the classic approach of repeated searches against the reference table.

```sql
DECLARE
    v_code_c ref_table.ref_string&type;
    cursor v_lookup_cur (p_code_n IN number) is
        select ref_string
        from ref_table
        where ref_num = p_code_n;
    cursor v_inbound_cur is
        select *
        from incoming_data;
BEGIN
    --Open a cursor to the incoming data.
    for inbound_rec in v_inbound_cur loop
        BEGIN
            --Calculate the reference string from the reference data.
            open v_lookup_cur(inbound_rec.coded_value);
            fetch v_lookup_cur into v_code_c;
            if v_lookup_cur.notfound then
                close v_lookup_cur;
                raise NO_DATA_FOUND;
            end if;
            close v_lookup_cur;
            dbms_output.put_line(v_code_c);
            --processing logic...
            --Commit each record as it is processed.
            commit;
        EXCEPTION
            when NO_DATA_FOUND then
                null;--Appropriate steps...
            when OTHERS then
                null;--Appropriate steps...
        END;
    END loop;
END;
/
```

Although this program may appear to be written efficiently, it is, in fact, hampered by the repeated queries against the reference table. Even though Oracle may have the entire reference table in memory, due to pinning or prior queries, a certain amount of overhead is still involved with processing the queries.
A more efficient technique is to load the entire reference table into a PL/SQL associative array. The numerical column (that the searches are performed against) is loaded as the array index. When a lookup against the reference data is required, the array is used instead of the actual reference table—the code in the incoming data that must be translated is used as the array index. The inherent nature of working with PL/SQL associative arrays is that if an invalid array index is used (meaning the code in the incoming data does not match any value in the reference table), the NO_DATA_FOUND exception will be raised.

Here is the same processing program rewritten using an associative array to store the reference data:

```sql
DECLARE
    type v_ref_table is table of ref_table.ref_string%type index by binary_integer;
    v_ref_array v_ref_table;
    v_code_c ref_table.ref_string%type;
    cursor v_lookup_cur is
        select *
        from ref_table;
    cursor v_inbound_cur is
        select *
        from incoming_data;
BEGIN
    --First, load the reference array with data from the reference table.
    for lookup_rec in v_lookup_cur loop
        v_ref_array(lookup_rec.ref_num) := lookup_rec.ref_string;
    end loop;
    --Open a cursor to the incoming data.
    for inbound_rec in v_inbound_cur loop
        BEGIN
            --Calculate the reference string from the reference data.
            v_code_c := v_ref_array(inbound_rec.codod.value);
            dbms_output.put_line(v_code_c);
            --processing logic...
            --Commit each record as it is processed.
            commit;
        EXCEPTION
            when NO_DATA_FOUND then
                null;--Appropriate steps...
            when OTHERS then
                null;--Appropriate steps...
        END;
    end loop;
END;
/
```

The result should be a drastic increase in the processing speed due to the reduced overhead in working with the PL/SQL associative arrays in comparison to the actual database table.

Finally, quite some time ago, the requirement that an associative array be indexed by a numeric
value was lifted. Thus, the index of an associative array can be a string value. This capability makes it possible to use the same solution when the coded values that need to be resolved are not necessarily of a numerical nature. Consider the traditional example that some inbound data is carrying a two-character representation of a state code that needs to be resolved and validated. A slight modification to the previous procedure, as shown next, makes this possible. The index type for the array must be a VARCHAR2 type.

```sql
DECLARE
    type v_ref_table is table of states_table.state_name type
        index by states_table.state_code type;
    v_ref_array v_ref_table;
    v_state_c states_table.state_name type;
    cursor v_lookup_cur is
        select state_code,
                state_name
        from states_table;
    cursor v_inbound_cur is
        select *
        from incoming data;
BEGIN
    --First, load the reference array with data from the reference table.
    for lookup_rec in v_lookup_cur loop
        v_ref_array(lookup_rec.state_code) := lookup_rec.state_name;
    end loop;
    --Open a cursor to the incoming data.
    for inbound_rec in v_inbound_cur loop
        BEGIN
            --Calculate the reference string from the reference data.
            v_state_c := v_ref_array(inbound_rec.coded_value);
            dbms_output.put_line(v_state_c);
            --processing logic...
            --Commit each record as it is processed.
            commit;
            EXCEPTION
                when NO DATA FOUND then
                    null; --Appropriate steps...
                when OTHERS then
                    null; --Appropriate steps...
            END;
        end loop;
    END;
END;
/
TIP
Load reference tables into PL/SQL associative arrays for faster lookups. This takes advantage of the performance of array indexes in PL/SQL.

Find and Tune the SQL When Objects Are Used
At times, the hardest part of tuning stored objects is finding the actual code that is stored in the database. This section looks at queries that retrieve the SQL that can be tuned. This section shows how to query views that retrieve information about the actual source code that exists behind the stored objects.

Retrieve the code for a procedure you created called PROCESS_DATE:

```sql
column       text  format a80
select       text
from          user_source
where          name = 'PROCESS_DATE'
order by       line;
```

This query works for procedures, triggers, or functions. For packages, change the last line in the query to:

```sql
order by       type, line;
```

```sql
TEXT
procedure process_date is
    test_num number;
begin
    test_num := 10;
    if test_num = 10 then
        update order_main
        set        process_date = sysdate
        where      order_num = 12345;
    end if;
end;
```

The following example retrieves the code for the familiar DBMS_RULE package:
The following example attempts to retrieve the package body for the DBMS_JOB package:
In this example, the package was wrapped (protected) using the WRAP command, and the output is unreadable. If you find yourself tuning the preceding code, you need sleep!

You can use the following query to retrieve the source code for a trigger:

```
column trigger_name      format a15
column trigger_type     format a15
column triggering_event format a15
column table_name       format a15
column trigger_body     format a25
select trigger_name, trigger_type, triggering_event, table_name, trigger_body
from user_triggers;
```

```
TRIGGER_NAME TRIGGER_TYPE TRIGGERING_EVENT TABLE_NAME TRIGGER_BODY
UPDATE TOTAL AFTER STATEMENT INSERT OR UPDATE ORDER MAIN begin
          update order_main
          set order_total = 10;
          end;
```

The following example shows how to find the dependencies for PL/SQL objects:
TIP

Finding the source code behind PL/SQL package procedures involves querying the USER_SOURCE and DBA_SOURCE views. Finding the source code behind a trigger involves querying the USER_TRIGGERS and DBA_TRIGGERS views. You can find dependencies among PL/SQL objects by querying the USER_DEPENDENCIES and DBA_DEPENDENCIES views.

Consider Time Component When Working with DATE Data Types

When working with the Oracle DATE data type, think of it as a TIME data type, which is more accurate. This is because the DATE data type always stores a complete temporal value, down to the second. It is impossible to insert a date value only into either a PL/SQL variable or a database column that is defined as a DATE. If you do not keep this behavior in mind during application design, the finished product may exhibit undesirable side effects. One of the most common side effects of improper date management within an application is when reports that filter the data by a date value return different results across multiple executions.

When a column or variable of this type (DATE) is initialized with a value, any missing component (if any) is automatically supplied by Oracle. If the initialization value contains only the date component, only then does Oracle supply the time component, and vice versa. This raises the question of how you can tell which component, if any, is missing during the initialization. Quite simply, both components are automatically present only when a date variable is initialized from another date variable. The system variable SYSDATE is one such date variable. Thus, whenever a column or variable is initialized from SYSDATE, it will contain a value representing the date and time when the initialization occurred.

If it is January 10, 1998, at 3:25:22 a.m., and you execute the following command
the value contained in the variable DATE_VAR_1 will be


You can also initialize a date variable using a text string. For example, if

```
Date_Var_2 date := '10-JAN-98';
```

the value contained in the variable DATE_VAR_2 will be
Here is a simple PL/SQL block that will allow you to see this for yourself:
TIP

A DATE data type always stores a complete temporal value, down to the second. It is impossible to insert a date value only into either a PL/SQL variable or a database column that is defined as a DATE.

At this point, it should be clear that DATE_VAR_1 and DATE_VAR_2 are not equal. Even though they both contain a date component of 10-JAN-98, they are not equal because their time components differ by almost three and a half hours. Herein lies the problem with a program that does not anticipate the time component that is inherent with date values. Consider an application that uses the SYSDATE variable to initialize the accounting date of records inserted into a database table. If a PL/SQL processing program (or a simple SQL SELECT statement) does not take the time component of the records into account, then records will be missed during processing.

Given that the date values in a table contain time values other than 12:00 midnight, the following statements would miss records. The problem is that the time is not the same and these statements all miss records.

```sql
select *
from table
where date_column = SYSDATE;
select *
from table
where date_column = trunc(SYSDATE);
select *
from table
where date_column = '10-JAN-98';
select *
from table
where date_column between '01-JAN-98' and '10-JAN-98';
```

The solution is to truncate the time on both sides of the WHERE clause.

One way to prevent this problem is to negate the difference in time components on both sides of
One note on these examples: If you modify the `NLS_DATE_FORMAT` to a different value than the default, these examples might not work. I used "dd-mon-yy hh:mm:ss" as my format, and the modified queries returned no rows. When I logged out and back in to reset the `NLS_DATE_FORMAT` setting, the same queries then returned rows.

The tuned solution is where the time is truncated on the noncolumn side of the `WHERE` clause. This technique has the undesired effect of suppressing any indexes that might otherwise improve query performance—the `TRUNC` function on the `COLUMN_NAME` suppresses the index on the column. The desired technique is to adjust the filter conditions to include all possible times within a given date (note in the example that .000011574 of one day is 1 second):

```sql
select * 
from table 
where date_column between trunc(SYSDATE) and 
    trunc(SYSDATE + 1) - .000011574;
```

```sql
select * 
from table 
where date_column between to_date('10-JAN-98') and 
to_date('11-JAN-98') - .000011574;
```

```sql
select * 
from table 
where date_column between to_date('01 JAN 98') and 
to_date('11-JAN-98') - .000011574;
```

**TIP**
The Oracle `DATE` data type has both date and time included in it. Avoid suppressing indexes when trying to match dates. The key is never to modify the column side in the `WHERE` clause. Do all
modifications on the noncolumn side. As you saw in Chapter 2, you can add a function-based index to overcome this issue.

Use PL/SQL to Tune PL/SQL

You can also use PL/SQL to time your PL/SQL and ensure that it is performing to your standards. Here is a simple example of how you can write a script that allows you to test and tune your procedures (a procedure called GET_CUSTOMER in this example) directly from SQL*Plus (or PL/SQL within SQL*Plus):

```sql
set serveroutput on
declare
cust_name char(100);
begin
dbms_output.put_line('Start Time:
  ||to_char(sysdate,'hh24:mi:ss'));
get_customer(11111,cust_name);
dbms_output.put_line('Complete Time:
  ||to_char(sysdate,'hh24:mi:ss'));
dbms_output.put_line(cust_name);
end;
/
```

TIP

Use PL/SQL to display the start and end times for your PL/SQL. Basically, don’t forget to use PL/SQL to tune your PL/SQL. Use things like the package DBMS_PROFILER (mentioned earlier in this chapter) to get timing statistics per line of PL/SQL code.

NOTE

You could also use DBMS_HPROF. The profiler reports the dynamic execution profile of a PL/SQL program organized by function calls, accounting for SQL and PL/SQL execution times separately. The plshprof command-line utility is in the $ORACLE_HOME/bin/ directory and generates an HTML report from either one or two profiler output files.

Understand the Implications of PL/SQL Object Location

In the old days at TUSC, we generally recommended storing the PL/SQL objects on the server side,
for many of the obvious reasons. The server is usually much more powerful and objects are reused much more often (especially when pinned into the shared pool). The security methods employed are also more straightforward. Sending the PL/SQL to be processed on the client side can be dependent on the power of the client and can lessen the number of roundtrips from client to server. But, when written correctly, the calls may be limited back to the server (see the next section for an example). There is certainly a continuing debate on this one, but with the evolving thin client, the server is probably the only place to store the PL/SQL. Figure 10-1 diagrams how PL/SQL is executed when stored on the server side. Some additional reasons for storing code on the server are listed here:

Figure 10-1. Executing an object on the server side

- Performance is improved because the code is already compiled code (p-code).
- You can pin objects in the Oracle SGA.
- It enables transaction-level security at the database level.
- You have less redundant code and fewer version control issues.
- You can query the source code online because it is stored in the data dictionary.
- Performing impact analysis is easier since the code is stored in the data dictionary.
- It uses less memory because only one copy of the code is in memory.
- If packages are used, then the entire package is loaded upon initially being referenced.

TIP
Where to store the PL/SQL code is an ongoing debate. Generally, the server side is the preferred place to store the code, and it may become the only choice as thin clients become more prevalent.
Use Rollback Segments to Open Large Cursors

This section is intended for developers and DBAs who are not using Oracle’s automatic undo management. Any skilled PL/SQL developer should be familiar with the need to size and use rollback segments properly when attempting large INSERTs/UPDATEs/DELETEs to the database. If a rollback segment of the appropriate size is not explicitly set prior to the performance of a large data manipulation operation, the operation may fail. The error code usually returned is “ORA-01562: failed to extend rollback segment.” The reason for the failure is that transactions that do not explicitly set the rollback segment use one that is randomly assigned by Oracle. If this randomly assigned rollback segment is insufficiently sized to hold the entire transaction, the operation fails. You can eliminate errors of this type by anticipating the amount of data that will be changed, choosing an appropriately sized rollback segment (the DBA_ROLLBACK_SEGS view is helpful in this regard), and setting this rollback segment just prior to the DML statement. The following example demonstrates the proper set of statements:

```sql
commit;
set transaction use rollback segment rbsl;
update big_table
set column_1 = column_1 * 0.234;
commit;
```

You can also determine the current UNDO retention period by querying the TUNED_UNDORETENTION column of V$UNDOSTAT. In DBA_TABLESPACES, query the column RETENTION, which contains a value of GUARANTEE/NOGUARANTEE to get the retention guarantee setting for the UNDO tablespace. The NOT APPLY value is used for tablespaces other than the UNDO tablespace.

It is a little known fact that Oracle uses rollback segments when cursors are employed, even if DML statements are not being issued from within the cursor loop. The rollback segments are used as a type of work area as a cursor loop is being executed. Thus, a cursor loop will quite possibly fail if a rollback segment of insufficient size is used to read the cursor. The failure does not occur immediately—only after numerous iterations of the cursor loop have been performed. Because the error message that is returned is the same as what would be returned when a single DML statement fails, many developers are fooled into thinking that the error lies elsewhere in their code. Valiant efforts are made to manage transaction sizes properly within the cursor loops, but to no avail. To successfully open a large cursor, it is imperative to set a large rollback segment just prior to the opening of the cursor:

```sql
commit;
set transaction use rollback segment rbs_big;
for Cl_Rec in Cl loop
  -- your processing logic goes here ...
end loop;
```
If large amounts of data are being manipulated within the cursor loop, the code should be setting rollback segments within the cursor loop as well. This prevents the DML statements from utilizing the same rollback segment that is being used to ensure that the large cursor can be read.

**TIP**

*If you are not using automatic undo management, then you may need to specify a large enough rollback segment when opening a large cursor.*

---

**Active Transaction Management: Process Large Quantities of Data**

When coding procedures that will process large quantities of data, remember to take into account the size of the rollback segments. The rollback segments are the weak link in a program that performs mass data manipulation. A procedure that performs a single COMMIT statement at the end just won’t do if it is processing millions of rows of data. It could be argued that a single transaction could be used to process mass quantities of data, provided the rollback segments were large enough. This logic has two flaws: (1) rarely is it feasible to devote gigabytes of valuable drive space to serve as undo space; and (2) should a hardware or software error occur, then the entire dataset would have to be reprocessed. Thus, active transaction management is always the desired technique when processing large quantities of data; it yields efficient utilization of drive space (devoted to undo segments) and provides for automatic recovery in the event of hardware/software failures. Also ensure that the undo tablespace has enough space to accommodate the UNDO_RETENTION setting.

Active transaction management is a coding technique that consists of three components: setting transactions for cursor and DML statements, performing intermittent database COMMITs, and utilizing a table column as a processing flag to indicate which records have been processed. Consider the following database procedure:
declare
counter number;
cursor C1 is
    select rowid,column_1,column_2,column_3
    from big_table
    where process_time is NULL;
begin
    Counter := 0;
    commit;
    set transaction use rollback segment rbs_big;
    for C1_rec in C1 loop
        -- Commit every 1000 records processed.
        if (Counter = 0) or (Counter >= 1000)
            then
                commit;
                set transaction use rollback segment rbs_medium;
                Counter := 0;
            else
                Counter := Counter + 1;
            end if;
        -- Processing logic...
        update big_table
        set process_time = sysdate
        where rowid = C1_rec.rowid;
    end loop;
    commit;
end;
/

The SET TRANSACTION statements ensure that an appropriately sized rollback segment is used for both cursor reading and DML statements on systems that use rollback segments. The database COMMIT for every 1000 records processed does two things: prevents the DML statements from exceeding the capacity of the rollback segment (or UNDO segment) and divides the records being processed into discrete units in the event that there is a hardware/software failure. Finally, the PROCESS_TIME column serves as the processing flag that allows the procedure to identify records that have not yet been processed. With automatic undo management, the database manages UNDO segments in an UNDO tablespace. When you start a transaction, it is assigned automatically to an available UNDO segment. You cannot specify which UNDO segment should be used, and you do not need to do so.

TIP
Maintaining sufficient space for rollback or undo segments can be critical in transactional processing. Limiting the amount of data manipulated between COMMITs is key to avoiding Snapshot Too Old errors.
Use Temporary Database Tables for Increased Performance

PL/SQL tables are great for specific cases, especially when repeated iterations are involved and the amount of data is relatively small. As outlined earlier in this chapter, the memory cost (per session) can add up fast if not used properly. When a temporary storage area is needed to house large volumes of records for a short period of time, the method of creating, indexing, and querying a temporary database table should be viewed as a viable and useful option. I have seen far too many developers abandon the common method of temporary database tables after the introduction and expansion of PL/SQL tables; remember, PL/SQL tables are not the preferred method in all cases.

Oracle writes UNDO data for temporary tables to facilitate transaction recovery, rollback to savepoints, read consistency, and reclaiming of space. Thus, transactions in temporary tables generate REDO data because you need to log the changes made to the rollback or undo segments. The redo generated should be less than the redo generated for DML on permanent tables.

Limit the Use of Dynamic SQL

Oracle provides the Oracle-supplied package DBMS_SQL and the native dynamic SQL command EXECUTE IMMEDIATE, both of which provide for or allow the creation of dynamic SQL and PL/SQL commands. These are extremely powerful features, but also dangerous if not used appropriately. When designing and developing Oracle applications, one of the hardest decisions that must be made is where to draw the line on building in dynamic capabilities and flexibility. Developing dynamic and flexible applications is extremely helpful from a functional perspective. However, the more dynamic and flexible an application, the more potential for performance degradation.

A completely accurate and functional application is considered a failure if it does not perform at acceptable levels. Users will reject an application if they have to wait to do their job. I am not advocating the elimination of dynamic or flexible applications, but a balance must exist. Build flexibility into applications when necessary, not just to make every application module more flexible for the future in case business rules may change. Only build flexibility into applications when you are sure the flexibility is needed and the performance impact will be negligible.

Both the DBMS_SQL package and the EXECUTE IMMEDIATE command provide the dynamic and flexible means in PL/SQL program units. Use these features when needed, but do not abuse them, unless you want to set yourself up for failure.

TIP

If you integrate the DBMS_SQL package into a PL/SQL program unit to create SQL statements dynamically for a production application, remember that optimizing the generated SQL statements will be difficult. Instead, use bind variables with dynamic SQL to minimize Shared Pool resource contention and maximize performance.
Use Pipelined Table Functions to Build Complex Result Sets

Occasionally, I encounter situations in which a DML SELECT statement is incapable of providing the necessary information. Typically, this occurs when the data doesn’t reside in database tables or the number of transformations necessary to get table data into a usable form exceeds the capabilities of SQL and inline functions. Historically, the solution to such a problem would have been the creation of a preprocessor that, when called, would accumulate the data in some type of intermediate table, perhaps a global temporary table, for subsequent extraction using a simple DML SELECT. However, pipelined table functions not only allow you to combine these two steps but also allow you to eliminate the overhead associated with maintaining the data in an intermediate table.

Pipelined table functions are functions that produce a collection of rows (such as a nested table) that can be queried like a physical database table or assigned to a PL/SQL collection variable. You can use a table function in place of the name of a database table in the FROM clause of a query or in place of a column name in the SELECT list of a query.

To demonstrate, I will start with the assumption that this simple table is the only table in my schema:

```sql
CREATE TABLE states
(
  state_code VARCHAR2(2) NOT NULL,
  state_name VARCHAR2(100) NOT NULL,
  CONSTRAINT states_pk PRIMARY KEY (state_code),
  CONSTRAINT states_u1x1 UNIQUE (state_name),
  CONSTRAINT states_chk1 CHECK (state_code = UPCHR(state_code))
);
```

The problem to be solved is that I need a way to create a SQL script to reproduce all of the custom constraints in my schema, subject to the following requirements:

- The script is to be created on an application server, not the database server, by a Java Server Pages (JSP) approach.
- The script needs to ensure that dependencies between constraints are taken into account.
- The script should leave disabled constraints in a disabled state when they are reproduced.
- The script should protect against revalidation of existing data when enabled check and foreign key restraints are reproduced.

Now, it *might* be possible to solve this problem with a huge SQL query using multiple table joins and several UNION clauses and a healthy dose of DECODE statements, but the end result would most likely be a monstrosity that would be difficult to maintain. So I will opt for a more elegant solution that involves pipelined table functions that, as you will see, are founded in some very basic PL/SQL functionality. By using a pipelined table function, I simplify what the JSP needs to do to get the
desired information from the database ... issue a simple DML SELECT statement. The pipelined table function will return the DDL commands to the JSP in the proper format, adhering to all the requirements. From the JSP’s perspective, the pipelined table function looks and behaves like a table, so it can simply issue the query and iterate over the returning result set, writing the commands to a file as they are fetched.

A pipelined table function is declared by specifying the PIPELINED keyword. The PIPELINED keyword indicates that the function returns rows iteratively. The return type of the pipelined table function must be a supported collection type, such as a nested table or a varray (it cannot be an associative array type). This collection type can be declared at the schema level or inside a package. Inside the function, you return individual elements of the collection type. Here is the package header for the solution to the problem. Note that the GET_CONSTRAINT_DDL function returns a collection type and uses the PIPELINED keyword.

```sql
CREATE OR REPLACE PACKAGE ddl_extract_pkg is

--Record and array types to support pipelined tabled functions.
TYPE sg_constraint_ddl_rec IS RECORD (ddl_name VARCHAR2(100),
                               ddl_text VARCHAR2(1000));

TYPE sg_constraint_ddl_array IS TABLE OF sg_constraint_ddl_rec;

--Public routines.
FUNCTION get_constraint_ddl return sg_constraint_ddl_array pipelined;

END ddl_extract_pkg;
/
```

In PL/SQL, the PIPE ROW statement causes a pipelined table function to return a row and continue processing. The statement enables a PL/SQL table function to return rows as soon as they are produced. The PIPE ROW statement may be used only in the body of pipelined table functions; an error is raised if it is used anywhere else. The PIPE ROW statement can be omitted for a pipelined table function that returns no rows. A pipelined table function may have a RETURN statement that does not return a value. The RETURN statement transfers the control back to the consumer and ensures the next fetch gets a NO_DATA_FOUND exception.

Before looking at the package body, I will briefly discuss some of the key components of the solution:

- First, to avoid the tedious assembly of reconstructive DDL from various dictionary tables, the DBMS_METADATA package is utilized. The DBMS_METADATA package is a supplied package that does the work of building DDL from the dictionary. It requires some initial PL/SQL-based configuration calls that would have invalidated its use in the “do it in a monstrous SQL statement” approach. By using the DBMS_METADATA package, you ensure that you will capture all of the nuances of reconstructive DDL (such as storage parameters, tablespaces, and segment attributes) if desired.
- Once the base reconstructive DDL has been obtained from DBMS_METADATA, it will be
The internal processing of the pipelined function is where the dependency order of the constraints must be taken into account. The order in which records are returned by the function (via the PIPE ROW statement) defines the order in which the calling DML SELECT statement receives them.

As cautioned in the *Oracle Database PL/SQL Language Reference*:

>A pipelined table function always references the current state of the data. If the data in the collection changes after the cursor opens for the collection, then the cursor reflects the changes. PL/SQL variables are private to a session and are not transactional. Therefore, read consistency, well known for its applicability to table data, does not apply to PL/SQL collection variables.

Now for the package body:

```sql
CREATE OR REPLACE PACKAGE BODY ddl_extract_pkg IS

--scrub_raw_ddl function.

--Description: This function performs basic scrubbing routines on a DDL command returned by dbms_metadata.get_ddl.

-- Syntax: scrub_raw_ddl(p_status c, p_cons_type c, p_ddl c);

-- Where: p_status_c = The current status (Enabled/Disabled).
-- p_cons_type_c = The constraint type (P, U, C, R).
-- p_ddl_c = The constraint reconstruction DDL.

FUNCTION scrub_raw_ddl (p_status_c IN varchar2,
                         p_cons_type_c IN varchar2,
                         p_ddl_c IN varchar2) return varchar2 IS
    v_new_ddl_c varchar2(1000);
    BEGIN
```
-- Capture the passed DDL.
v_new_ddl_c := p_ddl_c;
-- Trim off any carriage returns.
v_new_ddl_c := replace(v_new_ddl_c, chr(10), null);
-- Trim off any whitespace.
v_new_ddl_c := trim(v_new_ddl_c);
-- For Check and Relational constraints, if the constraint is currently disabled then we will leave it that way.
-- Otherwise, we will enable it but without the revalidation of existing data.
if ( p_cons_type_c in ('C', 'R') ) then
  if ( ( p_status_c = 'ENABLED' ) ) then
    if ( instr(v_new_ddl_c, ' NOVALIDATE') = 0 ) then
      v_new_ddl_c := v_new_ddl_c || ' NOVALIDATE';
    end if;
  end if;
end if;
-- Properly terminate the command.
v_new_ddl_c := v_new_ddl_c || ';';
-- Return.
return(v_new_ddl_c);
END scrub_raw_ddl;

-- get_constraint_ddl function.
--
-- Description: Pipelined table function returning proper DDL commands to reconstruct the custom constraints (PK, UK, CHK, FK) for all tables within the current schema.
--
FUNCTION get_constraint_ddl return sg_constraint_ddl_array pipelined is
  v_mdc_i integer;
v_raw_sql_c varchar2(1500);

-- The function returns a collection of records of type X.
-- So, in the code we will return single records of type X.
v_out_record sg_constraint_ddl_rec;

-- Cursor to control the extraction order to prevent dependency errors.
-- Check constraints, then PK, then UK, then FK.
-- We do this to prevent dependencies errors.
cursor v_extract_order_cur is
  select 1 as a_cons_orcd,
         'C' as a_cons_type,
         'CONSTRAINT' as a_cons_group
  from dual
  union all
  select 2, 'P', 'CONSTRAINT'
  from dual
  union all
  select 3, 'U', 'CONSTRAINT'
  from dual
  union all
  select 4, 'R', 'CONSTRAINT'
  from dual;

from dual
union all
select 4, 'R', 'REF_CONSTRAINT'
from dual
order by 1;

-- Cursor to access the custom constraints from the data dictionary.
cursor v_constraints_cur | p_type_c IN varchar2) is
select owner, table_name, constraint_name, constraint_type, status, validated
from user_constraints
where table_name = 'STATES'
and constraint_type = p_type_c
and generated <> 'GENERATED NAME';

BEGIN

-- Configure the dbms_metadata package.
v_ndc_i := dbms_metadata.session_transform;
dbms_metadata.set_transform_param(v_ndc_i, 'PRETTY', false);
dbms_metadata.set_transform_param(v_ndc_i, 'SEGMENT_ATTRIBUTES', false);
dbms_metadata.set_transform_param(v_ndc_i, 'STORAGE', false);
dbms_metadata.set_transform_param(v_ndc_i, 'TABLESPACE', false);
dbms_metadata.set_transform_param(v_ndc_i, 'CONSTRAINTS_AS_ALTER', true);
dbms_metadata.set_transform_param(v_ndc_i, 'CONSTRAINTS', true);
dbms_metadata.set_transform_param(v_ndc_i, 'SQLTERMINATOR', false);

-- Open the cursor that controls the extraction order...
for extract_order_rec in v_extract_order_cur loop
    -- Open the cursor to access the constraints of the
    -- current type (PK, UK, etc).
    for constraints_rec in v_constraints_cur(extract_order_rec.a_cons_type) loop
        -- Initialize the next pipeline record to be returned.
        v_out_record.ddl_name := constraints_rec.constraint_name;
        v_out_record.ddl_text := null;
        -- Get the raw DDL for the current constraint.
        v_raw_sql_c := dbms_metadata.get_ddl(extract_order_rec.a_cons_group, constraints_rec.constraint_name, constraints_rec.owner);
        -- Scrub the raw DDL.
        -- The cleaned DDL will be placed into the record
        -- being returned to the pipeline.
        v_out_record.ddl_text := scrub_raw_ddl(constraints_rec.status, extract_order_rec.a_cons_type, v_raw_sql_c);
        -- Return the constructed command to the pipeline.
        pipe row(v_out_record);
    end loop;
end loop;

end;
After the package is installed, executing it is as simple as issuing a DML SELECT statement ... almost. There are a couple of minor nuances to remember when accessing a pipelined table function from SQL:

- The SQL TABLE collection expression must be used to inform Oracle that the collection being returned from a pipelined table function should be treated as a table for purposes of query and DML operations.
- The desired columns to be accessed from the collection must be explicitly enumerated. The column list wildcard (*) cannot be used.

```sql
select x ddl_name,
       x ddl text
  from table (dl_extract pkg.get constraint ddl) x
order by 1;
```

<table>
<thead>
<tr>
<th>DDL NAME</th>
<th>DDL TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATES_CHK1</td>
<td>ALTER TABLE &quot;TRS3 PROC&quot;.&quot;STATES&quot; ADD CONSTRAINT &quot;STATES_CHK1&quot; CHECK (state_code = upper(state_code)) ENABLE NOVALIDATE;</td>
</tr>
<tr>
<td>STATES_PK</td>
<td>ALTER TABLE &quot;TRS3 PROC&quot;.&quot;STATES&quot; ADD CONSTRAINT &quot;STATES PK&quot; PRIMARY KEY (&quot;STATE CODE&quot;) ENABLE;</td>
</tr>
<tr>
<td>STATES_UK1</td>
<td>ALTER TABLE &quot;TRS3 PROC&quot;.&quot;STATES&quot; ADD CONSTRAINT &quot;STATES UK1&quot; UNIQUE (&quot;STATE NAME&quot;) ENABLE;</td>
</tr>
</tbody>
</table>

**TIP**

Avoid intermediate tables by using pipelined table functions to build complex result sets.

**Leave Those Debugging Commands Alone!**

During the development of nearly any PL/SQL module, it inevitably becomes littered with a plethora of debugging commands. More important than the debugging commands themselves is the strategic location chosen by the developer to maximize the benefit of the debugging. For complex algorithms, effective debugging often becomes artistic in nature, and only someone intimately familiar with the code knows the precise location of debug statements to yield maximum benefit. Unfortunately, prior to
putting the code into production, those strategically placed debugging statements must be either removed or disabled (commented out) because PL/SQL lacks the conditional compilation that is a given in many programming languages. Until 11g, that is! In 11g and 12c, Oracle has given the PL/SQL developer the power to leave those debugging commands in place so that they can be reactivated on the fly should an issue arise.

With conditional compilation, you can enter an if-then control structure that is only evaluated at compile time. The intent is to use the if-then control structure to control which textual statements (from the THEN or ELSE clauses) are included in the program as it compiles. The conditional compilation control structure is identified by the conditional compilation trigger character ($), which is prepended to the keywords (IF, THEN, ELSE, ELSIF, END, and ERROR) of a standard if-then block (the exception being that the block terminator is END in lieu of END IF). The Oracle PL/SQL compiler performs a preliminary scan of the source code looking for the conditional compilation trigger character, $. If any valid trigger characters are found, then the compiler evaluates the compilation condition to determine which code text, if any, should be included in the actual compilation of the code.

Here is the basic structure of the conditional compilation block:

```sql
$if test_expression $then text_to_include
    [ $elsif test_expression $then text_to_include ]
    [ $else text_to_include ]
$end
```

Conditional compilation uses either a selection directive or an inquiry directive to determine which text is to be included in the compiling program. The selection directive allows a static expression to be evaluated at compile time.

Here is the simplest form of a conditional compilation command that uses the selection directive:

```sql
$if static boolean expression $then text_to_include; $end
```

At compile time, if STATIC_BOOLEAN_EXPRESSION evaluates to TRUE, then the TEXT_TO_INCLUDE is included in the compiling program; otherwise, the TEXT_TO_INCLUDE is skipped. To demonstrate, I'll start with a package specification that will be used exclusively to store conditional compilation constants for debugging purposes:

```sql
CREATE OR REPLACE PACKAGE debug_pkg IS
    debug constant boolean := true;
END debug_pkg;
/
```

Next, I create the package specification for some fictional component of a business application:
CREATE OR REPLACE PACKAGE worker_pkg as
    PROCEDURE run_prcc;
END worker_pkg;
/

I follow that with the package body that includes a conditional compilation command referencing the static constant in the debugging package:

CREATE OR REPLACE PACKAGE BODY worker_pkg as
    PROCEDURE run_prcc is
        BEGIN
            dbms_output.put_line('Processing started.');
            if debug_pkg.debug then dbms_output.put_line('Debugging is on.'); end
            dbms_output.put_line('Processing completed.');
        END;
    END worker_pkg;
/

Since the static constant was set to TRUE at the time I compiled this package body, the extra DBMS_OUTPUT command is included in the compiled program. This can be verified by executing the RUN_PRC procedure:

set serverout on;
exec worker_pkg.run_prcc;

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed

Changing the DEBUG_PKG package causes all dependent objects to recompile, and, as that occurs, the current value of the conditional compilation control constant is used to determine if the debugging statements are compiled into the recompiled code:

CREATE OR REPLACE PACKAGE debug_pkg IS
    debug constant boolean := false;
END debug_pkg;
/

This time around, because the static constant was set to FALSE, the extra DBMS_OUTPUT
command is not included in the compiled program as the WORKER_PKG package automatically recompiles. This can be verified by executing the RUN_PRC procedure again:

```sql
set serverout on;
exec worker_pkg.run_prc;
```

Processing started.
Processing completed.
PL/SQL procedure successfully completed

Let's pause for a moment and perform a traditional activity of querying the data dictionary to retrieve the source of a stored package:

```sql
select text
  from user_source
 where name = 'WORKER_PKG'
   and type = 'PACKAGE BODY'
 order by line;
```

<table>
<thead>
<tr>
<th>TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEXT</td>
</tr>
</tbody>
</table>

```sql
PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is
    BEGIN
      dbms_output.put_line('Processing started.');
      $if dbfbug_pkg.dbfbug $then dbms_output.put_line('Debugging is on.'); $end
      dbms_output.put_line('Processing completed.');
    END;
END worker_pkg;
```

8 rows selected

What I discovered is that the _SOURCE (such as USER_SOURCE or DBA_SOURCE) dictionary tables can no longer be relied upon to reveal the precise code that is executing within the database. The _SOURCE dictionary tables are, after all, just that … the source code. To ascertain the exact code that has been compiled, taking into account conditional compilation, Oracle now provides the DBMS_PREPROCESSOR package:
Now back to the debugging package. To have a bit more granularity over which procedures are debugged, I simply need to introduce some procedure-specific control constants:

```sql
CREATE OR REPLACE PACKAGE debug_pkg IS
  debug_run_prc constant boolean := true;
  debug.xxx_prc constant boolean := false;
  debug.yyy_prc constant boolean := false;
  debug.zzz_prc constant boolean := false;
END debug_pkg;
/
```

And then I update the WORKER_PKG package to utilize the new constants:

```sql
CREATE OR REPLACE PACKAGE BODY worker_pkg as
  PROCEDURE run_prc is
    BEGIN
      dbms_output.put_line('Processing started.');
      $if debug_pkg.debug_run_prc $then
        dbms_output.put_line('Debugging is on.');
      $end
      dbms_output.put_line('Processing completed.');
    END;
END worker_pkg;
/
Let's make sure that everything is still working as expected:

```sql
set serverout on;
exec worker_pkg.run_prd;
```

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed.

Keep in mind that a physical dependency exists between the package containing the static constants and the packages referencing them for conditional compilation. Thus, if you alter the DEBUG_PKG package to change the setting for a single constant, it is still going to cause a cascading recompilation of all procedures/functions that are dependent upon that package—regardless of whether or not the changed constant is referenced in the dependent package. In an application with a large population of stored code, this may be undesirable behavior. In such scenarios, you can disperse the static constants across more packages, or as of Oracle Database 10g Release 2, you can switch to another method of controlling conditional compilation: *inquiry directives*.

First, I start by cleaning up a bit:

```sql
drop package debug_pkg;
```

Package dropped.

The conditional compilation inquiry directive allows the test conditions to be tied to the compilation environment via the following predefined directive names:

- Any of the Oracle PL/SQL compilation initialization parameters, such as PLSQL_CCFLAGS, PLSQL_CODE_TYPE, or PLSQL_WARNINGS
- The module line number from PLSQL_LINE
- The current source unit name from PLSQL_UNIT (note that this directive name returns NULL for anonymous blocks)
- A custom name-value pair introduced via PLSQL_CCFLAGS

For this example, I will construct a custom name-value pair via the PLSQL_CCFLAGS initialization parameter:

```sql
 alter session set PLSQL_CCFLAGS = 'MyDebugMode:TRUE';
```

Next I modify the test procedure to switch to an inquiry directive:
CREATE OR REPLACE PACKAGE BODY worker_pkg as
PROCEDURE run_pr is
BEGIN
  dbms_output.put_line('Processing started.');
  $if $$MyDebugMode $then
    dbms_output.put_line('Debugging is on.');
  $end
  dbms_output.put_line('Processing completed.');
END;
END worker_pkg;
/

And a quick test reveals that everything is working per expectations:

set serverout on;
exec worker_pkg.run_pr;

Processing started.
Debugging is on.
Processing completed.

PL/SQL procedure successfully completed.

Unlike when I was using selection directives tied to a static constant, altering the value of my custom inquiry directive does not cause automatic recompilation of the package:

alter session set PLSQL_CFLAGS - 'MyDebugMode:FALSE';

Session altered.
set serverout on;
exec worker_pkg.run_pr;

Processing started.
Debugging is on.
Processing completed.
PL/SQL procedure successfully completed.

Until another stimulus causes the package to recompile, the change in the custom inquiry directive will not be realized:
Optionally, to adjust the behavior of a specific package without altering the session, you can specify the PL/SQL persistent compiler parameters during a forced recompilation of the module:

```
alter package worker_pkg compile PLSQL_CCTAGO = 'MyDebugMode:TRUE' reuse settings;
```

The REUSE SETTINGS clause is used to bypass the normal compiler behavior of dropping and reloading (from the session) all the persistent compiler parameters. Thus, the only compiler parameter that is updated during the forced recompile is the one that was specified as part of the ALTER command.

The error directive provides a quick method for supplying debugging output within your procedures. For example, if you create a procedure that uses some PL/SQL functionality that was introduced in Oracle Database 12c, but this procedure also has to run on an Oracle 10.2 database, then you could use the error directive to write an error message identifying the database release as not supported by the procedure. See Example 2-59 in the Oracle Database PL/SQL Language Reference for 12c.

**TIP**

Suppress debugging commands in PL/SQL code with conditional compilation.
TIP
Use the static constants defined in DBMS_DB_VERSION as selection directives to control conditional compilation. The DBMS_DB_VERSION package specifies the Oracle version numbers and other information, which is useful for simple conditional compilation selections based on Oracle versions.

The “Look and Feel”: Just for the Beginners

Since many developers and DBAs who may read this book are beginners at PL/SQL, I am also including examples of a piece of PL/SQL code, a procedure, a function, a package, and a trigger. I believe it is important that you have a feel for what these objects look like and how they differ, especially if you haven’t seen some of them before. This section is intentionally placed as the last section of this chapter as a short reference section only and to give you a feel for how each looks. The goal is not to teach you how to write PL/SQL (please refer to Joe Trezzo’s PL/SQL Tips and Techniques [McGraw-Hill, 1999] for that).

Both procedures and functions can take parameters and can be called from PL/SQL. However, procedures typically perform an action. The parameters used in procedures can be in(put), out(put), or in(put)/out(put) parameters, whereas functions typically compute a value and the parameters can only be in(put) parameters. As a matter of fact, you can’t even specify the “direction” of the parameters. Functions only permit the passing of one return value. Functions are “selectable,” so you can create your own user-defined functions that return information (you can have multiple RETURN statements in a function, but each RETURN statement can only pass a single expression).

Functions can also be used when creating indexes so the index key is sorted in a fashion that matches your queries.

PL/SQL Example

Here is an example of a piece of PL/SQL code:
Here is an example of how to create a procedure. I have listed it here in case you have never witnessed one before:

```sql
create or replace procedure
get_cust (in_cust_no in char, out_cust_name out char, 
out_cust_addr1 out char, out_cust_addr2 out char, 
out_cust_city out char, out_cust_st out char, 
out_cust_zip out char, out_cust_poc out char) IS
begin
    select name, addr1, addr2, city, st, zip, poc
    into out_cust_name, out_cust_addr1, out_cust_addr2, 
        out_cust_city, out_cust_st, out_cust_zip, 
        out_cust_poc
    from customer cust, address addr
    where cust.cust_no = addr.cust_no
    and addr.primary_flag = 'Y'
    and cust.cust_no = in_cust_no;
end
get_cust;
```
Execute the Procedure from PL/SQL Example

Here is an example of how to execute a PL/SQL procedure from within a block of PL/SQL code. As before, I have listed it here in case you have never witnessed one before:

```sql
get_cust (12345, name, addr1, addr2, city, st, zip, poc);
```

Create a Function Example

Here is an example of how to create a function. Once again, I have listed it here in case you have never witnessed one before:

```sql
create or replace function get_cust_name (in_cust_no number)
return char
IS
    out_cust_name cust.cust_last_name&typec;
begin
    select cust.last_name
    into    out_cust_name
    from    cust
    where   customer_id = in_cust_no;
    return out_cust_name;
end get_cust_name;
```

Execute the GET_CUST_NAME Function from SQL Example

Here is an example of how to execute the GET_CUST_NAME function:

```sql
select get_cust_name (12345)
from    dual;
```

Create a Package Example
Database Trigger Example Using PL/SQL

Here is an example of how to create a trigger using PL/SQL:

```
create or replace package emp_actions IS
    -- package specification
    procedure hire_employee
        (empno NUMBER, ename CHAR, ...);
    procedure retired_employee (emp_id NUMBER);
end emp_actions;
/
create or replace package body emp_actions IS
    -- package body
    procedure hire_employee
        (empno NUMBER, ename CHAR, ...)
    is begin
        insert into emp VALUES (empno, ename, ...);
    end hire_employee;
    procedure fired_employee (emp_id NUMBER) IS
    begin
        delete from emp WHERE empno = emp_id;
    end fired_employee;
end emp_actions;
/
```

Tips Review

- In 12c, we also can combine invoker rights (AUTHID CURRENT_USER) with the Function Result Cache (RESULT_CACHE).
- It is now possible to create a PL/SQL subprogram inline SELECT statement utilizing the WITH clause declaration in 12c.
- Named notation continues to be the preferred method for passing parameters to subroutines. You can now extend this best practice approach to SQL statements to yield consistency across the entire code base.
In 12c, you can define an identity clause against a table column defined using a numeric type, instead of code that creates and uses a sequence object (Create Sequence privilege is required to create Identity Columns—since they are in fact sequential values or sequences).

The new CONTINUE statement creates loop constructs that are more streamlined, but there are no performance gains to be realized at this time.

Experienced and novice developers alike should leverage the PL/SQL compile-time warnings to catch obscured programming problems before code deployment.

The introduction of compound triggers in conjunction with execution order control are welcome enhancements.

Use the Oracle-supplied package DBMS_APPLICATION_INFO to log point-in-time information to the V$SESSION view to enable monitoring of long-running processes.

Log (INSERT) execution timing information into a database table for long-running PL/SQL program units to integrate a proactive performance-monitoring mechanism into your system. The database table can be reviewed at any point in time to determine if performance has decreased over time.

System load in terms of number of active sessions can have a large impact on the performance of program execution; therefore, modifying the database table logging method to include a column for the number of active sessions can be helpful. You can fill this column by adding one additional query to the program unit being executed to retrieve the count from the V$SESSION view.

When a PL/SQL program unit involves extensive looping or recursion, concentrate on reducing the execution time per iteration. The benefits add up fast, and it is easy to do the math to determine the overall improvement potential. Also review the looping or recursion for restructuring to reduce the number of iterations, while keeping the functionality. With the extreme flexibility of PL/SQL and SQL, a variety of ways typically exist to accomplish the same result. If a PL/SQL program unit is not performing optimally, sometimes you have to rewrite the logic another way.

Use the ROWID variable to enhance performance when SELECTing a record in a PL/SQL program unit and then manipulating the same record in the same PL/SQL program unit.

Ensure that all conditional comparisons compare the same data types. Additionally, ensure that the data types within the numeric family are comparing the same subtype.

Ensure the string of PL/SQL IF conditions appear in the order of most frequently satisfied, not a numerical or alphanumerical sequential order.

Use the PLS_INTEGER type when processing integers to improve performance. If a number with precision is assigned to a PLS_INTEGER variable, the value will be rounded to a whole number as if the ROUND function had been performed on the number.

Attempt to limit the calls to SYSDATE in iterative or recursive loops because overhead is associated with this variable. Set a PL/SQL date variable to SYSDATE in the declaration and reference the PL/SQL variable to eliminate the overhead.
Use the DBMS_SHARED_POOL.KEEP procedure to pin PL/SQL objects into the shared pool.

Use the DBMS_SHARED_POOL.KEEP procedure in PL/SQL to pin all packages when the database is started (if memory/shared pool permits) and to avoid errors involving loading packages in the future.

Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also large enough to potentially cause problems.

Query X$KSMSP to find all large pieces of PL/SQL that have appeared in the shared pool. These are candidates for pinning when the database has started.

You can recompile an entire schema (either all or just the invalid objects) with DBMS_UTILITY.COMPILE_SCHEMA.

Query DBA_TRIGGERS (for system-wide objects) or USER_TRIGGERS (for your schema only) to find the state of triggers and avoid errors with disabled triggers. Disabled triggers can have fatal results for an application: they don’t fail; they just don’t execute.

Load reference tables into PL/SQL associative arrays for faster lookups. This takes advantage of the performance of array indexes in PL/SQL.

Finding the source code behind PL/SQL package procedures involves querying the USER_SOURCE and DBA_SOURCE views. Finding the source code behind a trigger involves querying the USER_TRIGGERS and DBA_TRIGGERS views. You can find dependencies among PL/SQL objects by querying the USER_DEPENDENCIES and DBA_DEPENDENCIES views.

A DATE data type always stores a complete temporal value, down to the second. It is impossible to insert a date value only into either a PL/SQL variable or database column that is defined as a DATE.

The Oracle DATE data type has both date and time included in it. Avoid suppressing indexes when trying to match dates. The key is never to modify the column side in the WHERE clause. Do all modifications on the noncolumn side. As you saw in Chapter 2, you can add a function-based index to overcome this issue.

Where to store the PL/SQL code is an ongoing debate. Generally, the server side is the preferred place to store the code, and it may become the only choice as thin clients become more prevalent.

If you are using automatic undo management and flashback together, you may need to increase the size of a fixed UNDO tablespace (and the UNDO retention period, or an autoextend UNDO tablespace with a MAXSIZE limit). Snapshot Too Old errors during a flashback indicate that you need to ensure sufficient UNDO data is retained to support these flashback operations.

Maintaining sufficient space for rollback or undo segments can be critical in transactional processing. Limiting the amount of data manipulated between COMMITs is key to avoiding Snapshot Too Old errors.

If you integrate the DBMS_SQL package into a PL/SQL program unit to create SQL statements
dynamically for a production application, remember that optimizing the generated SQL statements will be difficult. Instead, use bind variables with dynamic SQL to minimize Shared Pool resource contention and maximize performance.

- Use bind variables with dynamic SQL to minimize resource contention and maximize performance.
- Avoid intermediate tables by using pipelined table functions to build complex result sets.
- Suppress debugging commands in PL/SQL code with conditional compilation.
- Use the static constants defined in DBMS_DB_VERSION as selection directives to control conditional compilation. The DBMS_DB_VERSION package specifies the Oracle version numbers and other information, which is useful for simple conditional compilation selections based on Oracle versions.

References

- Oracle Database PL/SQL Language Reference 12c Release 2 (Oracle Corporation).
- Frank Naude’s underground Oracle web page (www.orafaq.com).
- Oracle Database SQL Language Reference (Oracle Corporation).
- Joe Trezzo, Procedures, Functions, Packages, and Triggers (TUSC, 1999).

Thanks to Greg Bogode for the excellent update to this chapter for 12c! Bob Taylor did the several great updates to the previous versions of this chapter. Thanks, Bob! Joe Trezzo, and Dave Ventura of TUSC all made contributions to this chapter in the past.
With Oracle’s acquisition of Sun, a paradigm shift occurred in the database market, the hardware world, and the IT industry as a whole. While this current shift is well under way, signs are showing that a larger shift is on its way based on this acquisition. On September 18, 2016, Larry Ellison introduced Oracle Database 12cR2, available on the cloud first via the Oracle Database Exadata Express Cloud Service, which leverages the Sun acquisition and was rolled out at an outrageously low starting price of only $175/month—including all database options. This is the first step to consolidating Oracle on Oracle Cloud, filled with Sun servers. Not unknown to Wall Street, this acquisition and corresponding shift is called industry consolidation.

In the world of hardware, Oracle has widened its influence (their FS1 Flash Server is almost a petabyte of flash storage) and will challenge the Fortune 50 companies as one of the top performers as they continue to advance their own hardware to advance Oracle Cloud (with security at the silicon level). With Java, Oracle’s influence could quickly move into the consumer world, if they choose. Oracle’s recent partnership with GE has taken them into the Internet of Things (IOT) world and closer to the consumer world. Exadata was the beginning of Oracle’s move into the hardware world. Oracle has quickly followed that up with many versions of Exadata, Exalogic machines, Oracle Database Appliance, Exadata Storage Expansion Rack, Flash Server, ZFS Storage Appliance, Zero Data Loss Recovery Appliance, and SuperCluster, to name just a few. Their slogan “software and hardware engineered together” is certainly an accurate description of how well Exadata is performing, but it also reveals a barrier to entry for other companies that might try to compete. Exadata is hardware that combines the power of the database and features at the hardware level that other hardware providers will not be able to replicate easily (or at all). I’ve now worked on a quarter, half, and full rack of Exadata machines and every one of them performed with client-gasping performance. Every client I’ve talked to who is using Exadata is already considering adding more machines to other areas of their business. Exadata has quickly become the fastest-selling product Oracle has ever had (over 10,000 sold)!

Oracle has touched upon hardware in the past with the likes of ncube and the “ahead of its time” Network Computer (NC), perhaps the precursor to Google’s Chromebook. With the acquisition of Sun, Oracle dove into the water head first, introducing the Exadata box (prior to the acquisition of Sun, Oracle partnered with HP on Exadata V1). With the second and third versions of Exadata, the Exadata Storage Expansion Rack, Exalogic, and the latest Oracle Unbreakable Linux Kernel, Oracle
became a serious contender, if not the leader, in taking the entire stack—software to hardware. In September 2011, Oracle introduced the Oracle Database Appliance for small businesses and for departmental servers, and their new SPARC SuperCluster T4-4, which includes 16 T4 processors with 8 cores each (each core has 8 threads). This Solaris-based machine has 1200 threads total on the entire SuperCluster when you add all cores on the machine (more on the latest version of SuperCluster later in the chapter).

In early October 2011 at OpenWorld, Oracle introduced the Oracle Exalytics Business Intelligence Machine, which included the TimesTen In-Memory Database, Oracle Business Intelligence Enterprise Edition (OBIEE), and Essbase Analytics in 1T of memory—can you say instant BI! Oracle also introduced the Oracle Public Cloud (OPC) in 2011, now rebranded Oracle Cloud. Other hardware of note includes the Big Data Appliance for unstructured data using Hadoop and NoSQL, Pillar Storage Systems for SAN data, ZFS for NAS, and StorageTek server expandable to ten units that can store up to 1E of data with a 2:1 compression! In 2015, Oracle announced the previously mentioned FS1 Flash Array with nearly 1P of flash (912T) and started acquisitions targeting cloud companies. In 2016, Oracle announced the X6-2 Exadata (as well as the X6-8) with an all-flash option and the SuperCluster M7 (with security in the silicon) and announced that the 12cR2 database would first be offered on the Oracle Cloud. I’ll cover each of these new offerings briefly so you can see where they might fit in the future. Please see Oracle.com for the latest hardware offerings; this chapter serves as a basis for what will surely change quickly over time.

In this chapter, I’ll also cover the Big Data Appliance, Oracle Cloud, Real Application Clusters (RAC), and parallel features in Oracle. Oracle first introduced their parallel server in Oracle 6.1 (beta) and Oracle 6.2 (limited customer release production) but only widely used it on VAX/VMS. Not until Oracle9i, when they rewrote the code for the RAC product almost completely (95 percent I am told), did Oracle truly have a clustering product. In Oracle 10g, RAC not only matured but had become the cornerstone for grid computing (entire grids of servers using the Oracle RAC or clustering architecture). In 12c, RAC has become Oracle’s competitive advantage (as its clustered version has on Oracle’s MySQL Enterprise Edition database). RAC is also the centerpiece of Exadata, Exalogic, and SuperCluster hardware. In fact, Exadata became a quick way to have an eight-node RAC cluster almost instantly (Exadata X6-2; more on this shortly). In addition to using many servers to help increase availability and improve performance, Oracle has also improved the parallel query technology that was first introduced with Oracle release 7.1. In Oracle 12c, most operations can be parallelized and even tuned by the Adaptive Optimizer, including queries (parallel SQL execution), DML, DDL operations, intra-partition parallelism, parallelism for data replication and recovery, and data loading; multiple parallel query server processes can even execute against the same partition.

The tips covered in this chapter include the following:

- The march to the cloud and the Oracle Cloud (understanding what fits your needs)
- Exadata terminology and basics about the latest Exadata hardware platform, X6
- Basics about the Exadata Storage Expansion Rack
- Leveraging Smart Scans
- How fast is the Flash Cache
- Using storage indexes
Using Hybrid Columnar Compression (HCC)
Using I/O Resource Management (IORM)
Leveraging Exadata security, utilities, and best practices
Basics about the Oracle Database Appliance
Basics about the SuperCluster using the SPARC chip
Overview of the Big Data Appliance, ZFS, and StorageTek
Real Application Clusters (RAC) overview and architecture
Tuning the RAC interconnect and finding RAC wait events
Basic concepts of parallel operations
Parallel DDL and DML statements and operations
Managing parallel server resources and parallel statement queuing
Parallelism and partitions
Creating table and index examples using parallel operations
Parallel DML statements and examples
Monitoring parallel operations via the V$ views
Using EXPLAIN PLAN and AUTOTRACE on parallel operations
Tuning parallel execution and initialization parameters
Parallel loading
Performance comparisons and monitoring parallel operations
Optimizing parallel operations

The March to the Cloud (Past and Present)

I remember a CEO once telling me to watch for things the third time they come around as they often stick by then. The first push for outsourcing and hosting started around 30 years ago (mid-1980s to early 1990s). Some companies (around 5 to 20 percent, depending on industry and location) outsourced their IT operations to a third-party company. Some outsourced IT operations to local companies with off-shore workers to help reduce the price. This push lasted 5 to 10 years and then subsided after the market improved for most companies and horror stories circulated from those who outsourced. I recall in the late 1980s helping a company build a “screen scraper” to get their data back from a hosting company that was charging them exorbitant fees for a full download of their own data. Back then, people didn’t always buy the software; instead, they used it remotely and their data stayed remote. The cloud was very prevalent in the 1980s—it just wasn’t called “the cloud.”

Then around 18 years ago (late ’90s), the push for hosting and outsourcing came again. This time it was Wall Street pushing the latest dotcom hosting companies. The difference the second time around was that you didn’t have to outsource IT (if you didn’t want to), but instead could locate servers in a
more economical way (to some warehouse that had underground diesel tanks that would ensure the power could never go off). Some companies (around 10 to 30 percent, depending on industry and location) hosted their IT operations to a third-party company (often high-flying dotcom startups). The hosting company would provide a “cage” where your secure servers would reside (you could even go visit them). Some even hosted cages to local companies with off-shore workers, to help reduce the price even further. This push also lasted 5 to 10 years and subsided after the market improved for most companies and horror stories circulated of those crashed-and-burned dotcom startups. The biggest problem this time was being able to access your own systems so that you could get development or administration work completed in a reasonable amount of time (and deciding what to do once the dotcom crash started). It was a major event to go visit your servers in one of these highly secure warehouses. People would point through the cages at all the blinking lights.

Now there is a new push to the cloud (again led by Wall Street, but prompted by Amazon profits in the cloud). This includes using either “hosting” or “outsourcing” of IT operations. Cloud providers are ensuring that this time is different. The new cloud players (the four horsemen of the cloud) are the gold standard of the IT industry: Oracle, Amazon, Microsoft, and Google. They now say that everyone will be on the cloud soon (similar to predictions 5 years ago that everyone would own a tablet instead of a laptop, or even 2 years ago that a watch would replace your smartphone). Are things really different this time, or is this a repeat of the tablet market that will plateau at 20 or 30 percent? One certainty is that the number of mobile applications is growing fast and the smartphone market continues to dwarf all other markets. A sign that things may be different this time was revealed at Oracle OpenWorld in September 2016, which featured Larry Ellison showing Oracle Cloud performance that was staggering when compared to Amazon and pricing on Exadata that was so low it shocked the Oracle world (but, will they keep it that low?).

Let’s look at why there is such a big push for the cloud (some of these include “perceived” benefits to customers that move to the cloud):

1. There are better profit margins for cloud companies than they had prior to selling cloud (similar to hosting, outsourcing, and off-shoring). This is actually, by far, the number one reason for the cloud bandwagon; the cloud provider makes a killing, usually with unexpected add-on costs to customers (Wall Street loves this, and they are not in it for the long haul—either rise fast or get out of their way). Amazon has proven that profits from cloud services are huge!

2. Using cloud services lowers (perceived?) costs for IT operations (again, this is similar to hosting, outsourcing, and off-shoring). This is the number two reason why the cloud is big. Profits for the cloud customers go up as IT costs go down (at least initially).

3. It’s easier to administer and provide better customer service from IT when shifted to the cloud (debatable, as the past two times were). While it’s easier to maintain the cloud (since it’s difficult to change things), not much ever changes (which keeps costs down). Updates can happen automatically.

4. You are not tied to a specific company (yeah, right!). Currently, this is the case, but with consolidation, that could change (again, Wall Street loves the cloud because you probably won’t be able to get back out of the cloud, or you’ll pay dearly to get out, or they’ll be out of the cloud company’s stock by the time you get out, so they really don’t care).
Now let's look at what is truly different this time around (and will fuel the longevity of the cloud):

1. Cloud services are great for smaller companies that can’t afford a real IT department. They can obtain IT servers and operations to any scale they’ll ever need.

2. Connecting to social media and accessing marketing big data are faster over the cloud, as are leveraging this data and connecting it to mobile applications.

3. On Oracle Cloud, every company can have an encrypted backup that’s secure and offsite. This is a big plus to the many companies that still don’t have this protection.

4. Development can spin up a production-size server for testing for a couple of hours. This is a huge benefit, but still only relatively inexpensive.

5. Spinning up a data warehouse or two for a week is inexpensive.

6. You pay for what you use, scale up easily when you need to, and scale down easily when you need to (better than in the past). Because of the size of cloud companies, this works very well now compared to the first two times around.

7. Testing an extremely large server for a few hours to see if it’s worth buying is relatively inexpensive (compared to the costs of buying it).

8. Testing the new version of a product or a new database version with the current version of an application is easy. You can also test new versions of the database or middleware for new features or capabilities.

9. You can benefit from the economies of scale when consolidating many of your databases (you can do this on-premises, of course, yet many companies don’t).

10. Using Oracle Cloud, it’s easier to share pluggable databases (PDBs) with other companies for partnering.

11. The current generation of developers and DBAs is cloud-ready. They would rather use Google Docs in the cloud than require a machine running Microsoft Word everywhere they go. They don’t want to be tied to a specific computer, and they already do everything in the cloud.

12. Cloud companies will push companies that use their cloud toward success because they mutually benefit. CFOs get the tax benefit of OPEX (cloud) versus CAPEX (on-premises).

In the end, whether the cloud helps or detracts from your competitive advantage really depends on your costs, personnel, operations, and all of the preceding points. If your current IT operations are part of your competitive advantage (as is true for many large companies), you may hurt your company by moving to the cloud, if you’re not careful. But, if your IT operations are overworked, hindering your innovation, or mired in red tape, you may benefit from moving to the cloud. The CEO, CFO, CIO, department head, etc., individually or as a group, needs to make a serious and educated evaluation that discerns between all of the salient factors. The CFO will almost always agree to cloud adoption, as there are many short-term profits to be had that few CFOs will be able to resist. DBAs need to be well educated about the cloud so that they can offer sound advice when upper management starts pushing.

As previously discussed, whether they realize it or not, everyone does something in the cloud already (that is, the hybrid cloud model, a mix of cloud/on-premises, is already at 100 percent). Many things are done on the Internet (in the cloud), so predictions that a large number of companies will at
least embrace a hybrid cloud have already been true for a decade or two.

The following questions about the cloud remain in many people’s minds:

- Will the price stay low when the market consolidates? (Probably not.)
- Will it be easy in the future to move my data back if I want? (Hard to say.)
- Will it increase my competitive advantage to move further into the cloud? (Probably.)

With those questions yet to be answered fully, these are your options:

- Stay private.
- Go all-in on the public cloud (immediate OPEX benefit).
- Use a hybrid of public/private (true of almost everyone already—but, what’s the split?).
- Lease a server owned by Oracle but located on your own site (OPEX benefit on-premises; this
  is known as Cloud at the Customer).

Hopefully, you’re convinced from this overview that a portion of applications and IT operations
will be hosted on the cloud and that the cloud is here to stay. It’s prudent to be prepared for this
generational switch to cloud computing and the direction in which some things will progress in the
future.

The Oracle Cloud

As mentioned in the chapter introduction, on September 18, 2016, Larry Ellison introduced the
Oracle Database Exadata Express Cloud Service running the 12cR2 database for only $175/month,
including all database options. This includes one PDB of Oracle Enterprise Edition running on
Exadata with 20G of database storage and 120G of data transfer (there are increased data use and
transfer options for a higher price; see https://cloud.oracle.com for the latest pricing). With Larry’s
announcement, one of the fastest servers on the planet, running the latest version of the database
became the first cloud server that could begin a major Oracle IT march to the cloud. The ability to run
or test applications on an Exadata database machine for such a low price will be too good for
any Oracle development department to pass up. Moving your encrypted backup to the cloud now becomes
a 2017 exercise. Oracle also introduced, on the same day, Application Performance Monitoring
(APM) for DevOps. APM enables DBAs and developers to pinpoint performance problems at every
layer of the application (you’ll see screenshots later in this chapter).

Oracle’s Database as a Service (DBaaS) offering is Oracle Database Cloud Service. Setting up a
Database Cloud Service instance for the first time takes a few hours. Setting one up the second time
takes a few minutes. Initially you need to set up the networking and security, which allows access to
all products in the cloud, not just Oracle. I believe that Oracle Database Cloud Service will be a huge
opportunity for many shops to quickly spin up development servers for DevOps (Development
Operations—a new term meaning a mix of development and operations).

Oracle announced 12c Release 2 of the database will be released on the cloud first (September
18, 2016). This is not just a cloud-first event, but an Oracle-first event. This is similar to when
Oracle started releasing less important platform database software (AIX comes to mind) later than
Linux. Another example is Oracle releasing 12c on Express Edition (the free version) much later than Standard Edition (SE) or Enterprise Edition (EE). Oracle has a way of creating a bend in the road that you’ll probably soon be following to some degree. Also, Oracle has available currently in the cloud a database that you can use anytime (https://livesql.oracle.com) to learn SQL and PL/SQL. When I tried it September 24, 2016, it was already the 12.1.0.2 database. The cloud helps us to learn and test things much faster!

Now let’s keep you from becoming a dinosaur and teach you how to create your first Database in the Cloud (also known as a Database Cloud Service instance). To begin to use the Oracle Cloud, you can simple go to either of the following:

https://cloud.oracle.com/tryit (next click Try It in the database section to try out the Oracle Cloud for 30 days—the database is listed under PaaS and IaaS)

https://cloud.oracle.com/database (click Try It to only try the database)

The first thing to notice is that there are many video tutorials available. There is also a lot of information about the different roles needed for the cloud. Think of how long it would take you to spin up everything that you see in the Database Cloud Service instance shown in Figure 11-1.

![Database Cloud Service](image)

**FIGURE 11-1.** Your Database Cloud Service

Go to http://cloud.oracle.com/tryit to see the introductory page shown in Figure 11-2, where you can click the Try It button as seen in Figure 11-2.
Next, choose Database (Your Oracle Database in the Cloud) to set up a Database Cloud Service instance. Information about your 30-Day Trial comes up next. It includes an overview of the process as well as the ability to start the Database as a Service Trial. You’ll also be asked to log in to your Oracle account. After you sign on with your single sign-on to Oracle, you’ll be prompted to fill in the connection information requested, as shown in Figure 11-3. You’ll then click on Request Code to receive a verification code that goes to your phone. You then create a new account, agree to the terms and conditions, and then click on the Sign Up button (not shown in Figure 11-3, but at the bottom of this screen). You will receive an email with a link that will take you to the Oracle Cloud.
Congrats! You now have a Cloud Account. Oracle will send an e-mail to you so that you can sign in to the cloud. Once approved, your e-mail connects you to sign in to the Oracle Cloud (Figure 11-4). You can also sign into the cloud by going to the following link in the future:
You’ll get a welcome message and an immediate offer to get some free training if you need it (see Figure 11-5). Included in the Quick Start lesson is everything required to ensure you know how to set up Database as a Service. Those items include setting up SSH and using PuTTY (depending on the cloud service, SSH and PuTTY may not be available), Creating a Service Instance, Finding the Connection Details about your Database Instance, Enabling Secure Access, Connecting via SQL Developer, Performing Operations on your Cloud Database, and Monitoring your Database Service. Once you’re ready, click Get Started.
FIGURE 11-5. Click Get Started after going through the training.

Next, on the page shown in Figure 11-6, click Create Service to launch the Create Database Cloud Service Instance wizard. First, choose whether you want a VM preinstalled or want to set it up using DBCA. Also choose a billing frequency (hourly or monthly).

FIGURE 11-6. Click Create Service to build your first Database Service instance in the Cloud.
Next, choose either 11g (11.2.0.4) or 12c (12.1.0.2) as the database and then choose the edition of the database (Figure 11-7). Click Next.

**FIGURE 11-7. Choose the edition of the database release (pricing differs for each).**

Next, on the Service Details page (see Figure 11-8), choose the service name, size/shape of the server (very price specific), passwords, backup and recovery configuration, whether you’ll use an encrypted file to build the database from your on-premises database, etc. You can also set up a Standby Database using Data Guard, enable GoldenGate, and install the demo PDB. Click Next.
FIGURE 11-8. Choose the specific size and configuration of the database (pricing varies).

You’ll next be shown that the process of building your Database Cloud Service instance is in progress (Figure 11-9) and then you’ll be told that your database is ready to use.
Figure 11-10 shows my successfully created Database Cloud Service instance after I’ve created two different services (I’m in the process here of terminating one of them in Figure 11-10). Details for all services are listed.

As shown in the pull-down menu in Figure 11-11, I can now access (among other options) Enterprise Manager (EM) to manage the Database Cloud Service Instance (see Chapter 5 for EM details that can be monitored). Note that this is not the full Oracle Enterprise Manager (OEM or EM); it’s more like 12c Database Express, so you may want to ensure that it does what you need.
Clicking Open EM Console shows that my database Instance in the cloud has been up over 234 days (Figure 11-12). Also note that many of the settings and locations for files and the default that you would use if you installed the database.

I can click “CDB (2 PDBs)” and get to the details of the containers. Note that one of the PDBs in Figure 11-12 is the DEMOS PDB that I chose to install when I created the Database Cloud Service instance and the other is PDB1. I can take a look at Memory Management to see the various settings and allocation of memory similar to EM in my on-premises database (Figure 11-13).
As you can see, you have many different choices (refer to Chapter 5 for greater detail). You can easily check things like memory initialization parameters to see if the In-Memory Size is set (if you are using the In-Memory column store). You can then click Set to change a parameter.

Similar, but separate from EM, you can also use a new Oracle Cloud Service Solution called Oracle Management Cloud. In the initial launch of the Oracle Management Cloud at OpenWorld 2015, three services were packaged and released focusing on the highest customer pain points: Application Performance Monitoring, Log Analytics, and IT Analytics. There were three more announced at OpenWorld 2016. With them, customers gain real-time insight into application and infrastructure performance, optimizing (development, applications, and IT resources), and effectively planning for future business needs with data normalized and analyzed in visualizations that make the most sense to business stakeholders. Oracle Management Cloud services are powered by a big data platform behind the scenes providing real-time monitoring, rapid diagnostics, operational insight, and business analytics capabilities. Data uploaded is stored securely in a single unified big data platform and is automatically correlated and processed by a robust and scalable data pipeline that enables high-throughput processing of large amounts of data for analysis. Within the Oracle Management Cloud is Application Performance Monitoring (see Figure 11-14), which can be used to see greater detail in the cloud at every tier of operations. This is a cloud-only product. It shows performance and details at the database, application server, application, and even page level of the customer screen (thanks Oracle for the previous two screenshots).
You can also get additional details of the customer experience in viewing the application with a special focus on the application web page, as shown in Figure 11-15.
By using this detailed information, you can gauge the customer experience and head off potential problems with performance or errors before the customer complains.

The Oracle Cloud is here to stay! As the next few years go by, Oracle will only accelerate their cloud and mobile offerings to better serve you. It’s hard to predict how much of the corporate workload will make it to the cloud (predictions range from 40 to 90 percent) or how fast that corporations will be able to move that workload to the cloud generally are 5 to 10 years), but the acceleration of technology could also accelerate this migration. It’s important to become educated on all of these products so that you can discern for your company which products fit now and which ones deserve a wait-and-see approach. The Oracle Cloud is standards-based (you can move things from the Oracle Cloud to the Amazon cloud). Charges are on an hourly or monthly subscription basis (and you can even put the server on your own site). I certainly foresee there will be more cloud services and more cloud customers by the time you read this.

TIP
Get ready for the cloud by trying a simple DBaaS instance at http://cloud.oracle.com/tryit for free or by trying the new 12cR2 Oracle Database Exadata Express Cloud Service for $175/month.
Exadata Database Machine

Oracle’s Exadata Database Machine (Exadata) transformed Oracle into a serious hardware contender. By June 2011, Oracle had already sold their 1000th Exadata machine, by mid-2014 they had sold more than 10,000 Exadata machines, and the market has been growing since then as well. As mentioned, the Exadata machine now delivers 4.5M flash IOPS. This figure is sure to have changed by the time you read this. Oracle is accelerating the hardware world as they did the software world; you can now build anything you can dream of!

Exadata Terminology and the Basics

When I think of an Exadata Database Machine full rack (X6-2 at the time of writing in the fall of 2016), I think of it as a “prebuilt eight-node RAC cluster with Super SAN or all flash option.” The Exadata Database Machine includes all the power one needs to run an Oracle database environment and is also a highly flexible architecture (it has an eighth rack option all the way to multiple racks of Exadata interconnected as one).

The X6-2 model architecture includes (standard configuration—you can go larger!):

- Eight compute nodes, with a total of 352 cores for 8 servers and 2T (up to 6T) of DRAM per rack clustered together using Oracle GI clustering and RAC at the database tier.
- An additional 280 CPU cores (see next point for detail on each cell) per rack dedicated to storage with a super-fast, low-latency interconnect network (2 × 40 Gb/sec each way).
- 14 storage cells providing database and SQL-aware storage, each with 2 CPU sockets × 10 core CPUs × 14 storage cell = 280 CPUs on the storage. Two storage options are available:
  - **Disk storage** 1.3P of disk space: 12 disks × 8 TB × 14 storage cells, 7200 RPM drives per cell plus 4 × 3.2T NVMe PCIe flash cards
  - **All flash storage** 180T of Flash Cache (up to 358T is possible): 14 storage cells × 4 × 3.2T NVMe PCIe flash SSD

The X6-8 Exadata Rack is much like the X6-2 except that it comes with two or four database nodes, each with 8 × 18 core CPUs (144 CPU cores) and 2T of DRAM. My take on it: if you need it and can afford it—you want it (all flash X6-2, SuperCluster M7, or all flash FS1 are the best Oracle hardware solutions on the planet!).

**NOTE**

The Exadata X6’s have an all Flash Cache option (180T to 358T) instead of 168 × 8T disks (1.3P), combined with write through/write back capability. It has almost eliminated all physical I/O performance.
The Exadata X6’s also include 4 × 1/10 GbE copper Ethernet interfaces, 2 × 10 GbE optical Ethernet ports, and Integrated Lights Out Management (ILOM) for remote administration capabilities.

How fast is it? In general, it’s 5 to 100 times faster than much of the data warehousing competition and 20 times faster than most OLTP competition. A full rack Exadata can deliver up to 4.5M IOPS (I/Os per second) and a throughput of 350 GB/sec.

What makes it so fast? Fast hardware, many CPUs, Flash Cache, lots of DRAM (parallel query in DRAM in 11.2), compression (saves 10×–70×), partition pruning (saves 10×–100×), storage indexes (saves 5×–10×), and Smart Scan (saves 4×–10×). You can turn a 1T search into a 500M search or even 50M when you leverage all these features. If anything, I think Oracle might be understating the true power of this hardware (Oracle calls it a “database machine”).

---

Exadata Statistics

In 2008, Oracle released V1 of the Exadata; the original Exadata was on HP hardware. In 2009, Oracle released Exadata V2, which was an all Oracle/Sun solution after the Sun acquisition. The following year, in 2010, Exadata X2 was released, which was a hardware upgrade. In 2010, Oracle also introduced the X2-8 model. Around 2011, Oracle released the Exadata Storage Expansion Rack, with the goal of providing the flexibility of growing storage capacity without needing to upgrade compute capacity. In 2012, Oracle released Exadata X3, with significant improvements to usage and capacity of Flash Cache, which earned it the name “in-memory database.” At the same time, December 2013, Oracle released version X4, which included hardware upgrades and improved capacity and performance characteristics. One of the subtler changes in this version was that the interconnect used two InfiniBand IP links, in active/active mode. In January 2015, Oracle released version X5, which introduced all flash storage. Once again, the improvements came in the form of newer, faster Non-Volatile Memory Express (NVMe) flash cards and drives. The all flash drive option officially eliminated the option to use high-performance disks over high-capacity disks. Another key development with the X5 was the concept of “elastic configuration,” which fundamentally frees the customer from the rigid structure implied by quarter rack or half rack or full rack. The customer can mix and match compute versus storage nodes based on actual need and have capacity on demand. Earlier this year, Oracle released Exadata X6 (April 2016), which increased the core count on the compute nodes and doubled the Flash Cache capacity as well the pure flash storage capacity.

The X6-2 Exadata model comes in the following sizes and models:

- A full rack, which has eight compute servers (2 socket and 14 storage cells)
- A half rack, which has four compute servers and seven storage cells
- A quarter rack, which comes with two compute servers and three storage cells
- An eighth rack, which is the same hardware as a quarter rack, with half the CPU and half the disk activated

Traditionally, the largest issues with respect to scaling the Exadata have been hardware cost and licensing cost:
The supported scaling model was eighth rack → quarter rack → half rack → full rack. This assumed a built-in scaling of both CPU and storage.

Any specific DB options had to be licensed for all CPUs, needed or not.

As a result, the licensing cost increases were significant.

To address the licensing pain point, Oracle came out with the following innovative approaches and options:

- Starting with the X5 model class, called “Elastic Configuration,” Oracle allowed the end user to define the number of compute nodes versus the number of storage nodes in a rack.
- Starting with the X5 model, Oracle also developed on-demand capacity licensing.
- Around the time of the release of Exadata X6, Oracle supported the use of Oracle Virtual Machine (OVM) with Exadata.

An X6-2 full rack Exadata Database Machine includes:

- 8 compute servers:
  - 8 servers × 2 CPU sockets × 22 cores = 356 cores
  - 8 servers × 4 disks × 600G (10K RPM) local storage
  - 8 servers × 768G DRAM = 6144G DRAM (standard is 2T with 256G per server)
  - 3 InfiniBand switches (40 Gb/s) × 36 ports = 108 ports
- 14 storage servers:
  - 14 cells × 2 CPU sockets × 10 core/CPU = 280 cores
  - 14 cells × 128G = 1792G memory
- High Capacity Storage Option:
  - 14 × 12 × 8T 7200 RPM drives for 14 cells = 1344T raw storage (1.3P)
  - 14 × 4 × 3.2T NVMe PCIe flash cards = 179.2T of flash
- Extreme Flash Storage Option:
  - 14 cells × 8 3.2T NVMe PCIe 3.0 flash drives = 358.4T flash

An X6-8 Exadata machine includes the same as the X6-2 in terms of storage and options. The difference is in the compute options:

- 2 compute servers option:
  - 2 servers × 8 CPU sockets × 18 cores = 288 cores
  - 2 servers × 2T DRAM = 4T DRAM
- 4 compute servers option:
The following table shows some actual storage-related statistics:

<table>
<thead>
<tr>
<th>Raw Capacity (TB)</th>
<th>Eighth Rack</th>
<th>Quarter Rack</th>
<th>Half Rack</th>
<th>Full Rack</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC (Disk)</td>
<td>144.00</td>
<td>288.00</td>
<td>672.00</td>
<td>1344.00</td>
</tr>
<tr>
<td>EF (Flash)</td>
<td>38.40</td>
<td>76.80</td>
<td>179.20</td>
<td>358.40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Capacity—Normal Redundancy (TB)</th>
<th>HC (Disk)</th>
<th>EF (Flash)</th>
<th>HC (Disk)</th>
<th>EF (Flash)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eighth Rack</td>
<td>54.00</td>
<td>109.00</td>
<td>254.00</td>
<td>508.00</td>
</tr>
<tr>
<td>Quarter Rack</td>
<td>14.00</td>
<td>28.00</td>
<td>65.00</td>
<td>130.00</td>
</tr>
<tr>
<td>Half Rack</td>
<td>43.00</td>
<td>85.00</td>
<td>199.00</td>
<td>399.00</td>
</tr>
<tr>
<td>Full Rack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum Load Rate (TB/hr)</th>
<th>HC (Disk)</th>
<th>EF (Flash)</th>
<th>HC (Disk)</th>
<th>EF (Flash)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eighth Rack</td>
<td>2.50</td>
<td>5.00</td>
<td>11.00</td>
<td>21.00</td>
</tr>
<tr>
<td>Quarter Rack</td>
<td>3.00</td>
<td>5.00</td>
<td>11.00</td>
<td>21.00</td>
</tr>
<tr>
<td>Half Rack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Rack</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum SQL Bandwidth GB/s</th>
<th>HC Flash Metrics</th>
<th>EF (Flash)</th>
<th>HC Disk Only</th>
<th>EF (Flash)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eighth Rack</td>
<td>32.00</td>
<td>38.00</td>
<td>2.70</td>
<td>3.40</td>
</tr>
<tr>
<td>Quarter Rack</td>
<td>64.00</td>
<td>75.00</td>
<td>5.40</td>
<td>7.00</td>
</tr>
<tr>
<td>Half Rack</td>
<td>150.00</td>
<td>175.00</td>
<td>12.50</td>
<td>15.00</td>
</tr>
<tr>
<td>Full Rack</td>
<td>301.00</td>
<td>350.00</td>
<td>25.00</td>
<td>30.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum SQL Disk IOPS</th>
<th>HC Flash Metrics</th>
<th>EF (Flash)</th>
<th>HC Disk Only</th>
<th>EF (Flash)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eighth Rack</td>
<td>4,500,000.00</td>
<td>4,500,000.00</td>
<td>3900.00</td>
<td>3900.00</td>
</tr>
<tr>
<td>Quarter Rack</td>
<td>2,250,000.00</td>
<td>2,250,000.00</td>
<td>7800.00</td>
<td>7800.00</td>
</tr>
<tr>
<td>Half Rack</td>
<td>1,125,000.00</td>
<td>1,125,000.00</td>
<td>18,000.00</td>
<td>18,000.00</td>
</tr>
<tr>
<td>Full Rack</td>
<td>562,000.00</td>
<td>562,000.00</td>
<td>36,000.00</td>
<td>36,000.00</td>
</tr>
</tbody>
</table>

These are some important points to note about this table:

- HC = High Capacity; EF = Extreme Flash.
- The storage capacity does not take into account benefits of compression (HCC or Advanced Compression).
- Usable space is computed after taking into account ASM redundancy, DBFS and Flash Recovery Disk groups, ACFS disk, OS images/binaries, etc.
- The SQL metrics are based on 8K IOPS and take into account ASM redundancy, which issues multiple IOPS.
Exadata Storage Expansion Rack Briefly

As of July 2011, Oracle added an *Exadata Storage Expansion Rack* that allows you to grow storage capacity of the X6-2 and X6-8 by connecting to it via InfiniBand. This addition is great news for those who are looking to have petabytes (P) of information. It is also welcome news for those who would like to store more of their archived-to-tape data on disk. The Storage Expansion Rack can have up to 18 additional HC storage cells and 19 EF storage cells. Each cell has the exact same characteristics as the cells in the Exadata Database Machine racks.

- A single HC cells can add about 1.7 T/hr to the overall data load rate.
- A single EF cell can add about 2.0 T/hr to the data load rate.
- A fully loaded expansion rack with HC storage can add 690T of usable space with normal redundancy and 540T with high redundancy.
- A fully loaded expansion rack with EF storage can add 175T of usable space with normal redundancy and 140T with high redundancy.

Exadata Storage Server software uses the following features (covered in detail later in this chapter):

- Smart Scan technology
- Smart Flash Cache
- Storage indexes
- Hybrid Columnar Compression
- IORM/DBRM both available
- Smart Scans of data mining model scoring
- Automatic Storage Management (ASM)
- Backup with RMAN
- Restores using Flashback technologies
- Redundant power and InfiniBand switches

The Oracle database is capable of storing 8 exabytes (8E). Here’s what’s possible:

- In 2011, as noted in the prior edition of this book, it took 41,227 Storage Expansion Racks to get to the maximum 8E (exabytes of mirrored uncompressed storage) 11g Database. Compression gives you 80–500+ exabytes. At 10× compression, you would only need 4123 Storage Expansion Racks to get to 8E, and at 70× compression, you would only need 589 Storage Expansion Racks to get to 8E.

- In 2016, the X6-2 has 1.3P and it would take only 6154 Exadata X6-2s to get to the maximum 8E 12c Database. Compression gives you 80–500+ exabytes. At 10× compression, you would
only need 616 Storage Expansion Racks to get to 8E, and at 70× compression, you would only need 88 Storage Expansion Racks to get to 8E.

The Facebook data warehouse has about 0.3E of stored data and is growing at 0.2E per year, so it will reach 8E in about 38 years (except it will be faster, I predict, since Facebook’s growth will be faster in the future). Facebook would currently fit on 23 X6-2s with 10× compression or only four X6-2s with 70× compression (except, you need mirroring, standby, etc). That’s a lot better than the warehouses that house Facebook’s servers.

64 bit allows 16E to be in memory (18,446,744,073,709,551,616).

Smart Scans

Smart Scans are done internally by Oracle, and when they are used, you commonly realize a 10× savings in query time. Oracle filters data based on WHERE clause conditions (predicates), and it filters on row, column, and join conditions. Oracle also performs incremental backup filtering. Smart Scans work with uncommitted data, locked rows, chained rows, compressed data, and even encrypted data (since 11.2). You can see and monitor the benefits with Oracle Enterprise Manager Cloud Control.

Smart Scans leverage Bloom filters used for faster join filtering. Bloom filters are a quick way to search for matches. They save space and are transparent to the user. Bloom filters are basically hardware-level filters that test to see if the elements are in a set. Google BigTable uses Bloom filters to reduce disk lookups as well. Oracle’s join filtering is a perfect application for Bloom filters. Following are some simple Smart Scan comparisons.

Without Smart Scan (push whole table via network):
- 5T table scan
- Network bandwidth (40 Gb/s)
- 40 Gb/s = 5 GB/s (e.g., with 14 storage cells, each cell has a data transfer rate of 0.357 GB/s)

16 minutes, 40 seconds (5T at 5 GB/s)—without Smart Scan

With Smart Scan (limit first at hardware level):
- 5T table scan
- Limit result before it hits the network
- Effectively scan 21 GB/s (1.5G/storage cell × 14 cells)

3 minutes, 58 seconds (5T at 21 GB/s)—with Smart Scan
Flash Cache

The Flash Cache is composed of solid-state disks (information stored on chips). It is between 20×–50× faster than disk (depending on the disks). The Flash Cache caches *hot* data (frequently used data). It does this as the *last* step (so it returns data to you *first* and then caches it for next time based on the settings you give it). It uses PCIe-based flash cards (PCIe is Peripheral Component Interconnect Express). It knows which objects *not* to cache, such as full table scans, but *you* can also specify exactly which data you want to cache using the STORAGE clause or you can specify it at the table/partition level with CREATE/ALTER:

- **STORAGE CELL_FLASH_CACHE KEEP**
- **Table/partition level CREATE or ALTER**

Flash Cache also has a write-through cache that you can use to accelerate reads. With this feature, data written to disk *might* also be written to cache (again, stored in the cache *after* the user gets it written to disk) for future reads.

The Flash Cache caches:

- Hot data/index blocks
- Control file reads/writes
- File header reads/writes

The Flash Cache does not cache:

- Mirror copies, backups, or Data Pump
- Tablespace formatting
- Table scans (or, at least, this is rare; for example, small tables are possibilities)

The Flash Cache LRU (least recently used) settings for caching include:

- **CELL_FLASH_CACHE storage clause** The possible values are:
  - **DEFAULT** Normal, large I/Os not cached.
  - **KEEP** Use Flash Cache more aggressively/it may not occupy > 80 percent of all cache.
  - **NONE** Flash Cache not used.
- **CACHE (NOCACHE) hint** I/O cached/not-cached in the Flash Cache.
  - **SELECT /*+ CACHE */ …**
- **EVICT hint** Data removed from the Flash Cache. ASM rebalance data is evicted from cache when done.

Large I/O (full table scans) on objects with CELL_FLASH_CACHE set to DEFAULT are not cached.
Setting the KEEP cache is accomplished as follows:

```
ALTER TABLE CUSTOMER
STORAGE (CELL_FLASH_CACHE KEEP);
Table Altered.
```

Use the following query to see if a table is currently set to cache or not:

```
SELECT TABLE_NAME, TABLESPACE_NAME,
       CELL_FLASH_CACHE
FROM USER_TABLES
WHERE TABLE_NAME = 'CUSTOMER';
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>TABLESPACE_NAME</th>
<th>CELL_FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>R_TEST</td>
<td>KEEP</td>
</tr>
</tbody>
</table>

Here is how the Flash Cache works: A database request comes to CELLSRV (*cell storage server*). The CELLSRV (first time) gets data from disk and the data is cached based on settings, hints, and so on. The data that goes to WRITE may also be cached after being written if it is deemed that it may be needed again. The CELLSRV (next time) checks the Memory Hash Table that lists what is cached. If cached, the data goes to Flash Cache; if not cached, it may cache based on settings and so on. You can also query the hardware cells directly as listed here:

```
CELLCLI> list flashcache detail (allows you to monitor)
CELLCLI> list flashcachecontent where ObjectNumber=62340 detail
```

**SQL*Plus Query—is it working?**

```
SELECT NAME, VALUE
FROM V$SYSSTAT
WHERE NAME IN ('physical read total IO requests',
              'physical read requests optimized');
```

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical read total IO requests</td>
<td>36240</td>
</tr>
<tr>
<td>physical read requests optimized</td>
<td>23954</td>
</tr>
</tbody>
</table>

This second line times block size (*8192*) is the bytes of Flash Cache used; it’s working!
It is working ... 4G query:

```sql
SELECT NAME, VALUE, VALUE*8192 VALUE2
FROM V$SYSSTAT
WHERE NAME IN ('physical read total IO requests',
                 'physical read requests optimized');
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>VALUE2</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical read total IO requests</td>
<td>19,962,944</td>
<td>89,988,419,048</td>
</tr>
<tr>
<td>physical read requests optimized</td>
<td>2,803,003</td>
<td>22,978,584,576</td>
</tr>
</tbody>
</table>

run2...

```sql
SELECT NAME, VALUE, VALUE*8192 VALUE2
FROM V$SYSSTAT
WHERE NAME IN ('physical read total IO requests',
                 'physical read requests optimized');
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>VALUE2</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical read total IO requests</td>
<td>11,320,185</td>
<td>32,734,955,520</td>
</tr>
<tr>
<td>physical read requests optimized</td>
<td>3,203,224</td>
<td>26,240,811,008</td>
</tr>
</tbody>
</table>

run4...

```sql
SELECT NAME, VALUE, VALUE*8192 VALUE2
FROM V$SYSSTAT
WHERE NAME IN ('physical read total IO requests',
                 'physical read requests optimized');
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>VALUE2</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical read total IO requests</td>
<td>11,993,845</td>
<td>38,253,572,249</td>
</tr>
<tr>
<td>physical read requests optimized</td>
<td>3,793,000</td>
<td>31,072,256,008</td>
</tr>
</tbody>
</table>

It is working ... V$SQL:

```sql
SELECT sql_text, optimized_phy_read_requests, physical_read_requests,
       io_cell_offload_eligible_bytes
FROM v$sql
WHERE sql_text LIKE 'FIND YOUR SQL';
```

<table>
<thead>
<tr>
<th>SQL_TEXT</th>
<th>OPTIMIZED_PHY_READ_REQUESTS</th>
<th>PHYSICAL_READ_REQUESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO_CELL_OFFLOAD_ELIGIBLE_BYTES</td>
<td>567790</td>
<td>688309</td>
</tr>
</tbody>
</table>

run 2:

```sql
SELECT sql_text, optimized_phy_read_requests, physical_read_requests,
       io_cell_offload_eligible_bytes
FROM v$sql
WHERE sql_text LIKE 'FIND YOUR SQL';
```

<table>
<thead>
<tr>
<th>SQL_TEXT</th>
<th>OPTIMIZED_PHY_READ_REQUESTS</th>
<th>PHYSICAL_READ_REQUESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT ...</td>
<td>762747</td>
<td>906729</td>
</tr>
</tbody>
</table>

run 4:

```sql
SELECT sql_text, optimized_phy_read_requests, physical_read_requests,
       io_cell_offload_eligible_bytes
FROM v$sql
WHERE sql_text LIKE 'FIND YOUR SQL';
```

<table>
<thead>
<tr>
<th>SQL_TEXT</th>
<th>OPTIMIZED_PHY_READ_REQUESTS</th>
<th>PHYSICAL_READ_REQUESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELECT ...</td>
<td>1352166</td>
<td>1566537</td>
</tr>
</tbody>
</table>
NOTE
The Exadata PCIe card Smart Flash Cache (that is, the stored Exadata hardware PCIe Card Cache) is not the same as the Database Flash Cache (file stored) used with Oracle Enterprise Linux or Solaris only.

Finally, keep in mind that Flash Cache wears out faster than disks (see the specifications for more information; Flash Cache wears out faster in higher elevations). Oracle does give you uncounted “extra” space to make up for this, however.

Storage Indexes

A storage index utilizes minimum and maximum values for certain columns to help queries run faster by eliminating rows (similar to partitioning). A performance gain of 10× is common with storage indexes (could be higher/lower depending on the minimum/maximum and how many rows can be eliminated for a given query). These indexes primarily maintain summary information about the data (like metadata in a way). The memory structure resides in the cell level (storage). It groups data into min/max for various columns (based on usage patterns), and it eliminates I/Os where there is no match. A storage index is 100 percent transparent to the user. Indexing is performed at the hardware level, and one storage index is used for every 1M of disk. A storage index does not perform like a B-tree index, but more like partition elimination—where you skip data not meeting the query conditions. Oracle builds 100 percent of the storage indexes based on query patterns and data use; no additional coding is required. Consider the following queries to see if storage indexing is working on a two-node RAC cluster.

Is it working for me?

```
SELECT NAME, VALUE
FROM V$SYSSTAT
WHERE NAME LIKE ('%storage%');
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell physical IO bytes saved by storage index</td>
<td>25604736</td>
</tr>
</tbody>
</table>

This is the actual savings from an Exadata-built storage index; it’s working on this node!

Check both servers (only savings on one node during this test):
This is the actual savings from the Exadata-built storage index; it's working!

Hybrid Columnar Compression

Hybrid Columnar Compression (HCC), also known as Exadata Hybrid Columnar Compression (EHCC), is data that is organized by a hybrid of columns/rows and compressed versus data organized by basic row format. A performance gain anywhere from 10× to 30× is common. The tables are organized in compression units (CUs), which contain around 1000 rows (more or less depending on the amount of data in the rows). CUs span many blocks. HCC is very good for bulk-loaded data, but is not built for OLTP or single block read operations. It is primarily built for data warehouses and queried data, not for frequently updated data.

Using the old OLTP compression algorithm, you could get 2–3× compression or so. Yet, with HCC, 10× compression in a typical data warehouse is common. In limited tests, I got anywhere from 4–11×. HCC also allows archive compression (used for cold data), which gives you anywhere from 15× to 70× compression (I got approximately 32× compression in limited tests). The nice thing about HCC is that operations are faster because the query runs without decompression. The compressed version is processed in the Flash Cache, which results in lower I/O. The compressed version is also sent over InfiniBand; it is cloned compressed; and it is even backed up compressed! As a result, it scans much less (compressed) data!

Figure 11-16 is a logical representation of a CU. The image does not specifically show block headers and so on, but they are maintained for each block. The initial piece of a CU is a header that maintains the metadata associated with its contents. Among other things, it contains the starting point of each column within the CU.
A given column’s data can span over several blocks, and for that reason the CU header is structured similarly to chained rows within regular tables, with a pointer to the top of each column. Therefore, ROWID for an HCC-organized table must refer to the CU and not the block itself. For normal tables, the ROWID is composed of the following:

- FILE NUMBER or RELATIVE FILE NUMBER
- BLOCK NUMBER
- ROW NUMBER

In the case of HCC, the FILE NUMBER and BLOCK NUMBER actually relate to the CU itself. We can use `DBMS_ROWID.ROWID_RELATIVE_FNO` and `DBMS_ROWID.ROWID_BLOCK_NUMBER` to see how many rows are in each CU, an example of which can be seen in the following query. To see how many blocks were actually in use, not just allocated, we used the Oracle-provided PL/SQL package `DBMS_SPACE.UNUSED_SPACE`.

```
SELECT COUNT(*) FROM (SELECT DISTINCT DBMS_ROWID.ROWID_RELATIVE_FNO(RowID),
                        DBMS_ROWID.ROWID_BLOCK_NUMBER(RowID) FROM TABLE_NAME);
```

HCC can be deployed in multiple flavors:

- **HCC Query Low or Query High**: More suited for querying data. Lesser compression benefits but less costly to query. Query Low uses the LZO compression algorithm while Query High uses the ZLIB algorithm.

- **HCC Archive Low or Archive High**: More suited for archiving data, thus higher compression but more costly to query. Archive logs use the ZLIB algorithm while Archive High uses the BZIP2 algorithm.

Tables 11-1 and 11-2 provide a comparison of the compression ratio and CU usage statistics, respectively, by type of HCC.
TABLE 11-1. Compression Ratio by Compression Type

<table>
<thead>
<tr>
<th>HCC Type</th>
<th># of CUss</th>
<th>Blocks Used</th>
<th>Rows/CU</th>
<th>Blocks/CU</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCC Archive High</td>
<td>126</td>
<td>2413</td>
<td>29294.6</td>
<td>19.15</td>
</tr>
<tr>
<td>HCC Archive Low</td>
<td>656</td>
<td>3074</td>
<td>5626.7</td>
<td>4.69</td>
</tr>
<tr>
<td>HCC Query High</td>
<td>824</td>
<td>3094</td>
<td>4479.5</td>
<td>3.75</td>
</tr>
<tr>
<td>HCC Query Low</td>
<td>1926</td>
<td>7506</td>
<td>1916.5</td>
<td>3.90</td>
</tr>
</tbody>
</table>

TABLE 11-2. CU Usage Statistics by Compression Type

Data load rates will depend upon the nature and type of data load. Bulk load operations are better suited for HCC than single row inserts. Similarly, full table scans are better suited for HCC. Either way, there is a penalty that comes with using HCC. Figures 11-17 and 11-18 show sample data to that effect.

FIGURE 11-17. Data loads with compression
FIGURE 11-18. Effect of compression on full table scans

Another important point to understand is the locking behavior in HCC during updates. Oracle traditionally has maintained row-level locking as the mantra and rule. This rule does not apply to HCC in the same way. When a table is created to take advantage of HCC, irrespective of the type, locking is now managed and maintained at the CU level. What this means is that if a session updates a row that is currently stored using HCC compression type, then the session lock is taken at the CU level. In other words, another session that tries to update a second row in the same CU will be blocked by the first session and will have to wait on an “enq: TX - row lock contention” wait event (see Chapter 14 for detail on locks/latches). It is important to note that though the lock is effectively on a CU, the wait event reported is still a row-level lock. Oracle asserts that performance of UPDATEs and INSERTs with CUs has been improved in 12cR2.

Note that you can still use standard table compression for OLTP, and a single block lookup is still generally faster than other columnar storage. The updated rows migrate to normal/lower-level compression. HCC fully supports:

- B-tree indexes
- Bitmap indexes
- Text indexes
- Materialized views
- Partitioning
- Parallel queries
- Data Guard physical standby
Logical standby and Streams (in a future release)

Smart Scans of HCC tables!

I/O Resource Management

Oracle’s latest I/O Resource Management (IORM) tool can be used with Exadata to manage multiple workloads and set resources as you deem necessary. Although I don’t cover this in detail here, please consider the following ways that you can set up three instances with different resources. Instance A gets 50 percent, instance B gets 30 percent, and instance C gets 20 percent. You can further break down the 50 percent that instance A gets into the various user- and task-related percentages.

Set I/O resources for different instance

- Instance A = 50%
- Instance B = 30%
- Instance C = 20%

Further set I/O based on users and tasks

- Instance A Interactive = 50%
- Instance A Reporting = 20%
- Instance A Batch = 15%
- Instance A ETL = 15%

You can also continue to use Database Resource Manager (DBRM) as in the past. DBRM has been enhanced for Exadata. It allows management of inter- and intra-database I/O. With inter-database I/O, you manage using IORM and Exadata storage software. For intra-database I/O, you manage using Consumer Groups. You can set limits for CPU, UNDO, degree of parallelism (DOP), active sessions, and much more. Please see the Oracle documentation for more details. This section is only a brief introduction so you can see what’s possible.

Use All Oracle Security Advantages with Exadata

Oracle is known for its incredible security. Their first customer was the CIA (Central Intelligence Agency), so they’ve always been focused on security (for over 30+ years). Don’t forget to investigate these security and recovery options that are available with Exadata:

- Audit Vault
- Total Recall/Flashback (recovery)
- Database Vault
- Label security
- Advanced security
- Secure encrypted backup (Please use!) (also available—incremental backup with change tracking file, which is much faster)
- Data masking
- Data Guard (recovery)
- Failure groups (automatic for storage cell failure)

### Best Practices

There are many best practices that will help you get the most out of Exadata. I’ll start with a list of **must haves** and **don’t do’s**. Note, however, that these can change at any time, so check Oracle’s docs for the latest information.* Here is my list as of the writing of this chapter (late 2016):

- Must have Bundle Patch 5 (see Metalink Note 888828.1 for the latest).
- Must have ASM to use Exadata.
- Must have three floor tiles on a raised floor (must support 2219 lbs./964 kg) with holes (cooling) for a full rack (between 1560 CFM and 2200 CFM front to back—less for a half or quarter rack). You don’t want to melt it! All of this is subject to change, so please check the latest specifications.
- Must have the correct power needs (it is not standard).
- Must use Oracle Linux and Oracle DB 11.2 or 12c (current).
- Must use RMAN for backups.
- Ensure InfiniBand is connected and MTU is set to 65520.
- Check disk group balance and notes on auto-extend.
- Capture performance baselines *early* in your implementation.
- Consider a ZFS appliance with connectivity over InfiniBand for database backups. If you do so, please make sure to configure the database with Oracle dNFS for maximum benefit.
- Alternatively, consider StorageTek tape backup (many positive reviews but it is pricey).
- Use an ASM allocation unit (AU) size of 4M (currently).
- Don’t add any foreign hardware … or *no support!*
- Don’t change BIOS/firmware … or *no support!*

Next, I’d like to list some Oracle stated best practices. Note that these can change at any time, as
well, so please check your Oracle docs for the latest. Best practices include:

- CREATE ALL celldisk and griddisks.
- Use DCLI to run on all storage servers at once (helpful and saves time).
- Use IORM for resource management.
- Decide fast recovery area (FRA) and MAA needs before you install.
- Set log file size at 32G (whoa!).
- To optimize fast scan rates, ensure database extent sizes are at least 4M (locally managed tablespaces [LMTs] can have a uniform or auto-allocate extent policy).
- Move data with Data Pump (usually, but many other options are available).

Summary: Exadata = Paradigm Shift!

I’ve covered many Exadata topics in this section, including Exadata terminology and basics, Flash Cache, storage indexes, Smart Scans, Hybrid Columnar Compression, I/O Resource Manager, security, and best practices. To summarize, what makes Exadata fast is fast hardware, many CPUs, fast Flash Cache, lots of DRAM on database servers and storage, compression (saves 10×–70×), partition pruning (saves 10×–100×), storage indexes (saves 5×–10×), Smart Scan (saves 4×–10×), and other features not covered (see Oracle Docs for more information). Exadata is the best way to turn a 1T search into a 500M search or even a 50M search. I believe that Exadata is The Real Deal and will drive future accelerated hardware innovation by all major hardware vendors.

Oracle Database Appliance (ODA)

Exadata may be overkill for some customers. When Oracle introduced the Oracle Database Appliance, they were thinking about small- and medium-sized businesses (SMBs) and customers that needed departmental servers. The goal of ODA, however, is to have a quickly implemented, mid-sized server. Currently there are two different models where Oracle has one 10-core CPU in the X6-2S (128-384G RAM) and two 10-core CPUs in the X6-2M (256-768G RAM). Both systems come standard with 6.4T Flash (NVMe) that can be expanded to 12.8T and can run on Enterprise Edition (EE) or Standard Edition 2 (SE2) with licensing up to only two CPU cores (to save $$. The ODA X5-2 has two servers for a larger footprint. A database appliance can include:

- Oracle with ASM and RAC running on Oracle Linux
- High-availability fault tolerance—two nodes/dual server
- Cluster in a box (Oracle Clusterware comes installed)
- Oracle Appliance Manager (for quick patching and system management)
- Auto memory management, auto tuning, auto disk backup
The Oracle Database Appliance is now a little beefier since its introduction, but can be ready to go in a couple of hours (software and RAC is preloaded). It even has a phone-home capability; it calls for service and has one-button patching. Introducing the Oracle Database Appliance is just another way that Oracle is leveraging its Sun acquisition to create a full line of hardware that benefits its customers. While the hardware itself is inexpensive, the software license cost can certainly add up if you use the maximum CPU configuration, but it’s still much lower priced than a quarter rack at the current time (a quarter rack is over 2× faster though). I’m confident that this will evolve over time, so please check with Oracle for the latest configuration and pricing.

SuperCluster Using the M7 SPARC Chip
On September 26, 2011, Oracle announced the new SPARC SuperCluster T4-4 and I thought, “How will they ever top a 1000+ threaded system?” In 2016, new SuperCluster using the M7 SPARC chip includes built-in hardware encryption (on the silicon with near zero overhead), protection from memory attacks (again at the silicon level), up to 512 CPU cores, and 8T of DRAM per rack. It also has HCC for 10–15×+ compression. It was engineered with the 12c database and Exadata storage (including those benefits described in the previous Exadata sections). SuperCluster runs the Solaris operating system (Solaris 11 or Solaris 10) with hardware using the new M7 multithreaded SPARC processor.

Oracle is primarily targeting their Solaris install base to migrate to SuperCluster. Oracle’s goal is not only to make migrating easy for this install base, but also to give them the speed of Exadata and Exalogic in a single M7 SPARC-based machine. From reviewing the last few sections, you can see that Oracle is leveraging its Sun acquisition with the fastest hardware on earth for parallel database processing (rack(s) of Exadata), fastest middleware server or Internet eBusiness application server machine(s) (rack(s) of Exalogic), large company migration from Solaris to mix of Exadata/Exalogic speed systems (rack(s) of SuperCluster), small business or department server (Oracle Database Appliance(s)), and infinite storage (rack(s) of Exadata Storage Expansion Racks). I’m sure Oracle has already exceeded all of this, even as amazing as it sounded at the time I wrote this. My advice: Teach your kids Oracle!

Other Oracle Hardware to Consider
In this section, I cover some of the other hardware that you should at least consider as you implement your business solutions. All of these come from Oracle acquisitions.

Oracle Big Data Appliance X6-2
Oracle Big Data Appliance X6-2 is used to acquire, organize, analyze, and make sense of all the unstructured data in your company or on the Web. Big data is all the data associated with weblogs, social media, e-mail, sensors, photographs, videos, and all the other sources of big data that are coming. The Oracle Big Data Appliance is an engineered system that includes an open source version of Apache Hadoop, Oracle NoSQL Database (think of it as version 2 of Oracle, a highly scalable
key-value database), Oracle Data Integrator Application Adapter for Hadoop (simplifies data integration in Hadoop), Big Data SQL to connect all data sources querying with SQL (query Hadoop or Hive directly from Oracle SQL), and an open source version of R (Oracle R Enterprise integrates with the open source statistical environment R to deliver advanced analytics). You can also integrate the Oracle Big Data Appliance with the Oracle Database, Exadata, or Exalytics. When you use Oracle’s Big Data SQL to query Hadoop, you can apply security and access policies to Hadoop or other NoSQL (NoSQL ≠ Not only SQL) sources. Exadata features such as Smart Scan and storage indexes coexist with Hadoop itself. It runs on Linux and includes Java, MySQL, Big Data Plug-in, Oracle R, Oracle NoSQL, Cloudera Impala, Apache HBase, Apache, Spark, Apache Kafka, Cloudera Hadoop (CDH), and Cloudera Manager. The hardware side includes up to 792 cores (36 × 22-core processors), 14T DRAM, and 1.7P of storage.

ZFS Storage Servers

Sun ZFS Storage ZS4-4 has 6.9P of raw storage capacity. This is a high-performance network attached storage (NAS) system with SAN storage capabilities. It supports an active-active cluster option, supports Oracle Database HCC, and has data compression and inline deduplication. It has 6.9P of raw storage capacity (and can be configured with 3T of read optimized cache) with eight 15-core processors.

With Oracle Database 12c, ZFS now uses the Oracle Intelligent Storage Protocol, which watches access patterns and tunes itself for optimal performance. It includes full PDB-level analytics (ZS Analytics) with 12c. It also includes Exadata storage features such as HCC. ZFS is an 128-bit file system that can address 16E more data than 64-bit can.

StorageTek Modular Library System

One of the largest companies I know of recently had to recover from tape. Most companies have online fast recovery areas (FRAs) for quick recoveries, as well as online backups located on slower 2T SATA disks. But there is still a place for an offsite tape backup, and StorageTek makes it fast and easy. Looking inside one of these machines is like watching a production assembly line where tapes are moved around as needed automatically. Another benefit of the Sun acquisition was getting this incredible company called StorageTek. It is no surprise that Oracle now archives more data than anyone else in the world.

The StorageTek SL8500, with a maximum configuration of ten libraries (there are many models/sizes to choose from if you need something smaller), includes the ability to back up 500P native or 2.1E (1 Exabyte = 1000P) with a 2.5:1 compression (at a speed of 553 TB/hr). To put this in perspective, a decade ago (around 2005), a business magazine estimated that the average Fortune 1000 company had an average size of 1P for all of their databases. That means all Fortune 1000 databases could have been backed up with this device (maximum ten-library configuration) with a 2:1 compression in 2005. You can connect up to 32 of these libraries for a maximum tape backup capacity of 67E. After reading these last few sections, you should start to see the future of Oracle accelerating
Parallel Databases

A parallel clustered database is a complex application that provides access to the same database (group of data tables, indexes, and other objects) from any server in the cluster concurrently without compromising data integrity. Parallel databases typically contain multiple instances of a database (located on many nodes/servers) accessing the same physical storage or data concurrently. In terms of storage access type, parallel systems are implemented in two ways: a shared-nothing model or a shared-disk model.

In a shared-nothing model, also termed a data-partitioning model, each system owns a portion of the database and each partition can only be read or modified by the owning system. Data partitioning enables each system to locally cache its portion of the database in processor memory without requiring cross-system communication to provide data access concurrency and coherency controls. Both IBM’s and Microsoft’s databases can operate this way and have in the past. Perhaps Oracle’s adoption of the shared-disk model is what gave them a huge lead in grid computing and will help in the cloud.

In a shared-disk model, all the disks containing data are accessible by all nodes of the cluster. Disk sharing architecture requires suitable lock management techniques to control the update concurrency. Each of the nodes in the cluster has direct access to all disks on which shared data is placed. Each node has a local database buffer cache. Oracle’s RAC database operates this way.

With due emphasis on high availability and high performance, Oracle has provided Oracle Parallel Server (OPS) for a long time. With Oracle9i, it drove into the next generation and rebuilt OPS as Real Application Clusters (RAC). RAC follows the shared-disk model and thus has access to all the shared disks as well as to an extensive mechanism to coordinate the resources across the nodes. Shared-disk technology has advanced rapidly over the past few years, giving RAC added advantages. Storage area network (SAN) technology hides much of the complexity of hardware units, controllers, disk drives, and interconnects from the servers and provides just storage volumes. In the same way, a group of servers together in a cluster provides a single system image and computing resource. Oracle’s acquisition of Sun only strengthens an already-compelling RAC story.

Real Application Clusters (RAC)

High performance and high availability of information systems constitute key requirements for day-to-day business operations. As the dependence on stored information grew over the last couple of decades, large amounts of data are being accumulated and analyzed. There is an ever-increasing demand for high-performance databases, and at the same time, awareness of and requirements for keeping such databases online all the time has increased. Global operations and e-business growth depend very much on highly available stored data. With uneven and unpredictable loads on the database systems, it has become imperative for many business groups to search for high-performance systems and suitable parallel systems to support complex and large database systems. Scalability is another important feature. As the business grows, data accumulation and data interaction increase. More and more users and applications begin to use the database systems. The database systems should be able to support the increased demand for data without losing ground in performance and
Oracle9i introduced Real Application Clusters (RAC) to solve these issues. In Oracle 10g, Oracle started to perfect Grid Control for managing clusters of databases. In 11g, Oracle introduced Oracle RAC One Node. RAC One Node represents an Oracle RAC database that runs only one active Oracle database instance and can be managed using Server Control Utility (SVRCTL) as any Oracle RAC database. You can add nodes that can be used for failover, but you cannot add additional instances without first converting Oracle RAC One Node to Oracle RAC. You can convert from single instance to RAC One Node or RAC using Oracle’s Database Configuration Assistant (DBCA) at any time. You can use Online Database Relocation with SVRCTL to perform a live migration of the database instance and connections to one of the failover nodes. This gives you the ability to move a database easily from an overworked server to a less-utilized server in the same cluster. RAC One Node helps you to consolidate many databases into one cluster with minimal overhead while also providing the high-availability benefits of client failover, online rolling patch application, and rolling upgrades for the operating system and Oracle Clusterware. Please see the documentation for full details and use. Oracle also enhanced Grid Control to make adding or subtracting nodes as well as managing the cluster infrastructure easier. Oracle 11g also adds zero-downtime patching and a 64-bit ASM cluster file system, eliminating the need for a third-party cluster file system. This section by no means covers all aspects of RAC functioning. It merely highlights some important concepts and some of RAC’s inner workings. The scope of this book does not cover RAC specifically. You can switch from single-instance Oracle DB to RAC One Node or RAC at any time (if you have the appropriate licenses!). In 12c you can use In-Memory to replicate the IM column store on each node in a RAC cluster so that even memory used for analytics is fault-tolerant!

Oracle RAC Architecture

At a very high level, RAC is multiple Oracle instances (on separate nodes) accessing a single Oracle database. The database is a single physical database stored on a shared storage system. Each of the instances resides on a separate host (also called a node or server). All the nodes are clustered through a private interconnect, and all nodes have access to the shared storage. All the nodes concurrently execute transactions against the same database. The cluster manager software, usually supplied by the cluster vendor, provides a single system image, controls node membership, and monitors the node status. Broadly, the major components include:

- Nodes/servers
- High-speed private interconnect (connects the nodes together)
- Cluster Manager or OSD (operating system–dependent layer)
- Shared disk or storage
- Cluster file system or raw devices
- Volume manager
- Public network
Cluster Interconnect

If a block of data has been changed in the cache memory on one node and the user asks for it on another node, Oracle uses Cache Fusion to pass one block through the interconnect (such as InfiniBand) to the cache on the other node. Parallel processing relies on passing messages among multiple processors. Processors running parallel programs call for data and instructions and then perform calculations. Each processor checks back periodically with the other nodes or a master node to plan its next move or to synchronize the delivery of results. These activities rely on message-passing software, such as the industry-standard Message Passing Interface (MPI).

In parallel databases, there is a great deal of message passing and data blocks, or pages, transferring to the local cache of another node. Much of the functionality and performance depends on the efficiency of the transport medium or methodology. The transport medium becomes very critical for the overall performance of the cluster and usage of the parallel application. Because parallel databases do not impose any constraints on the nodes to which users can connect and access, users have a choice to connect to any node in the cluster. Irrespective of the nature of the application, OLTP, or data warehousing databases, the movement of data blocks from one node to another using the interconnect is widely practiced. The role of the cluster interconnect to provide some kind of extended cache encompassing the cache from all the nodes is one of the most significant design features of the cluster. In general, the cluster interconnect is used for the following high-level functions:

- Health, status, and synchronization of messages
- Distributed lock manager (DLM) messages
- Accessing remote file systems
- Application-specific traffic
- Cluster alias routing

High performance, by distributing the computations across an array of nodes in the cluster, requires the cluster interconnect to provide a high data transfer rate and low-latency communication between nodes. Also, the interconnect needs to be capable of detecting and isolating faults, and using alternative paths. Some of the essential requirements for the interconnect are:

- Low latency for short messages
- High speed and sustained data rates for large messages
- Low host-CPU utilization per message
- Flow control, error control, and heartbeat continuity monitoring
- Host interfaces that execute control programs to interact directly with host processes (OS bypass)
- Switch networks that scale well
Many of the cluster vendors have designed very competitive technology. Many of the interconnect products come close to the latency levels of a symmetric multiprocessing (SMP) bus.

**Internal Workings of the Oracle RAC System**

Oracle uses Global Cache Services to coordinate activity. A lock is treated as a held resource. RAC is a multi-instance database. Multiple instances access the same database concurrently. In terms of structure, the difference between a RAC instance and a stand-alone Oracle instance is miniscule. Besides all the usual Oracle background processes, many special processes are spawned to coordinate inter-instance communication and to facilitate resource sharing among nodes in a cluster. The Oracle documentation goes through all of the processes if you are interested in knowing more. Here is a brief description of some of the main ones:

- **ACMS** The Atomic Controlfile to Memory Service (ACMS) is an agent on a per-instance basis that helps to ensure a distributed SGA memory update is globally committed on success and globally aborted on failure.

- **LMON** The Global Enqueue Service Monitor (LMON) monitors the entire cluster to manage global enqueues and resources. LMON manages instance and process expirations and the associated recovery for the Global Cache Service.

- **LMD** The Global Enqueue Service Daemon (LMD) is the lock agent process that manages enqueue manager service requests for Global Enqueue Service enqueues to control access to global enqueues and resources. The LMD process also handles deadlock detection and remote enqueue requests.

- **LMSn** These Global Cache Service processes (LMSn) are processes for the Global Cache Service (GCS). RAC software provides for up to ten GCS processes. The number of LMSn processes varies depending on the amount of messaging traffic among nodes in the cluster. The LMSn processes do these things:
  - Handle blocking interrupts from the remote instance for Global Cache Service resources
  - Manage resource requests and cross-instance call operations for shared resources
  - Build a list of invalid lock elements and validate lock elements during recovery
  - Handle global lock deadlock detection and monitor lock conversion timeouts

- **LCK0 process** The Instance Enqueue Process manages global enqueue requests and cross-instance broadcast. Manages non–Cache Fusion and library/row cache requests.

- **RMSn** RAC management processes include tasks like the creation of resources as nodes are added.

- **RSMN** Remote Slave Monitor (RSMN) performs remote instance tasks for a coordinating process.

- **GTX0-j** The Global Transaction Process supports global XA transactions.
Global Cache Service (GCS) and Global Enqueue Service (GES)

GCS and GES (which are basically RAC components) play the key role in implementing Cache Fusion. GCS ensures a single system image of the data even though the data is accessed by multiple instances. GCS and GES are integrated components of Real Application Clusters that coordinate simultaneous access to the shared database and to shared resources within the database and database cache. GES and GCS together maintain a Global Resource Directory (GRD) to record information about resources and enqueues. The GRD remains in memory and is stored on all the instances. Each instance manages a portion of the directory. This distributed nature is a key point for fault tolerance of RAC.

The coordination of concurrent tasks within a shared cache server is called synchronization. Synchronization uses the private interconnect and heavy message transfers. The following types of resources require synchronization: data blocks and enqueues. GCS maintains the modes for blocks in the global role and is responsible for block transfers between instances. LMS processes handle the GCS messages and do the bulk of the GCS processing.

An enqueue is a shared memory structure that serializes access to database resources. It can be local or global. Oracle uses enqueues in three modes: null (N) mode, shared (S) mode, and exclusive (X) mode. Blocks are the primary structures for reading and writing into and out of buffers. An enqueue is often the most requested resource.

GES maintains or handles the synchronization of the dictionary cache, library cache, transaction locks, and DDL locks. In other words, GES manages enqueues other than data blocks. To synchronize access to the data dictionary cache, latches are used in exclusive (X) mode and in single-node cluster databases. Global enqueues are used in cluster database mode.

Cache Fusion and Resource Coordination

Because each node in a Real Application Cluster has its own memory (cache) that is not shared with other nodes, RAC must coordinate the buffer caches of different nodes while minimizing additional disk I/O that could reduce performance. Cache Fusion is the technology that uses high-speed interconnects to provide cache-to-cache transfers of data blocks between instances in a cluster. Cache Fusion functionality allows direct memory writes of dirty blocks to alleviate the need to force a disk write and reread (or ping) of the committed blocks. This is not to say that disk writes do not occur; disk writes are still required for cache replacement and when a checkpoint occurs. Cache Fusion addresses the issues involved in concurrency between instances: concurrent reads on multiple nodes, concurrent reads and writes on different nodes, and concurrent writes on different nodes.

Oracle only reads data blocks from disk if they are not already present in the buffer caches of any instance. Because data block writes are deferred, they often contain modifications from multiple transactions. The modified data blocks are written to disk only when a checkpoint occurs. Before I go further, you need to be familiar with a couple of concepts introduced with RAC: resource modes and resource roles. Because the same data blocks can concurrently exist in multiple instances, there are two identifiers that help to coordinate these blocks:

- **Resource mode** The modes are null, shared, and exclusive. The block can be held in different modes, depending on whether a resource holder intends to modify data or merely read it.
Resource role

The roles are locally managed and globally managed.

The Global Resource Directory is not a database. It is a collection of internal structures and is used to find the current status of the data blocks. Whenever a block is transferred out of a local cache to another instance’s cache, the GRD is updated. The following information about a resource is available in the GRD:

- Data Block Identifiers
- Location of most current versions
- Data block modes (N, S, X)
- Data block roles (local or global)

Past Image

To maintain data integrity, a new concept of past image was introduced in the 9i version of RAC. A *past image (PI)* of a block is kept in memory before the block is sent and serves as an indication of whether it is a dirty block. In the event of failure, GCS can reconstruct the current version of the block by reading PIs. This PI is different from a CR block, which is needed to reconstruct read-consistent images. The CR version of a block represents a consistent snapshot of the data at a point in time.

For example, Transaction-A of Instance-A has updated row-2 on block-5, and later another Transaction-B of Instance-B has updated row-6 on the same block-5. Block-5 has been transferred from Instance-A to Instance-B. At this time, the past image for block-5 is created on Instance-A.

SCN Processing

*System change numbers (SCNs)* uniquely identify a committed transaction and the changes it makes. An SCN is a logical timestamp that defines a committed version of a database at one point in time. Oracle assigns every committed transaction a unique SCN.

Within RAC, since you have multiple instances that perform commits, the SCN changes need to be maintained within an instance, but at the same time, they must also be synchronized across all instances with a cluster. Therefore, SCNs are handled by the Global Cache Service using the Lamport SCN generation scheme, or by using a hardware clock or dedicated SCN server. SCNs are recorded in the redo log so recovery operations can be synchronized in RAC.

Is RAC Unbreakable?

Can RAC be brought down? Sure it can. Any bad design or choice will bring it down. Besides the database itself, many components are involved in providing database service. RAC may be up and running, but clients may not be able to reach it. The intermediate network components involved between client machines and database servers may fail. Natural outages that destroy all of the hardware—fire, flood, and earthquake—will make the cluster and database inoperable.

Assuming that failures are localized or contained, however, RAC provides maximum protection and provides continuous database service. Even with the loss of many of the components, a RAC
Design is the key word. Just setting up two or more nodes is not enough; dual interconnects, dual paths to storage units, dual storage units, dual power supplies, dual public network interfaces, and so on, will create a robust RAC cluster. For example, this table shows the effects of individual component failures:

<table>
<thead>
<tr>
<th>Component</th>
<th>Effect of Failure</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU panic/crash</td>
<td>Node failed, other node still active.</td>
<td>Okay</td>
</tr>
<tr>
<td>Memory crash</td>
<td>Node failed, other node still active.</td>
<td>Okay</td>
</tr>
<tr>
<td>Interconnect</td>
<td>With dual interconnects</td>
<td>Okay</td>
</tr>
<tr>
<td>OS failure/freeze</td>
<td>Node failed, other node still active.</td>
<td>Okay</td>
</tr>
<tr>
<td>Cluster Manager s/w</td>
<td>Cluster freezes, all nodes go down. (Chapter 4 details 12c ASM fixes.)</td>
<td>Down</td>
</tr>
<tr>
<td>DB instance crash</td>
<td>Instance running on other node provides database service.</td>
<td>Okay</td>
</tr>
<tr>
<td>Control file (corrupt/lost)</td>
<td>Multiplexed control file used.</td>
<td>Okay</td>
</tr>
<tr>
<td>Redo log file</td>
<td>Multiplexed REDO file.</td>
<td>Okay</td>
</tr>
<tr>
<td>Lost datafile</td>
<td>Requires media recovery. (Mirroring could solve this.)</td>
<td>Down</td>
</tr>
<tr>
<td>Human error</td>
<td>Depends on type of mistake; Flashback can get you back up and running quickly!</td>
<td>Down</td>
</tr>
<tr>
<td>Dropped object</td>
<td>DB is available, but applications stall; Flashback to get back up and running quickly (Flashback PDB in 12c)!</td>
<td>Down</td>
</tr>
<tr>
<td>DB software bug</td>
<td>DB may stall on all instances. Rolling patches can keep systems up while fixing this.</td>
<td>Down</td>
</tr>
</tbody>
</table>

As long as one of the Oracle instances is available in the cluster, client applications have data access and can execute their applications without any problems. Oracle Exadata makes many of these events of the past non-issues because Exadata machines are already designed for dual components and high availability.

**Summary**

This section by no means covers all aspects of RAC internal functioning. It merely highlights some important concepts and some of the inner workings of RAC (subject to change, of course).
Understanding special RAC requirements and implementation of the global shared cache helps you properly plan RAC implementation and its usage. An entire book is needed to cover RAC fully, but the next few sections should help you with tuning RAC.

RAC Performance Tuning Overview
Performance issues related to a RAC implementation should focus on the following areas in the order listed:

- Traditional database tuning and monitoring (most of this book)
- RAC cluster interconnect performance (this chapter and Chapter 5)
- Monitoring workload performance (most of this book, especially Chapter 5)
- Monitoring contention uniquely associated with RAC (this chapter)
- Prior to tuning RAC-specific operations, tuning each instance separately:
  - APPLICATION tuning
  - DATABASE tuning
  - OS tuning
  - Begin tuning RAC

Normal or traditional database monitoring is covered in other areas of this book (especially Chapter 5). Aspects of database performance related to RAC are covered in this chapter. After tuning each instance individually, then focus on the processes that communicate through the cluster interconnect.

RAC Cluster Interconnect Performance
The most complex aspect of RAC tuning involves monitoring and the subsequent tuning of processes associated with the Global Resources Directory (GRD). The group of processes associated with the GRD is the Global Enqueue Service (GES) and the Global Cache Service (GCS). The GRD processes communicate through the cluster interconnects. If the cluster interconnects are not configured to process data packets efficiently, then the entire RAC implementation performs poorly. This is true regardless of performance-related tuning and configuration efforts in other areas.

Finding RAC Wait Events—Sessions Waiting
You can monitor sessions that wait on nonidle wait events that impact interconnect traffic with a query that lists GCS waits using the global dynamic performance view GV$SESSION_WAIT. You may also see these waits in a Statspack or AWR Report. The following are the major waits being
To identify the sessions experiencing waits on the system, perform the following tasks:

1. Query GV$SESSION_WAIT to determine whether any sessions are experiencing RAC-related waits (at the current time).
2. Identify the objects that are causing contention for these sessions.
3. Try to modify the object or query to reduce contention.

For example, query GV$SESSION_WAIT (shown next) to determine whether any sessions are experiencing RAC cache–related waits. Note that the GV$ views are used much more to show statistics for the entire cluster, whereas the V$ views still show statistics from a single node. If you plan to use RAC, you must extend the V$ views and queries to the GV$ views for multiple nodes. This section is only an initial guide to help you see all of the components. The scope of this book does not cover RAC specifically, but some things that will help you tune RAC.

```sql
SELECT inst_id, event, p1 FILE_NUMBER, p2 BLOCK_NUMBER, WAIT_TIME
FROM  gv$session_wait
WHERE event IN ('buffer busy global cr', 'global cache busy', 'buffer busy global cache');
```

The output from this query should look something like this:

```
<table>
<thead>
<tr>
<th>INST_ID</th>
<th>EVENT</th>
<th>FILE_NUMBER</th>
<th>BLOCK_NUMBER</th>
<th>WAIT_TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>global cache busy</td>
<td>9</td>
<td>150</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>global cache busy</td>
<td>9</td>
<td>150</td>
<td>10</td>
</tr>
</tbody>
</table>
```

Run this query to identify objects that are causing contention for these sessions and the object that corresponds to the file and block for each FILE_NUMBER/BLOCK_NUMBER combination returned (this query is a bit slower):
SELECT owner, segment_name, segment_type
FROM dba_extents
WHERE file_id = 9
AND 150 BETWEEN block_id AND block_id+blocks-1;

The output is similar to

<table>
<thead>
<tr>
<th>OWNER</th>
<th>SEGMENT_NAME</th>
<th>SEGMENT_TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM</td>
<td>MOD TEST IND</td>
<td>INDEX</td>
</tr>
</tbody>
</table>

Modify the object to reduce the chances for application contention by doing the following:

- Reduce the number of rows per block.
- Adjust the block size to a smaller block size.
- Modify INITRANS and FREELISTS.

RAC Wait Events and Interconnect Statistics

The RAC events are listed next in the Statspack or AWR Report if you are running RAC (multiple instances). As stated earlier, you need to run a Statspack or AWR Report for each instance that you have. For Statspack, you run the statspack.snap procedure and the sreport.sql script on each node you want to monitor to compare to other instances. One of the best methods for seeing if a node is operating efficiently is to compare the report from that node to one from another node that accesses the same database. I cover Cloud Control tuning in Chapter 5. Remember that single-instance tuning should be performed before attempting to tune the processes that communicate via the cluster interconnect—this is very important! In other words, tune the system in single instance before you move it to RAC.

Some of the top wait events that you may encounter are listed briefly next; wait events are covered in more detail in Chapter 14. The top global cache (gc) waits to look out for include:

- **gc current block busy** Happens when an instance requests a CURR (current version of a block) data block (wants to do some DML) and the block to be transferred is in use. A block cannot be shipped if Oracle hasn’t written the REDO for the block changes to the log file.

- **gc buffer busy** A wait event that occurs whenever a session has to wait for an ongoing operation on the resource to complete because the block is in use. The process has to wait for a block to become available because another process is obtaining a resource for this block.

- **gc cr request/gc cr block busy** This happens when one instance is waiting for blocks from another instance’s cache (sent via the interconnect). This wait says that the current instance
can’t find a consistent read (CR) version of a block in the local cache. If the block is not in the remote cache, then a db file sequential read wait will also follow this one. Tune the SQL that is causing large amounts of reads that get moved from node to node. Try to put users who are using the same blocks on the same instance so blocks are not moved from instance to instance. Some non-Oracle application servers move the same process from node to node looking for the fastest node (unaware that they are moving the same blocks from node to node). Pin these long processes to the same node. Potentially increase the size of the local cache if slow I/O combined with a small cache is the problem. Monitor V$SCR_BLOCK_SERVER to see if an issue like reading UNDO segments is occurring. Correlated to the waits, the values for P1,P2,P3 are file, block, lenum, respectively. For the value for P3, lenum, look in V$LOCK_ELEMENT for the row where LOCK_ELEMENT_ADDR has the same value as lenum. This happens when an instance requests a CR data block and the block to be transferred hasn’t arrived at the requesting instance. This wait is the one I see the most, and it’s usually because the SQL is poorly tuned and many index blocks are being moved back and forth between instances.

Figure 11-19 shows the AWR Report RAC Statistics section. You can see that there are six instances (nodes) in this cluster. You can also see things like the number of blocks sent and received as well as how many of the blocks are being accessed in the local cache (93.1 percent) versus the disk or another instance. As you would guess, accessing blocks in the local cache is faster, but accessing one of the remote caches on one of the other nodes is almost always faster (given a fast enough interconnect and no saturation of the interconnect) than going to disk.
### RAC Statistics

<table>
<thead>
<tr>
<th></th>
<th>Begin</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Instances:</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

### Global Cache Load Profile

<table>
<thead>
<tr>
<th></th>
<th>Per Second</th>
<th>Per Transaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Cache blocks received:</td>
<td>9.97</td>
<td>17.10</td>
</tr>
<tr>
<td>Global Cache blocks served:</td>
<td>10.30</td>
<td>17.67</td>
</tr>
<tr>
<td>GCS/GES messages received:</td>
<td>140.60</td>
<td>241.17</td>
</tr>
<tr>
<td>GCS/GES messages sent:</td>
<td>225.51</td>
<td>386.82</td>
</tr>
<tr>
<td>DBWR Fusion writes:</td>
<td>0.12</td>
<td>0.21</td>
</tr>
<tr>
<td>Estd Interconnect traffic (KB)</td>
<td>233.67</td>
<td></td>
</tr>
</tbody>
</table>

### Global Cache Efficiency Percentages (Target local+remote 100%)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer access - local cache %:</td>
<td>93.10</td>
</tr>
<tr>
<td>Buffer access - remote cache %:</td>
<td>2.39</td>
</tr>
<tr>
<td>Buffer access - disk %:</td>
<td>4.51</td>
</tr>
</tbody>
</table>

### Global Cache and Enqueue Services - Workload Characteristics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg global enqueue get time (ms):</td>
<td>64.3</td>
</tr>
<tr>
<td>Avg global cache cr block receive time (ms):</td>
<td>1.0</td>
</tr>
<tr>
<td>Avg global cache current block receive time (ms):</td>
<td>2.7</td>
</tr>
<tr>
<td>Avg global cache cr block build time (ms):</td>
<td>0.1</td>
</tr>
<tr>
<td>Avg global cache cr block send time (ms):</td>
<td>0.1</td>
</tr>
<tr>
<td>Global cache log flushes for cr blocks served %:</td>
<td>0.6</td>
</tr>
<tr>
<td>Avg global cache cr block flush time (ms):</td>
<td>0.9</td>
</tr>
<tr>
<td>Avg global cache current block on time (ms):</td>
<td>0.9</td>
</tr>
<tr>
<td>Avg global cache current block send time (ms):</td>
<td>0.3</td>
</tr>
<tr>
<td>Global cache log flushes for current blocks served %:</td>
<td>5.3</td>
</tr>
<tr>
<td>Avg global cache current block flush time (ms):</td>
<td>1.0</td>
</tr>
</tbody>
</table>
The following is another valuable query to derive session wait information. The INSTANCE_ID lists the instance where the waiting session resides. The SID is the unique identifier for the waiting session (GV$SESSION). The P1, P2, and P3 columns list event-specific information that may be useful for debugging. LAST_SQL lists the last SQL executed by the waiting session.

```
SET NUMWIDTH 10
COLUMN STATE FORMAT a7 tru
COLUMN EVENT FORMAT a25 tru
COLUMN LAST_SQL FORMAT a40 tru
SELECT sw.inst_id INSTANCE_ID, sw.sid SID, sw.state STATE, sw.event EVENT,
  sw.seconds_in_wait SECONDS_WAITING, sw.p1, sw.p2, sw.p3,
  sa.sql_text LAST_SQL
FROM gv$session_wait sw, gv$session s, gv$sqlarea sa
WHERE sw.event NOT IN ('rdbs ipc message', 'smon timer', 'pmon timer',
  'SQL*Net message from client', 'lock manager wait for remote message',
  'ges remote message', 'gcs remote message', 'gcs for action',
  'client message', 'pipe get', 'null event', 'PX Idle Wait',
  'single-task message', 'PX Dg: Execution Msg',
  'KXQF: kxqfseq - normal dequeue', 'listen endpoint status',
  'slave wait', 'wakeup time manager')
  AND sw.wait_time_micro > 0
  AND (sw.inst_id = s.inst_id and sw.sid = s.sid)
  AND (s.inst_id = sa.inst_id and s.sql_address = sa.address)
ORDER BY seconds_waiting DESC;
```

Here is a query that gives a description of the parameter names of the events seen in the last section:

```
COLUMN EVENT FORMAT a20 tru
COLUMN p1text FORMAT a25 tru
COLUMN p2text FORMAT a25 tru
COLUMN p3text FORMAT a25 tru
SELECT DISTINCT event EVENT, p1text, p2text, p3text
FROM gv$session_wait sw
WHERE sw.event NOT IN ('rdbs ipc message', 'smon timer', 'pmon timer',
  'SQL*Net message from client', 'lock manager wait for remote message',
  'ges remote message', 'gcs remote message', 'gcs for action',
  'client message', 'pipe get', 'null event', 'PX Idle Wait',
  'single-task message', 'PX Dg: Execution Msg',
  'KXQF: kxqfseq - normal dequeue', 'listen endpoint status',
  'slave wait', 'wakeup time manager')
  AND wait_time_micro > 0
ORDER BY event;
```

Some of the contents of the GV$SESSION_WAIT view are as follows:
<table>
<thead>
<tr>
<th>Column</th>
<th>Data Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INST_ID</td>
<td>NUMBER</td>
<td>Number of the instance in the RAC configuration.</td>
</tr>
<tr>
<td>SID</td>
<td>NUMBER</td>
<td>Session identifier.</td>
</tr>
<tr>
<td>SEQ#</td>
<td>NUMBER</td>
<td>Sequence number that uniquely identifies this wait, incremented for each wait.</td>
</tr>
<tr>
<td>Column</td>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>EVENT</td>
<td>VARCHAR2(64)</td>
<td>Resource or event for which the session is waiting.</td>
</tr>
<tr>
<td>P1TEXT</td>
<td>VARCHAR2(64)</td>
<td>Description of the first additional parameter.</td>
</tr>
<tr>
<td>P1</td>
<td>NUMBER</td>
<td>First additional parameter.</td>
</tr>
<tr>
<td>P1RAW</td>
<td>RAW(4)</td>
<td>First additional parameter.</td>
</tr>
<tr>
<td>P2TEXT</td>
<td>VARCHAR2(64)</td>
<td>Description of the second additional parameter.</td>
</tr>
<tr>
<td>P2</td>
<td>NUMBER</td>
<td>Second additional parameter.</td>
</tr>
<tr>
<td>P2RAW</td>
<td>RAW(4)</td>
<td>Second additional parameter.</td>
</tr>
<tr>
<td>P3TEXT</td>
<td>VARCHAR2(64)</td>
<td>Description of the third additional parameter.</td>
</tr>
<tr>
<td>P3</td>
<td>NUMBER</td>
<td>Third additional parameter.</td>
</tr>
<tr>
<td>P3RAW</td>
<td>RAW(4)</td>
<td>Third additional parameter.</td>
</tr>
<tr>
<td>WAIT_CLASS_ID</td>
<td>NUMBER</td>
<td>Identifier of the wait class.</td>
</tr>
<tr>
<td>WAIT_CLASS#</td>
<td>NUMBER</td>
<td>Number of the wait class.</td>
</tr>
<tr>
<td>WAIT_CLASS</td>
<td>VARCHAR2(64)</td>
<td>Name of the wait class.</td>
</tr>
<tr>
<td>WAIT_TIME</td>
<td>NUMBER</td>
<td>A nonzero value is the session's last wait time in hundredths of seconds. A zero value means the session is currently waiting; a negative 1 means it was less than a hundredth of a second (see WAIT_TIME_MICRO); a negative 2 means TIME_STATISTICS=FALSE.</td>
</tr>
<tr>
<td>SECONDS_IN_WAIT</td>
<td>NUMBER</td>
<td>If WAIT_TIME = 0, then SECONDS_IN_WAIT is the seconds spent in the current wait condition. If WAIT_TIME &gt; 0, then SECONDS_IN_WAIT is the seconds since the start of the last wait, and SECONDS_IN_WAIT - WAIT_TIME/100 is the active seconds since the last wait ended. This column is being deprecated in favor of WAIT_TIME_MICRO.</td>
</tr>
<tr>
<td>STATE</td>
<td>VARCHAR2(19)</td>
<td>State.</td>
</tr>
<tr>
<td>WAIT_TIME_MICRO</td>
<td>NUMBER</td>
<td>Amount of time (microseconds) in current wait if waiting, and amount of time since the start of the last wait if not currently waiting. This column is replacing the SECONDS_IN_WAIT column, which is being deprecated.</td>
</tr>
<tr>
<td>TIME_REMAINING_MICRO</td>
<td>NUMBER</td>
<td>If NULL, session is not waiting. If &gt; 0, it's the time remaining to wait for current wait to end. If = 0, process timed out. If negative 1, session may wait indefinitely.</td>
</tr>
<tr>
<td>TIME_SINCE_LAST_WAIT_TIME_MICRO</td>
<td>NUMBER</td>
<td>The value is 0 if session is currently waiting; otherwise, it's the time in microseconds since the last wait.</td>
</tr>
</tbody>
</table>
True proof of how much faster the database is in recent releases is evident with the move from waits being measured in seconds to waits being measured in microseconds.

**TIP**
*Use V$SESSION_WAIT or GV$SESSION_WAIT, Statspack, or the AWR Report to find RAC wait events.*

**GES Lock Blockers and Waiters**

Sessions that are holding global locks that persistently block others can be problematic to a RAC implementation and are, in many instances, associated with application design. Sessions waiting on a lock to release cannot proceed (hang) and are required to poll the blocked object to determine status. Large numbers of sessions holding global locks will create substantial interconnect traffic and inhibit performance. The following queries will help you find blocking sessions:
GES LOCK BLOCKERS:
--- INSTANCE_ID  The instance on which a blocking session resides
--- SID        Unique identifier for the session
--- GRANT LEVEL Lists how GES lock is granted to user associated w/ blocking session
--- REQUEST LEVEL Lists the status the session is attempting to obtain
--- LOCK_STATE Lists current status the lock has obtained
--- SEC        Lists how long this session has waited

SET numwidth 10
COLUMN LOCK_STATE FORMAT a16 tru;
COLUMN EVENT FORMAT a30 tru;

SELECT dl.inst_id INSTANCE_ID, s.sid SID, p.spid SPID,
   dl.resource_name RESOURCE_NAME,
   decode(substr(dl.grant_level,1,3), 'KJUSERNL', 'Null', 'KJUSERCR', 'Row-S (SS)',
         'KJUSERCW', 'Row-X (SX)', 'KJUSERPR', 'Share', 'KJUSERPW', 'S/Row-X (SSX)',
         'KJUSERREX', 'Exclusive', request_level) AS GRANT_LEVEL,
   decode(substr(dl.request_level,1,3), 'KJUSERNL', 'Null', 'KJUSERCR', 'Row-S (SS)',
         'KJUSERCW', 'Row-X (SX)', 'KJUSERPR', 'Share', 'KJUSERPW', 'S/Row-X (SSX)',
         'KJUSERREX', 'Exclusive', request_level) AS REQUEST_LEVEL,
   decode(substr(s.state,1,3), 'KJUSERCA', 'Canceling', 'KJUSERCV', 'Converting') AS LOCK_STATE,
   s.sid, sw.event EVENT, sw.wait_time_micro SEC
FROM  gv$ges_enqueue dl, gv$process p, gv$session s, gv$session_wait sw
WHERE  blocker = 1
AND    (dl.inst_id = p.inst_id AND dl.pid = p.spid)
AND    (p.inst_id = s.inst_id AND p.addr = s.paddr)
AND    (s.inst_id = sw.inst_id AND s.sid = sw.sid)
ORDER BY sw.wait_time_micro DESC;

GES LOCK WAITERS:
--- INSTANCE_ID  The instance on which a blocking session resides
--- SID        Unique identifier for the session
--- GRANT LEVEL Lists how GES lock is granted to user associated w/ blocking session
Cache Fusion Reads and Writes

*Cache Fusion reads* occur when a user on one system queries a block and then a user on another system queries the same block. The block is passed over the high-speed interconnect (versus being read from disk). *Cache Fusion writes* occur when a block previously changed by another instance needs to be written to disk in response to a checkpoint or cache aging. When this occurs, Oracle sends a message to notify the other instance that a fusion write will be performed to move the data block to disk. Fusion writes do not require an additional write to disk and are a subset of all physical writes incurred by an instance. The ratio DBWR fusion writes to physical writes shows the proportion of writes that Oracle manages with fusion writes.

Here is a query to determine ratio of Cache Fusion writes:

```
SELECT A.inst_id "Instance",
       A.VALUE/B.VALUE "Cache Fusion Writes Ratio"
FROM  GV$SYSSTAT A, GV$SYSSTAT B
WHERE  A.name='DBWR fusion writes'
    AND B.name='physical writes'
    AND B.inst_id=a.inst_id
ORDER BY A.INST_ID;
```

Here is some sample output:
A larger than usual value for Cache Fusion writes ratio may indicate:

- Insufficiently large caches
- Insufficient checkpoints
- Large numbers of buffers written due to cache replacement or checkpointing

Cluster Interconnect Tuning—Hardware Tier

Cluster interconnect tuning is a very important piece of the clustered configuration. Oracle depends on the cluster interconnect for movement of data between the instances. Using a dedicated private network for the interconnect is extremely important.

The speed of the cluster interconnect solely depends on the hardware vendor and the layered operating system. Oracle, in its current version, depends on the operating system and the hardware for sending packets of information across the cluster interconnect. For example, one type of cluster interconnect supported between Sun Fire 4800s is the User Datagram Protocol (UDP). However, Solaris on this specific version of the interconnect protocol has an OS limitation of a 64K packet size used for data transfer. To transfer 256K worth of data across this interconnect protocol would take this configuration over four round trips. On a high-transaction system where you have a large amount of interconnect traffic, this could cause a serious performance issue.

After the initial hardware and operating system level tests to confirm the packet size across the interconnect, perform subsequent tests from the Oracle database to ensure that there is not any significant added latency using cache-to-cache data transfer or the Cache Fusion technology. The query that follows provides the average latency of a consistent block request on the system. The data in these views are a cumulative figure since the last time the Oracle instance was bounced. The data from these views do not reflect the true performance of the interconnect or give a true picture of the latency in transferring data. To get a more realistic picture of performance, bounce all the Oracle instances and test again. To obtain good performance, the latency across the cluster interconnect must be as low as possible. Latencies on the cluster interconnect could be caused by

- Large number of processes in the run queues waiting for CPU or scheduling delays
- Platform-specific OS parameter settings that affect IPC buffering or process scheduling
- Slow, busy, or faulty interconnects

Oracle recommends that the average latency of a consistent block request typically should not exceed 15 milliseconds, depending on the system configuration and volume. When you are sending
many blocks across the interconnect, this figure is really too high (especially since going to disk is usually this fast). For a high-volume system, latency should be in the single-digit millisecond-to-microsecond range. The average latency of a consistent block request is the average latency of a consistent read request roundtrip from the requesting instance to the holding instance and back to the requesting instance.

In the preceding output, notice that the AVG CR BLOCK RECEIVE TIME is 443.78 (ms); this is significantly high when the expected average latency, as recommended by Oracle, should not exceed 15 (ms). A high value is possible if the CPU has limited idle time and the system typically processes long-running queries. However, an average latency of less than one millisecond with user-mode IPC is possible. Latency can also be influenced by a high value for the DB_MULTI_BLOCK_READ_COUNT parameter. This is because a requesting process can issue more than one request for a block, depending on the setting of this parameter. Correspondingly, the requesting process may have to wait longer. This kind of high latency requires further investigation of the cluster interconnect configuration and that tests be performed at the operating system level. When such high latencies are experienced over the interconnect, another good test is to perform a test at the operating system level by checking the actual ping time. Checking the ping time helps to determine if there are any issues at the OS level. After all, the performance issue may not be from data transfers within the RAC environment.

Apart from the basic packet transfer tests that you can perform at the database level, you can undertake other checks and tests to ensure that the cluster interconnect has been configured correctly. There are redundant private high-speed interconnects between the nodes participating in the cluster. Implementing network interface card (NIC) bonding or pairing helps interconnect load balancing and failover when one of the interconnects fails. The user network connection does not interfere with the cluster interconnect traffic. That is, they are isolated from each other. At the operating system level, the `netstat` and `ifconfig` commands display network-related data structures. In 12c, Oracle has Redundant Interconnect Usage. Oracle Grid Infrastructure and Oracle RAC can now make use of redundant network interconnects, without using other network technology, to enhance optimal
communication in the cluster. Redundant Interconnect Usage enables load-balancing and high availability across multiple (up to four) private networks (also known as *interconnects*). The output that follows, from `netstat -i`, indicates that four network adapters are configured and NIC pairing is implemented:

```
[oracleoradb3 oracle]$ netstat -i
Kernel Interface table
iface   MTU  Net   RX-OV  RX-ERR  RX-ERP  RX-OVR  TX-OV  TX-ERR  TX-ERP  TX-OVR  Flg
bond0   1500  0     3209   0       0       0     2028    0       0       0    UNredirected
bond0:1 1500  0     4360   0       0       0     6437    0       0       0    ExnoRx
bond1   1500  0     7880   0       0       0     10874   0       0       0    EnoRx
eth0    1500  0     1662   0       0       0     7096    0       0       0    PmanRx
eth1    1500  0     1647   0       0       0     2029    0       0       0    HnmanRx
eth2    1500  0     6390   0       0       0     6437    0       0       0    ExnoRx
eth3    1500  0     3490   0       0       0     4493    0       0       0    EnoRx
lo      16436 0     7491   0       0       0     7491    0       0       0    TRR
```

The values in the *IFACE* column are defined as follows:

- **bond0** The public interconnect created using the bonding functionality (bonds Eth0 and Eth1).
- **bond0:1** The Virtual IP (VIP) assigned to bond0.
- **bond1** A private interconnect alias created using bonding functionality (bonds ETH2 and ETH3).
- **ETH0** and **ETH1** The physical public interfaces that are bonded/paired together (bond0).
- **ETH2** and **ETH3** The physical private interfaces that are bonded/paired together (bond1).
- **lo** This is the loopback; that is, the output also indicates that a loopback option is configured. Verify whether Oracle is using the loopback option using the ORADEBUG command, which is discussed later in this section. The use of the loopback IP depends on the integrity of the routing table defined on each of the nodes. Modifying the routing table can result in the inoperability of the interconnect.

Also found in the preceding `netstat` output is the maximum transmission unit (MTU), which is set at 1500 bytes (this is a standard setting for UDP). MTU definitions do not include the data-link header. However, packet-size computations include data-link headers. The maximum packet size displayed by the various tools is MTU plus the data-link header length. To get the maximum benefit from the interconnect, MTU should be configured to the highest possible value supported. For example, a setting as high as 9K using jumbo frames would improve interconnect bandwidth and data transmission.

Apart from the basic packet transfer tests that you could perform at the OS level, you can undertake other checks and tests to ensure that the cluster interconnect has been configured correctly. Perform checks from the Oracle instance to ensure proper configuration of the interconnect protocol. If the following commands are executed as user SYS, a trace file is generated in the user dump destination directory that contains certain diagnostic information pertaining to the UDP/IPC configurations. (See
Chapter 13 for more on the DEBUG functionality.) Please do not use this until you read the Oracle documentation on it.

```sql
SQL> ORADEBUG SETMYPID
ORADEBUG IPC
```

The following is the extract from the trace file pertaining to the interconnect protocol. The output confirms that the cluster interconnect is being used for instance-to-instance message transfer:

```
SSKGXPT 0x3671e28 flags SSKGXPT_READPENDING info for network 0
  socket no 9    IP 172.16.193.1    UDP 59084
  sflags SSKGXPT_WRITE SSKGXPT_UP
  info for network 1
  socket no 0    IP 0.0.0.0     UDP 0
  sflags SSKGXPT_DOWN
context timestamp 0x4402d
no ports
```

The preceding output is from a Sun Fire 4800 and indicates the IP address and that the protocol used is UDP. On certain operating systems such as Tru64 (now discontinued) the trace output does not reveal the cluster interconnect information. The following NDD Unix command at the operating system level confirms the actual UDP size definition. The following output is from a SUN environment:

```
oradb1:RAC1:oracle # ndd -get /dev/udp
  name to get/set? udp_xmit_hiwat
  value?
  length?
  8192
  name to get/set? udp_recv_hiwat
  value?
  length?
  8192
```

This output reveals that the UDP has been configured for an 8K packet size. Applying this finding to the data gathered from Oracle’s views indicates that it would take 14,050 trips for all the blocks to be transferred across the cluster interconnect \((112,394/8 = 14,050)\). If this were set to be 64K, then the number of roundtrips would be significantly reduced \((112,394/64 = 1756)\) trips.

Another parameter that affects the interconnect traffic is `DB_FILE_MULTIBLOCK_READ_COUNT`. This parameter helps read a certain number of blocks at a time from disk. When data needs to be transferred across the cluster interconnect, this parameter determines the size of the block that each instance would request from the other during read transfers.
Sizing this parameter should be based on the interconnect latency and the packet sizes as defined by the hardware vendor and after considering operating system limitations (for example, the Sun UDP max setting is only 64K). The following kernel parameters define the UDP parameter settings:

- **UDP_RECV_HIWAT**
- **UDP_XMIT_HIWAT**

Setting these parameters to 65536 each increases the UDP buffer size to 64K.

Another parameter, **CLUSTER_INTERCONNECTS**, provides Oracle information on the availability of additional cluster interconnects that you could use for Cache Fusion activity across the cluster interconnect. The parameter overrides the default interconnect settings at the operating system level with a preferred cluster traffic network. While this parameter does provide certain advantages on systems where high interconnect latency is noticed by helping reduce such latency, configuring this parameter could affect the interconnect high-availability feature. In other words, an interconnect failure that is normally unnoticeable could instead cause an Oracle cluster failure as Oracle still attempts to access the network interface. The parameter also overrides the network classifications stored by `OIFCFG` in the Oracle Cluster Registry (OCR).

**Resource Availability**

Resources available on any machine or node or to an Oracle instance are limited, meaning they are not available in abundance, and if a process on the system needs them, they may not be immediately available. A physical limit is imposed on the amount of resources available on any system. For example, the processor resources are limited by the number of CPUs available on the system, and the amount of memory or cache area is limited by the amount of physical memory available on the system. Now, for an Oracle process, this is further limited by the actual amount of memory allocated to the SGA. Within the SGA, the shared pool, the buffer cache, and so on, are again preallocated from the shared pool area. These memory allocations are used by a regular single-instance configuration.

In a RAC environment, there are no parameters to allocate any global-specific resources, for example, global cache size or global shared pool area. Oracle allocates a certain portion of the available resources from the SGA for global activity. The availability of global resources can be monitored using the view `GV$RESOURCE_LIMIT`.

**Parallel Operations**

Using parallel operations enables multiple processes (and potentially processors) to work together simultaneously to resolve a single SQL statement. This feature improves data-intensive operations, is dynamic (the execution path is determined at run time), and (when wisely implemented) makes use of all of your processors and disk drives. There are some overhead costs and administrative requirements, but using parallel operations can improve the performance of many queries.

**Basic Concepts of Parallel Operations**
Consider a full table scan. Rather than have a single process execute the table scan, Oracle can create multiple processes to scan the table in parallel. The number of processes used to perform the scan is called the degree of parallelism (DOP). The degree can be set in a hint at the time of table creation or as a hint in the query. Figure 11-20 shows a full table scan of the EMP table broken into four separate parallel query server processes. (The degree of parallelism is four.) A fifth process, the query coordinator, is created to coordinate the four parallel query server processes.

If the rows returned by the full table scan shown in Figure 11-20 also need to be sorted, the resulting operation will look like Figure 11-21 instead. Now Oracle may use one process to coordinate the query, four processes to run the query, and four processes to sort the query. The total is now nine processes, although the degree of parallelism is still 4. If you have nine processors (CPUs), your machine can use all nine processors for the operation (depending on your system setup and other operations that are being performed at the same time). If you have fewer than nine processors available, you may encounter some CPU bottleneck issues as Oracle manages the query.
Because the query coordination parts of the operation take resources, fast-running queries are not usually enhanced (and may be degraded) with the use of parallel operations.

TIP
Using parallel operations on very small tables or very fast queries can also degrade performance because the query coordination may also cost performance resources. You should evaluate whether the parallel cost exceeds the nonparallelized cost.

Both queries in Figure 11-20 and Figure 11-21 require access to the physical disks to retrieve data, which is then brought into the SGA. Balancing data on those disks based on how the query is “broken up” makes a large I/O difference.

TIP
When the parallel degree is set to N, it is possible to use \((2*N) + 1\) total processes for the parallel operation. Although parallel operations deal with processes and not processors, when a large number of processors are available, Oracle generally uses the additional processors to run parallel queries, often enhancing the performance of the query.

Parallel DML and DDL Statements and Operations

Oracle supports parallelization of both DDL and DML operations. Oracle can parallelize the
The following operations on tables and indexes:

- SELECT
- UPDATE, INSERT, DELETE
- MERGE
- CREATE TABLE AS
- CREATE INDEX
- REBUILD INDEX
- MOVE/SPLIT/COALESCE PARTITION
- ENABLE CONSTRAINT

The following operations can also be parallelized within a statement:

- SELECT DISTINCT
- GROUP BY
- ORDER BY
- NOT IN
- UNION and UNION ALL
- CUBE and ROLLUP
- Aggregate functions such as SUM and MAX
- NESTED LOOPS joins
- SORT-MERGE joins
- Star transformations

Oracle uses the cost-based optimizer to determine whether to parallelize a statement and to determine the degree of parallelism applied. Most operations can be parallelized, including queries, DML, and DDL operations. Intrapartition parallelism is also supported; multiple parallel query server processes can execute against the same partition.

The degree of parallelism may be limited by a number of factors. Although the partitioning strategy does not play as significant a role for parallelism, you should still be aware of other limiting factors:

- The number of processors available on the server
- That you still need to have the partition option enabled, and UPDATE, DELETE, and MERGE are parallelized only for partitioned tables
- The number of parallel query server processes allowed for the instance, set via the PARALLEL_MAX_SERVERS initialization parameter
- The parallel degree limit supported for your user profile if you use the Database Resource
Manager

- The number of parallel query server processes used by other users in the instance
- The setting for the PARALLEL_ADAPTIVE_MULTI_USER parameter, which may limit your parallelism in order to support other users (if used; note that it is deprecated in 12c)

Monitoring your parallel operations in multiuser environments to guarantee they are allocated the resources that you planned for them to use is important. The Database Resource Manager can help allocate resources.

Managing Parallel Server Resources and Parallel Statement Queuing

If you use the Database Resource Manager to manage parallel server resources, and a consumer group uses up all its assigned resources, Oracle might be forced to downgrade the parallelism of the parallel statements issued by users assigned to that consumer group. You configure the allocation of parallel server resources for a consumer group with the PARALLEL_TARGET_PERCENTAGE directive. This directive specifies the maximum percentage of the parallel server pool that a particular consumer group can use.

In 12c, Oracle has parallel statement queuing, which offers the following features:

- When no more parallel servers are available, the parallel statement is queued. The parallel statement is dequeued and processed as parallel servers are freed up.
- A resource plan can be used to control the order of the parallel statement queue. When parallel servers are freed up, the resource plan is used to select a consumer group. The parallel query at the head of its queue is run.
- Parallel servers can be reserved for critical consumer groups.

This feature adds stability to the execution of SQL statements in parallel, but can introduce an additional wait time for parallel statements if the database server is running at full capacity. For a parallel statement to be queued, the following conditions must be met:

- The PARALLEL_DEGREE_POLICy initialization parameter is set to AUTO.
- The number of active parallel servers across all consumer groups exceeds the value of the PARALLEL_SERVERS_TARGET initialization parameter.
- The sum of the number of active parallel servers for the consumer group and the degree of parallelism of the parallel statement exceeds the target number of active parallel servers. In other words, \((V$RSRC_CONSUMER_GROUP.CURRENT_PQ_SERVERS_ACTIVE + DOP \text{ of statement}) > \left(\frac{\text{PARALLEL\_TARGET\_PERCENTAGE}}{100} \times \text{PARALLEL\_SERVERS\_TARGET}\right)\).
You can also use the `NO_STATEMENT_QUEUING` and `STATEMENT_QUEUING` hints in SQL statements to manage parallel statement queuing.

## Parallelism and Partitions

Oracle’s partitioning feature can have a significant impact on parallel operations. **Partitions** are logical divisions of table data and indexes, and partitions of the same table or index can reside in multiple tablespaces. Given this architecture, the following important distinctions exist with parallel operations on partitions:

- Operations are performed in parallel on partitioned objects **only** when more than one partition is accessed.
- If a table is partitioned into 12 logical divisions and a query executed against the table accesses only 6 of those partitions (because the dimension of the data dictates the partition in which the data is stored), a maximum of 6 parallel server processes can be allocated to satisfy the query. When partition granules are used to access a table or index, the maximum allowable DOP is the number of partitions (block range granules are the basic unit of most parallel operations, even on partitioned tables; partition granules are the basic unit of parallel index range scans, joins between two equipartitioned tables, parallel operations that modify multiple partitions of a partitioned object, and partitioned table/index creation).

## Inter- and Intra-operation Parallelization

Due to the distribution of data, the processor allocated to each parallel server process, and the speed of devices servicing the parallel server data request, each parallel query server process may complete at a different time. As each server process completes, it passes its result set to the next lower operation in the statement hierarchy. Any single parallel server process may handle or service statement operation requests from any other parallel execution server at the next higher level in the statement hierarchy.

**TIP**

Any server process allocated for a statement may handle any request from a process within the same statement. Therefore, if some processes are faster than others, the ones that are faster can process the rows produced by the child set of parallel execution processes as soon as they are available instead of waiting for the ones that are slower (but only at the next higher statement hierarchy level).

The optimizer evaluates a statement and determines how many parallel query server processes to
use during its execution. This intra-operation parallelization is different from interoperation parallelization. *Intra-operation parallelization* is dividing a single task within a SQL statement, such as reading a table, among parallel execution servers. When multiple parts of a SQL statement are performed in parallel, the results from one set of parallel execution servers are passed to another set of parallel execution servers. This is known as *interoperation parallelization*.

The degree of parallelism is applied to each operation of a SQL statement that can be parallelized, including the sort operation of data required by an ORDER BY clause. As shown earlier in Figure 11-21, a query with a degree of parallelism of 4 may acquire up to nine processes.

### Examples of Using Inter- and Intra-operations (PARALLEL and NO_PARALLEL Hints)

You can parallelize SQL statements via a SQL hint or with the object-level options declared for the table or index. The following listing illustrates a statement hint:

```sql
select /*+ parallel (ORDER_LINE_ITEMS) */
  Invoice_Number, Invoice_Date
from  ORDER_LINE_ITEMS
order by Invoice_Date;
```

The preceding statement does *not* specify a degree of parallelism. The default degree of parallelism dictated by the table definition or the initialization parameters will be used. When you create a table, you can specify the degree of parallelism to use for the table, as shown here:

```sql
create table ORDER_LINE_ITEMS
  (Invoice_Number NUMBER(12) not null,
   Invoice_Date DATE not null)
parallel 4;
```

When you execute queries against the ORDER_LINE_ITEMS table without specifying a degree of parallelism for the query, Oracle uses 4 as the default degree. To override the default, specify the new value within the PARALLEL hint, as shown in this next listing. Also shown in the listing is the PARALLEL_INDEX hint, whose only difference from the PARALLEL hint is that the index name is also specified.
This listing specifies a degree of parallelism of 6. As many as 13 parallel execution servers may be allocated or created to satisfy this query.

To simplify the hint syntax, use table aliases, as shown in the following listing. If you assign an alias to a table, you must use the alias, not the table name, in the hint.

```
select /*+ parallel (oli, 4) */
  Invoice_Number, Invoice_Date
from ORDER_LINE_ITEMS oli
order by Invoice_Date;
```

**TIP**

Using the PARALLEL hint enables the use of parallel operations. If you use the PARALLEL hint but do not specify the degree of parallelism with the hint or set it at the table level, the query still executes in parallel, but the DOP is calculated from the initialization parameters.

You can also “turn off” the use of parallel operations in a given query on a table that has been specified to use parallel operations. The ORDER_LINE_ITEMS table has a default degree of parallelism of 4, but the query shown here overrides that setting via the NO_PARALLEL hint:

```
select /*+ no_parallel (oli) */
  Invoice_Number, Invoice_Date
from ORDER_LINE_ITEMS oli
order by Invoice_Date;
```

**TIP**

The use of the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.

To change the default degree of parallelism for a table, use the PARALLEL clause of the ALTER TABLE command:
To disable parallel operations for a table, use the NOPARALLEL clause of the ALTER TABLE command (notice that there is an underscore with the hint, but none with the clause below):

```
alter table order_line_items
noparallel;
```

The coordinator process evaluates the following in determining whether to parallelize the statement:

- Hints contained in the SQL statement
- Session values set via the ALTER SESSION FORCE PARALLEL command
- Tables/indexes defined as parallel as well as table/index statistics

You are advised to specify an explicit degree of parallelism either in the SQL statement itself or in the table definition. You can rely on default degrees of parallelism for many operations, but for performance management of time-sensitive operations, you should specify the degree of parallelism using a hint.

**TIP**

Specify the degree of parallelism using a hint instead of relying on the table definition to ensure that all operations are tuned for the given query.

---

Creating Table and Index Examples Using Parallel Operations

To further illustrate the application of parallel operations in SQL statements, consider the implementations of parallel operations for table and index creation shown in the following listings.

**Using parallel operations for table creation**

```
alter table order_line_items
parallel (degree 4);
```
Using parallel operations for index creation

create index ORDER KEY on ORDER LINE ITEMS (Order Id, Item Id)
tablespace idx1
storage (initial 10m next 1m pctincrease 0)
parallel (degree 5) NOLOGGING;

The CREATE INDEX statement creates the ORDER_KEY index using parallel sort operations. The CREATE TABLE statement creates a new table ORDER_LINE_ITEMS with a degree of parallelism of 4 by selecting from an existing OLD_ORDER_LINE_ITEMS table using a parallel operation. In the preceding table creation listing, two separate operations within the CREATE TABLE command are taking advantage of parallelism: the query of the OLD_ORDER_LINE_ITEMS table is parallelized, and the insert into ORDER_LINE_ITEMS is parallelized.

NOTE
Although parallel queries increase the performance of operations that modify data, the redo log entries are written serially and could cause a bottleneck. By using the NOLOGGING option, you can avoid this bottleneck during table and index creation.

Because the writes to the redo log files are serial, redo log writes may effectively eliminate the parallelism you have defined for your statements. Using NOLOGGING forces the bulk operations to avoid logging, but individual INSERT commands are still written to the redo log files. If you use the NOLOGGING option, you must have a way to recover your data other than via the archived redo log files.

TIP
Use NOLOGGING to remove the I/O bottleneck caused by serial writes to the redo logs.

Up to this point, I have ignored the physical location of the data queried in the example SELECT statements. If a full-scanned table’s data is all contained on a single disk, you may succeed only in creating a huge I/O bottleneck on the disk. An underlying principle of the performance gains that you
can achieve using parallel operations is that the data is stored on different devices, all capable of being addressed independently of one another.

**TIP**

*Make sure your data is properly distributed or the parallel query server processes may add to existing I/O bottleneck problems.*

Not only that, but using the Parallel Execution Option (PEO) may make your system perform worse. If your system has processing power to spare but has an I/O bottleneck, using PEO will generate more I/O requests faster, creating a larger queue for the I/O system to manage. If you already have an I/O bottleneck, creating more processes against that same bottleneck will not improve your performance. You need to redesign your data distribution across your available I/O devices.

**TIP**

*Parallel processes commonly involve disk accesses. If the data is not distributed across multiple disks, using the Parallel Execution Option (PEO) may lead to an I/O bottleneck.*

Returning to the CREATE INDEX statement shown earlier in the “Using parallel operations for index creation” listing, consider the following tips:

- **Index creation uses temporary tablespace if there is not enough memory available to perform the sort in memory (SORT_AREA_SIZE).** Construct the temporary tablespace in such a way that the physical datafile are striped across at least as many disks as the degree of parallelism of the CREATE INDEX statement.

- **When adding/enabling a primary or unique key for a table, you cannot create the associated index in parallel.** Instead, create the index in parallel first and then use ALTER TABLE to add/enable the constraint and specify the USING INDEX clause. For this to work, the index must have the same name and columns as the constraint.

---

Monitoring Parallel Operations via the V$ Views

The V$ dynamic performance views are always a great place for instance monitoring and evaluating the current performance of the database; parallel operations are no exception. The key performance views for monitoring parallel execution at a system level are V$PQ_TQSTAT and V$PQ_SYSSTAT. In general, V$ views beginning with V$PQ give statistics and DBA information (mostly tuning information) whereas the V$PX views give details at the process level about parallel sessions and operations (mostly the mechanics). In the following sections, you will see examples of the most
commonly used V$ views for monitoring parallel operations.

V$PQ_SYSSTAT

V$PQ_SYSSTAT provides parallel statistics for all parallelized statement operations within the instance. V$PQ_SYSSTAT is ideal for evaluating the number of servers executing currently high-water mark levels and the frequency of startup and shutdown of parallel servers. The following listing illustrates the statistics found on a freshly started instance and then a query run where there was a degree of parallelism of 4:

```
select  Statistic, Value
from     V$PQ_SYSSTAT;
```

<table>
<thead>
<tr>
<th>STATISTIC</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servers Busy</td>
<td>4</td>
</tr>
<tr>
<td>Servers Idle</td>
<td>0</td>
</tr>
<tr>
<td>Servers Highwater</td>
<td>4</td>
</tr>
<tr>
<td>Server Sessions</td>
<td>4</td>
</tr>
<tr>
<td>Servers Started</td>
<td>0</td>
</tr>
<tr>
<td>Servers Shutdown</td>
<td>0</td>
</tr>
<tr>
<td>Servers Cleaned Up</td>
<td>0</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

As you can see, four parallel execution servers were used and no new processes were started.

Query V$PQ_SYSSTAT after a SELECT on a table defined with a hint specifying a parallel degree of 5. The following listing illustrates V$PQ_SYSSTAT output following the query. Note the values for Servers Busy and Servers Highwater.
In this case, the hint has overridden the default degree of parallelism defined for the table, using five parallel query server processes.

### TIP

*A PARALLEL hint overrides the degree of parallelism defined for a table when determining the degree of parallelism for an operation.*

### V$PQ_SESSTAT

To provide the current session statistics, query the V$PQ_SESSTAT view. Use this view to see the number of queries executed within the current session, as well as the number of DML operations parallelized. Here’s a sample output of a simple query from this view:

```sql
select   statistic, value
from     V$PQ_SYSSTAT;

<table>
<thead>
<tr>
<th>STATISTIC</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servers Busy</td>
<td>5</td>
</tr>
<tr>
<td>Servers Idle</td>
<td>0</td>
</tr>
<tr>
<td>Servers Highwater</td>
<td>8</td>
</tr>
<tr>
<td>Server Sessions</td>
<td>20</td>
</tr>
<tr>
<td>Servers Started</td>
<td>5</td>
</tr>
<tr>
<td>Servers Shutdown</td>
<td>4</td>
</tr>
<tr>
<td>Servers Cleaned Up</td>
<td>0</td>
</tr>
<tr>
<td>Queries Queued</td>
<td>0</td>
</tr>
<tr>
<td>Queries Initiated</td>
<td>1</td>
</tr>
<tr>
<td>Queries Initiated (IPQ)</td>
<td>0</td>
</tr>
<tr>
<td>DML Initiated</td>
<td>2</td>
</tr>
<tr>
<td>DML Initiated (IPQ)</td>
<td>0</td>
</tr>
</tbody>
</table>
...
The output shown in V$PQ_SESSTAT refers only to the current session, so it is most useful when performing diagnostics during testing or problem resolution processes. Note that V$PX_SESSTAT has a similar name but a completely different set of columns. V$PX_SESSTAT joins session information from V$PX_SESSION with the V$SESSTAT table. V$PX_SESSION can also give information on the process requested degree (REQ_DEGREE) as compared to the actual degree (DEGREE) that ends up being used. A listing of VS views related to parallel operations is given in the section “Other Parallel Notes” at the end of this chapter.

The next listing shows a simple example of querying V$PX_SESSTAT. In this example, if you tried to execute a parallel query where the specified degree of parallelism (12) is greater than PARALLEL_MAX_SERVERS (10), you might see the following:

```
Select DISTINCT Req_Degree, Degree
from V$PX_SESSTAT;
```

```
REQ_DEGREE | DEGREE
----------|--------
12         | 10     
```

The V$PX_SESSTAT view is populated only while a parallel operation is executing; as soon as the parallel operation finishes, the contents of this view are cleared.

Using EXPLAIN PLAN and AUTOTRACE on Parallel Operations

You can use the EXPLAIN PLAN command to see tuned parallel statements. When you create a PLAN_TABLE for your database (via the utlxplan.sql script in the /rdbms/admin subdirectory...
under the Oracle software home directory), Oracle includes columns that allow you to see how parallelism affects the query’s execution path. The information about the parallelization of the query is found in the OBJECT_NODE, OTHER_TAG, and OTHER columns in PLAN_TABLE.

**TIP**

New columns may be added to the PLAN_TABLE with each new release of Oracle. You should drop and re-create your PLAN_TABLE following each upgrade of the Oracle kernel. If you upgrade an existing database to a new version of Oracle, you should drop your old PLAN_TABLE and re-execute the utlxplan.sql script to see all of the new PLAN_TABLE columns. You can also view the plan using Oracle Enterprise Manager in the SQL Details page.

The OBJECT_NODE column is the name of the database link used to reference the object. The OTHER column provides information about the query server processes involved. The OTHER_TAG column describes the function of the OTHER column’s entries. The OTHER column contains a derived SQL statement—either for a remote query or for parallel query operations.

Table 11-3 shows the possible values for OTHER_TAG and their associated OTHER values.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARALLEL_COMBINED_WITH_CHILD</td>
<td>The parent of this operation performs the parent and child operations together; OTHER is NULL.</td>
</tr>
<tr>
<td>PARALLEL_COMBINED_WITH_PARENT</td>
<td>The child of this operation performs the parent and child operations together; OTHER is NULL.</td>
</tr>
<tr>
<td>PARALLEL_TO_PARALLEL</td>
<td>The SQL in the OTHER column is executed in parallel, and results are returned to a second set of query server processes.</td>
</tr>
<tr>
<td>PARALLEL_TO_SERIAL</td>
<td>The SQL in the OTHER column is executed in parallel, and the results are returned to a serial process (usually the query coordinator).</td>
</tr>
<tr>
<td>PARALLEL_FROM_SERIAL</td>
<td>The SQL operation consumes data from a serial operation and outputs it in parallel; OTHER is NULL.</td>
</tr>
<tr>
<td>SERIAL</td>
<td>The SQL statement is executed serially (the default); the OTHER column is NULL.</td>
</tr>
<tr>
<td>SERIAL_FROM_REMOTE</td>
<td>The SQL in the OTHER column is executed at a remote site.</td>
</tr>
</tbody>
</table>
TABLE 11-3. Possible Values for PLAN_TABLE.OTHER_TAG for Parallel Operations

When an operation is parallelized, it may be partitioned to multiple query server processes based on ranges of ROWID values; the ranges are based on contiguous blocks of data in the table. You can use the OTHER_TAG column to verify the parallelism within different query operations, and you can see the parallelized query in the OTHER column. For example, the query in this next listing forces a MERGE JOIN to occur between the CUSTOMERS and SALES tables; because a MERGE JOIN involves full table scans and sorts, multiple operations can be parallelized. You can use the OTHER_TAG column to show the relationships between the parallel operations.

```
Alter table sales parallel (degree 4);
Alter table customers parallel (degree 4);
select /*+ FULL(customers) FULL(sales) USE MERGE(customers sales)
    customers.cust_last_Name, sales.amout_sold
from customers, sales
where customers.cust_ID = sales.cust_ID
    and sales.time ID = to date('18-AUG-01', 'DD-MON-YY');
```

Next, you can see the partial EXPLAIN PLAN for the MERGE JOIN query:

```
MERGE JOIN
    SORT JOIN
    PARTITION RANGE SINGLE
        TABLE ACCESS FULL SALES
    SORT JOIN
        TABLE ACCESS FULL CUSTOMERS
```

As shown in the plan, Oracle performs a full table scan (TABLE ACCESS FULL) on each table, sorts the results (using the SORT JOIN operations), and merges the result sets. The query of PLAN_TABLE in the next listing shows the OTHER_TAG for each operation. The query shown in the listing following the OTHER_TAG for each operation generates the EXPLAIN PLAN listings.

```
select
    LPAD('',2*Level)||Operation|| ''||Options
    ||''||ObjectName Q Plan, Other Tag
from PLAN_TABLE
where Statement_ID = 'TEST'
connect by prior ID = Parent_ID and Statement_ID = 'TEST'
start with ID=1;
```

The result of the query for the MERGE JOIN example is shown here:
You can see (by their OTHER_TAG values) that each of the TABLE ACCESS FULL operations is parallelized and provides data to a parallel sorting operation. The SORT JOIN operations are PARALLEL_COMBINED_WITH_PARENT (their “parent” operation is the MERGE JOIN). The MERGE JOIN operation is PARALLEL_TO_SERIAL (the merge is performed in parallel; output is provided to the serial query coordinator process).

The OBJECT_NODE column values display information about the query server processes involved in performing an operation. The following listing shows the OBJECT_NODE column for the TABLE ACCESS FULL of CUSTOMERS operation performed for the MERGE JOIN query:

```
set long 1000
select Object_Node
  from PLAN_TABLE
where Operation||''||Options = 'TABLE ACCESS FULL'
  and Object_Name = 'CUSTOMERS';
```

As shown in this listing, the OBJECT_NODE column references a parallel query server process. (Q15000 is an internal identifier Oracle assigned to the process for this example.)

**TIP**

When using the EXPLAIN PLAN command for a parallelized query, you cannot rely on querying just the operations-related columns to see the parallelized operations within the EXPLAIN PLAN. At a minimum, you should query the OTHER_TAG column to see which operations are performed.
Oracle provides a second script, `utlxplp.sql`, also located in the `/rdbms/admin` subdirectory under the Oracle software home directory. The `utlxplp.sql` script queries the PLAN_TABLE, with emphasis on the parallel query data within the table. You must create the PLAN_TABLE (via the `utlxplan.sql` script) and populate it (via the EXPLAIN PLAN command) prior to running the `utlxplp.sql` script.

**TIP**

When using EXPLAIN PLAN for parallel operations, use the `utlxplp.sql` script to view the PLAN_TABLE.

## Using the SET AUTOTRACE ON/OFF Command

You can have the EXPLAIN PLAN automatically generated for every transaction you execute within SQL*Plus. The `set autotrace on` command causes each query, after being executed, to display both its execution path and high-level trace information about the processing involved in resolving the query.

To use the `set autotrace on` command, you must have first created the PLAN_TABLE table within your account. When using the `set autotrace on` command, you do not set a STATEMENT_ID, and you do not have to manage the records within the PLAN_TABLE. To disable the AUTOTRACE feature, use the `set autotrace off` command.

If you use the `set autotrace on` command, you will not see the EXPLAIN PLAN for your queries until after they complete—unless you specify TRACEONLY. The EXPLAIN PLAN command shows the execution paths without running the queries first. Therefore, if the performance of a query is unknown, use the EXPLAIN PLAN command before running it. If you are fairly certain that the performance of a query is acceptable, use `set autotrace on` to verify its execution path.

The next listing shows the effect of the `set autotrace on` command. When a MERGE JOIN query is executed, the data is returned from the query followed by the EXPLAIN PLAN. The EXPLAIN PLAN is in two parts: the first part shows the operations involved, and the second part shows the parallel-related actions. Here, you can see the first part of the AUTOTRACE output.
The AUTOTRACE output shows the operations and the objects on which they act. The information near the far right (Q1 and so on) identifies the parallel query servers used during the query. The AUTOTRACE also shows the step ID values to describe the parallelism of the execution path’s operations, as shown here (this one you can read from bottom to top).

### Tuning Parallel Execution and the Initialization Parameters

Parameters related to physical memory are generally set much higher in a database that uses parallel operations than in a nonparallel environment. If you are using MEMORY_TARGET (sets memory for PGA/SGA), you should set it higher for a system using parallel operations. Many of the related
parameters (detailed here) are set automatically, but you may want to set minimums. See Chapter 4 for information on setting MEMORY_TARGET and other initialization parameters. The settings shown in Table 11-4 are general parameter settings, but your settings must be based on your unique business environment. Also note that OPTIMIZER_PERCENT_PARALLEL and ENQUEUE_RESOURCES (deprecated in 10.2 and removed in 11g) are obsolete and thus not shown in this table.

<table>
<thead>
<tr>
<th>Initialization Parameter</th>
<th>Meaning</th>
<th>Suggested Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPATIBLE</td>
<td>Setting this parameter to the release level of the instance allows you to take advantage of all of the functionality built into the RDBMS engine. Oracle recommends backing up the database before changing this parameter!</td>
<td>Generally set to the default value for the database version. Standby databases must use a consistent setting for both the primary and standby.</td>
</tr>
<tr>
<td>DB_FILE_MULTIBLOCK_READ_COUNT*</td>
<td>Determines how many blocks are read at once during a full table scan. Improves the performance of parallel operations using table scans.</td>
<td>OS-dependent. On Windows and Linux this is 128.</td>
</tr>
<tr>
<td>PARALLEL_DEGREE_LIMIT</td>
<td>Sets the maximum DOP a statement can have when automatic DOP is used.</td>
<td>This is based on CPU threads and instances. Lower if DOP starts overloading system.</td>
</tr>
<tr>
<td>DML_LOCKS*</td>
<td>Sets the maximum number of DML locks acquired for the database. The default value assumes an average of four tables referenced per transaction.</td>
<td>Default value is 4*TRANSACTIONS. Increase to support parallel DML.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td><strong>PARALLEL_ADAPTIVE_MULTI_USER</strong></td>
<td>Reduces the degree of parallelism based on number of active parallel users and prevents overload. Potentially set this to FALSE and control parallel resources with the Database Resource Manager instead if needed (deprecated in 12c). OS-dependent; values range from 2148 to 65535. Setting this parameter to a larger value than the default leads to better throughput for parallel operations but uses more memory, which may cause performance problems for nonparallel operations or applications. Set higher for more parallel processes, but if you set it too high, shortages could occur. Default value is FALSE and recommended value is FALSE. Performance degradation could occur if this is set to TRUE at times, so be careful.</td>
<td></td>
</tr>
<tr>
<td><strong>PARALLEL_EXECUTION_MESSAGE_SIZE</strong></td>
<td>Specifies the size of messages for all parallel operations to communicate among themselves. Larger values than the default will require a larger shared pool size or related memory setting.</td>
<td></td>
</tr>
<tr>
<td><strong>PARALLEL_MAX_SERVERS</strong></td>
<td>Maximum number of parallel query server processes allowed to exist simultaneously.</td>
<td></td>
</tr>
<tr>
<td><strong>PARALLEL_FORCE_LOCAL</strong></td>
<td>Whether a parallel operation is restricted to a single instance in a RAC environment. Default value is FALSE and recommended value is FALSE. Performance degradation could occur if this is set to TRUE at times, so be careful.</td>
<td></td>
</tr>
<tr>
<td><strong>PARALLEL_MIN_PERCENT</strong></td>
<td>If this percentage of the degree of parallelism (number of servers) required by the query is not available, statement will terminate with an error (ORA-12627). This is effective when a serial execution of the statement is undesired. Default value is 0, range of values is 0–100. If 0, parallel operations will always execute in parallel. If 100, operations execute in parallel only if all servers can be acquired.</td>
<td></td>
</tr>
<tr>
<td><strong>PARALLEL_MIN_SERVERS</strong></td>
<td>Minimum number of servers created when instance originates. As servers idle out or terminate, the number of servers never falls below this number. 0 to OS limit. Realistically, start with 10–24 depending on resources. Consider changing if VS views show too heavy use of parallel queries. Set this parameter!</td>
<td></td>
</tr>
</tbody>
</table>
The parameters in the initialization file define and shape the environment used by parallel operations. You enable parallel operations for your commands by using a PARALLEL hint on a SQL statement or using the PARALLEL clause during a CREATE/ALTER table command. When you are considering adjusting any initialization parameter (or removing deprecated parameters), fully investigate the Oracle Database Administrator’s Guide, 12c, the Oracle Database Upgrade Guide, 12c, or the appropriate server installation guide for your system prior to experimenting with an Oracle database.
Parallel Loading

To use parallel data loading, start multiple SQL*Loader sessions using the PARALLEL keyword. Each session is an independent session requiring its own control file. This listing shows three separate direct path loads, all using the PARALLEL=TRUE parameter on the command line:

```
sqlldr USERID=SCOTT/PASS CONTROL=p1_CTL DIRECT=TRUE PARALLEL=TRUE
sqlldr USERID=SCOTT/PASS CONTROL=p2_CTL DIRECT=TRUE PARALLEL=TRUE
sqlldr USERID=SCOTT/PASS CONTROL=p3_CTL DIRECT=TRUE PARALLEL=TRUE
```

Each session creates its own log, bad, and discard files (p1.log, p1.bad, etc.) by default. You can have multiple sessions loading data into different tables, but the APPEND option is still required. APPEND is very fast because it fills only unused blocks. The SQL*Loader REPLACE, TRUNCATE, and INSERT options are not allowed for parallel data loading. If you need to delete the data using SQL commands, you must manually delete the data.

**TIP**

If you use parallel data loading, indexes are not maintained by the SQL*Loader session unless you are loading a single table partition. Before starting a parallel loading process, you must drop all indexes on the table and disable all of its PRIMARY KEY and UNIQUE constraints. After the parallel loads completely, you need to re-create or rebuild the table’s indexes. Inserting data using APPEND and UNRECOVERABLE is the fastest way to insert data into a table without an index. External tables may provide faster extract, transform, and load (ETL) operations.

In parallel data loading, each load process creates temporary segments for loading the data; the temporary segments are later merged with the table. If a parallel data load process fails before the load completes, the temporary segments will not have been merged with the table. If the temporary segments have not been merged with the table being loaded, no data from the load will have been committed to the table.

You can use the SQL*Loader FILE parameter to direct each data loading session to a different datafile. By directing each loading session to its own database datafile, you can balance the I/O load of the loading processes. Data loading is very I/O-intensive and must be distributed across multiple disks for parallel loading to achieve significant performance improvements over serial loading.

**TIP**

Use the FILE parameter to direct the writes generated by parallel data loads.
After a parallel data load, each session may attempt to re-enable the table’s constraints. As long as at least one load session is still under way, attempting to re-enable the constraints will fail. The final loading session to complete should attempt to re-enable the constraints, and it should succeed. You should check the status of your constraints after the load completes. If the table being loaded has PRIMARY KEY and UNIQUE constraints, you should first re-create or rebuild the associated indexes in parallel and then manually enable the constraints.

TIP
The PARALLEL option for data loading improves performance of loads, but it can also waste space when not properly used.

Optimizing Parallel Operations in RAC

The benefits of using parallel operations with an Oracle database have been well established, with the feature first being offered in version 7.1. Parallel execution of SQL statements on traditional Unix-based symmetric multiprocessor (SMP) architectures greatly increases utilization of the server and the speed of large resource-intensive operations. In a Real Application Clusters (RAC) architecture, the equivalent of a parallel SMP deployment is placed into effect and utilizes all the available servers (nodes) in the cluster. Use of parallel operations with RAC greatly enhances the scale-out cluster architecture.

Objectives of Parallel Operations

The objective of a parallel implementation is to use all available resources of the database platform architecture to increase overall processing potential. Resources included in this type of deployment are memory, processor, and I/O. Parallel operations that can be performed in any scale-up or single-system SMP image environment can also be performed in the scale-out RAC cluster environment. Operations that are included are as follows:

- Queries (based on full table scan)
- CREATE TABLE AS
- Index builds/rebuilds
- DML operations (INSERT, UPDATE, DELETE) on partitioned tables
- Data loads

You can perform the first four operations referenced in this list with the use of SQL hints or by setting the degree of parallelism at the object level. Configure node groups to restrict parallel
operations to specific nodes. Therefore, when implementing a large RAC architecture (more than two
two servers), allocate named servers to named groups to restrict or enable parallel operations.

## RAC Parallel Usage Models

Several usage models are available for parallel execution with RAC. Because splitting a query
across multiple nodes can degrade performance as well, take care when using the parallel query with
RAC! The models included are as follows:

- **Standard** Use of parallel query for large datasets. In this deployment, the degree of
  parallelism is usually defined to utilize all of the available resources in the cluster.
- **Restricted** This deployment restricts processing to specific nodes in the cluster. The
  referenced nodes can be logically grouped for specific types of operations.
- **Parallel index builds/rebuilds** In cases where large index builds are required, parallelism can
  be utilized to maximize the use of cluster node resources.

## Parallel Initialization Parameters

Several standard parameters can be set to implement parallel processes at the server level as
discussed earlier in the chapter. The two general parallel parameters to consider are as follows:

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARALLEL_MAX_SERVERS</td>
<td>Integer</td>
<td>Maximum number of parallel processes per instance</td>
</tr>
<tr>
<td>PARALLEL_MIN_SERVERS</td>
<td>Integer</td>
<td>Minimum number of server processes per instance</td>
</tr>
</tbody>
</table>

## V$ Views for Viewing Parallel Statistics

Several database views are used to obtain parallel operation statistics. The view names referenced
here are prefaced with the GV$ identifier, which depicts the RAC-level statistics:

- **GV$PQ_SYSSTAT**
  - All parallel-related statistics for the entire RAC configuration
- **GV$PQ_SESSTAT**
  - Session-specific parallel statistics by session ID
Create Table As

Using the CREATE TABLE AS (CTAS) feature within Oracle can be extremely useful for making copies of table objects. For large tables, the operation can be performed in parallel in the same manner as with the parallel query examples in the prior section. The SQL statement that follows is an example of using CTAS with the parallel option. Instance groups can also be used to restrict processing to specific nodes. Thus, based on the INSTANCE_GROUPS parameter, the query is executed only on the TEST1 node.

```
alter session set parallel_instance_group = 'TEST_20';
create table c_district_backup parallel (degree 3)
as
select *
from  c district;
```

Parallel Index Builds

Performing index creates or rebuilds for large tables is another resource-intensive operation where performance can be greatly improved with parallel operations. The INDEX CREATE statement requests a parallel degree of 6 for the operation. Similar to the previous examples, this operation can also utilize the INSTANCE_GROUPS parameter to restrict the operation to specific nodes.

```
alter session set parallel_instance_group = 'TEST_20';
create unique index C_STOCK_T1 on C_STOCK (s_i_id, s_w_id)
tablespace stock_index
parallel (degree 6);
```

Performance Considerations and Summary

The downside of parallel operations is the exhaustion of server resources. The easiest server resource to monitor is CPU utilization. If normal CPU utilization were relatively high, deploying a large number of parallel processes would not be advisable. Exceeding the total number of CPUs would cause performance degradation as well. Data layout is another immediate consideration. If I/O bottlenecks currently exist, use of parallel operations may exacerbate this condition. Ensure that datafiles for parallel target objects are spread across a reasonable number of disk spindles.

The use of parallel operations within a RAC deployment provides for the flexibility to utilize all
server hardware included in the cluster architecture. Utilizing instance groups, database administrators can further control the allocation of these resources based on application requirements or service level agreements.

Other Parallel Notes

Planning (or reengineering) the physical location of datafiles is key to successful parallel data access. Determine an appropriate degree of parallelism for each parallelized SQL statement and parallelize the creation of your physical design. Don’t let the initialization parameters dictate how the degree of parallelism is determined. Remember, you’re usually trying to optimize a small number of slow queries, not every table access. Experiment with conservative parameters; use parallel operations for table or index creations and hint the degree of parallelism you identify as optimal. Use proper syntax for the parallel hints or they will be ignored. Other V$ views that may be helpful to you include V$PX_SESSION (session performing parallel operations), V$PX_SESSTAT (statistics for sessions performing parallel operations), V$PX_PROCESS (parallel processes), V$PX_PROCESS_SYSSTAT (statistics for parallel execution servers), V$SESSTAT (user session statistics), V$FILESTAT (file I/O statistics), V$PARAMETER (initialization parameters), and V$PQ_TQSTAT (workload statistics for parallel execution servers).

The parallel features offered in Oracle are incredibly powerful tools when used in a targeted fashion—most databases can be tuned to place indexes in the right quantity and location to deliver acceptable performance. Use parallel operations for those statements that cannot be written any other way but to scan an entire table or address a partitioned large table/index. Parallelized operations are powerful tools for managing data warehouses or performing periodic maintenance activities. Configure the database environment to take full advantage of the benefits parallelism offers.

Oracle Documentation Is Online

Don’t forget that all of the Oracle documentation (multiple Oracle versions) for all of the products is online at http://docs.oracle.com.

Tips Review

- The cloud is here to stay. Ensure that you become educated on the Oracle Cloud so that you can discern which parts benefit your company and which parts require a wait-and-see approach.

- Get ready for the cloud by trying a simple DBaaS instance at http://cloud.oracle.com/tryit or http://cloud.oracle.com/database for free or by trying the new 12c R2 Oracle Database Exadata Express Cloud Service for $175/month.

- Exadata has been the next generation flagship hardware platform for relational database architecture. Get ready for it, it is constantly being updated.

- Use V$SESSION_WAIT or GV$SESSION_WAIT, Statspack, or the AWR Report to find RAC
Using parallel operations on very small tables or very fast queries can also degrade performance because the query coordination may also cost performance resources. You should evaluate whether the parallel cost exceeds the nonparallelized cost.

When the parallel degree is set to $N$, it is possible to use $(2*N) + 1$ total processes for the parallel operation. Although parallel operations deal with processes and *not* processors, when a large number of processors are available, Oracle generally uses the additional processors to run parallel queries, often enhancing the performance of the query.

Any server process allocated for a statement may handle any request from a process within the same statement. Therefore, if some processes are faster than others, the ones that are faster can process the rows produced by the child set of parallel execution processes as soon as they are available instead of waiting for the ones that are slower (but only at the next higher statement hierarchy level).

Using the PARALLEL hint enables the use of parallel operations. If you use the PARALLEL hint but do not specify the degree of parallelism with the hint or set it at the table level, the query still executes in parallel, but the DOP is calculated from the initialization parameters.

The use of the NO_PARALLEL hint disables parallel operations in a statement that would otherwise use parallel processing due to a parallel object definition.

Specify the degree of parallelism using a hint instead of relying on the table definition to ensure that all operations are tuned for the given query.

Use NOLOGGING to remove the I/O bottleneck caused by serial writes to the redo logs.

Make sure your data is properly distributed or the parallel query server processes may add to existing I/O bottleneck problems.

Parallel processes commonly involve disk accesses. If the data is not distributed across multiple disks, using the Parallel Execution Option (PEO) may lead to an I/O bottleneck.

A PARALLEL hint overrides the degree of parallelism defined for a table when determining the degree of parallelism for an operation.

New columns may be added to the PLAN_TABLE with each new release of Oracle. You should drop and re-create your PLAN_TABLE following each upgrade of the Oracle kernel. If you upgrade an existing database to a new version of Oracle, you should drop your old PLAN_TABLE and re-execute the utlxplan.sql script to see all of the new PLAN_TABLE columns. You can also view the plan using Oracle Enterprise Manager in the SQL Details page.

When using the EXPLAIN PLAN command for a parallelized query, you cannot rely on querying just the operations-related columns to see the parallelized operations within the EXPLAIN PLAN. At a minimum, you should query the OTHER_TAG column to see which operations are performed in parallel.

When using EXPLAIN PLAN for parallel operations, use the utlxplp.sql script to view the PLAN_TABLE.
Be sure your environment is properly configured to support the increase in processes, memory, and transactions generated by parallel operations.

If you use parallel data loading, indexes are not maintained by the SQL*Loader session unless you are loading a single table partition. Before starting a parallel loading process, you must drop all indexes on the table and disable all of its PRIMARY KEY and UNIQUE constraints. After the parallel loads completely, you need to re-create or rebuild the table’s indexes. Inserting data using APPEND and UNRECOVERABLE is the fastest way to insert data into a table without an index. External tables may provide faster extract, transform, and load (ETL) operations.

Use the FILE parameter to direct the writes generated by parallel data loads.

The PARALLEL option for data loading improves performance of loads, but it can also waste space when not properly used.

Exadata, Exalogic, Exadata Storage Expansion Rack, Oracle Database Appliance, SPARC SuperCluster, Exalytics BI Machine, ZFS, Pillar Storage, and the latest StorageTek combines probably more hardware speed than the entire hardware industry put out prior to Oracle buying Sun. Hardware speeds were doubling every 18 months; enter Oracle and hardware speed is now accelerating exponentially with Oracle at the wheel (in the last two years Oracle has probably accelerated hardware/software performance 2,000–20,000 times if you know how to use it). The Terabytes database will soon be the Exabytes database. Teach your kids Oracle!

References

“Advanced Compression with Oracle Database 11g R2,” Steven Lu (Oracle Corporation).
Oracle Exadata Database Machine X6-2 and X6-8, Oracle Specs, August 2016.
Oracle Data Warehousing Guide (Oracle Corporation).
Oracle Server Concepts (Oracle Corporation).
Oracle Server Reference (Oracle Corporation).
Oracle Server Tuning (Oracle Corporation).
Oracle Database Appliance, Oracle, October 2011.
“Oracle Enterprise Manager Deployment and High Availability Best Practices,” Jim Viscusi (Oracle Corporation), Jim Bulloch (Oracle Corporation), Steve Colebrook-Taylor (Barclays Global Investors).
Oracle Exadata Implementation Workshop, Oracle Corporation, McLean, Virginia.
Oracle Learning Library, multiple sessions/topics. (This resource is very good!!)
SPARC SuperCluster, Oracle, October 2016.

Special thanks to Sridhar Avantsa for additions to the Exadata and RAC sections. Thanks also go
to Madhu Tumma of Credit Suisse First Boston for writing the original section “Real Application Clusters” for this chapter. Jake Van der Vort did a major portion of the original parallel query chapter. Kevin Loney did the update to Oracle9i for the original parallel query chapter. Brad Nash did most of the Oracle 10g update and added the RAC information. Special thanks to Murali Vallath for many contributions to this chapter and his great book on RAC.

* This is an abbreviated list. Please see My Oracle Support Doc ID 757552.1 for the full document. Note 1274475.1 is the subsection for performance-specific information.
Senior DBAs often tell junior DBAs that back in version 6 they used to know every V$ view by heart. Version 6 had only 23 V$ views, so the DBAs from the old days had it pretty easy. Oracle 10gR2 had 372 V$ views and 613 X$ tables. Oracle 11gR2 has 525 V$ views and 945 X$ tables. Oracle 12cR2 has 746 V$ views and 1312 X$ tables (the number of tables and views depends on the version, OS, and options that you use as well). There are new V$ views related to the In-Memory column store and pluggable databases (PDBs) in 12c. There is also an additional column on many V$ views for Container ID (CON_ID) with PDBs and container databases (CDBs).

Almost every great tuning or DBA product has one aspect in common. Most of them access the V$ views to get the insightful information that is retrieved about the database, individual queries, or an individual user. Accessing the V$ views has become quite prevalent due to the numerous presentations by Joe Trezzo and other V$ gurus. If you currently don’t look at the V$ views, you don’t know what you’re missing. The V$ views look into the heart of the Oracle database. They are the link to moving from the average DBA to the expert DBA.

Chapter 13 more extensively explores the X$ tables, which are the underlying part of the V$ views. Appendixes B and C provide information about the V$ views and also the creation scripts from the X$ tables. Unfortunately, I can’t show every great V$ script due to space limitations, and I’ll try not to duplicate things that are covered in depth in other chapters. Please check my sessions on the Web for the latest V$ scripts available.

Topics covered in this chapter include the following:

- Creating V$ views and granting access to them in 12c
- Getting a listing of all V$ views in 12c
- Getting a listing of the X$ scripts that make up the V$ views in 12c
- Examining the underlying objects that make up the DBA_ and CDB_ views
- Querying V$DATABASE to get database creation time and archiving information
- Learning about the Automatic Workload Repository (AWR)
- Querying V/LICENSE to view licensing limits and warning settings
- Accessing V$OPTION to view all options that have been installed
- Querying V$SGA and using MEMORY_TARGET to allocate basic memory for 12c
Querying V$SGA when setting INMEMORY_SIZE for the In-Memory column store
Querying V$IM_SEGMENTS and V$IM_COLUMN_LEVEL for the In-Memory column store
Querying V$SGASTAT to allocate detailed memory for Oracle
Querying V$SGASTAT as the Root CDB user or PDB user
Finding initialization parameter settings in V$PARAMETER
Determining if an initialization parameter is modifiable at PDB level in V$PARAMETER
Determining memory for data (V$SYSSTAT and V$SYSMETRIC)
Determining memory for the data dictionary (V$ROWCACHE and V$SYSMETRIC)
Determining memory for shared SQL and PL/SQL (V$LIBRARYCACHE and V$SYSMETRIC)
Determining memory for the In-Memory column store (12.1.0.2+ only)
Querying V$CONTAINERS for CDB and PDB information
Querying for pluggable databases in V$PDBS at both PDB and CDB levels
Using the Result Cache
Deciding which objects need to be pinned and whether there is contiguous free memory (V$DB_OBJECT_CACHE)
Finding the problem queries by accessing V$SESSION_LONGOPS, V$SQLAREA, V$SQLTEXT, V$SESSION, and V$SESS_IO
Finding out what users are doing and which resources they are using
Identifying locking problems and killing the corresponding session
Finding users with multiple sessions
Balancing I/O using V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES
Checking privileges and roles
Finding Waits with V$SESSION, V$SESSION_WAIT, V$SESSION_EVENT, V$SESSION_WAIT_CLASS, V$SESSION_WAIT_HISTORY, V$SYSTEM_EVENT, and V$SYSTEM_WAIT_CLASS

Creating and Granting Access to V$ Views
The V$ views are created by the catalog.sql script (in $ORACLE_HOME/rdbms/admin). As of Oracle 12cR2, there are approximately 746 V$ views. The actual number varies by version and platform. Here is the number of views from Oracle 6 to Oracle 12cR2:
<table>
<thead>
<tr>
<th>Version</th>
<th>V$ Views</th>
<th>GV$ Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>23</td>
<td>(35?)</td>
</tr>
<tr>
<td>7.1</td>
<td>72 (+213% vs. V6)</td>
<td>126</td>
</tr>
<tr>
<td>8.0</td>
<td>132</td>
<td>200</td>
</tr>
<tr>
<td>8.1</td>
<td>185 (+157% vs. V7)</td>
<td>271 (+115% vs. V7)</td>
</tr>
<tr>
<td>9.0</td>
<td>227</td>
<td>352</td>
</tr>
<tr>
<td>9.2</td>
<td>259 (+29% vs. 8.1)</td>
<td>394 (+45% vs. 8.1)</td>
</tr>
<tr>
<td>10.1</td>
<td>340</td>
<td>543</td>
</tr>
<tr>
<td>10.2</td>
<td>372 (+44% vs. 9.1)</td>
<td>613 (+56% vs. 9.2)</td>
</tr>
<tr>
<td>11.1</td>
<td>484</td>
<td>798</td>
</tr>
<tr>
<td>11.2</td>
<td>525 (+41% vs. 10.2)</td>
<td>945 (+54% vs. 10.2)</td>
</tr>
<tr>
<td>12.1</td>
<td>606</td>
<td>1062</td>
</tr>
<tr>
<td>12.2</td>
<td>746 (+42% vs. 11.2)</td>
<td>1312 (+39% vs. 11.2)</td>
</tr>
</tbody>
</table>

The views are all created with the prefix $V_\$ and $GV_\$. Two of the views are created by the catldr.sql script, which is used for SQL*Loader direct load statistical information. The underlying view definitions (technically, these views are never created; their definitions are hard-coded into the binary) for each V$ and GV$ view can be seen in the V$ view named V$FIXED_VIEW_DEFINITION. The V$ views are created by selecting instance-specific information from GV$ views. For almost every V$ view, there is a corresponding GV$ view. GV$, or global V$, views contain the same information as the V$ views but across all instances of a RAC database (each instance is identified by its instance ID). The GV$ views are created by selecting from one or more X$ tables. A view is created for each V$_$ and GV$_$ view to allow users to access the view. Users cannot access the actual V$ views (they actually access the V$_$ views; the V$ objects are only visible to SYS). In other words, this method provides access to these views via a view on a view. The view name changes the prefix of each view to V$. Lastly, a public synonym is created for each view because the SYS user owns the tables. The following listing shows an example of a V$ and GV$ view creation in the cdfixed.sql script called by the catalog.sql script:

```sql
create or replace view v$_datafile as
select *
from v$datafile;
create or replace public synonym v$datafile for v$_datafile;

create or replace view gv$_datafile as
select *
from gv$datafile;
create or replace public synonym gv$datafile for gv$_datafile;
```
The complete sequence of events is detailed in the following steps.

1. The GV$ view definitions are created from the X$ tables when the database is created (note that the CON_ID [Container ID] column was not present in the previous version):
   ```sql
   create or replace view gv$fixed_table as
   select inst_id, kqftanam, kqftaobj, 'TABLE', index, con_id
   from x$kqfta
   union all
   select inst_id, kqftanam, kqftaobj, 'VIEW', 65537, con_id
   from x$kqfta
   union all
   select inst_id, kqftanam, kqftaobj, 'TABLE', 65537, con_id
   from x$kqfta;
   ```

2. The version-specific catalog script is executed as the following:
   ```sql
   SQL> @catalog (this is in the $ORACLE_HOME/rdbms/admin directory)
   ```

3. A V_$ view is created from the V$ view when the CREATE database script executes the following:
   ```sql
   create or replace view v$_fixed_table
   as
   select *
   from v$fixed_table;
   ```

4. A new V$ synonym is created on the V$_ view:
   ```sql
   create or replace public synonym v$fixed_table for v$_fixed_table;
   ```

5. A new GV$ synonym is created on the GV$_ view:
   ```sql
   create or replace public synonym gv$fixed_table for gv$_fixed_table;
   ```

TIP

The V$ views that are accessed by SYSTEM are actually synonyms that point to the V$_ views that are views of the original V$ views based on the X$ tables. (Better read that one again!)

The only operation that you can perform on these views is a SELECT. To provide access to the V$ views, you must grant access to the underlying V$_ view.

You cannot grant access to the V$ views (even as the SYS user), however:

```
connect sys/change_on_install as sysdba
Grant select on v$fixed_table to Richie;
ORA-02030: can only select from fixed tables/views.
```

Although the error message (following the preceding code) for attempting to grant access to V$FIXED_TABLE is erroneous, the GRANT is not allowed. You may, however, grant access to the
To connect to the SYS superuser, use the following:

```
Connect sys/change_on_install as sysdba
Connected.
```

To grant access to an underlying view to the desired user, use the following:

```
grant select on v_$fixed_table to Richie;
Grant succeeded.
```

To connect as the desired user, use this:

```
conn Richie/Rich
Connected.
```

Access the V$FIXED_TABLE view via the synonym V$FIXED_TABLE, which is created for V_$FIXED_TABLE with the following:

```
select count(*)
from v$fixed_table;
```

```
COUNT(*)
------
   2769
```

You still can’t access the V_$FIXED_TABLE even though that grant was made (SYS can access it, however):

```
select count(*)
from v_$fixed_table;
ORA-00942: table or view does not exist.
```

You can access the V_$FIXED_VIEW if you preface it with SYS:
To avoid confusion, give access to the V$_$ views and notify the DBA that he or she has access to the V$_$ views. Using this method, you may give access to the V$_$ view information without giving out the password for the SYS or SYSTEM accounts. The key is granting SELECT access to the original SYS owned V$_$ view.

**TIP**

When other DBAs need access to the V$_$ view information, but not the SYS or SYSTEM passwords, grant the user access to the V$_$ views. The user may then access the V$_$ views that have public synonyms to the V$_$ views. However, scripts could always be written to query the SYS.V$_$ views directly, to avoid the performance cost of dereferencing the public synonym, but this savings is small.

Please refer to Oracle documentation for guidelines and granting privileges to different levels of users. This is especially important when you have a very large number of users.

**CAUTION**

You should grant non-DBA users privileges to the V$_$ views only as needed, and use caution. Remember, performance costs come with querying the V$_$ views, and the larger your environment, the greater those costs.

---

Obtaining a Count and Listing of All V$_$ Views

To get a count of all V$_$ views for a given version of Oracle, query the V$_$FIXED_TABLE view. The number of V$_$ views continues to change even within the same version. The examples that follow display the V$_$ view queries for Oracle 12cR2. The frontier in the world of the V$_$ views continues to expand with each version of Oracle.

To get a count of V$_$ views, query as shown here:

```sql
conn Richie/Rich
select count(*)
from SYS.v_$fixed_table;
COUNT(*)
-------
2769
```
Many of the V$ views continue to be undocumented. The methods of exploring information continue to expand in Oracle because the number of views continues to expand. In Oracle8 (now desupported), the GV$ views were introduced. The GV$ (global V$) views are the same as the V$ views with an additional column for the instance ID (for RAC). In 12c, we now see an additional column in many for the Container ID (CON_ID) used for pluggable databases. To get a list of GV$ views, query as shown here (this is a partial listing; you’ll find a complete list of V$ views in Appendix B):

```sql
select name 
from v$fixed_table 
where name like 'GV%'
order by name
fetch first 7 rows only;
```

<table>
<thead>
<tr>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>GV$ACCESS</td>
</tr>
<tr>
<td>GV$ACTIVE_INSTANCES</td>
</tr>
<tr>
<td>GV$ACTIVE_SERVICES</td>
</tr>
<tr>
<td>GV$ACTIVE_SESSION_HISTORY</td>
</tr>
<tr>
<td>GV$ACTIVE_SESS_POOL_MTH</td>
</tr>
<tr>
<td>GV$ADVISOR_CURRENT_SQLPLAN</td>
</tr>
<tr>
<td>GV$ADVISOR_PROGRESS</td>
</tr>
</tbody>
</table>

7 rows selected.

TIP
Query V$FIXED_TABLE to obtain a listing of all GV$ and V$ views in the database. The GV$ views are the exact same as the V$ views, except the instance ID contains an identifier, and the GV$ views contain data for all instances of an Oracle RAC database.

Getting a Listing for the X$ Scripts That Make Up the V$ Views
To understand where the V$ view information comes from, query the underlying X$ tables (see Chapter 13 for X$ table information). At times, querying the underlying X$ tables may be advantageous because the V$ views are often the join of several X$ tables. The X$ tables are very cryptic because they are similar to the underlying table constructs of the Oracle data dictionary. Oracle creates V$ views in the SGA to allow users to examine the information stored in the X$ tables in a more readable format. In fact, when SELECTs are performed against the V$ views, the SELECTs are actually retrieving information out of the SGA—and more specifically, out of the X$ tables, which are truly memory constructs that interface the software code constructs (which is why they are so cryptic).

With the knowledge of the V$ view underlying a given SELECT statement, you have the capability to create customized views; simply copy the existing V$ view underlying the SELECT statement and modify it or create a new customized SELECT on the X$ tables. This technique allows more selective and more optimized queries. The next listing is used to access the underlying query to the X$ tables. To get a listing of the X$ tables that make up the V$ views, you must access the V$FIXED_TABLE_DEFINITION view (output formatted for readability).

```
select view_name, view_definition
from v$fixed_view_definition
where view_name = 'GV$FIXED_TABLE';
```

Output

<table>
<thead>
<tr>
<th>VIEW_NAME</th>
<th>VIEW_DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>GV$FIXED TABLE</td>
<td>select inst_id,kgftanam,kgftaobj,'TABLE',indx,con_id from x$kgfta union all select inst_id,kgflvnam,kgflvlobj,'VIEW',65537,con_id from x$kgflv</td>
</tr>
<tr>
<td></td>
<td>union all select inst_id,kgftdtanam,kgftdobj,'TABLE',65537,con_id from x$kgftd</td>
</tr>
</tbody>
</table>

TIP

Access the V$FIXED_VIEW_DEFINITION view to get all information about the underlying X$ tables that make up a V$ view. CON_ID (Container ID) is a new column you’ll see in 12c for pluggable databases.

Also note that, as of Oracle8, there are indexes on the underlying X$ tables to provide faster execution of queries performed on the V$ views (amazing that it took Oracle until version 8 to use...
indexes!). You can view the index information on the underlying X$ tables through the V$INDEXED_FIXED_COLUMN view (see Chapter 13 on X$ tables for more information).

Examining the Underlying Objects That Make Up the DBA_ Views

Some people think the DBA_ views also come from the X$ tables and/or the V$ views. They actually come from Oracle’s underlying database tables (although some access the X$ tables as well). To look at the objects that make up the DBA_ views, access DBA_VIEWS, as shown in this listing (also note there is a CDB_ view for every corresponding DBA_ view):

**NOTE**
You may need to use `set long 2000000` to see all of this output.

```sql
select text
from dba_views
where view_name='DBA_IND_PARTITIONS';

TEXT

select u.name, io.name, 'NC', io.subname, 0, ip.hiboundval, ip.hboundlen

SQL> set long 2000000
(RUN IT AGAIN)

select text
from dba_views
where view_name='DBA_IND_PARTITIONS';

TEXT (this listing has been shortened by about 110 lines for brevity)

select u.name, io.name, 'NC', io.subname, 0,
    ip.hiboundval, ip.hboundlen, row_number() over (partition by u.name,
    io.name, order by ip.part#),
    decode(bitand(ip.flags, 1), 1, 'UNDASABLE', 'ASABLE'), ts.name,
    ...
    (much code deleted for space - about 86 lines)...
from obj$ io, indpart$ ip, user$ u, ind$ i, indpart_param$ ipp, tab$ t,
where io.obj# = ip.obj# and io.owner# = u.user#
    ...
    (much code deleted for space - about 24 lines)...
```

Never modify the underlying objects; many DBAs have corrupted their database in this manner. Do not do the following, but note that it is possible:
Connect sys/change_on_install as sysdba
Connected.

DELETE FROM OSUS; -- Don't do this! If you commit, your database is over!
78239 rows deleted.
Rollback;
Rollback complete

Also consider the following CDB versus PDB example:

sqlplus / as sysdba (log on as CDB$ROOT user in Root CDB - Container DB)

```
select count(*) from cdb_tables;
    COUNT(*)
--------------
        7059

select count(*) from dba_tables;
    COUNT(*)
--------------
          2317

select count(*) from user_tables;
    COUNT(*)
--------------
          1221
```

alter session set container=PDB1;
Session altered.

```
select count(*) from cdb_tables;
    COUNT(*)
--------------
          2426

select count(*) from dba_tables;
    COUNT(*)
--------------
          2426

select count(*) from user_tables;
    COUNT(*)
--------------
          1235
```
Note the hierarchy: The main CDB contains information including the PDB, but the PDBs only hold their own information (but there may be multiple USERS in each PDB).

TIP
The DBA_views are not derived from the X$ tables or V$ views. The fact that you can delete rows from OBJ$ and ruin your database is a great reason to never be the SYS superuser. There is a CDB_view for every DBA_view, and the Root CDB_views also contain PDB information.

Using Helpful V$ Scripts
The rest of this chapter is dedicated to scripts that are helpful in analyzing different areas of the Oracle database. Many of these scripts are dynamic and provide valuable insight into areas of the database that you may need to analyze to determine resource contention at a point in time. Typically, the result is that the DBA performs some operation to eliminate the contention immediately by tuning a query or increasing an initialization parameter to reduce the resource contention in the future. Revoking access to a given ad hoc query user, or restricting his or her system resource use with profiles, could be an emergency option as well. The next four sections include scripts that retrieve the following:

- Basic database information
- Basic Automation Workload Repository (AWR) Information
- Basic licensing information
- Database options installed in your database

Basic Database Information

Getting the basic information about your instance is usually as easy as logging in to SQL*Plus because all of the information shows in the banner at that time. If you would like to see the full banner header, you can access the V$VERSION view to display the banner. The following listing shows a quick way to see the version you are using as well as other information:

Version Information:

```sql
select banner
from   v$version;
```
Output from 12.2:

Database Information:

```sql
select name, created, log_mode
from v$database;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>CREATED</th>
<th>LOG MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORCL</td>
<td>17-MAR-16</td>
<td>ARCHIVELOG</td>
</tr>
</tbody>
</table>

Accessing V$DATABASE gives you basic information concerning the database. The most important information in the output is to ensure that you are in the desired ARCHIVELOG mode. The output also gives you the exact date when the database was created, as you can see in the preceding listing.

Another way to view the archive log status for the database is to simply use the ARCHIVE LOG LIST command as the SYS user in SQL*Plus:

```sql
SQL> archive log list
```

<table>
<thead>
<tr>
<th>Database log mode</th>
<th>Archive Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automatic archival</td>
<td>Enabled</td>
</tr>
<tr>
<td>Archive destination</td>
<td>USE DB RECOVERY FILE DEST</td>
</tr>
<tr>
<td>Oldest online log sequence</td>
<td>418</td>
</tr>
<tr>
<td>Current log sequence</td>
<td>418</td>
</tr>
</tbody>
</table>

TIP
Query V$VERSION and V$DATABASE to view basic database information such as the version, to find out when your database was created, and to find out basic archiving information.
Basic Automatic Workload Repository (AWR) Information

With the advent of the Automatic Workload Repository (AWR), you now have many areas to watch. By default, the repository is populated every hour with a retention period of seven days. Here are some queries that are worth knowing for the AWR (the MMON background process is used to flush AWR data from memory to disk). See Chapter 5 for detailed information on AWR, licensing related to the V$ views based on the AWR, and using information from the AWR for tuning purposes.

How much space is the AWR using?

```
select occupant_name, occupant_desc, space_usage_kbytes
from v$sysaux_occupants
where occupant_name like '%AWR%';
```

What’s the oldest AWR information on the system?

```
select dbms_stats.get_stats_history_availability
from dual;
```

What’s the retention period for AWR information?

```
select dbms_stats.get_stats_history_retention
from dual;
```

To change the retention period for AWR information to 15 days:
EXEC dbms_stats.alter_stats_history_retention(15);

SELECT dbms_stats.get_stats_history_retention FROM dual;

GET_STATS_HISTORY_RETENTION
-----------------------------
  15

TIP
Query V$SYSAUX_OCCUPANTS to ensure that the Automatic Workload Repository (AWR) isn’t taking up too much space. Use DBMS_STATS to check history and retention.

Basic Licensing Information

The V$LICENSE view allows a DBA to monitor system activity in terms of overall database licensing, warnings, and current use at any time. It provides a DBA with a log of the maximum number of concurrent sessions at any time, which allows a company to ensure it is licensed properly. The current number of sessions is displayed along with the session warning level and session maximum level (as shown next).

As a DBA, execute the script periodically to find out the actual number of sessions on the system throughout the day. In this next listing, there is no limit on the number of users if the value is set to 0:

```
SELECT sessions_max sess_max, sessions_warning sess_warning, sessions_current sess_current, users_max FROM v$license;
```

<table>
<thead>
<tr>
<th>SESS MAX</th>
<th>SESS WARNING</th>
<th>SESS CURRENT</th>
<th>SESS HIGHWATER</th>
<th>USERS MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>100</td>
<td>44</td>
<td>10.5</td>
<td>0</td>
</tr>
</tbody>
</table>

Database Options Installed in Your Database

The script shown next describes what options are installed on your database and are available for use. If you have purchased a product that does not show up in this list, you may have incorrectly installed it. Query the V$OPTION view to check for installed products or log on to SQL*Plus to see the products that are installed (does your open source database do all this?).
```sql
select *
from v$option
order by parameter;
```

(selected rows displayed below - this returned 86 rows for my system)

### Output

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASM Proxy Instance</td>
<td>FALSE</td>
<td>0</td>
</tr>
<tr>
<td>Active Data Guard</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Adaptive Execution Plans</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Advanced Analytics</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Advanced Compression</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Basic Compression</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Cache Fusion Lock Accelerator</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Flashback Database</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Flashback Table</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Heat Map</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>In-Memory Aggregation</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>In-Memory Column Store</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Java</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Join index</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Managed Standby</td>
<td>TRUE</td>
<td>0</td>
</tr>
<tr>
<td>Online Index Build</td>
<td>TRUE</td>
<td>0</td>
</tr>
</tbody>
</table>
The previous listing shows that the database has the PARTITIONING option installed (TRUE), but it does not have Real Application Clusters (RAC) installed (FALSE). Also note that Automatic Storage Management (ASM) is FALSE because this is a test environment; however, ASM would almost always be used on most production systems.

TIP
Query the V$OPTION view to retrieve the Oracle options you have installed. The V$VERSION view gives you the versions of the installed base options.

Summary of Memory Allocated (V$SGA)
V$SGA gives the summary information for the System Global Area (SGA) memory structures of your system, as shown in the next listing. The “Database Buffers” is the number of bytes allocated to memory for data. It comes from the init.ora parameter DB_CACHE_SIZE, if set. The “Redo Buffers” comes primarily from the value of the init.ora parameter LOG_BUFFER, which is used to buffer changed records and flushed to the REDO logs whenever a COMMIT is issued.

Consider this smaller SGA output listed using the SHO SGA command:
FIGURE 12-1. The SGA listens when the In-Memory column store is used.

Consider the same query, but now a query to V$SGA (if I go to an individual PDB, I will get the exact same output—there is no “local” information):

```
COL VALUE FORMAT 999,999,999,999
COMPUTE SUM OF VALUE ON REPORT
BREAK ON REPORT
SELECT *
FROM   v$sga;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Size</td>
<td>4,429,320</td>
<td>0</td>
</tr>
<tr>
<td>Variable Size</td>
<td>281,020,920</td>
<td>0</td>
</tr>
<tr>
<td>Database Buffers</td>
<td>784,334,848</td>
<td>0</td>
</tr>
<tr>
<td>Redo Buffers</td>
<td>3,956,736</td>
<td>0</td>
</tr>
<tr>
<td>sum</td>
<td>1,073,741,824</td>
<td></td>
</tr>
</tbody>
</table>

Set the following initialization parameters to turn on the In-Memory column store (also referred to as IM or INMEMORY or In-Memory):
Setting the INMEMORY_SIZE

After setting the SGA_TARGET or INMEMORY_SIZE, you can check In-Memory (IM) segments. The V$IM_SEGMENTS view and the In-Memory column store are only available in 12.1.0.2 or later of the database. This view shows the memory allocated for all segments in the IM column store.

The following example shows how to create a one-column EMP7 table and put it into the IM:

```
CREATE TABLE emp7 (EMPNO number) INMEMORY;
Table created.
```

You can also alter it INMEMORY after it's created:

```
ALTER TABLE emp7 INMEMORY;
Table altered.
```

Check the EMP7 table in the V$IM_SEGMENTS view:

```
SELECT segment_name, bytes FROM v$im_segments WHERE segment_name='EMP7';
```

```
SEGMENT_NAME  BYTES
--------------- --------
EMP7           4194304
```

Check the EMP7 table in the V$IM_COLUMN_LEVEL view:
Please see Chapter 4 for detailed information about the In-Memory (IM) column store. The following are a few other helpful commands as you use IM.

Place the entire tablespace (puts tables/partitions/mv) into IM:

```sql
SQL> ALTER TABLESPACE tbcsp1 INMEMORY;
```

Instantly remove the EMP table from the IM column store:

```sql
SQL> ALTER TABLE emp NO INMEMORY;
```

Instantly remove D1 Partition(dept) from the IM column store:

```sql
SQL> ALTER TABLE dept MODIFY PARTITION d1 NO INMEMORY;
```

Exclude some columns from going into the IM (by default all columns go into the IM):

```sql
SQL> ALTER TABLE emp NO INMEMORY (ename, job, mgr, hiredate, deptno, sal, comm);
```

The main views to view IM information include V$IM_SEGMENTS, V$IM_USER_SEGMENTS, V$IM_COLUMN_LEVEL, USER_TABLES, and (the deep dive) V$KEY_VECTOR.

**TIP**

Query the V$IM_SEGMENTS and V$IM_COLUMN_LEVEL views to retrieve detailed information about specific objects that are stored in the In-Memory column store (only available in 12.1.0.2+).
Oracle simplified PGA memory management by introducing a PGA_AGGREGATE_TARGET parameter. In 12c, Oracle introduced the PGA_AGGREGATE_LIMIT parameter to ensure there is a cap on the PGA. Oracle also simplified SGA memory management by providing Automatic Shared Memory Management (ASMM) and by providing the SGA_TARGET parameter. Oracle offers Automatic Memory Management (AMM) that unifies both PGA memory and SGA memory in a single parameter setting, the MEMORY_TARGET parameter (see Chapter 4 for more information on all initialization parameters). As a result, Oracle provides a data dictionary table called V$MEMORY_DYNAMIC_COMPONENTS. Here is a query that shows the dynamic components using AMM parameters:

```sql
SELECT component, current_size, min_size, max_size
FROM v$memory_dynamic_components
WHERE current_size != 0;
```

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>CURRENT_SIZE</th>
<th>MIN_SIZE</th>
<th>MAX_SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>shared pool</td>
<td>184549376</td>
<td>184549376</td>
<td>184549376</td>
</tr>
<tr>
<td>large pool</td>
<td>4194304</td>
<td>4194304</td>
<td>4194304</td>
</tr>
<tr>
<td>java pool</td>
<td>12582912</td>
<td>12582912</td>
<td>12582912</td>
</tr>
<tr>
<td>SGA Target</td>
<td>536870912</td>
<td>536870912</td>
<td>536870912</td>
</tr>
<tr>
<td>DEFAULT buffer cache</td>
<td>327155712</td>
<td>327155712</td>
<td>327155712</td>
</tr>
<tr>
<td>Shared IO Pool</td>
<td>50331648</td>
<td>0</td>
<td>50331648</td>
</tr>
<tr>
<td>PGA Target</td>
<td>318767104</td>
<td>318767104</td>
<td>318767104</td>
</tr>
</tbody>
</table>

7 rows selected.

The V$MEMORY_TARGET_ADVICE view provides tuning advice for setting the MEMORY_TARGET parameter. Issue the following query to obtain advice on the effects of increasing or shrinking the MEMORY_TARGET parameter:
When MEMORY_TARGET is set, SGA_TARGET and PGA_AGGREGATE_TARGET initially have zero values (automatically set) unless you set minimum values (a maximum value for PGA can be set with PGA_AGGREGATE_LIMIT as of 12c). To use ASMM, set SGA_TARGET to a nonzero value.

Consider a larger SGA in this example and a different way to show it:

```
COLUMN value FORMAT 999,999,999,999

select *
from v$sga;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Size</td>
<td>2,188,768</td>
</tr>
<tr>
<td>Variable Size</td>
<td>4,513,073,696</td>
</tr>
<tr>
<td>Database Buffers</td>
<td>2,315,255,808</td>
</tr>
<tr>
<td>Redo Buffers</td>
<td>17,420,288</td>
</tr>
</tbody>
</table>

If SGA_TARGET is used, it dynamically resizes internally:
This output indicates a relatively large SGA (over 4.5G) with a buffer cache that includes DB_CACHE_SIZE, DB_KEEP_CACHE_SIZE, and DB_RECYCLE_CACHE_SIZE of over 2.5G. As discussed in Chapters 1 and 4, I could have just set the SGA_TARGET to something like 4.5G and set the other parameters to enforce minimum sizes only. The predominant part of the Variable Size category is the buffer cache and shared pool. (The shared pool for this SGA is 1G.) This SGA is over 4.5G of the actual physical system memory in the preceding listing. This information is also given in the AWR or Statspack Report (still available in 12cR2; see Chapter 14) and can also be displayed by issuing a SHOW SGA command as the SYS superuser.

### TIP

Access the V$SGA view to get a baseline idea of the system's physical memory allocated for data, shared pool, large pool, Java pool, and log buffering of Oracle.

---

### Detailed Memory Allocated (V$SGASTAT)

A VS view to query and retrieve more detailed information about memory allocation for the SGA is the V$SGASTAT view (most records are related to the shared pool). This view provides dynamic information about SGA and memory resources. It changes as the database is accessed. This statement describes the SGA sizes at a detailed level. The records FIXED_SGA, BUFFER_CACHE, and LOG_BUFFER are the same values for both V$SGA and V$SGASTAT. The remaining records in V$SGASTAT make up the only other V$SGA record (the Variable Size or Shared Pool record).

<table>
<thead>
<tr>
<th>Fixed Size (V$SGA)</th>
<th>= FIXED_SGA (V$SGASTAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database Buffers (V$SGA)</td>
<td>= BUFFER_CACHE (V$SGASTAT)</td>
</tr>
<tr>
<td>Redo Buffers (V$SGA)</td>
<td>= LOG_BUFFER (V$SGASTAT)</td>
</tr>
<tr>
<td>Variable Size (V$SGA)</td>
<td>= many other records (V$SGASTAT)</td>
</tr>
</tbody>
</table>

In Oracle 9.2, V$SGASTAT had only 43 total records; in 12cR2, it has 1312 records, as shown here (partial listing only; varies based on database use):
Some of this information is also given in the AWR or Statspack Report (see Chapter 14), along with the starting and ending values over the duration of the Statspack Report.

TIP
Querying V$SGASTAT provides a detailed breakdown for the Oracle SGA and details all aggregated buckets of shared pool allocation.

Detailed Memory Allocated (V$SGASTAT) for a PDB vs. Root CDB

When I go to an individual PDB and query a view, only the information for that PDB is displayed. As stated earlier, querying V$SGA is the same at the PDB level or CDB level. If I query V$SGASTAT, there are many more records at the CDB level (which includes the CDB and all PDBs) than at the PDB level:

```
alter session set container=CDB$ROOT;
Session altered.
select count(*)
from v$sgastat;
```
We can see that for the CDB, there are 1130 records and in the PDB only 47 records. One important note is that there are some CON_ID=0 records in the PDB (such as free memory that will be used by the PDB), but the used SGA items show as CON_ID=3 (or specific to this PDB).

**Finding spfile.ora/init.ora Settings in V$PARAMETER**

The script in the next listing displays the initialization parameters for your system. It also provides information on each parameter that identifies whether the current value is the default value (ISDEFAULT=TRUE). It further shows whether the parameter is modifiable with the ALTER SESSION command and with the ALTER SYSTEM command (ISSYS_MODIFIABLE=IMMEDIATE). You can modify these with the ALTER SESSION and ALTER SYSTEM commands instead of modifying the init.ora file and shutting down and restarting the instance. The example in this listing displays some of the initialization parameters that you can modify with one of the ALTER commands. (IMMEDIATE means it can be modified and it will take effect immediately.) Note that you can use an ALTER command, but for some parameters, such as O7_DICTIONARY_ACCESSIBILITY, you can only use an ALTER SYSTEM … SCOPE=SPFILE command to modify it, and then you have to bounce the database for it to take effect. The query here shows the parameter values in effect for the instance (not what is necessarily in the parameter file):

```sql
select name, value, isdefault, isses_modifiable, issys_modifiable
from v$parameter
where con_id = 0
order by name;
```

Query of V$PARAMETER:
Version-dependent columns are also available.

TIP
Query V$PARAMETER to get the current values for the initialization parameters. V$PARAMETER also shows which initialization parameters have been changed from their original defaults: ISDEFAULT=FALSE. It also shows which parameters may be changed only for a given session if ISSES_MODIFIABLE=TRUE. Lastly, it shows which parameters may be changed without shutting down and restarting the database for ISSYS_MODIFIABLE=IMMEDIATE as well as ISSYS_MODIFIABLE=DEFERRED for a parameter that is enforced for all new logins but not currently logged-on sessions. If the parameter ISSYS_MODIFIABLE=FALSE, then the instance must be shut down and restarted for the parameter to take effect. See Chapter 4 for more information on the initialization parameters.

Modifying an Initialization Parameter at PDB Level
You can gain some insight into which initialization parameters are modifiable at the PDB level (or just the CDB level) by using the following query (pluggable databases are covered in detail in Chapter 3):

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>ISDEFAULT</th>
<th>ISSSES</th>
<th>ISSYS_MODIFIABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>dictionary accessibility</td>
<td>FALSE</td>
<td>TRUE</td>
<td>FALSE</td>
<td>FALSE</td>
</tr>
<tr>
<td>active instance count</td>
<td>TRUE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
</tr>
<tr>
<td>sq_lq_processes</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>archive lag target</td>
<td>0</td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_diskgroups</td>
<td></td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_diskstring</td>
<td></td>
<td>TRUE</td>
<td>FALSE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>asm_power_limit</td>
<td>1</td>
<td>TRUE</td>
<td>TRUE</td>
<td>IMMEDIATE</td>
</tr>
<tr>
<td>...partial output listing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The following key initialization parameters are reported as modifiable: cursor_sharing, open_cursors, result_cache_mode, sort_area_size, db_cache_size, shared_pool_size, pga_aggregate_target, inmemory_size.

The key initialization parameter that is reported as *not* modifiable is memory_target.

### Determining If Data Is in Memory (V$SYSSTAT and V$SYSMETRIC)

Query V$SYSSTAT (as shown in the next listing) to see how often your data is being read from memory. V$SYSSTAT gives the hit ratio for the setting of the database block buffers. This information can help you identify when your system needs more data buffers (DB_CACHE_SIZE) or when a system is not tuned very well. (Both lead to low hit ratios.) Generally, you should ensure the read hit ratio is greater than 95 percent (95 percent of data is accessed from memory). Increasing the hit ratio on your system from 98 percent to 99 percent could mean performance that is 100+ percent faster (depending on what is causing the disk reads).
In 12c, you can also go directly to AWR information in V$SYSMETRIC. The V$SYSMETRIC view displays the system metric values captured for the most current time interval. It does this for a 60-second interval (INTSIZE_CSEC column = 6017) and another for a 15-second duration (INTSIZE_CSEC column = 1504); both are displayed in hundredths of a second. The following query displays the two rows:

```
SELECT metric_name, TO_CHAR(begin_time, 'DD-MON-YY HH24MISS') BEGIN_TIME,
       TO_CHAR(end_time, 'DD-MON-YY HH24MISS') END_TIME, value
FROM v$sysmetric
WHERE metric_name like '%Buffer Cache Hit Ratio%';
```

<table>
<thead>
<tr>
<th>METRIC_NAME</th>
<th>BEGIN_TIME</th>
<th>END_TIME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer Cache Hit Ratio</td>
<td>19 JUN 29 101614</td>
<td>19 JUN 29 101714</td>
<td>73.85</td>
</tr>
<tr>
<td>Buffer Cache Hit Ratio</td>
<td>19 JUN 29 101729</td>
<td>19 JUN 29 101844</td>
<td>100.00</td>
</tr>
</tbody>
</table>

In addition to the V$SYSMETRIC view, V$SYSMETRIC_SUMMARY displays a summary of system metric values for the long-duration system metrics (the 60-second ones) along with minimum, maximum, and average values over a 60-second duration. V$SYSMETRIC_HISTORY displays the last 90 minutes of 60-second duration metric values.

The hit ratio in this listing is very good, but that does not mean the system is perfectly tuned. A high hit ratio could mean that overly indexed queries are being used. If this hit ratio is well below 95 percent, you may need to increase the instance parameter, DB_CACHE_SIZE, or tune some of the queries that are causing disk reads (if possible and efficient to do so). One exception to this (many others are covered in Chapter 4) is when the distribution of data within the individual blocks is greatly skewed. Despite this possibility, hit ratios less than 90 percent almost always involve systems that are poorly tuned—other than those that are built in a Petri dish by someone who has built an extremely rare balance of data within each block (see Chapter 4 for additional information on data hit ratios).

You can also use the new V$DB_CACHE_ADVICE view to help you resize the data cache if you feel it is necessary. The next listing creates a list of values that shows you the effects of larger and smaller data caches and the resulting effect on physical reads (as buffers are increased, the value in the “Estd Phys Reads” column goes down):

```
SELECT 1-(SUM(decode(name, 'physical reads', value, 0))/
           (SUM(decode(name, 'db block gets', value, 0)) +
           SUM(decode(name, 'consistent gets', value, 0))))
FROM v$sysstat;
```

Read Hit Ratio
-------------
.996538641

In 12c, you can also go directly to AWR information in V$SYSMETRIC. The V$SYSMETRIC view displays the system metric values captured for the most current time interval. It does this for a 60-second interval (INTSIZE_CSEC column = 6017) and another for a 15-second duration (INTSIZE_CSEC column = 1504); both are displayed in hundredths of a second. The following query displays the two rows:
Determining Memory for the Data Dictionary (V$ROWCACHE)

You use the V$ROWCACHE view (as in this next listing) to find how often the data dictionary calls are effectively hitting the memory cache allocated by the SHARED_POOL_SIZE instance parameter. Chapter 4 discusses this in detail. The only goal here is to review the V$ view access. If the dictionary hit ratio is not adequate, the overall system performance suffers greatly.

```
select sum(gets), sum(getmisses), (1 - (sum(getmisses) / (sum(gets) + sum(getmisses)))) * 100 HitRate
from v$rowcache;
```

<table>
<thead>
<tr>
<th>SUM(GETS)</th>
<th>SUM(GETMISSES)</th>
<th>HITRATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>110673</td>
<td>670</td>
<td>99.9982558</td>
</tr>
</tbody>
</table>

You can also go directly to AWR information in V$SYSMETRIC:
The recommended hit ratio is 95 percent or greater (see Chapter 4 for some qualifications to this). If the hit ratio falls below this percentage, it indicates that the SHARED_POOL_SIZE parameter may need to be increased. But remember, you saw in the V$SGASTAT view that the shared pool is made up of many pieces, of which this is only one.

NOTE
Environments that make heavy use of public synonyms may struggle to get their dictionary cache hit rate higher than 75 percent even if the shared pool is huge. This is because Oracle must often check for the existence of nonexistent objects.

Determining Memory for the Shared SQL and PL/SQL (V$LIBRARYCACHE)

Accessing the V$LIBRARYCACHE view shows how well the actual statements (SQL and PL/SQL) are accessing memory. If the SHARED_POOL_SIZE parameter is too small, enough room may not be available to store all of the statements into memory. If the shared pool becomes extremely fragmented, large PL/SQL routines may not fit into the shared pool. If statements are not reused effectively, an enlarged shared pool may cause more harm than good (see Chapter 4 for additional details).

There is an execution ratio (pinhitratio) and a reload hit ratio. The recommended hit ratio for pin hits is 95+ percent, and the reload hit ratio should be 99+ percent (less than 1 percent reloads). Reloads occur when a statement has been parsed previously, but the shared pool is usually not large enough to keep in memory as other statements are parsed. The body of the statement is pushed out of memory (the head is still there); when the statement is again needed, a reload is recorded to reload the body. A reload could also occur if the execution plan for the statement changes. If either of the hit ratios falls below these percentages, it indicates that you should investigate the shared pool in greater detail. The following listing shows how to query for all of the information discussed (specifically, query V$LIBRARYCACHE to see if SQL is being reused):

```sql
select metric_name, value
from v$sysmetric
where metric_name = 'Row Cache Hit Ratio';
```

<table>
<thead>
<tr>
<th>METRIC_NAME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row Cache Hit Ratio</td>
<td>99.99</td>
</tr>
</tbody>
</table>

The recommended hit ratio is 95 percent or greater (see Chapter 4 for some qualifications to this). If the hit ratio falls below this percentage, it indicates that the SHARED_POOL_SIZE parameter may need to be increased. But remember, you saw in the V$SGASTAT view that the shared pool is made up of many pieces, of which this is only one.

NOTE
Environments that make heavy use of public synonyms may struggle to get their dictionary cache hit rate higher than 75 percent even if the shared pool is huge. This is because Oracle must often check for the existence of nonexistent objects.
The V$SYSMETRIC view also displays the Library Cache system metric values captured for the most current time interval for 60-second and 15-second durations. The following query displays two rows, one for the last 60-second intervals and one for the last 15-second intervals:

```sql
select metric_name, to_char(begin_time, 'DD-MON-YY HH24MISS') BEGIN_TIME,
       to_char(end_time, 'DD-MON-YY HH24MISS') END_TIME, value
from v$sysmetric
where metric_name like 'Library Cache Hit Ratio';
```

<table>
<thead>
<tr>
<th>METRIC_NAME</th>
<th>BEGIN_TIME</th>
<th>END_TIME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Cache Hit Ratio</td>
<td>19-JUN-16</td>
<td>140351</td>
<td>99.87</td>
</tr>
<tr>
<td>Library Cache Hit Ratio</td>
<td>19-JUN-16</td>
<td>140406</td>
<td>99.82</td>
</tr>
</tbody>
</table>

Query V$SQL_BIND_CAPTURE to see if binds per SQL statement are greater than 20 (issue):

```sql
select sql_id, count(*) bind_count
from v$sql_bind_capture
where child_number = 0
group by sql_id
having count(*) > 20
order by count(*)
;
```

<table>
<thead>
<tr>
<th>SQL_ID</th>
<th>BIND_COUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>9ggtwh66xg6nz</td>
<td>21</td>
</tr>
</tbody>
</table>

Find the problem SQL to fix:
Querying V$CONTAINERS and V$PDBS for Container Information

Pluggable databases (PDBs) are covered in detail in Chapter 3. This chapter will serve to cover the V$ views aspect of CDBs and PDBs only. In 12c you can have a container database (CDB) containing multiple PDBs. Pluggable databases are also known as multitenant databases because each “tenant” can reside in their own PDB. “Pluggable” databases can be unplugged from one container and plugged into another container easily, therefore making a database portable between environments and allowing upgrade of a database by unplugging from one environment at one version and plugging into a new environment at a higher version. You can also unplug from on-premises and plug into the cloud (or vice versa). This feature also allows a single pluggable database to be independently recovered (you can flashback a PDB in 12cR2).

As mentioned in Chapter 3, in 12cR2, the number of containers went from 254 in 12cR1 to 1000+. Oracle supports 252 PDBs in 12cR1 and 4096 PDBs in 12cR2. Here is what is in each container:
Querying V$CONTAINERS When Using Pluggable Databases

You can query the container information by accessing V$CONTAINERS. As an example, first I’ll log into the Root CDB which has two different tenants (PDB1 and PDB2), and then log into PDB1 and query V$CONTAINERS:

```
$ sqlplus / as sysdba -- (you are in CON_ID=1 as SYS)
```

Or

```
alter session set container=cdb$root; -- (you are in CON_ID=1 as SYS)
Session altered.
```

Next, I’ll query V$CONTAINERS (I’m in the Root CDB which shows four containers, 1–4):

```
select con_id, name
from v$containers;
```

<table>
<thead>
<tr>
<th>CON_ID</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CDB$ROOT</td>
</tr>
<tr>
<td>2</td>
<td>PDB$SEED</td>
</tr>
<tr>
<td>3</td>
<td>PDB1</td>
</tr>
<tr>
<td>4</td>
<td>PDB2</td>
</tr>
</tbody>
</table>

Finally, I’ll go into PDB1 and query V$CONTAINERS (now only one container appears, CON_ID=3):

```
```
In the next section, we’ll look into the corresponding PDB names (accessing V$PDBS) for each of the containers.

% Querying V$PDBS for Pluggable Database Information

You can query the pluggable database information by accessing V$PDBS. Again, first I’ll log into the Root CDB (showing two different methods of doing so) and then connect to PDB1:

```
sqplus / as sysdba --(you are in CON_ID=1 as SYS)
```

Or

```
alter session set container=cdb$sroot; --(you are in CON_ID=1 as SYS)
```

Session altered.

Next I query V$PDBS (which displays three PDBs, PDB$SEED, PDB1, and PDB_SS):

```
select name, open_mode, open_time
from v$pdbs;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>OPEN_MODE</th>
<th>OPEN_TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDB$SEED</td>
<td>READ ONLY</td>
<td>23-FEB-13 05.29.19.861 AM</td>
</tr>
<tr>
<td>PDB1</td>
<td>READ WRITE</td>
<td>23-FEB-13 05.29.25.846 AM</td>
</tr>
<tr>
<td>PDB_SS</td>
<td>READ WRITE</td>
<td>23-FEB-13 05.29.37.587 AM</td>
</tr>
</tbody>
</table>

3 rows selected.

Here is a different CDB (with three PDBs, PDB$SEED, PDB1, and PDB2):
Finally, I query V$PDBS while in PDB1 (now only one PDB appears, PDB1):

<table>
<thead>
<tr>
<th>CON_ID</th>
<th>NAME</th>
<th>OPEN_TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>PDB$SEED</td>
<td>15-JUL-16 03.44.23.369 PM</td>
</tr>
<tr>
<td>3</td>
<td>PDB1</td>
<td>15-JUL-16 03.44.25.710 PM</td>
</tr>
<tr>
<td>4</td>
<td>PDB2</td>
<td>15-JUL-16 03.44.27.510 PM</td>
</tr>
</tbody>
</table>

3 rows selected.

While logged into the Root CDB (CON_ID=1), all PDBs are listed in V$PDBs. While logged into an individual PDB (CON_ID=3 or PDB1 in the previous example), only information about that PDB is shown. There is also a V$PDB_INCARNATION view that is used to access information about a PDB incarnation (when a PDB is open with the RESETLOGS option).

TIP
Query V$CONTAINERS and V$PDBS to get detailed information on both containers and pluggable databases. When connected to the PDB, you only see information related to that specific PDB.

Using the Result Cache

Up to version 10g, the SHARED_POOL_SIZE consisted of the Library Cache and Dictionary Cache. You can obtain hit ratios for these caches by querying V$ROWCACHE and V$LIBRARYCACHE data dictionary views. Oracle 12c (and also 11g) provides an additional area of memory called Result Cache Memory (set with the RESULT_CACHE_MAX_SIZE parameter). This memory (also part of the shared pool) stores the results of SQL and PL/SQL functions in memory. The RESULT_CACHE_MODE initialization parameter controls the behavior of this memory. When RESULT_CACHE_MODE is set to MANUAL, queries need to employ a RESULT_CACHE hint to
use this memory. When RESULT_CACHE_MODE is set to FORCE, all queries use this memory, if possible. The following shows an example of a query using the RESULT_CACHE hint, resulting in the use of the Result Cache Memory:

```sql
select  /*+ result_cache */ deptno, avg(sal)
from    emp
group by deptno;
```

The following query displays the objects that are cached along with other attributes:

```sql
column cache_id format A25

select  type, status, name, cache_id, cache_key
from    view_result_cache_objects;
```

<table>
<thead>
<tr>
<th>Type</th>
<th>Status</th>
<th>Cache Name</th>
<th>CACHE_ID</th>
<th>CACHE_KEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependency</td>
<td>Published</td>
<td>SCOTT.EMP</td>
<td>SCOTT.EMP</td>
<td>SCOTT.EMP</td>
</tr>
<tr>
<td>Result</td>
<td>Published</td>
<td>select /*+ result cache */ deptno, avg(sal) from emp group by deptno</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 Rows selected.

The following query displays all the memory blocks and corresponding statistics:
The following query monitors Result Cache Memory usage. For a system that makes good use of Result Cache Memory, you should see a low value for Create Count Failures and a high value for Find Count.

col chunk for 9999999 HEADING 'Chunk#'
col offset for 9999999 HEADING 'Offset#'
col free for A5 HEADING 'Free?'
col position for 9999999 HEADING 'Position'

select chunk, offset, free, position
from v$result_cache_memory;

<table>
<thead>
<tr>
<th>Chunk#</th>
<th>Offset#</th>
<th>Free?</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>NO</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>NO</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
<td>NO</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>7</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
<td>YES</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>9</td>
<td>YES</td>
<td>0</td>
</tr>
</tbody>
</table>

...
Query V$LIBRARYCACHE to see how often your SQL and PL/SQL are being read from memory. The pinhitratio should generally be 95 percent or greater, and the number of reloads should not be greater than 1 percent. Query V$SQL_BIND_CAPTURE to see if binds per SQL are too high and CURSOR_SHARING is needed. Use the Result Cache to force results from a query to remain in the Result Cache Memory portion of the shared pool.

Identifying PL/SQL Objects That Need to Be Kept (Pinned)

Fragmentation resulting in several small pieces being available in the shared pool and not enough large contiguous pieces is a common occurrence in the shared pool. The key to eliminating shared pool errors (see Chapters 4 and 13 for more information) is to understand which objects can cause problems. Once you know the potential problem PL/SQL objects, you can then pin this code when the database is started (and the shared pool is completely contiguous). You can query the V$DB_OBJECT_CACHE view to determine PL/SQL that is both large and currently not marked kept.

This query shows only the current statements in the cache. The example in this listing searches for those objects requiring greater than 100K.

```
select name, sharable_mem
from v$db_object_cache
where sharable_mem > 100000
and type in ('PACKAGE', 'PACKAGE BODY',
             'FUNCTION', 'PROCEDURE')
and kept = 'NO';
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>SHARABLE_MEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD</td>
<td>653872</td>
</tr>
<tr>
<td>DBMS_SQLTUNE</td>
<td>507936</td>
</tr>
<tr>
<td>DBMS_SQLTUNE_INTERNAL</td>
<td>540112</td>
</tr>
<tr>
<td>DBMS_RCVMAN</td>
<td>678488</td>
</tr>
<tr>
<td>DBMS_SCHEDULER</td>
<td>238176</td>
</tr>
<tr>
<td>DBMS_BACKUP_RESTORE</td>
<td>256480</td>
</tr>
<tr>
<td>DBMS_STATS</td>
<td>1222768</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>
TIP
Query the `V$DB_OBJECT_CACHE` view to find objects that are not pinned and are also potentially large enough to cause fragmentation problems in the shared pool.

Finding Problem Queries by Monitoring `V$SESSION_LONGOPS`

If you want to track long-running SQL queries, Oracle provides a data dictionary table called `V$SESSION_LONGOPS`. Run the following query to get the SID, serial number, and message for long-running queries:

```sql
select sid, serial#, message
from v$session_longops;
```

<table>
<thead>
<tr>
<th>SID</th>
<th>SERIAL#</th>
<th>MESSAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>292</td>
<td>3211</td>
<td>Table Scan: SYSTEM.STATIS$USER_LOG: 2477 7 out of 24777 Blocks done</td>
</tr>
<tr>
<td>375</td>
<td>64234</td>
<td>Table Scan: SYSTEM.STATIS$USER_LOG: 2477 7 out of 24777 Blocks done</td>
</tr>
<tr>
<td>68</td>
<td>29783</td>
<td>Table Scan: SYSTEM.STATIS$USER_LOG: 2477 7 out of 24777 Blocks done</td>
</tr>
</tbody>
</table>

You can monitor the performance of SQL statements while they are being executed. Oracle provides two data dictionary views to monitor the performance of long-running statements: `V$SQL_MONITOR` and `V$SQL_PLAN_MONITOR` (additional columns you can add in 12c are IS_ADAPTIVE_PLAN and IS_FINAL_PLAN as well as CON_ID when accessing this view).
```sql
select key, sql_id, sql_exec_id,
to_char(max(sql_exec_start) , 'DD/MM/YYYY HH24:MI:SS')
sql_exec_start,
sql_child_address child_address
from v$sql_monitor
group by key, sql_id, sql_exec_id, sql_child_address
order by sql_exec_start;
```

<table>
<thead>
<tr>
<th>KEY</th>
<th>SQL_ID</th>
<th>SQL_EXEC_ID</th>
<th>SQL_EXEC_START</th>
<th>CHILD_ADD</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.6078E+11</td>
<td>ahevccymgw92jw</td>
<td>16777217</td>
<td>18/06/2016 12:59:08</td>
<td>28172AC0</td>
</tr>
<tr>
<td>3.3930E+11</td>
<td>ahevccymgw92jw</td>
<td>16777220</td>
<td>18/06/2016 12:59:11</td>
<td>28172AC0</td>
</tr>
<tr>
<td>1.6321E+11</td>
<td>ahevccymgw92jw</td>
<td>16777221</td>
<td>18/06/2016 12:59:12</td>
<td>28172AC0</td>
</tr>
<tr>
<td>2.7917E+11</td>
<td>ahevccymgw92jw</td>
<td>16777224</td>
<td>18/06/2016 12:59:14</td>
<td>28172AC0</td>
</tr>
<tr>
<td>2.3193E+11</td>
<td>ahevccymgw92jw</td>
<td>16777223</td>
<td>18/06/2016 12:59:14</td>
<td>28172AC0</td>
</tr>
</tbody>
</table>
```

col id format 999

col operation format a25

col object format a6

set colsep '|
set lines 100
The STAT column displays EXEC when the query is still running. This status shows which step is being executed at a point in time. In the V$SESSION_LONGOPS view, you can query the TIME_REMAINING and SOFAR columns, but using these to estimate how long something will take is tough. Oracle considers operations to be linearly running, so later operations may take longer than earlier ones (and vice versa). Lastly, not every long-running query shows up in this view. The following criteria must be met (note that it is not the scans that must meet the minimum block threshold, but the objects being scanned):

- Must be running over 6 seconds of actual time AND
- Be a full table scan of a table that occupies over 10,000 blocks OR
- Be a full index scan of an index that occupies over 1000 blocks OR
- Be a hash join (as few as 20 blocks reported to show up)

This changes from version to version; do your own testing to make sure.

```sql
select p.id, 
    rpad('', 5, ' ') || p.operation operation, 
    p.object_name object, 
    p.cardinality card, 
    p.cost cost, 
    substr(m.status, 1, 4) status, 
    m.output_rows
from v$sql_plan p, v$sql_plan_monitor m
where p.sql_id = m.sql_id
and p.child_address = m.sql_child_address
and p.plan_hash_value = m.sql_plan_hash_value
and p.id = m.plan_line_id
and m.sql_id = 'ahvcymgw32jw'
and m.sql_exec_id = '6777217'
and m.sql_exec_start_to_date('20/11/2018 12:59:08', 'DD/MM/YYYY HH24:MI:SS')
order by p.id;
```

<table>
<thead>
<tr>
<th>ID</th>
<th>OPERATION</th>
<th>OBJECT</th>
<th>CARD</th>
<th>COST</th>
<th>STAT</th>
<th>OUTPUT_ROWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td></td>
<td>4941855</td>
<td>DONE</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>RESULT CACHE</td>
<td>2k8xzg</td>
<td></td>
<td></td>
<td>DONE</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>unm7z5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0c8ssc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>mhy1t6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ph</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SORT</td>
<td></td>
<td>1</td>
<td></td>
<td>DONE</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>NESTED LOOPS</td>
<td>289220332</td>
<td>4941855</td>
<td>DONE</td>
<td>616317649</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>TABLE ACCESS</td>
<td>EMP</td>
<td>74130</td>
<td>65</td>
<td>DONE</td>
<td>150000</td>
</tr>
<tr>
<td>5</td>
<td>TABLE ACCESS</td>
<td>EMP</td>
<td>3902</td>
<td>67</td>
<td>DONE</td>
<td>616317649</td>
</tr>
</tbody>
</table>

6 rows selected.
Finding Problem Queries by Querying V$SQLAREA

V$SQLAREA provides a means of identifying the potential problem SQL statements or SQL statements that need to be optimized to improve overall database optimization by reducing disk access. The DISK_READS column displays the volume of disk reads being performed on the system. This, combined with the EXECUTIONS column (DISK_READS/EXECUTIONS), returns the SQL statements that have the most disk hits per statement execution. The DISK_READS value is set to 100000, but it could be set much higher or lower on production systems (depending on the database) to reveal only the top problem statements on your system. Once identified, review and optimize the top statements to improve overall performance. Typically, a statement with very large disk reads is not using an index or the execution path is forcing the statement to not use the proper indexes.

One potentially misleading part of the query in the following listing is the RDS_EXEC_RATIO column. RDS_EXEC_RATIO contains the number of disk reads divided by the executions. In reality, a statement may be read once using 100 disk reads and then forced out of memory (if memory is insufficient). If it is read again, then it will read 100 disk reads again and the RDS_EXEC_RATIO will be 100 (or 100 + 100 reads divided by 2 executions). But if the statement happens to be in memory the second time (memory is sufficient), the disk reads will be 0 (the second time) and the RDS_EXEC_RATIO will be only 50 (or 100 + 0 divided by 2 executions). Any statement that makes the top of this list is a problem and needs to be tuned—period!

NOTE
The following code was formatted for ease of reading.

```
select b.username username, a.disk_reads reads, a.executions exec, a.disk_reads /decode (a.executions, 0, 1, a.executions) rds_exec_ratio, a.sql_text Statement
from v$sqlarea a, dba_users b
where aarsing_user_id = b.user_id
and a.disk_reads >= 100000
order by a.disk_reads desc;
```

<table>
<thead>
<tr>
<th>USERNAME</th>
<th>READS</th>
<th>EXEC</th>
<th>RDS_EXEC_RATIO</th>
<th>STATEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADHOC1</td>
<td>7281934</td>
<td>1</td>
<td>7281934</td>
<td></td>
</tr>
<tr>
<td>ADHOC5</td>
<td>4230044</td>
<td>4</td>
<td>1057511</td>
<td></td>
</tr>
<tr>
<td>ADHOC1</td>
<td>301715</td>
<td>2</td>
<td>493853</td>
<td></td>
</tr>
</tbody>
</table>

The DISK_READS column in the preceding statement can be replaced with the BUFFER_GETS
column to provide information on SQL statements that may not possess the large disk hits (although they usually do) but possess a large number of memory hits (higher than normally desired). These statements are using a large amount of memory that is allocated for the data (DB_CACHE_SIZE). The problem is not that the statement is being executed in memory (which is good), but that the statement is hogging a lot of the memory. Many times, this problem is attributable to a SQL statement using an index when it should be doing a full table scan or a join. These types of SQL statements can also involve a join operation that is forcing the path to use a different index than desired, or using multiple indexes and forcing index merging or volumes of data merging. Remember, the bulk of system performance problems are attributable to poorly written SQL and PL/SQL statements.

TIP
Query the V$SQLAREA to find problem queries (and users).

Finding Out What Users Are Doing and Which Resources They Are Using

Joining V$SESSION and V$SQLTEXT displays the SQL statement that is currently being executed by each session, as shown here. This query is extremely useful when a DBA is trying to determine what is happening in the system at a given point in time.

```
select a.sid, a.username, s.sql_text
from v$session a, v$sqltext s
where a.sql_address = s.address
and a.sql_hash_value = s.hash_value
order by a.username, a.sid, s.piece;
```

<table>
<thead>
<tr>
<th>SID</th>
<th>USERNAME</th>
<th>SQL_TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>FLSQL USER</td>
<td>update s.employee set salary = 10000</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>select a.sid, a.username, s.sql_text</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>from v$session a, v$sqltext</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>where a.sql_address = s.address</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>and a.sql_hash_value = s.hash_value</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>order by a.username, a.sid, s.piece</td>
</tr>
</tbody>
</table>

...partial output listing

The SQL_TEXT column displays the entire SQL statement, but the statement is stored in the V$SQLTEXT view as a VARCHAR2(64) data type and, therefore, spans multiple records. The PIECE column is used to order the statement. To view the resources being used by each of the users, simply use the query in the next listing. The goal of this statement is to highlight the physical disk and
memory hits for each session. Recognizing users who are performing a large number of physical disk or memory reads is very easy.

```
select a.username, b.block_gets, b.consistent_gets, 
    b.physical_reads, b.block_changes, b.consistent_changes
from v$session a, v$sesg_io b
where a.sid = b.sid;
```

TIP

Query V$SESSION, V$SQLTEXT, and V$SESS_IO to find the problem users and what they are executing at a given point in time.

Finding Out Which Objects a User Is Accessing

Querying V$ACCESS can point you to potential problem objects (potentially missing indexes) once you have found the problem user or query on your system. It can also be helpful when you want to modify a particular object and need to know who is using it at a given point in time, as shown here:
This script displays all objects being accessed, including synonyms, views, and stored source code.

```
select a.sid, a.username, b.owner, b.object, b.type
from  v$session a, v$access b
where a.sid = b.sid;
```

<table>
<thead>
<tr>
<th>STD</th>
<th>USERNAME</th>
<th>OWNER</th>
<th>OBJECT</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>SCOTT</td>
<td>SYS</td>
<td>DBMS_APPLICATION_INFO</td>
<td>PACKAGE</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>SYS</td>
<td>DBMS_APPLICATION_INFO</td>
<td>PACKAGE</td>
</tr>
<tr>
<td>9</td>
<td>SYS</td>
<td>SYS</td>
<td>XSBH</td>
<td>TABLE</td>
</tr>
<tr>
<td>10</td>
<td>SYSTEM</td>
<td>PUBLIC</td>
<td>V$ACCESS</td>
<td>SYNONYM</td>
</tr>
<tr>
<td>10</td>
<td>SYSTEM</td>
<td>PUBLIC</td>
<td>V$SESSION</td>
<td>SYNONYM</td>
</tr>
<tr>
<td>10</td>
<td>SYSTEM</td>
<td>SYS</td>
<td>DBMS_APPLICATION_INFO</td>
<td>PACKAGE</td>
</tr>
<tr>
<td>10</td>
<td>SYSTEM</td>
<td>SYS</td>
<td>V$ACCESS</td>
<td>VIEW</td>
</tr>
<tr>
<td>10</td>
<td>SYSTEM</td>
<td>SYS</td>
<td>V$SESSION</td>
<td>VIEW</td>
</tr>
<tr>
<td>10</td>
<td>SYSTEM</td>
<td>SYS</td>
<td>V$ACCESS</td>
<td>VIEW</td>
</tr>
</tbody>
</table>

This script displays all objects being accessed, including synonyms, views, and stored source code.

**TIP**

Query V$ACCESS to find all objects that are being accessed by a user at a given time. This can help to pinpoint problem objects, while also being helpful when modifying a particular object (find out who is accessing it). However, this operation would be very expensive on a system with a large shared pool and hundreds of users.

---

Getting Detailed User Information

A method for analyzing user statistics is extremely valuable when testing a new or updated application module to determine overhead. This method also provides a window to a user who is having performance problems because it provides statistics on a variety of areas for each user. In addition, it can serve as a guideline for setting profiles to limit a particular user. The script in this next listing limits the statistics only to areas that have a value (b.value != 0).
Using Indexes

The V$OBJECT_USAGE view indicates whether the index is used but not how often it is used. You need to turn monitoring ON and OFF individually for indexes that you want to monitor. You initiate monitoring with the ALTER INDEX command, and index use is then tracked by querying the V$OBJECT_USAGE view. Here is a description of the V$OBJECT_USAGE view:

```
SQL> desc v$object_usage
```

<table>
<thead>
<tr>
<th>Name</th>
<th>Null?</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>INDEX_NAME</td>
<td>NOT NULL</td>
<td>VARCHAR2(30)</td>
</tr>
<tr>
<td>TABLE_NAME</td>
<td>NOT NULL</td>
<td>VARCHAR2(30)</td>
</tr>
<tr>
<td>MONITORING</td>
<td>NOT NULL</td>
<td>VARCHAR2(30)</td>
</tr>
<tr>
<td>USERID</td>
<td>NOT NULL</td>
<td>VARCHAR2(3)</td>
</tr>
<tr>
<td>START_MONITORING</td>
<td></td>
<td>VARCHAR2(19)</td>
</tr>
<tr>
<td>END_MONITORING</td>
<td></td>
<td>VARCHAR2(19)</td>
</tr>
</tbody>
</table>

Before any index is monitored, the view has no records:
You start monitoring on four indexes (connect to user schema-owning indexes):

```
alter index HRDT_INDEX1 monitoring usage;
alter index HRDT_INDEX2 monitoring usage;
alter index HRDT_INDEX3 monitoring usage;
alter index HRDT_INDEX4 monitoring usage;
```

The view now shows the four indexes with a start time but no use yet:

```
select index_name, table_name, monitoring, used,       
     start_monitoring, end_monitoring               
from v$object_usage;
```

```
INDEX_NAME | TABLE_NAME | MON | USE  | START_MONITORING     | END_MONITORING   
------------|------------|-----|------|----------------------|----------------- 
HRDT_INDEX1 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:34  |                
HRDT_INDEX2 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:38  |                
HRDT_INDEX3 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:46  |                
HRDT_INDEX4 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:52  |                
```

If you query using HRDT_INDEX1, the view now shows that this index has been used:

```
select index_name, table_name, monitoring, used,       
     start_monitoring, end_monitoring               
from v$object_usage;
```

```
INDEX_NAME | TABLE_NAME | MON | USE  | START_MONITORING     | END_MONITORING   
------------|------------|-----|------|----------------------|----------------- 
HRDT_INDEX1 | HRS_DETAIL | YES | YES  | 10/13/2016 03:11:34  |                
HRDT_INDEX2 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:38  |                
HRDT_INDEX3 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:46  |                
HRDT_INDEX4 | HRS_DETAIL | YES | NO   | 10/13/2016 03:11:52  |                
```

You end the monitoring on HRDT_INDEX4, and the view now shows an end monitoring time:
TIP
Use the `V$OBJECT_USAGE` view to find out if indexes are being used. Perhaps some indexes are not needed.

Identifying Locking Issues

Identifying locking issues is instrumental in locating the user who is waiting for someone or something else. You can use this strategy to identify users who are currently being locked in the system and to determine whether an Oracle-related process is truly locked or just running slowly. You can also identify the current statement that the locked user is currently executing. The next listing provides an example of identifying locking issues.

NOTE
These statements were not tuned in the early version of the book. (Now that’s embarrassing!)

You also need to identify the user in the system who is causing the problem of locking the previous user, as shown in this listing. (Usually this is the user/developer who presses ctrl-alt-del as you
JOHNSON will make everyone happy by forgetting a crucial WHERE clause. Unfortunately, JOHNSON has locked the authorized user of this table.

You can also look at locking in more detail to see exactly what’s running and blocking. In Chapter 9, I discuss block-level tuning; there I describe some of these columns and also how to perform queries to V$TRANSACTION (which shows all DML [UPDATE/INSERT/DELETE] transactions currently running). In the following listing, you can see four transactions all running at the same time to the same block of information. There is no blocking because the initrans is set to handle (at least set to 4 ITL slots—max of 24 slots) all four changes within the same block at the same time. If there was a problem, the LMODE would have been 0 and the REQUEST would have been 6 (TX6), as in the third query that follows.

Four users are updating different rows in the same block:

```sql
select /*+ ordered */ a.serial#, a.sid, a.username, b.id1, c.sql_text
from v$lock b, v$session a, v$sqltext c
where b.id1 in
  (select /*+ ordered */ distinct e.id1
     from v$lock c, v$session d
     where d.lockwait = e.kaddr)
and a.sid = b.sid
and c.hash value = a.sql hash value
and b.request = 0;
```

<table>
<thead>
<tr>
<th>SERIAL#</th>
<th>SID</th>
<th>USERNAME</th>
<th>ID1</th>
<th>SQL TEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>11</td>
<td>JOHNSON</td>
<td>393242</td>
<td>update authuser.emo set salary=90000</td>
</tr>
</tbody>
</table>
Here three users are trying to update the exact same row:

<table>
<thead>
<tr>
<th>USERNAME</th>
<th>SID</th>
<th>RBS</th>
<th>SLOT</th>
<th>SEQ</th>
<th>LMODE</th>
<th>REQUEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCOTT</td>
<td>146</td>
<td>6</td>
<td>32</td>
<td>85</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>SCOTT</td>
<td>152</td>
<td>4</td>
<td>39</td>
<td>21557</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>SCOTT</td>
<td>151</td>
<td>5</td>
<td>34</td>
<td>1510</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>SCOTT</td>
<td>161</td>
<td>7</td>
<td>24</td>
<td>44</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XID</th>
<th>XIDUSN</th>
<th>XIDSLOT</th>
<th>XIDSQN</th>
<th>STATUS</th>
<th>START_SCN</th>
</tr>
</thead>
<tbody>
<tr>
<td>060002000550000000</td>
<td>6</td>
<td>32</td>
<td>85</td>
<td>ACTIVE</td>
<td>16573480</td>
</tr>
<tr>
<td>040027000355400000</td>
<td>4</td>
<td>39</td>
<td>21557</td>
<td>ACTIVE</td>
<td>16573506</td>
</tr>
<tr>
<td>050022000600000000</td>
<td>5</td>
<td>34</td>
<td>1510</td>
<td>ACTIVE</td>
<td>16573415</td>
</tr>
<tr>
<td>070018000200000000</td>
<td>7</td>
<td>24</td>
<td>44</td>
<td>ACTIVE</td>
<td>16574420</td>
</tr>
</tbody>
</table>

```sql
select /*+ ordered */ username, v$lock.sid, trunc(id1/power(2,16)) rbs,
       bitand(id1,to_number('ffff', 'xxxx'))+0 slot,
       id2 seq, lmode, request
from v$lock, v$session
where v$lock.type = 'TX'
and v$lock.sid = v$session.sid;
```
Here two users are blocked:

```
SELECT sid, blocking_session, username, blocking_session_status
FROM v$session
WHERE username='SCOTT'
ORDER BY blocking_session;
```

<table>
<thead>
<tr>
<th>SID</th>
<th>BLOCKING_SESSION</th>
<th>USERNAME</th>
<th>BLOCKING_SESSION_STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>146</td>
<td>150</td>
<td>SCOTT</td>
<td>VALID</td>
</tr>
<tr>
<td>161</td>
<td>150</td>
<td>SCOTT</td>
<td>VALID</td>
</tr>
<tr>
<td>150</td>
<td></td>
<td>SCOTT</td>
<td>NO HOLDER</td>
</tr>
</tbody>
</table>

## Killing the Problem Session

A user may have run something that he or she really didn’t want to run, or a problem query may need to be eliminated during business hours and rerun at night. If the operation in the preceding section needs to be aborted, you could execute the statements in the next listing (to find and then kill the session):

```
select username, sid, serial#, program, terminal
from v$session;
```

You can also do this in a single statement using

```
select /*+ ordered */ username, v$lock.sid, trunc(idl/power(2,16)) rbs,
       bitand(idl,to_number('ffff','xxxx'))-0 slot,
       id2 seg, lmode, request
from v$lock, v$session
where v$lock.type = 'TX'
  and v$lock.sid = v$session.sid;

alter system kill session '150,47752';
System altered.
```

You can’t kill your own session though:
The order of parameters is SID and then SERIAL# (alter system kill session 'sid,serial#';). Make sure you describe V$SESSION (DESC V$SESSION) because many of its columns are helpful. In previous versions of Oracle, you could kill the current user session. Thankfully, you can no longer kill your own session accidentally, as just shown in the preceding listing.

**TIP**
Identify users who are locking others and kill their session (if necessary).

## Finding Users with Multiple Sessions
At times, users enjoy opening multiple sessions to accomplish several tasks at once, and this can be a problem. The problem may also be a developer who has built a poor application that begins spawning multiple processes. Either of these could degrade the system’s overall performance. In the following output, the usernames that are NULL are background processes. The query to the V$SESSION view in this listing displays these types of issues:

```sql
select username, count(*)
from v$session
group by username;
```

<table>
<thead>
<tr>
<th>USERNAME</th>
<th>COUNT(*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLSQL_USER</td>
<td>1</td>
</tr>
<tr>
<td>SCOTT</td>
<td>1</td>
</tr>
<tr>
<td>JOHNSON</td>
<td>9</td>
</tr>
<tr>
<td>DBSNMP</td>
<td>3</td>
</tr>
<tr>
<td>SYS</td>
<td>4</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>39</td>
</tr>
</tbody>
</table>

On certain OS platforms, if a user starts a session and reboots his or her PC, oftentimes the process continues in the background on the server as the user starts another session. If the user is running multiple reports on multiple terminals or PCs, this could also affect the system’s overall performance.
NOTE
The rows in V$SESSION that have NULL values for username are the Oracle background processes.

TIP
Identify users who are running multiple sessions and determine whether the problem is administrative (the user is using multiple terminals) or system related (sessions are not being cleaned or are spawning runaway processes).

Querying for Current Profiles
Profiles are limits on a given schema (user). The Oracle STIG (Security Technical Implementation Guide) Profile is provided in Oracle 12c. This is much stronger security than the DEFAULT profile. To view the profiles for your system, execute the query shown here:
Finding Disk I/O Issues

The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all...

<table>
<thead>
<tr>
<th>PROFILE</th>
<th>Resource Name</th>
<th>LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFAULT</td>
<td>CONNECT_TIME</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>CPU_PER_CALL</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>COMPOSITE_LIMIT</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>CPU_PER_SESSION</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>FAILED_LOGIN_ATTEMPTS</td>
<td>10</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>IDLE_TIME</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>INACTIVE_ACCOUNT_TIME</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>LOGICAL_READS_PER_CALL</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>LOGICAL_READS_PER_SESSION</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PASSWORD_LIFETIME</td>
<td>180</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PASSWORD_LOCK_TIME</td>
<td>1</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PASSWORD_REUSE_MAX</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PASSWORD_GRACE_TIME</td>
<td>7</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PASSWORD_REUSE_TIME</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PASSWORD_VERIFY_FUNCTION</td>
<td>NULL</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>PRIVATE_SGA</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>DEFAULT</td>
<td>SESSIONS_PER_USER</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>IDLE_TIME</td>
<td>15</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>PRIVATE_SGA</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>CONNECT_TIME</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>CPU_PER_CALL</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>COMPOSITE_LIMIT</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>CPU_PER_SESSION</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>FAILED_LOGIN_ATTEMPTS</td>
<td>3</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>INACTIVE_ACCOUNT_TIME</td>
<td>30</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>LOGICAL_READS_PER_CALL</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>LOGICAL_READS_PER_SESSION</td>
<td>DEFAULT</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>PASSWORD_LIFETIME</td>
<td>80</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>PASSWORD_LOCK_TIME</td>
<td>UNLIMITED</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>PASSWORD_REUSE_MAX</td>
<td>10</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>PASSWORD_REUSE_TIME</td>
<td>365</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>PASSWORD_VERIFY_FUNCTION</td>
<td>ORACLE STRONG VERIFY FUNCTION</td>
</tr>
<tr>
<td>CRAS_STIG_PROFILE</td>
<td>SESSIONS_PER_USER</td>
<td>DEFAULT</td>
</tr>
</tbody>
</table>

34 rows selected.

Finding Disk I/O Issues

The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all...
database datafiles and disks. Ideally, the physical reads and writes should be distributed equally. If the system is not configured properly, overall performance suffers. The script in this next listing identifies the actual distribution and makes identifying where an imbalance exists easy. Chapter 3 looks at this topic in great detail; this section just shows the quick-hit query to get a baseline.

```sql
select a.file#, a.name, a.status, a.bytes,
       b.phyrds, b.phywrts
from v$datafile a, v$filestat b
where a.file# = b.file#;
```

The queries in the following listings provide an improved formatted report for file and data distribution issues. The first listing gets the datafile I/O:
This second listing gets the disk I/O:

```
set trimspool on
set line 142
set pages 57
set newpage 0
set feedback off
set verify off
set term on
TTitle On
BTitle Off
Clear Breaks
break on TableSpace_Name
column TableSpace_Name for A12 head "TableSpace"
column Name for A50 head "File Name"
column Total for 999,999,990 head "Total"
column phyblkrd for 999,999,990 head "Physical Block Reads"
column phyblkwrt for 999,999,990 head "Physical Block Writes"
column avg_rd_time for 999999999 head "Average Read Time Per Block"
column avg_wrt_time for 999999999 head "Average Write Time Per Block"
column instance new_value_instance noprint
column today new_value_date noprint
select Global Name, Instance, to_char(sysdate, 'FXDay, Month DD, YYYY HH:MI') today
from Global_Name;
TTitle On
TTitle Left 'Date Run: ' _date skip 1-
connor 'Data File 1/0' skip 1 -
connor 'Instance Name: ' _instance skip 1
select C.TableSpace_Name, B.Name, A.Phyblkrd +
A.Phyblkwrt total, A.Phyrd, A.Phywrt, A.Phyblkrd, A.Phyblkwrt
from V$FileStat A, V$DataFile B, sys.dba_data_files C
where B.File# = A.File#
and B.File# = C.File_Id
order by TableSpace_Name, A.File#
/
select object_name, statistic_name, value
from v$segment_statistics
where value > 100000
order by value;

<table>
<thead>
<tr>
<th>OBJECT_NAME</th>
<th>STATISTIC_NAME</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDERS</td>
<td>space allocated</td>
<td>96551</td>
</tr>
<tr>
<td>ORDERS</td>
<td>space allocated</td>
<td>134181</td>
</tr>
<tr>
<td>ORDERS</td>
<td>logical reads</td>
<td>140976</td>
</tr>
<tr>
<td>ORDER_LINES</td>
<td>db block changes</td>
<td>183600</td>
</tr>
</tbody>
</table>
```
TIP

The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all database datafiles and disks. Ensure that both datafiles and disks are properly balanced for optimal performance.

The query in this listing shows the waits on the entire system as a whole:
Checking for Privileges and Roles

This section contains several V$ scripts that show various security privileges. The title of each script preceding each of the following listings gives you a quick idea of what it retrieves for you. The output can be very large, depending on your system, so run with caution!

Object-level privileges that have been granted by username
Object-level privileges that have been granted by grantee

```
select b.owner || '.' || b.table_name obj,
       b.privilege what_granted, b.grantable, a.username
from sys.dba_users a, sys.dba_tab_privs b
where a.username = b.grantee
order by 1,2,3;
```

System-level grants by username

```
select owner || '.' || table_name obj,
       privilege what_granted, grantable, grantee
from sys.dba_tab_privs
where not exists
  (select 'x'
   from sys.dba_users
   where username = grantee)
order by 1,2,3;
```

System-level grants by grantee

```
select b.privilege what_granted,
       b.admin_option, a.username
from sys.dba_users a, sys.dba_sys_privs b
where a.username = b.grantee
order by 1,2;
```

Roles granted by username

```
select privilege what_granted,
       admin_option, grantee
from sys.dba_sys_privs
where not exists
  (select 'x' from sys.dba_users
   where username = grantee)
order by 1,2;
```
Roles granted by grantee

```
select granted_role ||
    decode(admin_option, 'YES',
       ' (With Admin Option)', null) what_granted, granteec
from sys.dba_role_privs
where not exists
    (select 'x'
     from sys.dba_users
     where username = grantee)
order by 1;
```

Usernames with corresponding granted privileges

```
select a.username,
    b.granted_role || decode(admin_option,'YES',
       ' (With Admin Option)',null) what_granted
from     sys.dba_users a, sys.dba_role_privs b
where    a.username = b.grantee
UNION
select a.username,
    b.privilege || decode(admin_option,'YES',
       ' (With Admin Option)',null) what_granted
from     sys.dba_users a, sys.dba_sys_privs b
where    a.username = b.grantee
UNION
select a.username,
    b.table_name || ' - ' || b.privilege
    || decode(grantable,'YES',
       ' (With Grant Option)',null) what_granted
from     sys.dba_users a, sys.dba_tab_privs b
where    a.username = b.grantee
order by 1;
```
TIP
Document the privileges that you have for your system so you are ready for any type of security situation.

Usernames with corresponding profile, default tablespace, and temporary tablespace

```sql
Select username, profile, default_tablespace, temporary_tablespace, created
from sys.dba_users
order by username;
```

Wait Events V$ Views

This section contains several V$ scripts that show wait events. Personally, I prefer using the Statspack Report, the AWR Report, or Enterprise Manager to find wait events. That said, this section presents some nice views to look at wait events. Several new views have been added over the years, but the best thing in 11g and 12c is that everything you found in V$SESSION_WAIT in the past is now in V$SESSION.

To find out who is waiting right now, query V$SESSION_WAIT or V$SESSION:
To view specific waits for who is waiting right now, query V$SESSION_WAIT:

```sql
select event, sum(decode(wait_time, 0, 1, 0)) "Waiting Now",
       sum(decode(wait_time, 0, 0, 1)) "Previous Waits",
       count(*) "Total"
from v$session_wait
group by event
order by count(1);
```

**WAIT_TIME = 0** means that it's waiting

**WAIT TIME > 0** means that it previously waited this many ms

<table>
<thead>
<tr>
<th>EVENT</th>
<th>Waiting Now</th>
<th>Previous Waits</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>db file sequential read</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>db file scattered read</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>latch free</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>cnqceu</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>SQL*Net message from client 0</td>
<td>254</td>
<td></td>
<td>480</td>
</tr>
</tbody>
</table>

... 

To view the last ten waits for who is waiting, query V$SESSION_WAIT_HISTORY:

```sql
select event, sum(decode(wait_time, 0, 1, 0)) "Waiting Now",
       sum(decode(wait_time, 0, 0, 1)) "Previous Waits",
       count(*) "Total"
from v$session
group by event
order by count(1);
```

<table>
<thead>
<tr>
<th>EVENT</th>
<th>Waiting Now</th>
<th>Previous Waits</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>db file sequential read</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>db file scattered read</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>latch free</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>enqueue</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>SQL*Net message from client 0</td>
<td>254</td>
<td></td>
<td>480</td>
</tr>
</tbody>
</table>

...
To find what P1, P2, and P3 stand for, query V$EVENT_NAME:

```
SELECT * FROM v$session_wait_history sw, dba_extents de
WHERE de.file_id = sw.file_id
AND sw.p2 between de.block_id and de.block_id + de.blocks - 1
AND (event = 'buffer busy waits' OR event = 'write complete waits')
AND p1 IS NOT NULL
ORDER BY event, sid;
```

To view all waits since the session started, query V$SESSION_EVENT:

```
col name for a20
col p1 for a10
col p2 for a10
col p3 for a10
select event#, name, parameter1 p1, parameter2 p2, parameter3 p3
from v$event_name
where name in ('buffer busy waits', 'write complete waits');
```

<table>
<thead>
<tr>
<th>EVENT#</th>
<th>NAME</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>143</td>
<td>write complete waits</td>
<td>file</td>
<td>block</td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>buffer busy waits</td>
<td>file</td>
<td>block</td>
<td>id</td>
</tr>
</tbody>
</table>

To view all SESSION waits by class, query V$SESSION_WAIT_CLASS:

```
select sid, event, total_waits, time_waited
from v$session_event
where time_waited > 0
order by time_waited;
```

<table>
<thead>
<tr>
<th>SID</th>
<th>EVENT</th>
<th>TOTAL WAITS</th>
<th>TIME WAITED</th>
</tr>
</thead>
<tbody>
<tr>
<td>159</td>
<td>process startup</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>167</td>
<td>latch: redo allocation</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>168</td>
<td>log buffer space</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>166</td>
<td>control file single write</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

...
To view all waits since the system started, query V$SYSTEM_EVENT:

```
select event, total_waits, time_waited, event_id
from v$system_event
where time_waited > 0
order by time waited;
```

<table>
<thead>
<tr>
<th>EVENT</th>
<th>TOTAL_WAITS</th>
<th>TIME_WAITED</th>
<th>EVENT_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>cnq: TX - row lock contention</td>
<td>1196</td>
<td>366837</td>
<td>310662678</td>
</tr>
<tr>
<td>cnq: TM - contention</td>
<td>170</td>
<td>52074</td>
<td>668627460</td>
</tr>
<tr>
<td>db file sequential read</td>
<td>17387</td>
<td>21630</td>
<td>2632584166</td>
</tr>
<tr>
<td>control file parallel write</td>
<td>12961</td>
<td>23117</td>
<td>4078387448</td>
</tr>
<tr>
<td>db file scattered read</td>
<td>4708</td>
<td>15762</td>
<td>806183215</td>
</tr>
<tr>
<td>class slave wait</td>
<td>20</td>
<td>10246</td>
<td>1039184682</td>
</tr>
</tbody>
</table>

To view SYSTEM waits by class, query V$SYSTEM_WAIT_CLASS (you could also do a sum(total_waits) in the SELECT and add a group by wait_class):
To view SYSTEM waits by class, query V$ACTIVE_SESSION_HISTORY. This view also has many columns to check INMEMORY (INMEMORY_QUERY and others) as well as a SQL_ADAPTIVE_PLAN_RESOLVED column. Here are a couple of queries to the V$ACTIVE_SESSION_HISTORY view:

```sql
select wait_class, total_waits
from vsystem_wait_class
order by total_waits desc;
```

<table>
<thead>
<tr>
<th>WAIT_CLASS</th>
<th>TOTAL_WAITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle</td>
<td>161896</td>
</tr>
<tr>
<td>Other</td>
<td>65308</td>
</tr>
<tr>
<td>System I/O</td>
<td>24339</td>
</tr>
<tr>
<td>User I/O</td>
<td>22227</td>
</tr>
<tr>
<td>Application</td>
<td>1404</td>
</tr>
<tr>
<td>Commit</td>
<td>524</td>
</tr>
<tr>
<td>Network</td>
<td>522</td>
</tr>
<tr>
<td>Concurrency</td>
<td>221</td>
</tr>
<tr>
<td>Configuration</td>
<td>55</td>
</tr>
</tbody>
</table>

To view SYSTEM waits by class, query V$ACTIVE_SESSION_HISTORY. This view also has many columns to check INMEMORY (INMEMORY_QUERY and others) as well as a SQL_ADAPTIVE_PLAN_RESOLVED column. Here are a couple of queries to the V$ACTIVE_SESSION_HISTORY view:

```
-- In the query below, the highest count session in non-idle wait events.
select session_id, count(1)
from vactive_session_history
group by session_id
order by 2;

-- In the query below, find the SQL for the leader in non-idle wait events.
select c.sql_id, a.sql_text
from v$sql a, (select sql_id, count(1)
               from vactive_session_history b
               where sql_id is not null
               group by sql_id
               order by 2 desc)
  c
where rownum <= 5
order by rownum;
```

TIP
All wait event columns that are in V$SESSION_WAIT are now in V$SESSION. So make sure you query V$SESSION for wait information since it’s a faster view. V$ACTIVE_SESSION_HISTORY (ASH) rolls many of the great statistics into one view as well as one report (ASH Report).
Some of the Major V$ View Categories

The views in this section are categorized according to their primary function. Not all are listed (please see Appendix B for a complete listing of the V$ views with X$ table queries). You will often need to join one category to another category to retrieve the desired information. The V$ views can be queried the same as any other Oracle view, but keep in mind that the information in these tables changes rapidly. You can insert the information from the V$ views into a pre-created table to allow for the compilation of data over a period of time—data to be analyzed later or to build statistical reports and alerts based on different conditions in your database.

Most DBA monitoring tools on the market today use the V$ view (and X$ table) information. Querying this database information without a DBA monitoring tool requires that you have an in-depth understanding of the information stored in each view and how to query the view properly. Table 12-1 contains a list of V$ views categorized according to their primary function. The views are listed in categories related to the operation that they monitor. This list is not exhaustive. It contains only the most commonly used views. Some views have changed from version to version of Oracle.
<table>
<thead>
<tr>
<th>Category</th>
<th>Description and Associated VS Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pluggable databases</td>
<td>Information related to pluggable databases (PDBs) VS view: V$PDBS (also note VS views include CDB_PDBS, CDB_PDB_HISTORY, CDB_TABLES, and CDB_DATA_FILES)</td>
</tr>
<tr>
<td>In-Memory</td>
<td>Information related to In-Memory (M) Column Store VS views: V$INMEMORY_AREA, V$INMEMORY_XMEM_AREA, V$SIM_SEGMENTS, V$SIM_SEGMENTS_DETAIL, V$SIM_COLUMN_LEVEL, V$SIM_COL_CU, V$SIM_HEADER, V$SIM_SEG_EXT_MAP, V$SIM_USER_SEGMENTS, and V$SIM_KEY_VECTOR</td>
</tr>
<tr>
<td>Advisors</td>
<td>Information related to cache advisors VS views: V$ADVISOR_PROGESS, V$DB CACHE ADVICE, V$JAVA_POOL ADVICE, V$MEMORY_TARGET_ADVICE, V$SPGA_TARGET_ADVICE, V$SPGA_TARGET_ADVICE_HISTOGRAM, V$SPX_BUFFER_ADVICE, V$SHARED_POOL_ADVICE, V$SGA_TARGET_ADVICE, and V$STREAMS_POOL_ADVICE</td>
</tr>
<tr>
<td>Category</td>
<td>Description and Associated V$ Views</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Caches</td>
<td>Information related to the various caches, including objects, library, cursors, and the dictionary.</td>
</tr>
<tr>
<td>Cache fusion/RAC</td>
<td>Information related to RAC.</td>
</tr>
<tr>
<td>Control files</td>
<td>Information related to instance control files</td>
</tr>
<tr>
<td></td>
<td>VS views: V$CONTROLFILE, V$CONTROLFILE_RECORD_SECTION, and V$DATABASE</td>
</tr>
<tr>
<td>Cursors/SQL statements</td>
<td>Information related to cursors and SQL statements, including the open cursors, statistics, and actual SQL text</td>
</tr>
<tr>
<td>Database instances</td>
<td>Information related to the actual database instance</td>
</tr>
<tr>
<td></td>
<td>VS views: V$ACTIVE_INSTANCES, V$ARCHIVER_PROCESSES, V$BGPROCESS, V$DATABASE, V$INSTANCE, V$PROCESS, V$SGA, V$SGASTAT, V$BLOCKING_QUIESCE, and V$CLIENT_STATS</td>
</tr>
<tr>
<td>RAC</td>
<td>V$Bil and V$ACTIVE_INSTANCES</td>
</tr>
<tr>
<td>Category</td>
<td>Description and Associated V$ Views</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Direct Path operations</td>
<td>Information related to the SQL*Loader (and the Direct Path API), direct load option</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$LOADSTAT and V$LOADPSTAT</td>
</tr>
<tr>
<td>Distributed/</td>
<td>Information related to Distributed Services</td>
</tr>
<tr>
<td>heterogeneous services</td>
<td><strong>V$</strong> views: V$DBLINK, V$GLOBAL_TRANSACTION, V$GLOBAL_BLOCKED_LOCKS,</td>
</tr>
<tr>
<td></td>
<td>V$HS_AGENT, V$HS_PARAMETER, V$HS_SESSION, and V$IOSTAT_NETWORK</td>
</tr>
<tr>
<td>File mapping</td>
<td>Information related to file mapping</td>
</tr>
<tr>
<td>interface</td>
<td><strong>V$</strong> views: V$MAP_COMP_LIST, V$MAP_ELEMENT, V$MAP_EXT_ELEMENT, V$MAP_FILE,</td>
</tr>
<tr>
<td></td>
<td>V$MAP_FILE_EXTENT, V$MAP_FILE_IO_STACK, V$MAP_LIBRARY, and V$MAP_SUBELEMENT</td>
</tr>
<tr>
<td>Fixed view</td>
<td>Information related to the V$ tables themselves</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$FIXED_TABLE, V$FIXED_VIEW_DEFINITION, and V$INDEXED_FIXED_COLUMN</td>
</tr>
<tr>
<td>General</td>
<td>General information related to various pieces of system information</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$DB_FIPS, V$CONTEXT, V$GLOBALCONTEXT, V/LICENSE, V$OPTION,</td>
</tr>
<tr>
<td></td>
<td>V$RESERVED_WORDS, V$SQLCOMMAND, V$TEMPORARY_LOBS, V$THRESHOLD_TYPES,</td>
</tr>
<tr>
<td></td>
<td>V$TIMER, V$TIMEZONE_NAMES, V$STOPLEVELCALL, V$TYPE_SIZE, V$SEQUENCES,</td>
</tr>
<tr>
<td></td>
<td>V$VERSION, V$DB_TRANSPORTABLE PLATFORM, V$TRANSPORTABLE_PLATFORM, and</td>
</tr>
<tr>
<td></td>
<td>V$SCHEDULER_RUNNING_JOBS</td>
</tr>
<tr>
<td>I/O</td>
<td>Information related to I/O, including files and statistics</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$DATAFILE, V$DATAFILE_HEADER, V$DBFILE, V$DNS_F_KEY_CHANNELS,</td>
</tr>
<tr>
<td></td>
<td>V$DNS_FILES, V$DNS_SERVERS, V$DNS_STATS, V$FILESPACE_USAGE, V$FILESTAT,</td>
</tr>
<tr>
<td></td>
<td>V$WAITSTAT, V$TEMPSTAT, V$FILE_HISTOGRAM, V$FILEMETRIC, V$FILEMETRIC_HISTORY,</td>
</tr>
<tr>
<td></td>
<td>V$IOFUNMETRIC, V$IOFUNMETRIC_HISTORY, V$IO_CALIBRATION_STATUS,</td>
</tr>
<tr>
<td></td>
<td>V$IOSTAT_CONSUMER_GROUP, V$IOSTAT_FILE, V$IOSTAT_FUNCTION,</td>
</tr>
<tr>
<td></td>
<td>V$IOSTAT_FUNCTION_DETAIL, V$IOSTAT_NETWORK, V$NFS_CLIENTS, V$NFS_LOCKS,</td>
</tr>
<tr>
<td></td>
<td>V$NFS_OPEN_FILES, V$SECURITYFILE_TIMER, V$SEGMENT_STATISTICS,</td>
</tr>
<tr>
<td></td>
<td>V$SYSAUX_OCCUPANTS, V$TABLESPACE, V$TEMP_SPACE_HEADER, V$TEMPFILE, and</td>
</tr>
<tr>
<td></td>
<td>V$TEMPSEG_USAGE</td>
</tr>
<tr>
<td>Latches/locks</td>
<td>Information related to latches and locks</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$ACCESS, V$ENQUEUE_LOCK, V$ENQUEUE_STAT, V$EVENT_NAME,</td>
</tr>
<tr>
<td></td>
<td>V$GLOBAL_BLOCKED_LOCKS, V$LATCH, V$LATCHHOLDER, V$LATCHNAME,</td>
</tr>
<tr>
<td></td>
<td>V$LATCH_CHILDREN, V$LATCH_MISSES, V$LATCH_PARENT, V$LIBCACHE_LOCKS,</td>
</tr>
<tr>
<td></td>
<td>V$LCK, V$LOCK_TYPE, V$LOCKED_OBJECT, V$RESOURCE, V$RESOURCE_LIMIT,</td>
</tr>
<tr>
<td></td>
<td>V$TRANSACTION_ENQUEUETYPE, V$LCK, V$LCKI, and V$ENQUEUESTAT</td>
</tr>
<tr>
<td>RAC</td>
<td>Information related to RAC</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$SCR_BLOCK_SERVER, V$GCISHVMASTER_INFO, V$GCISHVMASTER_INFO,</td>
</tr>
<tr>
<td></td>
<td>V$GC_ELEMENT, V$GES_BLOCKING_ENQUEUE, V$GES_ENQUEUE, V$HVMASTER_INFO,</td>
</tr>
<tr>
<td></td>
<td>V$NFS_LOCKS, V$NFS_RESOURCES, and V$PROCESS</td>
</tr>
<tr>
<td>Log Miner</td>
<td>Information related to Log Miner</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$LOGMNR_CALBACK, V$LOGMNR_CONTENTS, V$LOGMNR_DICITIONARY</td>
</tr>
<tr>
<td></td>
<td>V$LOGMNR_LATCH, V$LOGMNR_LOGS, V$LOGMNR_PARAMETERS,</td>
</tr>
<tr>
<td></td>
<td>V$LOGMNR_PROCESS, V$LOGMNR_REGION, V$LOGMNR_SESSION, V$LOGMNR_STATS,</td>
</tr>
<tr>
<td></td>
<td>V$LOGMNR_TRANSACTION, and V$LOGMNR_DICITIONARY_LOAD</td>
</tr>
<tr>
<td>Metrics</td>
<td>Information related to metrics</td>
</tr>
<tr>
<td></td>
<td><strong>V$</strong> views: V$METRICNAME, V$SERVICEMETRIC, V$EVENTMETRIC, V$FILEMETRIC,</td>
</tr>
<tr>
<td></td>
<td>V$FILEMETRIC_HISTORY, V$IOFUNMETRIC, V$METRIC, V$METRIC_HISTORY,</td>
</tr>
<tr>
<td></td>
<td>V$SRCEMRGMETRIC, V$SRCEMRGMETRIC_HISTORY, V$SERVICEMETRIC_HISTORY,</td>
</tr>
<tr>
<td></td>
<td>V$SRRGMETRIC, V$SRRGMETRIC_HISTORY, V$SYSMETRIC, V$SYSMETRIC_HISTORY,</td>
</tr>
<tr>
<td></td>
<td>V$THRESHOLD_TYPES, V$WAITCLASSMETRIC, and V$WAITCLASSMETRIC_HISTORY</td>
</tr>
<tr>
<td>Category</td>
<td>Description and Associated V$ Views</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Multithreaded/</td>
<td>Information related to multithreaded and parallel servers, including connections, queues, dispatchers, and shared servers</td>
</tr>
<tr>
<td>shared servers</td>
<td><strong>V$ views:</strong> $\text{V$\text{CIRCUIT}}$, $\text{V$\text{DISPATCHER}}$, $\text{V$\text{DISPATCHER_RATE}}$, $\text{V$\text{QUEUE}}$, $\text{V$\text{QUEUE_ENG_MTH}}$, $\text{V$\text{REQUEST}}$, $\text{V$\text{SHARED_SERVER}}$, $\text{V$\text{SHARED_SERVER_MONITOR}}$, and $\text{V$\text{DISPATCHER_CONFIC}}$</td>
</tr>
<tr>
<td>Object usage</td>
<td>Information related to object use and dependencies</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{OBJECT_DEPENDENCY}}$, $\text{V$\text{OBJECT_PRIVILEGE}}$, and $\text{V$\text{OBJECT_USAGE}}$</td>
<td></td>
</tr>
<tr>
<td>Overall system</td>
<td>Information related to the overall system performance</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{AHT_TYPES}}$, $\text{V$\text{MON}}$, $\text{V$\text{EVENT_METRIC}}$, $\text{V$\text{EVENT_HISTOGRAM}}$, $\text{V$\text{EVENT_NAME}}$, $\text{V$\text{GLOBAL_TRANSACTION}}$, $\text{V$\text{HM_CHECK}}$, $\text{V$\text{MEMORY_CURRENT_RESIZE_OPS}}$, $\text{V$\text{OSSTAT}}$, $\text{V$\text{RESUMABLE}}$, $\text{V$\text{SEGMENT_STATISTICS}}$, $\text{V$\text{SHARED_POOL_RESERVED}}$, $\text{V$\text{SSGA}}$, $\text{V$\text{SORT_SEGMENT}}$, $\text{V$\text{STATNAME}}$, $\text{V$\text{SYS_OPTIMIZER_ENV}}$, $\text{V$\text{SYS_TIME_MODEL}}$, $\text{V$\text{SYSSTAT}}$, $\text{V$\text{SYSTEM_CURSOR_CACHE}}$, $\text{V$\text{SYSTEM_EVENT}}$, $\text{V$\text{SYSTEM_FIX_CONTROL}}$, $\text{V$\text{TEMPFILE}}$, $\text{V$\text{TEMPORARY_LOBs}}$, $\text{V$\text{TEMPSEG_USAGE}}$, $\text{V$\text{TEMP_EXTENT_MAP}}$, $\text{V$\text{TEMP_EXTENT_POOL}}$, $\text{V$\text{TEMP_SPACE_HEADER}}$, $\text{V$\text{TRANSACTION}}$, $\text{V$\text{SYSTEM_WAIT_CLASS}}$, $\text{V$\text{TEMP_HISTOGRAM}}$, $\text{V$\text{SWAITSTAT}}$, and $\text{V$\text{XML_AUDIT_TRAIL}}$</td>
<td></td>
</tr>
<tr>
<td>Parallel query and</td>
<td>Information related to the Parallel Query option</td>
</tr>
<tr>
<td>parallel execution</td>
<td><strong>V$ views:</strong> $\text{V$\text{EXECUTION}}$, $\text{V$\text{PARALLEL_DEGREE_LIMIT_MTH}}$, $\text{V$\text{PQ_SESSTAT}}$, $\text{V$\text{PQ_SLAVE}}$, $\text{V$\text{PQ_SYSTAT}}$, $\text{V$\text{PQ_TQSTAT}}$, $\text{V$\text{SP_INSTANCE_GROUP}}$, $\text{V$\text{PX_PROCESS}}$, $\text{V$\text{PX_PROCESS_SYSSTAT}}$, $\text{V$\text{PX_SESSION}}$, and $\text{V$\text{PX_SESSTAT}}$</td>
</tr>
<tr>
<td>Parameters</td>
<td>Information related to various Oracle parameters, including initialization and NLS per session</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{NLS_PARAMETERS}}$, $\text{V$\text{NLS_VALID_VALUES}}$, $\text{V$\text{SO\text{B}SO\text{L}TATE_PARAMETER}}$, $\text{V$\text{PARAMETER}}$, $\text{V$\text{PARAMETER2}}$, $\text{V$\text{SP_PARAMETER}}$, $\text{V$\text{SYSTEM_PARAMETER}}$, $\text{V$\text{SYSTEM_PARAMETER2}}$, and $\text{V$\text{PARAMETER_VALID_VALUES}}$</td>
<td></td>
</tr>
<tr>
<td>Redo logs</td>
<td>Information related to redo logs, including statistics and history</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{INSTANCE}}$, $\text{V$\text{LOG}}$, $\text{V$\text{LOGFILE}}$, $\text{V$\text{LOG_HIST}}$, $\text{V$\text{LOG_HISTORY}}$, $\text{V$\text{REDO_DEST_RESP_HISTOGRAM}}$, and $\text{V$\text{THREAD}}$ (RAC related)</td>
<td></td>
</tr>
<tr>
<td>Replication and</td>
<td>Information related to replication and materialized views</td>
</tr>
<tr>
<td>materialized views</td>
<td><strong>V$ views:</strong> $\text{V$\text{SM_REFRESH}}$, $\text{V$\text{RE_PROP}}$, and $\text{V$\text{RE_QUEUE}}$</td>
</tr>
<tr>
<td>Resource Manager</td>
<td>Information related to resource management</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{ACTIVE_SESSION_POOL_MTH}}$, $\text{V$\text{ACTIVE_SESSION_HISTORY}}$, $\text{V$\text{IO_CALIBRATION_STATUS}}$, $\text{V$\text{IOSTAT_CONSUMER_GROUP}}$, $\text{V$\text{RSRC_CONSUMER_GROUP_HISTORY}}$, $\text{V$\text{RSRC_CONSUMER_GROUP}}$, $\text{V$\text{RSRC_CONSUMER_GROUP_CPU_MTH}}$, $\text{V$\text{RSRC_PLAN}}$, $\text{V$\text{RSRC_PLAN_CPU_MTH}}$, $\text{V$\text{RSRC_PLAN_HISTORY}}$, $\text{V$\text{RSRC_SESSION_INFO}}$, $\text{V$\text{RSRC_CMGR_METRIC}}$, and $\text{V$\text{RSRC_METRIC_HISTORY}}$</td>
<td></td>
</tr>
<tr>
<td>Rollback segments and UNDO</td>
<td>Information on rollback segments, including statistics and transactions</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{RROI_NAME}}$, $\text{V$\text{RSCLI_STAT}}$, $\text{V$\text{TRANSACTION}}$, and $\text{V$\text{UNDO_STAT}}$</td>
<td></td>
</tr>
<tr>
<td>Security/privileges</td>
<td>Information related to security</td>
</tr>
<tr>
<td><strong>V$ views:</strong> $\text{V$\text{ENABLED_PRIVS}}$, $\text{V$\text{OBJECT_PRIVILEGE}}$, $\text{V$\text{PWFILE_USERS}}$, $\text{V$\text{VPD_POLICY}}$, $\text{V$\text{WAIT_ET}}$, and $\text{V$\text{XML_AUDIT_TRAIL}}$</td>
<td></td>
</tr>
<tr>
<td>Category</td>
<td>Description and Associated V$ Views</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sorting</td>
<td>Information related to sorting. V$ views: V$SORT_SEGMENT, V$TIMESTAMP, V$TEMPSPACE_USAGE, V$TEMP_EXTENT_MAP, V$TEMP_EXTENT_POOL, V$TEMP_SPACE_HEADER, and V$TEMPSTAT.</td>
</tr>
<tr>
<td>Standby databases (Data Guard)</td>
<td>Information related to standby databases. V$ views: V$ARCHIVE_DEST, V$ARCHIVE_DEST_STATUS, V$ARCHIVE_GAP, V$ARCHIVED_LOG, V$DATABASE, V$DATA_GUARD_STATUS, V$INSTANCE, V$FOREIGN_ARCHIVED_LOG, V$FIPS, V$FAILED_STATUS, V$LOGSTDBY_STATS, V$MANAGED_STANDBY, V$STANDBY_LOG, V$DATA_GUARD_CONFIG, V$DATA_GUARD_Status, V$LOGSTDBY_PROCESS, V$LOGSTDBY_PROGRESS, V$LOGSTDBY_STATE, V$LOGSTDBY_TRANSACTION, and V$STANDBY_EVENT_HISTOGRAM.</td>
</tr>
<tr>
<td>Category</td>
<td>Description and Associated V$ Views</td>
</tr>
<tr>
<td>-------------------</td>
<td>------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Misc, recent V$</td>
<td>Recent Views with Miscellaneous Information: V$ASM_ATTRIBUTE, V$ASM_DISK_IOSTAT, V$CALLTAG,</td>
</tr>
<tr>
<td></td>
<td>V$CLIENT_RFSUIT_CACHE_STATS, V$CORRPT_XID_LIST, V$CPool_CC_INFO,</td>
</tr>
<tr>
<td></td>
<td>V$CPool_CC_STATS, V$CPool_STATS, V$DETAILED_SESSION, V$DIAG_INFO,</td>
</tr>
<tr>
<td></td>
<td>V$DNSF5_CHANNELS, V$DNSF5_FILES, V$DNSF5_SERVERS, V$DNSF5_STATS,</td>
</tr>
<tr>
<td></td>
<td>V$DSYNDYNAMIC_REMASTERS, V$ENCRYPTED_TABLESPACES, V$ENCRYPTION_WALLET,</td>
</tr>
<tr>
<td></td>
<td>V$FLASHBACK_TXN_GRAPH, V$FLASHBACK_TXN_MODS, V$FOREIGN_ARCHIVED_LOG,</td>
</tr>
<tr>
<td></td>
<td>V$FS, FAILOVER_HISTOGRAM, V$FS, FAILOVER_STATS, V$HM_CHECK,</td>
</tr>
<tr>
<td></td>
<td>V$HM_CHECK_PARAM, V$HM_FINDING, V$HM_INFO, V$HM_RECOMMENDATION,</td>
</tr>
<tr>
<td></td>
<td>V$HM_RUN, V$INCMETER_CONFIG, V$INCMETER_INFO, V$INCMETER_SUMMARY,</td>
</tr>
<tr>
<td></td>
<td>V$IOFUNCMETRIC, V$IOFUNCMETRIC_HISTORY, V$IOSTAT_CONSUMER_GROUP,</td>
</tr>
<tr>
<td></td>
<td>V$IOSTAT_FILE, V$IOSTAT_FUNCTION, V$IOSTAT_NETWORK,</td>
</tr>
<tr>
<td></td>
<td>V$IO_CALIBRATION_STATUS, V$IR_FAILURE, V$IR.FAILURE_SET,</td>
</tr>
<tr>
<td></td>
<td>V$IR_MANUAL_CHECKLIST, V$IR_REPAIR, V$LOBSTAT, V$MEMORY_CURRENT, V$MEMORY_RESIZE_OPS,</td>
</tr>
<tr>
<td></td>
<td>V$MEMORY_DYNAMIC_COMPONENTS, V$MEMORY_RESIZE_OPS,</td>
</tr>
<tr>
<td></td>
<td>V$MEMORY_TARGET_ADVICE, V$NFS_CLIENTS, V$NFS_LOCKS, V$NFS_OPEN_FILES,</td>
</tr>
<tr>
<td></td>
<td>V$OBJECT_PRIVILEGE, V$PERSISTENT_PUBLISHERS, V$PERSISTENT_QUEUES,</td>
</tr>
<tr>
<td></td>
<td>V$PERSISTENT_SUBSCRIBERS, V$PROCESS_GROUP, V$PX_INSTANCE_GROUP,</td>
</tr>
<tr>
<td></td>
<td>V$REDO_DEST_RESP_HISTOGRAM, V$RESULT_CACHE_DEPENDENCY,</td>
</tr>
<tr>
<td></td>
<td>V$RESULT_CACHE_MEMORY, V$RESULT_CACHE_OBJECTS, V$RESULT_CACHE_STATISTICS,</td>
</tr>
<tr>
<td></td>
<td>V$RMAN_COMPRESSION_ALGORITHM, V$RMAN_ENCRYPTION_ALGORITHMS,</td>
</tr>
<tr>
<td></td>
<td>V$RSCMEMRGMETRIC, V$RSCMEMRGMETRIC_HISTORY, V$SECURITYFILE_TIMER,</td>
</tr>
<tr>
<td></td>
<td>V$SESSION_FIX_CONTROL, V$SQL_CS_HISTOGRAM, V$SQL_CS_SELECTIVITY,</td>
</tr>
<tr>
<td></td>
<td>V$SQL_CS_STATISTICS, V$SQL_FEATURE, V$SQL_FEATURE_DEPENDENCY,</td>
</tr>
<tr>
<td></td>
<td>V$SQL_FEATURE_HIERARCHY, V$SQL_HINT, V$SQL_MONITOR, V$SQL_PLAN_MONITOR,</td>
</tr>
<tr>
<td></td>
<td>V$SQLFN_ARG_METADATA, V$SQLFN_METADATA, V$SSCR_SESSIONS,</td>
</tr>
<tr>
<td></td>
<td>V$STREAMS_MESSAGE_TRACKING, V$SUBSCR_REGISTRATION_STATS,</td>
</tr>
<tr>
<td></td>
<td>V$SYSTEM_FIX_CONTROL, V$WAIT_CLAIMS, V$WORKLOAD_REPLAY_THREAD,</td>
</tr>
<tr>
<td></td>
<td>V$XS_SESSION, V$XS_SESSION_ATTRIBUTE, and V$XS_SESSION_ROLE</td>
</tr>
</tbody>
</table>

Other Miscellaneous

| Misc, V$          | VS views: V$ASM_ACF5SNAPSHOTS, V$ASM_ACF5VOLUMES, V$ASM_FILESYSTEM,                              |
|                   | V$ASM_USER, V$ASM_USERGROUP, V$ASM_USERGROUP_MEMBER, V$ASM_VOLUME,                               |
|                   | V$ASM_VOLUME_STAT, V$CPool_CONN_INFO, V$EMON, V$IOSTAT_FUNCTION_DETAIL,                         |
|                   | V$SLIBCACHE_LOCKS, V$PERSISTENT_QMN_CACHE, V$QMON.COORDINATOR_STATS,                           |
|                   | V$QMON_SERVER_STATS, V$QMON_TASK_STATS, V$QMON_TASKS, V$SQL_COMMAND,                           |
|                   | V$STANDBY_EVENT_HISTOGRAM, V$STREAMS_POOL_STATISTICS, and V$TOPLEVELCALL                         |

**NOTE**

The V$ROLLNAME view is created slightly differently than the other V$ views. The
**V$ROLLNAME** is a join of an X$ table and the UNDO$ table. Some of the V$ timing fields are dependent on the TIMED_STATISTICS init.ora parameter being set to TRUE; otherwise, there will be no timing data in these fields.

**Tips Review**

- The V$ views that are accessed by SYSTEM are actually synonyms that point to the V_ $ views that are views of the original V$ views based on the X$ tables.
- When other DBAs need access to the V$ view information, but *not* the SYS or SYSTEM passwords, grant the user access to the V_ $ views. The user may then access the V$ views that have public synonyms to the V_ $ views. However, scripts could always be written to query the SYS. V_ $ views directly, to avoid the performance cost of dereferencing the public synonym, but this savings is small.
- Query V$FIXED_TABLE to obtain a listing of all GV$ and V$ views in the database. The GV$ views are the exact same as the V$ views, except the instance ID contains an identifier, and the GV$ views contain data for all instances of an Oracle RAC database.
- Access the V$FIXED_VIEW_DEFINITION view to get all information about the underlying X$ tables that make up a V$ view. CON_ID (Container ID) is a new column you’ll see in 12c for pluggable databases in many V$ views.
- The DBA_ views are not derived from the X$ tables or V$ views. The fact that you can delete rows from OBJ$ and ruin your database is a great reason to never be the SYS superuser. There is a CDB_ view for every DBA_ view, and the Root CDB_ views also contain PDB information about all PDBs.
- Query V$VERSION and V$DATABASE to view basic database information such as the version, to find out when your database was created, and to find out basic archiving information.
- Query V$SYSAUX_OCCUPANTS to ensure that the Automatic Workload Repository (AWR) isn’t taking up too much space. Use DBMS_STATS to check history and retention.
- Query the V$OPTION view to retrieve the Oracle options you have installed. The V$VERSION view gives you the versions of the installed base options.
- Query the V$IM_SEGMENTS and V$IM_COLUMN_LEVEL views to retrieve detailed information about specific objects that are stored in the In-Memory (IM) column store (only available in 12.1.0.2+).
- Access the V$SGA view to get a baseline idea of the system’s physical memory allocated for data, shared pool, large pool, Java pool, and log buffering of Oracle. A new SGA parameter to set is INMEMORY_SIZE.
- Querying V$SGASTAT provides a detailed breakdown for the Oracle SGA and details all aggregated buckets of shared pool allocation. Query V$PARAMETER to get the current values for the initialization parameters. V$PARAMETER also shows which initialization parameters have been changed from their original defaults: ISDEFAULT= FALSE. It also shows which
parameters may be changed only for a given session if ISSES_MODIFIABLE=TRUE. Lastly, it shows which parameters may be changed without shutting down and restarting the database for ISSYS_MODIFIABLE=IMMEDIATE as well as ISSYS_MODIFIABLE=DEFERRED for a parameter that is enforced for all new logins but not currently logged-on sessions. If the parameter ISSYS_MODIFIABLE=FALSE, then the instance must be shut down and restarted for the parameter to take effect. See Chapter 4 for more information on the initialization parameters.

- Query V$CONTAINERS and V$PDBS to get detailed information on both containers and pluggable databases. When connected to the PDB, you only see information related to that specific PDB. Query V$LIBRARYCACHE to see how often your SQL and PL/SQL are being read from memory. The pinhitratio should generally be at 95 percent or greater, and the number of reloads should not be greater than 1 percent. Query V$SQL_BIND_CAPTURE to see if binds per SQL are too high and CURSOR_SHARING is needed. Use the Result Cache to force results from a query to remain in the Result Cache Memory portion of the shared pool.

- Query the V$DB_OBJECT_CACHE view to find objects that are not pinned and are also potentially large enough to cause fragmentation problems in the shared pool.

- Query the V$SQLAREA to find problem queries (and users).

- Query V$SESSION, V$SQLTEXT, and V$SESS_IO to find the problem users and what they are executing at a given point in time.

- Query V$ACCESS to find all objects that are being accessed by a user at a given time. This can help to pinpoint problem objects, while also being helpful when modifying a particular object (find out who is accessing it). However, this operation would be very expensive on a system with a large shared pool and hundreds of users.

- Use the V$OBJECT_USAGE view to find out if indexes are being used. Perhaps some indexes are not needed.

- Identify users who are locking others and kill their session (if necessary).

- Identify users who are holding multiple sessions and determine whether the problem is administrative (the user is using multiple terminals) or system related (sessions are not being cleaned or are spawning runaway processes).

- The views V$DATAFILE, V$FILESTAT, and DBA_DATA_FILES provide file I/O activity across all database datafiles and disks. Ensure that both datafiles and disks are properly balanced for optimal performance.

- Document the privileges that you have for your system so you are ready for any type of security situation. The Oracle STIG (Security Technical Implementation Guide) Profile is provided in Oracle 12c.

References
My Oracle Support (Metalink) Notes: 276103.1, 296765.1, 287679.1, 1019592.6 (Script Library),
Oracle Database SQL Language Reference, 12c Release 2 (Oracle Corporation).
Oracle Database Advanced Application Developer’s Guide (Oracle Corporation).
Joe Trezzo, “The V$ Arsenal: Key V$ Scripts Every DBA Should Use Regularly” (TUSC).

Joe Trezzo wrote most of this chapter for the original book. Also, thanks to Kevin Gilpin, Rama Balaji, Robert Freeman, Bob Yingst, and Greg Pucka who contributed to this chapter in some way.
CHAPTER 13

The X$ Tables and Internals Topics (Advanced DBA)

Why do people climb mountains? Because they are there! Why do people open the hood of their car and look at what’s inside? Because they can! Why do DBAs look at the X$ tables? Because they are there and they can!

Oracle now has 1312 X$ tables in 12cR2 (there were 945 in 11gR2), and they are the last frontier for the expert DBA to explore and analyze the deepest cavern of the Oracle database.Querying the X$ tables can give secrets to undocumented features and parameters, information about future Oracle versions, and shorter or faster routes to database information. The X$ tables are rarely mentioned in the Oracle documentation or the Oracle user community. Therefore, I am including them in this book as one of the only detailed references available. The queries in this chapter were tested accessing version 12.2 of the database.

The tips covered in this chapter include:

- Introducing the X$ tables
- Creating V$ views and X$ tables in 12c
- X$ tables comprising the V$ views (including V$MEMORY_AREA and V$PDBS)
- Obtaining a list of all the X$ tables in 12c
- Obtaining a list of all the X$ indexes in 12c
- Using hints with X$ tables and indexes
- Monitoring space allocations in the shared pool
- Creating queries to monitor the shared pool
- Obtaining information about redo log files
- Setting initialization parameters and X$KSPPCV (undocumented)
- Exploring buffer cache/data block details
- Obtaining database- and instance-specific information
- Effective X$ table use and strategy
Introducing the X$ Tables

The X$ tables are intriguing to mischievously curious DBAs. There are 1312 X$ tables in 12cR2, compared to only 945 X$ tables in 11gR2 (11.2.0.1). There are also 799 indexes on the X$ tables. Appendix C shows how to list all of these. The Oracle dynamic tables are designed similarly to many of the robust Oracle application data models. A set of tables is available to users (DBAs) via a set of synonyms on a set of views based on these tables. The synonym names start with V$ and are the object names published in the reference manual of the Oracle documentation set. These synonyms on the V$ views are used as the primary method of querying data from these tables. Interested DBAs, however, keep and use a toolkit of practical X$ table queries that supplement their V$ view queries.

The X$ tables contain instance-specific information spanning a variety of areas. They contain information about the current configuration of the instance, information about the sessions connected to the instance, and a gold mine of performance information. The X$ tables are platform-specific. The documented column definitions of the V$ views may be consistent from platform to platform, but the underlying SQL statements referencing the X$ tables may differ. The Oracle kernel consists of layers. The X$ table names contain an abbreviation for the particular kernel layer to which they pertain. They have been expanded for pluggable databases (PDBs) with CON_ID (Container ID) on many current tables/views (new X$ tables such as X$CON) and expanded in 12.1.0.2+ for In-Memory column store (X$KTSIMAU).

The X$ tables are not permanent or even temporary tables that reside in database datafiles. The X$ tables reside only in memory. When you start up your instance, they are created. They exist even before you create your control file. When you shut down your instance, they are destroyed. All 1312 X$ tables are defined right after the instance is started (before mount). They are defined, but they cannot all be queried. Many of them require at least a mounted, if not open, database. To observe this, query the X$KQFTA and X$KQFDT table after starting your instance with the NOMOUNT option.

The X$ tables are owned by the SYS database user and are read-only, which is why they are referred to as fixed tables and the V$ views are referred to as fixed views. This statement might be a juicy invitation for you to try to verify this read-only property. Any attempt to alter these tables with a DDL or DML statement is met with an ORA-02030 error.

Oracle has extensively used the DECODE function in the underlying SQL statements of the data dictionary views. If you compare the V$ view underlying SQL statements from version to version, you will likely find differences in the implementation of some V$ views. The columns of the V$ views may stay more constant in terms of their name and meaning, which allows Oracle RDBMS engineers to change the X$ tables from version to version while not disrupting too much of the Oracle
user community’s use of the V$ views. The fact that the V$ views are accessed through synonyms
gives Oracle engineers another level of flexibility to alter the underlying structures, also with little or
no impact on the user community’s use of the V$ views. Oracle’s extensive use of the DECODE
function in the underlying V$ view SQL statements also facilitates the platform-specific
implementation of a query, returning the generic data that a user of a particular V$ view expects from
platform to platform. Consequently, running the correct scripts when upgrading a database is
important to ensure the dictionary views are created in a way that matches the underlying X$ tables.

NOTE
Application designers and developers may save themselves some development and maintenance
pain by adopting a similar strategy. They can employ views and synonyms for application software
access to an application’s underlying tables and stored programmatic objects (Java and PL/SQL).

Although this section is by no means a complete treatment of useful X$ table queries, it introduces
some of the commonly used X$ table queries, grouped by the major tuning areas to which they
pertain. Because X$ table queries are a supplement to queries of fixed views rather than a
replacement for them, this section includes queries of both X$ tables and related fixed views.

Misconceptions About the X$ Tables

Do not use the X$ tables if you have a heart condition or are an inexperienced DBA—or you may ruin
the entire database. (At least this is what some people will tell you. Sounds pretty scary!)

The most common misconception about the X$ tables is that the DBA can drop one or update one,
thus ruining the database. However, X$ tables cannot be ruined. The only user who can select from
these tables is the SYS user. A SELECT statement is the only command available to be performed on
these X$ tables. An error occurs if you attempt to grant SELECT access to a user. Consider the
following attempts to drop or alter an X$ table in the following listings. In the first listing, you cannot
drop any of the X$ tables (even as the SYS user):

```
connect sys/change_on_install as sysdba
drop table x$ksppi;
ORA-02030: can only select from fixed tables/views
```

In this next listing, you are not able to update, insert, or delete any data in the X$ tables (even as the
SYS user):

```
```
When you mention the X$ tables, most people say, “Oh, pretty scary. I would never touch those tables.” The fact is DML commands (UPDATE, INSERT, DELETE) are not allowed on the X$ tables, even as the SYS superuser in 12cR2 (I tried).

Granting Access to View the X$ Tables

You cannot grant access to the X$ tables even if you are the SYS user. If you try to make grants to the X$ tables, you get the error in the following listing:

```sql
connect sys/change_on_install as sysdba
grant select on X$ksppi to richn;
ORA-02030: can only select from fixed tables/views
```

Although the error message for attempting to grant access to XSKSPPI in the previous code is a little cryptic at first, it clarifies that you can perform only a SELECT and that the grant is not allowed. However, you may build your own X$ views from the original X$ tables and then grant access to those views. Consider the examples in the following six listings, which give access to the X$KSPPI table via a view called X$_KSPPI and a synonym called X$KSPPI.

Connecting to the SYS superuser

```sql
connect sys/change_on_install as sysdba
Connected.

Creating a view mirroring the X$KSPPI table

```sql
create view rich$_ksppi as
select *
from x$ksppi;
View created.
```
Creating a synonym for the newly created view

create public synonym x$_ksppi for rich$_ksppi;
Synonym created.

Granting the desired user access to the newly created view

grant select on x$_ksppi to richn;
Grant succeeded.

Connecting as the desired user

conn richn/tusc
Connected.

Accessing the X$_KSPPI view via the synonym created for X$_KSPPI

select count(*)
from x$_ksppi;

COUNT(*)
46499

You can now give access to the X$ table information without giving the password to the SYS account. The key is creating a view that references the original SYS-owned X$ tables.

TIP
A DBA may need access to the X$ table information, but not the SYS password. Create a view under a different name that mirrors the desired tables. Name these tables according to the appropriate synonyms of the original tables.

Creating V$ Views and X$ Tables in 12c

The X$ tables are virtual or fixed tables, which are created in memory at database startup and maintained real-time in memory. These tables store up-to-date information on the current activity of the database at the current point in time or since the last database startup. In the SGA, V$ views are
created (see Chapter 12) on these X$ tables to allow users to view this information in a more readable format. The X$ tables are fixed tables, and because they have been created in memory, access to these tables is very limited.

The V$ views are known as the virtual tables, fixed tables, V$ tables, dynamic performance tables, and by a half-dozen other names. The first hurdle to understanding the X$ tables is to become familiar with their creation, security, content, and relationship to the V$ views.

In addition, these X$ tables are very cryptic in nature. They are similar to the underlying table construction of the Oracle data dictionary. Therefore, Oracle creates V$ views that are more readable and practical. In addition, Oracle has built other views (USER, DBA, ALL) within the scripts called by the catalog.sql script for easier use. Oracle has also created a public synonym on V$_$ views in the cdfixed.sql file that changes the name back to a view with a prefix of V$. An example of a V$_$ view and the creation of a V$ public synonym in cdfixed.sql is shown here (it resides in the $ORACLE_HOME/rdbms/admin directory):

```sql
create or replace view v$_$datafile as select * from v$datafile;
create or replace public synonym v$datafile for v$_$datafile;
grant select on v$$_$datafile to SELECT CATALOG ROLE;
```

NOTE

See Chapter 12 and Appendix B for detailed V$ view information and Appendix C for detailed X$ information.

Once the catalog.sql file has been executed, the V$ views are available only to users with the SELECT_CATALOG_ROLE privilege. At this point, you can grant access to V$ views by granting SELECT on the V$ view. Therefore, all SELECTs performed against the V$ views are actually retrieving information out of the SGA, more specifically out of the X$ tables. DBAs cannot modify X$ tables in any manner, and they cannot create indexes on these tables. Oracle began providing indexes on the X$ tables in version 8. In addition, the V$ views are the underlying views that are used for Oracle monitoring tools. Here you can see how to get a listing of all V$ views:

```sql
select kqfvinam name
from x$qfvi
order by kqfvinam;
```

Here is the partial output:
Note that the GV$ views are the same as the V$ tables except that you can see multiple instances with Oracle Real Application Clusters (RAC). The only difference between the GV$ and V$ tables is a column that shows the instance ID.

### The X$ Tables Comprising the V$ Views

To obtain a list of the X$ tables that comprise the V$ views, you must access the V$FIXED_VIEW_DEFINITION view. This view shows how the V$ views were created. By knowing which X$ tables comprise a V$ view, you may be able to build a faster query that goes directly to the X$ tables, as shown here (note that the CON_ID [Container ID] column has been added to many X$ tables for pluggable databases; see Chapter 12 for details):

```sql
select * 
from v$fixed_view_definition 
where view_name = 'GV$FIXED_TABLE';
```

Here is the output:
TIP
Access the X$KQFVI table for a listing of all V$ and GV$ views. Access the V$FIXED_VIEW_DEFINITION view to get all of the information regarding the underlying X$ tables that comprise a V$ view, including new views for containers (pluggable databases) and In-Memory column store (see both below).

V$INMEMORY_AREA and X$KTSIMAU in 12cR2
Also consider that there are now parameters and tables related to the INMEMORY setting used with the In-Memory column store (as of 12.1.0.2+). Here is the underlying X$ table behind the X$KTSIMAU view:

```
select * 
from v$fixed_view_definition 
where view_name = 'GV$INMEMORY_AREA';
```

Here is the output:

```
VIEW_NAME_    VIEW_DEFINITION
GV$INMEMORY_AREA select INST_ID, POOL, ALLOCATED_LEN, USED_LEN, STATUS, CON_ID
```

In 12c (12.1.0.2+), KTSIMAU stands for Kernel Transaction Segment In Memory Allocation Unit, which makes use of the GV$INMEMORY_AREA view (and in turn the V$INMEMORY_AREA view). See the section on naming conventions later in this chapter for a full list.

V$CONTAINERS and V$PDBS and X$CON in 12cR2
Also consider that there are now parameters and tables related to PDBs in 12c. Here is the underlying X$ table (X$CON) behind the V$CONTAINERS and V$PDBS views:

```
VIEW_NAME_    VIEW_DEFINITION
GV$INMEMORY_AREA select INST_ID, POOL, ALLOCATED_LEN, USED_LEN, STATUS, CON_ID
```
In 12c, there are new X$ tables for containers. X$CON is the primary X$ for containers that makes use of the V$PDBS and V$CONTAINERS views.

TIP
The X$ tables and V$ views have been expanded for pluggable databases with CON_ID (Container ID) on many current tables/views (new X$ tables such as X$CON) and expanded in 12.1.0.2+ for In-Memory column store (X$KTSIMAU).

Obtaining a List of All the X$ Tables in 12c
The names of the X$ tables are in the X$KQFTA table (which contains 1,275 of the X$ tables), the X$KQFDT table (which contains another 37 of the X$ tables), and the X$KQFVI table, which contains the V$/GV$ as described in the previous section. The V$FIXED_TABLE view combines all three of these tables so you can obtain a listing of any desired grouping. The query in this next listing shows how to obtain a listing of just the 1,312 X$ tables:

```
select * from v$fixed_view_definition
where view name in ('GV$PDBS', 'GV$CONTAINERS');
```
The following query shows output from X$KQFDT, which is a partial listing of the X$ tables:

```
select  name
from    v$fixed_table
where   name like 'X%'
order by name;
```

Following is the partial output (for a complete listing, see Appendix C):

```
NAME
---------------------
X$ABSTRACT_LOB
X$ACTIVECKPT
X$ASH
X$BH
X$BUFFER
X$BUFFER2
X$BUFFERED_PUBLISHERS
X$BUFFERED_QUEUES
X$BUFFERED_SUBSCRIBERS
X$CELL_NAME
... (there are 1312 in Oracle 12cR2)
```

The following query shows output from X$KQFDT, which is a partial listing of the X$ tables:

```
select  kqfdtnam, kqfdtequ
from    x$skqfdt;
```

```
KQFDTNAM                   KQFDTEQU
-------------------------------
X$KSSLTR_CHILDREN          X$KSSLTR
X$KSSLTR_PARENT            X$KSSLTR
X$KCVFONL                 X$KCVF
X$KCVFMR                    X$KCVF
X$KCVFALL                X$KCVF
X$KGLTABLE                 X$KGLOBAL
X$KGLBODY                  X$KGLOBAL
X$KGLTRIGGER               X$KGLOBAL
X$KGLINDEX                X$KGLOBAL
X$KGLCLUSTER               X$KGLOBAL
X$KGLCURSOR                X$KGLOBAL
... (there are 37 in Oracle 12cR2)
```
Obtaining a List of All the X$ Indexes in 12c

If you often query the V$ views or X$ tables for information, you will find it helpful to understand which indexes are being used, as shown here:

```sql
SELECT table_name, index_number, column_name
FROM v$indexfixed_fixed_column
ORDER BY table_name, index_number, column_name, column_position;
```

Here is the partial output:

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NUMBER</th>
<th>COLUMN_NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$ASH</td>
<td>1</td>
<td>NEED_AWR_SAMPLE</td>
</tr>
<tr>
<td>X$ASH</td>
<td>1</td>
<td>SAMPLE_ADDR</td>
</tr>
<tr>
<td>X$ASH</td>
<td>1</td>
<td>SAMPLE_ID</td>
</tr>
<tr>
<td>X$BUFFER</td>
<td>1</td>
<td>OBJNO</td>
</tr>
<tr>
<td>X$BUFFER2</td>
<td>1</td>
<td>OBJNO</td>
</tr>
<tr>
<td>X$DIAG_ADR_CONTROL</td>
<td>3</td>
<td>COLA</td>
</tr>
<tr>
<td>X$DIAG_ADR_INVALIDATION</td>
<td>3</td>
<td>ADR_PATH_IDX</td>
</tr>
<tr>
<td>X$DIAG_ALERT_EXT</td>
<td>3</td>
<td>ADR_PATH_IDX</td>
</tr>
<tr>
<td>X$DIAG_AMS_XACTION</td>
<td>3</td>
<td>ADR_PATH_IDX</td>
</tr>
<tr>
<td>X$DIAG_DDF_USR_ACTION</td>
<td>3</td>
<td>ADR_PATH_IDX</td>
</tr>
<tr>
<td>X$DIAG_DDE_USR_ACTION_DEF</td>
<td>3</td>
<td>ADR_PATH_IDX</td>
</tr>
<tr>
<td>X$DIAG_DDE_USR_ACT_PARAM</td>
<td>3</td>
<td>ADR_PATH_IDX</td>
</tr>
</tbody>
</table>

... (there are 799 X$ indexes in Oracle 12cR2)

Few of the X$ tables have multicolomn indexes, as shown in this listing:
To see the data about the X$ tables from which the information is retrieved, perform this query to the V$FIXED_VIEW definition table:

```sql
SELECT DISTINCT a.table_name, a.index_number, a.column_name, a.column_position
FROM v$indexed_fixed_column a, v$indexed_fixed_column b
WHERE a.table_name = b.table_name
AND a.index_number = b.index_number
AND a.column_name != b.column_name
ORDER BY a.table_name, a.index_number, a.column_position;
```

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>INDEX_NUMBER</th>
<th>COLUMN_NAME</th>
<th>COLUMN_POSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$ASH</td>
<td>1</td>
<td>SAMPLE ADDR</td>
<td>0</td>
</tr>
<tr>
<td>X$ASH</td>
<td>1</td>
<td>SAMPLE_ID</td>
<td>1</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>1</td>
<td>NEED_AWR_SAMPLE</td>
<td>2</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>2</td>
<td>SQUIX KESXMON</td>
<td>3</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>2</td>
<td>EXECD_KESXMON</td>
<td>1</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>2</td>
<td>EXECDSTART_KESXMON</td>
<td>2</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>2</td>
<td>SQUIX KESXMON</td>
<td>3</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>2</td>
<td>EXECD_KESXMON</td>
<td>1</td>
</tr>
<tr>
<td>X$KESXMON</td>
<td>2</td>
<td>EXECDSTART_KESXMON</td>
<td>2</td>
</tr>
<tr>
<td>X$XSF600</td>
<td>1</td>
<td>KTFBUSESEGTSN</td>
<td>0</td>
</tr>
<tr>
<td>X$XSF600</td>
<td>1</td>
<td>KTFBUSESEGFCO</td>
<td>1</td>
</tr>
<tr>
<td>X$XSF600</td>
<td>1</td>
<td>KTFBUSESEGFCO</td>
<td>1</td>
</tr>
<tr>
<td>X$KESKCHUNK</td>
<td>1</td>
<td>KTSLCHUNKTSA</td>
<td>0</td>
</tr>
<tr>
<td>X$KESKCHUNK</td>
<td>1</td>
<td>KTSLCHUNKSFKFCO</td>
<td>1</td>
</tr>
<tr>
<td>X$KESKCHUNK</td>
<td>1</td>
<td>KTSLCHUNKSFCBLKNC</td>
<td>2</td>
</tr>
</tbody>
</table>

To see the data about the X$ tables from which the information is retrieved, perform this query to the V$FIXED_VIEW definition table:

```sql
select * from v$fixed_view_definition
where view_name = 'GV$INDEXED_FIXED_COLUMN';
```

Here is the output (notice the CON_ID column in 12c for containers):

<table>
<thead>
<tr>
<th>VIEW_NAME</th>
<th>VIEW DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>V$INDEXED FIXED COLUMN</td>
<td>select c.inst id, kqftanam, kqfcoidx, kqfconam, kqfcoipo, c.con_id</td>
</tr>
<tr>
<td></td>
<td>from x$qfco c, x$qfta t</td>
</tr>
<tr>
<td></td>
<td>where t.indx = c.kqftcotab</td>
</tr>
<tr>
<td></td>
<td>and kqfcoidx != 0</td>
</tr>
</tbody>
</table>
Using Hints with X$ Tables and Indexes

As with other tables, you can also use hints with the X$ tables to achieve greater performance. The queries in the next two listings show the EXPLAIN PLAN and statistics while changing the driving table using an ORDERED hint. Note that I am using aliases for the tables and would need to hint the alias (and not the table) if I used a hint requiring the table (such as the index hint). The ORDERED hint does not require the table name but accesses tables in the order listed in the FROM clause.

Forcing the X$KSBDP table as the driving table

```
select /* ordered */ p.ksbdppro, p.ksbdpnam,
       d.ksbdppro, d.ksbdpnam
from x$ksbd p, x$ksbd d
where p indx = d indx;
```

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost</th>
<th>%CPU</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>100</td>
<td>2600</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
<tr>
<td>1</td>
<td>NESTED LOOPS</td>
<td></td>
<td>100</td>
<td>2600</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
<tr>
<td>2</td>
<td>FIXED TABLE FULL</td>
<td>X$KSBDP</td>
<td>100</td>
<td>4700</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
<tr>
<td>3</td>
<td>FIXED TABLE FIXED INDEX</td>
<td>X$KSBD (ind:1)</td>
<td>1</td>
<td>36</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
</tbody>
</table>

Using the ordered hint to force the driving table to be X$KSBDP

```
select /* ordered */ p.ksbdppro, p.ksbdpnam,
       d.ksbdppro, d.ksbdpnam
from x$ksbdp p, X$KSBD d
where p indx = d indx;
```

<table>
<thead>
<tr>
<th>Id</th>
<th>Operation</th>
<th>Name</th>
<th>Rows</th>
<th>Bytes</th>
<th>Cost</th>
<th>%CPU</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SELECT STATEMENT</td>
<td></td>
<td>100</td>
<td>2600</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
<tr>
<td>1</td>
<td>NESTED LOOPS</td>
<td></td>
<td>100</td>
<td>2600</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
<tr>
<td>2</td>
<td>FIXED TABLE FULL</td>
<td>X$KSBDP</td>
<td>100</td>
<td>3600</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
<tr>
<td>3</td>
<td>FIXED TABLE FIXED INDEX</td>
<td>X$KSBD (ind:2)</td>
<td>1</td>
<td>47</td>
<td>0</td>
<td>(0)</td>
<td>0:00:01</td>
</tr>
</tbody>
</table>

TIP

Access the V$INDEXED_FIXED_COLUMN view for a listing of all X$ table indexes.
Oracle generally uses the indexes as needed, but from time to time, you may use hints to achieve a desired result.

Monitoring Space Allocations in the Shared Pool

You can use the X$KSMLRU table to monitor space allocations in the shared pool that may be causing space allocation contention. The relevant columns in this table are as follows:

<table>
<thead>
<tr>
<th>Column</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADDR</td>
<td>Address of this row in the array of fixed tables</td>
</tr>
<tr>
<td>INDX</td>
<td>Index number of this row in the array of fixed tables</td>
</tr>
<tr>
<td>INST_ID</td>
<td>Oracle instance number</td>
</tr>
<tr>
<td>KSMLRCOM</td>
<td>Description of allocation type</td>
</tr>
<tr>
<td>KSMIRSIZ</td>
<td>Size in bytes of the allocated chunk</td>
</tr>
<tr>
<td>KSMLRNUM</td>
<td>Number of items flushed from the shared pool to allocate space</td>
</tr>
<tr>
<td>KSLRHON</td>
<td>Name of the object being loaded</td>
</tr>
<tr>
<td>KSMLROIIV</td>
<td>Hash value of the object being loaded</td>
</tr>
<tr>
<td>KSMIRSES</td>
<td>Session performing the allocation, joins to V$SESSION.SADDR</td>
</tr>
</tbody>
</table>

You can use the X$KSMSP table to examine the current contents of the shared pool:

```sql
select ksmchcls class, sum(ksmchlsiz) memory
from X$ksmsp
group by ksmchcls;
```

<table>
<thead>
<tr>
<th>CLASS</th>
<th>MEMORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-free</td>
<td>16,857,968</td>
</tr>
<tr>
<td>R-freea</td>
<td>2,119,144</td>
</tr>
<tr>
<td>R-recr</td>
<td>3,985,736</td>
</tr>
<tr>
<td>free</td>
<td>5,660,160</td>
</tr>
<tr>
<td>freeabl</td>
<td>71,699,564</td>
</tr>
<tr>
<td>perm</td>
<td>175,106,600</td>
</tr>
<tr>
<td>recr</td>
<td>43,330,536</td>
</tr>
</tbody>
</table>

When you use the X$KSMSP table to examine the current contents of the shared pool, each row represents a chunk of memory in the shared pool. The relevant columns in this table are as follows (note that the preceding query groups the chunks into classes via the ksmchcls command):
Creating Queries to Monitor the Shared Pool

The shared pool is often a key area impacted by performance. This section focuses on queries that help you investigate the shared pool.

ORA-04031 Errors

V$SHARED_POOL_RESERVED.REQUEST_FAILURES [or SUM(X$KGHLU.KGHLUNFU)] gives the number of ORA-04031 errors that have occurred since the instance was started. If any ORA-04031 errors are occurring, then SHARED_POOL_SIZE and/or JAVA_POOL_SIZE are too small, the shared pool is fragmented, or application code may not be being shared optimally. The query in this listing checks the ORA-04031 errors that have occurred since the instance was started. Also, see Chapter 4 for setting parameters related to automating memory management, including MEMORY_TARGET, MEMORY_MAX_TARGET, and/or SGA_TARGET.
If any ORA-04031 errors have occurred, then some SHARED_POOL_SIZE, JAVA_POOL_SIZE, and/or application tuning is in order. Consider one or more of the following:

- Pin large, high-use [high values for X$KSMLRU.KSMLRSIZ, COUNT(X$KSMLRU.KSMLRHON), and/or X$KSMLRU.KSMLRNUM] PL/SQL packages in memory with DBMS_SHARED_POOL.KEEP:
  
  ```sql
  EXECUTE dbms_shared_pool.keep('PACKAGENAME');
  ```

- Pin large, high-use Java classes with DBMS_SHARED_POOL.KEEP. You can pin a Java class by enclosing it in double quotes:
  
  ```sql
  EXECUTE dbms_shared_pool.keep('“FullJavaClassName”', 'JC');
  ```

### TIP

Enclose the class in double quotes if it contains a slash (/); otherwise, you will get an ORA-00995 error.

- Increase the size of the shared pool by increasing the SHARED_POOL_SIZE initialization parameter if the percentage of shared pool free memory is low and there is contention for library cache space allocation and/or more than zero occurrences of the ORA-04031 error. A section of Chapter 4 notes that increasing the shared pool is not always recommended if a low amount of shared pool memory is observed. If you are increasing the size of the shared pool, you might also need to raise the value of the parameters MEMORY_TARGET, MEMORY_MAX_TARGET, and/or SGA_TARGET (see Chapter 4 for additional information).

- Increase the size of the shared pool reserved area by increasing the SHARED_POOL_RESERVED_SIZE initialization parameter (the default is 5 percent of SHARED_POOL_SIZE).

- Promote the sharing of SQL, PL/SQL, and Java code by application developers.

---

### Large Allocations Causing Contention

The object being loaded (X$KSMLRU.KSMLRHON) is a *keep* candidate (consider keeping it with DBMS_SHARED_POOL.KEEP) if the X$KSMLRU.KSMLRCOM value is MPCODE or PLSQL%

If you use features such as Shared Servers (previously called MTS), Recovery Manager, or Parallel Query, you should configure a larger shared pool and also configure a large pool that is bigger than the default. These features will create large allocations in the shared pool and use the
large pool instead if it is large enough.

---

-- Amount of each type of shared pool allocation causing contention.

```
SELECT  ksmrcom, SUM(ksmlrsiz)
FROM    x$ksmrlru
GROUP BY ksmrcom;

<table>
<thead>
<tr>
<th>KSMRCOM</th>
<th>SUM(KSMLRSIZ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>qkxrc.e.kgghr</td>
<td>4156</td>
</tr>
<tr>
<td>idndef : qcuAllocId</td>
<td>4096</td>
</tr>
</tbody>
</table>
```

**TIP**

If $X$KSMLR.U.KSMLRCOM is similar to Fixed UGA, then a high amount of session-specific allocation is occurring, which suggests that OPEN_CURSORS may be set too high. This is relevant only in cases where Shared Servers are being used.

---

Shared Pool Fragmentation

This section takes a closer look at the shared pool using a plethora of queries to help you conduct detailed investigations when needed. (The shared pool is also discussed in detail in Chapter 4.) The shared pool may be fragmented if you observe a large number of entries in X$KSMLRU, particularly a large number of them with small KSMLRSIZ values, or if you observe many chunks of type “free” in X$KSMSP. Contrast this with a large number of entries in X$KSMLRU with medium to high values of KSMLRSIZ, which is not likely to be a symptom of a fragmented shared pool; rather, it indicates that large PL/SQL packages and/or Java classes need to be kept in the shared pool and possibly also that the shared pool itself is too small, and perhaps that application code is not being effectively shared (or some combination thereof). In identifying the problem, take the time to monitor the application code use over time to find out which code the user sessions are attempting to load. Network with application users, developers, designers, and application vendors. The queries in the following listings will help you find contention and fragmentation issues.

Finding contention and fragmentation issues

---

-- Names of and sessions for shared pool allocations causing contention.

```
SELECT  ksmrcom, ksmrsiz, ksmrses
FROM    x$ksmrlru
WHERE   ksmrsiz > 1000
ORDER BY ksmrsiz;
```
Fragmentation of shared pool

Following is the output on a smaller system:

<table>
<thead>
<tr>
<th>ChnkClass</th>
<th>SumChunkTypeMem</th>
<th>LargestChkOfThisTyp</th>
<th>NumOfChksThisTyp</th>
<th>PctTotSPMem</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-frocn</td>
<td>59000</td>
<td>21984</td>
<td>173</td>
<td>0%</td>
</tr>
<tr>
<td>R-recn</td>
<td>3977156</td>
<td>3977156</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>R-perm</td>
<td>16553296</td>
<td>4193168</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>R-free</td>
<td>21397980</td>
<td>2097032</td>
<td>65</td>
<td>6%</td>
</tr>
<tr>
<td>free</td>
<td>31038572</td>
<td>2396208</td>
<td>8893</td>
<td>9%</td>
</tr>
<tr>
<td>perm</td>
<td>51740844</td>
<td>2981312</td>
<td>29</td>
<td>15%</td>
</tr>
<tr>
<td>recn</td>
<td>86619156</td>
<td>44908</td>
<td>40129</td>
<td>24%</td>
</tr>
<tr>
<td>freeabl</td>
<td>146125076</td>
<td>334348</td>
<td>46223</td>
<td>42%</td>
</tr>
</tbody>
</table>

8 rows selected.

Next is the output on a larger Linux system (12cR2):
Information about SHARED_POOL_RESERVED_SIZE

--- Information regarding shared_pool_reserved_size.
SELECT free_space, free_count, max_free_size, max_used_size,
       request_misses, max_miss_size
  FROM v$shared_pool_reserved;

--- Amount of shared pool free memory.
SELECT *
FROM v$sgastat
WHERE name = 'free memory'
  AND pool = 'shared pool';

Amount of Java pool free memory
Library Cache Memory Use

A low library cache hit ratio is a symptom of one of several problems. The shared and/or Java pools may be too small; the SHARED_POOL_RESERVED_SIZE may be too small; CURSOR_SHARING may need to be set to FORCE; there may be inefficient sharing of SQL, PL/SQL, or Java code; or there may be insufficient use of bind variables. Investigate which application code is being used over time and how efficiently it is used (code sharing). Monitor the shared and Java pool “free space” over time. If the amount of free memory in the shared and Java pools is relatively high, no ORA-04031 errors are occurring, and the library cache hit ratio is low, then poor code sharing is probably occurring. The queries in the following listings help you investigate this area. I include some V$ view queries here because of the applicable nature to this subject.

```sql
-- Amount of java pool free memory.
SELECT *
  FROM v$sgastat
WHERE name = 'free memory'
AND pool = 'java pool';
```

<table>
<thead>
<tr>
<th>POOL</th>
<th>NAME</th>
<th>BYTES</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>java pool</td>
<td>free memory</td>
<td>44626369</td>
<td>0</td>
</tr>
</tbody>
</table>

```sql
-- Library cache hit ratio.
SELECT ROUND(SUM(pinhits)/SUM(pins),2)*100||'%' "Library Cache Hit Ratio"
FROM v$librarycache
ORDER BY namespace;
```

Library Cache Hit Ratio
------------------------
90%

Library cache reload ratio (note PDB is now a namespace)
-- Library cache reload ratio.
SELECT namespace,
    ROUND(DECODE(pins,0,1,rounds/pins),2)*100 || '%' "Reload Ratio"
FROM v$librarycache;

<table>
<thead>
<tr>
<th>NAMESPACE</th>
<th>Reload Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQL AREA</td>
<td>1%</td>
</tr>
<tr>
<td>TABLE/PROCEDURE</td>
<td>4%</td>
</tr>
<tr>
<td>BODY</td>
<td>0%</td>
</tr>
<tr>
<td>TRIGGER</td>
<td>0%</td>
</tr>
<tr>
<td>INDEX</td>
<td>12%</td>
</tr>
<tr>
<td>CLUSTER</td>
<td>0%</td>
</tr>
<tr>
<td>DIRECTORY</td>
<td>0%</td>
</tr>
<tr>
<td>QUEUE</td>
<td>0%</td>
</tr>
<tr>
<td>RULESET</td>
<td>0%</td>
</tr>
<tr>
<td>TEMPORARY TABLE</td>
<td>76%</td>
</tr>
<tr>
<td>TEMPORARY INDEX</td>
<td>19%</td>
</tr>
<tr>
<td>EDITION</td>
<td>0%</td>
</tr>
<tr>
<td>DDLINK</td>
<td>0%</td>
</tr>
<tr>
<td>OBJECT ID</td>
<td>0%</td>
</tr>
<tr>
<td>SCHEMA</td>
<td>0%</td>
</tr>
<tr>
<td>DBINSTANCE</td>
<td>0%</td>
</tr>
<tr>
<td>SQL AREA STATS</td>
<td>0%</td>
</tr>
<tr>
<td>ACCOUNT_STATUS</td>
<td>0%</td>
</tr>
<tr>
<td>SQL AREA BUILD</td>
<td>0%</td>
</tr>
<tr>
<td>PDB</td>
<td>0%</td>
</tr>
<tr>
<td>AUDIT POLICY</td>
<td>0%</td>
</tr>
<tr>
<td>USER PRIVILEGE</td>
<td>0%</td>
</tr>
<tr>
<td>FED APP</td>
<td>0%</td>
</tr>
<tr>
<td>CMP</td>
<td>0%</td>
</tr>
</tbody>
</table>

Library cache high-use objects (make this a top 10 list by adding WHERE ROWNUM<11)

-- Library cache high-use objects (You may want to limit listing).
SELECT name, type
FROM v$db_object_cache
ORDER BY executions;

Library cache object sizes

-- Library cache object sizes (you may want to limit listing).
SELECT *
FROM v$db_object_cache
ORDER BY sharable_mem;
Shared pool object sharing efficiency (you may want to limit these)

A high percentage of reloads indicates that the shared and/or Java pools are too small, code sharing is insufficient, and possibly also large code objects are repeatedly being used. Monitor the application code used over time. If particular large code objects are identified as frequently used, consider pinning them and/or increasing the size of the SHARED_POOL_RESERVED_SIZE. If features such as Shared Servers, Recovery Manager, or Parallel Query are used, consider a larger SHARED_POOL_SIZE and/or larger LARGE_POOL_SIZE (if setting parameters like MEMORY_TARGET and/or SGA_TARGET, please refer to Chapter 4 and ensure you always set a
High Number of Hard Parses

You should review similar queries with low numbers of executions to uncover opportunities to combine them into statements using bind variables. A high ratio of hard parses may mean that the shared pool itself is too small or perhaps a SQL statement is repeatedly nudging other code out of the precious shared pool or Java pool cache space. Identify these statements and consider pinning. Consider also setting the parameter CURSOR_SHARING = FORCE. The next listing shows various queries to view parse activity:
Mutex/Latch Waits and/or Sleeps

If mutex (mutual exclusion; see Chapter 14 for detail on mutexes) or latch waits are high but shared and Java pool free space is also high, consider reducing the size of the shared and/or Java pools. When this happens, it could indicate that sessions are spending time scanning the unnecessarily large list of free shared pool chunks (be very careful before you do this—the goal is to get everything in memory—so ensure that you have enough allocated). Monitor the amount of shared and Java pool free space over time. If ample free space is available in these pools and no ORA-04031 errors are occurring, consider reducing the sizes of these pools. Investigate when the miss ratio and sleeps are high for any of the mutexes/latches in the following list:
Row cache objects
Library cache
Shared pool
Shared Java pool

If free space in the shared and Java pools is low, then you should consider the other tuning areas, such as increasing the shared and/or Java pools, pinning objects, and combining similar SQL statements to use bind variables. The query in the next listing helps you acquire some of these metrics. A mutex (which replaced many types of library cache latches other than the library load lock latch) is used to eliminate the possibility of two processes simultaneously using a common resource (while one or both are trying to change it); when one session is changing it, the second can’t view it or change it, and when one session is viewing it, the second can’t change it.

Oracle moved from latches to mutexes in some areas of the library cache because mutexes are lighter weight and provide more granular concurrency than latches. Mutexes require less memory space and fewer instructions. Oracle uses mutexes instead of library cache latches and library cache pin latches to protect objects in the library cache. With a mutex, if I have the resource and you can’t get it after trying a specified number of times asking (spins), you sleep and try again a very short time later. Use the V$MUTEX_SLEEP view (covered in Chapter 12) in addition to the V$LATCH query listed next to query mutex/latch information:

```sql
SELECT name,
       ROUND(misses/decode(gets,0,1,gets),2)*100 || '%' as "WillWaitMissRatio",
       ROUND(immediate_misses/decode(immediate_gets,0,1,
                                      immediate_gets),2)*100 || '%' "ImmMissRatio",
       sleeps
FROM vslatch
WHERE name in ('row cache objects', 'shared pool');
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>WillWaitMissRatio</th>
<th>SLEEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ImmMissRatio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>row cache objects</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>shared pool</td>
<td>0%</td>
<td>0</td>
</tr>
</tbody>
</table>

No issues occur in the output above (minimal sleeps). Remember that before increasing the SHARED_POOL_SIZE, you should consider whether there are any shared pool or library latch/mutex waits. Depending on what you observe, it may actually be more appropriate to reduce the size of the shared pool, for instance, if you have a sufficient amount of free shared pool memory available, a low number of reloads, and a high number of shared pool latch waits. The reason to
consider reducing the shared pool in this case is that, with an oversized shared pool, sessions will hold the shared pool latch slightly longer than is needed otherwise because the shared pool needs to scan a larger amount of space to determine exactly where to allocate the space it is requesting. Fixing the issues causing a shared pool issue and then ensuring it is large enough to fit all statements in memory is a key to good performance. Fix the problem and then make sure the shared pool is large enough (too many people make it way too small and problems occur!).

Miscellaneous X$ Table Notes

After exhausting the previously discussed shared and Java pool tuning options, you could consider some undocumented parameters. The number of the library cache hash table bucket count can be increased by setting _KGL_BUCKET_COUNT (see Appendix A for more information on the undocumented initialization parameters); note that 9 (the default) puts this at 

\[(2 \times 2^{9}) \times 256 - 1 = 131,071\]

which should be more than enough for most systems. Oracle 12c still has an _KGL_LATCH_COUNT parameter. Remember that you should never set the underscore parameters without direction from Oracle Support. In 12c, each library cache bucket (131,071) is protected by a mutex! Also, in 12c, the _KGL_LATCH_COUNT is set at 0 and probably doesn’t need to be set, but consult with Oracle Support before setting this.

Adjusting this parameter is, as with all undocumented parameters, unsupported by Oracle. Implement such changes only under the direction of Oracle Support and after thoroughly testing under direct simulation of production conditions.

Note that any particular database may experience conditions that are a combination of two or more of the previous conditions. Frequently, you must evaluate multiple conditions and decide on two or more potential corrective measures.

Also note that after each query on X$KSMLRU, the values in this table are reset to zero. To effectively monitor the table, consider capturing the contents of it to a permanent table with an INSERT INTO … AS SELECT … statement or by simply spooling the output to a file. Furthermore, whenever you query X$KSMLRU, you might always want to select all of the columns instead of just one or the few you might be interested in at a particular moment; otherwise, you may miss some information that you later decide you want to see.

CAUTION

When “resetting” the X$KSMLRU table, note rows may still be in this table after each query. Do not interpret the remaining rows appearing after each query as entries pertaining to contention-causing code, but rather to preallocated entries in this table. If no problem statements are in X$KSMLRU, then the KSMLRHON and KSMLRSIZ values are NULL and zero, respectively. If they are non-NULL, then these rows pertain to contention-causing code. Make sure multiple DBAs do not simultaneously query X$KSMLRU, because each of them may observe misleading results.

Remember that when you decide to alter initialization parameters to remedy performance
problems, you can now alter many of them by using an ALTER SYSTEM command. Despite the ease of doing this, you should first test such changes on a test system. For example, if you attempt to make the SHARED_POOL_SIZE too small, the SQL*Plus session may hang and/or consume a large amount of memory and CPU resources during the execution of the ALTER SYSTEM command. Or, prior to Oracle9i, if you set the KGL_LATCH_COUNT parameter too high, you get an ORA-600 [17038] error when you next tried to start the database. The point here is to be careful and know what you’re doing before changing any of these parameters.

Obtaining Information About Redo Log Files

The X$KCCCP table contains information about the current redo log file. The X$KCCCLE table contains information about all redo log files, as shown here:

```
-- Percentage full of the current redo log file.
SELECT ROUND( (cpodr_bno/lesiz)*100 || '%' , PCTCURLogFull FROM x$kcccp a, x$kccl e b
WHERE a.cpodr_seq = leseq;
```

If you observe in V$LOG_HISTORY or in the “log file space waits” statistic that log switches are occurring more frequently than is appropriate for your database, you may decide to alter the redo log file configuration. You can perform this task while the database is open to users and all tablespaces are online. If you want to minimize the impact on database performance while this or other similar maintenance is performed that involves a DBA-induced log switch with the ALTER SYSTEM SWITCH LOG FILE command, you can use the query in the preceding listing to measure how much redo log information has to be copied to complete the archive of the current log file. This is particularly relevant in cases of databases with large redo log files (500M or larger).

You can also use this query as a tuning aid to measure how much redo activity is created by a particular transaction or process, if it is possible to isolate a particular database to one session that is guaranteed as the only creator of redo records, other than Oracle itself. Capturing before and after results of this query, when testing (such a transaction), may be useful.

Setting Initialization Parameters

The SPFILE allows DBAs to make persistent initialization parameter changes with the ALTER SYSTEM command without having to incorporate these changes manually into a traditional parameter file, or PFILE, to implement the persistence of the parameter change. SPFILEs also allow the DBA to save the current instance configuration instantaneously to a file for archival or backup purposes. This flexibility introduces a bit of initialization parameter management complexity in that the Oracle instance can be started with either a PFILE or an SPFILE. This complexity raises a few questions for
the DBA when managing initialization parameters. The DBA must know what Oracle will use as an initialization parameter file at instance startup time, where the initialization parameters will be saved when an ALTER SYSTEM … SCOPE=SPFILE or ALTER SYSTEM … SCOPE=BOTH command is issued, and whether a currently running Oracle instance was started using a PFILE, an SPFILE, or both.

If the SPFILE in the platform-specific default location with the platform-specific default name exists, then Oracle uses it to start the instance. To get Oracle to use an SPFILE other than the one residing in the default location with the default filename, you must first rename, relocate, or delete this default SPFILE, and then relocate and/or rename the desired SPFILE from the nondefault location to the default location and name. Alternatively, you can specify this nondefault SPFILE in the SPFILE initialization parameter in a PFILE that is used to start the instance.

Note that the concept of the platform-specific default name and location for the PFILE still exists; this concept is used if no SPFILE is in the SPFILE default location and name. As in pre–Oracle9i versions, you can use a nondefault PFILE to start an instance with the PFILE option of the STARTUP command. These are the only ways that Oracle will use a nondefault parameter file to start the instance. There is no STARTUP SPFILE command. SPFILEs and PFILEs are not interchangeable. SPFILEs are (mostly) binary files that can be altered only with ALTER SYSTEM commands and can be created only with CREATE SPFILE commands.

As in pre-Oracle9i versions, PFILEs are simply text files that may be created and altered with a text editor. An attempt to use an SPFILE in the STARTUP PFILE command will result in an ORA-01078 error. If an instance was started with an SPFILE, then any changes made using the ALTER SYSTEM … SCOPE=SPFILE command or ALTER SYSTEM … SCOPE=BOTH command are saved to the SPFILE that was used to start the instance, even if the default SPFILE exists and was not used to start the instance. If both a PFILE and an SPFILE are used to start an Oracle instance, Oracle overrides any parameters specified in the PFILE with those specified in the SPFILE, if any conflicts occur.

The question of which file was used to start an Oracle instance has five possible answers:

- On startup, the database first looks for spfile<SID>.ora in the default location, and then looks for spfile.ora in the default location. An SPFILE in the default location was used with the default name and no PFILE was used.
- A PFILE in the default location with the default name was used and a nondefault SPFILE was used.
- A nondefault PFILE was used and a nondefault SPFILE was used.
- A PFILE in the default location with the default name was used and no SPFILE was used.
- A nondefault PFILE was used and no SPFILE was used.

**NOTE**

Both an SPFILE and a PFILE may have been used to start an instance, however. Check the following queries in the order listed to answer the question of which files may have been used for...
the initialization parameters to start the instance.

## Case 1

Run the query in this listing to check for SPFILE-specified initialization parameters:

```sql
-- Check for spfile specified initialization parameters.
SELECT count(*) FROM v$spparameter WHERE isspecified = 'TRUE';
```

Or simply use the SQL*Plus command `SHOW PARAMETER SPFILE`. This tells you exactly which SPFILE was used to start the database (gets set automatically when the database is started without specifying a PFILE or SPFILE). If you start the database with the PFILE option, then this parameter is NULL. The following is the equivalent to the query in the preceding listing but involves less typing:

```sql
SQL> SHOW PARAMETER SPFILE
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>spfile</td>
<td>string</td>
<td>/u01/app/oracle/product/12.2.0/db home 1/dbs/spfileorcl.ora</td>
</tr>
</tbody>
</table>

## Case 2

Run this query to determine which SPFILE was used to start the instance:

```sql
-- Determine which spfile was used to start the instance.
SELECT value FROM v$parameter WHERE name = 'spfile';
```

Look for a PFILE in the default location. If the SPFILE parameter value from the query in the preceding listing (to V$PARAMETER) is non-NULL and the value is not the default value for the SPFILE, then a PFILE was used, and it specified an alternate SPFILE in the SPFILE parameter. If this
Case 3

If the SPFILE parameter value from the query in the Case 2 listing (to V$PARAMETER) is non-NULL and the value is not the default value for the SPFILE, then a PFILE was used, and it specified an alternate SPFILE in the SPFILE parameter. If this is the case and if the default PFILE does not exist, then you must determine the location of the nondefault PFILE. See Case 5.

Case 4

If the SPFILE parameter value from the query in the listing in Case 2 (to V$PARAMETER) is NULL, then a PFILE was used and no SPFILE was used. If this is the case and if the default PFILE exists, then it was used to start the instance.

Case 5

If it is determined from Cases 1 through 3 that no SPFILE was used at all, and that the default PFILE was not used, then the remaining possibility is that a nondefault PFILE was used and no SPFILE was used. Many site-specific possibilities exist for a nondefault PFILE. A database startup, shutdown, or backup script, a third-party backup or database management software package, or a site-specific Oracle software directory structure may give a clue to what this file is. If there is uncertainty about this file, you can save the existing configuration initialization parameters by querying some of the Oracle X$ tables pertinent to initialization parameters. There is also the possibility that OEM, which can store a local copy of the parameter file, started the database.

Several X$ tables are relevant to initialization parameters: X$KSPSPFILE, X$KSPPSV, X$KSPPSV2, X$KSPPCV, X$KSPPCV2, X$KSPPI, and X$KSPPO. The X$KSPSPFILE table lists the contents of the SPFILE. The V$SPPARAMETER view, which is based on the X$KSPSPFILE table, excludes parameter names that start with an underscore, unless such “underscore” or “undocumented” parameters were explicitly specified in an SPFILE, in a PFILE, or with an ALTER SYSTEM command and/or Oracle had to modify the DBA-specified value to fit a functional requirement of the parameter, such as a requirement that a particular parameter value be a prime number or a multiple of another DBA-specified parameter value, for example. To see all the parameter names, including those that the V$SPPARAMETER view excludes, query the X$KSPSPFILE table.

Note that if an SPFILE was not used to start an instance, then all of the values in the KSPSPFFTCTXSPVALUE column of X$KSPSPFILE are NULL and all of the values in the KSPSPFFTCTXISSPECIFIED column are FALSE. Conversely, if an SPFILE was used to start an instance, the values in the KSPSPFFTCTXISSPECIFIED column for which the particular parameter
was specified in the SPFILE are TRUE and the value in the KSPPSPFFTCTXSPVALUE column for such parameters is a non-NULL value.

The X$KSPPSV table lists the parameter names and values that are currently in effect for the instance. The V$SYSTEM_PARAMETER view, which is based on the X$KSPPSV table, excludes parameters that start with an underscore and have not been modified from their default value.

The X$KSPPSV2 table is very similar to the X$KSPPSV table. The difference is in how parameter values are stored that consist of lists of values. This table, like the X$KSPPSV table, lists parameters and parameter values that are currently in effect for this Oracle instance. A new session inherits parameter values from the system values. Each list parameter value appears as a separate row in the table. Presenting the list parameter values in this format enables you to quickly determine the values for a list parameter. For example, if a parameter value is “a,b” looking at X$KSPPSV does not tell you whether the parameter has two values (“a” and “b”) or one value (“a,b”). X$KSPPSV2 makes the distinction between the list parameter values clear. Correspondingly, the V$SYSTEM_PARAMETER2 view is based on the X$KSPPSV2 table.

The X$KSPPCV and X$KSPPCV2 tables are similar to the X$KSPPSV and X$KSPPSV2 tables, except that the X$KSPPCV and X$KSPPCV2 tables apply to the current session, not necessarily the whole instance. If a parameter is changed with an ALTER SESSION command, the change is reflected in the X$KSPPCV and X$KSPPCV2 tables. The V$PARAMETER and V$PARAMETER2 fixed views are based on the X$KSPPCV and X$KSPPCV2 tables, respectively.

The X$KSPPPI table lists the initialization parameter names, types, and statuses. The V$PARAMETER, V$PARAMETER2, V$SYSTEM_PARAMETER, and V$SYSTEM_PARAMETER2 fixed views are based on the X$KSPPCV, X$KSPPCV2, X$KSPPSV, and X$KSPPSV2 tables; each of these X$ tables is joined with the X$KSPPPI table in these fixed views to get the associated parameter names and other information. The query in this next listing is the query on which V$SYSTEM_PARAMETER is based, excluding the line in V$SYSTEM_PARAMETER that excludes parameter names that start with an underscore. The underlying SQL statements of the V$PARAMETER, V$PARAMETER2, and V$SYSTEM_PARAMETER2 fixed views have the same structure as the query in the listing in Case 2 described previously.

```
-- All initialization parameter settings in effect for the instance.
SELECT x.indx+1 InstanceNum,
       ksppinn ParamName,
       ksppity ParamType,
```
The V$OBSOLETE_PARAMETER fixed view, which is based on the X$KSPPO table, lists obsolete initialization parameters. For some of these, such as SPIN_COUNT, you may note that they are now undocumented parameters.

Exploring Buffer Cache/Data Block Details

Four key performance-related buffer cache topics are the current buffer statuses, the identification of segments that are occupying the block buffers, the detection of hot (popular or high contention) data blocks, and the cause of buffer-cache-related latch contention and wait events. These topics are relevant to buffer cache tuning in all Oracle versions, but there are additional considerations in Oracle8, 8i, and 9i. Oracle8 introduced the concept of multiple buffer pools. Oracle9i introduced the concept of multiple data block sizes and, therefore, the need for multiple buffer cache buffer sizes. This continues in 12cR2.

The X$ tables are used in the buffer-cache-related queries that follow:

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$B11</td>
<td>Status and number of pings for every buffer in the SGA; has one row for every block in memory used for data (set with DB_CACHE_SIZE)</td>
</tr>
<tr>
<td>X$KCBWDS</td>
<td>Statistics on all buffer pools available to the instance</td>
</tr>
<tr>
<td>X$KCBWBPD</td>
<td>Statistics on all buffer pools available to the instance, including buffer pool names</td>
</tr>
<tr>
<td>X$KCBWAIT</td>
<td>Number of and time spent in waits for buffer pool classes</td>
</tr>
<tr>
<td>X$KCBFWAIT</td>
<td>Buffer cache wait count and time by file</td>
</tr>
</tbody>
</table>
Buffer Statuses

A low number of buffers with a status of “Free” in X$BH does not necessarily mean that the buffer cache is undersized. It may, in fact, mean that the buffer cache is optimally sized such that Oracle will not have to perform frequent organization and maintenance on a superfluous number of buffers. Unfortunately, this same thought process leads many DBAs to undersize the buffer cache and leave memory sitting idle on their system. Similarly, if a large percentage of buffers are consistently free, then perhaps the buffer cache is oversized. See the subsequent sections discussing buffer cache contents, latches, and wait events for a better indication of the proper sizing and configuration of the buffer cache as it relates to the segments that are being used. Tuning and looking at Oracle at the block level is covered in detail in Chapter 9. The query in this listing shows how to see the state of the buffers in the buffer cache:
-- Buffer cache buffer statuses.
SET VERIFY off
COLUMN PctTotBCMem for all
SELECT /*+ ordered */
    tot_bc_mem.TotBCMem,
    decode(state,
        0,'Free',
        1,'Exclusive',
        2,'SharedCurrent',
        3,'ConsistentRead',
        4,'BeingRead',
        5,'InMediaRecoveryMode',
        6,'InstanceRecoveryMode',
        7,'BeingWritten',
        8,'Pinned',
        9,'Memory',
        10,'Write',
        11,'Donated',
        12,'protected',
        13,'securefile',
        14,'siop',
        15,'recckpt',
        16,'flashfree',
        17,'flashcur',
        18,'flashna') "BlockState",
    SUM(blsiz) "SumStateTypeMem",
    COUNT(1) "NumOfBlksThisTyp",
    ROUND(SUM(blsiz)/tot_bc_mem.TotBCMem,2)*100||"%" "PctTotBCMem"
FROM (SELECT sum(blsiz) TotBCMem
    FROM x$bh) tot_bc_mem,
    x$bh
GROUP BY tot_bc_mem.TotBCMem,
    decode(state,
        0,'Free',
        1,'Exclusive',
        2,'SharedCurrent',
        3,'ConsistentRead',
        4,'BeingRead',
        5,'InMediaRecoveryMode',
        6,'InstanceRecoveryMode',
        7,'BeingWritten',
        8,'Pinned',
        9,'Memory',
        10,'Write',
        11,'Donated',
        12,'protected',
        13,'securefile',
        14,'siop',
        15,'recckpt',
        16,'flashfree',
        17,'flashcur',
        18,'flashna') "BlockState"
Here is a quick reference listing the buffer states in X$BH:

```
ORDER BY SUM(blksiz);
CLEAR COLUMNS

<table>
<thead>
<tr>
<th>TOTBCMEM</th>
<th>BlockState</th>
<th>SumState</th>
<th>TypeMon</th>
<th>NumOfBlksThisTyp</th>
<th>PctTotBCMon</th>
</tr>
</thead>
<tbody>
<tr>
<td>209739776</td>
<td>Free</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>209739776</td>
<td>ConsistentRead</td>
<td>12828672</td>
<td></td>
<td></td>
<td>1566 68%</td>
</tr>
<tr>
<td>209739776</td>
<td>Exclusive</td>
<td>43368448</td>
<td></td>
<td></td>
<td>5294 21%</td>
</tr>
<tr>
<td>209739776</td>
<td>Exclusive</td>
<td>153542684</td>
<td></td>
<td></td>
<td>18743 71%</td>
</tr>
</tbody>
</table>
```
Segments Occupying Block Buffers

Noting the distribution of segment owners, types, and names among the occupied buffers is useful. Note, in particular, which objects occupy the most buffers. Observe the indexes currently in the cache. Question whether these indexes are appropriate. If they are nonselective indexes being used by selective queries (or vice versa), these indexes could be occupying precious buffers that could be used more effectively by the corresponding table blocks or by the blocks of other segments experiencing “buffer busy waits” wait events. Query V$SQLTEXT to observe the SQL statements currently using the segments occupying the highest percentages of the buffers and determine whether index usage in these statements is appropriate. The two queries in the following listings show the segments occupying block buffers and also the percentage of buffers occupied by segments in the buffer cache.
Percentage of buffers occupied by segments in the buffer cache

Note also that only segments that are of the same block size as the block size of the default pool (the default block size) may be assigned to the keep or recycle pools. As of the first release of Oracle9i, the keep and recycle pools are not available for use by segments that are not the default block size. This defeats some of the strategy involved with tuning segments that are either high or low access and are not the default block size. However, other tuning options are available for such segments, such as partitioning.

Pool-specific buffer cache buffer occupation
Hot Data Blocks and the Causes of Latch Contention and Wait Events

The segment blocks returned by the query in the next listing are ones that are being accessed frequently, particularly if the value of the TCH (touch count) column changes (higher and lower)
between consecutive executions of this query. The TCH column value is incremented every time a particular buffer is “touched” or “visited” by a transaction. This value can fluctuate as a buffer is moved up and down the Least Recently Used (LRU) list. The reason for the fluctuation is that Oracle internally adjusts the TCH value according to its position in the LRU list and other factors, such as how long it has been since the buffer was last touched. In some scenarios of this algorithm, Oracle internally resets the TCH value back to 1.
-- Segments Occupying Hot Buffers (could be slow for a large cache / test).
-- This query defines a "hot" buffer as a buffer that has
-- a touch count greater than 10.

COL NAME FOR A35
SELECT /*+ ordered */ u.username || ' ' || o.name name,
      so.object_type type,
      sum(bh.dbablk) dbablk,
      sum(bh.tch) touches
FROM x$hh bh, dba_users u, sys.obj$ o, sys.sys_objects so
WHERE bh.obj = o.obj#
  AND bh.obj = so.object_id
  AND o.owner# = u.user_id
  AND bh.tch > 10
ORDER BY bh.tch desc;

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>DBABLK</th>
<th>TOUCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS.FILES</td>
<td>TABLE</td>
<td>114</td>
<td>807</td>
</tr>
<tr>
<td>SYS.I_FILE# BLOCK#</td>
<td>INDEX</td>
<td>82</td>
<td>804</td>
</tr>
<tr>
<td>SYS.C_USER#</td>
<td>CLUSTER</td>
<td>92</td>
<td>746</td>
</tr>
<tr>
<td>SYS.C_USER#</td>
<td>CLUSTER</td>
<td>90</td>
<td>737</td>
</tr>
<tr>
<td>SYS.I_FILE# BLOCK#</td>
<td>INDEX</td>
<td>88</td>
<td>612</td>
</tr>
<tr>
<td>SYS.JOB$</td>
<td>TABLE</td>
<td>1473</td>
<td>506</td>
</tr>
<tr>
<td>SYS.JOB$</td>
<td>TABLE</td>
<td>1474</td>
<td>503</td>
</tr>
<tr>
<td>SYS.I_JOB_NEXT</td>
<td>TABLE</td>
<td>1490</td>
<td>485</td>
</tr>
<tr>
<td>SYS.I_FILE# BLOCK#</td>
<td>INDEX</td>
<td>85</td>
<td>396</td>
</tr>
<tr>
<td>SYS.C_USER#</td>
<td>CLUSTER</td>
<td>91</td>
<td>344</td>
</tr>
<tr>
<td>SYS.I_OBJ1</td>
<td>INDEX</td>
<td>54721</td>
<td>340</td>
</tr>
</tbody>
</table>

(Output truncated...)

-- Segments Occupying Hot Buffers (could be slow for a large cache / test).
-- This query defines a "hot" buffer as a buffer that has
-- a touch count greater than 10 and groups by OBJECT.

COL NAME FOR A35
SELECT /*+ ordered */ u.username || ' ' || o.name name,
      so.object_type type,
      count(bh.dbablk) blocks, sum(bh.tch) touches
FROM x$hh bh, dba_users u, sys.obj$ o, sys.sys_objects so
WHERE bh.obj = o.obj#
  AND bh.obj = so.object_id
  AND o.owner# = u.user_id
  AND bh.tch > 10
GROUP BY u.username || ' ' || o.name, so.object_type
ORDER BY touches desc;

<table>
<thead>
<tr>
<th>NAME</th>
<th>TYPE</th>
<th>BLOCKS</th>
<th>TOUCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS.C_FILE# BLOCK#</td>
<td>CLUSTER</td>
<td>131</td>
<td>20263</td>
</tr>
<tr>
<td>SYS.OBJ$</td>
<td>TABLE</td>
<td>75</td>
<td>10407</td>
</tr>
<tr>
<td>SYS.I_FILE# BLOCK#</td>
<td>INDEX</td>
<td>20</td>
<td>6063</td>
</tr>
</tbody>
</table>
Capture the SQL statements involving these segments by querying V$SQLTEXT for SQL_TEXT lines that contain these segment names, and analyze their execution plans with the EXPLAIN PLAN as described in Chapter 6. Consider the number of sessions accessing these blocks using the queries in this section and whether these blocks are tables or appropriate indexes. Table blocks appearing in this list that are being accessed by multiple sessions are candidates for the keep pool. Table segments in this list that incur frequent full table scans are candidates for being re-created in tablespaces that are configured for large block sizes (16K or larger). Conversely, table segments that incur single-row accesses are candidates for being re-created in tablespaces that are configured for smaller block sizes (2K, 4K, or 8K).

Note that you should balance rebuilding such single-row access tables in small block tablespaces with data locality considerations. If such a single-row access table is accessed frequently for similar data that is likely to be stored consecutively, then you should consider storing such segments in large block tablespaces instead of a small block tablespace. As a result, a lower number of physical block reads occurs because of the increased chance that the block containing the desired rows already resides in a buffer cache buffer from other recent queries.

Deciding how to size such objects depends on the default block size of the database and the amount of physical memory and SGA space available for creating a keep pool. Segments in buffers with a consistently low touch count are candidates for the recycle pool, depending on the block size of the particular table versus the default block size. You should review the application SQL code, particularly the indexing strategy, to reconsider the logic of accessing such blocks frequently, in an effort to reduce contention on them. The following queries will help. (Note that since 10gR2, the cache buffers chain latch can be shared—but not all the time. Also, in-memory UNDO [IMU] lessens issues with the buffer cache especially in 11g.) Although Oracle does in-memory updates all the time, this updating happens in the buffer cache. IMU is new because UNDO and REDO in Oracle9i had to be written out to disk quickly to protect the data.
Segments experiencing waits on the cache buffers' LRU chain latch

```
-- Segments Experiencing Waits on the Cache Buffers Chains Latch (slow - test)
SELECT /* ordered */
    de.owner || ' ' || de.segment_name, segment_name,
    dc.segment_type, segment_type,
    de.extent_id, extent,
    bh.dbablk - de.block_id + 1, block#,
    bh.lru_flag,
    bh.tch,
    lc.child#
FROM (SELECT MAX(sloops) MaxSloops
    FROM v$latch children
    WHERE name='cache buffers chains') max_sleeps,
    v$latch_children lc,
    X$sbh bh,
    dba_extents de
WHERE lc.name = 'cache buffers chains'
    AND lc.sloops > (0.8 * MaxSloops)
    AND bh.hladdr = lc.addr
    AND de.file_id = bh.file#
    AND de.block_id between bh.block_id and de.block_id + de.blocks - 1
ORDER BY bh.tch;
```

Sessions experiencing waits on the buffer busy waits or write complete waits events

```
-- Segments Experiencing Waits on Cache Buffers LRU Chain Latch (slow - test)
SELECT /*+ ordered */
    de.owner || ' ' || de.segment_name, segment_name,
    dc.segment_type, segment_type,
    de.extent_id, extent,
    bh.dbablk - de.block_id + 1, block#,
    bh.lru_flag,
    bh.tch,
    lc.child#
FROM (SELECT MAX(sloops) MaxSloops
    FROM v$latch children
    WHERE name='cache buffers lru chain') max_sleeps,
    v$latch_children lc,
    X$sbh bh,
    dba_extents de
WHERE lc.name = 'cache buffers lru chain'
    AND lc.sloops > (0.8 * MaxSloops)
    AND bh.hladdr = lc.addr
    AND de.file_id = bh.file#
    AND de.block_id between bh.block_id and de.block_id + de.blocks - 1
ORDER BY bh.tch;
```
Problem segments returned by queries in this section are likely to be the same as those returned by the query returning hot buffers earlier in this section. If they’re not, a possible explanation may be that such a segment is accessed frequently by one session, as shown by the hot buffer query, but there may be no contention for it by other sessions, as may be shown by the absence of that segment from the result set of the other queries in this section. Other than that scenario, the segments returned by a hot buffers query are likely to also be returned by the other queries in this section that show the problem segment. Each of these queries conveniently includes the blocks of the particular segments associated with the latches or waits in question.

For table segments, you can use the DBMS_ROWID PL/SQL package to map the file and block numbers returned by these queries to the corresponding table rows. If one or a set of segments consistently shows up in the result sets of the queries in this section, then these are highly used segments. Investigate the application to reconsider the use of these popular segments. Ask questions such as the following:

- Is the indexing scheme appropriate?
- Are PL/SQL (or Java) loop exit conditions included where they should be?
- Are superfluous tables included in join queries?
- Can any SQL code be reengineered to alter a join strategy, either with reengineered subqueries, inline views, or similar alternatives?
- Should some hints, like ORDERED, USE_HASH, etc., be used?
- Are statistics up to date?
- Do any of the involved tables have a high watermark that is well beyond the actual blocks that contain rows?
- Could a table or index make advantageous use of partitioning or histograms?
- Should you use a keep pool?

If a variety of different segments are repeatedly showing up in the result of the buffer-busy query,
the buffer cache is probably undersized or the disk subsystem is not writing changed (dirty) buffers out to the datafiles fast enough for them to be reused (or both). If there does not seem to be contention on particular segments, but rather on a varying set of segments, this problem indicates that Oracle is having trouble in general satisfying requests to load blocks into free buffers.

You should also review the storage parameter configuration of the problem segments returned by the queries in this section. Consider whether sufficient free lists are available for the tables and indexes that can be classified as high concurrent update (multiple sessions updating them concurrently). You should probably set free lists to two or higher for these segments, but do not set free lists higher than the number of CPUs in the database server. Another solution is to use Automatic Segment Space Management (ASSM). You should review the data block size and PCT_FREE because different conditions call for blocks of a table or index to contain more rows or fewer rows. In situations in which a particular segment block is popular, you may want to reconstruct the segment with a higher PCT_FREE; thus, the interblock contention for rows that were previously stored in the same block is reduced because the chance of those rows being stored in the same block has been reduced by simply reducing the number of rows that can be inserted into a block.

Obviously, more buffer cache buffers are required to accommodate a table reconstructed to have a larger PCT_FREE and, therefore, consist of more row-containing blocks. The trade-off is that this can reduce the performance of full table scan operations on such tables because more blocks must be visited to complete a full table scan. In general, you must consider the overall use of these tables and indexes to judge whether having more or fewer rows in the blocks of the particular table or index is more advantageous. These points can be summarized as follows:

- **Condition** Higher PCT_FREE and, therefore, fewer rows per block:
  - **Advantage** Less contention on updates of popular blocks.
  - **Disadvantage** The segment consists of more blocks and, therefore, reduces full table scan performance.

- **Condition** Lower PCT_FREE and, therefore, more rows per block:
  - **Advantage** There is a better chance that the block containing a requested row is already in a buffer cache buffer from a recent query. Full table scans will need to visit fewer blocks.
  - **Disadvantage** Blocks being updated may contain more contention. If a block contains a row to be updated, all the other rows (more of them) in that block are now in a copy of the block that is incompatible with other sessions requesting a read of other rows in that block; thus, another read-consistent copy of the block must be read into another buffer cache buffer.

### Obtaining Database- and Instance-Specific Information

You can obtain some database- and instance-specific information from the X$KCCDI table. Consider the following queries, which you can use to find overall instance- and database-specific information:
-- MAXLOGMEMBERS setting for a database.
SELECT dimlm
  FROM x$kccdi;

Datafile creation times

-- Datafile creation times.
SELECT indx file_id,
    fecrc_tim creation_date,
    file_name,
    tablespace_name
FROM x$kccfe int,
    dba_data_files dba
WHERE dba.file_id = int.indx + 1
ORDER BY file_name;

Background process names and process IDs

-- Background process names and process ids.
SELECT ksbdpnam ProcessName, ksbdppro OSPid
FROM x$ksbdp
WHERE ksbdppro != '00';
Various instance resources

Note that the last query has different values returned for the resource values on different platforms.

**Effective X$ Table Use and Strategy**

Consider creating a separate X$ query user who has his or her own X$ views on the SYS X$ tables, as described earlier in the chapter. This user could manually, or with DBMS_JOB, perform periodic queries to capture X$ table data into some other tables so the contents of the X$ tables can be examined over time. If you do this, keep in mind that the data in the X$ tables is highly transient. Some scripts or jobs written to capture such information will likely miss a lot of it. On the other hand, you do not want to query these tables so frequently that the queries themselves and their associated activity information are a non-negligible percentage of the data in the tables.

In monitoring the X$KSMRLRU table (and perhaps X$KSMSP and others), you may find it prudent
Oracle Internals Topics
Alas, more toys for the mischievously curious DBAs. Except for traces, you should not use the utilities described in the following sections in production without the guidance of Oracle Support. You can take them and run with them in a sandbox database to learn what useful information they provide.

Traces
Database sessions can be traced to collect session information about the work performed in the session and to diagnose problems. Traces can be turned on by a variety of methods:

- Set SQL_TRACE = TRUE with an ALTER SESSION command.
- Set SQL_TRACE = TRUE in the initialization parameter file.
- Execute the DBMS_SYSTEM.SET_SQL_TRACE_IN_SESSION( ) PL/SQL procedure for another session.
- Create traces with the $ORACLE_HOME/rdbms/admin/dbmssupp.sql script.
- Execute the DBMS_SYSTEM.SET_EV( ) PL/SQL procedure to set tracing events in another session.
- Use the ORADEBUG command.

**CAUTION**
*If you set SQL_TRACE = TRUE in the parameter file, it generates traces for every process connected to the database, including the background processes.*

The simplest method to invoke a trace of a session is for the session itself to enable tracing with the following command:

```
SQL> alter session set sql_trace=true;
Session altered.
```

Developers may do this themselves from SQL*Plus and may also include it in PL/SQL code using the EXECUTE IMMEDIATE facility. The DBA may optionally decide to make the trace files in the
user dump destination readable by all (Unix and OpenVMS) by setting the hidden parameter
_TRACE_FILES_PUBLIC to TRUE on instance startup.

Having users generate traces for themselves is simple but not always practical. Third-party
applications usually do not permit the code to be modified for the insertion of `TRACE`
commands, and there is usually no SQL prompt from where the trace can be started. You could use system logon
triggers to identify the user connecting and optionally start a trace, but there are easier methods at
your disposal.

In these situations, you need to be able to invoke a trace for another session. As the DBA, you have
a number of methods to do this. In each case, however, you need to know the SID and the SERIAL# of
the session you want to trace. You can find this information in the V$SESSION view, as shown here:

```sql
select sid, serial#
from v$session where username = 'NICOLA';
```

<table>
<thead>
<tr>
<th>SID</th>
<th>SERIAL#</th>
</tr>
</thead>
<tbody>
<tr>
<td>540</td>
<td>11</td>
</tr>
</tbody>
</table>

Once you have this information, you can use the `SET_SQL_TRACE_IN_SESSION` procedure of
the DBMS_SYSTEM package to invoke the trace. The procedure takes three arguments: SID,
SERIAL#, and a Boolean argument to start or stop the tracing. It is invoked as follows:

```sql
SQL> exec dbms_system.set_sql_trace_in_session(540,11,TRUE);
PL/SQL procedure successfully completed.
```

When sufficient tracing information has been collected, disable the trace as follows:

```sql
SQL> exec dbms_system.set_sql_trace_in_session(540,11,FALSE);
PL/SQL procedure successfully completed.
```

Alternatively, you can use the DBMS_SUPPORT package to start the trace. The
DBMS_SUPPORT package is an option that can be loaded into the database from the rdbms/admin
directory. To load the package, you must be connected to the database as a SYSDBA privileged user
and then run the `dbmssupp.sql` script.

The DBMS_SUPPORT package offers much of the same functionality for tracing as the
DBMS_SYSTEM package but with these additional features:

- It allows bind variables and session wait information to be optionally included in the trace file.
- It verifies the SID and SERIAL# specified for tracing, rejecting invalid combinations. This can
  be useful in critical situations. It can be very frustrating to have spent an hour believing you
  have collected useful trace information only to find that you mistyped something and the user
dump destination directory is empty.

Use the START_TRACE_IN_SESSION procedure of the DBMS_SUPPORT package to start the trace. The procedure takes four arguments: SID, SERIAL#, a Boolean specifying if wait information is recorded (default TRUE), and a Boolean specifying if bind variables are recorded (default FALSE). Invoke it as follows:

```sql
SQL> exec dbms_support.START_TRACE_IN_SESSION(540,13,TRUE,TRUE);
PL/SQL procedure successfully completed.
```

To stop tracing, use the STOP_TRACE_IN_SESSION procedure:

```sql
SQL> exec dbms_support.stop_trace_in_session(540,13);
```

Another method to invoke tracing for another session is to use the DBMS_SYSTEM.SET_EV method to set a tracing event for a session. This procedure allows database events to be set in any session in the database. By setting the 10046 event, you can gather complete tracing information about any session. As before, you need the SID and SERIAL# of the session you want to monitor. You can then set the event as follows:

```sql
SQL> exec dbms_system.set_ev(537,21,10046,12,'');
PL/SQL procedure successfully completed.
```

The first two arguments are the SID and SERIAL# of the session. The next argument is the event you want to set, which, in this case, is event 10046 to trace the session. The fourth argument sets the level of the event. Here the level is set to 12 to gather all wait and bind variable information in addition to the basic trace. The available levels are as follows:

<table>
<thead>
<tr>
<th>Level</th>
<th>Information Gathered</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>All tracing disabled.</td>
</tr>
<tr>
<td>1</td>
<td>Standard tracing enabled.</td>
</tr>
<tr>
<td>2</td>
<td>Same as level 1.</td>
</tr>
<tr>
<td>4</td>
<td>Standard trace plus bind variable information.</td>
</tr>
<tr>
<td>8</td>
<td>Standard trace plus wait information. Very helpful for spotting latch waits.</td>
</tr>
<tr>
<td>12</td>
<td>Standard trace plus bind and wait information.</td>
</tr>
<tr>
<td>16</td>
<td>Generates STAT line dumps for each execution (see note below).</td>
</tr>
</tbody>
</table>
NOTE

STAT dumping was amended in 11g so individual dumps are not aggregated across all executions but are dumped after execution. This change addresses cases where the cursor is not closed and, therefore, the STAT information is not dumped. Now Oracle guarantees to capture the STAT information following the execution.

To stop tracing, you need to set the event level to zero as follows:

```sql
SQL> exec dbms_system.set_ev(537,21,10046,12,'');
PL/SQL procedure successfully completed.
```

Finally, you could use the ORADEBUG facility to invoke the required trace. This will be explored further later in this chapter.

Once a trace file has been generated, you can use the standard TKPROF utility to interpret the contents of the trace. (The TKPROF tool is covered in detail in Chapter 6.) Oracle also offers the more advanced Trace Analyzer tool, which can be downloaded from My Oracle Support (see Note 224270.1). The more adventurous DBA may wish to examine the raw trace file, which can sometimes yield information not shown by TKPROF. The Trace Analyzer takes the trace files generated by the methods described previously and produces a series of formatted reports. The reports are typically written to the user dump destination directory. The reports are very detailed and can take an extended period of time to produce, especially if your server is running poorly to begin with. To generate the report, you need to know the name of the trace file generated, and then you can invoke the Trace Analyzer as follows:
Parameter 1:
Trace Filename or control_file.txt (required)
Value passed to trcanlizr.sql:
------------------------------
TRACE_FILENAME: DEMOUC2 ora_16319.trc

Analyzing DEMOUC2 ora_16319.trc

To monitor progress, login as TRCANLZER into another session and execute:
SQL> SELECT * FROM trca5_log_v;
... analyzing trace(s) ...

Trace Analyzer completed.
Review first trcanlizr_error.log file for possible fatal errors.
Review next trca_e44266.log for parsing messages and totals.

Copying now generated files into local directory

TKPROF: Release 11.2.0.1.0 - Development on Wed May 18 11:50:05 2011
Copyright (c) 1982, 2009, Oracle and/or its affiliates. All rights reserved.

    adding: trca_e44266.html (deflated 89%)
    adding: trca_e44266.log (deflated 84%)
    adding: trca_e44266.tkprof (deflated 94%)
    adding: trca_e44266.txt (deflated 85%)
    adding: trcanlizr_error.log (deflated 81%)
test of trca_e44266.zip OK
deleting: trcanlizr_error.log
Archive: trca_e44266.zip

<table>
<thead>
<tr>
<th>Length</th>
<th>Date</th>
<th>Time</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>140676</td>
<td>05-18-11</td>
<td>11:50</td>
<td>trca_e44266.html</td>
</tr>
<tr>
<td>15534</td>
<td>05-18-11</td>
<td>11:50</td>
<td>trca_e44266.log</td>
</tr>
<tr>
<td>17065</td>
<td>05-18-11</td>
<td>11:50</td>
<td>trca_e44266.tkprof</td>
</tr>
<tr>
<td>69535</td>
<td>05-18-11</td>
<td>11:50</td>
<td>trca_e44266.txt</td>
</tr>
<tr>
<td>242810</td>
<td></td>
<td></td>
<td>4 files</td>
</tr>
</tbody>
</table>

File trca_e44266.zip has been created

TRCANLZER completed.
The finished HTML report summarizes the trace file (see Figure 13-1). The report includes all of the details found on TKPROF, plus additional information normally requested and used for a transaction performance analysis.

DBMS_TRACE Package

The DBMS_TRACE package is another method of tracing, but unlike the preceding examples, it is designed specifically to trace PL/SQL rather than individual sessions. It can be extremely useful when trying to debug PL/SQL programs. To use the DBMS_TRACE package, the DBA must first load the following scripts from the rdbms/admin directory as a SYSDBA user:

```
TRACETAB.SQL
DBMSPBT.SQL
PRVTPBT.PLB
```

Once the packages are loaded, PL/SQL can be traced using two methods:
All PL/SQL code created by the session after this point will have the additional hooks to allow it to be traced, including anonymous PL/SQL blocks. However, code created before this point cannot be traced with the DBMS_TRACE package. Alternatively, any existing PL/SQL package, procedure, or function can be recompiled using the following command:

```
SQL> alter session set plsql_debug=true;
```

TIP
Anonymous PL/SQL blocks cannot be traced using the “compile debug” method. PL/SQL tracing for the entire session must be enabled with the ALTER SESSION SET PLSQL_DEBUG=TRUE command.

Now to trace the PL/SQL code execution, you can start with the following command:

```
SQL> alter [PROCEDURE | FUNCTION | PACKAGE BODY] <procedure name> compile debug;
```

The argument here specifies which lines of PL/SQL to trace. The options are
TRACE_ALL_LINES to trace every line executed, TRACE_ENABLED_LINES to trace only PL/SQL that was explicitly compiled with the debug option, TRACE_ALL_EXCEPTIONS to trace only exceptions, and TRACE_ENABLED_EXCEPTIONS to trace only exceptions of PL/SQL that was explicitly compiled with the debug option. When the tracing is complete, disable it with the following command:

```
SQL> execute dbms_trace.set plsql trace(dbms_trace.trace all lines);
```

The results of the trace can be seen in the PLSQL_TRACE_EVENTS table owned by the SYS schema, as shown here:
An event is similar to a system trigger in an Oracle instance. A trigger can capture pertinent information about the instance and individual database sessions to trace files. If an event is set in an initialization parameter file or with an ALTER SYSTEM or ALTER SESSION setting, then Oracle captures information to a trace file based on the conditions set in the event. Several events can be set. These can be described with the `oerr` command-line facility. Try the following command (in Unix only):

```
oerr ora 10046
```

A particularly useful tuning tool is event 10046 (described in Chapter 9 in detail). This event can be enabled in the initialization parameter file with the following line (although this is not something that you generally want to set at the database level):

```
event - '10046 trace name context forever, level 8'
```

Or it is more likely to be used at the session level with an ALTER SESSION command:

```
alter session set events '10046 trace name context forever, level 12';
```

The trace information is captured to a file in the USER_DUMP_DEST directory derived from the
DIAGNOSTIC_DEST parameter in the initialization parameter file. This event is equivalent to setting SQL_TRACE = TRUE in the initialization parameter file. At level 12, this event setting includes the values of bind variables and the occurrences of wait events. Other events are useful in troubleshooting database and performance issues. Do not set events in production databases without first consulting with Oracle Support and testing them in a test database.

You can use the ORADEBUG command (covered later in this chapter in the “ORADEBUG” section) or the DBMS_SUPPORT PL/SQL package to set events in sessions other than the current session. Also, to UNSET this event, you use

```sql
alter session set events '10046 trace name context off';
```

& Dumps

Several structures in an Oracle instance or database can be dumped to a trace file for low-level analysis, such as these:

- Control files
- Datafile headers
- Redo log file headers
- Instance state
- Process state
- Library cache
- Data blocks (covered in detail in Chapter 9)
- Redo blocks

Create these dumps with these commands:

```sql
alter session set events 'immediate trace name CONTROL level 10';
alter session set events 'immediate trace name PITR_HDRS level 10';
alter session set events 'immediate trace name REDOEDR level 10';
alter session set events 'immediate trace name SYSTEMSTATE level 10';
alter session set events 'immediate trace name PROCESSTATE level 10';
alter session set events 'immediate trace name library cache level 10';
alter system dump datafile 10 block 2057;
alter system dump logfile '<logfilenamn>';`

The trace files containing this dump information are in the USER_DUMP_DEST directory.
You use the ORADEBUG command for troubleshooting the instance or sessions. The ORADEBUG command can capture current instance state information, set events in sessions, and perform other low-level diagnostics. Type `oradebug help` from SQL*Plus to get the usage list shown next.

**NOTE**
You must be connected to AS SYSDBA to be able to access ORADEBUG (version dependent listing —run this for your own version).
The following example shows using the ORADEBUG command to invoke a trace of another session. Let’s say a user complains of slow performance on a database, or you have identified the process ID from the operation system. To get the SPID, use the following query:

```sql
select spid
from v$process
where addr = (select paddr from v$session where username = 'NICOLA');
```

Then you use the SETOSPID command to attach to the process and invoke the trace:

```sql
select spid
from v$process
where addr = (select paddr from v$session where username = 'NICOLA');
SQL> oradebug setospid 6941
Oracle pid: 28, Unix process pid: 18273, Image: oracle@dc-unal110.myinstance.com (TNS V1 V3)
```

Now that you are attached, you can invoke the trace by setting the 10046 event. Here, I select a level 12 to force all bind variables and wait information to be written to the trace file:

```sql
SQL> oradebug event 10046 trace name context forever, level 12
Statement processed.
```

The session is now tracing. If you want to see the name of the trace file being generated, use the TRACEFILE_NAME option as follows:
This shows you the name and location of the trace file. This file can then be processed with the TKPROF analysis tool to obtain detailed information about the operations of the monitored process.

If your Oracle database has trace file-size limitations specified in the SPFILE or init.ora file, you can override this from ORADEBUG using the following command:

```
SQL> oradebug unlimited
Statement processed.
```

The DBA should remember, however, that Oracle buffers its writes to the trace file, and so the information contained in the file might not be completely up to date. Fortunately, the ORADEBUG command gives you the ability to flush the trace file write buffer as follows:

```
SQL> oradebug flush
Statement processed.
```

The ORADEBUG command can also be used to suspend the execution of a process. For example, you might have a long-running database job that is about to fail due to space, or an intensive update job that you want to disable during a backup. The ORADEBUG command allows specific sessions to be suspended as follows:

```
SQL> oradebug setospid 6943
Oracle pid: 11, Unix process pid: 6943, image: oraclclwdb%dc-mvndb3

SQL> oradebug suspend
Statement processed.
```

The Oracle operating system process 6943 is now suspended and will remain that way until you issue the ORADEBUG RESUME command.

**TIP**

Do not use ORADEBUG SUSPEND on the Microsoft Windows platform. Due to the thread-based processing model of Windows, the whole database will be suspended, not just the process you are
When you want to disable tracing for the specified session, you can use the following ORADEBUG command:

```
SQL> oradebug event 10046 trace name context off
Statement processed.
```

## trcsess Utility

Oracle provides users with another tracing utility: `trcsess`. This utility can be found in the bin directory under Oracle Home. The tool is designed to read database trace files and extract information the DBA is interested in. Trace information can be located based on session information (SID and serial number), client identifier, service name, action name, or module name. The tool is primarily designed for use in shared server or connection pooling environments where multiple processes may have to be traced to capture all relevant information. The tool does not interpret the trace information; it simply aggregates multiple trace files into a single one based on the criteria provided. The result is a combined trace file that can be analyzed using TKPROF, TRCANLZR, or another tool. For additional information on this tool, see My Oracle Support Note 280543.1.

## Reading the Trace File

The preceding section showed several methods that can be used to generate a trace of a session. Once the session being traced has completed, the DBA needs to locate, read, and interpret the trace file. The trace file is written to the directory pointed to by the user dump destination parameter. You can see it from SQL*Plus with the following command:

```
SQL> show parameter user_dump_dest
NAME                TYPE          VALUE
------------------  ----------      --------------------------
user_dump_dest     string        /home/oracle/app/oracle/diag/rdbms/demoui2/DEMUUC2/trac
```

The trace file has the filename format `<sid>_ora_<process id>.trc`. The process ID can be found in the V$PROCESS view as follows:
So, in this example, my trace file name is

/home/oracle/app/oracle/diag/rdbs/democ2/DEMOC22/trace/DEMOC22 ora 4508.trc

Once located, I can read the trace file with the TKPROF tool (see Chapter 6) or the Trace Analyzer tool, shown earlier in this chapter. However, the curious DBA might be interested to see the contents of the trace file for himself or herself. Because the raw trace file is written in ANSI format, reading it can be accomplished with any standard file browser or editor. The trace file shows the traced session as a series of blocks. Each block represents a database call and is separated by a single line. At the top of the trace file is the standard trace file header that many DBAs are already familiar with:

The trace file then shows each database call that was executed in the traced session in sequential order. The following example shows a simple SELECT statement:

```
select spid
from  gv$process vp, gv$session vs
where vs.sid = userenv('SID')
and    vs.paddr = vp.addr
and    vs.inst_id = vp.inst_id;
```
The first line shows information about the statement being executed. The tags can be interpreted as follows:

<table>
<thead>
<tr>
<th>Tag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Len</td>
<td>Length of SQL statement.</td>
</tr>
<tr>
<td>Dep</td>
<td>Recursive depth of the cursor. Blocks where dep is not zero are recursive calls made by the database on the user's behalf. Time spent here contributes to the &quot;recursive CPU&quot; usage recorded in V$SYSSTAT.</td>
</tr>
<tr>
<td>Uid</td>
<td>Schema user ID of parsing user—see USER_ID in DBA_USERS.</td>
</tr>
<tr>
<td>Oct</td>
<td>Oracle command type.</td>
</tr>
<tr>
<td>Lid</td>
<td>Privilege user ID—may not be the same as parsing user if executing another user's PL/SQL code.</td>
</tr>
<tr>
<td>Tim</td>
<td>Timestamp—the value is the value in V$TIMER when the line was written. Pre-Oracle9i, the times recorded by Oracle are centiseconds (10 mS). As of Oracle9i, some times are microseconds (1/1,000,000ths of a second).</td>
</tr>
<tr>
<td>Hv</td>
<td>SQL hash—maps to SQL_HASH in V$SQLAREA.</td>
</tr>
<tr>
<td>Ad</td>
<td>SQL address—maps to SQL_ADDRESS in V$SQLAREA.</td>
</tr>
<tr>
<td>Sqiid</td>
<td>SQL ID—the SQLID of the statement.</td>
</tr>
</tbody>
</table>

The trace file then shows the text of the SQL statement being executed. In this case, I am selecting the BIRTHDATE from the USER_DETAIL table. You can also see from the trace file that this statement has been assigned cursor #7.

**TIP**

Cursors may be reassigned if the cursor is closed and released. Therefore, when reading a long trace file, remember that a cursor number referenced at one part of the trace file may not represent the same SQL statement as it does elsewhere in the trace file.

The trace file next shows the operations Oracle performs to actually satisfy the query. This basically amounts to a series of executions (EXEC) and fetches (FETCH). Both the EXEC and FETCH trace lines report the following tracing information:
Applying this knowledge to the EXEC line from my trace, I can determine the following:

- A total of 6999 ms of CPU was used for this EXEC.
- Total elapsed time was 51312 ms.
- Physical reads were zero.
- Buffers retrieved in CR (consistent read) mode were 84.
- Buffers retrieved in current mode were zero.
- Library cache misses was 1 (this statement was not found in the cache).
- Rows processed was zero.
- Recursive call depth was zero (this was a user call).
- Optimizer goal was all rows.

# Wait Information and Response Time

The trace file also includes wait (WAIT) information. This shows the length of time Oracle spent waiting for certain items between parsing, executing, and fetching data. In this trace file, you can see this wait event:
The NAM field shows the event that was waited on. The ELA field shows the length of time waited. The meaning of the P1, P2, and P3 fields depends on the event. The information shown can also be observed by inspecting the GV$SESSION_WAIT view during statement execution. In this example, you can also see that Oracle waited on a “SQL*Net message to client” event for 5 ms. The wait is followed by this:

```
FETCH #7: c=0, p=0, cr=13, cu=0, mis=0, r=1, dep=0, og=1, plh=1254678500, t
im=1305924518570284
```

The FETCH step takes 142 ms, reads 13 buffers in CR mode, and processes 1 row. The 142 ms includes the 5 ms from the WAIT step. Elapsed times for all WAIT events immediately preceding an EXEC or FETCH operation are incorporated in the total elapsed time shown for that event:

```
WAIT #7: name 'SQL*Net message from client' ela 193 driver id 1650615232 #bytes 1 p3 0 obj# 91921 tim=1305924518570221
```

The elapsed time for the FETCH operation shown on line 3 includes the elapsed times from lines 1 and 2.

### Recursive Calls

The trace file identifies recursive calls by showing the call depth of each call. In the following extract, you see a user call (cursor #50) being serviced by a recursive call (cursor #54), which itself is serviced by two recursive calls (cursor #35).

```
EXEC #35: c=0, e=71, p=0, cr=0, cu=0, mis=0, r=0, dep=2, og=4, tim=4232475309356
FETCH #25: c=0, e=49, p=0, cr=2, cu=0, mis=0, r=1, dep=2, og=4, Lim=4232475309366
EXEC #54: c=0, e=6986, p=0, cr=3, cu=0, mis=0, r=1, dep=1, og=4, Lim=4232475309925
EXEC #50: c=8000, e=31087, p=0, cr=9, cu=0, mis=0, r=0, dep=0, og=4, Lim=4232475305361
```

The CPU time, elapsed time, OS block reads, and CR and current block reads for all recursive calls are added to the totals for the originating call. In the preceding example, the total elapsed time
for cursor #50 of 31,087 ms includes the 4,986 ms elapsed time for cursor #54, which itself includes the 71 ms spent executing in cursor #35 and the 48 ms spent fetching.

## Module Info

The raw trace file includes module information recorded by calls to the DBMS_APPLICATION_INFO package:

```
APPNAME mod='SES' mh=3264509754 act='Job ID: 3407193' wh=1464295440
```

The entry includes the following tags:

<table>
<thead>
<tr>
<th>Tag</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mod</td>
<td>Module</td>
</tr>
<tr>
<td>Mh</td>
<td>Module hash value (see V$SESSION)</td>
</tr>
<tr>
<td>Act</td>
<td>Action</td>
</tr>
<tr>
<td>Ah</td>
<td>Action hash (see V$SESSION)</td>
</tr>
</tbody>
</table>

## Commit

Commit operations are shown in the trace file as XCTEND (Transaction END) calls:

```
XCTEND rlbk=0, rd only=0
```

The `rlbk` tag has a value of 1 if a rollback is performed or zero if it is committed. The `rd_only` tag has a value of 1 if the transaction was read-only or zero if blocks were changed.

The `rlbk` tag has a value of 1 if a rollback is performed or zero if it is committed. The `rd_only` tag has a value of 1 if the transaction was read-only or zero if blocks were changed.

## Unmap

The unmap operation records when temporary tables are cleaned up:
The flag records the same information as for EXEC and FETCH operations.

## Bind Variables

One of the most powerful features of the 10046 trace with a level of 8 or 12 is that bind variable information is captured in the trace. You can see this in the raw trace file as a series of BIND operations. The following example is taken from an 11g database with cursor sharing set to FORCE:

```
DARSING IN CURSCR #7 len=57 dcp=0 uid=86 oct=3 lid=86 tim=1305924518518576
hv=4215611582 ad='3b6269dc' sqlid='gl2x557xma55z'
select birthdate from arijak where firstname = :"SYS_B_0"
END OF STMT
```

In the preceding example, the SQL statement is shown as you see it in the V$SQLTEXT view, with the bind variable represented as SYS_B_0. However, the BIND operation listed shows that the bind variable zero of cursor 1 is being bound to the value 'Alex'. Note that you must be careful when interpreting the BIND information. Oracle replaces all static values with dynamically generated variable names such as SYS_B_n. However, named variables are not replaced. The BIND statements are listed in strict sequential order, with each value being bound to the next variable in the statement. Consider the following statement:

```
select *
from SPROGS
where name != 'Nicola'
and birthdate > ( to date(:BIRTHDAY,'DDMONYY'))
```

If CURSOR_SHARING is set to FORCE, the value 'Nicola' is replaced with the variable SYS_B_0 and the value 'DDMONYY' is replaced with SYS_B_1. For the purposes of binding, however, SYS_B_0 is treated as variable 0, BIRTHDAY is treated as variable 1, and SYS_B_1 is treated as variable 2:
When tracing larger, more complex queries, remember that SYS_B_n does not necessarily bind to variable n.

**Errors**

The raw trace file will include errors that occur during the period of the trace. Two types of errors are recorded: execution errors and parsing errors. Parsing errors occur when the SQL statement cannot be parsed due to problems such as syntax or object permissions:

The preceding trace line shows error ORA-936 when parsing cursor #7. The information includes all of the same information as a successful parse operation, except for the SQL hash and address, as the failed statement is not stored in the library cache.

Execution errors simply list the error code and the time of the error:

The preceding trace line shows that error ORA-1555 was raised during the execution of cursor #76.

**Some Common X$ Table Groups**

Some of the X$ tables can be logically grouped as shown in Tables 13-1 through 13-44. This is by no means a complete list. The descriptions for these tables are updated to the best of my knowledge (listed here are only a small and limited number of X$ tables even within a group). Oracle Corporation does not provide a full description list. In the final section of the chapter, I include a very nice definition tree structure that was provided for an earlier version of the X$ tables. You can
certainly use this with most versions to help you understand the naming conventions much better.

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description (* = being deprecated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCKCL</td>
<td>Features in use by the database instance that may prevent downgrading to a previous release.*</td>
</tr>
<tr>
<td>X$KCKFM</td>
<td>Some sort of information about the version of database or database parts.*</td>
</tr>
<tr>
<td>X$KCKTY</td>
<td>Features in use by the database instance that may prevent downgrading to a previous release.*</td>
</tr>
<tr>
<td>X$KSULI</td>
<td>Information about license limits.</td>
</tr>
<tr>
<td>X$OPTION</td>
<td>Installed options.</td>
</tr>
<tr>
<td>X$VERSION</td>
<td>Oracle RDBMS software version.</td>
</tr>
</tbody>
</table>

**TABLE 13-1. Version/Installation**
### TABLE 13-2. Instance/Database

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSKSUSSGSTA</td>
<td>Instance statistics.</td>
</tr>
<tr>
<td>XSKCCDI</td>
<td>Main source of information for V$DATABASE.</td>
</tr>
<tr>
<td>XSKSMUD</td>
<td>SGA component sizes (&quot;SHOW SGA&quot;).</td>
</tr>
<tr>
<td>XSKSMSS</td>
<td>Detailed SGA statistics.</td>
</tr>
<tr>
<td>XSKSPPCV</td>
<td>Parameters and values that are in effect for the session.</td>
</tr>
<tr>
<td>XSKSPPCV2</td>
<td>Parameters and values that are in effect for the session. List parameter</td>
</tr>
<tr>
<td></td>
<td>values appear as separate rows.</td>
</tr>
<tr>
<td>XSKSPPI</td>
<td>Parameter names and descriptions.</td>
</tr>
<tr>
<td>XSKSPPO</td>
<td>Obsolete parameters.</td>
</tr>
<tr>
<td>XSKSPPSV</td>
<td>Parameters and values that are in effect for the instance.</td>
</tr>
<tr>
<td>XSKSPPSV2</td>
<td>Parameters and values that are in effect for the instance. List parameter</td>
</tr>
<tr>
<td></td>
<td>values appear as separate rows.</td>
</tr>
<tr>
<td>XSKSPVLD_VALUES</td>
<td>Valid values for parameters that accept ordinal values (also called list</td>
</tr>
<tr>
<td></td>
<td>parameters).</td>
</tr>
<tr>
<td>XSKSPSPFIIIF</td>
<td>Parameter names specified with an SPFILE.</td>
</tr>
<tr>
<td>XSKSQDN</td>
<td>Database name.</td>
</tr>
<tr>
<td>XSOPTION</td>
<td>Installed options.</td>
</tr>
<tr>
<td>XSKVII</td>
<td>Instance limits and other instance metadata (includes miscellaneous</td>
</tr>
<tr>
<td></td>
<td>information).</td>
</tr>
<tr>
<td>XSKVIT</td>
<td>State of various buffer cache conditions.</td>
</tr>
<tr>
<td>XSKSU_XSINST</td>
<td>Main source of information for V$INSTANCE.</td>
</tr>
<tr>
<td>XSQUIESCE</td>
<td>Quiescent state of the instance.</td>
</tr>
</tbody>
</table>

### TABLE 13-3. NLS (National Language Support)

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KUSUIV</td>
<td>Valid values of NLS parameters.</td>
</tr>
<tr>
<td>X$NLS_PARAMETERS</td>
<td>Current values of NLS parameters.</td>
</tr>
</tbody>
</table>
### TABLE 13-4. Time Zones

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$TIMEZONE_NAMES</td>
<td>Time zone names.</td>
</tr>
<tr>
<td>X$TIMFZONE_FIL</td>
<td>Time zone file and version used by the database.</td>
</tr>
</tbody>
</table>

### TABLE 13-5. Archive Log Files/Destinations/Processes

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCCAL</td>
<td>Information about archive log files from the control file.</td>
</tr>
<tr>
<td>X$KCRRARCH</td>
<td>Information about the ARCH processes for the current instance.</td>
</tr>
<tr>
<td>X$KCRRDSTAT</td>
<td>Archive destination status.</td>
</tr>
</tbody>
</table>

### TABLE 13-6. Datafiles

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCCFE</td>
<td>File creation and other metadata.</td>
</tr>
<tr>
<td>X$KCCTF</td>
<td>Temp file I/O information.</td>
</tr>
<tr>
<td>X$KCVFH</td>
<td>Information source of V$DATAFILE and V$DATAFILE_HEADER.</td>
</tr>
<tr>
<td>X$KCHO</td>
<td>File I/O information.</td>
</tr>
<tr>
<td>X$KCFTIO</td>
<td>Temp file I/O information.</td>
</tr>
<tr>
<td>X$KVVFHALL</td>
<td>Datafile information similar to information in V$DATAFILE.</td>
</tr>
<tr>
<td>X$KTFBFTE</td>
<td>Free extents in files (ktfb free extents).</td>
</tr>
<tr>
<td>X$KTFBHC</td>
<td>Datafile information (similar to DBA DATA FILES).</td>
</tr>
</tbody>
</table>

### TABLE 13-7. Control Files

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCCCF</td>
<td>Control file information.</td>
</tr>
<tr>
<td>X$KCCOR</td>
<td>Datafile offline information from the control file.</td>
</tr>
<tr>
<td>X$KCCRS</td>
<td>Information about the control file record sections.</td>
</tr>
<tr>
<td>X$KCCRT</td>
<td>Log file information from the control files.</td>
</tr>
</tbody>
</table>
### TABLE 13-8. Redo Log Files

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCCCP</td>
<td>Redo log block information.</td>
</tr>
<tr>
<td>X$KCCFN</td>
<td>Information about file numbers. Info for all file types.</td>
</tr>
<tr>
<td>X$KCCLE</td>
<td>Information about redo log files in need of archiving.</td>
</tr>
</tbody>
</table>

### TABLE 13-9. Tablespaces

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCCCT</td>
<td>Tablespace information.</td>
</tr>
</tbody>
</table>

### TABLE 13-10. Sort/Temp Segments

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCBTFK</td>
<td>Encrypted tablespaces.</td>
</tr>
<tr>
<td>X$KEWXOCT</td>
<td>SYSAUX tablespace occupants.</td>
</tr>
<tr>
<td>X$KTFTHC</td>
<td>Space usage in each temp tablespace.</td>
</tr>
<tr>
<td>X$KTFTMF</td>
<td>Status of each unit of all temp tablespaces (temp map extents/blocks).</td>
</tr>
<tr>
<td>X$KTISSO</td>
<td>Sort segment activity by session.</td>
</tr>
<tr>
<td>X$KTTTSC</td>
<td>Temp segment usage: blocks used, cached, etc.</td>
</tr>
<tr>
<td>X$KSTSSD</td>
<td>System temporary sort segment data.</td>
</tr>
<tr>
<td>X$KTTTETS</td>
<td>Tablespace usage metrics.</td>
</tr>
</tbody>
</table>

### TABLE 13-11. Rollback/Undo Segments

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KTFBUF</td>
<td>Rollback/undo segment block/extent usage.</td>
</tr>
<tr>
<td>X$KTIVS</td>
<td>Rollback/undo segment stats.</td>
</tr>
<tr>
<td>X$KTUGD</td>
<td>Global rollback/undo data.</td>
</tr>
<tr>
<td>X$KTURD</td>
<td>Rollback/undo segment stats.</td>
</tr>
<tr>
<td>X$KTUSMST</td>
<td>Rollback/undo segment stats.</td>
</tr>
<tr>
<td>X$KTUXE</td>
<td>Rollback/undo segment activity: wraps, etc.</td>
</tr>
</tbody>
</table>
### TABLE 13-12. Temporary Objects

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCVFHTMP</td>
<td>Tempfile information.</td>
</tr>
<tr>
<td>X$KDLT</td>
<td>Temporary LOB information.</td>
</tr>
</tbody>
</table>

### TABLE 13-13. Database Links

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$UGANCO</td>
<td>Database link information.</td>
</tr>
</tbody>
</table>

### TABLE 13-14. Materialized Views

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KNSTMVR</td>
<td>Materialized view and refresh information.</td>
</tr>
<tr>
<td>X$KNSTRPP</td>
<td>Current parallel propagation information for replication.</td>
</tr>
<tr>
<td>X$KNSTRQU</td>
<td>Replication deferred transaction queue statistics.</td>
</tr>
</tbody>
</table>

### TABLE 13-15. Replication
### TABLE 13-16. Backup

<table>
<thead>
<tr>
<th><strong>X$ Table</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCCBF</td>
<td>Information from the control file about datafile and control file backups (RMAN).</td>
</tr>
<tr>
<td>X$KCCBL</td>
<td>Information from the control file about redo and archived log backups (RMAN).</td>
</tr>
<tr>
<td>X$KCCBP</td>
<td>Backup piece information from the control file (RMAN).</td>
</tr>
<tr>
<td>X$KCCBS</td>
<td>Backup set information from the control file (RMAN).</td>
</tr>
<tr>
<td>X$KCCCC</td>
<td>Datafile copy corruptions from the control file (RMAN).</td>
</tr>
<tr>
<td>X$KCCDC</td>
<td>Datafile copy information from the control file (RMAN).</td>
</tr>
<tr>
<td>X$KCCFC</td>
<td>Corruption in datafile backups (RMAN).</td>
</tr>
<tr>
<td>X$KCVFHONL</td>
<td>Backup status of all online datafiles.</td>
</tr>
<tr>
<td>X$KSFQDVNT</td>
<td>Supported backup devices (RMAN).</td>
</tr>
<tr>
<td>X$KSFQP</td>
<td>Performance information about ongoing or recently completed backups.</td>
</tr>
<tr>
<td>X$KSFVQST</td>
<td>Backup information.</td>
</tr>
<tr>
<td>X$KSFVSL</td>
<td>Backup information.</td>
</tr>
<tr>
<td>X$KSFVSTA</td>
<td>Backup information.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>X$ Table</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCRFX</td>
<td>Statistics about the current recovery process.</td>
</tr>
<tr>
<td>X$KCRMF</td>
<td>Statistics and status of files involved in recovery.</td>
</tr>
<tr>
<td>X$KCRMX</td>
<td>Statistics and status of files involved in recovery.</td>
</tr>
<tr>
<td>X$KCVFHMRR</td>
<td>Displays status of files during media recovery.</td>
</tr>
<tr>
<td>X$KRVSLSV</td>
<td>Recovery slave status.</td>
</tr>
<tr>
<td>X$KRVSLSVS</td>
<td>Recovery slave statistics.</td>
</tr>
<tr>
<td>X$KTPRXRS</td>
<td>Information about fast start servers performing parallel recovery.</td>
</tr>
<tr>
<td>X$KTPRXRT</td>
<td>Information about transactions Oracle is currently recovering.</td>
</tr>
<tr>
<td>X$ESTIMATED_MTTR</td>
<td>Estimates on the I/O work required if an instance recovery is needed right now.</td>
</tr>
<tr>
<td>X$TARGETRBA</td>
<td>Target recovery block accesses or target redo block accesses.</td>
</tr>
</tbody>
</table>
### TABLE 13-17. Recovery

<table>
<thead>
<tr>
<th><code>X$ Table</code></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>X$KCCDL</code></td>
<td>Information about deleted objects. Recovery catalog resync operation uses this to speed its optimize operation.</td>
</tr>
<tr>
<td><code>X$KCPA</code></td>
<td>Descriptions of archivelog backups taken with proxy copy.</td>
</tr>
<tr>
<td><code>X$KCPD</code></td>
<td>Descriptions of datafile and control file backups taken with proxy copy.</td>
</tr>
<tr>
<td><code>X$KCRM</code></td>
<td>RMAN configuration.</td>
</tr>
<tr>
<td><code>X$KCRSR</code></td>
<td>RMAN status.</td>
</tr>
</tbody>
</table>

### TABLE 13-18. RMAN

<table>
<thead>
<tr>
<th><code>X$ Table</code></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>X$KCCSL</code></td>
<td>Standby database log files.</td>
</tr>
<tr>
<td><code>X$KNSTACR</code></td>
<td>Standby database information: logical standby process stats.</td>
</tr>
<tr>
<td><code>X$KNSTASI</code></td>
<td>Standby database information: logical standby apply process.</td>
</tr>
</tbody>
</table>

### TABLE 13-19. Standby Databases
### TABLE 13-20. LogMiner

<table>
<thead>
<tr>
<th><code>$ Table</code></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>$XQESMMMSGA</code></td>
<td>Messages that each background process processes.</td>
</tr>
<tr>
<td><code>$XQKSBCGSFS</code></td>
<td>Session optimizer fix control.</td>
</tr>
<tr>
<td><code>$XSLOGMNR_CALLBACK</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_COL$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_COLTYPE$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_CONTENTS</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_DICTIONARY</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_ENCRYPTED_OBJ$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_ENCRYPTION_PROFILE$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_IND$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_INDPART$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_LOGFILE</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_LOGS</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_PARAMETERS</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_PROCESS</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_OBJ$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_REGION</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_SESSION</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TAB$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TABCOMPARTS</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TABSUBPART$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TSS$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TYPE$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TABPART$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_TABSUBPART$</code></td>
<td></td>
</tr>
<tr>
<td><code>$XSLOGMNR_USERS$</code></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 13-21. Sessions/Processes

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KOCST1</td>
<td>Object cache statistics for the current session.</td>
</tr>
<tr>
<td>X$KSLES</td>
<td>Waits on event by sessions.</td>
</tr>
<tr>
<td>X$KSQLR</td>
<td>Session enqueue resource usage.</td>
</tr>
<tr>
<td>X$KSUSIO</td>
<td>I/O statistics for each session.</td>
</tr>
<tr>
<td>X$KSQLOP</td>
<td>Session information about long-running operations.</td>
</tr>
<tr>
<td>X$KSUMYTA</td>
<td>Statistics for the current session.</td>
</tr>
<tr>
<td>X$KSUPL</td>
<td>Session information.</td>
</tr>
<tr>
<td>X$SUPR</td>
<td>Main source of information for V$PROCESS.</td>
</tr>
<tr>
<td>X$KUSE</td>
<td>Information in V$SESSION.</td>
</tr>
<tr>
<td>X$KUSLCON</td>
<td>Information about how each session is connected and authenticated.</td>
</tr>
<tr>
<td>X$KUSECST</td>
<td>Session waits, including wait parameters.</td>
</tr>
<tr>
<td>X$KUSESTA</td>
<td>Session performance statistics.</td>
</tr>
</tbody>
</table>

### TABLE 13-22. Session Performance

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KTCXB</td>
<td>Transaction information, including locks requested and held, rollback</td>
</tr>
<tr>
<td></td>
<td>segments used by the transaction, and the type of transaction.</td>
</tr>
<tr>
<td>X$KTFTBTXNGRAPH</td>
<td>Flashback transaction graph.</td>
</tr>
<tr>
<td>X$KTFTBTXNMODS</td>
<td>Flashback transaction modifications.</td>
</tr>
<tr>
<td>X$KTLUQORY</td>
<td>Flashback transaction query.</td>
</tr>
<tr>
<td>X$KTLUXF</td>
<td>Transaction entry table.</td>
</tr>
</tbody>
</table>

### TABLE 13-23. Transactions

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$K2GTE</td>
<td>Information on the currently active global transactions.</td>
</tr>
<tr>
<td>X$K2GTE2</td>
<td>Information on the currently active global transactions.</td>
</tr>
</tbody>
</table>

### TABLE 13-24. Global Transactions
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KGSKASP</td>
<td>All available active session pool resource allocation methods.</td>
</tr>
<tr>
<td>X$KGSKCH</td>
<td>Data related to currently active resource consumer groups.</td>
</tr>
<tr>
<td>X$KGSKCP</td>
<td>All resource allocation methods defined for resource consumer groups.</td>
</tr>
<tr>
<td>X$KGSKDOPP</td>
<td>Available parallel degree limit resource allocation methods.</td>
</tr>
<tr>
<td>X$KGSKPFT</td>
<td>Names of all currently active resource plans.</td>
</tr>
<tr>
<td>X$KGSKQUEP</td>
<td>Available queue resource allocation methods.</td>
</tr>
<tr>
<td>X$KSRMSGDES</td>
<td>Queue messages.</td>
</tr>
<tr>
<td>X$KSRMSGO</td>
<td>Queue publisher/subscriber information.</td>
</tr>
<tr>
<td>X$KWQSI</td>
<td>Read/write statistics on queues.</td>
</tr>
</tbody>
</table>

**TABLE 13-25.** Advanced Queuing (AQ)/Resource Management
<table>
<thead>
<tr>
<th>Table Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XS$KCLCRST</td>
<td>Information about block server background processes used in cache fusion.</td>
</tr>
<tr>
<td>XS$KJBL</td>
<td>RAC DLM information.</td>
</tr>
<tr>
<td>XS$KJBLFX</td>
<td>RAC information.</td>
</tr>
<tr>
<td>XS$KJBR</td>
<td>RAC DLM resource statistics.</td>
</tr>
<tr>
<td>XS$KJDRHIV</td>
<td>RAC instance information (the current and previous master instances and the number of re-masterings of Global Enqueue Service resources).</td>
</tr>
<tr>
<td>XS$KJDR?CMI IV</td>
<td>RAC instance information (the current master instances and the number of re-masterings of Global Cache Service resources except those belonging to files mapped to a particular master).</td>
</tr>
<tr>
<td>XS$KJDR?CMPF</td>
<td>RAC instance information (the previous master instances and the number of re-masterings of Global Cache Service resources except those belonging to files mapped to a particular master).</td>
</tr>
<tr>
<td>XS$KJICVT</td>
<td>RAC DLM information (statistics for local and remote GES enqueue operations).</td>
</tr>
<tr>
<td>XS$KJILKFT</td>
<td>RAC DLM information.</td>
</tr>
<tr>
<td>XS$KJIRFT</td>
<td>RAC DLM information (information about all resources currently known to the DLM).</td>
</tr>
<tr>
<td>XS$KJISFT</td>
<td>RAC DLM information (miscellaneous Oracle RAC statistics).</td>
</tr>
<tr>
<td>XS$KJITRFT</td>
<td>RAC DLM information (information about the message ticket usage).</td>
</tr>
<tr>
<td>XS$KJMDDP</td>
<td>RAC information.</td>
</tr>
<tr>
<td>XS$KJMSDP</td>
<td>RAC information.</td>
</tr>
<tr>
<td>XS$KJXM</td>
<td>RAC information.</td>
</tr>
<tr>
<td>XS$KSIMAT</td>
<td>RAC information instance attributes.</td>
</tr>
<tr>
<td>XS$KSIMAV</td>
<td>RAC information attribute values for all instances.</td>
</tr>
<tr>
<td>XS$KSIMSI</td>
<td>Map of instance names to instance numbers for all instances mounting a particular database.</td>
</tr>
</tbody>
</table>

**TABLE 13-26. Real Application Clusters**
<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KGLCLUSTER</td>
<td>Likely currently loaded or recently referenced clusters.</td>
</tr>
<tr>
<td>X$KGLCURSOR</td>
<td>Statistics on shared SQL area without the GROUP BY clause and contains one row for each child of the original SQL text entered.</td>
</tr>
<tr>
<td>X$KGLINDLX</td>
<td>Object names with currently held locks and other information about these locks.</td>
</tr>
<tr>
<td>X$KGLNA</td>
<td>Text of SQL statements belonging to shared SQL cursors.</td>
</tr>
<tr>
<td>X$KGLNA1</td>
<td>Text of SQL statements belonging to shared SQL cursors: newlines and tabs not replaced with spaces.</td>
</tr>
<tr>
<td>X$KGLOB</td>
<td>Database objects that are cached in the library cache. Objects include tables, indexes, clusters, synonym definitions, PL/SQL procedures and packages, and triggers.</td>
</tr>
<tr>
<td>X$KGLST</td>
<td>Library cache performance and activity information.</td>
</tr>
<tr>
<td>X$KKSBV</td>
<td>Bind variable data (depending on setting of CURSOR_SHARING) for cursors owned by the current session.</td>
</tr>
<tr>
<td>X$KSCS</td>
<td>Information about why nonshared child cursors are nonshared.</td>
</tr>
<tr>
<td>X$KSSRD</td>
<td>Redirected SQL statements.</td>
</tr>
<tr>
<td>X$KQFVI</td>
<td>SQL statements of all the fixed views.</td>
</tr>
<tr>
<td>X$KQLFXPL</td>
<td>Execution plan for each child cursor loaded in the library cache.</td>
</tr>
<tr>
<td>X$KQLSFT</td>
<td>Information about subordinate caches currently loaded in the library cache.</td>
</tr>
<tr>
<td>X$KSEI</td>
<td>Wait statistics (totals) for each event.</td>
</tr>
<tr>
<td>X$KXSBDB</td>
<td>SQL or session bind data.</td>
</tr>
<tr>
<td>X$KXSCC</td>
<td>Shared cursor cache. V$SQL_CURSOR debugging information for each cursor associated with the session querying this view. Memory use by each cursor of a session SQL cursor cache.</td>
</tr>
<tr>
<td>X$QESMMIWT</td>
<td>Shared memory management instantaneous working. Join to X$QKSMMWDS.</td>
</tr>
<tr>
<td>X$QKSMMWDS</td>
<td>Shared memory management working data size. Library cache memory use by child cursors.</td>
</tr>
</tbody>
</table>

**TABLE 13-27. Library Cache**
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KCHLU</td>
<td>Shared pool reserved list performance information.</td>
</tr>
<tr>
<td>X$KGICS</td>
<td>Systemwide cursor usage statistics: opens, hits, count, etc.</td>
</tr>
<tr>
<td>X$KSMFSV</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$KSMHP</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$KSMIRU</td>
<td>Shared memory: specific, loaded objects and their sizes, pin candidates.</td>
</tr>
<tr>
<td>X$KSMFS</td>
<td>SGA sizes: fixed SGA, DB_BLOCK_BUFFERS, LOG_BUFFER.</td>
</tr>
<tr>
<td>X$KSMSS</td>
<td>SGA size: shared pool (also listed in Table 13-2, “Instance/Database”).</td>
</tr>
<tr>
<td>X$KSMJS</td>
<td>SGA size: Java pool.</td>
</tr>
<tr>
<td>X$KSMLS</td>
<td>SGA size: large pool.</td>
</tr>
<tr>
<td>X$KSMPP</td>
<td>Very similar to X$KSMSP, without DLR and IDX columns varying numbers on Linux, Solaris, and NT.</td>
</tr>
<tr>
<td>X$KSMSP</td>
<td>Shared pool section sizes/values, etc.</td>
</tr>
<tr>
<td>X$KSMSPR</td>
<td>Shared pool reserved memory statistics/sizes.</td>
</tr>
<tr>
<td>X$KSMSP_LSNLW</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$KSMSP_NWEX</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$KSMUP</td>
<td>Instance and memory structure sizes/statistics.</td>
</tr>
</tbody>
</table>

**TABLE 13-28. Shared Memory**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$ACTIVECKPT</td>
<td>Checkpoint statistics information.</td>
</tr>
<tr>
<td>X$BH</td>
<td>Status and number of pings for every buffer in the SGA.</td>
</tr>
<tr>
<td>X$KCBHS</td>
<td>DBWR histogram statistics.</td>
</tr>
<tr>
<td>X$KCBFWAIT</td>
<td>Buffer cache wait count and time by file.</td>
</tr>
<tr>
<td>X$KCBKPS</td>
<td>Buffer cache block prefetch statistics.</td>
</tr>
<tr>
<td>X$KCBLSC</td>
<td>Buffer cache read/write/wait performance statistics.</td>
</tr>
<tr>
<td>X$KCBS</td>
<td>Buffer cache set read performance statistics.</td>
</tr>
<tr>
<td>X$KCBWAIT</td>
<td>Number of and time spent in waits for buffer pool classes.</td>
</tr>
<tr>
<td>X$KCBWBPD</td>
<td>Statistics on all buffer pools available to the instance, including buffer pool names.</td>
</tr>
<tr>
<td>X$KCBWDS</td>
<td>Statistics on all buffer pools available to the instance.</td>
</tr>
<tr>
<td>TABLE 13-29. Buffer Cache</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>X$ Table</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>X$KQRFP</td>
<td>Information about parent objects in the data dictionary.</td>
</tr>
<tr>
<td>X$KQRF</td>
<td>Information about subordinate objects in the data dictionary.</td>
</tr>
<tr>
<td>X$KQRPLD</td>
<td>Rowcache information: parent/child definition.</td>
</tr>
<tr>
<td>X$KQRS</td>
<td>Rowcache information: subordinate cache definition.</td>
</tr>
<tr>
<td>X$KQRST</td>
<td>Rowcache performance statistics.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 13-30. Rowcache</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>X$ Table</strong></td>
</tr>
<tr>
<td>X$KGLK</td>
</tr>
<tr>
<td>X$KSQFQ</td>
</tr>
<tr>
<td>X$KSQST</td>
</tr>
<tr>
<td>X$KTADM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 13-31. Locks/Enqueues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>X$ Table</strong></td>
</tr>
<tr>
<td>X$KSLD</td>
</tr>
<tr>
<td>X$KSIW</td>
</tr>
<tr>
<td>X$KSIPO</td>
</tr>
<tr>
<td>X$KLSWC</td>
</tr>
<tr>
<td>X$SUPRLAT</td>
</tr>
<tr>
<td>X$MUTEX_SLEEP</td>
</tr>
<tr>
<td>X$MUTEX_SLEEP_HISTORY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 13-32. Latches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>X$ Table</strong></td>
</tr>
<tr>
<td>X$KDHS</td>
</tr>
<tr>
<td>X$KDST</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 13-33. Optimizer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>X$ Table</strong></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
### TABLE 13-34. Shared Servers

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KMCQS</td>
<td>Multithread message queue information.</td>
</tr>
<tr>
<td>X$KMCVC</td>
<td>Virtual circuit connection message transport statistical information.</td>
</tr>
<tr>
<td>X$KMMDI</td>
<td>Shared Servers dispatcher performance information.</td>
</tr>
<tr>
<td>X$KMMDP</td>
<td>Shared Servers dispatcher performance information.</td>
</tr>
<tr>
<td>X$KMMRD</td>
<td>Shared Servers dispatcher information.</td>
</tr>
<tr>
<td>X$KMMSG</td>
<td>Shared Servers process performance information.</td>
</tr>
<tr>
<td>X$KMMSI</td>
<td>Shared Servers process information.</td>
</tr>
</tbody>
</table>

### TABLE 13-35. Parallel Query

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KXPCDS</td>
<td>PQ coordinator dequeue stats.</td>
</tr>
<tr>
<td>X$KXPCMS</td>
<td>PQ coordinator message stats.</td>
</tr>
<tr>
<td>X$KXPCST</td>
<td>PQ coordinator query stats.</td>
</tr>
<tr>
<td>X$KXPDP</td>
<td>Metadata about current PQ sessions, such as number of degree of parallelism, etc.</td>
</tr>
<tr>
<td>X$KXPPFT</td>
<td>Parallel query information.</td>
</tr>
<tr>
<td>X$KXPSDS</td>
<td>PQ slave dequeue stats.</td>
</tr>
<tr>
<td>X$KXPSMS</td>
<td>PQ slave message stats.</td>
</tr>
<tr>
<td>X$KXPSST</td>
<td>PQ slave query stats.</td>
</tr>
<tr>
<td>X$KXPSYS</td>
<td>Parallel query system statistics.</td>
</tr>
<tr>
<td>X$KXPSNS</td>
<td>Performance statistics for sessions running parallel execution.</td>
</tr>
<tr>
<td>X$KXQROW</td>
<td>Statistics on parallel execution operations, query statistics row.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>XS$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSKZDOS</td>
<td>Operation system role related security.</td>
</tr>
<tr>
<td>XSKZTPD</td>
<td>Fine-grained security policies and predicates associated with the cursors currently in the library cache.</td>
</tr>
<tr>
<td>XSKZSPR</td>
<td>Privileges enabled for a session.</td>
</tr>
<tr>
<td>XSKZSRQ</td>
<td>Roles enabled for a session.</td>
</tr>
<tr>
<td>XSKZSRT</td>
<td>List of users who have been granted SYSDBA and SYSOPER privileges (remote password file table entries).</td>
</tr>
</tbody>
</table>

### TABLE 13-37. Resource/Consumer Groups

<table>
<thead>
<tr>
<th>XS$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSKGSKPP</td>
<td>Available CPU resource allocation methods defined for resource plans.</td>
</tr>
<tr>
<td>XSKGSKQUEP</td>
<td>Available queuing resource allocation methods.</td>
</tr>
<tr>
<td>XSKGSKTH</td>
<td>Possibly RCG names.</td>
</tr>
<tr>
<td>XSKGSKTO</td>
<td>Possibly RCG types and attributes.</td>
</tr>
</tbody>
</table>

### TABLE 13-38. Contexts

<table>
<thead>
<tr>
<th>XS$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$CONTEXT</td>
<td>Context information.</td>
</tr>
<tr>
<td>X$GLOBALCONTEXT</td>
<td>Context information.</td>
</tr>
</tbody>
</table>

**NOTE**

“Contexts” has nothing to do with Oracle Text, which used to be called “Context.”

### TABLE 13-39. Heterogeneous Services

<table>
<thead>
<tr>
<th>XS$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSHS_Session</td>
<td>Information about the HS agents currently running on a given host.</td>
</tr>
<tr>
<td>XSHS_SESSION</td>
<td>Information about the HS agents currently running on a given host.</td>
</tr>
</tbody>
</table>
### TABLE 13-40. PL/SQL

<table>
<thead>
<tr>
<th>XS Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KWDDEF</td>
<td>PL/SQL reserved words.</td>
</tr>
</tbody>
</table>

#### TABLE 13-41. Loader/Direct Path API

<table>
<thead>
<tr>
<th>XS Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSKLCIE</td>
<td>Errors that occurred when updating indexes on a table during a load using the Direct Path API.</td>
</tr>
<tr>
<td>XSKLPT</td>
<td>Statistics about the number of rows loaded into a partition, or subpartition, during a load using the Direct Path API.</td>
</tr>
</tbody>
</table>

#### TABLE 13-42. Java Source

<table>
<thead>
<tr>
<th>XS Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSJIOXFC</td>
<td>Compile, resolve, reference information – Java classes.</td>
</tr>
<tr>
<td>XSJIOXFD</td>
<td>Compile, resolve, reference information</td>
</tr>
<tr>
<td>XSJIOXFR</td>
<td>Compile, resolve, reference information – Java resources.</td>
</tr>
<tr>
<td>XSJIOXFS</td>
<td>Source name and/or code.</td>
</tr>
<tr>
<td>XSJIOXFT</td>
<td>Reference names, resolve information, compile information, class name information.</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>$DUAL</td>
<td>Everybody loves the permanent table DUAL, including Oracle. When the</td>
</tr>
<tr>
<td></td>
<td>database is in a nomount or mount state, the permanent table DUAL is not</td>
</tr>
<tr>
<td></td>
<td>available. For some operations, such as recovery, which Oracle needs to do</td>
</tr>
<tr>
<td></td>
<td>when the database is in a nomount or mount state, Oracle queries $DUAL.</td>
</tr>
<tr>
<td>$QFCO</td>
<td>Indexed columns of dynamic performance tables.</td>
</tr>
<tr>
<td>$QFDT</td>
<td>Fixed dynamic or derived tables.</td>
</tr>
<tr>
<td>$QFPP</td>
<td>Fixed procedural object names.</td>
</tr>
<tr>
<td>$QF57</td>
<td>Sizes of various database component types.</td>
</tr>
<tr>
<td>$QFTA</td>
<td>Names of all the fixed tables.</td>
</tr>
<tr>
<td>$QFVI</td>
<td>Names of all the fixed views.</td>
</tr>
<tr>
<td>$SBDD</td>
<td>Descriptions of the background processes.</td>
</tr>
<tr>
<td>$SBDP</td>
<td>Background process names.</td>
</tr>
<tr>
<td>$SI FD</td>
<td>Wait event names.</td>
</tr>
<tr>
<td>$SURLMT</td>
<td>System resource limits.</td>
</tr>
<tr>
<td>$SUSD</td>
<td>Statistics descriptions.</td>
</tr>
<tr>
<td>$TIMER</td>
<td>Lists the elapsed time in hundredths of seconds since the beginning of the</td>
</tr>
<tr>
<td></td>
<td>epoch.</td>
</tr>
</tbody>
</table>

**TABLE 13-43. Miscellaneous Tables**
<table>
<thead>
<tr>
<th>Table</th>
<th>Probable Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$VINST</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$RFMTE</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$RFMP</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KTSPSTAT</td>
<td>Undo/rollback information.</td>
</tr>
<tr>
<td>X$KSXRSG</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KSRREPQ</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KSXRMSG</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KSXRCONQ</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KSXRCH</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KSXAFA</td>
<td>Node affinity.</td>
</tr>
<tr>
<td>X$KSUSEX</td>
<td>Session information.</td>
</tr>
<tr>
<td>X$KSURU</td>
<td>Resource usage by session.</td>
</tr>
<tr>
<td>X$SUPGS</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$SUPGP</td>
<td>Process group info.</td>
</tr>
<tr>
<td>X$KUCF</td>
<td>Resource limits for Resource Manager.</td>
</tr>
<tr>
<td>X$SRMPCTX</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$SRCHDL</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$SRCDESM</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$SRCCTX</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$SMNS</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$SMNIM</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$SMMEM</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$SMJCH</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$SMDD</td>
<td>Shared memory information.</td>
</tr>
<tr>
<td>X$KRBAFF</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KQDPG</td>
<td>PGA row cache cursor stats.</td>
</tr>
<tr>
<td>X$KSAI</td>
<td>Cursor allocation info.</td>
</tr>
<tr>
<td>X$KGLXS</td>
<td>Library cache information.</td>
</tr>
<tr>
<td>X$KGLTRIGGER</td>
<td>Triggers in library cache.</td>
</tr>
<tr>
<td>X$KGLTR</td>
<td>Library cache information.</td>
</tr>
<tr>
<td>X$KGLTABLE</td>
<td>Tables in library cache.</td>
</tr>
<tr>
<td>X$KGLSN</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KGLAUF</td>
<td>Object authorizations.</td>
</tr>
</tbody>
</table>
TABLE 13-44. Other X$ Tables

<table>
<thead>
<tr>
<th>Table Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$KGLRD</td>
<td>Unknown</td>
</tr>
<tr>
<td>X$KDNNSSF</td>
<td>Lock information.</td>
</tr>
<tr>
<td>X$KCRMT</td>
<td>Cache fusion information.</td>
</tr>
<tr>
<td>X$KCLQN</td>
<td>Cache fusion information.</td>
</tr>
<tr>
<td>X$KCLLS</td>
<td>Cache fusion information.</td>
</tr>
<tr>
<td>X$KCLFX</td>
<td>Cache fusion information.</td>
</tr>
<tr>
<td>X$KLCURST</td>
<td>Cache fusion information.</td>
</tr>
<tr>
<td>X$KCBWH</td>
<td>Information about functions pertaining to the buffer cache.</td>
</tr>
<tr>
<td>X$KCBSW</td>
<td>Buffer cache information.</td>
</tr>
<tr>
<td>X$KCBSH</td>
<td>Buffer cache information.</td>
</tr>
<tr>
<td>X$KCBSDS</td>
<td>Buffer cache information.</td>
</tr>
<tr>
<td>X$KBBLRIST</td>
<td>Buffer cache information.</td>
</tr>
<tr>
<td>X$KCBKWRL</td>
<td>Buffer cache write list.</td>
</tr>
<tr>
<td>X$KBBLF</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$KBBLS</td>
<td>Unknown.</td>
</tr>
<tr>
<td>X$CKPTBUF</td>
<td>Checkpoint information.</td>
</tr>
<tr>
<td>X$CN</td>
<td>Container information (for use with PDBs).</td>
</tr>
<tr>
<td>X$CKPTBUF</td>
<td>INMEMORY information (for use with In-Memory column store or IM).</td>
</tr>
</tbody>
</table>

Some Common X$ Table and Non-V$ Fixed View Associations

Table 13-45 lists non-V$ fixed views (V$ views are listed in Appendixes B and C) that are based on at least one X$ table. Many of the fixed views are based on one or more X$ tables, plus other fixed views. You can use this list with $ORACLE_HOME/rdbms/admin/sql.bsq and $ORACLE_HOME/rdbms/admin/migrate.bsq as an aid in deciphering the meaning of X$ table and column contents and in constructing queries that join X$ tables to other X$ tables or to fixed views.
Fixed View
COLUMN_PRIVILEGES
DBA_BLOCKERS
DBA_DATA_FILES

Base X$ Tables and/or Fixed Views
OBJAUTHS, COLS, OBJS, USERS, X$KZSRO
V$SESSION_WAIT, X$KSQRS, VS_LOCK, X$KSUST
FILE$, TS$, V$DBFILE, X$KTFBHC
Table 13-45 lists the X$ table column joins used in fixed views.

**Common X$ Table Joins**

Table 13-46 lists the X$ table column joins used in fixed views.
<table>
<thead>
<tr>
<th>X$ Table and Column</th>
<th>Associated X$ Table and Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$BH.LE_ADDR</td>
<td>X$LE.LE_ADDR</td>
</tr>
<tr>
<td>X$KCCFN.FNFNNO</td>
<td>X$KTTFTHC.KTFTHTCTFNO</td>
</tr>
<tr>
<td>X$HS_SESSION.FDS_INST_ID</td>
<td>X$HOFP.FDS_INST_ID</td>
</tr>
<tr>
<td>X$KCBSC.BPID</td>
<td>X$KCBWBPD.BP_ID</td>
</tr>
<tr>
<td>X$KCBSC.INST_ID</td>
<td>X$KCBWBPD.INST_ID</td>
</tr>
<tr>
<td>X$KCBWDS.SID</td>
<td>X$KCBWBPD.BP_LO_SID</td>
</tr>
<tr>
<td>X$KCBWDS.SET_ID</td>
<td>X$KCBWBPD.BP_HI_SID</td>
</tr>
<tr>
<td>X$KCCFE.FEFNH</td>
<td>X$KCCFN.FNNUUM</td>
</tr>
<tr>
<td>X$KCCFE.FENUM</td>
<td>X$KCCFN.FNFNNO</td>
</tr>
<tr>
<td>X$KCCFE.FENUM</td>
<td>X$KCCFN.FNFNNO</td>
</tr>
<tr>
<td>X$KCCFE.FENUM</td>
<td>X$KCCFN.FNNUUM</td>
</tr>
<tr>
<td>X$KCCFN.FNFX</td>
<td>X$KCVFHTMP.HTMPXFIL</td>
</tr>
<tr>
<td>X$KCCFN.FNFX</td>
<td>X$KCVFH.HCFIL</td>
</tr>
<tr>
<td>X$KCCFN.FNFX</td>
<td>X$KTTFTHC.KTFTHTCTFNO</td>
</tr>
<tr>
<td>X$KCCLE.INST_ID</td>
<td>X$KCCRT.INST_ID</td>
</tr>
<tr>
<td>X$KCCLE.LETHR</td>
<td>X$KCCRT.RTNUM</td>
</tr>
<tr>
<td>X$KCCTF.TFFNH</td>
<td>X$KCCFN.FNNUUM</td>
</tr>
<tr>
<td>X$KCCTF.TFNUN</td>
<td>X$KCCFN.FNFNNO</td>
</tr>
<tr>
<td>X$KCFTIO.KCFTIOFNO</td>
<td>X$KCCTF.TFNUM</td>
</tr>
</tbody>
</table>
NOTE
See Appendixes B and C for detailed listings of all V$ views and X$ tables. There are 1312 X$ tables in Oracle 12.2. Appendix C lists all X$ tables along with all indexes. There is also a cross-listing of many X$ to V$ tables.

X$ Table Naming Conventions (My Favorite Section of This Book!)
This summary lists X$ table definitions. The last revision was in Oracle 7.3.2, and the main purpose of this section is to show the naming conventions (these are great to get to know some of the Oracle acronyms; I’ve included these despite the fact that many are now outdated, but it is still nice to see where some of these names came from originally).
[K]ernel Layer

[2]-Phase Commit
X$K2GTE  - Current 2PC tx
X$K2GTE2 - Current 2PC tx

[C]ache Layer
[B]uffer Management
   Buffer [H]ash
      XSBH - Hash Table

   Buffer LRU Statistics
      X$KCBCHB - [C]urrent [B]uffers (buckets) - lru_statistics
      X$KCBRBH - [R]ecent [B]uffers (buckets) - lru_extended

   Buffer [W]AITs
      X$KCBWAIT - Waits by block class
      X$KCBFWAIT - Waits by File

[W]orking Sets - 7.3 or higher
   X$KCBWDS - Set [D]escriptors

[C]ontrol File Management
[C]ontrol [F]ile List - 7.0.16 or higher
   X$KCCCF - Control File Names & status

[D]atabase [I]nformation
   X$KCCDI - Database Information

Data [F]iles
   X$KCCFEB - File [E]ntries (from control file)
   X$KCCFN - [F]ile [N]ames
Log Files
XSKCCL - Log File Entries
XSKCCLH - Log History (archive entries)

Thread Information
XSKCCRT - [R]edo [T]hread Information

File Management
XSKCFIO - File [IO] Statistics

Lock Manager Component (LCK)
[H]ash and Bucket Tables - 7.0.15 to 7.1.1, and 7.2.0 or higher
XSKCLFH - File [H]ash Table
XSKCLFI - File Bucket Table

X$LE - Lock [E]lements
X$LE STAT - Lock Conversion [STAT]istics
X$KCLFX - Lock Element [F]ree list statistics - 7.3 or higher
X$KCLLS - Per LCK free list statistics - 7.3 or higher
X$KCLQN - [N]ame (hash) table statistics - 7.3 or higher

[R]edo Component
[M]edia recovery - kcrare.h - 7.3 or higher
XSKCRM - [F]ile context
XSKCRMT - [T]hread context
XSKCRMX - Recovery Context

[F]ile read
XSKCRFX - File Read Context - 7.3 or higher

Recovery Component
[F]ile [H]eaders
XSKCDFH - All file headers
XSKCDFHMR - Files with [M]edia [R]ecovry [R]equired
XSKCDFSOL - [ONLINE]ine File headers

Compatibility Management - 7.1.1 or higher
XSKCCE - [C]ompatibility Segment [E]ntries
X$KCKTY - Compatibility [T]ype
X$KCKPM - Compatibility [F]or [M]ats (index into XSKCCE)

Data Layer
Sequence [N]umber Component
XSKDNCE - Sequence [C]ache [E]ntries - 7.2 or lower

Sequence Enqueue - common area for enqueue objects
XSKDNSSC - [C]ache Enqueue Objects - 7.2 or lower
XSKDNSSF - [F]lush Enqueue Objects - 7.2 or lower
XSKDNST - Cache [STAT]istics - 7.2 or lower
Inde[X] Block Component
X$KDXXHS - Index [H]i[S]togram
X$KDXST - Index [ST]atistics

[G]eneric Layer
[H]eap Manager
X$KGHILU - State (summary) of (L)R(U) heap(s) - defined in ksmh.h

[I]nstantiation Manager
[C]ursor [C]ache
X$KGICC - Session statistics - defined in kqlf.h
X$KGICS - System wide statistics - defined in kqlf.h

[L]ibrary Cache Manager (defined and mapped from kqlf)
Bind Variables
X$KKSBV - Library Object [B]ind [V]ariables

Object Cache
X$KGLOB - All [O]bjects
X$KGLTABLE - Filter for [TA]ble[s]
X$KGLBODY - Filter for [BO]dy (packages)
X$KGLTRIGGER - Filter for [TRIG]ger[s]
X$KGLINDEX - Filter for [IN]dex[es]
X$KGLCLUSTER - Filter for [CLUS]ter[s]
X$KGLCURSOR - Filter for [CURS]or[s]

Cache Dependency
X$KGLDP - Object [D]ependency table
X$KGLRD - [R]ead only [D]ependency table - 7.3 or higher

Object Locks
X$KGLLK - Object [L]ock[s]

Object Names
X$KGLNA - Object [NA]mes (sql text)
X$KGLNAL - Object [NA]mes (sql text) with newlines - 7.2.0 or higher

Object Pins
X$KGLPN - Object [PI][N][S]

Cache Statistics
X$KGLST - Library cache [ST]atistics

Translation Table
X$KGLTR - Address [TR]anslation

Access Table
X$KGLXS - Object Access Table

Authorization Table - 7.1.5 or higher
X$KGLAJ - Object Authorization table
Latch Cleanup - 7.0.15 or higher
X$KGLLC - [L]atch [C]leanup for Cache/Fin Latches

[Q]omplic Layer
[S]harded Objects
X$KKSAT - Cursor [A]location [T]information - 7.3.2 or higher

[Q]oader
[L]ibrary
X$KLCLNT - [C]ontent [T]racking Statistics
X$KLLTAB - [T]able Statistics

[M]ulti-Threaded Layer
[C]ircuit component
X$KMQOS - Current [Q]ueue [S]ate
X$KMVC - [V]irtual [C]ircuit state

[M]onitor Server/dispatcher
[D]ispatcher
X$KMMD - [D]ispatcher [I]nfo (status)
X$KMMDP - [D]ispatcher Config ( [D]ispatch info )

[S]erver
X$KMMSI - [S]erver [I]nfo (status)
X$KMMGG - [G]lobal info (global statistics)
X$KMMDR - [R]equest timing [D]istributions

[S]QL Version and Option Layer
[Q]euals
X$VERSION - Library versions

Kernel [O]ptions - 7.1.3 or higher
X$OPT - Server options

[Q]uery Layer
[D]ictionary Cache Management
X$KQDPG - [PG]eared row cache cursor statistics

[F]ixed Tables/views Management
X$KQFCO - Table [CO]lumn definitions
X$KQFDT - [D]erived [T]ables
X$KQFSZ - Kernel Data structure type [S]ize [Z]es
X$KQFTA - Fixed [T]ables
X$KQFTV - Fixed [V]iews
X$KQFVT - [V]iew [T]ext definition - 7.2.0 or higher

[R]ow Cache Management
X$KQRST - Cache [S]tatistics
X$KQRFD - [P]arent Cache [D]efinition - 7.1.5 or higher
X$KQRSD - [S]ubordinate Cache [D]efinition - 7.1.5 or higher
Service Layer

[Detached Process]
X$XSEDE - Detached Process [D]efinition (info)
X$XSEDP - Detached [P]rocess Descriptor (name)
X$MESSAGES - Background Message table

[Instance Management - 7.3 or higher]
X$XSIMAT - Instance [A]tributes
X$XSIMAV - [A]tribute [V]alues for all instances
X$XSIMSI - [S]erial and [I]instance numbers

[Lock Management]
[Event Waits]
X$XSLED - Event [D]escriptors
X$XSLEI - [I]nstance wide statistics since startup
X$XSLES - Current [S]ession statistics

[Latch]
X$XSLLEI - Latch [D]escriptor [name]
X$XSLLEI - Latch statistics [ + Child latchess @ 7.3 or higher ]
X$XSLMW - Latch context ([M]here) descriptors - 7.3+
X$XSLPO - Latch [P]ost statistics - 7.3 or higher

[Memory Management]
[V]context areas
X$XSMDX - [E][X]tended statistics on usage - 7.3.1 or lower

Heap Areas
X$XSMSP - SGA Hea[P]
X$XSPSP - [P]GA Hea[P] - 7.3.2 and above
X$XSMUP - [U]GA Hea[P] - 7.3.2 and above
X$XSPHP - Any [H]ea[P] - 7.3.2 and above
X$XSMSPR - [S]hared [P]ool [R]eserved List - 7.1.5 or higher

[Least recently used shared pool chunks]
X$XSMLRU - LR[U] flushes from the shared pool

[S]GA Objects
X$XSMDSD - Size [D]efinition for Fixed/Variable summary
X$XSMS5S - Statistics (lengths) of SGA objects

SGA [Memory]
X$XSMRM - map of the entire SGA - 7.2.0 or higher
X$XSMF5S - Addresses of [F]ixed [S]GA [V]ariables - 7.2.1+

[Parameter Component]
X$XSPPL - [P]arameter [L]ists (Names)
X$XSPPPCV - [C]urrent Session [V]alues - 7.3.2 or above
X$XSPPSV - [S]ystem [V]alues - 7.3.2 or above
Enqueue Management
  X$KQDSP - Global [D]atabase [N]ame
  X$KQSEQ - [E]n[Q]ueue Object
  X$KQRES - Enqueue [R]esource
  X$KQST - Enqueue [S]tatistics by [T]ype

User Management
  Cost
    X$KUSCF - Cost [F]unction (resource limit)

License
    X$KUSLL - License [L]imits

Language Manager
    X$NLSP - NLS [P]arameters - NLS parameters
    X$KULV - NLS [V]aild Values - 7.1.2 or higher

Statistics
    X$SUMYSTA - [M]y [S]tatistics (current session)

Process Info
    X$KUSPL - Process (resource) [L]imits
    X$KUSPLAT - [L]atch Holder
    X$KUSPK - Process object

Resource
    X$KURU - Ressource [U]age

Statistics
    X$USD - [D]escriptors (statistic names)
    X$SUSSSTA - [G]lobal [ST]atistics

Sessions
    X$USEBCST - Session status for events
    X$USESTA - Session [ST]atistics
    X$USRCON - [CON]ection Authentication - 7.2.1 or higher
    X$USR - [SE]ssion Info
    X$USSC - [S]ystem [I]o [O]0 statistics per session

Timer
    X$UTM - Ti[M]e in 1/100th seconds

Instance [X]
    X$USXINST - [INST]ance state

Trace management:
    X$TRACE - Current traced events
    X$TRACES - All possible traces
    X$TSTEX - Code [EX]ecution - 7.2.1 or higher
Execution Management
- Device/Node Affinity - 7.3.2 and above
  X$KEXXAF - Current File/Node Affinity

Transaction Layer
- Table Access Definition
  X$KTADM - DML lock

Control Component
- X$KCXB - Transaction Object

Segments - 7.3 or higher
- X$KSTSSD - Sorted Segment Descriptor - per table space state

Tablespace
- X$KTVS - Valid Space

Undo
- X$KTURD - Inuse Descriptors
- X$KUXE - Transaction Entry (table) - 7.3.2 or above

Performance Layer
- Information tables
  X$KVII - Initialization Instance parameters
  X$KVSS - Sizes of structure elements
  X$KVIT - Transitory Instance parameters

Security Layer
- Dictionary Component
  X$KZDCS - [DS] roles

Security State
- X$KZSPR - Enabled [PR]ivilages
- X$KZSPR - Enabled [RO]les

Remote Logins - 7.1.1 or higher
- X$KZSR - Remote Password File Table entries

Execution Layer
- Parallel Query (Execute Fast) - 7.1.1 or higher
  Process and Queue Manager
  Statistics - 7.1.3 or higher
  X$KPPYS - System Statistics
  X$KFPDP - Attached Process (slave) statistics
  X$KFPQROW - Table Queue Statistics - 7.3.2 or higher

Coordinator Component
- X$KPPCST - Query Statistics
- X$KPPCMS - Message Statistics
- X$KPPCDS - Queue Statistics
X$ Table Naming Conventions with CON_ID and INMEMORY

In 12c, many X$ tables now have the CON_ID (Container ID) column for pluggable databases. The following are some major tables/views that include CON_ID in the X$ tables and V$ views:

<table>
<thead>
<tr>
<th>X$ Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XSCON</td>
<td>Containers (Main container X$ table accessed by VSCONTAINERS and V$PDBS)</td>
</tr>
<tr>
<td>X$KSMSD</td>
<td>Kernel Service layer Memory management Size Definition (SGA–V$SGA)</td>
</tr>
<tr>
<td>X$KSMSP</td>
<td>Kernel Service layer Memory management SGA heap (Shared Pool)</td>
</tr>
<tr>
<td>XSBH</td>
<td>Buffer Hash (Hash table for all blocks in DB Cache for Data–V$SBH)</td>
</tr>
<tr>
<td>X$KSQRS</td>
<td>Kernel Service layer enQueue management ReSource (Locks–VSLOCK)</td>
</tr>
<tr>
<td>X$KSSLRT</td>
<td>Kernel Service layer Lock management Latches (TRee?) - (Latches V$S$Latch)</td>
</tr>
<tr>
<td>X$KSLWT</td>
<td>Kernel Service layer Lock Wait (Waits–V$SESSION_WAIT)</td>
</tr>
<tr>
<td>X$KSUSRSTA</td>
<td>Kernel Service layer User Statistics Global Statistics (V$SYSSTAT)</td>
</tr>
<tr>
<td>X$KSLOP</td>
<td>Kernel Service layer User management Longops - (slow–V$SESSION_LONGOPS)</td>
</tr>
<tr>
<td>X$KGLST</td>
<td>Kernel Generic layer Library cache STatistics (Shared Pool V$LIBRARYCACHE)</td>
</tr>
<tr>
<td>X$CELL_NAME</td>
<td>Cell Name (disk—hardware specific—also, V$CELL, V$CELL_DISK)</td>
</tr>
</tbody>
</table>

Also in 12c, there are several new INMEMORY V$ views (most identified earlier in the chapter) that access the X$ tables, particularly the X$KTSIMAU table:
Future Version Impact in 12cR2

As noted several times in this chapter, the V$ views and X$ tables are constantly being enhanced as more and more features are added to Oracle. In 12c, the performance of SELECTs on V$ views and X$ tables has improved and they have been expanded to include CON_ID (Container ID) on many of the underlying X$ tables for PDBs (as well as INMEMORY in views and tables). More changes will certainly come in the future (did you see Oracle Cloud coming?)!

Why don’t I climb mountains? I don’t have the time—I’m a DBA!
Why do I open the hood of my car and look at what’s inside? To impress my wife!
Why do I look at the X$ tables? Because I don’t spend a lot of time climbing mountains, and I don’t know what’s really under the hood of my car, but I do know how to use these to my advantage! Now you do, too!

Tips Review

- The X$ tables and V$ views have been expanded for pluggable databases with CON_ID (Container ID) on many current tables/views (new X$ tables such as X$CON) and expanded in 12.1.0.2+ for In-Memory column store (X$KTSIMAU).

- When you mention the X$ tables, most people say, “Oh, pretty scary. I would never touch those tables.” The fact is that DML commands (UPDATE, INSERT, DELETE) are not allowed on the X$ tables, even as the SYS superuser in 12cR2 (I tried).

- Only the SYS superuser can SELECT from the X$ tables. An error occurs if an attempt is made to grant SELECT access to a user. But the X$ tables are not completely harmless. Because they are not documented, they could lead to data being misinterpreted. For example, if a V$ view definition is modified to use a brand-new X$ table, but the DBA has created his or her own view on the X$ tables, he or she might not have accurate information following an upgrade.

- A DBA may need access to the X$ table information, but not the SYS password. Create a view under a different name that mirrors the desired tables. Name these tables according to the appropriate synonyms of the original tables.

- Access the X$KQFVI table for a listing of all V$ and GV$ views. Access the V$FIXED_VIEW_DEFINITION view to get all of the information regarding the underlying X$ tables that comprise a V$ view, including new views for containers (pluggable databases) and In-Memory (IM).

- Query V$FIXED_TABLE for names of the X$ tables, or you can also access two X$ tables X$KQFTA and X$KQFDT for partial listings that, when combined, make up the full list. In 12c, new X$ tables include X$CON (containers) and X$KTSIMAU (In-Memory).
Access the V$INDEXED_FIXED_COLUMN view for a listing of all X$ table indexes.

Oracle generally uses the indexes and uses the correct driving table as needed for accessing the X$ tables, but from time to time, you may use hints to achieve a desired result.

Enclose the class in double quotes if it contains a slash (/); otherwise, you will get an ORA-00995 error.

If X$KSMLRU.KSMLRCOM is similar to Fixed UGA, then a high amount of session-specific allocation is occurring, which suggests that OPEN_CURSORS may be set too high. This is relevant only in cases where Shared Servers are being used.

Anonymous PL/SQL blocks cannot be traced using the “compile debug” method. PL/SQL tracing for the entire session must be enabled with the ALTER SESSION SET PLSQL_DEBUG=TRUE command.

Do not use ORADEBUG SUSPEND on the Microsoft Windows platform. Due to the thread-based processing model of Windows, the whole database will be suspended, not just the process you are attached to.

Cursors may be reassigned if the cursor is closed and released. Therefore, when reading a long trace file, remember that a cursor number referenced at one part of the trace file may not represent the same SQL statement as it does elsewhere in the trace file.

12cR2 includes 1312 X$ tables. The naming conventions continue with a few changes for containers and In-Memory.

References
Steve Adams, Oracle8i Internal Services for Waits, Latches, Locks, and Memory (O’Reilly, 1999).
Tony Jambu, Select Magazine column.
Frank Naude’s underground Oracle web page (www.orafaq.com).
Oracle Database SQL Language Reference, 12c Release 2 (Oracle Corporation).
Oracle Database Advanced Application Developer’s Guide (Oracle Corporation).
Tanel Poder, “Memory Management and Latching Improvements in Oracle9i and 10g” (http://integrid.info/).
Tip of the Week, Wolfgang Genser (for an idea on making touch counts faster), www.oracle.com.
Joseph Trezzo, “Journey to the Center of the X$ Tables” (TUSC).
Joseph Trezzo, “Get the Most Out of Your Money: Utilize the v$ Tables” (IOUG, 1994).

Metalink Notes
186859.995, 1066346.6, 153334.995, 258597.999, 235412.999, 135223.1, 221860.999, 104933.1, 83222.996, 43600.1, 129813.999, 10630.996, 86661.999, 4256.997, 2497.997, 102925.1, 95420.1, 14848.997, 235412.999, 62172.1, 135223.1, 221860.999, 83222.996, 163424.1, 104397.1, 33883.1,
Graham Thornton updated the 11g version of the chapter. Graham Thornton and Kevin Gilpin helped with the incredible job of updating this chapter in 10g. (Please read it quietly and with an English accent.)
Using Statspack and the AWR Report to Tune Waits, Latches, and Mutexes

If you could choose just two Oracle utilities to monitor and find performance problems on your system, you should choose Enterprise Manager (Chapter 5) and the Automatic Workload Repository (AWR) Report and/or Statspack (both covered in this chapter). In Oracle 12cR2, the AWR Report has much more information than you can find with Statspack—and a whole lot more when it comes to impact tuning! Statspack remains in 12cR2 but has few improvements and does not currently include In-Memory statistics. The Statspack utility has been available and free since Oracle 8.1.6 to monitor database performance. Statspack originally replaced the UTLBSTAT/UTLESTAT scripts available with earlier versions of Oracle. The AWR Report leverages the AWR statistics and can be executed within Oracle Enterprise Manager Cloud Control, if desired; it will probably replace Statspack for good in the future. Although the AWR Report has some very nice things in it that Statspack doesn’t have, you must license the Oracle Diagnostics Pack to access the AWR dictionary views necessary for the AWR Report. Statspack is still a free utility that many people use (which is why I include coverage of it in this chapter). Although you are not supposed to modify the Statspack code, you can modify it. If you modify the code, however, Statspack is not supported.

In this chapter, you learn how to install the AWR Report and Statspack, how to manage them, and how to run and interpret the reports generated. Statspack includes data for both proactive and reactive tuning and is probably the best way to query most of the relevant V$ views and X$ tables and view the results in a single report. The AWR Report is a great way to mine the AWR for aggregate performance data in a report similar to, but better than, the Statspack Report. I’ll cover Statspack first, but only because it’s a starting point to the AWR, which is by far more advanced and comprehensive and should be used instead of Statspack if at all possible.

Tips covered in this chapter include the following:

- What’s new in 12c for Statspack and the AWR (PERFSTAT at the CDB level in 12.2)
- Creating a tablespace to hold the Statspack data apart from your application and SYSTEM objects
- Finding the files needed to create, manage, and drop the Statspack objects
- Changing the PERFSTAT password and locking the account when it is no longer in use
Selecting the proper level for your reporting

Times to avoid running Statspack Reports

Running the AWR Report and Statspack together: cautionary notes

Using Oracle Enterprise Manager Cloud Control to run the AWR Report

Tuning the top wait events, including Oracle Database 12c mutex wait events

Using the Segment Statistics sections of the reports to find issues

Tuning latches and mutexes, including 12cR2 In-Memory latches

Tuning at the block level to find hot blocks and interested transaction list (ITL) problems

The top ten things to look for in the 12cR2 AWR Report and Statspack output

Managing the Statspack data and analyzing and purging it as needed

Monitoring Statspack space usage

Including Statspack data in your backup and upgrade plans

Using the ADDM Report (text) as a stand-alone tool

What’s New in 12cR2 (12.2) Statspack and the AWR Report

Oracle Database 12c offers a few new details in the reports. I have listed the ones here that I see as important and helpful to both the AWR and Statspack Reports. New features in 12cR2 include the following:

Setting up Statspack and AWR for pluggable databases (PDBs) and the container database (CDB) is important. We’ll discuss how to set them up and analyze for different PDBs and the CDB, but one very important setup note in 12.2 is that PERFSTAT can now be created in the CDB. In 12.1, you have to either create a common user (C##PERFSTAT) or only run the script in a PDB or run the sqlsessstart.sql script first in the CDB and then run spcreate.sql. In 12.2, the ALTER SESSION contained in sqlsessstart.sql is now part of spcreate.sql.

MEMORY_TARGET is an initialization parameter for sizing all memory since Oracle 10g (see Chapter 4). With 12c (12.1.0.2), Oracle now includes INMEMORY_SIZE in the MEMORY_TARGET parameter (otherwise it’s included in the SGA_TARGET if INMEMORY_SIZE is unset or set to 0).

In the IO Stats section in 12.2, you will see some In-Memory (IM) population statistics.

In the 12.2 LATCH MISS section, you’ll see even more IM information on latches, including In-Memory columnar segment latch misses (and others).

You must ensure that idle events are set (in 12.1 many of my top waits were idle events—in 12.2 this was corrected). In 12.1, there were many idle events inserted into
You use `spup112.sql` to upgrade 11gR2 to 12c Statspack. You also use `spup12102.sql` and `spup12200.sql` to update to 12.1.0.2 and 12.2, respectively. The `spup112.sql` script adds many new and needed idle events.

Sections on the new Foreground Processes, Background Processes, and a combination of both are now included in the report.

DB time is contained in many sections.

Physical memory is now displayed in gigabytes (G) instead of megabytes (M).

In 12.1, some of the Statspack results in the PDBs versus the CDB didn’t have the right statistics (i.e., sometimes Statspack showed the aggregate totals of the CDB in the PDB incorrectly, but percentages for the ratios at the PDB level were correct). In the AWR, it correctly showed the totals in the CDB and PDB, but had the wrong percent in the PDB. The things that I checked were correct at both levels in 12.2, so as with tuning and with different versions, ensure this is correct depending on which report you use.

At the end of the report you’ll see initialization parameters including these 12cR2 ones: `COMPATIBLE=12.2.0.0.0`, `INMEMORY_SIZE`, and `PGA_AGGREGATE_LIMIT` (you’ll see them because you are now using them, hopefully).

### Installing Statspack

Statspack must be installed in every database to be monitored (and that includes every pluggable database that you want to monitor separately). If you are using the AWR Report (preferable), you do not need to run Statspack. Prior to installing Statspack, you should create a tablespace to hold the Statspack data. If you don’t specify a tablespace, the SYSAUX tablespace is used. During the installation process, you are prompted for the name of the tablespace to hold the Statspack database objects. You should also designate a temporary tablespace that will be large enough to support the large INSERTs and DELETEs Statspack may perform.

The installation script, named `spcreate.sql`, is found in the `/rdbms/admin` subdirectory under the Oracle software home directory. The `spcreate.sql` script creates a user named PERFSTAT. (In 12.1, while this works in a single PDB, if you run this in the main CDB, it will fail, as the CDB requires a common user, such as `C##PERFSTAT`. This is fixed in 12.2.)

**TIP**

Allocate at least 120M for the initial creation of the PERFSTAT schema’s objects.

To start the `spcreate.sql` script, change your directory to `ORACLE_HOME/rdbms/admin` and log in to SQL*Plus using an account with SYSDBA privileges:
During the installation process, you are prompted for the PERFSTAT user password (for security purposes, a default password is no longer included); then you are prompted for a default tablespace for the PERFSTAT user (a list of available tablespaces is displayed along with this prompt). You are also asked to specify a temporary tablespace for the user. Once you have provided default and temporary tablespaces for the PERFSTAT account, the account is created and the installation script logs in as PERFSTAT and continues to create the required objects. If there is not sufficient space to create the PERFSTAT objects in the specified default tablespace, the script returns an error.

The `spcreate.sql` script calls three scripts: `spcusr.sql` to create the user, `spctab.sql` to create the underlying tables, and `spcpkg.sql` to create the packages. When run, each of these scripts generates a listing file (`spcusr.lis`, etc.). Although you start the installation script while logged in as a SYSDBA-privileged user, the conclusion of the installation script leaves you logged in as the PERFSTAT user. If you want to drop the PERFSTAT user at a later date, you can run the `spdrop.sql` script (which calls `spdusr.sql` and `spdtab.sql`) located in the ORACLE_HOME/rdbms/admin directory.

### Security of the PERFSTAT Account

The `spcusr.sql` script creates the PERFSTAT account and asks you to supply a password (the default was PERFSTAT in previous versions). The Statspack utility does not need to use the PERFSTAT default password; change the password after the installation process completes. Also, remember that in 12c, passwords are case sensitive. This is controlled by an initialization parameter `SEC_CASE_SENSITIVE_LOGON`. The default is TRUE, which makes passwords case sensitive by default. Set this to FALSE to disable this feature (see Chapter 4 for more information on initialization parameters). Consider the following case-sensitivity issue, if my username/password was perfstat/perfstat (which it shouldn’t be, because it would be too easy to hack):

```sql
SQL> connect perfstat/perfstat
Connected.

SQL> connect PERFSTAT/perfstat
Connected.

SQL> connect perfstat/PERFSTAT
ERROR: ORA-01017: Invalid username/password; logon denied.
Warning: You are no longer connected to ORACLE.
```

The PERFSTAT user is granted the SELECT_CATALOG_ROLE and privileges on many of the V$_ views (which allows you to query the corresponding VS views; see Chapter 12). The
PERFSTAT user is also granted several system privileges (CREATE/ALTER SESSION, CREATE TABLE, CREATE VIEW, CREATE/DROP PUBLIC SYNONYM, CREATE SEQUENCE, and CREATE PROCEDURE). PERFSTAT is also granted EXECUTE privilege on DBMS_SHARED_POOL and DBMS_JOB. Any user who can access your PERFSTAT account can select from all of the dictionary views. For example, such a user could query all of the database account usernames from DBA_USERS, all the segment owners from DBA_SEGMENTS, and the currently logged-in sessions from V$SESSION. The PERFSTAT account, if left unprotected, provides a security hole that allows intruders to browse through your data dictionary and select targets for further intrusion.

In addition to the privileges it receives during the installation process, the PERFSTAT account also has any privileges that have been granted to PUBLIC. If you use PUBLIC grants instead of roles for application privileges, you must secure the PERFSTAT account. You can lock and unlock database accounts as needed. To lock the PERFSTAT account when you are not using Statspack, use the ALTER USER command, as shown in the following listing:

```
alter user PERFSTAT account lock;
```

When you need to gather statistics or access the Statspack data, you can unlock the account:

```
alter user PERFSTAT account unlock;
```

### Post-Installation

Once the installation process is complete, the PERFSTAT account owns 72 tables and 72 indexes, 75 public synonyms (PUBLIC actually owns all of the public synonyms), a sequence, a view, and a package (with body).

You use the package, named Statspack, to manage the statistics collection process and the data in the tables. The collection tables, whose names all begin with “STATS$,” use column definitions based on the V$ view definitions. For example, the columns in STATS$WAITSTAT are the columns found in V$WAITSTAT, with three identification columns added at the top:
The CLASS, WAIT_COUNT, and TIME columns are based on the CLASS, COUNT, and TIME columns from V$WAITSTAT. Statspack has added these identification columns:

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNAP_ID</td>
<td>An identification number for the collection. Each collection is called a snapshot and is assigned an integer value.</td>
</tr>
<tr>
<td>DBID</td>
<td>A numeric identifier for the database.</td>
</tr>
<tr>
<td>INSTANCE_NUMBER</td>
<td>A numeric identifier for the instance for RAC installations.</td>
</tr>
</tbody>
</table>

Each collection you perform is given a new SNAP_ID value that is consistent across the collection tables. You need to know the SNAP_ID values when executing the statistics report provided with Statspack.

Gathering Statistics

As mentioned in the previous description of the SNAP_ID column, each collection of statistics is called a snapshot. Snapshots of statistics have no relation to snapshots or materialized views used in replication. Rather, a snapshot is a point-in-time collection of the statistics available via the V$ views and is given a SNAP_ID value to identify it. You can generate reports on the changes in the statistics between any two snapshots. With Statspack, you can collect as many snapshots as you need and then generate reports against any combination of them. The Statspack Report is only valid if the database is not shut down and restarted between the evaluated snapshots.

TIP

Be sure the TIMED_STATISTICS database initialization parameter is set to TRUE prior to gathering statistics.

To generate a snapshot of the statistics, execute the SNAP procedure of the Statspack package, as shown in the following listing. You must be logged in as the PERFSTAT user to execute this
When you execute the SNAP procedure, Oracle populates your STATSS$ tables with the current statistics. You can then query those tables directly, or you can use the standard Statspack Report (to see the change in statistics between snapshots).

Snapshots should be taken in one of two ways, depending on the purpose:

- **To evaluate performance during specific tests of the system** For these tests, you can execute the SNAP procedure manually, as shown in the prior example.

- **To evaluate performance changes over a long period of time** To establish a baseline of system performance, you may generate statistics snapshots on a scheduled basis. For these snapshots, you should schedule the SNAP procedure execution via the Oracle Scheduler or via an operating system scheduler.

For the snapshots related to specific tests, you may wish to increase the collection level, which lets you gather more statistics. As noted in the section “Managing the Statspack Data” later in this chapter, each snapshot has a cost in terms of space usage and query performance. For example, since the V$SYSSTAT view has 1,688 rows in 12.2 (note we have CDB and PDBs now), whereas there were only 588 rows in Oracle 11.2 on Windows (628 on Linux), every snapshot generates 1,688 rows in STATSS$SYSSTAT. In 10.2, there were only 347 rows in V$SYSSTAT. Avoid generating thousands of rows of statistical data with each snapshot unless you plan to use them.

To support differing collection levels, Statspack provides the I_SNAP_LEVEL parameter. By default, the level value is set to 5. Prior to changing the level value, generate several snapshots and evaluate the reports generated. The default level value is adequate for most reports. Alternative level values are listed in the following table:
The greater the collection level, the longer the snapshot will take. The default value (5) offers a significant degree of flexibility during the queries for the most resource-intensive SQL statements. The parameters used for the resource-intensive SQL portion of the snapshot are stored in a table named STATS$STATSPACK_PARAMETER. You can query STATS$STATSPACK_PARAMETER to see the settings for the different thresholds during SQL statement gathering. Its columns include SNAP_LEVEL (the snapshot level), EXECUTIONS_TH (threshold value for the number of executions), DISK_READS_TH (threshold value for the number of disk reads), and BUFFER_GETS_TH (threshold value for the number of disk reads).

For a level 5 snapshot using the default thresholds, SQL statements are stored if they meet any of the following criteria:

- The SQL statement has been executed at least 100 times.
- The number of disk reads performed by the SQL statement exceeds 1000.
- The number of parse calls performed by the SQL statement exceeds 1000.
- The number of buffer gets performed by the SQL statement exceeds 10,000.
- The sharable memory used by the SQL statement exceeds 1M.
- The version count for the SQL statement exceeds 20.

When evaluating the snapshot’s data and the performance report, keep in mind the SQL threshold parameter values are cumulative. A very efficient query, if executed enough times, will exceed 10,000 buffer gets. Compare the number of buffer gets and disk reads to the number of executions to determine the activity each time the query is executed.

To modify the default settings for the thresholds, use the MODIFY_STATSPACK_PARAMETER procedure in the STATSPACK package. Specify the snapshot level via the I_SNAP_LEVEL parameter, along with the parameters to change. Table 14-1 lists the available parameters for the
MODIFY_STATSPACK_PARAMETER procedure.

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Range of Values</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>l_SNAP_LEVEL</td>
<td>0, 5, 6, 7, 10</td>
<td>5</td>
<td>Snapshot level</td>
</tr>
<tr>
<td>l_UCOMMENT</td>
<td>Any text</td>
<td>Blank</td>
<td>Comment for the snapshot</td>
</tr>
<tr>
<td>l_EXECUTIONS_TH</td>
<td>Integer &gt;= 0</td>
<td>100</td>
<td>Threshold for the cumulative number of executions</td>
</tr>
<tr>
<td>l_DISK_READS_TH</td>
<td>Integer &gt;= 0</td>
<td>1000</td>
<td>Threshold for the cumulative number of disk reads (physical reads)</td>
</tr>
<tr>
<td>l_PARSE_CALLS_TH</td>
<td>Integer &gt;= 0</td>
<td>10000</td>
<td>Threshold for the cumulative number of parse calls</td>
</tr>
<tr>
<td>l_BUFFER_GETS_TH</td>
<td>Integer &gt;= 0</td>
<td>100000</td>
<td>Threshold for the cumulative number of buffer gets (logical reads)</td>
</tr>
<tr>
<td>l_SHARABLE_MEM_TH</td>
<td>Integer &gt;= 0</td>
<td>1048576</td>
<td>Threshold for the amount of shareable memory allocated</td>
</tr>
<tr>
<td>l_VERSION_COUNT_TH</td>
<td>Integer &gt;= 0</td>
<td>20</td>
<td>Threshold for the number of versions of the SQL statement</td>
</tr>
<tr>
<td>lSEG_BUFF_BUSY_TH</td>
<td>Integer &gt;= 0</td>
<td>100</td>
<td>Threshold for the number of buffer busy waits on a segment</td>
</tr>
<tr>
<td>lSEG_ROWLOCK_W_TH</td>
<td>Integer &gt;= 0</td>
<td>100</td>
<td>Threshold for the number of row lock waits on a segment</td>
</tr>
<tr>
<td>lSEG_ITL_WAITS_TH</td>
<td>Integer &gt;= 0</td>
<td>100</td>
<td>Threshold for the number of ITL waits on a segment</td>
</tr>
<tr>
<td>lSEG_CR_BKS_SD_TH</td>
<td>Integer &gt;= 0</td>
<td>10000</td>
<td>Threshold for the number of consistent read (CR) blocks served for a segment</td>
</tr>
<tr>
<td>lSEG_CU_BKS_SD_TH</td>
<td>Integer &gt;= 0</td>
<td>10000</td>
<td>Threshold for the number of current (CU) blocks served for a segment</td>
</tr>
<tr>
<td>lSEG_PHY_READS_TH</td>
<td>Integer &gt;= 0</td>
<td>10000</td>
<td>Threshold for the number of physical reads on a segment</td>
</tr>
<tr>
<td>lSEG_LOG_READS_TH</td>
<td>Integer &gt;= 0</td>
<td>100000</td>
<td>Threshold for the number of logical reads on a segment</td>
</tr>
<tr>
<td>l_SESSION_ID</td>
<td>Valid SID from V$SESSION</td>
<td>0</td>
<td>Session ID of an Oracle session, if you wish to gather session-level statistics</td>
</tr>
<tr>
<td>l_MODIFY_PARAMETER</td>
<td>True or False</td>
<td>False</td>
<td>Set to True if you wish to save your changes for future snapshots</td>
</tr>
</tbody>
</table>
To increase the BUFFER_GETS threshold for a level 5 snapshot to 100,000, issue the following command ("-" indicates the command continues on the next line):

```sql
EXECUTE STATSPACK.MODIFY_STATSPACK_PARAMETER -
  (i_snap_level=>5, i_buffer_gets_th=>100000, -
   i_modify_parameter=>'true');
```

If you plan to run the SNAP procedure on a scheduled basis, you should pin the Statspack package following database startup. The following listing shows a trigger that is executed each time the database is started. The KEEP procedure of the DBMS_SHARED_POOL package pins the Statspack package in the shared pool. As an alternative to pinning, you can use the SHARED_POOL_RESERVED_SIZE initialization parameter to reserve shared pool area for large packages.

```sql
create or replace trigger PIN_ON_STARTUP
after startup on database
begin
    DBMS_SHARED_POOL.KEEP ('PERFSTAT.STATSPACK', 'P');
end;
/
```

**TIP**

*Pin the Statspack package following database startup if you plan to run the SNAP procedure on a scheduled basis.*

## Running the Statistics Report

If you have generated more than one snapshot, you can report on the statistics for the period between the two snapshots. The database must not have been shut down between the times the two snapshots were taken. When you execute the report, you need to know the SNAP ID values for the snapshots. If you run the report interactively, Oracle provides a list of the available snapshots and the times they were created.

To execute the report, go to the /rdbms/admin directory under the Oracle software home directory. Log in to SQL*Plus as the PERFSTAT user and run the `spreport.sql` file found there:
Oracle displays the database and instance identification information from V$INSTANCE and V$DATABASE and then calls a second SQL file, sprepins.sql.

The sprepins.sql script generates the report of the changes in the statistics during the snapshot time interval. The available snapshots are listed, and you will be prompted to enter beginning and ending snapshot IDs. Unless you specify otherwise, the output is written to a file named sp_beginning_ending.lst (for example, sp_1_2.lst for a report between SNAP_ID values of 1 and 2—this will be exactly what you get when you run your first Statspack Report).

TIP
A second report, sprepsql.sql, can be used for additional research into the problem SQL statements identified via the spreport.sql report.

The Automatic Workload Repository (AWR) and the AWR Report

The AWR Report reports on the AWR stored data and is definitely the next generation of the Statspack Report. It does require additional licensing, so ensure that you are licensed to use it. The AWR collects database statistics every 60 minutes (on the hour) out of the box (this is configurable), and this data is maintained for a week and then purged. The statistics collected by the AWR are stored in the database. The AWR Report accesses the AWR to report statistical performance information similar to how Statspack has always done. Because the AWR schema was originally based on the Statspack schema, you will find much of what is included in Statspack in the AWR Report. Learning the AWR Report if you are familiar with Statspack is easy, but you will not find everything in Statspack that you find in the AWR Report. There are some newer/cooler parts of the AWR Report that Statspack users will definitely value.

The AWR data is stored separately from the Statspack data, so running both is a bit superfluous. If you choose to run both, ensure that you stagger AWR data collection from the Statspack collection—by at least 30 minutes—to avoid a performance hit as well as conflicts. You could also run both as you switch from one reporting tool to the other for overlap to ensure that you have coverage that shows comparison reports.

The Oracle database uses the AWR for problem detection and analysis as well as for self-tuning. A number of different statistics are collected by the AWR, including wait events, time model statistics, active session history statistics, various system- and session-level statistics, object usage statistics, and information on the most resource-intensive SQL statements. To properly collect database statistics, set the initialization parameter STATISTICS_LEVEL to TYPICAL (the default) or ALL. Other Oracle Database 12c features use the AWR, such as Automatic Database Diagnostic Monitor (ADDM) and other Enterprise Manager Cloud Control features as discussed in Chapter 5.
If you want to explore the AWR, feel free to do so. The AWR consists of a number of tables owned by the SYS schema and typically stored in the SYSAUX tablespace (currently no method exists that I know of to move these objects to another tablespace). All AWR table names start with the identifier "WR." AWR tables come with three different type designations:

- Metadata (WRM$)
- Historical/convertible data (WRH$, WRR$, and WRI$)
- AWR tables related to advisor functions (WRI$)

Most of the AWR table names are pretty self-explanatory, such as WRM$_SNAPSHOT or WRH$_ACTIVE_SESSION_HISTORY (a very valuable view to check out). Also, Oracle Database 12c offers several DBA views that allow you to query the AWR repository. The views start with DBA_HIST and are followed by a name that describes the view. These include views such as DBA_HIST_FILESTATS, DBA_HIST_DATAFILE, and DBA_HIST_SNAPSHOT.

**TIP**

*If you choose to run both Statspack and the AWR, ensure that you stagger the AWR data collection from Statspack collection by at least 30 minutes to avoid a performance hit as well as conflicts. If you are running the AWR Report, you should not also need to run Statspack.*

---

**Manually Managing the AWR**

Although the AWR is meant to be automatic (Oracle is capturing this information “out of the box”), provisions for manual operations impacting the AWR are available. You can manually modify the snapshot collection interval and retention criteria, create snapshots, and remove snapshots from the AWR. I will describe these processes in more detail in the next few sections, but please refer to the Oracle documentation for full coverage of the AWR.

You can modify the snapshot collection interval using the DBMS_WORKLOAD_REPOSITORY package. The procedure DBMS_WORKLOAD_REPOSITORY.MODIFY_SNAPSHOT_SETTINGS is used in this example to modify the snapshot collection so it occurs every 15 minutes and retention of snapshot data is fixed at 20,160 minutes (exactly 14 days):

```sql
-- This causes the repository to refresh every 15 minutes
-- and retain all data for 2 weeks.
exec dbms_workload_repository.modify_snapshot_settings -
[retention=>20160, interval=> 15];
```

Setting the interval parameter to 0 disables all statistics collection.
To view the current retention and interval settings for the AWR, use the DBA_HIST_WR_CONTROL view. There are two new columns in the 12c view: CON_ID (Container ID) and View Location. Here is an example of how to use this view:

```
select *
from dba_hist_wr_control;
```

<table>
<thead>
<tr>
<th>DBID</th>
<th>SNAP INTERVAL</th>
<th>RETENTION</th>
<th>TOPSQL CON_ID</th>
<th>VIEW LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1444324921</td>
<td>01:00:00:00</td>
<td>NONE</td>
<td>DEFAULT</td>
<td>1</td>
</tr>
</tbody>
</table>

In the preceding example, you see that the snapshot interval is every hour (the default), and the retention is set for eight days.

You can use the DBMS_WORKLOAD_REPOSITORY package to create or remove snapshots. The DBMS_WORKLOAD_REPOSITORY.CREATE_SNAPSHOT procedure creates a manual snapshot in the AWR, as seen in this example:

```
exec dbms_workload_repository.create_snapshot;
```

You can see what snapshots are currently in the AWR by using the DBA_HIST_SNAPSHOT view, as seen in this example:

```
select snap_id, begin_interval_time, end_interval_time
from dba_hist_snapshot
order by 1;
```

<table>
<thead>
<tr>
<th>SNAP_ID</th>
<th>BEGIN_INTERVAL_TIME</th>
<th>END_INTERVAL_TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>375</td>
<td>11-MAY-16 11.00.37.796 PM</td>
<td>13-MAY-11 01.16.48.897 PM</td>
</tr>
<tr>
<td>376</td>
<td>13-MAY-16 01.16.48.897 PM</td>
<td>13-MAY-11 02.00.29.909 PM</td>
</tr>
<tr>
<td>377</td>
<td>13-MAY-16 02.00.29.909 PM</td>
<td>13-MAY-11 03.00.42.797 PM</td>
</tr>
<tr>
<td>378</td>
<td>13-MAY-16 03.00.42.797 PM</td>
<td>13-MAY-11 04.00.55.608 PM</td>
</tr>
</tbody>
</table>

Each snapshot is assigned a unique snapshot ID that is reflected in the SNAP_ID column. If you have two snapshots, the earlier snapshot always has a smaller SNAP_ID than the later snapshot. The END_INTERVAL_TIME column displays the time that the actual snapshot was taken.

Sometimes you might want to drop snapshots manually. The DBMS_WORKLOAD_REPOSITORY.DROP_SNAPSHOT_RANGE procedure can be used to remove a range of snapshots from the AWR. This procedure takes two parameters, LOW_SNAP_ID and HIGH_SNAP_ID, as seen in this example:
AWR Automated Snapshots

Oracle automatically gathers statistics for the AWR, and does so as long as the STATISTICS_LEVEL initialization parameter is set to TYPICAL or ALL (the default is TYPICAL). Setting the STATISTICS_LEVEL to BASIC disables many Oracle features including the AWR. To check your STATISTICS_LEVEL run the following:

```
exec dbms_workload_repository.drop_snapshot_range -
(low snap id=>1107, high snap id=>1108);
```

AWR Snapshot Reports

Oracle provides reports that you can run to analyze the data in the AWR. These reports are much like the Statspack Reports. The AWR has two reports: `awrrpt.sql`, which is the main AWR Report, and `awrrpti.sql`. Both reports are available in the `$ORACLE_HOME/rdbms/admin` directory. The output of these reports (run from SQL*Plus) is essentially the same, except that `awrrpti.sql` allows you to define a specific instance to report on. The reports are much like the Statspack Reports of old, in that you define beginning and ending snapshot IDs, along with the report’s output filename. Additionally, you can opt to produce the report in either text format or HTML format. As you will see when you run `awrrpt.sql`, the following simple example shows how similar this is to Statspack, other than the text itself (Statspack-looking output), or HTML (the screenshots in this chapter are both the text and the HTML) output:
With the new 12cR2 AWR Report, you can choose to get text (similar to Statspack output), HTML, or the new Active HTML format (which summons OEM at the end of the report if desired) when you run `awrrpt.sql`. The HTML format is much better than text, as you can click various links within the report to navigate among sections easily. You can also run the AWR Report within OEM.

As when using Statspack, creating a baseline in the AWR is a good idea. A baseline is defined as a range of snapshots that you can use to compare with other pairs of snapshots. The Oracle database server will exempt the snapshots assigned to a specific baseline from the automated purge routine. The main purpose of a baseline is, therefore, to preserve typical runtime statistics in the AWR repository, allowing you to run the AWR snapshot reports on the preserved baseline snapshots at any time and compare them to recent snapshots contained in the AWR. This way you can compare current performance (and configuration) to established baseline performance, which can help you determine database performance problems.

You can use the `CREATE_BASELINE` procedure contained in the `DBMS_WORKLOAD_REPOSITORY` stored PL/SQL package to create a baseline, as seen in this example (you could also create a snapshot when nobody is on the system as a comparison):

```
exec dbms_workload_repository.create_baseline -
  (start_snap_id=>1109, end_snap_id=>1111, -
  baseline_name=>'EOM Baseline');
```

Baselines can be seen using the `DBA_HIST_BASELINE` view, as seen in the following example:
In this case, the column BASELINE_ID identifies each individual baseline that has been defined. The name assigned to the baseline is listed, as are the beginning and ending snapshot IDs.

You can remove a baseline using the DBMS_WORKLOAD_REPOSITORY.DROP_BASELINE procedure, as seen in this example, which drops the EOM Baseline that I just created:

```
EXEC dbms_workload_repository.drop_baseline -
(baseline_name=>'EOM Baseline', Cascade=>FALSE);
```

**NOTE**
The CASCADE parameter causes all associated snapshots to be removed if it is set to TRUE; otherwise, the snapshots are cleaned up automatically by the AWR automated processes.

---

Run the AWR Report in Oracle Enterprise Manager

Although, as I have demonstrated, you can use the DBMS_WORKLOAD_REPOSITORY package to manage the AWR repository, you can also manage the AWR from Oracle Enterprise Manager. Enterprise Manager is covered in detail in Chapter 5, but some of the AWR Report screens are covered in this chapter. Enterprise Manager provides a nice interface into the management of the AWR and also provides an easy method for creating the AWR Report. Navigate to the database you wish to report on, then go to the Performance tab as seen in Figure 14-1. You can then click AWR.
FIGURE 14-1. AWR is located on the Performance drop-down tab.

The next AWR screen (Figure 14-2) provides a summary of the current AWR settings and gives you an option to modify them and has a button to Run AWR Report. You can also review details about the snapshots in the AWR and create baseline AWR snapshots (called preserved snapshot sets in Enterprise Manager). Some of the important things you’ll see on the edit page include snapshot retention, how often snapshots are collected (or if collection is turned off), and the collection level.

FIGURE 14-2. AWR collection settings, snapshots and Run AWR Report button

If you click the Edit button to the right of snapshot retention, the Edit Settings page displays information regarding snapshot retention and snapshot intervals that can be changed. You can also click on the Run Compare Periods Report button in Figure 14-2 to compare two sets of snapshot pairs. Clicking on this button displays the screen we see in Figure 14-3. Here you can enter starting and ending snapshots for the AWR Report. As long as the snapshots exist, you can run a report starting with any snapshot and ending with any snapshot. If you take snapshots every hour, you can either run a report for an hour or run a report spanning 24 hours (as long as the instance is not shut down at any time between snapshots). If you are running Real Application Clusters (RAC), you must run the report for each instance individually. Comparing snapshots allows you to determine if differences exist
between a baseline snapshot and a recent set of snapshots. Using the report generated from this action, you can determine if the current system performance is diverging from the baseline performance in some way.

---

**FIGURE 14-3. Running the Compare Periods Report using the AWR**

You might investigate the following Oracle scripts for more information: `awrginp.sql`, `awrgrpt.sql`, and `awrgrpti.sql`. When you click on the Run AWR Report button in Figure 14-2, you just need to choose beginning and ending snapshot IDs (like you did in the Run Compare Periods Report) and click Generate Report as you did in Figure 14-3. Also, the AWR and ADDM support RAC and the In-Memory column store in 12cR2.

---

**TIP**

*If you use Oracle Enterprise Manager (OEM), you can run the AWR Report directly from Cloud Control or Database Control from multiple versions of OEM.*

When you generate an AWR Report, you will probably see a little clock (this screen is not displayed here), which tells you that the report is being generated. Then you will see the actual report (shown in Figure 14-4) as it is displayed in Enterprise Manager. You can also generate the report (`awr_report_425_431.html` in my case) in a file that can be viewed at any time by clicking Save To File. Many of the AWR Report screenshots in this chapter come from this report, but I also show a higher-volume example at times. You can see from Figure 14-4 and (in the next section) Figure 14-5 that the beginning of the AWR Report looks similar to the beginning of the Statspack Report (this one is for snaps 2239 to 2243 on 12.2.0.0.2). We’ll see shortly that the AWR Reports and Statspack Reports vary in structure and what’s included. Notably missing in the Statspack Report in 12.2 is the In-Memory information, which is seen in the AWR Report in Figure 14-5.
**FIGURE 14-4.** The actual AWR Report is browsable or savable to a file.

**Interpreting the Statspack and AWR Report Output**
Several sections are included in both the Statspack and AWR Reports. I cover each of the main sections, along with information on what to look for and how to use information that appears to be problematic. Most information must be combined with additional research to solve an issue, leading to an optimized system.

The Header Information and Cache Sizes

The first section of both the AWR Report and Statspack Report contains information about the database itself, including information on the database name, ID, release number, and host. Following this information is information on when the snapshot was started and ended and how many sessions were active. Always check to ensure the snapshot interval is what you were trying to measure, and make sure that it’s a long enough interval to make it representative. If your interval is five minutes, that is almost always not long enough unless you are measuring something very short in duration. If your interval is five days, then you will have all kinds of peaks and valleys that average out, so it may be too long. But having one-day, one-hour (at peak), and one-hour (at non-peak) Statspack Reports handy is great to compare to a problem Statspack Report for any given day when an anomaly occurs on your system. Generally, a Statspack Report should cover at least an hour of time and should be strategically timed to measure problematic periods of time. You may also want to look at an entire day so you can compare days over a period of time.

The first section of the Statspack Report is Cache Sizes. Prior to 12c, this was also the first section in the AWR Report, but it has been moved down a few sections in 12c (the Load Profile section is now first, as you saw in Figure 14-4). An example of the Statspack header information and Cache Sizes section is displayed next. The equivalent information in the AWR Report is displayed in Figure 14-5 (with the Cache Sizes section cut and pasted from its new, later location for easy comparison). The notable difference between the Cache Sizes section in the two reports is that the 12cR2 Statspack Report does not include the In-Memory Area. Both reports include Buffer Cache (DB_CACHE_SIZE), Shared Pool Size (SHARED_POOL_SIZE), Std Block Size (DB_BLOCK_SIZE), and Log Buffer (LOG_BUFFER).
We'll see that the In-Memory information is also absent in places like the Load Profile and other areas of the Statspack Report. If you are using In-Memory, the Statspack Report will not be sufficient—use the AWR Report!
The Load Profile

The next portion of the Statspack Report output, following the basic information, provides per-second and per-transaction statistics for the Load Profile. As previously indicated, the corresponding section in the AWR Report in 12c now appears first. Figure 14-6 shows the equivalent AWR Report information. The Load Profile section is excellent for monitoring throughput and load variations on your system. As the load on the system increases, you will see larger numbers per second. As you tune the system for maximum efficiency, you will usually see lower numbers for the per-transaction statistic. This is a great section to see if the load is changing day to day. The following listing shows sample output for the Statspack Load Profile section. The notable differences in the AWR Report in 12c are that it includes “IM scan rows” for the In-Memory (IM) column store and several Read/Write IO statistics. (The IM scan rows data in Figure 14-6 shows you that IM is working!)
<table>
<thead>
<tr>
<th></th>
<th>Per Second</th>
<th>Per Transaction</th>
<th>Per Exec</th>
<th>Per Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB Time(s):</td>
<td>0.1</td>
<td>1.6</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>DB CPU(s):</td>
<td>0.0</td>
<td>1.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Redo size:</td>
<td>44,985.4</td>
<td>1,192,112.0</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Logical reads:</td>
<td>14,631.6</td>
<td>287,817.5</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Block changes:</td>
<td>161.9</td>
<td>4,289.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Physical reads:</td>
<td>38.7</td>
<td>1,025.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Physical writes:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>User calls:</td>
<td>4.6</td>
<td>123.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Parses:</td>
<td>34.7</td>
<td>919.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Hard parses:</td>
<td>6.5</td>
<td>171.5</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>W/A MB processed:</td>
<td>79,128.1</td>
<td>2,097,159.2</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Logons:</td>
<td>0.3</td>
<td>7.5</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Executes:</td>
<td>91.5</td>
<td>2,434.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Rollbacks:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>Transactions:</td>
<td>0.0</td>
<td>0.0</td>
<td>0.00</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**FIGURE 14-6. The AWR Report Load Profile section**
The Load Profile helps to identify both the load and type of activity being performed. In both the Statspack example and AWR example, the activity recorded includes a large amount of both logical and physical activity, but especially redo activity (I performed a lot of INSERTs during this snapshot range).

Things to look for include the following:

- A large increase in Logical reads or Physical reads compared to a normal load for this period.
- An increase in Redo size and Block changes indicate increased DML (INSERT/UPDATE/DELETE) activity.
- A hard parse occurs when a SQL statement is executed and is not currently in the shared pool. A hard parse rate greater than 100 per second could indicate that bind variables are not being used effectively; the CURSOR_SHARING initialization parameter should be used; or you have a shared pool–sizing problem. (See Chapter 4 on sizing the shared pool and a detailed discussion related to this.)
- A soft parse occurs when a SQL statement is executed and it is currently in the shared pool. A very high soft parse rate could indicate program inefficiencies that need to be examined in greater detail to see if there is a problem that needs to be fixed.

TIP
Get to know your system by reviewing and understanding your system’s regular Load Profile. Significant changes to the Load Profile during what should be similar workloads or common times during the day may warrant further investigation.

Instance Efficiency

The Instance Efficiency section continues to grow and shows information for many of the common hit ratios. In 12c, the AWR Report has added Flash Cache Hit %. Great DBAs generally keep an eye on this section so they can be alerted to significant changes in system behavior when compared historically (you have to know your system for this to be helpful). Hit ratios are a great alert mechanism for general potential problems or specific potential problems, such as bad SQL that has been introduced recently into the system. This can give you the opportunity to find the issue and address it before it has a serious/noticeable effect on the system. Waits (covered in depth later in this chapter) are another excellent way to find major problems, but waits usually show up after the problem becomes a larger issue. Unfortunately, by that time, the business users will often raise it as a problem.

Monitoring hit ratios as an alert is just one piece among the thousands of pieces of your tuning arsenal. The reason that so many tuning tips are provided in this book is that in writing about tuning, I am writing about all of the turns that the optimizer will make and how to be alerted to a problem or compensate for any issues. Although I don’t believe you could capture everything in a book (you’d be
un-writing the hardest part of Oracle—the optimizer), I do believe this compilation helps solve many of them. Some DBAs (usually those trying to sell you a tuning product or DBAs who don’t know the system well) minimize the importance of hit ratios (proactive tuning) and focus completely on waits (reactive tuning), since focusing on waits is a great way to solve the current burning problems quickly (also covered in this book). By monitoring the Instance Efficiency section and Load Profile section (and using all of Statspack and Enterprise Manager), the DBA combines reactive and proactive tuning and will discover some problems before the users scream or wait events hit the Top 5 or Top 10 list. The listing that follows shows how well this Statspack section shows you all of the common hit ratios at once.

### Instance Efficiency Indicators

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer Nowait %</td>
<td>100.00</td>
</tr>
<tr>
<td>Buffer Hit %</td>
<td>99.74</td>
</tr>
<tr>
<td>Library Hit %</td>
<td>83.19</td>
</tr>
<tr>
<td>Execute to Parse %</td>
<td>62.24</td>
</tr>
<tr>
<td>Parse CPU to Parse Elapsed %</td>
<td>70.34</td>
</tr>
<tr>
<td>Redo NoWait %</td>
<td>100.00</td>
</tr>
<tr>
<td>Optimal W/A Exec %</td>
<td>100.00</td>
</tr>
<tr>
<td>Soft Parse %</td>
<td>81.34</td>
</tr>
<tr>
<td>Latch Hit %</td>
<td>100.00</td>
</tr>
<tr>
<td>% Non-Parse CPU</td>
<td>84.57</td>
</tr>
</tbody>
</table>

Things to look for include the following:

- A Buffer Nowait % of less than 99 percent. This value is the ratio of hits on a request for a specific buffer where the buffer was immediately available in memory. If the ratio is low, then there are (hot) blocks being contended for that should be found in the Buffer Wait section.

- A Buffer Hit % of less than 95 percent. This value is the ratio of hits on a request for a specific buffer when the buffer was in memory and no physical I/O was needed. While originally one of the few methods of measuring memory efficiency, it still is an excellent method for showing how often you need to do a physical I/O, which merits further investigation as to the cause. Unfortunately, if you have unselective indexes that are frequently accessed, that will drive your hit ratio higher, which can be a misleading indication of good performance to some DBAs. When you effectively tune your SQL and have effective indexes on your entire system, this issue is not encountered as frequently and the hit ratio is a better performance indicator. A high hit ratio is not a measure of good performance, but a low hit ratio is often a sign of performance that can be improved or should at least be looked into.

- A hit ratio that is steadily at 95 percent and then one day goes to 99 percent should be checked for bad SQL or a bad index that is causing a surge of logical reads (check the load profile and top buffer gets SQL).

- A hit ratio that is steadily at 95 percent and then drops to 45 percent should be checked for bad SQL or a dropped index (check the top physical reads SQL) causing a surge in physical reads that are not using an index or an index that has been dropped (I’ve seen this more often than you can imagine).

- A Library Hit % of less than 95 percent. A lower library hit ratio usually indicates that SQL is being pushed out of the shared pool early (could be due to a shared pool that is too small). A
lower ratio could also indicate that bind variables are not used or some other issue is causing SQL not to be reused (in which case, a smaller shared pool may only be a bandage that potentially fixes a resulting library latch problem). Despite the rants about lowering your shared pool all the time to fix library cache and shared pool latching issues, most multiterabyte systems I’ve seen with heavy usage have shared pools in the gigabytes without any issues because they’ve fixed the SQL issues. You must fix the problem (use bind variables or CURSOR_SHARING) and then appropriately size the shared pool. I’ll discuss this further when I get to latch issues.

- An In-memory Sort % of less than 95 percent in OLTP. In an OLTP system, you really don’t want to do disk sorts. Setting the MEMORY_TARGET or PGA_AGGREGATE_TARGET (or SORT_AREA_SIZE in previous versions) initialization parameter effectively eliminates this problem. Note that In-memory Sort % appears only in the AWR Report (as in 11g), not in the Statspack Report.

- A Soft Parse % of less than 95 percent. As covered in the Load Profile section (last section), a soft parse ratio that is less than 80 percent indicates that SQL is not being reused and needs to be investigated.

- A Latch Hit % of less than 99 percent is usually a big problem. Finding the specific latch will lead you to solving this issue. I cover this in detail in the “Latch Free” section later in the chapter.

- A Flash Cache Hit % (only appears in the AWR Report on 12c) of less than 90 percent could be a problem if you have a large amount of Flash Cache (system dependent). If you are using Exadata, Chapter 11 provides some queries to help tune this problem if you’re not appropriately using your Flash Cache.

Figure 14-7 shows how the Instance Efficiency section looks in the AWR Report (no longer the same as Statspack).

![Instance Efficiency Percentages (Target 100%)](image)

**FIGURE 14-7. The AWR Report Instance Efficiency Percentages section**

If you regularly run the AWR Report or Statspack, comparing hit ratios from one day to another can be a great barometer as to whether something drastic has changed. If an index was dropped on a frequently accessed column, the buffer hit ratio could drop dramatically, giving you something to
investigate. If an index was added to a table, it could cause the buffer hit ratio to soar if it causes a table join to occur in the wrong order, causing massive numbers of buffers to be read, but by using poor indexes. A library hit ratio that rises or falls greatly from one day to the next indicates changing SQL patterns. Latch hit ratio changes can indicate contention issues that you need to investigate more.

Hit ratios can be a very proactive tool for a DBA who regularly monitors and understands a given production system, whereas many of the other tuning tools are reactive to problems that have already occurred.

TIP
Hit ratios are a great barometer of the health of your system. A large increase or drop from day to day is an indicator of a major change that needs to be investigated. Investigating waits is like investigating an accident that has already occurred, whereas investigating a change in hit ratios is like looking into the intersection with a changing traffic pattern that may cause an accident in the future if something is not adjusted. Generally, buffer and library cache hit ratios should be greater than 95 percent for OLTP, but they could be less for a data warehouse that performs many full table scans.

Remember also that a system with very high ratios in this section of the report may still have performance problems. As described previously, a poorly written query can cause volumes of index searches to join to other indexes, causing a high hit ratio (with lots of buffer gets), which is not good in this case. The database is doing most of its work in memory, but it shouldn’t be doing so much work. Good hit ratios don’t show the whole picture either. There are always cases where the database is working very efficiently, but performance is still bad; this report only shows the database operations, not the application operations, server actions, or networking issues that also impact the performance of the application.

 Shared Pool Statistics

The Shared Pool Statistics section that follows the Instance Efficiency section (both in the AWR Report and Statspack) shows the percentage of the shared pool in use and the percentage of SQL statements that have been executed multiple times (as desired). Combining this data with the library, parse, and latch data helps you to size the shared pool. The following listing shows sample shared pool statistics from the Statspack Report (Figure 14-5 showed this for the AWR):

<table>
<thead>
<tr>
<th>Shared Pool Statistics</th>
<th>Begin</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory Usage %</td>
<td>76.33</td>
<td>76.74</td>
</tr>
<tr>
<td>% SQL with executions&gt;1</td>
<td>61.03</td>
<td>61.89</td>
</tr>
<tr>
<td>% Memory for SQL w/exec&gt;1</td>
<td>75.89</td>
<td>76.57</td>
</tr>
</tbody>
</table>
As shown by the data in the preceding listing, at the time of the second snapshot, 76.74 percent of the shared pool’s memory was in use. Of the statements in the shared pool, only 61.89 percent had been executed more than once, indicating a potential need to improve cursor sharing in the application. Adjusting the shared pool settings is covered in detail in Chapter 4.

Top Wait Events

The Top Wait Events section of Statspack is probably the most revealing section in the entire report when you are trying to eliminate bottlenecks quickly on your system. This section of the report shows the Top 5 Wait Events. The 12c AWR Report, as shown in Figure 14-8, now has Top 10 Foreground Events by Total Wait Time followed by Wait Classes by Total Wait Time instead of the Top 5 Timed Events that Statspack has in it.
In Statspack, we get the Top 5 Waits followed by the full list of Wait Events, and the Background Wait Events. Identifying major wait events helps to target your tuning efforts to the most burning issues on your system. If TIMED_STATISTICS is TRUE, then the events are ordered in time waited; if FALSE, then the events are ordered by the number of waits (in testing Microsoft Windows, this still was ordered by wait time). For example, the following listing shows the Top 5 Timed Events for a report interval:
In the preceding example, the db file sequential read waits show an incredible number of waits (almost 400,000,000, which, assuming a 8K block size, is 3.2T of data read) and an incredible amount of time spent waiting on db file sequential reads. For this report, this wait event was due to a badly written SQL statement using too many indexes and reading many more blocks than it should have. Slow disk access contributed to the slow performance because of the large number of blocks needing to be read (heavy I/O can lead to high SPU as well), but the real issue was the SQL itself (as usual). After tuning the code for only a single day, over 90% of all disk reads were eliminated. Well over 5T of reads were eliminated (over 3T just in the SQL statement causing these reads alone) in a 24-hour period.

Here is another example, showing the Top 5 Wait Events for a system:

<table>
<thead>
<tr>
<th>Event</th>
<th>Waits</th>
<th>Time (s)</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>db file sequential read</td>
<td>399,394,399</td>
<td>2,562,115</td>
<td>52.26</td>
</tr>
<tr>
<td>CPU time</td>
<td>960,825</td>
<td>19.60</td>
<td></td>
</tr>
<tr>
<td>buffer busy waits</td>
<td>122,302,412</td>
<td>540,757</td>
<td>11.03</td>
</tr>
<tr>
<td>PL/SQL lock timer</td>
<td>4,077</td>
<td>243,056</td>
<td>4.96</td>
</tr>
<tr>
<td>log file switch</td>
<td>188,701</td>
<td>187,648</td>
<td>3.33</td>
</tr>
</tbody>
</table>

In the preceding listing, you see a large number of waits related to reading a single block (db file sequential read) and also waits for latches (latch free). You also see some pretty high waits for some of the writing to both datafiles and log files, as well as other potential issues with log file contention. To solve these issues (and to identify which ones are truly major issues), you must narrow them down by investigating the granular reports within other sections of Statspack or the AWR Report.

The following is a sample listing of waits on this very intense system (not as bad as the preceding one, though). Note that all waits were in one section.
Statspack and the AWR Reports have sections on Foreground Wait Events, Background Wait Events, and Wait Events (fg and bg). A partial listing of these three sections is displayed next. Although only a partial listing, I’ve tried to include many of the most common problems. After the listing, I will discuss some of the common events that cause problems.
Next are some of the most common problems; explanations and potential solutions are given as well. These sections are very important and worth their weight in gold!

### DB File Scattered Read

The db file scattered read wait event generally indicates waits related to full table scans or fast full index scans. With the speed of disks and added Flash Cache, less indexing is certainly a wave of the future (especially on Exadata and Exalogic), but not yet. As full table scans are pulled into memory, they are scattered throughout the buffer cache since it is generally unlikely that they fall into contiguous buffers. A large number of db file scattered read waits indicates that there may be missing or suppressed indexes. This could also be preferred because performing a full table scan may be more efficient than an index scan. Check to ensure full table scans are necessary when you see these waits. Try to cache small tables to avoid reading them into memory over and over again. Locate the

<table>
<thead>
<tr>
<th>Event</th>
<th>Waits</th>
<th>% Tim</th>
<th>Total Wait (s)</th>
<th>Avg Wait (ns)</th>
<th>Waits /txn</th>
<th>% Total Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>db file parallel write</td>
<td>686</td>
<td>0</td>
<td>13</td>
<td>18</td>
<td>4.1</td>
<td>18.4</td>
</tr>
<tr>
<td>log file parallel write</td>
<td>910</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>5.4</td>
<td>5.6</td>
</tr>
<tr>
<td>control file parallel write</td>
<td>359</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td>control file sequential read</td>
<td>934</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5.5</td>
<td>.8</td>
</tr>
<tr>
<td>os thread startup</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0.2</td>
<td>.4</td>
</tr>
<tr>
<td>direct path read</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>0.0</td>
<td>.1</td>
</tr>
</tbody>
</table>


-> s - second, cs - centisecond, ms - millisecond, us - microsecond

-> %Timeouts: value of 0 indicates value was < .5%. Value of null is truly 0

-> Only events with Total Wait Time (s) >= .001 are shown

-> ordered by Total Wait Time desc, Waits desc (idle events last)

<table>
<thead>
<tr>
<th>Event</th>
<th>Waits</th>
<th>% Tim</th>
<th>Total Wait (s)</th>
<th>Avg Wait (ns)</th>
<th>Waits /txn</th>
<th>% Total Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>db file parallel write</td>
<td>686</td>
<td>0</td>
<td>13</td>
<td>18</td>
<td>4.1</td>
<td>18.4</td>
</tr>
<tr>
<td>direct path read</td>
<td>652</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>3.9</td>
<td>9.0</td>
</tr>
<tr>
<td>cnq: XO - fast object checkp</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>4108</td>
<td>0.0</td>
<td>6.0</td>
</tr>
<tr>
<td>log file parallel write</td>
<td>910</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>5.4</td>
<td>5.6</td>
</tr>
<tr>
<td>direct path write</td>
<td>246</td>
<td>0</td>
<td>4</td>
<td>15</td>
<td>1.5</td>
<td>5.5</td>
</tr>
<tr>
<td>db file scattered read</td>
<td>62</td>
<td>0</td>
<td>3</td>
<td>45</td>
<td>0.4</td>
<td>4.0</td>
</tr>
<tr>
<td>control file parallel write</td>
<td>359</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>2.1</td>
<td>2.6</td>
</tr>
<tr>
<td>control file sequential read</td>
<td>3,542</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>21.0</td>
<td>1.2</td>
</tr>
<tr>
<td>log file switch completion</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>127</td>
<td>0.0</td>
<td>.4</td>
</tr>
<tr>
<td>os thread startup</td>
<td>35</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>0.2</td>
<td>.4</td>
</tr>
<tr>
<td>log file sync</td>
<td>65</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.4</td>
<td>.2</td>
</tr>
<tr>
<td>db file sequential read</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>0.0</td>
<td>.1</td>
</tr>
</tbody>
</table>
data on disk systems that have either more disk caching or are buffered by the OS file system cache. DB_FILE_MULTIBLOCK_READ_COUNT (default is 128 for Windows or Linux) can make full scans faster (but it could also influence Oracle to do more of them). You can also partition tables and indexes so only a portion of the entire table or index is scanned. Slow file I/O (slow disks) can cause these waits. Correlated to each of the waits are the values for P1,P2,P3=file, block, blocks.

DB File Sequential Read
The db file sequential read event generally indicates a single block read (an index read, for example). A large number of db file sequential reads can indicate poor table joining orders or unselective indexing. This number will certainly be large (normally) for a high-transaction, well-tuned system. You should correlate this wait with other known issues within the Statspack or AWR Report such as inefficient SQL. Check to ensure index scans are necessary and check join orders for multiple table joins. The DB_CACHE_SIZE parameter also determines how often these waits show up; hash-area joins causing problems should show up in the PGA memory but similarly are memory hogs that can cause high wait numbers for sequential reads or can also show up as direct path read/write waits. Range scans can read a lot of blocks if the data is spread over many different blocks (density within blocks could cause issues with range scans, and reverse key indexes could be problematic with range scans). Loading data in a sorted manner can help range scans and reduce the number of blocks read. Partitioning can help, as it can eliminate some blocks. Look for unselective indexes that are causing a lot of db file sequential reads. Locate the data on disk systems that either have more disk caching and/or are buffered by OS file system cache. Correlated to the waits are the values for P1,P2,P3=file, block, blocks.

Buffer Busy Waits IDs and Meanings
A buffer busy wait is a wait for a buffer that is being used in an unsharable way. Buffer busy waits should not be greater than 1 percent. Check the buffer wait statistics section (or V$WAITSTAT) to find out where the wait is. Follow the solution in this section for buffer busy waits associated with segment header, UNDO header, UNDO block, data block, and index block. Correlated to the waits are the values for P1,P2,P3=file, block, id (see the list in the following table from My Oracle Support). Some people argue that buffer busy waits can be helped by adding more ITL slots (initrans), but the information shown in the table should make it evident that initrans can help in the appropriate situation (based on the correlated TX enqueue wait).
<table>
<thead>
<tr>
<th>Reason Code (ID)</th>
<th>8.1.6-9.2</th>
<th>&gt;=10.1</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>1003</td>
<td>100</td>
<td>n/a</td>
<td>You want to NEW the block, but the block is currently being read by another session (most likely for undo).</td>
</tr>
<tr>
<td>1007</td>
<td>200</td>
<td>n/a</td>
<td>You want to NEW the block, but someone else is using the current copy so you have to wait for them to finish.</td>
</tr>
<tr>
<td>1010</td>
<td>230</td>
<td>n/a</td>
<td>Trying to get a buffer in CR/CRX mode, but a modification has started on the buffer that has not yet been completed.</td>
</tr>
<tr>
<td>Number</td>
<td>Value</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1012</td>
<td>n/a</td>
<td>A modification is happening on a SCUR or XCUR buffer, but has not yet completed.</td>
<td></td>
</tr>
<tr>
<td>1012 (duplicate)</td>
<td>231</td>
<td>CR/CRX scan found the CURRENT block, but a modification has started on the buffer that has not yet been completed.</td>
<td></td>
</tr>
<tr>
<td>1013</td>
<td>130</td>
<td>Block is being read by another session and no other suitable block image was found, e.g., CR version, so you have to wait until the read is completed. This wait may also occur after a buffer cache assumed deadlock. The kernel can’t get a buffer in a certain amount of time and assumes a deadlock. Therefore, it reads the CR version of the block. This should not have a negative impact on performance, and basically replaces a read from disk with a wait for another process to read it from disk, as the block needs to be read one way or another. You want the CURRENT block either shared or exclusive but the block is being read into cache by another session, so you have to wait until its read() is completed. You want to get the block in current mode, but someone else is currently reading it into the cache. Wait for them to complete the read. This occurs during buffer lookup.</td>
<td></td>
</tr>
<tr>
<td>1014</td>
<td>110</td>
<td>The session wants the block in SCUR or XCUR mode. If this is a buffer exchange or the session is in discrete TX mode, the session waits for the first time and the second time escalates the block as a deadlock and so does not show up as waiting very long. In this case, the statistic “exchange deadlocks” is incremented, and you yield the CPU for the “buffer deadlock” wait event.</td>
<td></td>
</tr>
<tr>
<td>1016 (duplicate)</td>
<td>210</td>
<td>During buffer lookup for a CURRENT copy of a buffer, you have found the buffer but someone holds it in an incompatible mode so you have to wait.</td>
<td></td>
</tr>
</tbody>
</table>
Buffer Busy/Segment Header
If the wait is on a segment header, you can increase the free lists or freelist groups (this can even help single instances) or increase the PCTUSED-to-PCTFREE gap. Use Automatic Segment Space Management (ASSM). If you are using ASSM, Oracle does this for you by using bitmap free lists. ASSM also removes the need to set PCTUSED.

Buffer Busy/UNDO Header
If the wait is on an UNDO header, you can address this by adding rollback segments or increasing the size of the UNDO area.

Buffer Busy/UNDO Block
If the wait is on an UNDO block, you should try to commit more often (but not too often, or you’ll get “log file sync” waits) or use larger rollback segments or UNDO areas. You may need to reduce the data density on the table driving this consistent read or increase the DB_CACHE_SIZE. Sizing initialization parameters is covered in Chapter 4.

Buffer Busy/Data Block
If the wait is on a data block, you can move “hot” data to another block to avoid this hot block or use smaller blocks (to reduce the number of rows per block, making it less “hot”). Check for scanning unselective data, and fix queries that are causing this or partition the table to eliminate unnecessary data scans. You can also increase initrans for a hot block (where users are simultaneously accessing the same block). Don’t set initrans too high, as this takes 24 bytes per ITL slot, and you only need enough for the number of users accessing the exact same block for DML at the same time (usually something like 6 is more than enough). When a DML (INSERT/UPDATE/DELETE) occurs on a block, the lock byte is set in the block and any user accessing the record(s) being changed must check the ITL for information related to building the before image of the block. Oracle Database writes information into the block, including all users who are “interested” in the state of the block, in the interested transaction list (ITL). To decrease waits in this area, you increase the initrans, which creates the space in the block to allow multiple ITL slots (for multiple DML user access). The default is two ITL slots per index or data block. You can also increase the PCTFREE value on the table where this block exists (Oracle uses space in PCTFREE to add ITL slots up to the number specified by MAXTRANS when there are not enough slots prebuilt with the specified initrans). The value for MAXTRANS defaults to 255. Check for correlated TX4 enqueue waits as well. Each ITL slot takes about 24 bytes of space, so don’t just set initrans to 255, or you may unnecessarily waste space.

Buffer Busy/Index Block
Use reverse key indexes and/or smaller blocks (to reduce the number of rows per block). Note that reverse key indexes can slow down range scans where you want the data to be sequentially located in the same block. Check for scanning unselective indexes (bad code/bad indexes). You may want to rebuild the index or partition the index to decrease the number of accesses to it. Increase initrans for a
hot block (not too high, as this takes 24 bytes per slot) where multiple users are accessing the same block for DML (see “Tuning and Viewing at the Block Level” later in the chapter for more information on ITL). Check for correlated TX4 enqueue waits as well.

### Latch Free

*Latches* are low-level queuing mechanisms (they’re accurately referred to as *mutual exclusion mechanisms*) used to protect shared memory structures in the System Global Area (SGA). Latches are like locks on memory that are very quickly obtained and released. Latches are used to prevent concurrent access to a shared memory structure. If the latch is not available, a latch free miss is recorded. Most latch problems (waits, misses, and sleeps) are related to the failure to use bind variables (library cache mutex and shared pool latch), REDO generation issues (redo allocation latch), buffer cache contention issues (cache buffers lru chain), and hot blocks in the buffer cache (cache buffers chains). The library cache pin (protects cursors/SQL) and library cache latch (protects the library cache) are both replaced by *mutexes* (program objects that negotiate mutual exclusion among threads). There are also latch and mutex waits related to bugs; check My Oracle Support (Metalink) for bug reports if you suspect this is the case. If the latch miss ratio is greater than 0.5 percent, you should investigate the issue. If the latch miss ratio is greater than 2 percent and there are a large number of them, you may have a serious problem.

**TIP**

*The library cache pin (protects cursors/SQL) and library cache latch (protects the library cache) are both replaced by mutexes (program objects that negotiate mutual exclusion among threads).*

### Cursor: pin S

The library cache pin (protects cursors/SQL) is replaced with a library cache mutex. The cursor: pin S wait event happens because one session is waiting on another to increment (or decrement) the reference count (an exclusive atomic update to the mutex structure itself) to keep track of its use. SQL with high execution counts can cause this. You can modify a statement and insert a comment into it so several statements do the same thing but are slightly different (this is the reverse of using bind variables where you’re trying to use only one statement). Also, see the upcoming “Oracle Bugs” section for bugs related to this wait event. No blockers exist for this type of wait event. Correlated to each of the waits are the values for P1,P2,P3=idn, value, where. From value, you can get the session ID holding the mutex along with the reference count, and from where, you can locate where in the code the mutex was requested from; this value is helpful to Oracle Support.

### Cursor: pin S wait on X

This wait event is more likely to occur than the cursor: pin S wait. If you are not reusing SQL, you may see many cursor: pin S wait on X waits. A session wants a mutex in S (share mode) on a cursor (SQL statement), but another session is holding that mutex in X (exclusive) mode. The session in S
mode is usually waiting on a hard parse of a cursor by the other session, which is holding the mutex in
exclusive X mode. You’ll also see the reverse of this: cursor: pin X wait on S. Consider setting CURSOR_SHARING as described in Chapter 4. This may also occur if the shared pool is under a heavy load or undersized. Correlated to each of the waits are the values for P1,P2,P3=idn, value, where. From value, you can get the session ID holding the mutex along with the reference count, and from where, you can locate where in the code the mutex was requested from; this value is helpful to Oracle Support.

Library cache: mutex X
As of 11g (and continuing into 12c), the library cache latches are replaced by mutexes. Because there are many more of these structures now, the wait events become much more specific. The library cache mutex is generally used when you are pinning or unpinning code into the library cache. Limiting this behavior is key; this often includes using CURSOR_SHARING and appropriately sizing the shared pool. Under heavy loads, this wait event can exacerbate an already overloaded CPU. Correlated to each of the waits are the values for P1,P2,P3=idn, value, where. From value, you can get the session ID holding the mutex, and from where, you can locate where in the code the mutex was requested from; this value is helpful to Oracle Support.

Enqueue
An enqueue is a lock that protects a shared resource. Locks protect shared resources such as data in a record to prevent two people from updating the same data at the same time. Locks include a queuing mechanism, which is FIFO (first in, first out). Note that Oracle’s latching mechanism is not FIFO. Enqueue waits usually point to the ST enqueue, the HW enqueue, and the TX4 enqueue. The ST enqueue is used for space management and allocation for dictionary-managed tablespaces. Use locally managed tablespaces (LMTs), or try to preallocate extents or at least make the next extent larger for problematic dictionary-managed tablespaces. HW enqueues are used with the high-water mark of a segment; manually allocating the extents can circumvent this wait. TX4 is one of the most common enqueue waits.

TX4 enqueue waits are usually the result of one of three issues. The first issue involves duplicates in a unique index; you need to roll back to free the enqueue. The second concerns multiple updates to the same bitmap index fragment. Because a single bitmap fragment may contain multiple ROWIDs, you need to issue a commit or a rollback to free the enqueue when multiple users are trying to update the same fragment. The third and most likely issue arises when multiple users are updating the same block. If there are no free ITL slots when multiple users want to perform DML on a different row of the same block, a block-level lock could occur. You can easily avoid this scenario by increasing the initrans to create multiple ITL slots and/or by increasing the PCTFREE on the table (so Oracle can create the ITL slots as needed). You could also use a smaller block size so there are fewer rows in the block and thus greater concurrency on the data is allowed. Two other TX4 waits are also less prevalent: waiting for a prepared statement and inserting a row into an index where another transaction is splitting the index block. When users want to change the exact same record in a block, a TX6 lock results. Lastly, while you no longer get long-lasting TM locks, which are table locks when you don’t index foreign keys, be sure to consider indexing foreign keys to avoid performance issues. Correlated to the transaction waits are the values for P1,P2,P3=lock type and mode, lockid1, lockid2
Log File Switch
If you see the log file switch wait event, then all commit requests are waiting for “logfile switch (archiving needed)” or “logfile switch (chkpt.Incomplete).” Ensure that the archive disk is not full or slow. DBWR may be too slow due to I/O. You may need to add more or larger REDO logs, and you may also need to add database writers if the DBWR is the problem.

Log Buffer Space
When a change is made, the change is copied to the log buffer. If the log buffer doesn’t get written fast enough to the redo logs, it can cause log buffer space issues (things get backed up). Space issues can also be a problem when you commit a very large amount of data at once (make the log buffer larger for these types of transactions). This wait usually occurs because you are writing to the log buffer faster than LGWR can write the buffer contents out to the redo logs, or because log switches are too slow, but usually not because the log buffer is too small (although this is also the case at times). To address this problem, increase the size of the log files, or get faster disks to write to, but, as a last resort, increase the size of the log buffer (in very large systems, it is not uncommon to see a log buffer in the tens of megabytes). You might even consider using solid-state disks or flash disks for their high speed for redo logs.

Log File Sync
When a user changes data in a record, the block the record is contained in is copied to the log buffer (many records/rows are contained in a block). When a commit or rollback is issued, the log buffer is flushed (copied) to the redo logs by the LGWR (Log Writer). The process of writing the changed data from the log buffer to the redo log and getting a confirmation that the write successfully occurred is called a log file sync. To reduce log file sync waits, try to commit more records at once (try to commit a batch of 50 instead of one at a time if possible). If you commit 50 records one at a time, 50 log file syncs need to occur. Put redo logs on a faster disk or alternate redo logs on different physical disk arrays to reduce the archiving effect on the LGWR (or use solid-state disks or flash disks). Don’t use RAID 5 because it is very slow for applications that write a lot; potentially consider using filesystem direct I/O or raw devices, which are very fast at writing information. Correlated to the waits are the values for P1,P2,P3=buffer#, unused, unused.

Global Cache CR Request
When using multiple instances (RAC/Grid/Cloud), a global cache cr request wait occurs when one instance is waiting for blocks from another instance’s cache (sent via the interconnect). This wait says that the current instance can’t find a consistent read (cr) version of a block in the local cache. If the block is not in the remote cache, then a db file sequential read wait will also follow this one. Tune the SQL that is causing large amounts of reads that get moved from node to node. Try to put users who are using the same blocks on the same instance so the blocks are not moved from instance to instance. Some non-Oracle application servers move the same process from node to node looking for the
fastest node (unaware they are moving the same blocks from node to node). Pin these long processes to the same node. Potentially increase the size of the local cache if slow I/O combined with a small cache is the problem. Monitor V$CR_BLOCK_SERVER to see if an issue like reading UNDO segments has occurred. Correlated to the waits are the values for P1,P2,P3=file, block, lenum (look in VSLOCK_ELEMENT for the row where LOCK_ELEMENT_ADDR has the same value as lenum).

Log File Parallel Write
Put redo logs on fast disks (or use solid-state disks or flash disks) and don’t use RAID 5. Separate redo logs from other data that might slow them down and ensure tablespaces are not left in hot backup mode. Correlated to the waits are the values for P1,P2,P3=files written to, blocks, requests.

DB File Parallel Write
Fix or speed up the operating system I/O and file system I/O by doing the database writing to database files. Correlated to the waits are the values for P1,P2,P3=files, blocks, requests/timeout.

Direct Path Read
Oracle usually does direct path reads to read blocks directly into the PGA. Direct path reads are used for things such as sorting, parallel querying, and read-aheads. The time here does not always reflect the true wait time. This is usually an issue with the file I/O (see if any disks are I/O bound using OS utilities, as described in Chapter 16). Check for sorting on disk instead of in memory (located in the Instance Statistics section of the report, discussed later in the chapter). Using async I/O could reduce the elapsed time, although it may not reduce the wait time. Correlated to the waits are the values for P1,P2,P3=file, start block, number of blocks.

Direct Path Write
Direct path writes are used for such things as direct load operations, parallel DML, and writes to uncached LOBs (Large Objects). The time here does not always reflect the true wait time. This wait usually reflects an issue with the file I/O (see if any disks are I/O bound using OS utilities, as described in Chapter 16). Check for sorting on disk (located in the Instance Statistics section of the report). Using async I/O could reduce the elapsed time, although it may not reduce the wait time. Correlated to the waits are the values for P1,P2,P3=file, start block, number of blocks.

Async Disk I/O
Oracle is waiting for the completion of an async write or for an async slave to write. The problem could arise from I/O issues with the DBWR (Database Writer), the LGWR (Log Writer), the ARCH (Archiver), and the CKPT (checkpoint process), but is usually some file I/O issue.

Idle Events
Several idle wait events are listed after the output that can be ignored. Idle events are generally listed
at the bottom of each section and include things like SQL*Net messages to or from the client and other background-related timings. Idle events are listed in the STAT$IDLE_EVENT table. In 12cR1, there were several idle events that were listed in the Top Waits, but that issue has been corrected in 12cR2.

Some of the most common wait problems and potential solutions are outlined here:

<table>
<thead>
<tr>
<th>Wait Problem</th>
<th>Potential Fix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential read</td>
<td>Indicates many index reads—tune the code (especially joins).</td>
</tr>
<tr>
<td>Scattered read</td>
<td>Indicates many full table scans—tune the code; cache small tables; get more Flash Cache.</td>
</tr>
<tr>
<td>Free buffer</td>
<td>Increase the DB_CACHE_SIZE; shorten the checkpoint; tune the code.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>Segment header—add free lists or freelist groups.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>Data block—separate “hot” data; use reverse key indexes; use smaller blocks; increase initrans (debatable); reduce block popularity; make I/O faster.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>UNDO header—add rollback segments or UNDO areas or simply use automatic undo management.</td>
</tr>
<tr>
<td>Buffer busy</td>
<td>UNDO block—commit more; use larger rollback segments or undo areas or simply use automatic undo management.</td>
</tr>
<tr>
<td>Latch/mutex wait</td>
<td>Investigate the detail.</td>
</tr>
<tr>
<td>Enqueue—ST</td>
<td>Use LMTs or preallocate large extents.</td>
</tr>
<tr>
<td>Enqueue—HW</td>
<td>Preallocate extents above the high-water mark.</td>
</tr>
<tr>
<td>right Enqueue—TX4</td>
<td>Increase initrans or use a smaller block size on the table or index.</td>
</tr>
<tr>
<td>Enqueue—TX6</td>
<td>Fix the code that is making the block unsharable (use V$LOCK to find).</td>
</tr>
<tr>
<td>Enqueue—TM</td>
<td>Index foreign keys; check application locking of tables.</td>
</tr>
<tr>
<td>Log buffer space</td>
<td>Increase the log buffer; use faster disks for the redo logs.</td>
</tr>
<tr>
<td>Log file switch</td>
<td>Archive destination slow or full; add more or larger redo logs.</td>
</tr>
<tr>
<td>Log file sync</td>
<td>Commit more records at a time; use faster redo log disks; use raw devices.</td>
</tr>
<tr>
<td>Write complete waits</td>
<td>Add database writers; checkpoint more often; buffer cache too small.</td>
</tr>
<tr>
<td>Idle event</td>
<td>Ignore it.</td>
</tr>
</tbody>
</table>

Following are some common idle events (by type of idle event):

- Dispatcher timer (shared server idle event)
- Lock manager wait for remote message (RAC idle event)
Pipe get (user process idle event)
- Pmon timer (background process idle event)
- PX idle wait (parallel query idle event)
- PX deq credit: need buffer (parallel query idle event)
- PX deq: execution msg (parallel query idle event)
- Rdbms ipc message (background process idle event)
- Smon timer (background process idle event)
- SQL*Net message from client (user process idle event)
- Virtual circuit status (shared server idle event)

Oracle 12c Statspack Report also has a Wait Event Histogram that shows how many of the waits fall into various buckets. The 12c AWR Report also shows three histogram sections (1 to 64 microseconds, 512 microseconds to 32 ms, 32 ms to 2 sec+), all the way down to 1 microsecond. This type of histogram is also provided for file I/O by tablespace to show if you are waiting on mostly short waits with a few very long waits or many medium-length waits. A partial listing for this is below:

```
   Wall Event Histogram  DB/Inst: ORCL/orcl  Snapshots: 1 2
   -> Total Waits - units: K is 1000, M is 1000000, G is 1000000000
   -> % of Waits - column heading: < 1m is truly <1024ms, >=1m is truly >1024ms
   -> % of Waits - value: .0 indicates value was <.05%, null is truly 0
   -> Ordered by Event (idle events last)

<table>
<thead>
<tr>
<th>Event</th>
<th>Total Waits</th>
<th>Total</th>
<th>&lt;1ms</th>
<th>&lt;2ms</th>
<th>&lt;4ms</th>
<th>&lt;8ms</th>
<th>&lt;16ms</th>
<th>&lt;32ms</th>
<th>&lt;1s</th>
<th>&gt;1s</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADR block file read</td>
<td>6</td>
<td>65.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disk file operations I/O</td>
<td>60</td>
<td>120.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LGWR wait for redo copy</td>
<td>13</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SQL*Net break/reset to cli</td>
<td>364</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>async descriptor resize</td>
<td>350</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>control file parallel writ</td>
<td>359</td>
<td>89.7</td>
<td>7.1</td>
<td>2.8</td>
<td>1.8</td>
<td>1.7</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>control file sequential rea</td>
<td>3542</td>
<td>99.3</td>
<td>.1</td>
<td>.1</td>
<td>.2</td>
<td>.1</td>
<td>.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>db file parallel writ</td>
<td>686</td>
<td>29.6</td>
<td>5.7</td>
<td>6.7</td>
<td>7.6</td>
<td>8.3</td>
<td>32.1</td>
<td>9.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>db file scattered read</td>
<td>62</td>
<td>11.3</td>
<td>4.8</td>
<td>14.5</td>
<td>14.5</td>
<td>54.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>db file sequential read</td>
<td>6</td>
<td>16.7</td>
<td>33.3</td>
<td>50.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>direct path read</td>
<td>652</td>
<td>3.8</td>
<td>3.1</td>
<td>1.8</td>
<td>65.3</td>
<td>18.6</td>
<td>7.7</td>
<td>.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>direct path writ</td>
<td>246</td>
<td>22.4</td>
<td>14.6</td>
<td>6.1</td>
<td>4.9</td>
<td>18.7</td>
<td>18.7</td>
<td>14.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

The Enqueue Activity section actually spells out the type of enqueue. For instance, if it is a TX Enqueue, it will now say TX Transaction or TM for DML. If that isn’t good enough, it goes one step further and even tells you the type of transaction and then it gives the Requests, Gets, Waits, and a few
other bits of helpful information. See Figure 14-9 for a look at this section in the AWR Report.

TIP
Tuning by wait events is one of the best possible reactive tuning methods.

& Oracle Bugs

There are also Oracle bugs (Oracle used to call bugs undocumented features) to watch for that can
cause a large number of wait events. Several bugs are related to the new mutex wait events. The first
diagnostic step to resolve these issues is to apply the latest patchset available in your platform. Most
of the buffer cache issues related to bugs can be avoided by applying these patchsets listed in the
appropriate bug note. The following table summarizes the most common bugs related to Library
Cache problems, possible workarounds, and the patchset that fixes the problem (it will be listed in
the bug note when you go to it; thanks to My Oracle Support for these listings).

The following are “cursor: pin S” waits that are related to bugs and fixed in 11g/12c:

<table>
<thead>
<tr>
<th>Bug</th>
<th>Fixed</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14380605</td>
<td>12.2</td>
<td>High “library cache lock,” “cursor: pin S wait on X,” and “library cache: mutex X” waits (affects 12.1, 11.2), Database hang on 12cR1 with “cursor: pin S wait on X,” “row cache lock,” and “library cache load lock.”</td>
</tr>
<tr>
<td>22500027</td>
<td>12.2</td>
<td>Improve concurrent mutex request handling.</td>
</tr>
<tr>
<td>9499302</td>
<td>11.1.0.7.7, 11.2.0.2, 12.1.0.0</td>
<td>Wrong wait events in 11.2 (“cursor: mutex S” instead of “cursor: mutex X”).</td>
</tr>
</tbody>
</table>

The following are “library cache: mutex X”–related bugs and fixed in 11g/12c (note that one is
also solved above in 12.2):

<table>
<thead>
<tr>
<th>Bug</th>
<th>Fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>8431767</td>
<td>12.2</td>
</tr>
<tr>
<td>21759047</td>
<td>12.2</td>
</tr>
<tr>
<td>8860198</td>
<td>11.2.0.2, 12.1.0.0</td>
</tr>
<tr>
<td>10417/16</td>
<td>12.1.0.0, 11.2.0.2</td>
</tr>
<tr>
<td>Exadata</td>
<td></td>
</tr>
<tr>
<td>11818335</td>
<td>11.2.0.2.2, 12.1.0.0</td>
</tr>
<tr>
<td>10204505</td>
<td>12.1.0.0</td>
</tr>
</tbody>
</table>

High “library cache: mutex X” when using Application Context.
High “library cache: mutex X” when many sessions executing against a partitioned table.
High “library cache: mutex X” waits using XMLType.
Mutex X waits in 11g on an instance with heavy Java usage.
Additional support for bug 10411618 to allow dynamic mutex wait scheme changes.
SCIA autotune can cause row cache misses, Library Cache reloaded, and parsing.
### The Life of an Oracle Shadow Process

Here is a breakdown of the life of an Oracle shadow process and where it might be waiting as it lives. This table is adapted from Oracle Doc ID 61998.1 and shows what’s happening in less than one second within Oracle.

<table>
<thead>
<tr>
<th>State</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDLE</td>
<td>Waits for “SQL<em>Net message from client” (waiting for the user). Receives the SQL</em>Net packet requesting PARSE/EXECUTE of a statement.</td>
</tr>
<tr>
<td>ON CPU</td>
<td>Decodes the SQL*Net packet.</td>
</tr>
<tr>
<td>WAITING</td>
<td>Waits for “latch free” to obtain the library cache mutex. Gets the library cache mutex.</td>
</tr>
<tr>
<td>ON CPU</td>
<td>Scans the shared pool for the SQL statement, finds match, frees mutex (if the statement, cursor, is already in memory, it does—“cursor: pin S”), sets up links to the shared cursor, etc., and begins to execute.</td>
</tr>
<tr>
<td>WAITING</td>
<td>Waits for “db file sequential read”; you need a block not in the cache (waits for I/O).</td>
</tr>
<tr>
<td>ON CPU</td>
<td>Block read from disk complete. Execution continues. Construct SQL*Net packet with first row of data to send to client and sends.</td>
</tr>
<tr>
<td>WAITING</td>
<td>Waits on “SQL*Net message from client” for acknowledgment packet received.</td>
</tr>
<tr>
<td>IDLE</td>
<td>Waits for next SQL*Net message from client.</td>
</tr>
</tbody>
</table>
The RAC events are listed next in the report if you are running RAC (multiple instances). As stated earlier, you need to run Statspack or the AWR Report for each instance that you have. For Statspack, you run the `statspack.snap` procedure and `spreport.sql` script on each node you want to monitor to compare to other instances. The greatest comparison report is one from another node that accesses the same database. I cover more on tuning RAC in Chapter 11 and will not repeat that information here. It’s very important to remember that single-instance tuning should be performed before attempting to tune the processes that communicate via the cluster interconnect. In other words, tune the system as a single instance before you move it to RAC. For the AWR on RAC, you can run `awrdrpt.sql` to get a global report. However, according to `spdoc.txt`, section 4.2, for Statspack, it works only for a single database instance.

Some of the top wait events that you may encounter are listed briefly next and covered in more detail in Chapter 11. The top global cache (gc) waits to look for include the following:

- **gc (global cache) current block busy** Happens when an instance requests a CURR data block (wants to do some DML) and the block to be transferred is in use.

- **gc (global cache) buffer busy** A wait event that occurs whenever a session has to wait for an ongoing operation on the resource to complete because the block is in use.

- **gc (global cache) cr request** Happens when an instance requests a CR data block and the block to be transferred hasn’t arrived at the requesting instance. This is the one I see the most, and it’s usually because the SQL is poorly tuned and many index blocks are being moved back and forth between instances.

Figure 14-10 shows the AWR Report RAC Statistics section. You can see that there are six instances (nodes) in this cluster. You can also see things like the number of blocks sent/received as well as how many of the blocks are being accessed in the local cache (93.1 percent) as opposed to on the disk or in another instance. As you would guess, accessing blocks in the local cache is faster, but accessing one of the remote caches on one of the other nodes is almost always faster (given a fast enough interconnect and no saturation of the interconnect) than going to disk (more on this in Chapter 11).
## RAC Statistics

<table>
<thead>
<tr>
<th>Number of Instances:</th>
<th>Begin</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

### Global Cache Load Profile

<table>
<thead>
<tr>
<th></th>
<th>Per Second</th>
<th>Per Transaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Cache blocks received:</td>
<td>9.97</td>
<td>17.10</td>
</tr>
<tr>
<td>Global Cache blocks served:</td>
<td>10.30</td>
<td>17.87</td>
</tr>
<tr>
<td>GCS/GES messages received:</td>
<td>140.60</td>
<td>241.17</td>
</tr>
<tr>
<td>GCS/GES messages sent:</td>
<td>225.51</td>
<td>386.92</td>
</tr>
<tr>
<td>DBWR Fusion writes:</td>
<td>0.12</td>
<td>0.21</td>
</tr>
<tr>
<td>Estd Interconnect traffic (KB):</td>
<td>233.67</td>
<td></td>
</tr>
</tbody>
</table>

### Global Cache Efficiency Percentages (Target local+remote 100%)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer access - local cache %:</td>
<td>93.10</td>
</tr>
<tr>
<td>Buffer access - remote cache %:</td>
<td>2.39</td>
</tr>
<tr>
<td>Buffer access - disk %:</td>
<td>4.51</td>
</tr>
</tbody>
</table>

### Global Cache and Enqueue Services - Workload Characteristics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg global enqueue get time (ms):</td>
<td>64.3</td>
</tr>
<tr>
<td>Avg global cache or block receive time (ms):</td>
<td>1.0</td>
</tr>
<tr>
<td>Avg global cache current block receive time (ms):</td>
<td>2.7</td>
</tr>
<tr>
<td>Avg global cache or block build time (ms):</td>
<td>0.1</td>
</tr>
<tr>
<td>Avg global cache or block send time (ms):</td>
<td>0.1</td>
</tr>
<tr>
<td>Global cache log flushes for or blocks served %:</td>
<td>0.6</td>
</tr>
<tr>
<td>Avg global cache or block flush time (ms):</td>
<td>0.9</td>
</tr>
<tr>
<td>Avg global cache current block pin time (ms):</td>
<td>0.9</td>
</tr>
<tr>
<td>Avg global cache current block send time (ms):</td>
<td>0.3</td>
</tr>
<tr>
<td>Global cache log flushes for current blocks served %:</td>
<td>5.3</td>
</tr>
<tr>
<td>Avg global cache current block flush time (ms):</td>
<td>1.0</td>
</tr>
</tbody>
</table>

---

**FIGURE 14-10.** The AWR Report RAC Statistics section
The most resource-intensive SQL statements in the database are listed next, in descending order of CPU, Elapsed Time, Buffer Gets (or Gets), Disk Reads (or Reads), Executions, Parse Calls, Sharable Memory, and Version Count. Depending on where the problem is, you have plenty of places to investigate. If you saw many buffer gets as the top wait event (db file sequential reads), then you would investigate the statements in the descending order of buffer gets (focusing on the worst ones that are at the top of the list). Because the buffer gets statistic is cumulative, the query with the most buffer gets may not be the worst-performing query in the database; it may just have been executed enough times to earn the highest ranking. Compare the cumulative number of buffer gets to the cumulative number of disk reads for the queries; if the numbers are close, then you should evaluate the EXPLAIN PLAN for the query to find out why it is performing so many disk reads. Near the end of the 12cR2 AWR Report (discussed later in the chapter), Oracle has even provided Top SQL with Top Events (correlating the two).

If the disk reads are not high but the buffer gets are high and the executions are low, then the query is either using a bad index or performing a join in the wrong order. This is also a system problem, as you are using a lot of your memory unnecessarily. Here is an example of this listing:

```
SQL ordered by Gets  DB/Inst: ORCL/orcl  Snaps: 1-2
--> End Buffer Gets Threshold:      10000 Total Buffer Gets:       943,141
--> Captured SQL accounts for 139.0% of Total Buffer Gets
  > SQL reported below exceeded 1.0% of Total Buffer Gets

<table>
<thead>
<tr>
<th>Buffer Gets</th>
<th>Executions</th>
<th>Gets per Sec</th>
<th>Elapsed Time</th>
<th>Disk Reads</th>
<th>Swap/Sort</th>
</tr>
</thead>
<tbody>
<tr>
<td>494,112</td>
<td>12</td>
<td>41,170.6</td>
<td>58.2</td>
<td>10.17</td>
<td>3274221911</td>
</tr>
</tbody>
</table>
| select owner, segment_name, blocks from dba_segments where table_name = 'table'

<table>
<thead>
<tr>
<th>Buffer Gets</th>
<th>Executions</th>
<th>Gets per Sec</th>
<th>Elapsed Time</th>
<th>Disk Reads</th>
<th>Swap/Sort</th>
</tr>
</thead>
<tbody>
<tr>
<td>299,446</td>
<td>11</td>
<td>39,040.3</td>
<td>58.6</td>
<td>10.07</td>
<td>3274221911</td>
</tr>
</tbody>
</table>
| select owner, segment_name, blocks from dba_segments where table_name = 'table'

<table>
<thead>
<tr>
<th>Buffer Gets</th>
<th>Executions</th>
<th>Gets per Sec</th>
<th>Elapsed Time</th>
<th>Disk Reads</th>
<th>Swap/Sort</th>
</tr>
</thead>
<tbody>
<tr>
<td>371,498</td>
<td>12</td>
<td>56,780.0</td>
<td>29.5</td>
<td>6.62</td>
<td>4274149170</td>
</tr>
</tbody>
</table>
| select count(*) from emp

You may also see the internal Oracle data dictionary operations listed as part of these sections. Your application commands commonly account for the great majority of the buffer gets and disk reads performed by the database. If the shared pool is flushed between the execution times of the two snapshots, the SQL portion of the output report will not necessarily contain the most resource-intensive SQL executed during the period. V$SQL shows SQL for multiple users with the same statement, and it shows child cursors; V$SQL_PLAN_STATISTICS shows the execution stats for each cached cursor; and V$SQL_PLAN_STATISTICS_ALL shows the joins plan and stats and many other performance-related statistics.

The AWR Report has many Top SQL sections. Oracle now shows how many of the Physical Reads (or Reads) need to be optimized; see the SQL ordered by Physical Reads (UnOptimized) section. An example of the SQL Statistics section is shown in Figure 14-11. It includes the following subsections:
### SQL Statistics

- SQL ordered by Elapsed Time
- SQL ordered by CPU Time
- SQL ordered by User I/O Wait Time
- SQL ordered by Gets (buffer gets—usually index reads)
- SQL ordered by Reads (physical reads)
- SQL ordered by Physical Reads (UnOptimized)
- SQL ordered by Executions
- SQL ordered by Parse Calls
- SQL ordered by Sharable Memory
- SQL ordered by Version Count
- Complete List of SQL Text (huge!)

#### FIGURE 14-11. The AWR Report SQL Statistics section

<table>
<thead>
<tr>
<th>Elapsed Time [s]</th>
<th>Executions</th>
<th>Elapsed Time per Exec [s]</th>
<th>%Total</th>
<th>%CPU</th>
<th>%IO</th>
<th>SQL Id</th>
<th>SQL Module</th>
<th>SQL Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>95.63</td>
<td>1</td>
<td>95.63</td>
<td>56.82</td>
<td>30.13</td>
<td>5.00</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) SELECT * FROM users...</td>
<td></td>
</tr>
<tr>
<td>42.10</td>
<td>1</td>
<td>42.10</td>
<td>42.10</td>
<td>13.24</td>
<td>5.00</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) SELECT * FROM users...</td>
<td></td>
</tr>
<tr>
<td>25.59</td>
<td>1</td>
<td>25.59</td>
<td>25.59</td>
<td>8.17</td>
<td>1.00</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) SELECT * FROM users...</td>
<td></td>
</tr>
<tr>
<td>23.42</td>
<td>2</td>
<td>11.71</td>
<td>7.30</td>
<td>54.60</td>
<td>2.90</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) select output from table(dbsms...</td>
<td></td>
</tr>
<tr>
<td>16.98</td>
<td>2</td>
<td>8.49</td>
<td>2.12</td>
<td>5.34</td>
<td>2.00</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) select output from table(dbsms...</td>
<td></td>
</tr>
<tr>
<td>9.41</td>
<td>2</td>
<td>4.70</td>
<td>4.70</td>
<td>2.95</td>
<td>0.00</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) select output from table(dbsms...</td>
<td></td>
</tr>
<tr>
<td>6.41</td>
<td>210.73</td>
<td>0.00</td>
<td>0.00</td>
<td>2.02</td>
<td>0.00</td>
<td><a href="mailto:sqiplus@177Beta2.example.com">sqiplus@177Beta2.example.com</a></td>
<td>(TNS V1-V3) select output from table(dbsms...</td>
<td></td>
</tr>
</tbody>
</table>
TIP
Tuning the top 25 buffer get and top 25 physical get queries can yield system performance gains of anywhere from 5 percent to 5000+ percent. The SQL section of the Statspack Report tells you which queries to consider tuning first. The top 10 SQL statements should not be substantially more than 10 percent of all of your buffer gets or disk reads. Near the end of the new 12c AWR Report, the Top SQL is connected with the Top Events to help you even more!

Instance Activity Statistics
Following the SQL statement listing, you will see the list of changes to statistics from V$SYSSTAT. Entitled “Instance Activity Stats,” the V$SYSSTAT statistics are useful for identifying performance issues not shown in the prior sections. Here is a partial Statspack listing with some of the key sections listed. Note the excellent IMU (in memory undo) statistics; IMUs are covered in “Tuning and Viewing at the Block Level,” later in this chapter.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Total</th>
<th>per Second</th>
<th>per Trans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batched IO (bound) vector count</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Event</td>
<td>12cR2</td>
<td>12cR1</td>
<td>12cR2</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>Batched IO (full) vector count</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Block Cleanout Optim referenced</td>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Cursor + sqs area evicted</td>
<td>13</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>CPU used by this session</td>
<td>3,183</td>
<td>3.9</td>
<td>18.8</td>
</tr>
<tr>
<td>CPU used when call started</td>
<td>3,141</td>
<td>3.9</td>
<td>18.6</td>
</tr>
<tr>
<td>CR blocks created</td>
<td>100</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>consistent gets</td>
<td>366,674,801</td>
<td>10,176.4</td>
<td>336.5</td>
</tr>
<tr>
<td>db block changes</td>
<td>19,788,834</td>
<td>565.4</td>
<td>18.2</td>
</tr>
<tr>
<td>db block gets</td>
<td>41,812,892</td>
<td>1,194.7</td>
<td>30.4</td>
</tr>
<tr>
<td>dirty buffers inspected</td>
<td>1,234,544</td>
<td>24.4</td>
<td>1.1</td>
</tr>
<tr>
<td>enque c waits</td>
<td>97,613</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td>free buffer requested</td>
<td>20,053,138</td>
<td>573.0</td>
<td>18.1</td>
</tr>
<tr>
<td>IMU CR rollbacks</td>
<td>100</td>
<td>0.1</td>
<td>0.6</td>
</tr>
<tr>
<td>IMU Flushes</td>
<td>249</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td>IMU Redo allocation size</td>
<td>196,696</td>
<td>241.6</td>
<td>1,163.9</td>
</tr>
<tr>
<td>IMU commits</td>
<td>147</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>IMU contention</td>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>IMU kitchg flush</td>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>IMU pool not allocated</td>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>IMU recursive-transaction flush</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>IMU undo allocation size</td>
<td>873,968</td>
<td>1,073.7</td>
<td>5,171.4</td>
</tr>
<tr>
<td>IMU- failed to get a private str</td>
<td>3</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>index fast full scans (full)</td>
<td>20,606</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>leaf node splits</td>
<td>21,066</td>
<td>0.6</td>
<td>0.0</td>
</tr>
<tr>
<td>logons cumulative</td>
<td>188</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>parse count (hard)</td>
<td>54,681</td>
<td>1.6</td>
<td>0.1</td>
</tr>
<tr>
<td>parse count (total)</td>
<td>1,278,323</td>
<td>56.5</td>
<td>1.8</td>
</tr>
<tr>
<td>physical reads</td>
<td>19,320,574</td>
<td>552.0</td>
<td>17.7</td>
</tr>
<tr>
<td>physical writes non checkpoint</td>
<td>2,027,920</td>
<td>57.9</td>
<td>1.9</td>
</tr>
<tr>
<td>recursive calls</td>
<td>5,020,246</td>
<td>143.4</td>
<td>4.6</td>
</tr>
<tr>
<td>sorts (disk)</td>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sorts (memory)</td>
<td>1,333,031</td>
<td>20.1</td>
<td>1.2</td>
</tr>
<tr>
<td>sorts (rows)</td>
<td>14,754,401</td>
<td>422.7</td>
<td>23.6</td>
</tr>
</tbody>
</table>

These statistics can also be found in the AWR Report. In Figure 14-12, you can see that in 12cR2 the AWR Report now presents a helpful Key Instance Activity Stats section before the full list of stats in the Instance Activity Stats section.
Things to Look for in the Instance Statistics Section

Compare the number of sorts performed on disk to the number performed in memory; increase the MEMORY_TARGET (if used and if needed to be increased) and the minimum PGA_AGGREGATE_TARGET (or SORT_AREA_SIZE for earlier versions) or maximum PGA_AGGREGATE_LIMIT (in 12cR2) to reduce disk sorts (see Chapter 4 for more information). If physical reads are high, you are probably performing full table scans. If there is a significant number of full table scans of large tables, evaluate the most-used queries and try to reduce this inefficiency by
using indexes. A large number for consistent gets signals potentially over-indexed or nonselective index use. If dirty buffers inspected is high (over 5 percent) relative to free buffer requested, the memory parameters for the SGA may be too small (see Chapter 4 for additional use of these parameters and settings), or you may not be checkpointing often enough. If leaf node splits are high, consider rebuilding indexes that have grown and become fragmented if they are causing a performance degradation. The following sections look at a few of these scenarios.

The following listing shows the applicable rows from this section of the report:

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Total</th>
<th>per Second</th>
<th>per Trans</th>
</tr>
</thead>
<tbody>
<tr>
<td>sorts (disk)</td>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sorts (memory)</td>
<td>3,062</td>
<td>3.8</td>
<td>18.1</td>
</tr>
<tr>
<td>sorts (rows)</td>
<td>134,856</td>
<td>165.7</td>
<td>796.0</td>
</tr>
<tr>
<td>table scan rows gotten</td>
<td>30,089,991</td>
<td>36,965.6</td>
<td>178,047.3</td>
</tr>
<tr>
<td>table scans (direct read)</td>
<td>1</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>table scans (long tables)</td>
<td>5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>table scans (short tables)</td>
<td>1,285</td>
<td>1.6</td>
<td>7.6</td>
</tr>
</tbody>
</table>

In the preceding example, the database performed almost all sorts in memory during the reporting interval. Of the table scans performed, most were of very small tables. The table scans (short tables) are tables that are smaller than 2 percent of the buffer cache in Oracle 12c.

TIP
If many sorts are being performed to disk (greater than 1–5 percent of the total number of rows being sorted), you may need to increase the initialization parameters associated with sorting. See Chapter 4 for more information on these.

Key Areas to Consider
A few key areas to consider are explained in this section:

- **Consistent gets** The number of blocks read from the buffer cache for queries without the SELECT FOR UPDATE clause. The value for this statistic plus the value of the “db block gets” statistic constitute what is referred to as logical reads (all reads cached in memory). These are usually the CURRENT version of the block, but can also be a Consistent Read (CR) version.

- **DB block gets** The number of blocks read in the buffer cache that were accessed for INSERT, UPDATE, DELETE, or SELECT FOR UPDATE statements. These are CURRENT versions of the block. When these are changed, they are reflected in the “db block changes” value.

- **Physical reads** The number of data blocks that were not read from the buffer cache. This could
be reads from disks, OS cache, or disk cache to satisfy a SELECT, SELECT FOR UPDATE, INSERT, UPDATE, or DELETE statement.

By adding the “consistent gets” and “db block gets,” you get the number of logical reads (memory reads). Using the following equation, you can calculate the buffer (data) cache hit ratio:

\[
\text{Hit Ratio} = \frac{\text{Logical Reads} - \text{Physical Reads}}{\text{Logical Reads}}
\]

TIP
The buffer cache hit ratio should be greater than 95 percent. If it is less than 95 percent, you should consider increasing the size of the data cache by increasing the MEMORY_TARGET (if used) or increasing the minimum setting for the DB_CACHE_SIZE initialization parameter (given that physical memory is available to do this).

- **Dirty buffers inspected** The number of dirty (modified) data buffers that were aged out on the least recently used (LRU) list. A value here indicates that the DBWR is not keeping up. You may benefit by adding more DBWRs.

TIP
If “dirty buffers inspected” is greater than 1–2 percent of “free buffer requested,” consider increasing the database writers as detailed in Chapter 3.

- **Enqueue waits (timeouts)** The number of times that an enqueue (lock) was requested and the specific one that was requested was not available. If this statistic is greater than 0, investigate the locking issues.

- **Free buffer inspected** Includes buffers that were skipped because they were dirty, pinned, or busy. If you subtract those values (“dirty buffers inspected” and “buffer is pinned count”) from this statistic, it leaves the buffers that could not be reused due to latch contention. A large number would be a good indicator of a too-small buffer cache. There is also a “free buffer requested” section that you can compare to this.

- **Parse count** The number of times a SQL statement was parsed (total count). You can also check the version count of the SQL section to correlate with this one.

- **Recursive calls** The number of recursive calls to the database. This type of call occurs for a few reasons—misses in the Dictionary Cache, dynamic storage extension, and when PL/SQL statements are executed. Generally, if the number of recursive calls is more than four per process, you should check the Dictionary Cache hit ratio, and see if there are tables or indexes with a large number of extents. Unless you have PL/SQL, the ratio of recursive calls to user calls should be 10 percent or less.
- **REDO size** The size in bytes of the amount of REDO information that was written to the redo logs. This information can be used to help size the redo logs. Additional information on REDO sizing is in Chapter 3.

- **Sorts (disk)** The number of sorts that were unable to be performed in memory and, therefore, required the creation of a TEMP segment in the temporary tablespace. This statistic divided by the sorts (memory) should not be greater than 5 percent. If it is, you should increase the SORT_AREA_SIZE (if used) or PGA_AGGREGATE_TARGET (note that you may need to increase MEMORY_TARGET if you don’t set a minimum value for PGA_AGGREGATE_TARGET or you may need to increase MEMORY_TARGET if you increase the PGA_AGGREGATE_TARGET) parameter in the init.ora file.

- **Sorts (memory)** The number of sorts that were performed in memory.

- **Sorts (rows)** The total number of rows that were sorted.

---

**TIP**

The “sorts (disk)” statistic divided by the “sorts (memory)” statistic should not be greater than 1–5 percent. If it is, you should increase the PGA_AGGREGATE_TARGET/PGA_AGGREGATE_LIMIT (or SORT_AREA_SIZE and/or MEMORY_TARGET) parameter in the initialization file (if physical memory is available to do this). Remember that the memory allocated for SORT_AREA_SIZE is a per-user value and PGA_AGGREGATE_TARGET is across all sessions. See Chapter 4 for more information.

- **Table fetch by rowid** The number of rows that were accessed by using a ROWID. This ROWID came from either an index or a “WHERE ROWID = …” statement. A high number usually indicates a well-tuned application as far as fetching the data goes.

- **Table fetch continued row** The number of rows that were fetched that were chained or migrated.

---

**TIP**

If chained rows are indicated, the problem needs to be fixed as soon as possible if performance degradation is evident. Chained rows can cause severe degradation of performance if a large number of rows are chained. See Chapter 3 for tips on eliminating chaining.

- **Table scans (long tables)** A long table is one that is larger than _SMALL_TABLE_THRESHOLD (which is a hidden/undocumented parameter) with no CACHE clause. The default value of _SMALL_TABLE_THRESHOLD is 2 percent of the buffer cache in Oracle 12c and since 10g, _SMALL_TABLE_THRESHOLD is a dangerous parameter to modify without careful benchmarking of the effects. As this affects all tables
accessing it, increasing this parameter significantly, if at all, is unwise, as it can cause blocks to age more quickly and reduce your hit ratio. In Oracle, this parameter is the number of db blocks up to which the table is considered small. This threshold is used to determine the cut-off point for direct-read operations. Any object that is smaller than the value of _SMALL_TABLE_THRESHOLD will not be worth performing direct reads for and thus will be read through the buffer cache. If the number of table scans per transaction is greater than 0, you may wish to review the application SQL statements and try to increase the use of indexes. Oracle does not want a large table to overrun the buffer cache; that’s the reason this parameter ensures that every table larger than 2 percent of the buffer cache is considered a long table.

**TIP**

*If full table scans are being performed, serious performance issues may result and data hit ratios will be distorted. These tables need to be identified so the appropriate indexes are created or used. See Chapters 8 and 9 on query tuning for more information.*

- **Table scans (short tables)** A short table is one that is less than 2 percent of the buffer cache. Full table scans on short tables are preferred by Oracle.

**Tablespace and File I/O Statistics**

The next section of the Statspack Report provides the I/O statistics. Prior to the Tablespace IO Stats and File IO Stats sections, there is a section that shows the I/O stats grouped by function, including the types of reads that are occurring (see the listing):

If the I/O activity is not properly distributed among your files, you may encounter performance
bottlenecks during periods of high activity. As a rule of thumb, you don’t want more than 100 I/Os per second per 10,000 RPM disk (even with a RAID array). If the Av Rd(ms) column (Average Reads per millisecond) is higher than 14 ms (given a fair amount of reading is being done), you may want to investigate, since most disks should provide at least this much performance. If rows in this column show 1,000 ms or more in the Av Rd(ms) column or in the Av Buf Wt(ms) column (Average Buffer Writes per millisecond), you probably have some type of I/O problem, and if it shows ###### (meaning it couldn’t fit the value in the size of the field), then you have a serious I/O problem of some kind (this can also be a formatting problem, but anything greater than 1,000 is a problem when a fair number of reads are being done).

I have seen I/O issues that are related to other problems, yet show up as an I/O problem. For disks with a lot of memory cached on the disk, the I/O time is often less than 1 ms for a disk where heavy reading is being done. You should use this section of the report to identify such bottlenecks and to measure how effectively you have resolved those problems. If you have the choice between 15K RPM 600G SAS drives and 7.2K RPM 2T SATA disks—always choose the SAS drives unless it’s for archived information that will almost never be accessed.

Set the DB_FILE_MULTIBLOCK_READ_COUNT parameter in the initialization file (SPFILE or init.ora) to help improve the read time. This parameter controls the number of blocks that can be read in one I/O when a full table scan is being performed. In 12c, the default is set to 128, so it should be sufficient. Setting it can reduce the number of I/Os needed to scan a table, thus improving the performance of the full table scan. Unfortunately, the optimizer might do more full table scans as a result of setting DB_FILE_MULTIBLOCK_READ_COUNT (you don’t want this behavior), so you may also need to set the OPTIMIZER_INDEX_COST_ADJ to a number, such as 10, to eliminate this problem and drive the use of indexes (be careful with this parameter and see Chapter 4 and Appendix A before setting it). Here is an example listing from this section of the report:

<table>
<thead>
<tr>
<th>Tablespace</th>
<th>Reads</th>
<th>Reads/s</th>
<th>Rd(ms)</th>
<th>Blks/Rd</th>
<th>Writes</th>
<th>Writes/s</th>
<th>Buffer Av Wt(ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS_ORDERS</td>
<td>1,108,981</td>
<td>32</td>
<td>12.1</td>
<td>1.0</td>
<td>1,086,453</td>
<td>29</td>
<td>6,445</td>
</tr>
<tr>
<td>TS_ORDER_SUM</td>
<td>967,168</td>
<td>28</td>
<td>12.5</td>
<td>1.0</td>
<td>675,617</td>
<td>19</td>
<td>51</td>
</tr>
<tr>
<td>TS_ORDER_LINES</td>
<td>1,289,292</td>
<td>40</td>
<td>10.1</td>
<td>1.0</td>
<td>22,930</td>
<td>1</td>
<td>1,752</td>
</tr>
</tbody>
</table>

Here are descriptions of some of the columns appearing in this output:
<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLESPACE</td>
<td>The name of the tablespace.</td>
</tr>
<tr>
<td>READS</td>
<td>The number of physical reads that were performed on the datafile to retrieve data.</td>
</tr>
<tr>
<td>AV BLKS/RD</td>
<td>The number of blocks per read that were read from the datafile to satisfy an average read.</td>
</tr>
<tr>
<td>WRITES</td>
<td>The number of writes to the data file.</td>
</tr>
</tbody>
</table>

Following the Tablespace IO Stats section, you’ll see a File IO Stats section, as you can see here:


--->Mx Rd Bkt: Max bucket time for single block read
--->ordered by Tablespace, File

<table>
<thead>
<tr>
<th>Tablespace</th>
<th>Filename</th>
<th>Av</th>
<th>Av</th>
<th>Mx</th>
<th>Av</th>
<th>Av</th>
<th>Av</th>
<th>Buffer</th>
<th>BufWt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Reads</td>
<td>Reads/s</td>
<td>Rd</td>
<td>Bkt Blds/Rd</td>
<td>Writes</td>
<td>Writes/s</td>
<td>Waits</td>
<td>(ms)</td>
</tr>
<tr>
<td>EXAMPLE</td>
<td>C:\APP\USER\ORADATA\ORCL\EXAMPLE01.DBF</td>
<td>1</td>
<td>0</td>
<td>0.0</td>
<td>1.0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FLOW_1046531734508653</td>
<td>C:\APP\USER\ORADATA\ORCL\FLOW_1046531734508653.DBF</td>
<td>1</td>
<td>0</td>
<td>0.0</td>
<td>1.0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FLOW_1054429114609071</td>
<td>C:\APP\USER\ORADATA\ORCL\FLOW_1064429114609071.DBF</td>
<td>1</td>
<td>0</td>
<td>0.0</td>
<td>1.0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SYSAUX</td>
<td>C:\APP\USER\ORADATA\ORCL\SYSAUX01.DBF</td>
<td>3</td>
<td>0</td>
<td>6.7</td>
<td>16</td>
<td>1.0</td>
<td>110</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>SYSTEM</td>
<td>C:\APP\USER\ORADATA\ORCL\SYSTEM01.DBF</td>
<td>5</td>
<td>0</td>
<td>6.0</td>
<td>16</td>
<td>1.0</td>
<td>215</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>UNDOBS1</td>
<td>C:\APP\USER\ORADATA\ORCL\UNDOBS01.DBF</td>
<td>1</td>
<td>0</td>
<td>0.0</td>
<td>1.0</td>
<td>1</td>
<td>81</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>USERS</td>
<td>C:\APP\USER\ORADATA\ORCL\USERS01.DBF</td>
<td>79</td>
<td>0</td>
<td>10.3</td>
<td>107.0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C:\APP\USER\ORADATA\ORCL\USERS02.DBF</td>
<td>32</td>
<td>0</td>
<td>32.2</td>
<td>62.3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C:\APP\USER\ORADATA\ORCL\USERS03.DBF</td>
<td>79</td>
<td>0</td>
<td>11.6</td>
<td>120.9</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C:\APP\USER\ORADATA\ORCL\USERS04.DBF</td>
<td>529</td>
<td>1</td>
<td>0.0</td>
<td>127.2</td>
<td>4,935</td>
<td>6</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
An example of the AWR Report IO Stats section is displayed in Figure 14-13. You can also see from this figure that Oracle gives tablespace I/O and file I/O information as well in this section.

Following the tablespace I/O statistics is a file I/O section breakdown—a very granular look at how the I/O is being distributed across the datafiles. If one of the datafiles is getting a majority of the reads and writes, you may be able to improve performance by creating multiple datafiles on separate disks or by striping the datafile across multiple disks. Also, stay away from RAID 5 (Chapter 3 has more on this) or you’ll get slower write times. In 12c, Oracle allows you to move “hotter” data to the fastest portion of the disk. I show you how to do this in Chapter 5 on Enterprise Manager.

**TIP**

*If the number of physical reads is heavier on one physical disk, balancing the data properly or using ASM correctly will probably improve performance. See Chapter 3 for tips on fixing I/O problems (and using ASM) with either datafiles or tablespaces.*
One of the best data dictionary views that Oracle provides is V$SEGMENT_STATISTICS. This view quickly became a DBA favorite after its introduction in Oracle9i. Using this view, you can view Segment Statistics reports for everything you could ever need. Here are the sections that the AWR Report now shows:

- Segments by Logical Reads
- Segments by Physical Reads
- Segments by Physical Read Requests
- Segments by UnOptimized Reads
- Segments by Optimized Reads
- Segments by Direct Physical Reads
- Segments by Physical Writes
- Segments by Physical Write Requests
- Segments by Direct Physical Writes
- Segments by Table Scans
- Segments by DB Block Changes
- Segments by Row Lock Waits
- Segments by ITL Waits
- Segments by Buffer Busy Waits
- Segments by Global Cache Buffer Busy (RAC only)
- Segments by CR Blocks Received (RAC only)
- Segments by Current Blocks Received (RAC only)

Figure 14-14 shows the section of the AWR Report dedicated to segment statistics. This is particularly useful for finding what specific INDEX or DATA segment is causing a bottleneck of some kind. Finding specific ITL waits was also very difficult prior to Oracle providing this additional detail. Now, in the Segment Statistics section, you can see the exact number of ITL waits by owner, tablespace name, object name, and subobject name (such as an index partition subobject name).
Segment statistics are a great way to pinpoint performance problems to a given table, index, or partition. Oracle provides many segment-level statistics in both the AWR Report and Statspack.

Additional Memory Statistics

Following the I/O statistics, both reports list many memory sections, including a section for sizing the MEMORY_TARGET (which includes the 12cR2 INMEMORY_SIZE area), a section on all of the dynamic components related to the MEMORY_TARGET, a buffer pool advisory (for sizing the DB_CACHE_SIZE), buffer cache statistics by pool (default, keep, and recycle), instance recovery statistics (the number of REDO blocks), shared pool sizing advisory, and the PGA memory statistics and advisory. I won’t be able to cover all of them here (initialization parameter sizing is covered in
Chapter 4), but I show a sample listing of several of these sections next. The MEMORY_TARGET advisor (first listing) shows that by setting this above the current setting (Size Factor = 1; MEMORY_TARGET = 6.56G), I will not get additional benefits given the current load at this time. If the load changes, these values will change as well.

You can easily see, under Memory Dynamic Components (shown next), exactly where memory is currently being allocated. Here, you see the SGA_TARGET is 4.272G, the DB_CACHE_SIZE is 2.208G, the PGA_AGGREGATE_TARGET is 2.288G, and the shared pool is just under 1G. The Statspack Report does not list the In-Memory areas, whereas the AWR Report lists the In-Memory Area, In Memory RO Extension Area, and In Memory RW Extension Area in the 12cR2 Memory Dynamic Components section.

<table>
<thead>
<tr>
<th>Memory Size (M)</th>
<th>Factor</th>
<th>Est. DB Time (s)</th>
<th>Advice Reset</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,280</td>
<td>.5</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>4,920</td>
<td>.8</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>5,740</td>
<td>.9</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>6,560</td>
<td>1.0</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>7,380</td>
<td>1.1</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>8,200</td>
<td>1.3</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>9,020</td>
<td>1.4</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>9,840</td>
<td>1.5</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>10,660</td>
<td>1.6</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>11,480</td>
<td>1.8</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>12,300</td>
<td>1.9</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>13,120</td>
<td>2.0</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>
The next section is Buffer Pool Advisory. While much of this information is shown in other sections, the Buffer Pool Statistics section is very detailed in this part of the report. It shows individual buffer pools for the keep and recycle pools, if they are used (Chapter 4 includes more information on using these buffer pools). This section also shows information for the different block sizes if you use multiple block sizes. As with MEMORY_TARGET, I also have an advisor (see the following listing) that shows my current setting for the DB_CACHE_SIZE or memory allocated for data buffers (Size Factor = 1; DB_CACHE_SIZE = 2.208G). From this, you can see that I will not get many additional benefits, given the current load at this time, by increasing this value. If the load changes, these values will change as well. The hit ratio (99 percent) is shown in this listing.

<table>
<thead>
<tr>
<th>Cache</th>
<th>Begin Snap</th>
<th>End Snap</th>
<th>Op Count</th>
<th>Last Op Type/Mode</th>
<th>Last Op Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>D:buffer cache</td>
<td>2,209</td>
<td>2,289</td>
<td>0</td>
<td>INITIAL</td>
<td></td>
</tr>
<tr>
<td>PGA Target</td>
<td>2,289</td>
<td>2,289</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
<tr>
<td>SGA Target</td>
<td>4,272</td>
<td>4,272</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
<tr>
<td>Shared T0 Pool</td>
<td>928</td>
<td>928</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
<tr>
<td>java pool</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
<tr>
<td>large pool</td>
<td>32</td>
<td>32</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
<tr>
<td>shared pool</td>
<td>1,024</td>
<td>1,024</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
<tr>
<td>streams pool</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>STATIC</td>
<td></td>
</tr>
</tbody>
</table>

Buffer Pool Advisory  DB/Inst: ORCL/orcl  End Snap: 2
-> Only rows with estimated physical reads >0 are displayed
-> ordered by Pool, Block Size, Buffers For Estimate
The next couple of sections (not all displayed here) relate to the memory needed for PGA and sorting or the PGA_AGGREGATE_TARGET (which is now limited by the 12cR2 PGA_AGGREGATE_LIMIT parameter). There are also sections with shared pool statistics. The PGA_AGGREGATE_TARGET section is listed here (this value is sufficient with 100 percent of the hits being done in memory):

<table>
<thead>
<tr>
<th>Size for Rst (M)</th>
<th>Size Factor</th>
<th>Buffers (thousands)</th>
<th>Phys Reads Factor</th>
<th>Estimated Phys Reads (thousands)</th>
<th>Est Phys Read Time for Rds</th>
</tr>
</thead>
<tbody>
<tr>
<td>208</td>
<td>.1</td>
<td>26</td>
<td>1.0</td>
<td>17,025</td>
<td>5,091</td>
</tr>
<tr>
<td>416</td>
<td>.2</td>
<td>51</td>
<td>1.0</td>
<td>16,918</td>
<td>4,936</td>
</tr>
<tr>
<td>624</td>
<td>.3</td>
<td>77</td>
<td>1.0</td>
<td>16,893</td>
<td>4,999</td>
</tr>
<tr>
<td>832</td>
<td>.4</td>
<td>102</td>
<td>1.0</td>
<td>16,881</td>
<td>4,882</td>
</tr>
<tr>
<td>1,040</td>
<td>.5</td>
<td>128</td>
<td>1.0</td>
<td>16,801</td>
<td>4,653</td>
</tr>
<tr>
<td>1,248</td>
<td>.6</td>
<td>154</td>
<td>1.0</td>
<td>16,801</td>
<td>4,766</td>
</tr>
<tr>
<td>1,456</td>
<td>.7</td>
<td>179</td>
<td>1.0</td>
<td>16,800</td>
<td>4,764</td>
</tr>
<tr>
<td>1,664</td>
<td>.8</td>
<td>205</td>
<td>1.0</td>
<td>16,798</td>
<td>4,761</td>
</tr>
<tr>
<td>1,872</td>
<td>.9</td>
<td>230</td>
<td>1.0</td>
<td>16,795</td>
<td>4,758</td>
</tr>
<tr>
<td>2,080</td>
<td>1.0</td>
<td>256</td>
<td>1.0</td>
<td>16,794</td>
<td>4,755</td>
</tr>
<tr>
<td>2,298</td>
<td>1.1</td>
<td>282</td>
<td>1.0</td>
<td>16,792</td>
<td>4,751</td>
</tr>
<tr>
<td>2,516</td>
<td>1.2</td>
<td>307</td>
<td>1.0</td>
<td>16,790</td>
<td>4,750</td>
</tr>
<tr>
<td>2,744</td>
<td>1.3</td>
<td>333</td>
<td>1.0</td>
<td>16,789</td>
<td>4,748</td>
</tr>
<tr>
<td>2,972</td>
<td>1.4</td>
<td>359</td>
<td>1.0</td>
<td>16,788</td>
<td>4,746</td>
</tr>
<tr>
<td>3,200</td>
<td>1.5</td>
<td>384</td>
<td>1.0</td>
<td>16,786</td>
<td>4,743</td>
</tr>
<tr>
<td>3,438</td>
<td>1.6</td>
<td>410</td>
<td>1.0</td>
<td>16,785</td>
<td>4,740</td>
</tr>
<tr>
<td>3,676</td>
<td>1.7</td>
<td>435</td>
<td>1.0</td>
<td>16,784</td>
<td>4,737</td>
</tr>
<tr>
<td>3,912</td>
<td>1.8</td>
<td>461</td>
<td>1.0</td>
<td>16,781</td>
<td>4,736</td>
</tr>
<tr>
<td>4,160</td>
<td>1.9</td>
<td>512</td>
<td>1.0</td>
<td>16,777</td>
<td>4,731</td>
</tr>
</tbody>
</table>

-> Standard block size Pools D: default, K: keep, R: recycle
-> Default Pools for other block sizes: 2k, 4k, 8k, 16k, 32k
-> Buffers: the number of buffers. Units of K, M, G are divided by 1000

<table>
<thead>
<tr>
<th>Pool</th>
<th>Buffers</th>
<th>Hit%</th>
<th>Buffer Gets</th>
<th>Physical Reads</th>
<th>Physical Writes</th>
<th>Free Writ</th>
<th>Buffer Comp Waits</th>
<th>Buffer Busy Waits</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>271K</td>
<td>99</td>
<td>850,912</td>
<td>5,920</td>
<td>8,860</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The Instance Recovery Stats section is listed next:

The Shared Pool Advisory and the SGA Target Advisory sections follow the Latch section (I’ve moved them here to present them with the other SGA components). Both of these are set sufficiently at the current load (a size factor greater than 1.0 yields no additional savings: SHARED_POOL_SIZE = 1G and SGA_TARGET = 4.272G). You may even consider decreasing them if this load is representative of your system during normal loads.
The next section, SGA Memory Summary, is a great breakdown of the SGA areas that you are using during this snapshot interval. You can also see this real time by executing a SHO SGA command.
The AWR Report shows statistics on the following advisories. Figure 14-15 shows the AWR Report for a 12.2 SGA with In-Memory Area set from SQL*Plus and then the SGA Target Advisory.
Connected to:
Oracle Database 12c Enterprise Edition Release 12.1.0.2.0 - 64bit Production
With the Partitioning, OLAP, Advanced Analytics and Real Application Testing options

SQL> show sga

Total System Global Area 4194304000 bytes
Fixed Size 2932336 bytes
Variable Size 570425744 bytes
Database Buffers 2013265920 bytes
Redo Buffers 13844480 bytes
In-Memory Area 1593835520 bytes

![SGA Target Advisory Table]

FIGURE 14-15. The AWR Report SGA Target Advisory (preceded by SGA with In-Memory Area)

- Instance Recovery Stats
- MTTR Advisory
- Buffer Pool Advisory
- PGA Aggr Summary
- PGA Aggr Target Stats
- PGA Aggr Target Histogram
- PGA Memory Advisory
- Shared Pool Advisory
- SGA Target Advisory
- Streams Pool Advisory
- Java Pool Advisory
TIP

In Oracle 12c, multiple data block sizes are allowed. The AWR Report and/or Statspack shows statistics for each of these block sizes individually. Many advisories are available to help you size the SGA that both the AWR Report (see Figure 14-15) and Enterprise Manager (graphically, see Chapter 5) suggest. These suggestions should be tested first, however, and are not always the best choice. As Robert Freeman would say, “Your mileage may vary.”

UNDO Statistics

The next section provides UNDO segment statistics. The first part of this section shows the UNDO tablespace and the number of transactions and UNDO blocks for the entire tablespace. Next, it gives information about how many UNDO blocks are utilized and the number of transactions that have occurred for a given segment (UNDOSTAT ROW). The AWR Report in Oracle provides a summary and UNDO segment stats, some that were not available in previous versions. This new output is shown in Figure 14-16.
While I have eliminated the ROLLSTAT information from this version of the book (since most people now use AUTO UNDO), this information can still be reported in Statspack. By using the configuration file, *sprepcon.sql*, you can modify the DISPLAY_ROLLSTAT parameter.

**Latch and Mutex Statistics**

Latches are low-level queuing mechanisms (the accurate term is *mutual exclusion mechanisms*) used to protect shared memory structures in the SGA (memory). Latches are like locks on memory that are very quickly obtained and released, consuming roughly 32 bytes. Latches are used to prevent concurrent access to a shared memory structure. If the latch is not available, a latch free miss is recorded. The *library cache pin* (protects cursors/SQL) and *library cache latch* (protects the Library Cache) are both replaced by *mutexes* (program objects that negotiate mutual exclusion among threads). Most latch and mutex problems (waits, misses, and sleeps) are related to the failure to use...
bind variables (library cache mutex waits and shared pool latch waits), REDO generation issues (redo allocation latch waits), buffer cache contention issues (cache buffers lru chain waits), and hot blocks in the buffer cache (cache buffers chain waits). There are also latch and mutex waits related to bugs; check My Oracle Support (Metalink) for bug reports if you suspect this is the case. When latch miss ratios are greater than 0.5 percent, you should investigate the issue. If the latch miss ratio is greater than 2 percent and there are a large number of them, you may have a serious problem. The cache buffers chains (CBC) latch can be shared and is still heavily used in 12cR2.

Two types of latches are available: willing to wait latches (one example is a shared pool latch) and not willing to wait latches (an example is a redo copy latch). A process that is willing to wait will try to acquire a latch. If none are available, it spins and then requests the latch again. It continues to do this up to the _SPIN_COUNT initialization parameter (note that spinning costs CPU). The _SPIN_COUNT default is 2000 for shared latches (20,000 for exclusive latches found by querying X$KSLLCLASS—all eight classes are set to 20,000); also note that for mutexes, the default for the _MUTEX_SPIN_COUNT is 255. If the process can’t get a latch after spinning up to the _SPIN_COUNT, it goes to sleep, to not do anything for a while, and then wakes up after one centisecond (one hundredth of a second). It does this twice. The process then starts this whole cycle again, spinning up to the _SPIN_COUNT and then sleeping for twice as long (two centiseconds). After doing this again, it doubles again. So the pattern is 1, 1, 2, 2, 4, 4, and so on. It repeats this until it gets the latch. Every time the latch sleeps, the process creates a latch sleep wait.

Some latches are “not willing to wait.” A latch of this type does not wait for the latch to become available. It immediately times out and tries to obtain the latch again. A redo copy latch wait is an example of a “not willing to wait” latch. A “not willing to wait” latch generates information for the IMMEDIATE_GETS and the IMMEDIATE_MISSES columns of the V$LATCH view and also in the Statspack Report. The hit ratio for these latches should approach 99 percent, and the misses should never fall below 1 percent.

By viewing the Latch Activity section of Statspack or querying the V$LATCH view, you can see how many processes had to wait (a latch miss) or sleep (a latch sleep) and the number of times they had to sleep. If you see ##### in any field, it usually means bad news, as the value exceeds the length of the field. V$LATCHHOLDER, V$LATCHNAME, and V$LATCH_CHILDREN are also helpful in investigating latch issues. Here is a partial listing of the latch activity section; there are six sections related to latches (Latch Activity, Latch Sleep, Latch Miss, Mutex Sleep Summary, Parent Latch Statistics, and Child Latch Statistics) for the AWR Report and Statspack Report (this Statspack Report has no major problems as I am not missing more than 1 percent—partial display latches only):
Figures 14-17 and 14-18 show similar statistics from the AWR Report, including the new Mutex Sleep Summary in Figure 14-18. Note in Figure 14-17 the new 12cR2 In-Memory column store latches that mirror some of those in the buffer cache (i.e., IM Global dictionary latch, etc.). Some of the In-Memory latches include
FIGURE 14-17. The AWR Report Latch Activity section (12cR2 includes many new In-Memory latches)

<table>
<thead>
<tr>
<th>Latch Name</th>
<th>Get Requests</th>
<th>Pct Get Miss</th>
<th>Avg Sps/Miss</th>
<th>Wait Time (s)</th>
<th>NoWait Requests</th>
<th>Pct NoWait Miss</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQ Background: interrupt command latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>400</td>
<td>0.00</td>
</tr>
<tr>
<td>AQ Coord jobx_kwebagn latch</td>
<td>382</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>AQ Stashed master pool latch</td>
<td>382</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>AQ deg hash table latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ASM db client latch</td>
<td>7,723</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ASM map operation hash table</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ASM network stats latch</td>
<td>204</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>ASM remote client latch</td>
<td>204</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>AWN Alerted Metric element list</td>
<td>79,451</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Change Notification Hash table latch</td>
<td>3,845</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Column stats entry latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Consistent RBA</td>
<td>2,091</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>DML lock allocation</td>
<td>1,996</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Event Group Locks</td>
<td>1,962</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FIB s.o chain latch</td>
<td>66</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FOB CSP latch</td>
<td>3</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>FOB consolidated a.s a latch</td>
<td>66</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>File State Object Pool Parent Latch</td>
<td>153</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>GCS logfile block</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>GCS logfile write queue</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hang Manager wait event statistics</td>
<td>762</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IO Statistics latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM Stats Stripe Latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM Stats main anchor latch</td>
<td>2,110</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM access tracking extent</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM activity tracking latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM Global dictionary latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM Global dictionary queue latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>LM Global dictionary rw latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M area sb latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M area sb latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>M emb latch</td>
<td>5</td>
<td>0.00</td>
<td></td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
A mutex (which replaces many types of library cache latches) is used to eliminate the possibility of two processes simultaneously using a common resource (while one or both are trying to change it); when one session is changing the resource, the second can’t view it or change it, and when one session is viewing the resource, the second can’t change it.

Oracle moved from latches to mutexes because a mutex is lighter weight and provides more granular concurrency than latches. A mutex requires less memory space and fewer instructions. Mutexes take advantage of CPU architecture that has "compare and swap" instructions (and similar types of benefits). Without going into a lot of detail, Oracle uses mutexes (mutual exclusion) instead of library cache latches and library cache pin latches to protect objects. With a mutex, if I have the resource and you can’t get it after trying a specified number of times (spins), you sleep and try again a very short time later. In 10g, Oracle also used mutexes for pins, but you could use the undocumented parameter _KKS_USE_MUTEX_PIN=FALSE to override it. This parameter is no longer available in 12c. A mutex, while similar to a latch, protects a single object, whereas a latch usually protects a group of objects.

When you receive wait events on cursor: pin S wait on X, you are probably waiting on a hard parse; the session needs a mutex in share mode on a resource and someone has it in exclusive mode. A pin is when a session wants to re-execute a statement that’s in the Library Cache. Waits for pins generally happen with high rates of SQL execution, whereas waiting for a resource held in exclusive mode (X) usually is related to hard parsing. When a session wants a mutex in S (share mode) on a cursor (SQL statement), but another session is holding that mutex in X (exclusive) mode, the session waiting for the mutex in S mode will sleep. After asking enough times and not getting the latch, the session sleeps for a short time and then it begins trying again to get the mutex. A mutex is also not FIFO (first in, first out); order is not guaranteed. All of this is for efficiency.

Library cache latches have been replaced with mutexes. In fact, all library cache latches are replaced with mutexes other than the library cache load lock. The following queries help you find

---

**FIGURE 14-18. The AWR Report Mutex Sleep Summary**

<table>
<thead>
<tr>
<th>Mutex Type</th>
<th>Location</th>
<th>Sleeps</th>
<th>Wait Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Cache</td>
<td>kglget2 2</td>
<td>141</td>
<td>2</td>
</tr>
<tr>
<td>Cursor Pin</td>
<td>kkslicc [KKSCHLPIN2]</td>
<td>7</td>
<td>-2</td>
</tr>
<tr>
<td>Library Cache</td>
<td>kglldl1 85</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

---

- In-Memory area latch
- In-Memory columnar segment hash table latch
- In-Memory columnar ts extent map chunk latch
- In-Memory global pool latch
information related to mutex wait events when you get them. (This is an example of a cursor: pin S wait on X wait event; check My Oracle Support for your exact wait and related values. Specific wait events are covered later in this section.)

P1 is the idn, which is the HASH_VALUE of the SQL statement I am waiting on. I can query V$SQL or V$SQLAREA to get the actual SQL_TEXT:

```sql
select sql_text
from v$sqlarea
where hash_value=&&P1;
```

P2 is the mutex value, which is the session id (higher bits) and reference count (which is 0 if I am sleeping/waiting for an X mode holder):

```sql
select decode(trunc(&&P2/4294967296), 0, trunc(&&P2/65536),
      trunc(&&P2/4294967296)) STD_HOLDING_THE_MUTEX
from dual;
```

I can also go to V$SESSION to see the blocker:

```sql
select action, blocking session, blocking session status, sql id
from v$session
where sid = &SID HOLDING THE MUTEX;  (get this from query above)
```

P3 is the location in the code where the wait is occurring. Knowing this location can be very helpful when Oracle Support is helping you with an issue. The library cache: mutex X wait event has the same values for P1, P2, and P3 according to Oracle’s documentation. You can also investigate the V$MUTEX_SLEEP and V$MUTEX_SLEEP_HISTORY views for more information. You will generally find that the mutex type is almost always a library cache mutex or cursor pin mutex when querying these views. Cursor parent and cursor stat mutexes also show up in these views. See the following sample queries showing mutex sleeps:

```sql
select mutex_type, count(*), sum(sleeps)
from v$mutex_sleep
group by mutex_type;
```
One thing to remember about sleeping processes: These processes may also be holding other latches/mutexes that will not be released until the process is finished with them. This can cause even more processes to sleep while waiting for those latches. So you can see how important it is to reduce contention as much as possible. The following table explains the columns in this part of the report:

<table>
<thead>
<tr>
<th>Mutex Type</th>
<th>Count(*)</th>
<th>Sum(Sleeps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Cache</td>
<td>8</td>
<td>3691</td>
</tr>
<tr>
<td>Cursor Pin</td>
<td>4</td>
<td>1605</td>
</tr>
<tr>
<td>Cursor Parent</td>
<td>2</td>
<td>129</td>
</tr>
<tr>
<td>Hash Table</td>
<td>2</td>
<td>27</td>
</tr>
</tbody>
</table>

```
select mutex_type, count(*), sum(sleeps)
from v$mutex_sleep_history
group by mutex_type;
```

<table>
<thead>
<tr>
<th>Mutex Type</th>
<th>Count(*)</th>
<th>Sum(Sleeps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Cache</td>
<td>201</td>
<td>3691</td>
</tr>
<tr>
<td>Cursor Pin</td>
<td>63</td>
<td>889</td>
</tr>
<tr>
<td>Cursor Parent</td>
<td>20</td>
<td>244</td>
</tr>
<tr>
<td>Hash Table</td>
<td>14</td>
<td>75</td>
</tr>
</tbody>
</table>

One thing to remember about sleeping processes: These processes may also be holding other latches/mutexes that will not be released until the process is finished with them. This can cause even more processes to sleep while waiting for those latches. So you can see how important it is to reduce contention as much as possible. The following table explains the columns in this part of the report:

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LATCH NAME</td>
<td>The name of the latch.</td>
</tr>
<tr>
<td>GETS</td>
<td>The number of times a &quot;willing to wait&quot; request for a latch was requested and it was available.</td>
</tr>
<tr>
<td>MISSES</td>
<td>The number of times a &quot;willing to wait&quot; request for a latch was initially requested but was not available.</td>
</tr>
<tr>
<td>SLEEPS</td>
<td>The number of times a &quot;willing to wait&quot; request for a latch failed until the spin count was exceeded and the process went to sleep. The number of sleeps may be greater than the misses. Processes may sleep multiple times before obtaining the latch.</td>
</tr>
<tr>
<td>NOWAIT MISSES</td>
<td>The number of times an immediate (not willing to wait) request for a latch was unsuccessful.</td>
</tr>
</tbody>
</table>

The following are some latches and mutexes to look for and remember.

**Latch Free** When latch free is high in the wait events section of the report, then problems need to be investigated in the latch section of the report. This section helps you look for which latches are problematic. The problem could be a sleeping latch (couldn’t get the latch and now it’s sleeping until the next try) or a spinning latch (waiting and retrying based on spin count).

**Library Cache Mutex, Cursor Pin Mutex, and Shared Pool Latch** The Library Cache is a hash table you access through an array of hash buckets (similar to the buffer cache). The memory for the
Library Cache comes from the shared pool (the Dictionary Cache used for Oracle internal objects is also part of the shared pool). The library cache mutex serializes access to objects in the library cache. Every time a SQL or PL/SQL procedure, package, function, or trigger is executed, this library cache mutex is used to search the shared pool for the exact statement so it can be reused. A single shared pool latch protected the allocation of memory in the Library Cache; seven child latches are available for this.

Contention for the shared pool latch, cursor pin mutex, or library cache mutex primarily occurs when the shared pool is too small or when statements are not reused. When an executable form of a SQL cursor is found in the shared pool, it is a soft parse and it is reused; when it's not found, it’s a hard parse or library cache miss (which requires more resources, CPU, and library cache latches/mutexes because it has to rebuild the executable form of the SQL). Per the Oracle 12c documentation: “Reuse of shared SQL for multiple users running the same application avoids hard parsing (reparing a statement). Soft parses provide a significant reduction in the use of resources, such as the shared pool and library cache latches.” Statements are not generally reused when bind variables are not used. Common but not exact SQL can flood the shared pool with statements. Increasing the size of the shared pool, at times, only makes the problem worse. You can also set the value of the initialization parameter CURSOR_SHARING=FORCE to help fix this issue and to reduce problems when bind variables are not used. CURSOR_SHARING=FORCE substitutes bind variables for literals (not just reduced latch/mutex contention, but also less shared pool use in the library cache area and a faster parse). Note that in 12c, Oracle uses adaptive cursor sharing, which enables a SQL statement to use multiple execution plans (which is also true of those that contain bind variables).

If you are not reusing SQL, you may see quite a few cursor: pin S wait on X wait events, in which waiting on a hard parse, a session wants a mutex in S (share) mode on a cursor (SQL statement), but another session is holding that mutex in X (exclusive) mode. You’ll also see the reverse of this, cursor: pin X wait on S. The shared pool latch and library cache mutex issues also occur when space is needed in the Library Cache when the shared pool is too small for the number of SQL statements that need to be processed. A hard parse occurs when a new SQL statement is issued that does not exist in the shared pool currently because it has to be parsed. Oracle has to allocate memory for the statement from the shared pool, as well as check the statement syntactically and semantically. A hard parse is very expensive in terms of both CPU used and the number of mutexes that need to be used. A soft parse occurs when a session issues a SQL statement that is already in the shared pool, and it can use an existing version of that statement. As far as the application is concerned, it has asked to parse the statement. While space is being freed up to load a SQL or PL/SQL statement, the shared pool latch (held for allocate and free) is being held exclusively and other users must wait. You can help to reduce contention by increasing the shared pool or by pinning large SQL and PL/SQL statements in memory using the DBMS_SHARED_POOL.KEEP procedures to avoid reloads. Pinning helps reduce many of the mutex and latch waits and ORA-4031 issues as well.

You can increase the number of the library cache hash table bucket count by setting _KGL_BUCKET_COUNT (see Appendix A for more information on the undocumented initialization parameters); note that 9 (the default) puts this at \((2^{9th}\) power)*256\)–1 = 131,071, which should be more than enough for most systems. The _KGL_LATCH_COUNT parameter (which is set to 0) is still in 12c. Remember that you should never set the underscore parameters without direction from Oracle Support. In 12c, each library cache bucket (131,071) is protected by a mutex!
Note that a count of X$KSMSP shows how many shared pool pieces there are; each row in the table represents a piece of memory in the shared pool. Columns to note are KSMCHCOM (describes the piece of memory), KSMCHPTR (the physical address of the piece of memory), KSMCHSIZ (piece size), and KSMCHCLS (the state/class of the piece of memory). Useful values of KSMCHCLS include the following:

- **recr** A re-creatable piece currently in use that can be a candidate for flushing when the shared pool is low in available memory.
- **freeabl** A freeable piece of memory that is currently in use and not a candidate for flushing but can be freed.
- **free** A free unallocated piece of memory.
- **perm** A permanently allocated piece of memory that can’t be freed without deallocating the entire heap.

The shared pool architecture is similar to the buffer cache in that there are a fixed number of hash buckets (that grow to the next level as needed) protected by a fixed number of library cache mutexes (unless changed, as noted earlier). The number of buckets and latches is often (but not always) prime to avoid hashing anomalies. At startup, the database allocates 509 hash buckets and a library cache mutex for each bucket rounded up to the nearest prime number. As the number of objects in the library cache increases, Oracle increases the number of hash buckets in the following order: 509, 1021, 2039, 4093, 8191, 16381, 32749, 65521, 131071, and 4292967293. You can set the number of hash buckets by setting _KGL_BUCKET_COUNT as described earlier. When installed, the default value was 9, which gave me a Library Cache hash table bucket count of 131,071, and a library cache mutex count of 131,071 (many more than in the past; this should reduce a lot of contention). A single hash bucket can contain multiple SQL statements and potentially long hash chains, which explains why you can see long library cache mutex hold times even when no space allocation is needed and no LRU list search is involved.

Also note that a SQL hash value is not the only value used in determining which hash bucket is used; the initial tree starts with object handles, which include name, namespace (CURSOR is the main namespace; others include trigger and cluster), lock owner, lock waiter, pin owner, pin waiter, and other pre-SQL items. The object handle then points to the next level of the tree, the data heap itself (where the statement itself is for a cursor), which includes the type of heap, name (for example, SCOTT.EMP), flags (things like wrapped, valid), tables (for example, privilege, dependencies), and data blocks (everything else—the SQL text). This means that you can have hundreds of identical SQL statements all referenced by different users, and they will be distributed fairly evenly across the hash buckets with no super-long hash chains full of identical SQL, but you will need a larger shared pool. If the statement is not in the Library Cache, the library load lock latch (this is still a latch, and the only library cache latch that I saw in 12c) is used to load it (the library cache mutex and shared pool latch are also needed in this process).

If the preceding paragraphs are complex or confusing, just focus on this paragraph. The main key to limiting latch and mutex issues on the library cache mutex or shared pool latch is to use bind variables, to use cursor sharing, to parse things once and execute them many times, to use SESSION_CACHED_CURSORS to move the cursors from the shared pool to the PGA, and, if you are sharing cursors and using bind variables, to increase the shared pool (although if you are not...
sharing statements, reducing it may help). Lastly, try not to do any DDL (ALTER, GRANT, REVOKE…) that would cause things to be invalidated and/or reloaded.

NOTE
I’ve seen more 10–100G+ shared pools in Oracle 12c than ever before.

Redo Copy Latch The redo copy latch is used to copy REDO records from the PGA into the redo log buffer. The number of redo copy latches has a default of 2*CPU_COUNT, but you can set this using the _LOG_SIMULTANEOUS_COPIES initialization parameter (the default was 2 copy latches on my system, but I’ve seen it set to 16 as well). Increasing this parameter may help to reduce contention for the redo copy latch.

Redo Allocation Latch The redo allocation latch allocates the space in the redo log buffer. You can reduce contention by increasing the size of the log buffer (LOG_BUFFER) or by using the NOLOGGING feature, which reduces the load on the redo log buffer. You should also try to avoid unnecessary commits.

Row Cache Objects The row cache objects latch contention usually means that contention is present in the data dictionary. This contention may also be a symptom of excessive parsing of SQL statements that depend on public synonyms. Increasing the shared pool usually solves this latch problem. You usually increase the shared pool for a library cache mutex problem well before this one is a problem. Also, according to My Oracle Support (Metalink Note 166474.1), “Use Locally Managed tablespaces for your application objects, especially indexes. This will decrease Row Cache locks in a surprising fashion and consequently avoid common hanging problems.”

Cache Buffers Chains (CBC) The cache buffers chains (CBC) latch is needed to scan the SGA buffer cache for database cache buffers. In Oracle 12c, the CBC can be shared, eliminating much of the contention. Tuning the code to use fewer buffers (and hence fewer CBCs) is the best solution to eliminating problems with this latch. Also, reducing the popularity of the block reduces the length of the hash chain (as discussed in the next item).

CBC latches are used when searching for, adding, or removing a buffer from the buffer cache. The buffer hash table, X$BH, holds headers (on a hash chain protected by a CBC latch) that point to DB_BLOCK_BUFFERS (data block buffers) in memory. Buffers are “hashed to a chain,” and the _DB_BLOCK_HASH_BUCKETS parameter defines the number of chains (buckets) to which a buffer will hash. The more buckets (chains) present, the smaller the “chain” length will be with buffers hashed to the same chain (as long as the number is prime). The CBC latches are used to protect a buffer list in the buffer cache. If _DB_BLOCK_HASH_BUCKETS was not set to a prime number in the past, you probably had many buffers hashed to one chain and none hashed to others (causing hot blocks to tie up other blocks on the chain) because of hashing anomalies.

In 12c, my _DB_BLOCK_HASH_BUCKETS was set to a default of exactly 1M (1,048,576 = 1024*1024), which was about 4× the number of _DB_BLOCK_BUFFERS (set by Oracle behind the scenes based on the DB_CACHE_SIZE). Contention on this latch could indicate a “hot block” or bad
setting for \_DB\_BLOCK\_HASH\_BUCKETS prior to 9. Prior to version 8, Oracle made this the prime number higher than DB\_BLOCK\_BUFFERS/4, which worked pretty well, although multiple blocks still got hashed to the same chain. In 8, Oracle made this DB\_BLOCK\_BUFFERS*2, but they forgot to make it prime (which, because it is a hashed value, caused many blocks to be hashed to the same chain); many users experienced severe problems with this latch (you can set \_DB\_BLOCK\_HASH\_BUCKETS = next prime(DB\_BLOCK\_BUFFERS*2) to solve this issue in prior versions). Since 9, Oracle sets it to a value reducing this contention, and there are enough “hash latches,” as people often call them. Your mileage may vary, so I continue to leave this section in the book. I also leave very important notes about other versions since most DBAs that I know still run multiple versions of the Oracle database. You will access many hash latches (latches used to scan the hash chain) because you need one every time you access a block, but you should not have a miss ratio of over 1–2 percent on this latch. In 12c, these hash latches (CBC latches) are shared, and the hash chain can be scanned in both directions.

CR Versions for a Given Block Only one block is CURRENT, and no more than six other CR versions of the block are allowed. All of them are located on the same doubly linked (can move both ways) hash chain. In 12c, you can see more than six versions of a block in memory for high volumes of SELECTs to a given block. They are in multiple states, but only six are in a state=3 (CR), and only one is a state=1 (CURRENT). The number of CR blocks is limited to six as any DML activity clears or as more DML tries to be performed in a given block. For DML, you need the CURRENT version (of which there is only one CURRENT version of any given block), and for a read query, you can use the CURRENT version if it is not being used, and/or you can build a CONSISTENT READ (CR) version by applying any UNDO needed to the CURRENT version of a changed block after cloning it. This process of cloning a block to build a CR version may include: reading the ITL, mapping to the UNDO header (the ITL also maps directly to the UNDO block), and applying the UNDO to get the correct CR version that you need, which happens when IMU is not used (more on IMUs later in “Tuning and Viewing at the Block Level”). When IMU is used, everything happens at the block level in memory until a commit or rollback. When you have multiple versions of a block (one CURRENT and a few CR versions), the hash chain gets longer, and the CBC latch gets held longer as it scans the hash chain. This is why Oracle now limits the number of clones (CR versions) of a block (limits the chain length). Although you can change this by setting \_DB\_BLOCK\_MAX\_CR\_DBA, which is the maximum allowed number of CR buffers for a given DBA (data block address), it’s a setting that performs well out of the box.

Hot Blocks Blocks often accessed in the buffer cache cause “cache buffers chains” latch issues, or hot blocks. Hot blocks may also be a symptom of poorly tuned SQL statements. A hot record creates a hot block that can cause issues for other records inside that block as well as any block “hashed” to the same chain. To find the hot block, query V\_LATCH\_CHILDREN for the address and join it to V\_BH to identify the blocks protected by this latch (doing this shows all blocks affected by the hot block). You can identify the object by querying the DBA\_EXTENTS view according to the file# and DBABLK found in V\_BH. Using a reverse-key index, if the hot block is on an index, moves sequential records to other blocks so they are not locked up by the hot block in the chain. If the hot block is the index root block, a reverse-key index won’t help.

Cache Buffers LRU Chain The cache buffers lru chain latch is used to scan the least recently used
(LRU) chain containing all of the blocks in the buffer cache. A small buffer cache, excessive buffer cache throughput, many cache-based sorts, and the DBWR not keeping up with the workload are all culprits that can cause this issue. Try to fix the queries that are causing the excessive logical reads and/or use multiple buffer pools.

Some of the most common latch problems and potential solutions are described in the following table (note that there is also a shard latch if using 12cR2 sharding):

<table>
<thead>
<tr>
<th>Latch/Mutex Problem</th>
<th>Potential Fix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Library Cache</td>
<td>Use bind variables; adjust the SHARED_POOL_SIZE.</td>
</tr>
<tr>
<td>Shared pool</td>
<td>Use bind variables; adjust the SHARED_POOL_SIZE.</td>
</tr>
<tr>
<td>REDO allocation</td>
<td>Minimize REDO generation and avoid unnecessary commits.</td>
</tr>
<tr>
<td>REDO copy</td>
<td>Increase _LOG_SIMULTANEOUS_COPIES.</td>
</tr>
<tr>
<td>Row cache objects</td>
<td>Increase the shared pool size.</td>
</tr>
<tr>
<td>Cache buffers chain</td>
<td>Increase _DB_BLOCK_HASS1_BUCKET or make it prime.</td>
</tr>
<tr>
<td>Cache buffers lru chain</td>
<td>Use multiple buffer pools or fix queries causing excessive reads. Check the INMEMORY_SIZE to ensure it is appropriate for the In-Memory column store.</td>
</tr>
<tr>
<td>In-Memory latch</td>
<td></td>
</tr>
</tbody>
</table>

Since Oracle9i (for people with multiple versions of Oracle to manage), you could configure LRU latches so each buffer pool has $n$ CPUs’ worth of latches. For example, if the system has eight CPUs, you should set

```
buffer_pool_keep = buffers:XXXX, lru_latches=8
buffer_pool_recycle = buffers:YYYY, lru_latches=8
```

Here, $XXXX$ and $YYYY$ are the desired number of buffers in the keep and recycle pools, respectively. There is really no reason to have more LRU latches than the number of processes that may be concurrently executing.

In 12c, the parameters are now DB_KEEP_CACHE_SIZE and DB_RECYCLE_CACHE_SIZE, and both accept only the size in bytes (you cannot specify LRU_LATCHES):

```
db_keep_cache_size= 4G (you can also use K or M, and the default is 0)
db_recycle_cache_size=1G (you can also use K or M, and the default is 0)
```

Some latch problems have often been bug related in the past, so make sure you check My Oracle Support (Metalink) for issues related to latches. Any of the latches that have a hit ratio less than 99 percent should be investigated. Some of the more common latches on the problem list were detailed in this chapter and include the cache buffers chains, redo copy, library cache mutex, and the cache buffers lru chain.
TIP
Latches are like locks on pieces of memory (or memory buffers). If the latch hit ratio is less than 99 percent, you have a serious problem because not even the lock to get memory can be gotten. Oracle 12cR2 has a shard latch (for sharding), and many In-Memory latches, including in-memory area latch, in-memory columnar segment hash table latch, in-memory columnar ts extent map chunk latch, and in-memory global pool latch.

Tuning and Viewing at the Block Level (Advanced)

Infrequently, when you have a hot block or some other block-level issue, you may need to find the exact location of the block for a given object and the number of versions (as was discussed in the preceding section). Here, I briefly discuss some of the block-level Oracle details.

CAUTION
This section should not be used by beginners.

An internal table called the buffer hash table (X$BH) holds block headers. Blocks are linked to a hash chain that is protected by a CBC latch (cache buffers chains latch). This links to the actual address located in memory (the memory set up with DB_CACHE_SIZE, SGA_TARGET, or MEMORY_TARGET, if used, which is the cache used for data). For a given block in Oracle, only one version of a block is CURRENT, and there are no more than five other CR versions of the block. So only six versions of a given block (maximum) are in memory at a time. Later in this section, I tell you how to control this with an undocumented parameter. Oracle recommends that you not use the undocumented parameters unless you are directed by Oracle Support or your database may not be supported.

When you perform a DML transaction (INSERT, UPDATE, or DELETE), you always need the CURRENT version of a block. Oracle has something called an in-memory undo (IMU), which can give you some hard-to-understand results when you are viewing information at the block level (whether it’s dirty or not). IMU was new as of 10g; what it means is that the UNDO records and REDO records for some transactions are stored in memory until the transaction commits. When a CR block is needed, the database first checks to see if the UNDO records are stored in the memory pool; if so, it applies the UNDO and REDO records from memory instead of retrieving them from the UNDO segments and redo logs/buffers (doing this in memory is much faster). When you are querying a block for the first time, you always use the CURRENT version of a block. If the block is being used, you build a clone of the block called a CONSISTENT READ (CR) version by applying any UNDO needed to the CURRENT version of the block to get it to a point in time that makes it useful to you (perhaps you need a version of the block before DML was performed and not committed by another
This complex, Oracle-patented process may include reading the ITL and mapping the record to the UNDO header, or else mapping it directly to the UNDO block and then applying the UNDO to get the correct CR version that you need. Let’s take a look at how this happens:

1. User 1 updates a record in block 777 (user 1 has not committed).
2. User 2 queries the same block and sees that the lock byte is set for a row being queried.
3. User 2 goes to the ITL portion of the block and gets the XID (transaction ID).
4. The XID maps to the UNDO block, which holds the information before the update was performed. If using IMU, then a check is done to see if the UNDO for this transaction is available in memory before going to the UNDO block.
5. A clone of the block is made (call it block 778).
6. The UNDO information is applied to the block, rolling it back to where it used to be (its contents go to a past state, including the SCN).
7. Block 777 is a CURRENT block.
8. Block 778 is a CONSISTENT READ block before the user 1 update occurred.
9. If another user performs a query against the same block before the commit, that user can also read the CR version.

Note especially the fact that the block is not rolled back to what it was, but it is rolled forward (to what it used to be). While the result is the same, how Oracle performs this operation is critical to understanding how Oracle works. Oracle blocks are always moving forward in time (this is why the REDO works if the machine gets turned off—it’s always applying things forward sequentially). There are also links to all blocks for the LRU and LRU-W (least recently used–write) chains to help make buffer replacement and writing much faster. These links are also maintained in the buffer headers.

Here are some nice (rarely found) queries to get block-level information.
Finding the block number (56650) for a given object (EMP1)
Finding the versions (1 CURRENT and 5 CR versions) of a block for a given block number (56650)
NOTE
In the preceding listing, state=1 is CURRENT and state=3 is CR; only the CURRENT block is (can be) dirty.

Finding the setting for the maximum CR versions of a block

```
SELECT a.kappinn, b.kappstvl, b.kappstdf, a.kappdcsc
FROM x$kapp1 a, x$kappov b
WHERE a.index = b.index
AND SUBSTR(kappinn,1,1) = '_'
AND kappinn LIKE 'A%'
ORDER BY kappinn;
```

Enter a value for 1: db_block_max_cr_dba

<table>
<thead>
<tr>
<th>KAPPINN</th>
<th>KAPPSTVL</th>
<th>KAPPSTD</th>
<th>KAPPDCSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>db block max cr dba</td>
<td>6</td>
<td>TRUE</td>
<td>Maximum Allowed Number of CR buffers per dba</td>
</tr>
</tbody>
</table>

Dumping what’s inside the block for EMP1

```
SQL> SELECT header_file, header_block, blocks FROM dba_segments
2  WHERE segment_name = 'EMP'
3  AND owner = 'SCOTT';

<table>
<thead>
<tr>
<th>HEADER_FILE</th>
<th>HEADER_BLOCK</th>
<th>BLOCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>27</td>
</tr>
</tbody>
</table>

ALTER SYSTEM DUMP DATAFILE 4 BLOCK 28;
System Altered.
```

TIP
Never go to the block level unless you absolutely have to go there. The block level is a great place to find hot block and ITL issues, but it takes a lot of time and energy on the part of an advanced DBA to pinpoint problems at this level.

Dictionary and Library Cache Statistics
The next two sections contain the Dictionary and Library Cache information. Listed first is all of the
data dictionary information. This data pertains to all of the objects in the database. This information
is accessed for every SQL statement that gets parsed and again when the statement is executed. The
activity in this area can be very heavy. Maintaining a good hit ratio is very important to prevent
recursive calls back to the database to verify privileges. You can also evaluate the efficiency of the
Dictionary Cache by querying the V$ROWCACHE view. The query that follows shows the
information that the Statspack Report lists for this section of the report:

---

Dictionary Cache Stats  DB/Inst: ORCL/orcl  Snaps: 1 2

<table>
<thead>
<tr>
<th>Cache</th>
<th>Get Requests</th>
<th>Pct Miss</th>
<th>Scan Reqs</th>
<th>Pct Miss</th>
<th>Mod Reqs</th>
<th>Final Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>dc_awr_control</td>
<td>3</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>dc_global_oids</td>
<td>28</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td>dc_histogram_data</td>
<td>1,095</td>
<td>13.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>667</td>
</tr>
<tr>
<td>dc_histogram_data2</td>
<td>972</td>
<td>25.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>739</td>
</tr>
<tr>
<td>dc_objects</td>
<td>6,775</td>
<td>1.9</td>
<td>0</td>
<td>21</td>
<td>1,985</td>
<td></td>
</tr>
<tr>
<td>dc_pros</td>
<td>60</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>dc_rollback_segments</td>
<td>22</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>dcSegments</td>
<td>1,609</td>
<td>0.1</td>
<td>0</td>
<td>201</td>
<td>419</td>
<td></td>
</tr>
<tr>
<td>dc_tablespace_quotas</td>
<td>494</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>dc_tablespaces</td>
<td>1,568</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>dc_users</td>
<td>3,841</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>101</td>
</tr>
<tr>
<td>outstanding alerts</td>
<td>2</td>
<td>100.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>sch_tg_oids</td>
<td>2</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

The second part of this section of the report deals with the performance of the Library Cache.
These statistics are generated from the V$LIBRARYCACHE view. The Library Cache contains the
shared SQL and PL/SQL areas. These areas are represented by the BODY, SQL AREA,
TABLE/PROCEDURE, and TRIGGER values (these are values in the NAMESPACE column). They
contain all of the SQL and PL/SQL statements that are cached in memory. The other names are areas
that Oracle uses. If your PCT MISS value is high in this section of the report, you may need to
improve cursor sharing in your application or increase the size of the shared pool (as discussed in the
“Top Wait Events” section of this chapter). The following listing shows sample data for this section:

---

Library Cache Activity  DB/Inst: ORCL/orcl  Snaps: 1 2

-->"Pct Misses" should be very low
Here is what the columns mean in this part of the report:

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAMESPACE</td>
<td>The name of the library namespace.</td>
</tr>
<tr>
<td>GET REQUESTS</td>
<td>The number of times the system requested a handle to an object in this namespace.</td>
</tr>
<tr>
<td>PCT MISS (Get Miss Ratio)</td>
<td>The number of gethits divided by the number of gets is the gethit ratio. The gethits are the number of times a request was made for an object and the object was already in the cache. The hit ratio should be as close to 0.99 as possible. The PCT MISS should be less than 1 percent.</td>
</tr>
<tr>
<td>PIN REQUESTS</td>
<td>The number of times an item in the cache was executed. A high number is what you are after.</td>
</tr>
<tr>
<td>PCT MISS (Pin Miss Ratio)</td>
<td>The number of pinhits divided by the number of pins shows the pinhit ratio. Pinhits are the number of times that objects the system is pinning are already in the cache. This ratio should be as close to 1 as possible. The miss ratio should be less than 1 percent.</td>
</tr>
<tr>
<td>Reloads</td>
<td>The number of Library Cache misses on an execution step. The number of reloads divided by the number of pins should be around 0 percent. If the ratio between this is greater than 1 percent, you should probably increase the size of the shared pool. These are hard parses!</td>
</tr>
<tr>
<td>INVALIDATIONS</td>
<td>The total number of times objects in this namespace were marked invalid because a dependent object was modified. These are hard parses!</td>
</tr>
</tbody>
</table>
If the pinhit ratio is less than 0.95 when the report is run for an extended period of time, the 
SHARED_POOL_SIZE is probably too small for your best system performance. If the reloads are 
greater than 1 percent, this also points to a SHARED_POOL_SIZE that is too small.

SGA Memory Statistics

Following an SGA memory summary (from V$SGA) and a listing of the memory changes during the 
snapshot interval, the reports both list the database initialization parameters in use at the beginning 
and end of the report.

Taken as a whole, the report generates a significant amount of data, allowing you to develop a 
profile of the database and its usage. By drawing on the initialization, file I/O, and SGA data, you can 
develop an understanding of the major components in the database configuration. Here is a sample 
listing of this section of the report:
### SGA Memory Summary

**DB/Inst:** ORCL/orcl  **Snaps:** 1-2

<table>
<thead>
<tr>
<th>SGA regions</th>
<th>Begin Size (Bytes)</th>
<th>End Size (Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Database Buffers</td>
<td>2,315,255,908</td>
<td></td>
</tr>
<tr>
<td>Fixed Size</td>
<td>2,188,768</td>
<td></td>
</tr>
<tr>
<td>Redo Buffers</td>
<td>17,420,288</td>
<td></td>
</tr>
<tr>
<td>Variable Size</td>
<td>4,513,073,696</td>
<td></td>
</tr>
<tr>
<td><strong>sum</strong></td>
<td><strong>6,847,938,560</strong></td>
<td></td>
</tr>
</tbody>
</table>

### SGA breakdown difference

**DB/Inst:** ORCL/orcl  **Snaps:** 1-2

- Top 35 rows by size, ordered by Pool, Name (note rows with null values for Pool column, or Names showing free memory are always shown)
- Null value for Begin MB or End MB indicates the size of that Pool/Name was insignificant, or zero in that snapshot

<table>
<thead>
<tr>
<th>Pool</th>
<th>Name</th>
<th>Begin MB</th>
<th>End MB</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>java p free memory</td>
<td>16.0</td>
<td>16.0</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>large</td>
<td>PX msg pool</td>
<td>7.8</td>
<td>7.8</td>
<td>0.00</td>
</tr>
<tr>
<td>large</td>
<td>free memory</td>
<td>24.2</td>
<td>24.2</td>
<td>0.00</td>
</tr>
<tr>
<td>shared</td>
<td>ASH buffers</td>
<td>15.5</td>
<td>15.5</td>
<td>0.00</td>
</tr>
<tr>
<td>shared</td>
<td>CCUR</td>
<td>77.1</td>
<td>77.6</td>
<td>0.64</td>
</tr>
<tr>
<td>shared</td>
<td>PileOpenBlock</td>
<td>10.5</td>
<td>10.5</td>
<td>0.00</td>
</tr>
<tr>
<td>shared</td>
<td>KGLH0</td>
<td>17.4</td>
<td>17.4</td>
<td>0.07</td>
</tr>
<tr>
<td>shared</td>
<td>KGLHD</td>
<td>21.5</td>
<td>21.6</td>
<td>0.31</td>
</tr>
<tr>
<td>shared</td>
<td>KGLS</td>
<td>28.8</td>
<td>29.0</td>
<td>0.64</td>
</tr>
<tr>
<td>shared</td>
<td>PCUR</td>
<td>40.7</td>
<td>41.1</td>
<td>0.82</td>
</tr>
<tr>
<td>shared</td>
<td>PLDIA</td>
<td>12.8</td>
<td>12.8</td>
<td>0.00</td>
</tr>
<tr>
<td>shared</td>
<td>DLMCID</td>
<td>15.1</td>
<td>15.1</td>
<td>0.00</td>
</tr>
<tr>
<td>shared</td>
<td>EQLA</td>
<td>393.6</td>
<td>396.4</td>
<td>0.70</td>
</tr>
<tr>
<td>shared</td>
<td>db_block_hash_buckets</td>
<td>22.3</td>
<td>22.3</td>
<td>0.00</td>
</tr>
<tr>
<td>shared</td>
<td>free memory</td>
<td>242.4</td>
<td>238.1</td>
<td>-1.75</td>
</tr>
<tr>
<td>stream</td>
<td>free memory</td>
<td>16.0</td>
<td>16.0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>buffer_cache</td>
<td>2,208.0</td>
<td>2,208.0</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>fixed_sga</td>
<td>2.1</td>
<td>2.1</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>log_buffer</td>
<td>16.6</td>
<td>16.6</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>shared_io_pool</td>
<td>928.0</td>
<td>928.0</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### SQL Memory Statistics

**DB/Inst:** ORCL/orcl  **Snaps:** 1-2

<table>
<thead>
<tr>
<th></th>
<th>Begin</th>
<th>End</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg Cursor Size (KB):</td>
<td>36.81</td>
<td>36.79</td>
<td>-.05</td>
</tr>
<tr>
<td>Cursor to Parent ratio:</td>
<td>2.78</td>
<td>2.78</td>
<td>.16</td>
</tr>
<tr>
<td>Total Cursors:</td>
<td>12,334</td>
<td>12,395</td>
<td>.49</td>
</tr>
<tr>
<td>Total Parents:</td>
<td>6,928</td>
<td>6,951</td>
<td>.33</td>
</tr>
</tbody>
</table>
This last section shows the parameters in the initialization file that are set to a value other than the default (see Figure 14-19). The list is generated by querying the V$PARAMETER view where the default column is equal to FALSE. This list can be used as a reference. While you are tuning the database, these parameters can provide a record of how the database performed with certain values. The output that follows shows this section of the Statspack Report:

### init.ora Parameters

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Begin value</th>
<th>End value (if different)</th>
</tr>
</thead>
<tbody>
<tr>
<td>audit_file_dest</td>
<td>/u01/app/oracle/admin/orcl/adump</td>
<td></td>
</tr>
<tr>
<td>audit_trail</td>
<td>DB</td>
<td></td>
</tr>
<tr>
<td>compatible</td>
<td>12:2:3:0:0</td>
<td></td>
</tr>
<tr>
<td>control_file</td>
<td>/u02/app/oracle/oradata/orcl/control01.ctl, /u03/app/oracle/fast_recovery_area/orcl/control02.ctl</td>
<td></td>
</tr>
<tr>
<td>db_block_size</td>
<td>8192</td>
<td></td>
</tr>
<tr>
<td>db_create_file_dest</td>
<td>/u02/app/oracle/oradata</td>
<td></td>
</tr>
<tr>
<td>db_name</td>
<td>orcl</td>
<td></td>
</tr>
<tr>
<td>db_recovery_file_dest</td>
<td>/u03/app/oracle/fast_recovery_area</td>
<td></td>
</tr>
<tr>
<td>db_recovery_file_dest_size</td>
<td>3621446000</td>
<td></td>
</tr>
<tr>
<td>diagnostic_dest</td>
<td>/u01/app/oracle</td>
<td></td>
</tr>
<tr>
<td>dispatchers</td>
<td>(PROTOCOL=TCP) (SERVICE=orcl001)</td>
<td></td>
</tr>
<tr>
<td>instance_name</td>
<td>orcl</td>
<td></td>
</tr>
<tr>
<td>local_listener</td>
<td></td>
<td></td>
</tr>
<tr>
<td>log_archive_format</td>
<td>%d_%s_%s.dbf</td>
<td></td>
</tr>
<tr>
<td>open Cursors</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>optimizer_mode</td>
<td>RUT</td>
<td></td>
</tr>
<tr>
<td>sga_aggregate_target</td>
<td>262144000</td>
<td></td>
</tr>
<tr>
<td>processes</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>remote_login_passwordfile</td>
<td>EXCLUSIVE</td>
<td></td>
</tr>
<tr>
<td>sga_target</td>
<td>1073741824</td>
<td></td>
</tr>
<tr>
<td>undo_tablespace</td>
<td>UNDOTEST1</td>
<td></td>
</tr>
</tbody>
</table>

### init.ora Multi-Valued Parameters

- This section only displays parameters that have more than one value
- 'NULL' indicates a missing parameter value
- A blank in the 'End Snapshot' indicates the same value as the 'Begin Snapshot'

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Begin value</th>
<th>End value (if different)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control_files</td>
<td>/u02/app/oracle/oradata/orcl/control01.ctl</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/u03/app/oracle/fast_recovery_area/orcl/control02.ctl</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 14-19. The AWR Report initialization parameters**
Top 15 Things to Look for in AWR Report and Statspack Output

As you’ve seen throughout this chapter, AWR Report is much better than Statspack. Some DBAs still use Statspack (and it’s free), so I’ve included it in this chapter. Many DBAs already know how to use Statspack but are not always sure what to check regularly. Remember to separate OLTP and batch activity when you run Statspack because they usually generate different types of waits. The SQL script spauto.sql can be used to run Statspack every hour on the hour. See the script in $ORACLE_HOME/rdbms/admin/spauto.sql for more information (note that JOB_QUEUE_PROCESSES, which is the maximum number of job queue slave processes, must be greater than 0). Since every system is different, this is only a general list of things you should regularly check in your Statspack or AWR output:

- Top 10 foreground wait events in AWR (timed events) or Top 5 Timed Events in Statspack
- Top Background Wait Events
- Load profile (includes In-Memory)
- Other wait events (working their way to the Top 5)
- Latch waits/Mutex sleeps (in 12cR2, there are many In-Memory latches)
- Top SQL
- Instance efficiency hit ratios out of the ordinary
- Instance activity
- File I/O and segment statistics
- Memory allocation
- Buffer waits
- Initialization Parameters (near the end of each report)
- In the AWR Report, the Active Session History (ASH) Report (described a bit later), which includes sections for Top SQL with Top Events and Top Event P1/P2/P3 Values
- In the AWR Report in 12cR2, GoldenGate and Streams Replication sections (if relevant to your system)
- Use of In-Memory effectively

A final note on the top 10 foreground wait events is to look for bugs when you have a high number of wait events that are normally not so high. You can only do this if you are regularly monitoring your reports or if you have captured baselines for comparisons. Take a look at the bug in Figure 14-20 from My Oracle Support that shows the behavior of a high number of “Library Cache: Mutex X” on Koka Cursors (LOBs) Non-Shared that dominates the Top 5 Wait Events. This is a clue you may have a bug to search for or a real bad SQL statement. See the appropriate section of this chapter for how to fix major problems depending on the wait event.
Managing the Statspack Data

If you are one of the holdouts still using Statspack, you should manage the data generated by Statspack to guarantee that the space usage and performance of the Statspack application meets your requirements as the application data grows. Managing Statspack data includes the following steps:

1. Regularly analyze the Statspack data. At a minimum, you should analyze the Statspack schema prior to running the `spreport.sql` script:
   ```sql
   execute dbms_utility.analyze_schema('PERFSTAT', 'COMPUTE');
   ```

2. Purge old data. Because you cannot generate valid interval reports across database shutdown/startup actions, data prior to the last database startup may not be as useful as the most current data. When the data is no longer needed, purge it from the tables. Oracle provides a script, `sppurge.sql`, to facilitate purges. The `sppurge.sql` script, located in the `/rdbms/admin` directory under the Oracle software home directory, lists the currently stored snapshots and prompts you for two input parameters: the beginning and ending snapshot numbers for the purge. The related records in the STATSS tables are then deleted. Due to the size of the transactions involved, databases using rollback segments should force the session to use a large rollback segment during the deletes:
The `spurge` script prompts you to back up your old statistics before purging them. You can back up the data by exporting the PERFSTAT schema.

3. Truncate the Statspack tables when the data is not needed. Old statistical data may no longer be relevant, or you may have imported the old statistics during database migrations or creations. To truncate the old tables, execute the `sptrunc.sql` SQL*Plus script from within the PERFSTAT account. The script is located in the `/rdbms/admin` directory under the Oracle software home directory.

4. Include the Statspack tables in your backup scheme. If you are using Export, Oracle provides a parameter file named `spuexp.par` to assist you.

5. Include the Statspack tables in your space monitoring procedures.

### Upgrading Statspack

To upgrade old Statspack data to a new version of the database, execute the scripts provided by Oracle. Oracle does not support upgrading Statspack directly from 8.1.6 to 9.0.1 or 9.2 to 10.2 or 11; you must go through multiple steps. The scripts only upgrade your current schema to the next release level, for example 9.0.1 to 9.2, so you might have to run multiple scripts to complete the upgrade (note that even upgrades from Oracle8 are included with the 12cR2 release):

1. Upgrade from the 9.0 Statspack objects to 9.2 by executing the `spup90.sql` script.
2. Upgrade from the 9.2 Statspack objects to 10.1 by executing the `spup92.sql` script.
3. Upgrade from the 10.1 Statspack objects to 10.2 by executing the `spup10.sql` script.
4. Upgrade from the 10.2 Statspack objects to 11 by executing the `spup102.sql` script.
5. Upgrade from the 11.01 Statspack objects to 11.2 by executing the `spup1101.sql` script.
6. Upgrade from the 11.2 Statspack objects to 11.2.0.2 by executing the `spup11201.sql` script.
7. Upgrade from the 11.2.0.2 Statspack objects to 12.1 by executing the `spup112.sql` script.
8. Upgrade from the 12.1 Statspack objects to 12.1.0.2 by executing the `spup12102.sql` script.
9. Upgrade from the 12.1.0.2 Statspack objects to 12.2 by executing the `spup12200.sql` script.

### Deinstalling Statspack

Since Statspack includes public synonyms as well as private objects, you should remove the application via a SYSDBA-privileged account. Oracle provides a script, `spdrop.sql`, to automate the deinstallation process. From within the `/rdbms/admin` directory under the Oracle software home directory, log in to SQL*Plus and execute the script as shown in the following listing:
The `spdrop.sql` script calls scripts (`spdtab.sql`, `spdusr.sql`) that will drop the tables, the package, the public synonyms, and the PERFSTAT user. To reinstall Statspack, execute the `spcreate.sql` script, as shown earlier in this chapter.

**Quick Notes on the New ADDM Report**

You can also use the Automatic Database Diagnostics Monitor (ADDM) Report, called `addmrpt.sql`, to analyze a snapshot range. Run the `addmrpt.sql` script from SQL*Plus (the script is located in the `$ORACLE_HOME/rdbms/admin` directory). The script provides you with a list of snapshots from which you can generate the report (like Statspack or the AWR Report from SQL*Plus). You select a begin snapshot and an end snapshot, and finally, you define the name of the report that you want `addmrpt.sql` to create. The `addmrpt.sql` script then runs the ADDM analysis on the snapshot pair you entered and provides the output analysis report. Using ADDM through Enterprise Manager Cloud Control (covered in Chapter 5) is much more detailed and is recommended. The resulting report contains a header and then detailed findings. The command to run it is listed here, and following that command is the header; yours should look much like this example (note that if you `shutdown` between snapshots of the AWR or ADDM that you are running the report for, it will result in an ORA-20200 error—instance shutdown between snaps):
Current Instance

<table>
<thead>
<tr>
<th>DB Id</th>
<th>D3 Name</th>
<th>Inst Num</th>
<th>Instance</th>
<th>Host</th>
</tr>
</thead>
<tbody>
<tr>
<td>1272868336</td>
<td>ORCL</td>
<td>1</td>
<td>orcl</td>
<td>USER-PC</td>
</tr>
</tbody>
</table>

Instances in this Workload Repository schema

<table>
<thead>
<tr>
<th>DB Id</th>
<th>Inst Num</th>
<th>DB Name</th>
<th>Instance</th>
<th>Host</th>
</tr>
</thead>
<tbody>
<tr>
<td>* 1272868336</td>
<td>1</td>
<td>ORCL</td>
<td>orcl</td>
<td>USER-PC</td>
</tr>
</tbody>
</table>

Using 1272868336 for database Id
Using 1 for instance number

Specify the number of days of snapshots to choose from

Entering the number of days (n) will result in the most recent (n) days of snapshots being listed. Pressing <return> without specifying a number lists all completed snapshots.

Listing the last 3 days of Completed Snapshots

<table>
<thead>
<tr>
<th>Instance</th>
<th>DB Name</th>
<th>Snap Id</th>
<th>Snap Started</th>
<th>Snap Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>orcl</td>
<td>ORCL</td>
<td>342</td>
<td>09 May 2011 15:38</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td>358</td>
<td>11 May 2011 04:00</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>359</td>
<td>11 May 2011 05:00</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>360</td>
<td>11 May 2011 06:00</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>361</td>
<td>11 May 2011 07:00</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>362</td>
<td>11 May 2011 08:00</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>363</td>
<td>11 May 2011 11:44</td>
<td>1</td>
</tr>
</tbody>
</table>

Specify the Begin and End Snapshot Ids

Enter value for begin_snap: 358
Begin Snapshot Id specified: 358

Enter value for end_snap: 363
End Snapshot Id specified: 363
Now look at the report output:

ADDM Report for Task 'TASK_468'

Analysis Period

AWR snapshot range from 358 to 363.
Time period starts at 11 MAY 11 04.00.49 AM
Time period ends at 11 MAY 11 11.44.42 AM

Analysis Target

Database 'ORCL' with DB ID 1272868336.
Database version 11.2.0.1.0.
ADDM performed an analysis of instance orcl, numbered 1 and hosted at USER-PC.

Activity During the Analysis Period

Total database time was 12314 seconds.
The average number of active sessions was .44.

A summary information section is related to the ADDM analysis. Following the header and individual findings, the summary is listed. An example of one such finding is seen here:
If SQL issues are discovered, the finding looks like the one shown here, suggesting that I run the Tuning Advisor to tune the statement:
A few interesting things appear in this report. First, the finding indicates that the problem identified had a 51 percent overall impact in the DB time. In other words, the ADDM report is sorting its findings according to those processes that are consuming the most database time. I see, looking at this finding further, that it is a SQL statement that is causing problems (usually the source of most issues), and ADDM suggests that I tune the statement. Oracle gives me the SQL address and hash value so I can find the SQL statement in the SQL area. Note that the ACTION suggests that I run the SQL Tuning Advisor to generate some suggested tuning actions on the SQL statement in question. In Chapter 5 and Chapter 8, I discuss the SQL Tuning Advisor and show you just how it can help you tune SQL statements in Oracle Database 12c.

If not enough work has been done on the instance or if not enough work is being done currently, instead of giving you suggestions, it displays the following:

```
THERE WAS NOT ENOUGH INSTANCE SERVICE TIME FOR ADDM ANALYSIS.
```

The ADDM report is a good start for getting tips for tuning. As with any new utility, there is room for improvement and growth in future releases of Oracle, and it is best used from the Enterprise Manager interface if possible. I have not addressed other aspects related to ADDM in this section, such as user-defined alerts and the SQL Tuning Advisor, which I discussed in Chapter 5 and Chapter 8.

While ADDM is helpful, there is also an Active Session History (ASH) Report at the end of the AWR Report with a few very worthwhile sections to explore. My favorites are Top SQL with Top Events (Figure 14-21) and Top Event P1/P2/P3 Values (Figure 14-22).
FIGURE 14-21. The ASH Report Top SQL with Top Events section

FIGURE 14-22. The ASH Report Top Event P1/P2/P3 Values section
TIP
The ADDM Report can be a helpful tuning utility, but ADDM is better used through Oracle Enterprise Manager for maximum benefits. The ASH Report also has some nice areas worth investigating, including my favorites: Top SQL with Top Events and Top Event P1/P2/P3 Values.

Scripts in 12cR2
Here is a listing of scripts that you will find in 12cR2. Please refer to the documentation for a complete description of each of these.

<table>
<thead>
<tr>
<th>Script</th>
<th>Description</th>
<th>Calls</th>
<th>Run As</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>spcreate.sql</td>
<td>Creates the Statspack environment.</td>
<td>spcpkg.sql</td>
<td>SYSDBA</td>
<td>Any instance</td>
</tr>
<tr>
<td>spdrop.sql</td>
<td>Drops the entire Statspack environment.</td>
<td>spdtab.sql and spdusr.sql</td>
<td>SYSDBA</td>
<td>Any instance</td>
</tr>
<tr>
<td>sreport.sql</td>
<td>The main script to generate the Statspack Report.</td>
<td>sprepins.sql</td>
<td>PERFSTAT</td>
<td>Any instance</td>
</tr>
<tr>
<td>sprepins.sql</td>
<td>Generates a Statspack Instance Report for the database and instance specified.</td>
<td>srsqinsl.sql</td>
<td>PERFSTAT</td>
<td>Oracle RAC and Data Guard systems</td>
</tr>
<tr>
<td>spssql.sql</td>
<td>Generates a Statspack SQL Report for a given SQL hash value.</td>
<td></td>
<td>PERFSTAT</td>
<td>Any instance</td>
</tr>
<tr>
<td>File</td>
<td>Description</td>
<td>User</td>
<td>Requirements</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------</td>
<td>-------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>sprsqins.sql</td>
<td>Generates a Statspack SQL Report for the SQL hash value specified for the database and instance specified.</td>
<td></td>
<td>Oracle RAC and Data Guard systems</td>
<td></td>
</tr>
<tr>
<td>spauto.sql</td>
<td>Automates Statspack statistics collection (snap) using DBMS_JOB.</td>
<td></td>
<td>Any instance with JOB_QUEUE_PROCESSES &gt; 0</td>
<td></td>
</tr>
<tr>
<td>sprepcon.sql</td>
<td>Configures SQL*Plus variable to set things like thresholds. Called automatically as part of the Statspack instance report.</td>
<td></td>
<td>Instances where you want to show or hide sections of the report</td>
<td></td>
</tr>
<tr>
<td>sppurge.sql</td>
<td>Purges a range of snapshot IDs for a given database instance (does not purge baseline snapshots).</td>
<td></td>
<td>Use Statspack package procedure instead</td>
<td></td>
</tr>
<tr>
<td>sptrunc.sql</td>
<td>Truncates all performance data in Statspack tables (CAREFUL!).</td>
<td></td>
<td>Any instance</td>
<td></td>
</tr>
<tr>
<td>spuexp.par</td>
<td>Exports parameter file for exporting the entire PERFSTAT user.</td>
<td></td>
<td>Taking export backups of the PERFSTAT schema</td>
<td></td>
</tr>
<tr>
<td>spup816.sql</td>
<td>To upgrade from 8.1.6 to 8.1.7.</td>
<td>SYSDBA</td>
<td>DB with 8.1.6 version of Statspack schema and a valid backup</td>
<td></td>
</tr>
<tr>
<td>spup817.sql</td>
<td>To upgrade from 8.1.7 to 9.0.</td>
<td>SYSDBA</td>
<td>DB with 8.1.7 version of Statspack schema and a valid backup</td>
<td></td>
</tr>
<tr>
<td>spup90.sql</td>
<td>To upgrade from 9.0 to 9.2.</td>
<td>SYSDBA</td>
<td>DB with 9i version of Statspack schema and a valid backup</td>
<td></td>
</tr>
</tbody>
</table>
NOTE

You must use the specific version of Statspack with that version of the database (for instance, you must use the 12.2 Statspack schema with the 12.2 database). Also note that spdoc.txt is the complete instruction and documentation file for Statspack.
 allocated at least 120M for the initial creation of the PERFSTAT schema’s objects. Oracle 12c requires approximately the same space as Oracle 11g. You must license the Oracle Diagnostics Pack to access the AWR dictionary views necessary for the AWR Report. Statspack does not include In-Memory information, but the 12cR2 AWR Report does.

- Be sure the TIMED_STATISTICS database initialization parameter is set to TRUE prior to gathering statistics.

- Pin the Statspack package following database startup if you plan to run the SNAP procedure on a scheduled basis.

- A second report, `spresql.sql`, can be used for additional research into the problem SQL statements identified via the `spreport.sql` report.

- If you choose to run both Statspack and the AWR, ensure that you stagger the AWR data collection from the Statspack collection by at least 30 minutes to avoid a performance hit as well as conflicts. If you are running the AWR Report, you should not also need to run Statspack.

- With the new 12cR2 AWR Report, you can choose to get text (similar to Statspack output), HTML, or the new Active HTML format (which summons OEM at the end of the report if desired) when you run `awrrpt.sql`. The HTML format is much better than text, as you can click various links within the report to navigate among sections easily. You can also run the AWR Report within OEM.

- If you use Oracle Enterprise Manager (OEM), you can run the AWR Report directly from Cloud Control or Database Control from multiple versions of OEM.

- Get to know your system by reviewing and understanding your system’s regular Load Profile. Significant changes to the Load Profile during what should be similar workloads or common times during the day may warrant further investigation. The In-Memory (IM) statistics are not a part of the Statspack Report in 12cR2, but are contained in the AWR Report.

- The library cache pin (protects cursors/SQL) and library cache latch (protects the Library Cache) are both replaced by mutexes (program objects that negotiate mutual exclusion among threads).

- Tuning by wait events is one of the best possible reactive tuning methods.

- In 12cR2, the top 10 foreground wait events in the AWR Report reveal to you the largest issues on your system at the macro level (Top 5 timed events in Statspack). Rarely do these waits point you to a specific problem. Other parts of the AWR Report or Statspack Report will tell you why you are receiving the waits.

- Tuning the top 25 buffer get and top 25 physical get queries can yield system performance gains of anywhere from 5 percent to 5000+ percent. The SQL section of the Statspack Report tells you which queries to consider tuning first. The top 10 SQL statements should not be substantially more than 10 percent of all of your buffer gets or disk reads. Near the end of the new 12c AWR Report, the Top SQL is connected with the Top Events to help you even more!
If many sorts are being performed to disk (greater than 1–5 percent of the total number of rows being sorted), you may need to increase the initialization parameters associated with sorting. See Chapter 4 for more information on these.

The buffer cache hit ratio should be greater than 95 percent. If it is less than 95 percent, you should consider increasing the size of the data cache by increasing the MEMORY_TARGET (if used) or increasing the minimum setting for the DB_CACHE_SIZE initialization parameter (given that physical memory is available to do this).

If full table scans are being performed, serious performance issues may result and data hit ratios will be distorted. These tables need to be identified so the appropriate indexes are created or used. See Chapters 8 and 9 on query tuning for more information.

If the number of physical reads is heavier on one physical disk, balancing the data properly or using ASM correctly will probably improve performance. See Chapter 3 for tips on fixing I/O problems with either data files or tablespaces. See Chapter 3 for tips on fixing I/O problems (and using ASM) with either datafiles or tablespaces.

In Oracle 12c, multiple data block sizes are allowed. The AWR Report and/or Statspack shows statistics for each of these block sizes individually. Many advisories are available to help you size the SGA that both the AWR Report and Enterprise Manager (see Chapter 5) suggest. These suggestions should be tested first, however, and are not always the best choice. As Robert Freeman would say, “Your mileage may vary.”

Latches are like locks on pieces of memory (or memory buffers). If the latch hit ratio is less than 99 percent, you have a serious problem because not even the lock to get memory can be gotten. Oracle 12cR2 has a shard latch (for sharding), and many In-Memory latches, including in-memory area latch, in-memory columnar segment hash table latch, in-memory columnar ts extent map chunk latch, and in-memory global pool latch.

Never go to the block level unless you absolutely have to go there. The block level is a great place to find hot block and ITL issues, but it takes a lot of time and energy on the part of an advanced DBA to pinpoint problems at this level.

The ADDM Report can be a helpful tuning utility, but ADDM is better used through Oracle Enterprise Manager for maximum benefits. The ASH Report also has some nice areas worth investigating, including my favorites: Top SQL with Top Events and Top Event P1/P2/P3 Values.

References
Steve Adams, Oracle8i Internal Services for Waits, Latches, Locks, and Memory (older, but excellent) (O’Reilly, 1999).
Robert Freeman, Oracle 12c New Features (Oracle Press).
Notes from Richard Powell, Cecilia Gervasio, Russell Green, and Patrick Tearle.
Randy Swanson and Bob Yingst, “STATSPACK Checklist” (2002).
My Oracle Support (Metalink) Notes: 135223.1, 135223.1, 148511.1, 148511.1, 155971.1,
181306.1, 22908.1, 29787.1, 33567.1, 39017.1, 61998.1, 62172.1, 62160.1, 34405.1, 727400.1,
1298015.1, 1268724.1, 1310764.1, and 62354.1.

Special thanks to Robert Freeman, who contributed much of the AWR information. Thanks to
Kevin Loney for the entire installation portion of this chapter written for the last version and some
added notes. Tuning is an iterative process; as Hollyann always says: “If at first you don’t succeed,
skydiving is not for you; try tuning instead!” Thanks to Greg Pucka for the original chapter on
estat/bstat. Rich Niemiec upgraded this chapter (painful as usual!).
CHAPTER 15

Performing a Quick System Review (DBA)

Oracle 12c introduced many new features that can be leveraged for automatic tuning. While some DBAs are great at planning and implementing a new version, fewer are good at evaluating and effectively implementing the new features that will help their system. In 12c, you now have to consider pluggable databases (PDBs, introduced in Chapter 3) and how to leverage an additional In-Memory (IM; see Chapter 4) column store (if licensed). With the introduction of Enterprise Manager Cloud Control (Chapter 5) combined with the Automatic Workload Repository (AWR) and the AWR Report (see Chapter 14 for a comparison to Statspack), you can monitor and tune your system in different and more productive ways. And with the advent of SQL Performance Analyzer (SPA), the SQL Tuning Advisor, the Adaptive Optimizer (12c), Real Application Testing, Exadata Simulation, and the Result Cache comes different ways to fix your system more productively. One of the keys to a good system review is checking to see if you’ve implemented the features that fit your needs and have a good return on the license cost of the feature as well as the time it takes to implement it. Although nobody seems to like tests or evaluations, simple evaluations can help to point out future performance problems and/or current issues.

One of the key approaches to achieving a focus on improving and maintaining excellent system performance is to perform a system review on at least an annual basis. This review could be an internal review or an external review of your system performance. Many companies have developed methods for measuring system performance and overall system speed that are tailored directly for their system. This chapter does not describe the six-month process that many of the more detailed evaluations propose; instead, it serves as a very simple barometer of how your system rates compared to others in the industry. Variations in your business processes may cause your score to be higher or lower using this simple review. You will need to adjust these scales and/or some of the criteria to fit your unique system. Tips covered in this chapter include the following:

- The Total Performance Index (TPI) and reasons you might want to use it
- How to evaluate your Education Performance Index (EPI)
- How to evaluate your System Performance Index (SPI)
- How to evaluate your Memory Performance Index (MPI)
- How to evaluate your Disk Performance Index (DPI)
- How to evaluate your Total Performance Index (TPI)
- An overall system review example
The immediate action items list
The system information list
Rating the DBA with the help of an impartial expert

**Total Performance Index (TPI)**

I created the Total Performance Index (TPI) as a basic tool for Oracle DBAs to measure their system and compare it to other systems, using a quick and simple scoring method as shown in the following table. This index is only meant to be a barometer to see if improvements might be beneficial. Many system categories differ based on your business case and system use, but this system tells you how close or far your system is to or from others in the industry. Four categories are included: Education, System, Memory, and Disk. This chapter shows how you can measure your TPI using several simple queries (including example ratings). For detailed information on a particular category, please refer to the chapter in this book related to that issue. To help identify how your system is progressing, use your TPI to compare future growth in the number of users or changes in hardware and software. You can also customize the index to conform to tools you use most often, such as Oracle Enterprise Manager (OEM) or Automatic Database Diagnostic Monitor (ADDM). The following table gives you the overall breakdown by index:

<table>
<thead>
<tr>
<th>Category Index</th>
<th>Maximum Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education Performance Index (EPI)</td>
<td>250</td>
</tr>
<tr>
<td>System Performance Index (SPI)</td>
<td>250</td>
</tr>
<tr>
<td>Memory Performance Index (MPI)</td>
<td>250</td>
</tr>
<tr>
<td>Disk Performance Index (DPI)</td>
<td>250</td>
</tr>
<tr>
<td><strong>Total Performance Index (TPI)</strong></td>
<td><strong>1000</strong></td>
</tr>
</tbody>
</table>

**Education Performance Index (EPI)**

This section measures the knowledge and education of your technical staff members. The following table illustrates how to receive a perfect EPI score. This rating system is not meant to be an all-encompassing benchmark of knowledge and education, but rather a barometer to see how your staff might benefit from educational improvements.
<table>
<thead>
<tr>
<th>Category</th>
<th>Level Required</th>
<th>Maximum Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBAs required to tune database</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>Developers required to tune code written</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>DBAs last trained in tuning</td>
<td>Less than 1 year</td>
<td>30</td>
</tr>
<tr>
<td>Developers last trained in tuning</td>
<td>Less than 1 year</td>
<td>30</td>
</tr>
<tr>
<td>DBAs proficient in Enterprise Manager</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>DBAs proficient in using the V$ views</td>
<td>Yes</td>
<td>20</td>
</tr>
<tr>
<td>DBAs trained on 12c new features</td>
<td>Yes</td>
<td>20</td>
</tr>
<tr>
<td>Developers trained on 12c new features</td>
<td>Yes</td>
<td>20</td>
</tr>
<tr>
<td>DBAs trained to use EXPLAIN PLAN</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Developers trained to use EXPLAIN PLAN</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>DBAs trained to use SQL Performance Analyzer and SQL Tuning Advisor</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Developers trained to use SQL Performance Analyzer and SQL Tuning Advisor</td>
<td>Yes</td>
<td>10</td>
</tr>
</tbody>
</table>

**Education Performance Index (EPI)**

| Section Total | 250 |

**Rate Your System**
<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are DBAs required to tune the database?</td>
<td>30</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Are developers required to tune the code that they write?</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>When is the last time that your DBAs attended a training course that included tuning?</td>
<td>30</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>When is the last time that your developers attended a training course that included tuning?</td>
<td>30</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Are DBAs proficient in using Oracle Enterprise Manager as a performance tuning tool?</td>
<td>30</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Are DBAs proficient in using the V$ views to find or fix deeper performance issues?</td>
<td>20</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Have DBAs been trained on 12c new features, including the In-Memory column store and CDB/PDBs?</td>
<td>20</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Have developers been trained on 12c new features that are applicable?</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Have DBAs been trained on how to use EXPLAIN PLAN/DBMS_XPLAN? (See Chapter 6.)</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>
Grade Your System

<table>
<thead>
<tr>
<th>EPI Grade</th>
<th>Comments</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>Top 10 percent of most systems</td>
<td>250</td>
</tr>
<tr>
<td>A</td>
<td>Top 20 percent of most systems</td>
<td>210–249</td>
</tr>
<tr>
<td>B</td>
<td>Top 40 percent of most systems</td>
<td>150–209</td>
</tr>
<tr>
<td>C</td>
<td>Top 70 percent of most systems</td>
<td>90–149</td>
</tr>
<tr>
<td>Needs help now</td>
<td>Bottom 30 percent of most systems</td>
<td>&lt;90</td>
</tr>
</tbody>
</table>

TIP
Measuring your EPI (Education Performance Index) can be helpful in identifying educational improvements that might be beneficial.

System Performance Index (SPI)
This section measures overall system issues. The following table illustrates how to receive a perfect SPI score. This rating system is not meant to be an all-encompassing benchmark of overall system issues; rather, it is a barometer to see if your system might benefit from improvements.
<table>
<thead>
<tr>
<th>Category</th>
<th>Level Required</th>
<th>Maximum Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside party database review performed</td>
<td>&lt;1 year</td>
<td>30</td>
</tr>
<tr>
<td>IT goals aligned with business goals</td>
<td>&lt;1 year</td>
<td>30</td>
</tr>
<tr>
<td>Ran AWR or Statspack last</td>
<td>&lt;1 month</td>
<td>30</td>
</tr>
<tr>
<td>Asked users about performance issues</td>
<td>&lt;2 months</td>
<td>30</td>
</tr>
<tr>
<td>Backup encrypted and tested</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>Outside party database review performed</td>
<td>&lt;1 year</td>
<td>30</td>
</tr>
<tr>
<td>Outside party operating system review performed</td>
<td>&lt;1 year</td>
<td>20</td>
</tr>
<tr>
<td>Statistics/AWR frequency</td>
<td>AUTO</td>
<td>10</td>
</tr>
<tr>
<td>Good use/investigation of partitioning</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Good use/investigation of compression</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Good application of 12c new features</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Parallel Query used or tested for gains</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>System Performance Index (SPI)</td>
<td>Section Total</td>
<td>250</td>
</tr>
</tbody>
</table>

**Rate Your System**
<table>
<thead>
<tr>
<th>Question</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>When is the last time your database was reviewed by a business user?</td>
<td></td>
</tr>
<tr>
<td>&lt;1 year</td>
<td>30 points</td>
</tr>
<tr>
<td>1–2 years</td>
<td>20 points</td>
</tr>
<tr>
<td>&gt;2 years</td>
<td>0 points</td>
</tr>
<tr>
<td>Score</td>
<td>30</td>
</tr>
<tr>
<td>Are IT goals regularly aligned with objectives of the business to ensure IT is delivering business ROI on IT investments?</td>
<td></td>
</tr>
<tr>
<td>&lt;1 year</td>
<td>30 points</td>
</tr>
<tr>
<td>1–2 years</td>
<td>20 points</td>
</tr>
<tr>
<td>&gt;2 years</td>
<td>0 points</td>
</tr>
<tr>
<td>Score</td>
<td>30</td>
</tr>
<tr>
<td>When is the last time you ran and reviewed the results of the AWR Report or Statspack? Are you regularly reviewing Oracle Performance Advisors? (See Chapter 14.)</td>
<td></td>
</tr>
<tr>
<td>&lt;1 month</td>
<td>30 points</td>
</tr>
<tr>
<td>1–3 months</td>
<td>20 points</td>
</tr>
<tr>
<td>4–6 months</td>
<td>10 points</td>
</tr>
<tr>
<td>&gt;6 months</td>
<td>0 points</td>
</tr>
<tr>
<td>Score</td>
<td>20</td>
</tr>
<tr>
<td>When is the last time users of your system were asked about system performance or where things could be improved? Are thresholds set appropriately?</td>
<td></td>
</tr>
<tr>
<td>&lt;2 months</td>
<td>30 points</td>
</tr>
<tr>
<td>3–6 months</td>
<td>20 points</td>
</tr>
<tr>
<td>7–12 months</td>
<td>10 points</td>
</tr>
<tr>
<td>&gt;1 year</td>
<td>0 points</td>
</tr>
<tr>
<td>Score</td>
<td>20</td>
</tr>
<tr>
<td>Has your backup plan been tested to determine if it would work and the time that it would take to recover? Is it an encrypted backup?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>30 points</td>
</tr>
<tr>
<td>No</td>
<td>0 points</td>
</tr>
<tr>
<td>Score</td>
<td>30</td>
</tr>
<tr>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>When is the last time your database was reviewed by an outside party?</td>
<td>&lt;1 year 30 points</td>
</tr>
<tr>
<td></td>
<td>1–2 years 20 points</td>
</tr>
<tr>
<td></td>
<td>&gt;2 years 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>When is the last time that your operating system and storage layout was reviewed by an outside party?</td>
<td>&lt;1 year 20 points</td>
</tr>
<tr>
<td></td>
<td>1–2 years 10 points</td>
</tr>
<tr>
<td></td>
<td>&gt;2 years 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>How frequently do you collect statistics?</td>
<td>AUTO 10 points</td>
</tr>
<tr>
<td></td>
<td>Monthly 5 points</td>
</tr>
<tr>
<td></td>
<td>Unsure 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Has partitioning been evaluated or implemented, and is it in use where advantageous?</td>
<td>Yes 10 points</td>
</tr>
<tr>
<td></td>
<td>Not needed 10 points</td>
</tr>
<tr>
<td></td>
<td>Not tested 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Has compression been evaluated or implemented, and is it in use where advantageous?</td>
<td>Yes 10 points</td>
</tr>
<tr>
<td></td>
<td>Not needed 10 points</td>
</tr>
<tr>
<td></td>
<td>Not tested 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Have 12c new features been evaluated or implemented, and are they in use where advantageous?</td>
<td>Yes 10 points</td>
</tr>
<tr>
<td></td>
<td>Not needed 10 points</td>
</tr>
<tr>
<td></td>
<td>Not tested 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Has Parallel Query been evaluated, and is it in use where advantageous?</td>
<td>Yes 10 points</td>
</tr>
<tr>
<td></td>
<td>Not needed 10 points</td>
</tr>
<tr>
<td></td>
<td>Not tested 0 points</td>
</tr>
<tr>
<td>Score</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example System Performance Index (SPI)                                      Total Score 220 (A+)
Measuring your SPI (System Performance Index) can be helpful in identifying overall system improvements that might benefit your system.

**Memory Performance Index (MPI)**

This section measures memory use and allocation. The following table illustrates how to receive a perfect MPI score. This rating system is not meant to be an all-encompassing benchmark of memory use and allocation; rather, it is a barometer to see if your system might benefit from memory use and allocation improvements.

<table>
<thead>
<tr>
<th>Category</th>
<th>Level Required</th>
<th>Maximum Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 25 (worst memory) statements tuned</td>
<td>Yes</td>
<td>60</td>
</tr>
<tr>
<td>Top 10 statements’ memory use*</td>
<td>&lt;5 percent</td>
<td>30</td>
</tr>
<tr>
<td>Buffer cache hit ratio (can also measure variance)*</td>
<td>&gt;98 percent</td>
<td>30</td>
</tr>
<tr>
<td>Dictionary cache hit ratio (can also measure variance)*</td>
<td>&gt;98 percent</td>
<td>30</td>
</tr>
<tr>
<td>Library cache hit ratio (can also measure variance)*</td>
<td>&gt;98 percent</td>
<td>30</td>
</tr>
<tr>
<td>PGA sorts in memory (can also measure variance)*</td>
<td>&gt;98 percent</td>
<td>30</td>
</tr>
<tr>
<td>Buffers in X$BH at state=0*</td>
<td>10–25 percent</td>
<td>20</td>
</tr>
<tr>
<td>Using Result cache effectively*</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Pin/cache frequently used objects*</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td><strong>Memory Performance Index (MPI)</strong></td>
<td></td>
<td><strong>Section Total</strong> 250</td>
</tr>
</tbody>
</table>

*Adjust value only where needed based on knowledge of system and if IM cache is also used.*
Top 25 “Memory Abuser” Statements Tuned

I have found that the top 25 statements accessed on most systems, when left untuned, make up over 75 percent of all memory and disk reads of the entire system. The code that follows lists and illustrates how to find the top 25 worst memory abusers.

Query to get the top 25 worst memory abusers

```sql
set serverout on size 1000000
declare
top25 number;
text1 varchar2(4000);
x number;
len1 number;
cursor cl is
select buffer_gets, substr(sql_text,1,4000)
from v$sqlarea
order by buffer_gets desc;
begin
    dbms_output.put_line('Gets'||' '||'Text');
    dbms_output.put_line('----------'||' '||'---------------------');
    open cl;
    for i in 1..25 loop
        fetch cl into top25, text1;
        dbms_output.put_line(rpad(to_char(top25,9)||' '||substr(text1,1,66)));
        len1:=length(text1);
        x:=66;
        while len1 > x 1 loop
            dbms_output.put_line(' '||substr(text1,x,66));
            x:=x+66;
        end loop;
    end loop;
end loop;
end;
/
```

Sample partial output
Rate Your System

How many of your top 25 memory statements in the V$SQLAREA view have you attempted to tune?

- 0 statements: 0 points
- 1–5 statements: 20 points
- 6–15 statements: 40 points
- 16–25 statements: 60 points

Score: 60

Top 10 “Memory Abusers” as a Percent of All Statements

I have found that the top 10 statements accessed on most systems, when left untuned, can make up over 50 percent of all memory reads of the entire system. This section measures how severe the most harmful memory-using statements are, as a percentage of the entire system.

Script to retrieve this percentage

```
select sum(pct_budgets) "Percent"
from   (select rank() over ( order by buffer_gets desc ) as rank_budgets,
          to_char(100 * ratio_to_report(buffer_gets) over ()), '999.99') pct_budgets
where  rank_budgets < 11;
```

Sample output

```
Percent
--------
 4.03
```

PL/SQL procedure successfully completed.
Rate Your System

Take your top 10 memory read statements in the V$SQLAREA view.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;25%</td>
<td>0</td>
</tr>
<tr>
<td>20-25%</td>
<td>10</td>
</tr>
<tr>
<td>5-19%</td>
<td>20</td>
</tr>
<tr>
<td>&lt;5%</td>
<td>30</td>
</tr>
</tbody>
</table>

Score 30

Buffer Cache Hit Ratio

You don’t have to use the actual hit ratio as a scoring mechanism; you can use the variance from the norm instead. The buffer cache hit ratio represents how often frequently requested blocks of data have been found in the memory structure without requiring disk access. Hit ratios are used more in third-party tuning products than ever before, and they are also being used more by Oracle than ever before, primarily because they are a great barometer. But hit ratios can be misleading and should always be used as a barometer and indicator that you may want to look deeper. Nobody ever uses hit ratios as the sole way to tune a system (as some people claim), just as an indicator to know where to dig deeper (I’ve asked this in very large sessions and nobody ever uses only hit ratios). People who say you shouldn’t use hit ratios at all don’t generally understand their value or how to use them. The DBAs who don’t look at hit ratios can miss a major issue that could have been potentially fixed at a very low cost. Hit ratios are very rarely the indicator of good performance, but often can be an indicator of bad performance. Their best use is as a barometer or an indicator of changing performance. Hit ratios can be easily calculated by using the dynamic performance view V$SYSSTAT and V$SYSMETRIC (see Chapter 12 for additional examples). See Chapter 4 for initialization parameters used for memory allocation within Oracle.

Query for buffer cache hit ratio

```sql
select (1 - (sum(decode(name, 'physical reads', value, 0)) / (sum(decode(name, 'db block gets', value, 0)) + sum(decode(name, 'consistent gets', value, 0))))) * 100 "Hit Ratio"
from v$sysstat;
```

Sample output

```
Hit Ratio
---------
98.8249067
```
Rate Your OLTP System

What is your buffer cache hit ratio?  
(You can also use variance from the norm as the scoring mechanism.)

<table>
<thead>
<tr>
<th>Rating</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;90%</td>
<td>0</td>
</tr>
<tr>
<td>90–94%</td>
<td>10</td>
</tr>
<tr>
<td>95–98%</td>
<td>20</td>
</tr>
<tr>
<td>&gt;98%</td>
<td>30</td>
</tr>
</tbody>
</table>

Score: 30

You can also expand the preceding query to include the actual ratings in your result. The query that follows shows how this is accomplished using the DECODE function. You can also apply this to the remainder of the queries in this chapter if you would like to include the score in your results. At TUSC, we always used a PL/SQL procedure to accomplish the results (we also displayed them graphically).

Query for hit ratio with rating

```sql
select (1 - (sum(decode(name, 'physical reads', value, 0)) / (sum(decode(name, 'db block gets', value, 0)) + sum(decode(name, 'consistent gets', value, 0))))) * 100 "Hit Ratio", decode(sign((1-(sum(decode(name, 'physical reads', value, 0)) / (sum(decode(name, 'db block gets', value, 0)) + sum(decode(name, 'consistent gets', value, 0))))) * 100 - 98),1,30, decode(sign((1-(sum(decode(name, 'physical reads', value, 0)) / (sum(decode(name, 'db block gets', value, 0)) + sum(decode(name, 'consistent gets', value, 0))))) * 100 - 95),1,20, decode(sign((1-(sum(decode(name, 'physical reads', value, 0)) / (sum(decode(name, 'db block gets', value, 0)) + sum(decode(name, 'consistent gets', value, 0))))) * 100 - 90),1,10,0)) "Score"
from v$sysstat
/
```

Sample output

<table>
<thead>
<tr>
<th>Hit Ratio</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.8805856</td>
<td>30</td>
</tr>
</tbody>
</table>

The data in V$SYSSTAT reflects the statistics for logical and physical reads for all buffer pools. To derive the hit ratio for the buffer pools individually, query the V$BUFFER_POOL_STATISTICS dynamic performance view.

The buffer cache hit ratio can be used to validate physical I/O simulated in the dynamic performance view V$DB_CACHE_ADVICE. This dynamic performance view provides information that assists in sizing the cache by providing information that predicts the number of physical reads for
each possible cache size. Included in the data is a physical read factor, which predicts the number of physical reads that are estimated to change if the buffer cache is resized to a given value. To use V$DB_CACHE_ADVICE, set the parameter DB_CACHE_ADVICE to ON and allow a representative workload to stabilize prior to querying the view. Following is the query to validate physical I/O simulated by the buffer cache advisory.

**Query to validate physical I/O**

```
COLUMN size_for_estimate FORMAT 999,999,999,999 heading 'Cache Size in MB'
COLUMN buffers_for_estimate FORMAT 999,999,999 heading 'Buffers'
COLUMN estd_physical_read_factor FORMAT 999.99 heading 'Estd Phys Read Pctr'
COLUMN estd_physical_reads FORMAT 999,999,999 heading 'Estd Phys Reads'

SELECT size_for_estimate,
       buffers_for_estimate,
       estd_physical_read_factor,
       estd_physical_reads
FROM V$DB_CACHE_ADVICE
WHERE name = 'DEFAULT'
  AND block_size = (SELECT value FROM V$PARAMETER
                         WHERE name = 'db_block_size')
  AND advice_status = 'ON'
/
```

**Sample output**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>501</td>
<td>1.36</td>
<td>11,130</td>
</tr>
<tr>
<td>8</td>
<td>1,002</td>
<td>1.27</td>
<td>10,427</td>
</tr>
<tr>
<td>12</td>
<td>1,503</td>
<td>1.19</td>
<td>9,743</td>
</tr>
<tr>
<td>16</td>
<td>2,004</td>
<td>1.00</td>
<td>8,205</td>
</tr>
<tr>
<td>20</td>
<td>2,505</td>
<td>.96</td>
<td>7,901</td>
</tr>
<tr>
<td>24</td>
<td>3,006</td>
<td>.84</td>
<td>6,956</td>
</tr>
<tr>
<td>28</td>
<td>3,507</td>
<td>.81</td>
<td>6,629</td>
</tr>
<tr>
<td>32</td>
<td>4,008</td>
<td>.76</td>
<td>6,249</td>
</tr>
</tbody>
</table>

(...Simplistic Listing Displayed)

© Dictionary Cache Hit Ratio

The Dictionary Cache hit ratio displays the percentage of memory reads for the data dictionary and other objects.

**Query for Dictionary Cache hit ratio**
The Library Cache hit ratio reveals the percentage of memory reads for actual statements and PL/SQL objects. Note that a high hit ratio is not always good; see Chapter 4 for a detailed explanation.

**Query for Library Cache hit ratio**

```sql
select (1-(sum(getmisses)/sum(gets))) * 100 "Hit Ratio"
from v$rowcache;
```

**Sample output**

<table>
<thead>
<tr>
<th>Hit Ratio</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;85%</td>
<td>0 points</td>
</tr>
<tr>
<td>86-92%</td>
<td>10 points</td>
</tr>
<tr>
<td>92-98%</td>
<td>20 points</td>
</tr>
<tr>
<td>&gt;98%</td>
<td>30 points</td>
</tr>
</tbody>
</table>

**Rate Your System**

What is your Dictionary Cache hit ratio? (You can also use variance from the norm as the scoring mechanism.)

The hit percentage is 99.97 percent, which means that only 0.03 percent of executions resulted in reparsing.

**Rate Your System**

![Sample output](image)

The hit percentage is 99.97 percent, which means that only 0.03 percent of executions resulted in reparsing.
PGA Memory Sort Ratio

Automatic PGA Memory Management simplifies the way PGA memory is allocated. By default, PGA Memory Management is enabled. When running in this mode, Oracle adjusts, dynamically, the size of the portion of the PGA memory dedicated to work areas, which is based on 20 percent of the SGA memory size. When running in Automatic PGA Memory Management mode, sizing of work areas for all sessions is automatic. In 10g, the total amount of PGA memory available to active work areas in the instance is automatically derived from the SORT_AREA_SIZE or the PGA_AGGRREGATE_TARGET (preferred) initialization parameter. In 11g, if you use the MEMORY_TARGET parameter, Oracle manages both the SGA and PGA. In 12c, Oracle limits the upper bound for the PGA with PGA_AGGRREGATE_LIMIT. See Chapter 4 for initialization parameters used for memory allocation within Oracle and a discussion of the new parameters in 12c and Automatic Memory Management (AMM).

The objective is to have sort operations in the PGA performed in memory versus in the I/O subsystem (on disk) when possible. Statistics related to PGA memory sorts can be derived by the query in the next section or from the AWR Report, which reflects overall values for sorts in memory and disk, as well as the percentage of those in memory. The values reflect activity since the start of the instance. Values for a PGA Memory Sort Ratio greater than 98 percent are desired. Depending on the value of the memory currently allocated to the PGA by AMM (or set with PGA_AGGRREGATE_TARGET and PGA_AGGRREGATE_LIMIT), user sorts may fit into memory or be performed on disk in a specified temporary tablespace if this initialization parameter is not high enough to hold the sort.

Query for PGA Memory Sort Ratio

You can receive specific sorting statistics (memory, disk, and rows) by running the following queries or go to the AWR Report or Statspack output file (report.txt) to get these statistics (see Chapter 14 for more information on Statspack and the AWR Report).

Query to get PGA Memory Sort Ratio
Rate Your System

What percentage of sorts are performed in memory?

<table>
<thead>
<tr>
<th>Percentage</th>
<th>0 points</th>
<th>10 points</th>
<th>20 points</th>
<th>30 points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;90%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90-94%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95-98%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;98%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Percentage of Data Buffers Still Free

When you start the Oracle database, users start using memory for their queries. Although this memory is reusable when the user’s query is complete, when the following query runs on a system after two hours of processing, it is a good indication of how quickly the buffers are being used up (high-volume systems may need to vary the time frame to be much shorter). The number of free buffers divided by the total number of records in X$BH (which is the total data block buffers allocated—one record in the table for each buffer) is the percentage. Also note that you have to run this query as SYS.

Remember that having many free buffers is not necessarily the best situation. See Chapter 13 on queries to this table for more information. This could also be done from the In-Memory (IM) column store as well if you are licensed for this and use it (see Chapter 4 for detailed information and queries on IM). For a data warehouse, you might split half the scoring for the buffer cache and the other half for the IM column store.

Query for free data buffers

```
select a.value "Disk Sorts", b.value "Memory Sorts",
round(:100*b.value/decode(a.value+b.value,0,1,a.value+b.value)),2) "Per Cent Memory Sorts"
from v$sysstat a, v$sysstat b
where a.name = 'sorts (disk)'
and b.name = 'sorts (memory)';
```
Rate Your System

SET VERIFY off
COLUMN PctTotBCMem for all
SELECT /*+ ordered */
    tot_bc_mem.TotBCMem,
    decode(state,
        0, 'Free',
        1, 'Exclusive',
        2, 'SharedCurrent',
        3, 'ConsistentRead',
        4, 'BeingRead',
        5, 'InModuRecoveryMode',
        6, 'InInstanceRecoveryMode',
        7, 'BeingWritten',
        8, 'Pinned',
        9, 'Memory',
        10, 'write',
        11, 'Donated') "BlockState",
    SUM(blsiz) "SumStateTypeMem",
    COUNT(1) "NumOfBlksThisTyp",
    ROUND(SUM(blsiz)/tot_bc_mem.TotBCMem,2)*100 || '%' "PctTotBCMem"
FROM (SELECT sum(blsiz) TotBCMem
    FROM xshh) tot_bc_mem,
    xshh
GROUP BY tot_bc_mem.TotBCMem,
    decode(state,
        0, 'Free',
        1, 'Exclusive',
        2, 'SharedCurrent',
        3, 'ConsistentRead',
        4, 'BeingRead',
        5, 'InModuRecoveryMode',
        6, 'InInstanceRecoveryMode',
        7, 'BeingWritten',
        8, 'Pinned',
        9, 'Memory',
        10, 'write',
        11, 'Donated')
ORDER BY SUM(blsiz);
CLEAR COLUMNS

<table>
<thead>
<tr>
<th>TOTBCMEM</th>
<th>BlockState</th>
<th>SumStateTyocMem</th>
<th>NumOfBlksThisTyp</th>
<th>PctTotBCMem</th>
</tr>
</thead>
<tbody>
<tr>
<td>209719776</td>
<td>Free</td>
<td>12828672</td>
<td>1566</td>
<td>6%</td>
</tr>
<tr>
<td>209719776</td>
<td>ConsistentRead</td>
<td>43368448</td>
<td>5294</td>
<td>21%</td>
</tr>
<tr>
<td>209719776</td>
<td>Exclusive</td>
<td>153522656</td>
<td>18743</td>
<td>73%</td>
</tr>
</tbody>
</table>
Note that the reason you get 0 points for greater than 25 percent free is because the data buffers are probably oversized and potentially wasting memory (ensure the system has been running awhile). The scoring should be tailored to your individual system use. Remember this rating is only a general guideline and one that definitely needs to be tailored to your system.

Using the Result Cache Effectively

The Result Cache is a separate shared memory pool to store query results. This Result Cache is allocated directly from the shared pool upon database startup but is maintained separately. The Result Cache allows a query’s result (for instance, a sum of all salaries after being calculated) to be cached in memory, allowing for large performance improvements for future queries executed multiple times that require the same results. By default, the Result Cache is set to 0.25 percent of the value of MEMORY_TARGET (if set), 0.50 percent of the value of SGA_TARGET (if set), or 1 percent of the SHARED_POOL_SIZE parameter (if set). You can also set it directly by using the RESULT_CACHE_MAX_SIZE=\text{amount} and the RESULT_CACHE_MODE=force parameters (set to force to use it automatically). Setting RESULT_CACHE_MAX_SIZE to 0 disables the Result Cache feature. You can use DBMS_RESULT_CACHE.FLUSH to clear it. Note results are not passed between RAC/Grid nodes. Please see Chapter 4 for more information. Also, check the documentation for other restrictions and rules.

Rate Your System

<table>
<thead>
<tr>
<th>Are you using the Result Cache effectively?</th>
<th>Yes/no need</th>
<th>10 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>0 points</td>
<td></td>
</tr>
</tbody>
</table>

Score 10

Pinning/Caching Objects

Objects can be pinned into memory using DBMS_SHARED_POOL.KEEP if they are often-used objects, as shown in Chapter 10. Tables can also be pinned into memory by caching the table when it
is created, or by using the ALTER command to cache a table. See Chapter 7 for more information on caching tables.

Some of the recommended packages to consider for pinning are the following:

- DBMS_ALERT
- DBMS_DDL
- DBMS_OUTPUT
- DBMS_SESSION
- DBMS_STANDARD
- DBMS_ALERT
- DBMS_DESCRIBE
- DBMS_LOCK
- DBMS_PIPE
- DBMS_SHARED_POOL
- DBMS_UTILITY

**Rate Your System**

Do you pin PL/SQL objects or cache tables when needed?

- Yes/no need
- Yes: 10 points
- No: 0 points

**Example Memory Performance Index (MPI)**

<table>
<thead>
<tr>
<th>MPI Grade</th>
<th>Comments</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+</td>
<td>Top 10 percent of most systems</td>
<td>&gt;230</td>
</tr>
<tr>
<td>A</td>
<td>Top 20 percent of most systems</td>
<td>200–230</td>
</tr>
<tr>
<td>B</td>
<td>Top 40 percent of most systems</td>
<td>160–199</td>
</tr>
<tr>
<td>C</td>
<td>Top 70 percent of most systems</td>
<td>100–159</td>
</tr>
<tr>
<td>Needs help now</td>
<td>Bottom 30 percent of most systems</td>
<td>&lt;100</td>
</tr>
</tbody>
</table>

**Grade Your System**

Measuring your MPI (Memory Performance Index) can be helpful in identifying potential memory allocation and usage improvements that could benefit your system.

**Disk Performance Index (DPI)**

This section measures disk use. The following table illustrates how to receive a perfect DPI score.

This rating system is not meant to be an all-encompassing benchmark of disk use; rather, it is a barometer to see if disk use improvements might be beneficial. With the advent of storage area
networks (SANs) and other disk and disk-caching technology, you may need to alter the rating system to be more appropriate for your system. Strongly consider using Oracle features such as Automatic Storage Management (ASM), Locally Managed Tablespaces (LMTs), and Automatic Segment Space Management (ASSM). (See Chapter 3 for more information on these features.)

<table>
<thead>
<tr>
<th>Category</th>
<th>Level Required</th>
<th>Maximum Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 25 (worst disk) statements tuned</td>
<td>Yes</td>
<td>60</td>
</tr>
<tr>
<td>Top 10 statements’ disk use</td>
<td>&lt;5 percent</td>
<td>40</td>
</tr>
<tr>
<td>Tables/indexes collocated or ASM</td>
<td>No</td>
<td>30</td>
</tr>
<tr>
<td>Mission-critical table in LMTs</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>Redo logs on fast disks or SSD</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>Automatic undo management</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>Using pluggable databases effectively</td>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td><strong>Disk Performance Index (DPI)</strong></td>
<td></td>
<td><strong>Section Total 250</strong></td>
</tr>
</tbody>
</table>

Top 25 “Disk-Read Abuser” Statements Tuned

I have found that the top 25 statements with the most disk reads accessed on most systems, when left untuned, can make up over 75 percent of all disk and/or memory reads of the entire system. This section lists the most intense 25 disk-reading statements for the entire system. The example that follows shows a pretty well-tuned system where only data dictionary queries show up (you would usually not tune these).

Query to get the 25 worst disk-read abusers

```sql
set serverout on size 1000000
declare
top25 number;
text1 varchar2(4000);
x number;
len1 number;
cursor cl is
select disk_reads, substr(sql_text,1,4000)
from v$sqldataarea
order by disk_reads desc;
```
Rate Your System

How many of your top 25 disk-read statements in the V$SQLAREA view have you attempted to tune?

- 0 points
- 1-5 points
- 6-15 points
- 16-25 points
- Score 60

Top 10 Disk-Read Abusers as Percentage of All Statements

This section measures the effect of the top 10 heaviest disk-reading statements as a percentage of the entire system.

Script to retrieve this percentage
Set serverout on;
DECLARE
   CURSOR c1 is
      select disk_reads
      from v$sqlarea
      order by disk_reads DESC;
   CURSOR c2 is
      select sum(disk_reads)
      from v$sqlarea;
   Sumof10 NUMBER:=0;
   mydr NUMBER;
   mytotdr NUMBER;
BEGIN
   dbms_output.put_line('Percent');
   dbms_output.put_line('--------');
   OPEN c1;
   FOR i IN 1..10 LOOP
      FETCH c1 INTO mydr;
      sumof10 := sumof10 + mydr;
   END LOOP;
   CLOSE c1;
   OPEN c2;
   FETCH c2 INTO mytotdr;
   CLOSE c2;
   dbms_output.put_line(sumof10/mytotdr*100);
END;
/

Sample output

Percent
4.59

Alternative—simple and fast SQL

```sql
SELECT SUM(pct_bufgets) FROM (SELECT rank() OVER (ORDER BY disk_reads DESC) AS rank_bufgets,
                                 TO_CHAR(100 * ratio_to_report(disk_reads) OVER ()), '999.99') pct_bufgets
WHERE rank_bufgets < 11;
```

4.59
Tables/Indexes Separated or Using ASM

Tables and their corresponding indexes should be located on separate physical disks for smaller systems to decrease file I/O for a given disk. This is, of course, becoming harder to do, as DBAs are often unaware of where things are because of how a SAN may be managed. In Enterprise Manager, Oracle gives you a way to see and move hot (frequently used) and cold (not frequently used) data. Moving data to a hotter or colder region of the disk is now very easy. Information lifecycle management (ILM), or the management of data throughout its lifetime, is becoming more and more important. In Oracle 12c, ILM is simplified through the Heat Map, which automatically collects segment- and row-level statistics, used to define compression and storage policies that are automatically maintained throughout the life cycle of the data (see Chapter 3). Older data can now be kept longer on physical, but slower, disks. Newer data can be cached to ensure speed when accessing it. Chapter 3 covers physical data and I/O in great detail and provides queries to assist in this matter. Note that if you use ASM, you should ensure that when you add new disks, you follow the tips on rebalancing that are listed in Chapter 3. ASM has a feature called intelligent data placement that enables you to specify hot/cold disk regions in ASM to ensure that frequently accessed data is placed on the fast/outermost (hot) tracks. It also has the new Heat Map that can be used (even in Enterprise Manager).

Rate Your System

Mission-Critical Table Management

Locally managed tablespaces (LMTs) with ASSM is the norm. Also, review row chaining; row-
chaining is also common when the database block size is too small. Tablespaces implemented using ASSM are sometimes referred to as locally managed tablespaces with bitmap segment-space management, or bitmap tablespaces. To use ASSM, create locally managed tablespaces, with the segment space management clause set to AUTO. ASSM in locally managed tablespaces eliminates the need to specify the PCTUSED, FREELISTS, and FREELIST GROUPS storage attributes for the tablespace. If possible, switch from manual space management to ASSM.

When a table is updated and the updated record block does not have enough room to fit the changes, a record is “chained” to another block. In this situation, a record spans more than one block and, in most instances, creates additional I/O. By analyzing a table for chained rows and querying the CHAINED_ROWS table, identifying tables that have chained records is possible. The CHAINED_ROWS table is created using the script utlchain.sql or utlchn1.sql, which resides in a file under the $ORACLE_HOME/rdbms/admin directory, where Oracle software is located (note that the exact name and location may vary depending on your platform). You may also consider the ALTER TABLE SHRINK SPACE COMPACT command, but please investigate the use/restrictions of this command in the Oracle documentation beforehand. To populate the CHAINED_ROWS table, use the ANALYZE command. The ANALYZE command has an option to determine chained rows in a table as follows:

```
ANALYZE table TABLE_NAME list chained rows into chained_rows;
Table analyzed.
```

The command places the output into a table called CHAINED_ROWS. The following query selects the most informative columns of the CHAINED_ROWS table:

```
SELECT OWNER_NAME, /*owner of object*/
     TABLE_NAME,  /*Name of table*/
     CLUSTER_NAME, /*Name of cluster if applicable*/
     HEAD_ROWID,  /*ID of the first part of the row*/
     ANALYZE_TIMESTAMP /*Timestamp associated with last analyze*/
FROM CHAINED_ROWS;
```

**Rate Your System**

Are mission-critical tables stored in LMTs with ASSM, and do you address chaining issues?

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>0 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td>30 points</td>
</tr>
</tbody>
</table>

**Score**: 0 (0 points)

**& Key Oracle Files Separated**
Separating often-accessed Oracle datafiles or effectively using ASM and the Heat Map can help eliminate I/O bottlenecks as well as eliminate potential saturation of the disk’s memory cache. Separating heavily written files (especially redo logs) generally improves performance.

Rate Your System

Are redo logs on different disks than database datafiles?

<table>
<thead>
<tr>
<th>Option</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>30</td>
</tr>
<tr>
<td>Disk array</td>
<td>20</td>
</tr>
<tr>
<td>No</td>
<td>0</td>
</tr>
</tbody>
</table>

Score: 20

Automatic Undo Management

Automatic undo management (AUM) should be used where possible. When configured in this manner, the database automatically determines how long UNDO data should be kept on the basis of the length of time queries take to run. UNDO data preserved within this window of time is said to be in the unexpired state. After this time, the state of the UNDO data changes to expired. UNDO data is a good candidate for overwriting only when it is in the expired state. The length of time that Oracle keeps UNDO data in the unexpired state depends on tablespace configuration. When creating a database with the Database Configuration Assistant (DBCA), the UNDO tablespace is set, by default, to extend itself automatically to maintain unexpired UNDO for the longest-running query. You can also specify a minimum UNDO retention period (in seconds) by setting the UNDO_RETENTION initialization parameter. This is only used with AUTOEXTEND tablespaces. Oracle extends the UNDO tablespace up to the size of MAXSIZE. Only when it is not possible to expand anymore is unexpired UNDO data overwritten.

When using a fixed-sized UNDO tablespace, Oracle automatically keeps the UNDO data in the unexpired state for the longest possible time for the tablespace of the specified size. If the UNDO tablespace does not have adequate free or expired space to store active UNDO data generated by current transactions, then Oracle might be forced to overwrite the unexpired UNDO data. This situation might cause long-running queries to fail with an error and an alert.

In the event that AUTOEXTEND is disabled (by default it is enabled) for automatic undo management, autoextending the UNDO tablespace will require adjusting the size of the tablespace manually. In this case, ensure that the tablespace is large enough to meet the read-consistency requirements for the longest-running query. Also, if using flashback features, then make certain the tablespace is large enough to accommodate flashback operations. The queries listed next estimate the number of bytes required when sizing the UNDO tablespace under different conditions. With AUM, you do not have to create individual UNDO segments (Oracle does it for you). If you use AUM, you do not have to specify rollback segments.

The following information is appropriate for UNDO query A, B, and C. Sizing an UNDO tablespace requires three pieces of information:
(UR) UNDO_RETENTION in seconds
(UPS) Number of UNDO data blocks generated per second
(DBS) Overhead, which varies based on extent and file size (DB_BLOCK_SIZE)

\[ \text{UndoSpace} = (UR \times (UPS \times DBS) + DBS) \]

Or, when the guesstimate equates to 0, then add a multiplier (24) to the overhead (DBS) to derive more appropriate results:

\[ \text{UndoSpace} = [UR \times (UPS \times DBS)] + (DBS \times 24) \]

Two pieces of information can be obtained from the initialization file: UNDO_RETENTION and DB_BLOCK_SIZE. The third piece of the formula requires a query against the database. The number of UNDO blocks generated per second can be acquired from V$UNDOSTAT as follows:

```sql
SELECT (SUM(undoblks))/ SUM ((end_time - begin_time) * 86400) FROM v$undostat;
```

To convert days to seconds, you multiply by 86,400, the number of seconds in a day. The result of the query returns the number of UNDO blocks per second. This value needs to be multiplied by the size of an UNDO block, which is the same size as the database block defined in DB_BLOCK_SIZE. The query that follows represents a point-in-time estimate based on the UNDO blocks per second at the time of execution. The query can be utilized when UNDO space has not been allocated. If this time frame is during high activity or a worst-case scenario for UNDO, then the results derived provide a good estimate.

**Segment/file query**

```sql
col file_name for a40
SELECT segment_name, file_name
FROM dba_data_files, dba.rollback_segs
WHERE dba.data_files.file_id = dba rollback.segs.file_id;
```

**Sample output**
Rate Your System

Are you utilizing automatic undo management?

| No | 0 points |
| Yes | 30 points |

Using Pluggable Databases Effectively

The pluggable databases architecture, new in 12c and covered in detail in Chapter 3, enables you to have a container database (CDB) with multiple pluggable databases (PDBs). As a quick review, pluggable databases are also called *multitenant databases* because each “tenant” can have their own PDB. “Pluggable” databases can be unplugged from one CDB and plugged into another CDB easily, therefore making databases portable between environments and allowing upgrade of a database by unplugging it from one environment at one version and plugging it into a new environment at a higher version. You can also unplug from an on-premises CDB and plug into the cloud (or vice versa). This feature also allows a single PDB to be independently recovered (you can flashback an individual PDB in 12cR2). Because each PDB looks to an application like any traditional Oracle database (called a non-CDB), no application changes are needed to work with the PDB architecture. Non-CDBs are now deprecated.

The following are some notes to keep in mind regarding CDB/PDBs (subject to change):

- CDB = container database (has a root database and also a seed PDB).
- PDB = pluggable database (plugged into a CDB).
- Non-CDB = traditional Oracle database instance (neither a CDB nor a PDB).
- Why PDBs? To consolidate hundreds of database on one machine. Too many resources are required when you add up the SGAs for each of the instances when not using PDBs. One CDB has one SGA and resources shared for multiple PDBs.
- Share PDBs (big data sources, acquisitions, partners, shared research, governments).
- In 12cR2, can refresh a read-only PDB, can flashback an individual PDB, and can recover an individual PDB.
- Move existing PDBs to a new platform or location or clone them (snapshot).
- Patch/upgrade a PDB by plugging it into a CDB at a later version.

The following shows how to determine whether a database is a CDB or a non-CDB (this is a CDB, as indicated by YES in the CDB column):

```sql
select name, created, cdb, con_id
from v$database;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>CREATED</th>
<th>CDB</th>
<th>CON_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDB1</td>
<td>19-FEB-12</td>
<td>YES</td>
<td>0</td>
</tr>
</tbody>
</table>

Use the following command to see how many PDBs you have. As the output shows, I have three PDBS, but only PDB_SS and PDB1 were created by me (each PDB might represent a different application). PDB$SEED was created by Oracle when I installed the database. I can clone the seed PDB (which in itself is not used) to create new, empty PDBs.

```sql
select name, open_mode, open_time
from v$pdb;
```

<table>
<thead>
<tr>
<th>NAME</th>
<th>OPEN_MODE</th>
<th>OPEN_TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDB$SEED</td>
<td>READ ONLY</td>
<td>23-FEB-13 05.29.19.861 AM</td>
</tr>
<tr>
<td>PDB1</td>
<td>READ WRITE</td>
<td>23-FEB-13 05.29.25.846 AM</td>
</tr>
<tr>
<td>PDB SS</td>
<td>READ WRITE</td>
<td>23-FEB-13 05.29.37.587 AM</td>
</tr>
</tbody>
</table>

**Rate Your System**

Are you using PDBs effectively? How many databases have you consolidated using the new multitenant structure (i.e., how many PDBs do you have)?

<table>
<thead>
<tr>
<th>Use non-CDB</th>
<th>0 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>10 points</td>
</tr>
<tr>
<td>3</td>
<td>20 points</td>
</tr>
<tr>
<td>&gt;3</td>
<td>30 points</td>
</tr>
</tbody>
</table>

Score: 10

Example Disk Performance Index (DPI)

Total Score: 220 (A)
TIP
Measuring your DPI (Disk Performance Index) can be helpful in identifying potential disk improvements that might benefit your system.

Total Performance Index (TPI)
The Total Performance Index is the composite score of the Education, System, Memory, and Disk indexes, as shown here:

<table>
<thead>
<tr>
<th>Category Index</th>
<th>Maximum Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education Performance Index (EPI)</td>
<td>250</td>
</tr>
<tr>
<td>System Performance Index (SPI)</td>
<td>250</td>
</tr>
<tr>
<td>Memory Performance Index (MPI)</td>
<td>250</td>
</tr>
<tr>
<td>Disk Performance Index (DPI)</td>
<td>250</td>
</tr>
<tr>
<td><strong>Total Performance Index (TPI)</strong></td>
<td><strong>1000</strong></td>
</tr>
</tbody>
</table>

Example Education Performance Index (EPI)
Total Score 160 (B)

Example System Performance Index (SPI)
Total Score 220 (A+)

Example Memory Performance Index (MPI)
Total Score 240 (A+)

Example Disk Performance Index (DPI)
Total Score 220 (A)

Example Total Performance Index (TPI)
Total Score 840 (A)

Grade Your System
Measuring your TPI (Total Performance Index) can be helpful in identifying bottlenecks; it is a simple barometer of your overall system performance and may help you find areas needing improvement.

Overall System Review Example
The following is an example rating scale. You can use the rating results to generate a yearly review for your system. Some of the items (such as backup and recovery ratings) are not covered in depth. The objective of this section is to give you ideas of some of the areas you might consider reviewing. This is not an actual client system review but a slightly modified version of several reviews to help generate discussion items for your review template. The goal is to give you a “feel” for a review.

Rating System
Here is an example rating report that you may use as a guideline as you detail an overall review and its ratings. Having a review that includes a rating for items that desperately need improvement or attention (where appropriate) is important in generating manager support. In many cases, DBAs need managerial support to be allowed the time to address major issues with their system. At times, if the system is up and running, upper management may not realize that a change is needed. This review can be a catalyst for needed change as issues are identified.
TIP
Have your system reviewed on an annual basis by an outside party or, at the minimum, by someone inside your company.

Example System Review Rating Categories

The following table summarizes the results of the system review. Although some TPI categories are discussed, this section is an addition to the TPI that goes into greater depth. An overview of the recommended changes should follow this section, and the TPI rating could precede or follow this section. This section is more subjective, so an experienced person who you respect should make these evaluations. The ratings should include more detailed comments than those given here as an example. The recommended changes should be detailed with supporting documentation.

NOTE
This is an example, not an actual review.
<table>
<thead>
<tr>
<th>Category</th>
<th>Grade</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall review</td>
<td>C+</td>
<td>The system is running poorly at times due to an insufficient amount of memory allocated for the data. Currently the new In-Memory (IM) column stores isn’t being used, but it could be leveraged nicely for data warehousing. Several areas need to be corrected for substantially improved system performance, especially as additional users and data are added. Oracle 12c new features are not implemented. In addition to not leveraging IM, the system is also not leveraging PDBs. Enterprise Manager features, such as SPA and the AWR Report, could help with tuning, but are not being used on a regular basis. An Exadata simulation might be worth running to evaluate new hardware, and the Oracle Public Cloud should be considered for an encrypted backup and developer testing.</td>
</tr>
<tr>
<td>Architecture</td>
<td>B</td>
<td>The overall architecture is good, but the SAN and cache should be investigated to determine whether I/O distribution across available controllers can be improved. Compression should be investigated to save space and improve performance.</td>
</tr>
<tr>
<td>Hardware sizing</td>
<td>A−</td>
<td>The hardware is well sized for the business activity, but future growth may dictate a hardware evaluation in the near future. The system is not tuned to take full advantage of the current hardware.</td>
</tr>
<tr>
<td>Security</td>
<td>F</td>
<td>Passwords are never changed, even when employees leave the company. Several unprotected files have hard-coded passwords. The default accounts are not locked when unused. This is unacceptable! The security information that Oracle provides at <a href="http://www.oracle.com/security">www.oracle.com/security</a> has not been reviewed.</td>
</tr>
<tr>
<td>Memory allocation</td>
<td>B+</td>
<td>Of the 2G of memory, MEMORY_TARGET is set effectively, but more of the memory can be allocated to data by setting a (larger) minimum for the DB_CACHE_SIZE. Consider more Flash Cache (of some brand) to improve performance. Start investigating where you can utilize the Result Cache and IM for better performance.</td>
</tr>
<tr>
<td>Database tuning</td>
<td>D−</td>
<td>The top 25 queries make up 98 percent of all resource usage. No effort has been made to tune these queries.</td>
</tr>
<tr>
<td>Disk configuration</td>
<td>B</td>
<td>Disk I/O is reasonably balanced but could be improved by partitioning a few of the hardest-hit tables and indexes.</td>
</tr>
<tr>
<td>Redo logs</td>
<td>B+</td>
<td>Redo logs are sized well, but you may want to add a few more of them for batch processing when they switch much faster.</td>
</tr>
</tbody>
</table>
Items Requiring Immediate Action

Once you have reviewed your system, you need to make a comprehensive list of items that you need to address immediately. The following list is a summary (partial list only) of some of the issues that could warrant immediate action after a review:

- Lock the default accounts when unused! Let’s do it now.
- SYSTEM and SYS passwords in production should be different in development.
- Any default or commonly used passwords should be changed. Change all user passwords, as security is currently compromised.
- MEMORY_TARGET has been set, but minimums have not been set correctly for key initialization parameters. The minimum setting for DB_CACHE_SIZE needs to be increased immediately (MEMORY_TARGET is set correctly though)! You can do this with the system running if the MEMORY_TARGET is large enough. You can also use SGA_TARGET, so the...
DB_CACHE_SIZE is used only as a minimum for the SGA (see Chapters 1 and 4 for more information). PGA_AGGREGATE_LIMIT should be set to limit a runaway PGA.

- The top 25 queries causing disk and memory reads need to be tuned.

**TIP**

*A system review should always include immediate action items. This ensures that the time needed for improvements will be allocated.*

## Other Items Requiring Action

The second list that you should make includes items needing attention *after* the most pressing issues have been addressed. A summary example list is shown here. Your list should include more detail on how the action will be corrected.

- Monitor the items detailed in this document at least once per quarter with the current growth rate of the system. Ensure that you are estimating future system size. Leverage the Oracle Public Cloud to offload infrequently used data.
- Resize the database objects that are currently oversized and undersized.
- Change all passwords at least once per quarter.
- Fix file protection so users are unable to delete Oracle software.
- Remove hard-coded passwords from scripts and backup jobs.
- Consider adding additional indexes for the top 25 worst disk-read queries to improve query performance.

If you’re making initialization parameter changes, compile a list with both the current and suggested values. Refer to Appendix A for a complete list of initialization parameters with descriptions. Lastly, make sure you repeat the review after you have made the changes to ensure everything has been implemented correctly.

## System Information List

This section describes some of the system information that you should gather and keep with the review. As you look back on a review, you need to know what the system parameters were at the time of the review. Any ratings of specific items (such as backup and recovery) could be placed in this section. I also have included a sample DBA review that illustrates some of the areas that may be reviewed. Have someone else rate your DBA skills so you can continue to improve. This section has been greatly simplified for the book. It is a quick list designed to give a “picture” of the system as
Memory-Related Values

The following are memory-related questions and answers about the system:

- What is the current memory for the hardware? **400G.**
- What is the current number of users? **5000 total/500 concurrent.**
- What will be the future number of users? **1000–1500 concurrent in the next three months.**
- What other software is used on the system? **None that has a major influence.**
- Is the system client/server or browser/server? **Browser/server.**
- What response times are required? **Subsecond—OLTP transactions make up main mix.**
- How large is the database? **Currently 20T, with 500G currently free in the database.**
- How large are often-accessed tables? **One million rows is the average/100 million for the largest table.**
- What future software will affect memory? **None.**
- Are you implementing any other features/options? **Oracle In-Memory column store as soon as possible, Oracle GoldenGate in three months, Violin Memory Flash Memory in the next three months, and investigating Exadata and Oracle Public Cloud (and Amazon Web Services) over the next year.**

Disk-Related Values

The following are disk-related questions and answers:

- What is the maximum SAN capacity for the hardware? **20× current capacity.**
- What disk sizes are available? **4T and 8T.**
- What size will the database be in one year? **10 to 100 percent larger than current.**
- Is there a RAID (striping) level for database files/OS? **Yes; RAID 1+0.**
- Will you have multiplexed redo logs? **Yes.**
- What software will be installed in the future? **No additions in near future.**
- What system utilities will be installed? **Oracle Enterprise Manager with Diagnostics Pack.**
- What transfers happen nightly? **Bulk order transfers.**
Any earlier notes on implementation? Pluggable databases as soon as possible, Violin Memory Flash Memory in the next three months, and investigating Exadata and Oracle Public Cloud (and Amazon Web Services) over the next year.

**CPU-Related Values**

The following are CPU-related questions and answers:

- What is the maximum number of processors for the hardware? 6 dual currently/12 quad maximum.
- Is there a future upgrade path? Yes; path to 64 quad core processors.
- What is the transaction processing load? 60 percent CPU average/90 percent sustained maximum.
- What is the batch load? Some heavy at night/okay during the day.
- Are hot backups employed? RMAN backups are employed with archiving.
- Are batch processes running during the day? None affect performance.
- Will Parallel Query be used in the future? Currently being used on some processes.
- Will there be a future distributed setup? Yes, with Oracle GoldenGate.

**Backup- and Recovery-Related Information**

The following are backup- and recovery-related questions and answers:

- Does the system require 7×24 use? No, it is 6×24.
- How fast will recovery need to be (on-disk backup)? 12-hour maximum.
- Are there “standby” disks in case of failure? No, four-hour turnaround from HP.
- How much data is “backed up”; is it being “tape-striped” with parity? Unknown.
- Has the UPS been established? Yes.
- Are export files also taken? No.
- Are cold backup procedures in place? Not applicable.
- Are export procedures in place? Needs improvement/Implement Data Pump compatibility for export/import control files (new in 11g).
- Are hot backup procedures in place? Excellent.
- Is the backup encrypted? No.
Is it possible to use encrypted backup to the cloud? **Yes.**

Is the fast recovery area (FRA) sized properly? **Yes.**

Are disaster recovery procedures in place? **Needs improvement (Data Guard suggested).**

The following is an example of some of the areas you may evaluate in a backup and recovery rating. Most Oracle DBA books evaluate features like these in greater depth. The layout should be identical to your system review.

<table>
<thead>
<tr>
<th>Category</th>
<th>Grade</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>12c new features used</td>
<td>A</td>
<td>Very good</td>
</tr>
<tr>
<td>Backup and recovery overall and is it encrypted</td>
<td>A</td>
<td>Excellent. Recovery was tested in a simulated database failure. Backup is encrypted.</td>
</tr>
<tr>
<td>Backup procedures</td>
<td>A</td>
<td>Excellent</td>
</tr>
<tr>
<td>Archiving procedures</td>
<td>A</td>
<td>Excellent</td>
</tr>
<tr>
<td>Recovery procedures</td>
<td>A−</td>
<td>Should have scripts ready to go for a recovery</td>
</tr>
<tr>
<td>Enterprise Manager setup</td>
<td>A+</td>
<td>Excellent</td>
</tr>
<tr>
<td>Hardware/ASM setup/tuned</td>
<td>B</td>
<td>Good</td>
</tr>
<tr>
<td>Backup knowledge</td>
<td>A</td>
<td>Very good</td>
</tr>
<tr>
<td>Recovery knowledge</td>
<td>A</td>
<td>Very good</td>
</tr>
<tr>
<td>Disaster backup</td>
<td>A+</td>
<td>Excellent</td>
</tr>
<tr>
<td>Disaster recovery</td>
<td>A</td>
<td>Very good, rolling forward still being worked on</td>
</tr>
</tbody>
</table>

### Naming Conventions and/or Standards and Security Information Questions

The following are naming convention, standards-related, or security-related questions and answers:

- Have you reviewed naming conventions being used? **Excellent**
- Have you checked file protections on key Oracle files? **Poor**
- Have you checked database security procedures, including info shared in the cloud? **Poor**
- Have you checked password procedures? **Poor**
- Have you reviewed the Oracle security information that exists at [www.oracle.com/security](http://www.oracle.com/security) and the security information that you can find at the following link: [http://www.oracle.com/technetwork/topics/security/articles/index.html](http://www.oracle.com/technetwork/topics/security/articles/index.html)? **Not complete**
DBA Knowledge Rating

Having all DBAs reviewed by an impartial expert is paramount to identifying and improving their skills. Often, the primary DBA is too busy to attend training sessions or improve their skills on new versions of Oracle. Assessing DBAs helps identify their strengths and weaknesses. This process will fail if this review is used against a person. It must be used with the goal of identifying and improving skills.

<table>
<thead>
<tr>
<th>Category</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBA knowledge overall</td>
<td>A</td>
</tr>
<tr>
<td>Oracle 12c new features</td>
<td>A</td>
</tr>
<tr>
<td>Oracle Enterprise Manager</td>
<td>A+</td>
</tr>
<tr>
<td>Oracle architecture/PDBs</td>
<td>A−</td>
</tr>
<tr>
<td>Oracle objects/memory areas</td>
<td>B+</td>
</tr>
<tr>
<td>Oracle internals</td>
<td>B+</td>
</tr>
<tr>
<td>Oracle initialization parameters</td>
<td>B+</td>
</tr>
<tr>
<td>Oracle query tuning</td>
<td>A</td>
</tr>
<tr>
<td>Oracle database tuning</td>
<td>A</td>
</tr>
<tr>
<td>Oracle backup</td>
<td>A</td>
</tr>
<tr>
<td>Oracle recovery</td>
<td>A</td>
</tr>
<tr>
<td>Oracle ASM/hardware</td>
<td>B−</td>
</tr>
<tr>
<td>Oracle utilities</td>
<td>A</td>
</tr>
<tr>
<td>Operating system</td>
<td>B+</td>
</tr>
</tbody>
</table>

TIP

Reviewing a DBA’s ability should be done only if the review is used as a means of improving the DBA’s skills. Reviewing a person is a very sensitive issue and must be done by someone who has the goal of improvement in mind first and foremost. Critical knowledge for 12c includes the ability to use pluggable databases and the In-Memory column store, and the ability to review where the public cloud might be used (if at all).

Other Items to Consider in Your TPI and System Review

As I stated earlier, my goal in this chapter is to give the most basic barometer as a starting guide.
There are many things here that may or may not be important to your specific system. Following are some items that I also think may be important to consider in the system review that you develop and the TPI that you customize for your system:

- Are you effectively using ASM in your storage architecture?
- Do you have appropriate flashback technology implemented (including flashback PDB) as a means of accelerated recovery and high availability? No query is slower than the one accessing a system that is down!
- Are statistics being collected often enough (or too often)? Are they being collected too often on tables that are generally static? Is everything automated correctly?
- Have you used AWR and ADDM (see Chapters 5 and 14 for more information) to diagnose and fix potential problems?
- Has using Enterprise Manager Cloud Control made you faster at deploying new nodes and diagnosing RAC issues?
- Do you understand how to leverage the cloud and have you investigated leveraging the public cloud for use/nonuse? Are you leveraging big data, encrypted cloud backups, offsite storage and developer cloud systems?
- Are you testing new hardware in the public cloud instead of first buying it?
- Have you consolidated databases to a multitenant system leveraging pluggable databases?
- Do you have a sufficient test and development system to ensure proper testing before moving code to production? Can you test in the public cloud to save time, money, and effort?
- Have you set initialization parameters effectively that need minimum settings such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, PGA_AGGREGATE_LIMIT, JAVA_POOL_SIZE, and INMEMORY_SIZE? Have you investigated the use of MEMORY_TARGET?
- Do you have an encrypted backup, or could your system potentially face downtime, causing severe delays in production performance? Once again, no query is slower than the one accessing a system that is down!
- Are you ready for the next hardware upgrade? Have you considered Real Application Testing or testing on Oracle Cloud? Have you investigated future hardware return on investment (ROI), such as Violin Memory or other flash memory arrays, Oracle Exadata, Exalogic, or Exadata Storage Expansion Rack?

**Tips Review**

- Measuring your EPI (Education Performance Index) can be helpful in identifying educational improvements that might be beneficial.
- Measuring your SPI (System Performance Index) can be helpful in identifying overall system improvements that might be beneficial.
Measuring your MPI (Memory Performance Index) can be helpful in identifying potential memory allocation and usage improvements that could benefit your system, especially with 12c IM.

Measuring your DPI (Disk Performance Index) can be helpful in identifying potential disk improvements that might benefit your systems, especially with PDBs and ASM.

Measuring your TPI (Total Performance Index) can be helpful in identifying bottlenecks; it is a simple barometer of your overall system performance and may help you find areas needing improvement.

Have your system reviewed on an annual basis by an outside party or, at the minimum, by someone inside your company.

A system review should always include immediate action items. This ensures that the time needed for improvements will be allocated.

Reviewing a DBA’s ability should be done only if the review is used as a means of improving the DBA’s skills. Reviewing a person is a very sensitive issue and must be done by someone who has the goal of improvement in mind first and foremost in mind. Critical knowledge for 12c includes the ability to use pluggable databases and the In-Memory column store, and the ability to review where the public cloud might be used (if at all).

If you can’t effectively monitor your own system, then contract someone who can. The cost of maintaining a database is usually far less than the cost of downtime when problems occur. With the advent of Oracle Cloud, it’s easier to monitor from an outside party.

Include 12c new features (covered throughout this book) in your items to review as needed.

References
Maurice Aelion, Dr. Oleg Zhooravlev, and Arie Yuster, *Tuning Secrets from the Dark Room of the DBA*.
Memory Performance Index, Disk Performance Index, Education Performance Index, Total Performance Index, MPI, DPI, EPI, SPI and TPI (Copyright TUSC/RJN 1998–2016).
*Oracle Database New Features Guide*, versions 11g and 12c (Oracle Corporation).
*Oracle Database SQL Language Reference*, versions 11g and 12c (Oracle Corporation).

Many thanks to Brad Nash for updating the 10g version of this chapter. Thanks to Lucas Niemiec for testing the queries in this chapter. Thanks to Randy Swanson, Judy Corley, Sean McGuire, and Greg Pucka of TUSC for contributions to this chapter in previous versions.
Monitor the System Using Unix Utilities (DBA)

Part of being able to solve performance problems includes being able to use operating system utilities effectively. Using the correct utilities to find CPU, memory, and disk I/O issues is crucial to identifying where performance problems exist. Today’s DBAs and system managers increasingly include performance management as part of their duties. This chapter focuses on a few key and basic commands that will help you look at Oracle. It is meant for DBAs who are not as familiar with Unix or Linux.

Basically, two main categories of activities are needed for system management. The first, accounting and monitoring, consists of tools such as accounting logs, software monitors, hardware monitors, or manual logs to monitor system usage, workload, performance, availability, and reliability. Accounting and monitoring help system administrators perform load balancing and control resource usage. The second category, performance analysis, consists of using the monitored data to determine what system tuning is required and, by predicting future workload, when upgrading is required. In a broad sense, system performance refers to how well the computer resources accomplish the work they are supposed to do. This chapter gives you the utilities you need to accomplish both of these objectives.

Because the system utilities are part of Unix and vary from vendor to vendor, this chapter draws its details from one vendor and makes brief mention of other vendors. Including the details from Solaris, Linux, HP-UX, and AIX would take up too much space. Oracle is dedicated to Linux, most recently with Oracle Linux with Unbreakable Enterprise Linux Kernel. Oracle also is dedicated to Solaris with the acquisition of Sun Microsystems and has announced that Exadata and Exalogic will run on both Oracle Linux and Solaris. SAP has certified a version of Oracle Linux and has also decided to certify SAP on Exadata.

Unix/Linux Utilities

This chapter focuses on tips related to Unix and Linux utilities and shell scripts that can be used to find problems as well as gather statistics for monitoring. Tips covered in this chapter include:

- Using the `sar` command to monitor CPU usage
- Using `sar` and `vmstat` to monitor paging/swapping
- Using the `sar` command to monitor disk I/O problems
Finding the worst user on the system using the \texttt{top} command

Using the \texttt{uptime} command to monitor the CPU load

Using the \texttt{mpstat} command to identify CPU bottlenecks

Combining \texttt{ps} with selected V$ views

Using \texttt{iostat} to identify disk I/O bottlenecks

Determining shared memory usage using \texttt{ipcs}

Monitoring system load using \texttt{vmstat}

Monitoring disk free space

Monitoring network performance

\section*{Using the sar Command to Monitor CPU Usage}

The \texttt{sar} command has many different switches that you can set to display different pieces of performance information. With the \texttt{–u} switch, \texttt{sar} can be used to monitor CPU utilization. The \texttt{sar} utility is an effective way to see a quick snapshot of how much the CPU is “bogged down” or utilized (100 percent is not a good thing). Run this utility on a regular basis to get a baseline for your system, enabling you to identify when your system is running poorly. The \texttt{sar} command has the following benefits:

- Provides great information that you can use for performance tuning and monitoring
- Logs to a disk file (but does not provide per-process information)
- Requires low overhead to run
- Is found on most Unix and Linux platforms

\subsection*{\texttt{sar} –u (Check for CPU Bogged Down)}

With the \texttt{–u} switch, you can use \texttt{sar} to monitor CPU utilization. Of the two numbers following the switch for \texttt{sar} (in the following example the switch is \texttt{–u}), the first displays the number of seconds between \texttt{sar} readings, and the second is the number of times you want \texttt{sar} to run. Here is a sample report on HP-UX showing CPU utilization (the default):

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>%usr</td>
<td>Percent of CPU running in user mode</td>
</tr>
<tr>
<td>%sys</td>
<td>Percent of CPU running in system mode</td>
</tr>
<tr>
<td>%wio</td>
<td>Percent of CPU running idle with a process waiting for block I/O</td>
</tr>
<tr>
<td>%idle</td>
<td>Percent of CPU that is idle</td>
</tr>
</tbody>
</table>
A low %idle time could point to which processes are using the most CPU or an underpowered CPU. Use the `ps` or `top` command (discussed later in this chapter) to find a CPU-intensive job. A poorly written query requiring a large amount of disk access can also cause a large amount of CPU usage as well.

In the following `sar` output, the cause for concern is the large values being returned for %wio (waiting for block I/O) versus actual heavy CPU usage:

```
# sar -u 10 8

<table>
<thead>
<tr>
<th>Time</th>
<th>%usr</th>
<th>%sys</th>
<th>%wio</th>
<th>%idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:55:53</td>
<td>80</td>
<td>14</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>11:56:03</td>
<td>70</td>
<td>14</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>11:56:13</td>
<td>72</td>
<td>13</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>11:56:23</td>
<td>76</td>
<td>14</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>11:56:33</td>
<td>73</td>
<td>10</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>11:56:43</td>
<td>71</td>
<td>8</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>11:56:53</td>
<td>67</td>
<td>9</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>11:57:03</td>
<td>69</td>
<td>10</td>
<td>17</td>
<td>4</td>
</tr>
</tbody>
</table>

Average 73 11 13 4
```

A low %idle time could point to which processes are using the most CPU or an underpowered CPU. Use the `ps` or `top` command (discussed later in this chapter) to find a CPU-intensive job. A poorly written query requiring a large amount of disk access can also cause a large amount of CPU usage as well.

In the following `sar` output, the cause for concern is the large values being returned for %wio (waiting for block I/O) versus actual heavy CPU usage:

```
# sar -u 5 4

<table>
<thead>
<tr>
<th>Time</th>
<th>%usr</th>
<th>%sys</th>
<th>%wio</th>
<th>%idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:29:58</td>
<td>20</td>
<td>20</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>14:30:03</td>
<td>17</td>
<td>23</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>14:30:08</td>
<td>19</td>
<td>14</td>
<td>67</td>
<td>0</td>
</tr>
<tr>
<td>14:30:13</td>
<td>22</td>
<td>11</td>
<td>67</td>
<td>0</td>
</tr>
</tbody>
</table>

Average 21 16 64 0
```

This list shows a high %wio time, pointing toward a disk contention problem. The `iostat` command (discussed later in this chapter) can be used to pinpoint disk contention.

**TIP**

Use the `sar -u` command to see a quick snapshot of how much work the CPU is doing and whether the CPU is overwhelmed. Run `sar` on a regular basis to get a baseline for your system so you can identify when your system is running poorly. However, at times low CPU idle time can also be an I/O issue, not a CPU issue.

Here are some things to look for in `sar`’s output:
Low CPU idle times
- High percentage of time spent waiting on I/O or %wio > 10
- Bottlenecks with %sys > 15, which could indicate that swapping, paging, or backups are causing a bottleneck
- Abnormally high %usr, which could be due to applications not being tuned properly or CPU overutilization

The sar –d Command (Find I/O Problems)

The `sar –d` command reports the activity of block devices on the system for each disk or tape drive. This command helps identify heavily accessed disks and unbalanced disk I/O. Disk-stripping software frequently can help in cases where the majority of disk access goes to a handful of disks. When a large amount of data is making heavy demands on one disk or one controller, striping distributes the data across multiple disks and controllers. When the data is striped across multiple disks, accesses to it are averaged over all the I/O controllers and disks, thus optimizing overall disk throughput. Some disk-stripping software also provides support for Redundant Array of Inexpensive Disks (RAID) and the ability to keep one disk in reserve as a *hot standby* (that is, a disk that can be automatically rebuilt and used when one of the production disks fails). When thought of in this manner, RAID can be a very useful feature in terms of performance because a system that has been crippled by hard drive failure will be viewed by your user community as having pretty bad performance.

This information may seem obvious, but it is important to overall system performance. Frequently, the answer to disk performance simply rests on matching the disk architecture to system use. On Linux, the `sar –d` command does not return as much information, so you might want to use the `iostat` command instead. Here are some examples using `sar –d` to find disk I/O issues:

```
# sar -d

09:34:54  device  %busy avque  r/w/s  blks/s  avwait  avserv
09:34:59  c0t6d0  0.60  0.50  1  6  3.84  5.38
          c1t6d0  0.20  0.50  1  6  3.85  3.76
          c2t0d0  0.20  0.50  4  50  2.60  0.89
          c7t0d2  8.78  21.61  270  4315  10.33  1.77
          c7t0d3  8.78  21.82  267  4273  10.77  1.80
          c7t0d4  23.15  0.50  252  13019  5.06  1.51
          c7t0d5  0.60  0.50  1  19  6.15  6.48
09:35:04  c0t6d0  2.60  0.50  16 140  5.04  1.69
          c1t6d0  0.40  0.50  1  7  1.12  9.02
          c2t0d0  1.60  1.23  10 152  6.01  5.20
          c7t0d1  2.40  1.07  10 155  5.45  6.31
          c7t0d2  0.80  19.28  15 234  10.02  1.71
          c7t0d3  0.40  21.89  12 198  10.89  1.85
          c7t0d4  24.60  0.50  274 10357  5.04  1.22
```
Things to watch for in the `sar -d` output include the following:

- `%busy` on a device that is greater than 50 percent
- If `avwait` is greater than `avserv`
- Unbalanced disk I/O load

Here’s an example using `sar -d` that shows a disk I/O bottleneck. A high `%busy` and high `avque` indicates a disk I/O bottleneck. Consider the following output, where disk `sd17` is a big problem (it is 100 percent busy). If this condition persisted, an analysis of disk `sd17` should lead to a reorganization of information from `sd17` to a less-used disk. The `sar` command allows two significant numerical inputs (as shown next): the first is the number of seconds between running `sar`, and the second is how many times to run it (less than 5 indicates a five-second interval and 2 indicates two repetitions).

```bash
# sar -d 5 2

<table>
<thead>
<tr>
<th>device</th>
<th>%busy</th>
<th>avque</th>
<th>r+w/s</th>
<th>blks/s</th>
<th>avwait</th>
<th>avserv</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:37:11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fd0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd1</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd3</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd6</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd15</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd16</td>
<td>13</td>
<td>0.1</td>
<td>5</td>
<td>537</td>
<td>0.0</td>
<td>26.4</td>
</tr>
<tr>
<td>sd17</td>
<td>100</td>
<td>6.1</td>
<td>85</td>
<td>1951</td>
<td>0.0</td>
<td>72.4</td>
</tr>
<tr>
<td>sd18</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>13:37:16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fd0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd1</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd3</td>
<td>1</td>
<td>0.0</td>
<td>1</td>
<td>16</td>
<td>0.0</td>
<td>32.7</td>
</tr>
<tr>
<td>sd6</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sd15</td>
<td>3</td>
<td>0.1</td>
<td>1</td>
<td>22</td>
<td>0.0</td>
<td>92.3</td>
</tr>
<tr>
<td>sd16</td>
<td>13</td>
<td>0.1</td>
<td>5</td>
<td>570</td>
<td>0.0</td>
<td>25.3</td>
</tr>
<tr>
<td>sd17</td>
<td>100</td>
<td>6.1</td>
<td>85</td>
<td>1962</td>
<td>0.0</td>
<td>71.2</td>
</tr>
<tr>
<td>sd18</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Tuning Disk-Bound Systems**

Faster disks, disk cache, and flash take care of many disk-bound issues for larger customers, but I have a few points in this section for smaller customers without that luxury. Conceptually, upgrading
disk systems is fairly easy. Get faster disks, get faster controllers, and get more disks. The problem is predicting how much of an improvement you can expect from a given upgrade. If the system is truly spindle bound, and the load is parallelizable such that adding more disks is practical, this route is almost always the best way to go. When a straightforward upgrade path exists, no more likely or predictable way to improve a system’s I/O exists than to increase the number of disks. The problem is that a straightforward path for this sort of upgrade isn’t always obvious.

For example, assume you have one state-of-the-art disk on its own controller storing sendmail’s message queue, and the system has recently started to slow down. There are two ways to add a second disk effectively to a sendmail system. First, you could add the disk as its own filesystem and use multiple queues to divide the load between the disks. This upgrade will work, but it will become more difficult to maintain and potentially unreliable if it is repeated too many times. Second, you could perform a more hardware-centric solution, upgrading to either create a hardware RAID system, install a software RAID system to stripe the two disks together, or add NVRAM (nonvolatile RAM—retains its contents even when power is lost) to accelerate the disk’s performance. With any of these solutions, upgrading the filesystem might also become necessary. None of these steps is a trivial task, and there’s no way to be nearly as certain about the ultimate effect on performance with the addition of so many variables.

Obviously, you can’t add disks without considering the potential effect on the I/O controller. Some systems have limits that restrict the number of controllers that can be made available to the operating system. Although I rarely push the limits of controller throughput with a small number of disks because e-mail operations are so small and random, adding so many disks on a system that you run out of chassis space in which to install controller cards is possible.

Any time a system has I/O problems, do not make the mistake of quickly dismissing the potential benefits of running a high-performance filesystem. This solution is usually inexpensive and effective, and where available, it can offer the best bang for the buck in terms of speed improvement. If I am asked to specify the hardware for an e-mail server, in situations where I have complete latitude in terms of hardware vendors, I know I can get fast disks, controllers, RAID systems, and processors for any operating system. The deciding factor for the platform then usually amounts to which high-performance file systems are supported. This consideration is that important.

If a RAID system is already in use, performance might potentially be improved by rethinking its setup. If the storage system is running out of steam using RAID 5 but has plenty of disk space, perhaps going to RAID 0+1 will improve performance and increase the box’s hardware life. If the system is having problems with write bandwidth, lowering the number of disks per RAID group and, therefore, having a greater percentage of the disk space devoted to parity may help. Using some of your unused space is certainly preferable to buying a new storage system. Changing the configuration of the storage system is especially worth considering if it wasn’t set up by someone who really understands performance tuning.

If a RAID system has been set up suboptimally, you may be able to improve its performance by upgrading. Vendors often provide upgrade solutions to their RAID systems that can improve their throughput, both in terms of hardware components and the software that manages the system.

Lastly, to save money, the system might have originally included insufficient NVRAM or read cache. Performance might improve dramatically if you increase the NVRAM.

You can also use `tunefs/tune2fs` to help with disk issues. (On AIX, use `chfs`.) The `tunefs/tune2fs` command lists the current characteristics of a file system (careful—some commands
cannot be run on an active system, so check your documentation for more information before running these):

tuneefs -v .../rdsk/c0txdx

To set minfree (the percentage of reserved filesystem blocks) to 5 percent, use the following command (be careful, however; setting this could increase the overhead for file writes and reduce the file system’s ability to avoid fragmentation):

tuneefs -m 5 /dev/dsk/c2d5s0

To change rotational delay from 1 to 0 (generally the default set with newfs and mkfs is 0, which should make tuning this with tuneefs unnecessary):

tuneefs -d 0 /dev/rdsk/c0txd0

Refer to Chapter 3 for additional information on tuning disk I/O at the database level.

The sar –b Command (Check the Buffer Cache)

The sar –b command reports on the system’s buffer cache activities (not the Oracle buffer cache). It gives you the number of transfers per second between system buffers and block devices. The main parameters to look for are as follows:

- Read cache: %rcache > 90%, indicating the potential for bad disk I/O
- Write cache: %wcache < 70%, likewise indicating the potential for bad disk I/O
To look deeper into the buffer cache operation, consider a typical HP processor module. It consists of a CPU, a cache, a transaction look-aside buffer (TLB), and a coprocessor. These components are connected together with buses, and the processor module itself is connected to the system bus. The cache is a very high-speed memory unit. Typical access times are 10–20 nanoseconds (ns), compared to RAM, which is typically 80–90 ns. The cache can be accessed in one CPU cycle. Its contents and instructions and data that was recently or is anticipated to be used by the CPU are stored here. The TLB is used to translate virtual addresses into physical addresses. It’s a high-speed cache whose entries consist of pairs of recently used virtual addresses and their associated physical addresses. The coprocessor is a specialized piece of hardware that does complex mathematical numerical instructions. For memory management in Unix, `vhand` is the paging daemon. The buffer cache, as you can see from the HP example, is a pool of memory designed to decrease file access time. Here are some other noteworthy buffer cache characteristics:

- The buffer cache can have a fixed state.
- The default system uses dynamic size allocation.
- The buffer cache can increase performance of disk reads and writes.
- Data is flushed from the buffer cache by the Sync process.

### The sar –q Command (Check the Run Queue and Swap Queue Lengths)

The `sar –q` command reports on the system’s run queue lengths and swap queue lengths. On Linux, it also gives the average load numbers. The `–q` switch gives the length of the run queue (runq-sz), the percentage of time the run queue was occupied (%runocc), the length of the swap queue (swpq-sz), and the percentage of time the swap queue was occupied (%swpocc); the smaller these numbers, the better. You need to compare `sar –q` to `sar –w` data to see if the runq-sz is greater than 4 or the %swpocc is greater than 5, which signals a potential issue.

```
sar –q

10:00:18 runq-sz %runocc swpq-sz %swpocc
10:00:23 0.0 0 0.0 0
10:00:28 0.0 0 0.0 0
10:00:33 0.0 0 0.0 0
10:00:38 0.0 0 0.0 0
10:00:43 1.0 5 0.0 0

Average 1.0 1 0.0 0
```
Using the sar and vmstat Commands to Monitor Paging/Swapping

A quick way to determine if any swapping activity has occurred since the system started is to issue the command `vmstat -s`. Having a non-zero value in the swp/in and swp/out columns is a good indicator of a possible problem. You can delve into more detail using the `sar` command, which you can also use to check for system paging and swapping. Depending on the system, any paging and swapping could be a sign of trouble. In a virtual memory system, paging is when users who are not currently active are moved from memory to disk (a small issue). Swapping is when users who are currently active are moved to disk due to insufficient memory (very large issue). Swapping and paging could easily take an entire book due to the depth of the subject. Simple and fast commands to get a general picture of the state of your system are covered in this chapter.

Using sar –p to Report Paging Activities

The following table describes the fields displayed with the `sar –p` command. On Linux, use `sar -B`. On AIX, use `sar -r`.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>atch/s</td>
<td>Page faults per second that are satisfied by reclaiming a page currently in memory (per second); (if the field name is faults/s on Linux with a -B)</td>
</tr>
<tr>
<td>pgin/s</td>
<td>Page-in requests per second</td>
</tr>
<tr>
<td>ppgin/s</td>
<td>Pages paged in per second</td>
</tr>
<tr>
<td>pflt/s</td>
<td>Page faults from protection errors per second (illegal access to page) or “copy-on-writes”</td>
</tr>
<tr>
<td>vflt/s</td>
<td>Address translation page faults per second (valid page not in memory)</td>
</tr>
<tr>
<td>slock/s</td>
<td>Faults per second caused by software lock requests requiring physical I/O</td>
</tr>
</tbody>
</table>

```
# sar -p 5 4

<table>
<thead>
<tr>
<th></th>
<th>atch/s</th>
<th>pgin/s</th>
<th>ppgin/s</th>
<th>pflt/s</th>
<th>vflt/s</th>
<th>slock/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:37:41</td>
<td>13.15</td>
<td>20.12</td>
<td>179.03</td>
<td>11.16</td>
<td>2.19</td>
<td>58.57</td>
</tr>
<tr>
<td>14:37:46</td>
<td>34.33</td>
<td>20.56</td>
<td>186.23</td>
<td>4.19</td>
<td>1.40</td>
<td>57.49</td>
</tr>
<tr>
<td>14:37:51</td>
<td>22.36</td>
<td>19.56</td>
<td>151.30</td>
<td>2.20</td>
<td>0.00</td>
<td>60.88</td>
</tr>
<tr>
<td>14:37:56</td>
<td>24.75</td>
<td>22.36</td>
<td>147.90</td>
<td>1.80</td>
<td>0.00</td>
<td>60.28</td>
</tr>
<tr>
<td>Average</td>
<td>27.37</td>
<td>20.11</td>
<td>161.81</td>
<td>7.58</td>
<td>8.14</td>
<td>60.85</td>
</tr>
</tbody>
</table>
```

The key statistic to look for is an inordinate number of page faults of any kind. A high value usually
indicates a high degree of paging. Remember that paging is not nearly as bad as swapping, but as paging increases, swapping will soon follow. You can review the daily reports over a period of time to see if paging is steadily increasing during a specific time frame. The command `sar -p` without any time intervals shows you the paging statistics from the entire day if you have enabled periodic automatic monitoring.

Using sar –w to Report Swapping and Switching Activities

The `sar` command with the `-w` switch shows swapping activity. On Linux, use the `-w` switch. On AIX, you have only paging, not swapping. The `sar-w` command displays the swpin/s, swpot/s, bswin/s, and bswot/s fields, which are the number of transfers and number of 512-byte units transferred for swapins and swapouts (including initial loading of some programs). The field pswch/s shows context switches that occur per second. pswch/s should be less than 50. Examine swapping activity closely if swpot/s rises above 0.

```
#sar -w 5 4

SunOS hrdev 5.10 Generic sun4m 08/05/08

<table>
<thead>
<tr>
<th></th>
<th>swpin/s</th>
<th>bswin/s</th>
<th>swpot/s</th>
<th>bswot/s</th>
<th>pswch/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:45:22</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
<td>294</td>
</tr>
<tr>
<td>14:45:27</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
<td>312</td>
</tr>
<tr>
<td>14:45:32</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
<td>322</td>
</tr>
<tr>
<td>14:45:37</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
<td>327</td>
</tr>
<tr>
<td>Average</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0</td>
<td>312</td>
</tr>
</tbody>
</table>
```

A high count for process switching points toward a memory deficiency because actual process memory is being paged. Swapping is not a problem in the preceding example.

Using sar –r to Report Free Memory and Free Swap

The following command line and output illustrate the `sar` command with the `-r` switch:

```
```
When freemem (free memory—listed here in 512-byte blocks) falls below a certain level, the system starts to page. If it continues to fall, the system then starts to swap out processes—a sign of a rapidly degrading system. Look for processes taking an extreme amount of memory, or else an excessive number of processes. On Linux and HP-UX, use `vmstat`.

### Using sar –g to Report Paging Activities

The following table describes the fields displayed with the `–g` switch. On Linux, use `sar –B`. On AIX, use `sar –r`.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pgout/s</td>
<td>Page-out requests per second.</td>
</tr>
<tr>
<td>ppgout/s</td>
<td>Pages paged out per second.</td>
</tr>
<tr>
<td>pgfree/s</td>
<td>Pages per second placed on the freelist by the page-stealing daemon.</td>
</tr>
<tr>
<td>pgscan/s</td>
<td>Pages per second scanned by the page-stealing daemon.</td>
</tr>
<tr>
<td>%ufs</td>
<td>The percentage of Unix File System (UFS) inodes taken off the freelist by iget (a routine called to locate a file's inode entry) that had reusable pages associated with them. These pages are flushed and cannot be reclaimed by processes. This is the percentage of igets with page flushes.</td>
</tr>
</tbody>
</table>

A high ppgout value (pages being moved out of memory) points toward a memory deficiency.
Using sar –wpgr to Report on Memory Resources

More information about the system's utilization of memory resources can be obtained by using sar –wpgr (this combines the previously listed switches):

```bash
% sar wpgr 5 5
07:42:30 swpin/s pswin/s swpot/s bswot/s pswch/s
    atch/s pgin/s ppgin/s pflt/s vflt/s slock/s
    pgout/s ppgout/s pgfree/s pgscan/s $s5ipf
    freemem freeswp
07:42:35  c.00  c.00  c.00  c.00  5.04
         c.00  c.00  c.00  c.00  6.20  11.78
         c.00  c.00  c.00  c.00  0.00
         33139  163023
...
Average  c.00  c.00  c.00  c.00  515
Average  c.00  0.32  0.40  2.54  5.56  16.03
Average  c.00  c.00  c.00  c.00  0.00
Average  32926  183015
```

Check for page-outs (pgout/s means page-out requests per second; ppgout/s means page-out pages per second), and watch for their consistent occurrence. Look for a high incidence of address translation faults (vflt/s). Check for swap-outs (swpot/s). Occasional swap-outs may not be a cause for concern, as some number of them is normal (for example, inactive jobs). However, consistent swap-outs are usually bad news, indicating that the system is very low on memory and is probably sacrificing active jobs. If you find evidence of memory shortages in any of these, you can use ps to look for memory-intensive jobs.

**TIP**

*Use the sar command to monitor and evaluate memory use and the potential need for additional memory. Paging is generally the movement of inactive processes from memory to disk. A high degree of paging is generally the predecessor to swapping. Swapping is the movement of active processes from memory to disk. If swapping starts to escalate, your system begins the downward “death spiral.” Fixing memory hogs or adding memory is the correct solution.*

**What’s a Good Idle Percentage for the CPU?**

The optimum idle percentage depends on the system size and variation in time accessed. For instance, a system that is accessed with heavy CPU usage for short periods of time may have an 80 percent average CPU idle time. In contrast, a system with very small jobs, but many of them, may have the
same 80 percent average CPU idle time. In 12c, consolidating systems by using multitenant databases usually results in the idle percentage being much higher and the heavy usage periods being much lower (by averaging all systems into one). The idle percentage is not as important as what is available when you run a job that must complete immediately (and is very important to the business). A 50-percent idle CPU may be a problem for the company with a large CPU-bound job that must complete quickly, whereas a 10-percent idle CPU may be more than enough for a company that has a very small job (requiring little CPU) that must complete quickly. Oracle generally attempts to use the entire available CPU to complete a job.

I have found it helpful to run `sar` at regularly scheduled intervals throughout the day. The overhead of running `sar` is minimal, and it can be a great help in determining what was happening on your system last week when the problem actually started occurring. You have the ability to keep information in report format for 30 days by default. The following entries in crontab produce a snapshot of the system state every 20 minutes during working hours:

```
20,40 8-17 * * 1-5 /usr/lib/sa/sa1
```

The next entry produces a report of important activities throughout the workday:

```
5 18 * * 1-5 /usr/lib/sa/sa2 -s 8:00 -e 18:01 -i 1200 -A
```

To access the report at any time, simply type `sar` with the appropriate switches and you will see output for each sampling period. For further information, see your man pages for “sar,” “sa1,” and “sa2.”

**TIP**

In 12c, consolidating systems by using multitenant databases usually results in the CPU idle percentage being much higher and the heavy CPU usage periods being much lower (by averaging all systems into one). Using pluggable databases to average out the load on a single multitenant system can be very effective!

**CPU Scheduler and Context Switching**

The goal in tuning is to keep the CPU as busy as possible so it uses all available resources allotted to get things done faster. The five major process states are as follows:

- **SRUN** The process is running or runnable.
- **SSLEEP** The process is waiting for an event in memory or on the swap device.
- **SZOMB** The process has released all system resources except for the process table. This is
the final process state.

- **SIDL** The process is being set up via `fork` and/or `exec`.
- **SSTOP** The process has been stopped by job control or by process tracing and is waiting to continue.

The CPU scheduler handles context switches and interrupts. In multiprocessing environments, a *context switch* is when one process is suspended from execution on the CPU, its current state is recorded, and another process starts its execution. Obviously, in computer processing environments, the goal is good CPU and computer system component design in order to reduce context switch management overhead, or to have a processing load that works more efficiently and does not require too many context switches. Context switching occurs when any of the following occur:

- A time slice expires
- A process exits
- A process puts itself to sleep
- A process puts itself in a stopped state
- A process returns from user mode from a system call but is no longer the most eligible process to run
- A real-time priority process becomes ready to run

### Checking Oracle CPU Utilization Within Oracle

This section explains how to examine the processes running in Oracle. `V$SYSSTAT` shows Oracle CPU usage for all sessions. The statistic “CPU used by this session” actually shows the aggregate CPU used by all sessions. `V$SESSTAT` shows Oracle CPU usage per session. You can use this view to see which particular session is using the most CPU.

For example, if you have eight CPUs, then, for any given minute in real time, you have eight minutes of CPU time available. On Windows and Unix-based systems, this can be either user time or system mode time (“privileged” mode, in Windows). If your process is not running, it is waiting. CPU utilized by all systems may, therefore, be greater than one minute per interval.

At any given moment, you know how much time Oracle has utilized on the system. So if eight minutes are available and Oracle uses four minutes of that time, then you know that 50 percent of all CPU time is used by Oracle. If your process is not consuming that time, then some other process is. Return to the system to discover what process is using up the CPU. Identify the process, determine why it is using so much CPU, and see if you can tune it. If the `CPU_COUNT` initialization parameter is manually set to 4 for an instance running on an eight-CPU system, that could also explain why it was only using up to 50 percent of the CPU resources. By default, an instance has `CPU_COUNT` set to the number of physical CPUs (or cores) on the server, but this parameter can be changed.

The major areas to check for Oracle CPU utilization are

- Reparsing SQL statements
Finding the Worst User on the System Using the `top` Command

The `top` command shows a continuous display of the most active processes. DBAs and operations experts often run this (or similar utilities) at the first sign of system performance issues. This display automatically updates itself on the screen every few seconds. The first lines give general system information, while the rest of the display is arranged in order of decreasing current CPU usage (the worst user is on “top”). If your system does not have `top` installed, it is commonly available from [http://sunfreeware.com](http://sunfreeware.com) or various other sources on the Web. Simply do a web search for “`top program download`” and you should be rewarded with multiple locations from which to download the program. On AIX, the command is `topas`. On Solaris, both `prstat` and `top` are available.

```
# top
```

Cpu states: 0.0% idle, 91.0% user, 17.7% kernel, 0.0% wait, 0.5% swap
Memory: 785M real, 12M free, 318M swap, 1588M free swap

<table>
<thead>
<tr>
<th>PID</th>
<th>USERNAME</th>
<th>PRI</th>
<th>NICE</th>
<th>SIZE</th>
<th>RES</th>
<th>STATE</th>
<th>TIME</th>
<th>WCPU</th>
<th>CPU</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>23626</td>
<td>psoft</td>
<td>-25</td>
<td>2</td>
<td>208M</td>
<td>4890K</td>
<td>cpu</td>
<td>1:20</td>
<td>22.47%</td>
<td>99.63%</td>
<td>oracle</td>
</tr>
<tr>
<td>15619</td>
<td>root</td>
<td>-15</td>
<td>4</td>
<td>2372K</td>
<td>716K</td>
<td>sleep</td>
<td>22:19</td>
<td>0.61%</td>
<td>3.81%</td>
<td>pmon</td>
</tr>
<tr>
<td>20434</td>
<td>oracle</td>
<td>33</td>
<td>0</td>
<td>207M</td>
<td>2340K</td>
<td>sleep</td>
<td>2:47</td>
<td>0.23%</td>
<td>1.14%</td>
<td>oracle</td>
</tr>
<tr>
<td>20404</td>
<td>oracle</td>
<td>33</td>
<td>0</td>
<td>93M</td>
<td>2300K</td>
<td>sleep</td>
<td>2:28</td>
<td>0.23%</td>
<td>1.14%</td>
<td>oracle</td>
</tr>
<tr>
<td>23650</td>
<td>root</td>
<td>33</td>
<td>0</td>
<td>2052K</td>
<td>1584K</td>
<td>cpu</td>
<td>0:00</td>
<td>0.23%</td>
<td>0.95%</td>
<td>top</td>
</tr>
<tr>
<td>23625</td>
<td>psoft</td>
<td>27</td>
<td>2</td>
<td>5080K</td>
<td>3420K</td>
<td>sleep</td>
<td>0:17</td>
<td>1.59%</td>
<td>0.38%</td>
<td>sql</td>
</tr>
<tr>
<td>23554</td>
<td>root</td>
<td>27</td>
<td>2</td>
<td>2260K</td>
<td>1300K</td>
<td>sleep</td>
<td>0:01</td>
<td>0.66%</td>
<td>0.38%</td>
<td>br2.1.adm</td>
</tr>
<tr>
<td>15818</td>
<td>root</td>
<td>21</td>
<td>4</td>
<td>8160K</td>
<td>2716K</td>
<td>sleep</td>
<td>2:05</td>
<td>0.04%</td>
<td>0.19%</td>
<td>proctool</td>
</tr>
<tr>
<td>697</td>
<td>root</td>
<td>34</td>
<td>0</td>
<td>8140K</td>
<td>1620K</td>
<td>sleep</td>
<td>55:46</td>
<td>0.00%</td>
<td>0.00%</td>
<td>Xsun</td>
</tr>
<tr>
<td>20630</td>
<td>psoft</td>
<td>-9</td>
<td>2</td>
<td>7056K</td>
<td>2748K</td>
<td>sleep</td>
<td>7:14</td>
<td>0.67%</td>
<td>0.00%</td>
<td>PSRUN</td>
</tr>
<tr>
<td>20854</td>
<td>psoft</td>
<td>-8</td>
<td>2</td>
<td>208M</td>
<td>4664K</td>
<td>sleep</td>
<td>4:21</td>
<td>0.52%</td>
<td>0.00%</td>
<td>oracle</td>
</tr>
<tr>
<td>737</td>
<td>oracle</td>
<td>22</td>
<td>0</td>
<td>3844K</td>
<td>1756K</td>
<td>sleep</td>
<td>2:56</td>
<td>0.00%</td>
<td>0.00%</td>
<td>tnslsnr</td>
</tr>
<tr>
<td>2749</td>
<td>root</td>
<td>28</td>
<td>0</td>
<td>1512K</td>
<td>736K</td>
<td>sleep</td>
<td>1:03</td>
<td>0.00%</td>
<td>0.00%</td>
<td>ipNet</td>
</tr>
<tr>
<td>18529</td>
<td>root</td>
<td>14</td>
<td>10</td>
<td>2232K</td>
<td>1136K</td>
<td>sleep</td>
<td>0:56</td>
<td>0.00%</td>
<td>0.00%</td>
<td>xlock</td>
</tr>
<tr>
<td>1</td>
<td>root</td>
<td>33</td>
<td>0</td>
<td>412K</td>
<td>130K</td>
<td>sleep</td>
<td>0:55</td>
<td>0.00%</td>
<td>0.00%</td>
<td>init</td>
</tr>
</tbody>
</table>

The preceding display shows the top user to be psoft with a PID (Process ID) of 23626 (this output may be slightly different on your system). This user is using 99.63 percent of one CPU. If this output persisted for any length of time, finding out *who* this is and *what* he or she is doing would be imperative! I will show how to link this back to an Oracle user employing the `ps` command and querying the V$ views later in this chapter.
TIP
Use the `top` command to find the worst user on the system at a given point in time (the `kill` command usually follows for many DBAs). If the worst query lasts only a short period of time, it may not be a problem; but if it persists, additional investigation may be necessary.

Monitoring Tools

There are GUI monitoring tools available (Oracle Cloud Control comes to mind) on most platforms that either come bundled with the software or are available on the Internet. The Task Manager and "perfmon" are available on Windows; `sdtprocess` and Management Console are available for later versions of Solaris (once again http://sunfreeware.com has a plethora of free tools); `nmon` (within `topas` command) is available for AIX; and tools like Superdome Support Management Station (SMS), glance, and HP Servicecontrol Manager are available for HP. When using any tools, remember to manage system performance with the following guidelines:

- Measure performance continuously.
- Assess systems and applications.
- Select the tool to use.
- Monitor.
- Troubleshoot issues that arise.
- Remove bottlenecks.
- Optimize applications.
- Plan for future workloads.

You will also find it worthwhile to remember to always use basic tuning guidelines:

- Do not tune at random except to solve an emergency.
- Measure before and after you tune.
- Tune one area at a time, and only change one thing at a time.
- Always use at least two tools when possible to evaluate tuning decisions.
- Know when to say stop!

Using the `uptime` Command to Monitor CPU Load

The `uptime` command is an excellent utility for quickly viewing the CPU load averages for the past 1,
The `uptime` command also displays how long the system has been running (the `uptime`) and the number of users on the system. You want to look at the load average. This is the number of jobs in the CPU run queue for the last 1, 5, and 15 minutes. Note that this is not the percentage of CPU being used.

```
# uptime
3:10pm up 5 day(s), 19:04, 2 users, load average: 2.10, 2.50, 2.20
```

I have found that a system with an average run queue of 2–3 is acceptable. If you add the following script to your cron table to run every hour, your average system load will be e-mailed to you every two hours:

```
{uptime; sleep 120; uptime; sleep 120; uptime;} | mailx -s uptime
you@company.com
```

**TIP**

Use `cron` and `uptime` to have your system load e-mailed to you on a regular basis. See your Unix manual for any specific syntax when using these commands.

### Using the `mpstat` Command to Identify CPU Bottlenecks

The `mpstat` command is a tool on Solaris, Linux, and AIX that reports per-processor statistics in tabular form. When using the `mpstat` command, you set the time interval between reports and the number of times `mpstat` should repeat. Each row of the table represents the activity of one processor. The first table shows the summary of activity since boot time. Pay close attention to the `smtx` measurement, which indicates the number of times the CPU failed to obtain a mutex (mutual exclusion lock). Mutex stalls waste CPU time and degrade multiprocessor scaling. In the example that follows, there are four processors numbered 0–3, and a system that is heading toward disaster is displayed (this output is specific to Solaris).
TIP
If the smtx column for the `mpstat` output is greater than 200, you are heading toward CPU bottleneck problems.

Combining `ps` with Selected V$ Views
Which process is using the most CPU? The following `ps` Unix command lists the top nine CPU users (much like the `top` command in “Finding the Worst User on the System Using the top Command,” earlier in this chapter):
This command lists the %CPU used, the process ID (PID), the Unix username, and the command that was executed. If the top user was an Oracle user, you could then get the information on the process from Oracle using the queries listed next. You do this by passing the system PID obtained from the `ps` command into the following queries:

```sql
-- ps_view.sql
col username format a15
col osuser format a10
col program format a20
set verify off
select a.username, a.osuser, a.program, spid, sid, a.serial#
from v$sessions a, v$process b
where a.paddr = b.addr
and spid = '&spid';

-- ps_sql.sql
set verify off
column username format a15
column sql_text format a60
undefine sid
define serial#
accept sid prompt 'sid: '
accept serial prompt 'serial#': '
select 'SQL Currently Executing: '
from dual;

select b.username, a.sql_text
from v$sql a, v$session b
where b.sql_address = a.address
and b.sql_hash_value = a.hash_value
and b.sid = &sid
and b.serial# = '&serial';
```
The following output shows an example that identifies the top CPU user utilizing the previously described commands and scripts:

```
$ ps -e -o pcpu,pid,user,args | sort -k 3 -r | tail

<table>
<thead>
<tr>
<th>%CPU</th>
<th>PID</th>
<th>USER</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>650</td>
<td>nobody</td>
<td>/opt/SUNWsymon/sbin/sm_logscand</td>
</tr>
<tr>
<td>0.4</td>
<td>3242</td>
<td>oracle</td>
<td>ora_dbwr_DM6</td>
</tr>
<tr>
<td>0.4</td>
<td>3264</td>
<td>oracle</td>
<td>ora_dbwr_DMO</td>
</tr>
<tr>
<td>0.4</td>
<td>3316</td>
<td>oracle</td>
<td>ora_dbwr_CNV</td>
</tr>
<tr>
<td>0.4</td>
<td>4383</td>
<td>oracle</td>
<td>ora_dbwr_qat</td>
</tr>
<tr>
<td>0.5</td>
<td>3</td>
<td>root</td>
<td>fsflush</td>
</tr>
<tr>
<td>0.8</td>
<td>654</td>
<td>root</td>
<td>/opt/SUNWsymon/sbin/sm_krd -i 10</td>
</tr>
<tr>
<td>1.7</td>
<td>652</td>
<td>root</td>
<td>/opt/SUNWsymon/sbin/sm_configfd -i 10</td>
</tr>
<tr>
<td>3.6</td>
<td>4602</td>
<td>oracle</td>
<td>oracleCNV (LOCAL=NO)</td>
</tr>
</tbody>
</table>
```

$ sqlplus system/manager

SQL> @ps_view

Enter value for pid: 4602

Note that I use 4602 as the input, as it is the PID for the worst CPU from the `ps` command:

```
old 4: and spid='&pid'
new 4: and spid='4602'
```

```
USERNAME | OSUSER | PROGRAM          | SPID | SID | SERIAL#
---------|--------|------------------|------|-----|--------
DBAENT   | mag    | sqlplus@hrtest   | 4602 | 10  | 105    
```

SQL> @ps_sql

sid: 10
serial#: 105

Note that I use 10 as the SID and 105 as the serial#, as they were the values retrieved in the preceding query (PS_VIEW.SQL):

```sql
select b.username, a.sql_text
from v$open_cursor a, v$session b
where b.sql_address = a.address
and b.sql_hash_value = a.hash_value
and b.sid = &sid
and b.serial# = '&serial';
```
Putting it all together (setting headings off), you get

If you had a problem with users executing ad hoc queries and received problem queries that showed up in this result on a regular basis, you could add an automated kill command at the end to automate your job completely.

TIP
Combine operating system utilities with Oracle utilities to find problematic users quickly and effectively.

CPU/Memory Monitoring Tool (Task Manager) on
Windows

Task Manager can be used to monitor CPU and memory use under Windows. You can also select the columns to display in Task Manager, one of which is the process ID. However, because Oracle uses threaded processes, I did not find this feature useful in mapping to Oracle session IDs.

Using the iostat Command to Identify Disk I/O Bottlenecks

You can also use the `iostat` command to identify a disk bottleneck. The `iostat` command reports terminal and disk I/O activity, as well as CPU utilization. The first line of the output is for everything since booting the system, whereas each subsequent line shows only the prior interval specified.

Depending on the flavor of Unix, this command has several options (switches). The most useful switches are usually `-d` (transfers per second by disk), `-x` (extended statistics), `-D` (reads and writes per second by disk), `-t` (terminal or tty), and `-c` (CPU load). The basic format for this is:

```
iostat [option] [disk] [interval] [count]
```

Using the `-d` switch, you can list the number of kilobytes transferred per second for specific disks, the number of transfers per second, and the average service time in milliseconds. This displays I/O only; it doesn’t distinguish between read and writes.

Using `iostat –d for Disk Drives sd15, sd16, sd17, and sd18`

The output that follows shows that sd17 is severely overloaded compared to the other drives. Moving information from sd17 to one of the other drives would be a good idea if this information is representative of disk I/O on a consistent basis.
Using `iostat –D`

The `-D` switch reports the reads per second, writes per second, and percentage disk utilization:

```
$ iostat -D sd15 sd16 sd17 sd18 5 5
```

<table>
<thead>
<tr>
<th>rps</th>
<th>wps</th>
<th>util</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.3</td>
</tr>
<tr>
<td>0</td>
<td>25</td>
<td>90.6</td>
</tr>
<tr>
<td>0</td>
<td>24</td>
<td>94.7</td>
</tr>
<tr>
<td>0</td>
<td>24</td>
<td>93.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>rps</th>
<th>wps</th>
<th>util</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0</td>
<td>6.2</td>
</tr>
<tr>
<td>227</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

This shows that the activity on sd17 is entirely read activity, whereas the activity on sd16 is strictly write activity. Both drives are at a peak level of utilization, and I may also have I/O problems. These statistics were gathered during a backup of sd17 to sd16. Your system should never look this bad!

Using `iostat –x`

Using the `-x` switch reports extended disk statistics for all disks. This combines many of the switches mentioned previously.

```
extended_disk_statistics
<table>
<thead>
<tr>
<th>disk</th>
<th>r/s</th>
<th>w/s</th>
<th>Kr/s</th>
<th>Kw/s</th>
<th>wait</th>
<th>activ</th>
<th>svc_t</th>
<th>%w</th>
<th>%b</th>
</tr>
</thead>
<tbody>
<tr>
<td>fd0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sd1</td>
<td>0.0</td>
<td>0.0</td>
<td>23.2</td>
<td>6.4</td>
<td>0.0</td>
<td>0.0</td>
<td>31.3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>sd3</td>
<td>0.0</td>
<td>1.2</td>
<td>0.0</td>
<td>9.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sd6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>sd15</td>
<td>0.0</td>
<td>1.6</td>
<td>0.0</td>
<td>12.8</td>
<td>0.0</td>
<td>0.1</td>
<td>93.3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>sd16</td>
<td>0.0</td>
<td>5.8</td>
<td>0.0</td>
<td>315.2</td>
<td>0.0</td>
<td>0.1</td>
<td>25.0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>sd17</td>
<td>73.0</td>
<td>2.8</td>
<td>912.1</td>
<td>117.2</td>
<td>0.0</td>
<td>6.9</td>
<td>90.8</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>sd18</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
```
Combining iostat –x with Logic in a Shell Script

The script in this section takes the iostat –x output, sorts it by the busy field (%b), and prints out the ten busiest disks for the listed interval. Some options for this script are listed here, followed by the script example and output:

- This is the diskbusy script built on 1/1/2009:
  - The shell is running in !/bin/ksh.
  - This script gets an iostat –x listing and sorts it by %b field.
  - Change print $10 to sort by a different field.
  - Change to iostat –x 5 5 to get a different interval and count (5 seconds/5 times).
  - Change tail to tail –20 to get the top 20 busiest disks only.

```
iostat -x | awk '/^disk/'
iostat -x 5 5 | grep -v '^[ ]' | grep -v '^[ ]disk' | awk '{
    print $10", ", "$0
}
}' | sort -n | awk -F, '{
    print $2
}' | tail
```

Running the preceding shell script, I receive this output:
In the preceding example, I run `iostat` five times and the top ten busiest disks are displayed over all five runs. The disk `sd17` is listed five times because it hits the combined top ten all five times that `iostat` is run.

TIP

*Use the `sar` and `iostat` commands to find potential disk I/O problem areas. Utilizing the capabilities of shell scripting with these commands embedded can further enhance these commands.*

### Using the `ipcs` Command to Determine Shared Memory

Another helpful memory command that you can use to monitor the Oracle SGA is the `ipcs` command. The `ipcs` command displays the size of each shared memory segment for the SGA. If there is not enough memory for the entire SGA to fit in a contiguous piece of memory, the SGA will be built in noncontiguous memory segments. In the event of an instant crash, the memory might not be released. If this happens to you, note that the `ipcrm` command removes the segments (`ipcrm -m` for memory segments and `ipcrm -s` for semaphore segments). Use `ipcs -b` on Solaris and `ipcs -a` on Linux, HP-UX, and AIX.

```bash
# ipcs -b

Shared Memory:

m  204 0x171053d8 --rw-r----- oracle   dba  65336
m  205 0x1f1053d8 --rw-r----- oracle   dba 100659200
m  206 0x271053d8 --rw-r----- oracle   dba 1740800

Semaphores:

s 393216 00000000 --ra-r----- oracle   dba  300
```
In the preceding example, the SGA is built in three noncontiguous segments (making up the 100M+ SGA). The instance is then shut down and started with a smaller SGA (so the SGA is made up of contiguous pieces of memory). After the SGA has been lowered to 70M, I again issue the `ipcs` command:

```
# ipcs -b

Shared Memory:
  m  4403 0x0f1053d8 --rw-r----- oracle   dba 71118848

Semaphores:
  s  393218 00000000 --ra-r----- oracle   dba  300
```

Fitting the entire SGA into a single shared memory segment is generally preferable because of the overhead that can be required to track more than one segment and the time required to switch back and forth between those segments. You can increase the maximum size of a single shared memory segment by increasing the SHMMAX setting in the `/etc/system` file (or `/etc/sysctl.conf` depending on version). See the Oracle installation documentation for more specific information for your platform. On Solaris 10, the setting of the shared memory parameters moved to resource control, so if you modify the `/etc/system` file, any changes you make are ignored. Lastly, if you configure Hugepages, then the memory is pulled from a pool, and semaphores are not used. AMM requires the use of semaphores, so if you set MEMORY_TARGET (see Chapter 4 for setting the initialization parameters), you cannot use Hugepages.

**TIP**

Use the `ipcs` command to see if your SGA is built using multiple noncontiguous pieces of memory. A database crash can cause this to be problematic by not releasing the memory. Use the `ipcrm` command (only if the SGA pieces are not released after a database crash) to then remove the SGA pieces from memory. Do not issue the `ipcrm` command with a running database.

### Using the `vmstat` Command to Monitor System Load

The `vmstat` command is a conglomeration of many of the other commands listed in this chapter. The advantage of `vmstat` is you get to see everything at once. The problem with `vmstat` is that you get to see everything at once and must evaluate it.

The `vmstat` command shows you these sets of processes:

```
r Processes that are currently running
b Processes that are able to run but are waiting on a resource
w Processes that are able to run but have been swapped out
```
It additionally offers this information about CPU usage:

- **us**: Percentage of user time for normal and priority processes
- **sy**: Percentage of system time
- **id**: Percentage of idle time

```
# vmstat 5 3
procs memory page  all
         io           swa
 r  b  w  swap  free  ro  mf  pi  pi  dr  sr  so  sv  si  se  si  se
-- -- -- ----- ------ ---- --- ---- ---- ---- ---- ---- ---- ---- ----
19  0  0  1972992 28296 0  2  363  0  0  0  70  51  0  0  783  4348
23  0  0  1972992 27926 0  42  287  0  0  0  65  22  0  0  778  4519
21  0  0  1972992 27926 0  36  287  0  0  0  65  22  0  0  778  4519
  4  0  0  1981326 6878 0  42  287  0  0  0  65  22  0  0  778  4519
```

Having any process in the `b` or `w` column is usually a sign of a problem system (the preceding system has a problem if this continues). If processes are blocked from running, the CPU is likely to be overwhelmed or a device is hung. The CPU idle time that is displayed in the preceding example is 0. Clearly the system is overwhelmed, as processes are blocked and people are waiting to get CPU time. On the reverse side, if the idle time is high, you may not be using your system to its full capacity (not balancing activities efficiently) or the system may be oversized for the task. I like to see an idle time of 5–20 percent for a static (not adding new users) system.

Be aware that as the amount of time the system is waiting on I/O requests increases, the amount of idle time on the CPU decreases. This is because system resources have to be expended to track those waiting I/O requests. I mention this to make sure that you take a look at the whole picture before making a decision. Eliminating an I/O bottleneck may free up significant amounts of CPU time. Time spent tracking I/O is reflected as `sy` or system time in the `vmstat` output.

In the CPU columns of the report, the `vmstat` command summarizes the performance of multiprocessor systems. If you have a two-processor system and the CPU load is reflected as 50 percent, that doesn’t necessarily mean that both processors are equally busy. Rather, depending on the multiprocessor implementation, it may indicate that one processor is almost completely busy and the next is almost idle. The first column of `vmstat` output also has implications for multiprocessor systems. If the number of runnable processes is not consistently greater than the number of processors, it is less likely that you can get significant performance increases by adding more CPUs to your system.

You can also use the `vmstat` command to view system paging and swapping. The `po` (page-out) and `pi` (page-in) values indicate the amount of paging that is occurring on your system. A small amount of paging is acceptable during a heavy usage cycle but should not occur for a prolonged period of time. On most systems, paging will occur during Oracle startup.

**TIP**

Use the `vmstat` command to find blocked processes (users waiting for CPU time) and also for
paging or swapping problems. The `vmstat` command is a great way to see many of the `sar` options in one screen.

## Monitoring Disk Free Space

Often DBAs, especially those without in-house system administrators, need to monitor disk free space closely. For example, if the filesystem containing your archived redo logs fills, all activity on your database can instantly come to a halt! What follows is a script that allows you to monitor disk free space easily; it sends an e-mail message to you if there is an issue. I would schedule this script to run about every 15 minutes. Scheduling a program to run at specified intervals is usually done through the `cron` process. You add or remove entries with the command `crontab -e`. This command should open your `crontab` file in a vi editor. Here’s an example that checks disk free space every 15 minutes:

```
0,15,30,45 * * * * /usr/local/bin/diskfreespace.sh
```

This script runs the `diskfreespace.sh` program every 15 minutes, every day. For further information about scheduling programs via `cron`, refer to your system’s man pages on “`crontab`.” The command to view the man page (help page) for `crontab` is `man crontab` from the Unix prompt.

Finally, here is an example script to check file system free space on your host; it then sends an e-mail message to you if there is less than 5 percent free space. You can edit this script for more or less free space by changing `$PERC -gt 95` to, for example, `$PERC -gt 90`. This alerts you when the system has less than 10 percent free space. Note that this script is designed for Linux and will run unmodified on Solaris. To run it on HP-UX, change the command `df -kl` to `df -kp`.

```bash
#!/bin/sh
# script name: diskfreespace.sh
#
# df -k | grep -iv filesystem | awk '{ print $6 "$H" }' | while read LIN; do
PERC `echo \"S\" | awk '{ print $2 }'`
if [ "$PERC -gt 95" ]; then
  echo "$date - $LIN\" space used on "$hostname" is almost full" | mailx -a "$LIN" on "$hostname" at $CLIENT is almost full" rich@usc.com
fi
done
```

### The `df` Command

One of the biggest and most frequent problems that systems have is running out of disk space, particularly in `/tmp` or `/usr`. There is no magic answer to the question, “How much space should be
allocated to these directories?” but a good rule of thumb is between 1500K and 3000K for /tmp and roughly twice that for /usr (with larger systems these values need to be larger yet, especially for /tmp). Other filesystems should have about 5 or 10 percent of the system’s available capacity. The df command shows the free disk space on each disk that is mounted. The -k option displays the information about each filesystem in columns, with the allocations in KB. On HP-UX, use bdf.

```
% df -k
```

<table>
<thead>
<tr>
<th>Filesystem</th>
<th>kbytes</th>
<th>used</th>
<th>avail</th>
<th>capacity</th>
<th>Mounted on</th>
</tr>
</thead>
<tbody>
<tr>
<td>/dev/dsk/c0t0d0s0</td>
<td>38111</td>
<td>21173</td>
<td>13128</td>
<td>62%</td>
<td>/</td>
</tr>
<tr>
<td>/dev/dsk/c0t0d0s6</td>
<td>246167</td>
<td>171869</td>
<td>74888</td>
<td>78%</td>
<td>/usr</td>
</tr>
<tr>
<td>/proc</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>/proc</td>
</tr>
<tr>
<td>fd</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
<td>/dev/fd</td>
</tr>
<tr>
<td>swap</td>
<td>860849</td>
<td>632</td>
<td>858660</td>
<td>0%</td>
<td>/tmp</td>
</tr>
<tr>
<td>/dev/dsk/c0t0d0s57</td>
<td>108247</td>
<td>90109</td>
<td>18138</td>
<td>53%</td>
<td>/home</td>
</tr>
<tr>
<td>/dev/dsk/c0t0d0s5</td>
<td>492351</td>
<td>179384</td>
<td>312967</td>
<td>40%</td>
<td>/opt</td>
</tr>
<tr>
<td>qfs:/home/proc/met</td>
<td>77963</td>
<td>47127</td>
<td>30836</td>
<td>67%</td>
<td>/home/met</td>
</tr>
</tbody>
</table>

From this display, you can see the following information (all entries are in KB):

<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>kbytes</td>
<td>Total size of usable space in file system (size is adjusted by allotted head room)</td>
</tr>
<tr>
<td>used</td>
<td>Space used</td>
</tr>
<tr>
<td>avail</td>
<td>Space available for use</td>
</tr>
<tr>
<td>capacity</td>
<td>Percentage of total capacity used</td>
</tr>
<tr>
<td>Mounted on</td>
<td>Mount point</td>
</tr>
</tbody>
</table>

The usable space has been adjusted to take into account a 10-percent reserve head room adjustment and thus reflects only 90 percent of actual capacity. The percentage shown under capacity is, therefore, used space divided by the adjusted usable space.

The du Command

Once you know that you need space, du (disk usage) is a nice command to find out who’s hogging the space. Here are some nice du commands you can use to find the sizes of current directories within a mount:

```
du -sk * | sort -n (compute in 1K blocks)
du -sh * | sort -n (human readable - report values in K, G, etc.)
```
Here is a version of the same command that ensures you remain in that single filesystem and don’t travel to other filesystems. For instance, if you run the following in /, it will show you only the subdirectories and files in /, and won’t go into other filesystems like /opt or /tmp.

```
du -xk . | sort -nr | more
```

### Monitoring Network Performance with netstat

One way to check for network loading is to use `netstat` without any parameters:

```
% netstat
```

<table>
<thead>
<tr>
<th>TCP</th>
<th>Local Address</th>
<th>Remote Address</th>
<th>Syn</th>
<th>Send-Q</th>
<th>Rwnd</th>
<th>Revc-Q</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAA1.1023</td>
<td>bbb2.login</td>
<td>8760</td>
<td>0</td>
<td>8763</td>
<td>C</td>
<td>ESTABLISHED</td>
<td></td>
</tr>
<tr>
<td>AAA1.listen</td>
<td>Cccs.12345</td>
<td>8760</td>
<td>0</td>
<td>8763</td>
<td>C</td>
<td>ESTABLISHED</td>
<td></td>
</tr>
<tr>
<td>AAA1.login</td>
<td>Dddd.1319</td>
<td>8760</td>
<td>0</td>
<td>8753</td>
<td>C</td>
<td>ESTABLISHED</td>
<td></td>
</tr>
<tr>
<td>AAA1.2782</td>
<td>AAA1.32774</td>
<td>16384</td>
<td>0</td>
<td>16384</td>
<td>C</td>
<td>ESTABLISHED</td>
<td></td>
</tr>
</tbody>
</table>

In the report, the important field is `send-q`, which indicates the depth of the send queue for packets. If the numbers in `send-q` are large and increasing across several of the connections, the network is probably bogged down.

### Corrective Network Actions

If you suspect that there are problems with the integrity of the network itself, you must try to determine where the faulty piece of equipment is. If the problem is that the network is extremely busy, thus increasing collisions, time-outs, retransmissions, and so on, you may need to redistribute the workload more appropriately. By partitioning and segmenting the network nodes into subnetworks that more clearly reflect the underlying workloads, you can maximize overall network performance. Installing additional network interfaces in your gateway and adjusting the addressing on the gateway to reflect the new subnetworks accomplishes this. Altering your cabling and implementing some of the more advanced intelligent hubs may be needed as well. By reorganizing your network, you maximize the amount of bandwidth that is available for access to the local subnetwork. Make sure systems that regularly perform NFS mounts of each other are on the same subnetwork.

If you have an older network and are having to rework your network topology, consider replacing the older coax-based networks with the more modern twisted-pair types, which are generally more reliable and flexible. Make sure the workload is on the appropriate machine(s). Use the machine with the best network performance to do its proper share of network file service tasks. Check your network for diskless workstations. These require large amounts of network resources to boot up,
swap, page, etc. With the cost of local storage decreasing constantly, it is getting harder to believe that diskless workstations are still cost-effective when compared to regular workstations. Consider upgrading the workstations so they support users locally, or at least minimize their use of the network. If your network server has been acquiring more clients, check its memory and its kernel buffer allocations for proper sizing. If the problem is that I/O-intensive programs are being run over the network, work with the users to determine what can be done to make that requirement a local, rather than a network, one. Educate your users to make sure they understand when they are using the network appropriately and when they are being wasteful with this valuable resource.

Modifying the Configuration Information File

Solaris uses the /etc/system file for modification of kernel-tunable variables. The basic format is this:

```
set parameter = value
```

It can also have this format:

```
set [module:]variblename = value
```

The /etc/system file can also be used for other purposes (for example, to force modules to be loaded at boot time, to specify a root device, and so on). The /etc/system file is used for permanent changes to the operating system values. Temporary changes can be made using adb (Android Debug Bridge) kernel debugging tools. The system must be rebooted for the changes to become active using /etc/system. Once you have made your changes to this file, you can recompile to make a new Unix kernel. The command is mkmkernel -s system. This new kernel, called vmunix.test, is placed in the /stand/build directory. Next, you move the present stand/system file to /stand/system.prev; then you can move the modified file /stand/build/system to /stand/system. Then you move the currently running kernel /stand/vmunix to /stand/vmunix.prev, and then move the new kernel, /stand/build/vmunix.test, into place in /stand/vmunix (i.e., mv /stand/build/vmunix.test /stand/vmunix). The final step is to reboot the machine to make your changes take effect.

Other Factors That Affect Performance

Good performance is difficult to define. Two common, but different and not necessarily equivalent, measures are used for performance. **Response time** is the time between the instant the user presses the enter key and the time the system provides a response. **Throughput** is the number of transactions accomplished in a fixed period of time. Of the two measures, throughput is the better measure of how much work is actually getting accomplished. Response time is more visible and, therefore, used more frequently; it is a better measurement for meeting the system’s business objectives. Some people don’t
look at everything when tuning. Remember to check all of these:

- **All hardware** Are the CPUs fast enough and are there enough of them? How much memory is there; is it enough?

- **Operating system and application software** Is the system configured correctly for the current environment?

- **People** Are people trained sufficiently on the system and applications to optimize their productivity?

- **Changes** What changes in workload and user requirements can be expected to occur?

A resource is a bottleneck if the size of a request exceeds the available resource. A *bottleneck* is a limitation of system performance due to the inadequacy of the hardware or software component or the system’s organization.

### Tuning a CPU System

- Upgrade to faster or more processors.
- Upgrade the system with a larger data/instruction cache.
- Spread applications across multiple systems and disks.
- Run long batch jobs during off-peak hours whenever possible.
- `nice` (a command that changes the priority of a process) unimportant applications.
- Lock frequently used processes in memory.
- Turn off system accounting.
- Optimize the applications.

### Tuning Memory-Bound Systems

- Add physical memory.
- Add flash.
- Use diskless workstations rather than X-terms.
- Reduce MAXDSIZ.
- Reduce the use of memory locking.
- Identify programs with memory leaks.
- Tune the applications.
- Reduce the size of the kernel drivers and subsystems.
- Reduce the size of the buffer cache.
Disk Tuning

- Add disk drives.
- Add disk channels.
- Use faster disks or add flash.
- Use striping.
- Use mirroring.
- Balance I/O across multiple spindles.
- Dedicate a disk section to an application.
- Use raw disk I/O.
- Increase the system buffer cache.
- Increase the kernel table sizes.
- Use the `tunefs` and `tunefs` NFS commands.

Volume Manager Factors That Can Affect Performance

- File system parameters
- Fragmentation
- Mirroring
- Scheduling
- Spindles
- Strictness
- Striping
- Workload
- Work type

Other Sources to Improve Performance

Another tool worth investigating is the Oracle Cluster Health Monitor (CHM). You can use it to track operating system resources on each node. CHM tracks every process and device level continuously. You can set thresholds, which when they are hit, set off an alert. Historical information can also be replayed. For more information see [www.oracle.com/technetwork/database/enterprise-edition/ipd-overview-130032.pdf](http://www.oracle.com/technetwork/database/enterprise-edition/ipd-overview-130032.pdf).

Oracle ORION Calibration Tool is another tool that you can use to create a representative workload that stresses a storage array in the same manner as your production application. Orion issues I/Os against raw disks using the same libraries an Oracle database would issue. It can also
help you fine-tune the storage array for a production application. For more information see https://docs.oracle.com/database/121/TGDBA/pfgrf_iodesign.htm#TGDBA015.

Lastly, please see My Oracle Support (Metalink) Note 224176.1 for additional information on using operating system commands to diagnose Oracle Performance issues.

**Tips Review**

- Use the **sar** `-u` command to see a quick snapshot of how much work the CPU is doing and whether the CPU is overwhelmed. Run `sar` on a regular basis to get a baseline for your system so you can identify when your system is running poorly. However, at times low CPU idle time can also be an I/O issue, not a CPU issue.

- Use the **sar** command to monitor and evaluate memory use and the potential need for additional memory. **Paging** is generally the movement of inactive processes from memory to disk. A high degree of paging is generally the predecessor to swapping. **Swapping** is the movement of active processes from memory to disk. If swapping starts to escalate, your system begins the downward “death spiral.” Fixing memory hogs or adding memory is the correct solution.

- In 12c, consolidating systems by using multitenant databases usually results in the CPU idle percentage being much higher and the heavy CPU usage periods being much lower (by averaging all systems into one). Using pluggable databases to average out the load on a single multitenant system can be very effective!

- Use the **top** command to find the worst user on the system at a given point in time. (the **kill** command usually follows for many DBAs). If the worst query lasts only a short period of time, it may not be a problem; but if it persists, additional investigation may be necessary.

- Use **cron** and **uptime** to have your system load e-mailed to you on a regular basis. See your Unix manual for any specific syntax when using these commands.

- If the smtx column for the **mpstat** output is greater than 200, you are heading toward CPU bottleneck problems.

- Combine operating system utilities with Oracle utilities to find problematic users quickly and effectively.

- Use the **sar** and **iostat** commands to find potential disk I/O problem areas. Utilizing the capabilities of shell scripting with these commands embedded can further enhance these commands.

- Use the **ipcs** command to see if your SGA is built using multiple noncontiguous pieces of memory. A database crash can cause this to be problematic by not releasing memory. Use the **ipcrm** command (only if the SGA pieces are not released after a database crash) to then remove the SGA pieces from memory. Do not issue the **ipcrm** command with a running database.

- Use the **vmstat** command to find blocked processes (users waiting for CPU time) and also for paging or swapping problems. The **vmstat** command is a great way to see many of the **sar**
options in one screen.

References


Many thanks to Alwyn Santos and Dana MacPhail, who contributed tips to this version of the chapter. Thanks also to Doug Freyburger, Mike Gallagher, Judy Corley, and Jon Vincenzo, who updated previous versions that we built upon.
Oracle 12c Release 2 has 412 different documented and 4237 different undocumented initialization parameters. This means you have a total of 4649 initialization parameters to play with; you can do a `count(*)` of `X$KSPPI` for the total number of parameters both documented and undocumented (you need to be SYS to access the X$ tables). A count of `V$PARAMETER` gives you a count of only the documented parameters. When I refer to the undocumented parameters, I am referring to parameters that start with an underscore (_), although some of them are actually even documented. There are also several parameters that I call documented (no “_” in front of them), but they are not really documented, only externalized or available for use, usually for backward compatibility. Even these numbers vary slightly on different versions of Oracle and platforms. The initialization parameters vary (in both name and number) according to the database version and release used. Run the queries listed in this appendix (accessing the `V$PARAMETER` view and the `X$KSPPI` table) on your version of the database to get the number of parameters and details for your specific version.

Tips covered in this appendix include the following:

- Desupported and deprecated initialization parameters
- Top 25 documented initialization parameters with descriptions and suggested settings
- Top 20 documented initialization parameters that you better not forget (option dependent)
- Top 13 undocumented initialization parameters (Shhh!)
- Bonus 11 undocumented initialization parameters (mostly Exadata)
- Complete listing of documented initialization parameters (412 in 12cR2)
- Query for undocumented initialization parameters (4237 in 12cR2)

Since every system is set up differently, my top 25 may not be the same as your top 25 (so feel free to write in this book as if it were yours). Hopefully, this appendix will give you a place to start until someone writes the 1000-page book on all of the initialization parameters. Please refer to Chapter 4 for a detailed look at the most important initialization parameters.

Obsoleted/Desupported Initialization Parameters
The following are some of the Oracle 12cR2 obsoleted/desupported initialization parameters (query V$OBSOLETE_PARAMETER for the full list of 154 obsolete parameters). Obsolete means these parameters are gone, although they sometimes become undocumented parameters, which means that they have an underscore (_) in front of them.

- DDL_WAIT_FOR_LOCKS
- DRS_START
- GC_FILES_TO_LOCKS
- DB_BLOCK_LRU_LATCHES (undocumented parameter with default of 8)
- _KGL_LATCH_COUNT (shows as both obsolete and undocumented; default of 0)
- MAX_COMMIT_PROPAGATION_DELAY
- PLSQL_NATIVE_LIBRARY_DIR
- PLSQL_NATIVE_LIBRARY_SUBDIR_COUNT
- ROW_LOCKING (undocumented parameter with default of ALWAYS)
- SQL_VERSION

**Deprecated Initialization Parameters**

The following are Oracle 12cR2 deprecated initialization parameters. You can use these for backward compatibility, but they are probably going away in the future. To list the deprecated parameters for a given version, run the following SQL statement (note that 23 records were returned for this query in 12cR2, versus 26 in 12cR1, although some of these were deprecated in the past as noted in the list):

```sql
select name
from   v$parameter
where  isdeprecated = 'TRUE';
```

- ACTIVE_INSTANCE_COUNT
- BACKGROUND_DUMP_DEST (replaced in 11.1 by DIAGNOSTIC_DEST)
- BUFFER_POOL_KEEP (replaced in 9i with DB_KEEP_CACHE_SIZE)
- BUFFER_POOL_RECYCLE (replaced in 9i with DB_RECYCLE_CACHE_SIZE)
- COMMIT_WRITE (as of 12.2, use COMMIT_LOGGING and COMMIT_WAIT)
- CURSOR_SPACE_FOR_TIME (as of 11.1)
- FAST_START_IO_TARGET (replaced in 9i with FAST_START_MTTR_TARGET)
- INSTANCE_GROUPS (as of 11.1)
LOCK_NAME_SPACE (as of 10.1)
LOG_ARCHIVE_START (as of 11.2)
PARALLEL_ADAPTIVE_MULTI_USER (as of 12.2)
PLSQL_DEBUG (as of 11.1)
PLSQL_V2_COMPATIBILITY (as of 11.1)
RDBMS_SERVER_DN (as of 12.2)
REMOTE_OS_AUTHENT (as of 11.1)
RESOURCE_MANAGER_CPU_ALLOCATION (as of 11.1)
SEC_CASE_SENSITIVE_LOGON (as of 12.1)
SERIAL_REUSE (as of 10.2)
SQL_TRACE (as of 10.2)
STANDBY_ARCHIVE_DEST (as of 11.1)
USER_DUMP_DEST (as of 11.1, replaced by DIAGNOSTIC_DEST)
UTL_FILE_DIR (as of 12.1)

Top 25 Initialization Parameters

The following list is my list of the top 25 most important initialization parameters, in order of importance. Your top 25 may vary somewhat from my top 25 because everyone has a unique business, unique applications, and unique experiences.

1. MEMORY_TARGET This is the initialization parameter setting for all of the memory allocated to both the PGA and SGA combined (new in as of 11g). Setting MEMORY_TARGET enables Automatic Memory Management, so Oracle allocates memory for you based on system needs, but you can also set minimum values for key parameters. MEMORY_TARGET is used for everything that SGA_TARGET was used for but now additionally includes the PGA (especially important as MEMORY_TARGET now includes the important area PGA_AGGREGATE_TARGET). Important parameters such as DB_CACHE_SIZE, SHARED_POOL_SIZE, PGA_AGGREGATE_TARGET, LARGE_POOL_SIZE, and JAVA_POOL_SIZE are all set automatically when you set MEMORY_TARGET. Setting minimum values for important initialization parameters in your system is also a very good idea.

2. MEMORY_MAX_TARGET This is the maximum memory allocated for Oracle and the maximum value to which MEMORY_TARGET can be set.

3. DB_CACHE_SIZE Initial memory allocated to data cache or memory used for data itself. This parameter doesn’t need to be set if you set MEMORY_TARGET or SGA_TARGET, but setting a value for this as a minimum setting is a good idea. Your goal should always be toward a memory resident database or at least toward getting all data that will be queried in memory.
4. **SHARED_POOL_SIZE** Memory allocated for data dictionary and for SQL and PL/SQL statements. The query itself is put in memory here. This parameter doesn’t need to be set if you set MEMORY_TARGET, but setting a value for this as a minimum is a good idea. Note that SAP recommends setting this to 400M. Also note that the Result Cache gets its memory from the shared pool and is set with the RESULT_CACHE_SIZE and RESULT_CACHE_MODE (FORCE/AUTO/MANUAL) initialization parameters. Lastly, an important note since 11g is that this parameter now includes some SGA overhead (12M worth) that it previously did not (in 10g). Set this 12M higher than you did in 10g!

5. **INMEMORY_SIZE** The In-Memory column store resides in this area, which is separate from the buffer cache used to store data in memory. Tables, tablespaces, partitions, and other objects can have single columns stored in this memory area in a compressed fashion. This allows for much faster analytics (like summing an individual column). Oracle builds indexes to make this even faster based on ranges of values. Also, INMEMORY_QUERY should be set to ENABLED (the default). Additional INMEMORY settings are described in Chapter 4.

6. **SGA_TARGET** If you use Oracle’s Automatic Shared Memory Management, this parameter is used to determine the size of your data cache, shared pool, large pool, and Java pool automatically (see Chapter 4 for more information). Setting this to 0 disables it. This parameter doesn’t need to be set if you set MEMORY_TARGET, but you may want to set a value for this as a minimum setting for the SGA if you’ve calibrated it in previous versions. The SHARED_POOL_SIZE, LARGE_POOL_SIZE, JAVA_POOL_SIZE, and DB_CACHE_SIZE are all set automatically based on this parameter (or MEMORY_TARGET if used). INMEMORY_SIZE is also included in this number.

7. **PGA_AGGREGATE_TARGET** and **PGA_AGGREGATE_LIMIT** The _TARGET is a soft memory cap for the total of all users’ PGAs. This parameter doesn’t need to be set if you set MEMORY_TARGET, but setting a value as a minimum setting is a good idea. Note that SAP specifies to set this to 20 percent of available memory for OLTP and 40 percent for OLAP. The _LIMIT sets the upper limit that is allowed (the hard memory cap).

8. **SGA_MAX_SIZE** Maximum memory that SGA_TARGET can be set to. This parameter doesn’t need to be set if you set MEMORY_TARGET, but you may want to set a value if you use SGA_TARGET.

9. **OPTIMIZER_MODE** FIRST_ROWS, FIRST_ROWS_\_n, or ALL_ROWS. Although RULE/CHOOSE are definitely desupported and obsolete and people are often scolded for even talking about it, I was able to set the mode to RULE in 11gR2. Consider the following error I received when I set OPTIMIZER_MODE to a mode that doesn’t exist (SUPER_FAST):

```
SQL> alter system set optimizer_mode=super_fast;
```

**ERROR:**
ORA-00996: invalid value SUPER_FAST for parameter optimizer_mode, must be from among first_rows_1000, first_rows_100, first_rows_10, first_rows_1, first_rows, all_rows, choose, rule

10. **SEC_MAX_FAILED_LOGIN_ATTEMPTS** If the user fails to enter the correct password after this many tries (new as of 11g) the server process drops the connection and the server process is terminated. The default is 3 (consider increasing this value for less secure systems). A similar parameter in my top 25 list in the prior edition included
SEC_CASE_SENSITIVE_LOGON, which was new as of 11g, but is deprecated as of 12.1. Be careful if you’re still using this parameter in 11g (fix case issues with passwords by ensuring passwords can be lower, upper, or mixed case before you upgrade to 12c!).

11. CURSOR_SHARING Converts literal SQL to SQL with bind variables, reducing parse overhead. The default is EXACT. Consider setting it to FORCE after research (see Chapter 4 for more information).

12. OPTIMIZER_USE_INVISIBLE_INDEXES The default is FALSE to ensure invisible indexes are not used by default (new as of 11g). Set this parameter to TRUE to use all of the indexes and to check which ones might have been set incorrectly to be invisible; this could be a helpful tuning exercise, or it could also bring the system to a halt, so only use it in development.

13. OPTIMIZER_USE_PENDING_STATISTICS The default is FALSE to ensure pending statistics are not used, whereas setting this to TRUE enables all pending statistics to be used (new as of 11g).

14. OPTIMIZER_INDEX_COST_ADJ Coarse adjustment between the cost of an index scan and the cost of a full table scan. Set between 1 and 10 to force index use more frequently. Setting this parameter to a value between 1 and 10 pretty much guarantees index use, however, even when not appropriate, so be careful because it is highly dependent on the index design and implementation being correct. Please note that if you are using Oracle Applications 11i, setting OPTIMIZER_INDEX_COST_ADJ to any value other than the default (100) is not supported (see Metalink Note 169935.1). I’ve seen a benchmark where this was set to 200. Also, see bug 4483286. SAP suggests that you not set it for OLAP, but set it to 20 for OLTP.

15. DB_FILE_MULTIBLOCK_READ_COUNT For full table scans to perform I/O more efficiently, this parameter reads the given number of blocks in a single I/O. The default value is 128 in 11gR2, but it is usually noted not to change this from the default.

16. LOG_BUFFER Server processes making changes to data blocks in the buffer cache generate redo data into the log buffer. SAP says to use the default, whereas Oracle Applications sets it to 10M. I’ve seen benchmarks with it set over 100M.

17. DB_KEEP_CACHE_SIZE Memory allocated to the keep pool or an additional data cache that you can set up outside the buffer cache for very important data that you don’t want pushed out of the cache.

18. DB_RECYCLE_CACHE_SIZE Memory allocated to a recycle pool or an additional data cache that you can set up outside the buffer cache and in addition to the keep cache described in item 17. Usually, DBAs set this up for ad hoc user query data with poorly written queries.

19. OPTIMIZER_USE_SQL_PLAN_BASELINES The default is TRUE, which means Oracle uses these baselines if they exist (new as of 11g). Note that Stored Outlines are deprecated (discouraged but they still work) in 11g, as they are replaced with SQL Plan Baselines.

20. OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES The default is FALSE, which means that Oracle does not capture them by default, but if you create some, it will use them as stated in the previous parameter (new as of 11g).

21. LARGE_POOL_SIZE Total blocks in the large pool allocation for large PL/SQL and a few other Oracle options less frequently used.
22. **STATISTICS_LEVEL** Used to enable advisory information and optionally keep additional OS statistics to refine optimizer decisions. **TYPICAL** is the default.

23. **JAVA_POOL_SIZE** Memory allocated to the JVM for Java stored procedures.

24. **JAVA_MAX_SESSIONSPACE_SIZE** Upper limit on memory that is used to keep track of the user session state of Java classes.

25. **OPEN_CURSORS** Specifies the size of the private area used to hold (open) user statements. If you get an “ORA-01000: maximum open cursors exceeded,” you may need to increase this parameter, but make sure you are **closing** cursors that you no longer need. Prior to 9.2.0.5, these open cursors were also cached and, at times, caused issues (ORA-4031) if **OPEN_CURSORS** was set too high. As of 9.2.0.5, **SESSION_CACHED_CURSORS** now controls the setting of the PL/SQL cursor cache. Do **not** set the parameter **SESSION_CACHED_CURSORS** as high as you set **OPEN_CURSORS**, or you may experience ORA-4031 or ORA-7445 errors. SAP recommends setting this to 2000; Oracle Applications has **OPEN_CURSORS** at 600 and **SESSION_CACHED_CURSORS** at 500.

![Image](image.png)

**TIP**

*Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.*

**Top 20 Initialization Parameters Not to Forget**

This section details some other important initialization parameters. However, these parameters may be important only in certain cases or only if you are using a certain feature or version of Oracle:

1. **CONTROL_FILES** The location of your control files. You should have at least three copies.

2. **COMPATIBLE** Set this to the correct version, or you’ll miss things in the new version. Set to at least 12.2.0.0.0 for 12cR2.

3. **OPTIMIZER_FEATURES_ENABLE** If this is not set, you are missing out on new features. My 12.2 system had this set to 12.2.0.1, but the version that I was on was 12.2.0.0.2.

4. **OPTIMIZER_ADAPTIVE_FEATURES** The default is **TRUE**. You should not change this unless you want to turn this off (not advisable). Two related parameters are **OPTIMIZER_ADAPTIVE_REPORTING_ONLY**, which is set to **FALSE** by default and used to only report on Adaptive Use (for testing). **OPTIMIZER_INMEMORY_AWARE** should also stay at the default of **TRUE** when using INMEMORY.

5. **AUDIT_TRAIL** The default is set to **DB** in 12cR2. This parameter enables auditing for many major commands, including CREATE, ALTER, GRANT, and AUDIT.

6. **DIAGNOSTIC_DEST** Trace, Alert, and Core Dump files are now in a new location. The **DIAGNOSTIC_DEST** specifies the root directory where these files are located. A basic
example on how this works is to set the DIAGNOSTIC_DEST to a location (/u01/app/oracle), for example. The corresponding locations for the dump files become

```
DIAGNOSTIC_DEST\DIAG\RDBMS\dbname\instname\trace
```

(note that I have PDBs):

- background_dump_dest = /u01/app/oracle/diag/rdbms/cdb1/cdb1/trace
- user_dump_dest = /u01/app/oracle/diag/rdbms/cdb1/cdb1/trace
- core_dump_dest = /u01/app/oracle/diag/rdbms/cdb1/cdb1/cdump
- Alert files go to /u01/app/oracle/diag/rdbms/cdb1/cdb1/cdump

7. **UNDO_MANAGEMENT** Set this to AUTO (default) for automatic undo management.

8. **UNDO_TABLESPACE** Set this to the tablespace to use for undo management (UNDOTBS1 is the default).

9. **UNDO_RETENTION** The UNDO retention time in seconds (900 is the default).

10. **SPFILE** This gives the location of the binary SPFILE used for startup. You can create a readable PFILE with the command `CREATE PFILE='path_and_name' FROM SPFILE='path and name';` and you can create an SPFILE from a PFILE or from MEMORY. You can also do a `startup` (using the SPFILE) or do a `startup pfile=...` to use a given PFILE (initSID.ora or any name you specify). The SPFILE is in the ORACLE_HOME\dbs directory. Chapter 4 has additional information.

11. **DB_BLOCK_SIZE** Default block size for the database. A smaller block size reduces contention by adjacent rows, but a larger block size lowers the number of I/Os needed to pull back more records. A larger block size also helps in range scans where the blocks desired are sequentially stored. An 8K block size is used for most applications and is the default.

12. **CLUSTER_DATABASE** You must set this to FALSE for single instance. With pluggable databases, there are now CDB_CLUSTER and CDB_CLUSTER_NAME parameters.

13. **UTL_FILE_DIR** Set to use the UTL_FILE package. Note that in 11g, the UTL_FILE package no longer opens a file if it is a symbolic link (created to close a known security hole). This parameter is deprecated in 12c and is unset (try to move away from this).

14. **LOG_CHECKPOINT_INTERVAL** Checkpoint frequency (in OS blocks—most OS blocks are 512 bytes) at which Oracle performs a database write of all dirty (modified) blocks to the datafiles in the database. Oracle also performs a checkpoint if more than one-quarter of the data buffers are dirty in the db cache and also on any log switch. The LGWR (log writer) also updates the SCN in the control files and datafiles with the SCN of the checkpoint.

15. **FAST_START_MTTR_TARGET** Bounds time to complete a crash recovery. This is the time (in seconds) that the database takes to perform crash recovery of a single instance. If you set this parameter, LOG_CHECKPOINT_INTERVAL should **not** be set to 0. If you don’t set this parameter, you can still see your estimated MTTR (mean time to recovery) by querying `V$INSTANCE_RECOVERY` for `ESTIMATED_MTTR`.

16. **RECOVERY_PARALLELISM** Recover using the Parallel Query option for a faster recovery.

17. **MAX_SHARED_SERVERS** Upper limit on shared servers when using shared servers.

18. **LICENSE_MAX_SESSIONS** and **LICENSE_MAX_USERS** These limit concurrent and
named users (default is 0).

19. LICENSE_SESSIONS_WARNING Here, you specify at which session+1 you get a license warning (default is 0).

20. CELL_OFFLOAD_PROCESSING The default is TRUE (several other CELL parameters to consider include CELL_OFFLOAD_COMPACTION, CELL_OFFLOAD_DECRYPTION, CELL_OFFLOAD_PARAMETERS, CELL_OFFLOAD_PLAN_DISPLAY, and CELL_OFFLOAD_PROCESSING), which means that Smart Scans are set to be ON for Exadata (if you are using it). (Exadata only.)

TIP
Oracle includes some excellent options. Unfortunately, some of them do not work unless you have the initialization parameter set correctly.

Top 13 Undocumented Initialization Parameters (As I See It)

The following list is my list of the top 13 undocumented initialization parameters in order of importance. Your top 13 may vary somewhat, depending on your need for one of these parameters. Although the following warning describes well the risks associated with using these parameters, I note that the fastest RAC TPC (Transaction Processing Council) benchmark uses 17 undocumented parameters, as do many of the TPC benchmarks that I’ve seen.

CAUTION
These 13 parameters are not supported by Oracle, and I do not recommend using them on a production system. Use them only if directed by Oracle Support and if you have thoroughly tested them on your crash-and-burn system (and your closest friend has been using them for years). Undocumented initialization parameters can lead to database corruption (although some of them can get your database back up when it becomes corrupted).

1. _ALLOW_RESETLOGS_CORRUPTION This parameter saves you when you have corrupted redo logs. It allows the database to open with the datafiles at different SCN synchronization levels. This means some datafiles may contain changes that other datafiles do not (like the RBS or UNDO tablespace). This parameter may allow you to get to your data, but there is no easy way to determine if the data that is available after using this parameter is logically consistent. Regardless of data consistency, the DBA has to rebuild the database afterward. Failure to do so results in multiple ORA-600 errors occurring within the database at a later time.
2. **_CORRUPTED_ROLLBACK_SEGMENTS** Setting this parameter can be a means of last resort when you have corrupted ROLLBACK segments, which you can list with this parameter to be skipped. The _CORRUPTED_ROLLBACK_SEGMENTS parameter can force the database open after a failed recovery, but at a very high cost.

_CORRUPTED_ROLLBACK_SEGMENTS allows the database to open by assuming every transaction in the ROLLBACK segments is a complete, committed transaction. This leads to logical corruption throughout the database and can easily corrupt the data dictionary. An example would be where you transfer money from one bank to another. The transaction would only be complete if you can verify that all parts of it are complete. In Oracle, when creating a table, think of all the individual dictionary objects that are updated: fet$, uet$, tab$, ind$, col$, etc. By setting this parameter, you allow table creation to succeed, even if only fet$ was updated, but not uet$, or even if tab$ was updated, but not col$. Use it when you have no other means of recovery and export/import/rebuild soon after.

**CAUTION**
These first two parameters do not always work or may corrupt the database so badly that you cannot perform once the database is open. If they are used and do not work, then Oracle Support cannot do anything to salvage the database if the DBA breaks down and calls Support, but the DBA can do several things before using these parameters that will allow other recovery methods to be used afterward. So if you must use these parameters, please ensure that you use them with the help of Oracle Support. One good reason to use Oracle Support in this effort is the fact that the _ALLOW_RESETLOGS_CORRUPTION parameter is problematic, often requiring an event to be set as well, to get the database open.

3. **_HASH_JOIN_ENABLED** Enables/disables hash joining if you have the memory needed. The default value is TRUE.

4. **_IN_MEMORY_UNDO** Makes in-memory undo for top-level transactions (Oracle’s IMU really messed up my block-level tuning presentation as blocks in memory became more complex). The default is TRUE. Some applications have you set this to FALSE, so please check your application carefully for this parameter. This is one of the things that makes Oracle fast, so be careful changing this parameter!

5. **_TRACE_FILES_PUBLIC** This parameter allows users to see the trace output without giving them major privileges elsewhere. The default is FALSE; both Oracle and SAP set this to TRUE.

6. **_FAST_FULL_SCAN_ENABLED** This allows fast full index scans if only the index is needed. The default is TRUE, but Oracle Applications often recommends this be set to FALSE.

7. **_KSMG_GRANULE_SIZE** This is the granule size multiple for SGA granule pieces of memory such as SHARED_POOL_SIZE and DB_CACHE_SIZE.

8. **_HASH_MULTIBLOCK_IO_COUNT** Number of blocks that a hash join will read/write at once.
9. **INDEX JOIN ENABLED** Used to enable/disable the use of index joins. Default is TRUE.

10. **OPTIMIZER_ADJUST_FOR_NULLS** Adjust selectivity for null values. Default is TRUE.

11. **TRACE_POOL_SIZE** Trace pool size in bytes.

12. **B_TREE_BITMAP_PLANS** Enables the use of bitmap plans for tables with only b-tree indexes. The default is TRUE, but many applications recommend setting this to FALSE.

13. **UNNEST_SUBQUERY** Enables the unnesting of correlated or complex subqueries. The default is TRUE.

**TIP**

Undocumented initialization parameters can corrupt your database! Some of them can help you salvage a corrupted database. Try to use these only when all other choices have failed and with the help of Oracle Support.

Here are five additional initialization parameters that you can use for latch contention:

1. **_KGL_LATCH_COUNT** Number of library cache latches (set this to the next prime number higher than 2*CPU). Setting this parameter too high (>66) causes ORA-600 errors (bug 1381824). KGL stands for Kernel Generic Library or the Library Cache portion of the shared pool (there is also a Dictionary Cache portion). Many *KGL* undocumented parameters are available for debugging and improving shared pool performance. Be careful with this one as it shows up in obsolete parameters, but still shows as undocumented as well.

2. **_LOG_SIMULTANEOUS_COPIES** The number of redo copy latches (or simultaneous copies allowed into the redo log buffer). Redo records are written to the redo log buffer requiring the redo copy latch when changes are made. Use this parameter to reduce the contention on multi-CPU systems (default is 2).

3. **_DB_BLOCK_HASH_BUCKETS** Must be prime (set to next prime number higher than 2*Cache buffers) in versions 9i and 10g (there is an algorithm change in 11g). This parameter should not be a problem or need to be set as of 10g. On my system, this value was set to a default of 1048576 when there were only 332930 db block buffers (certainly eliminating hash chain issues). A _DB_BLOCK_HASH_LATCHES parameter (set to 32768, by default, in my system) is also available. My system is just under 7G MEMORY_TARGET.

4. **_DB_BLOCK_MAX_CR_DBA** The maximum number of consistent read (CR) blocks for a given database block address (DBA). The default is 6 (six copies maximum of a CR block). Before this parameter was set, large use applications updating many rows within the same block caused so many CR versions that there were incredible issues with latches on the hash chain looking for the correct version of a given block (see the previous parameter for related information).

5. **_SPIN_COUNT** Determines how often the processor takes a new request (reduces CPU timeouts). Also determines how many times a process tries to get a latch until it goes to sleep (when it is a willing-to-wait latch). Many processes spinning to get a latch can cost a lot of
CPU, so be careful if you increase this value. In Oracle 7, this parameter was called the _LATCH_SPIN_COUNT. The default is 1.

**Bonus 11 Undocumented Initialization Parameters**

Here are 11 more undocumented parameters that are mostly new as of Oracle 11gR2 that I think are worth looking into, but that I’ve not personally tested too much (other than the INIT_SQL_FILE parameter, which I’ve added to the bottom of the list; it is well worth reading through).

1. **_KCFIS_STORAGEIDX_DISABLED** Don’t use storage index optimization on storage cells if this is set to TRUE. The default is FALSE. (*Exadata only.*)
2. **_BLOOM_FILTER_ENABLED** Set to TRUE by default. With Exadata, bloom filters are used for join filtering with smart scans. _BLOOM_PRUNING_ENABLED also has a default of TRUE. Set these to FALSE to disable. (*Exadata only.*)
3. **_COLUMN_COMPRESSION_FACTOR** Set to 0 by default.
4. **_IMU_POOLS** Located in the memory UNDO pools. The default is 3.
5. **_NESTED_LOOP_FUDGE** The default is 100 (probably means 100 percent, similar to OPTIMIZER_INDEX_COST_ADJ, but I’ve not tested it).
6. **_OPTIMIZER_MAX_PERMUTATIONS** The default is 2000 (seems high to me, but I’ve not tested it). This parameter determines the optimizer’s maximum permutations per query block. (Note that 183 hidden parameters starting with _OPTIMIZER% are available.)
7. **_PGA_MAX_SIZE** The maximum size of PGA for one process. Must be prime (set to next prime number greater than 2*Cache buffers) in version 9i and 10g (there is an algorithm change in 12c; mine was set to around the PGA_AGGREGATE_TARGET). This parameter should not be a problem or need to be set as of 10g.
8. **_OPTIMIZER_IGNORE_HINTS** The default is FALSE. Could be a way to check if you really need all of those hints you’ve put in over the years.
9. **_ALLOW_READ_ONLY_CORRUPTION** The default is FALSE. This allows read-only open even if the database is corrupt. Careful with this parameter; consult Oracle Support.
10. **_OPTIM_PEEK_USER_BINDS** The default is TRUE, which allows Oracle to peek at the user’s bind variable. Setting this FALSE when peeking is not favorable can lead to huge performance gains since Oracle peeks and uses the same plan that is not optimized for the next bind. Related to this is OPTIMIZER_ADAPTIVE_CURSOR_SHARING, which has a default of TRUE but is also often set to FALSE.
11. **_INIT_SQL_FILE** This SQL file (and its location) is executed upon database creation (usually sql.bsq, very interesting to read if you have a long night available). It is in the $ORACLE_HOME\rdbms\admin directory by default.

The hidden parameters are used mainly by the Oracle development group. The implementation of hidden parameters can change from release to release, even when you only applied a patch to your database. Because they are not documented and *not supported*, they may not work as you expect, or as is described here. For a query that gives you a complete listing of all undocumented parameters,
their default values, and descriptions, see the section “Listing of Undocumented Initialization Parameters (X$KSPPI/X$KSPPCV),” later in this chapter.

Listing of Documented Initialization Parameters (V$PARAMETER)
The following query retrieves the listing that follows on 12cR2 (412 rows returned on Linux). This particular query was run on 12.2.0.0.2.

```
Col name format a33
Col value for a10
Col ismodified for a5
Col description for a28 word_wrapped

select name, value, ismodified, description
from v$parameter
order by name;
```

The following listing contains the output for this query and includes the parameter names, values, whether the parameter can be modified, and a brief description.

<table>
<thead>
<tr>
<th>NAME</th>
<th>VALUE</th>
<th>ISMOD</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBPROF_140</td>
<td>FALSE</td>
<td>FALSE</td>
<td>Enable use of cryptographic libraries in FIPS mode, public</td>
</tr>
<tr>
<td>SY_DICnTRnARY_ACCESSIBILITY</td>
<td>FALSE</td>
<td>FALSE</td>
<td>Version 7 Dictionary Accessibility Support</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>active_instance_count</td>
<td>FALSE</td>
<td>number of active instances in the cluster database</td>
<td></td>
</tr>
<tr>
<td>agg_imc_enabled</td>
<td>TRUE</td>
<td>FALSE Enable IMC support on ADG</td>
<td></td>
</tr>
<tr>
<td>allowDeprecatedRPCs</td>
<td>YES</td>
<td>FALSE Allow deprecated TTC RPCs</td>
<td></td>
</tr>
<tr>
<td>allowGlobalDblinks</td>
<td>FALSE</td>
<td>FALSE LDAP lookup for DBLINKS</td>
<td></td>
</tr>
<tr>
<td>allowGroupAccessToSga</td>
<td>FALSE</td>
<td>FALSE Allow read access for SGA to users of Oracle owner group</td>
<td></td>
</tr>
<tr>
<td>approx_for_aggregation</td>
<td>FALSE</td>
<td>FALSE Replace exact aggregation with approximate aggregation</td>
<td></td>
</tr>
<tr>
<td>approx_for_count_distinct</td>
<td>FALSE</td>
<td>FALSE Replace count distinct with approx count distinct</td>
<td></td>
</tr>
<tr>
<td>approx_for_percentile</td>
<td>none</td>
<td>FALSE Replace percentile* with approx_percentile</td>
<td></td>
</tr>
<tr>
<td>aq_tm_processes</td>
<td>1</td>
<td>FALSE number of AQ Time Managers to start</td>
<td></td>
</tr>
<tr>
<td>archive_lag_target</td>
<td>0</td>
<td>FALSE Maximum number of seconds of redo's the standby could lose</td>
<td></td>
</tr>
<tr>
<td>asm_diskgroups</td>
<td></td>
<td>FALSE disk groups to mount automatically</td>
<td></td>
</tr>
<tr>
<td>asm_diskstring</td>
<td></td>
<td>FALSE disk set locations for discovery</td>
<td></td>
</tr>
<tr>
<td>asm_io_processes</td>
<td>0</td>
<td>FALSE number of I/O processes in the ASM I/O SERVER instance</td>
<td></td>
</tr>
<tr>
<td>asm_power_limit</td>
<td>1</td>
<td>FALSE number of parallel relocations for disk rebalancing</td>
<td></td>
</tr>
<tr>
<td>asm_preferred_read_failure_groups</td>
<td></td>
<td>FALSE preferred read failure groups</td>
<td></td>
</tr>
</tbody>
</table>
audit_file_dest /u01/app/oracle/admin/orcl/adump False Directory in which auditing files are to reside

audit_sys_operations TRUE FALSE enable sys auditing

audit_syslog_level FALSE Syslog facility and level

audit_trail DB FALSE enable system auditing

awr_snapshot_time_offset 0 FALSE Setting for AWR Snapshot Time Offset

background_core_dump partial FALSE Core Size for Background Processes

background_dump_dest /u01/app/oracle/product/12.2.0/dbhome_1/rdbms/log FALSE Detached process dump directory

backup_tape_io_slaves FALSE FALSE BACKUP Tape I/O slaves

bitmap_merge_area_size 1048576 FALSE maximum memory allow for BITMAP MERGE

blank_trimming FALSE FALSE blank trimming semantics parameter

buffer_pool_keep FALSE FALSE Number of database blocks/latches in keep buffer pool

buffer_pool_recycle FALSE FALSE Number of database blocks/latches in recycle buffer pool

cdb_cluster FALSE FALSE if TRUE startup in CDB Cluster mode

cdb_cluster_name orcl FALSE CDB Cluster name

cell_offload_compaction ADAPTIVE FALSE Cell packet compaction strategy

cell_offload_decryption TRUE FALSE enable SQL processing offload of encrypted data to cells

cell_offload_parameters FALSE FALSE Additional cell offload parameters
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cell_offload_plan_display</td>
<td>AUTO</td>
<td>FALSE Cell offload explain plan display</td>
</tr>
<tr>
<td>cell_offload_processing</td>
<td>TRUE</td>
<td>FALSE enable SQL processing offload to cells</td>
</tr>
<tr>
<td>cell_offloadgroup_name</td>
<td></td>
<td>FALSE Set the offload group name</td>
</tr>
<tr>
<td>cellmemory_clause_default</td>
<td></td>
<td>FALSE Default cellmemory clause when no DDL specified</td>
</tr>
<tr>
<td>circuits</td>
<td></td>
<td>FALSE max number of circuits</td>
</tr>
<tr>
<td>client_result_cache_lag</td>
<td>3000</td>
<td>FALSE client result cache maximum lag in milliseconds</td>
</tr>
<tr>
<td>client_result_cache_size</td>
<td>0</td>
<td>FALSE client result cache max size in bytes</td>
</tr>
<tr>
<td>clonedb</td>
<td>FALSE</td>
<td>FALSE clone database</td>
</tr>
<tr>
<td>cluster_database</td>
<td>FALSE</td>
<td>FALSE if TRUE startup in cluster database node</td>
</tr>
<tr>
<td>cluster_database_instances</td>
<td>1</td>
<td>FALSE number of instances to use for sizing cluster db SGA structures</td>
</tr>
<tr>
<td>cluster_interconnects</td>
<td></td>
<td>FALSE interconnects for RAC use</td>
</tr>
<tr>
<td>commit_logging</td>
<td></td>
<td>FALSE transaction commit log write behaviour</td>
</tr>
<tr>
<td>commit_point_strength</td>
<td>1</td>
<td>FALSE Bias this node has toward not preparing in a two-phase commit</td>
</tr>
<tr>
<td>commit_wait</td>
<td></td>
<td>FALSE transaction commit log wait behaviour</td>
</tr>
<tr>
<td>commit_write</td>
<td></td>
<td>FALSE transaction commit log write behaviour</td>
</tr>
<tr>
<td>common_user_prefix</td>
<td>C###</td>
<td>FALSE Enforce restriction on a prefix of a Common User/Role/Profile name</td>
</tr>
</tbody>
</table>
compatible 12.2.0.0.0 FALSE Database will be completely compatible with this software version

connection_brokers ((TYPE=DEDICATED) (BR KERS=1)), ((TYPE=EM ON) (BROKER S=1))

control_file_record_keep_time 7 FALSE control file record keep_time in days

control_files /u02/app/oracle/orcl/c control01.ctl, /u03/app/oracle/cast recovery_area/orcl/control02.ctl

control_management_pack_access DIAGNOSTIC FALSE declares which manageability packs are enabled

core_dump_dest /u01/app/oracle/diag/orcl/cdmp

cpu_count 1 FALSE number of CPUs for this instance

create_bitmap_area_size 8388608 FALSE size of create bitmap buffer for bitmap index

create_stored_outlines FALSE create stored outlines for DML statements

cursor_bind_capture_destination memory+disk FALSE Allowed destination for captured bind variables
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cursor_invalidation</td>
<td>IMMEDIATE</td>
<td>FALSE default for DDL cursor invalidation semantics</td>
</tr>
<tr>
<td>cursor_sharing</td>
<td>EXACT</td>
<td>FALSE cursor sharing mode</td>
</tr>
<tr>
<td>cursor_space_for_time</td>
<td>FALSE</td>
<td>FALSE use more memory in order to get faster execution</td>
</tr>
<tr>
<td>data_guard_sync_latency</td>
<td>0</td>
<td>FALSE Data Guard SYNC latency</td>
</tr>
<tr>
<td>data_transfer_cache_size</td>
<td>0</td>
<td>FALSE Size of data transfer cache</td>
</tr>
<tr>
<td>db_16k_cache_size</td>
<td>0</td>
<td>FALSE Size of cache for 16K buffers</td>
</tr>
<tr>
<td>db_2k_cache_size</td>
<td>0</td>
<td>FALSE Size of cache for 2K buffers</td>
</tr>
<tr>
<td>db_32k_cache_size</td>
<td>0</td>
<td>FALSE Size of cache for 32K buffers</td>
</tr>
<tr>
<td>db_4k_cache_size</td>
<td>0</td>
<td>FALSE Size of cache for 4K buffers</td>
</tr>
<tr>
<td>db_8k_cache_size</td>
<td>0</td>
<td>FALSE Size of cache for 8K buffers</td>
</tr>
<tr>
<td>db_big_table_cache_percent_target</td>
<td>0</td>
<td>FALSE Big table cache target size in percentage</td>
</tr>
<tr>
<td>db_block_buffers</td>
<td>0</td>
<td>FALSE Number of database blocks cached in memory</td>
</tr>
<tr>
<td>db_block_checking</td>
<td>FALSE</td>
<td>FALSE header checking and data and index block checking</td>
</tr>
<tr>
<td>db_block_checksum</td>
<td>TYPICAL</td>
<td>FALSE store checksum in db blocks and check during reads</td>
</tr>
<tr>
<td>db_block_size</td>
<td>8192</td>
<td>FALSE Size of database block in bytes</td>
</tr>
<tr>
<td>db_cache_advice</td>
<td>CN</td>
<td>FALSE Buffer cache sizing advisory</td>
</tr>
<tr>
<td>db_cache_size</td>
<td>0</td>
<td>FALSE Size of DEFAULT buffer pool for standard block size buffers</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>db_create_file_dest</td>
<td>/u02/app/oracle/orda</td>
<td>FALSE default database location</td>
</tr>
<tr>
<td>db_create_online_log_dest_1</td>
<td>FALSE online log/controlfile destination #1</td>
<td></td>
</tr>
<tr>
<td>db_create_online_log_dest_2</td>
<td>FALSE online log/controlfile destination #2</td>
<td></td>
</tr>
<tr>
<td>db_create_online_log_dest_3</td>
<td>FALSE online log/controlfile destination #3</td>
<td></td>
</tr>
<tr>
<td>db_create_online_log_dest_4</td>
<td>FALSE online log/controlfile destination #4</td>
<td></td>
</tr>
<tr>
<td>db_create_online_log_dest_5</td>
<td>FALSE online log/controlfile destination #5</td>
<td></td>
</tr>
<tr>
<td>db_domain</td>
<td>FALSE directory part of global database name stored with CREATE DATABASE</td>
<td></td>
</tr>
<tr>
<td>db_file_multiblock_read_count</td>
<td>128</td>
<td>FALSE db block to be read each IO</td>
</tr>
<tr>
<td>db_file_name_convert</td>
<td>FALSE datafile name convert patterns and strings for standby/clone db</td>
<td></td>
</tr>
<tr>
<td>db_files</td>
<td>200</td>
<td>FALSE max allowable # db files</td>
</tr>
<tr>
<td>db_flash_cache_file</td>
<td>FALSE flash cache file for default block size</td>
<td></td>
</tr>
<tr>
<td>db_flash_cache_size</td>
<td>0</td>
<td>FALSE flash cache size for db_flash_cache_file</td>
</tr>
<tr>
<td>db_flashback_retention_target</td>
<td>1440</td>
<td>FALSE Maximum Flashback Database log retention time in minutes.</td>
</tr>
<tr>
<td>db_index_compression_inheritance</td>
<td>NONE</td>
<td>FALSE options for table or tablespace level compression inheritance</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>db_keep_cache_size</td>
<td>0</td>
<td>FALSE Size of KEEP buffer pool for standard block size buffers</td>
</tr>
<tr>
<td>db_lost_write_protect</td>
<td>None</td>
<td>FALSE enable lost write detection</td>
</tr>
<tr>
<td>db_name</td>
<td>orcl</td>
<td>FALSE database name specified in CREATE DATABASE</td>
</tr>
<tr>
<td>db_performance_profile</td>
<td>FALSE</td>
<td>Database performance category</td>
</tr>
<tr>
<td>db_recovery_file_dest</td>
<td>/u03/app/oracle/fast_recovery_area</td>
<td>FALSE default database recovery file location</td>
</tr>
<tr>
<td>db_recovery_file_dest_size</td>
<td>2621440000</td>
<td>FALSE database recovery files size limit</td>
</tr>
<tr>
<td>db_recycle_cache_size</td>
<td>0</td>
<td>FALSE Size of RECYCLE buffer pool for standard block size buffers</td>
</tr>
<tr>
<td>db_securefile</td>
<td>PREFERRED</td>
<td>FALSE permit securefile storage during lob creation</td>
</tr>
<tr>
<td>db_ultra_safe</td>
<td>OFF</td>
<td>FALSE Sets defaults for other parameters that control protection levels</td>
</tr>
<tr>
<td>db_unique_name</td>
<td>orcl</td>
<td>FALSE Database Unique Name</td>
</tr>
<tr>
<td>db_unrecoverable_scn_tracking</td>
<td>TRUE</td>
<td>FALSE Track nologging SCN in controlfile</td>
</tr>
<tr>
<td>db_writer_processes</td>
<td>2</td>
<td>FALSE number of background database writer processes to start</td>
</tr>
<tr>
<td>dbwr_io_slaves</td>
<td>0</td>
<td>FALSE DBWR I/O slaves</td>
</tr>
<tr>
<td>ddl_lock_timeout</td>
<td>0</td>
<td>FALSE timeout to restrict the time that dds wait for dml lock</td>
</tr>
<tr>
<td>default_sharing</td>
<td>metadata</td>
<td>FALSE Default sharing clause</td>
</tr>
<tr>
<td>deferred_segment_creation</td>
<td>TRUE</td>
<td>FALSE defer segment creation to first insert</td>
</tr>
</tbody>
</table>
dg_broker_config_file1  
/racle/product/12.2.0/dbhome_1/dbs/dr1orc1.dat

dg_broker_config_file2  
/racle/product/12.2.0/dbhome_1/dbs/dr2orc1.dat

dg_broker_start  
FALSE  
FALSE start Data Guard broker (DMON process)

diagnostic_dest  
False  
FALSE diagnostic base directory

disablepdb_feature  
FALSE  
FALSE Disable features

disk_async_io  
TRUE  
FALSE Use async I/O for random access devices

dispatchers  
(PROTOCOL=TCP) (SERV=orclXDB)  
FALSE specifications of dispatchers

distributed_lock_timeout  
60  
FALSE number of seconds a distributed transaction waits for a lock

dml_locks  
2076  
FALSE dml locks - one for each table modified in a transaction

dnfs_batch_size  
4096  
FALSE Max number of async I/O requests queued per session

dst_upgrade_insert_conv  
TRUE  
FALSE Enables/Disables internal conversions during DST upgrade

enable_ddl_logging  
FALSE  
FALSE enable ddl logging

enable_dnfs_dispatcher  
FALSE  
FALSE Enable DNFS Dispatcher

enable_goldengate_replication  
FALSE  
FALSE goldengate replication enabled
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enable_pdb_isolation</td>
<td>FALSE</td>
<td>FALSE Enables Pluggable Database isolation inside a CDB</td>
</tr>
<tr>
<td>enable_pluggable_database</td>
<td>FALSE</td>
<td>FALSE Enable Pluggable Database</td>
</tr>
<tr>
<td>enabled_PDBs_on_standby</td>
<td>*</td>
<td>FALSE List of Enabled PDB patterns</td>
</tr>
<tr>
<td>encrypt_new_tablespaces</td>
<td>CLOUD_ONLY FALSE</td>
<td>whether to encrypt newly created tablespaces</td>
</tr>
<tr>
<td>event</td>
<td>FALSE</td>
<td>FALSE debug event control - default null string</td>
</tr>
<tr>
<td>exafusion_enabled</td>
<td>1</td>
<td>FALSE Enable Exafusion</td>
</tr>
<tr>
<td>external_keystore_credential_location</td>
<td>FALSE</td>
<td>external keystore credential location</td>
</tr>
<tr>
<td>fal_client</td>
<td>FALSE</td>
<td>FALSE FAL client</td>
</tr>
<tr>
<td>fal_server</td>
<td>FALSE</td>
<td>FALSE FAL server list</td>
</tr>
<tr>
<td>fast_start_io_target</td>
<td>0</td>
<td>FALSE Upper bound on recovery reads</td>
</tr>
<tr>
<td>fast_start_mtttr_target</td>
<td>0</td>
<td>FALSE MTTTR target in seconds</td>
</tr>
<tr>
<td>fast_start_parallel_rollback</td>
<td>LOW</td>
<td>FALSE max number of parallel recovery slaves that may be used</td>
</tr>
<tr>
<td>file_mapping</td>
<td>FALSE</td>
<td>FALSE enable file mapping</td>
</tr>
<tr>
<td>fileio_network_adaptors</td>
<td>FALSE</td>
<td>Network Adaptors for File I/O</td>
</tr>
<tr>
<td>filesystemio_options</td>
<td>none</td>
<td>FALSE IO operations on filesystem files</td>
</tr>
<tr>
<td>fixed_date</td>
<td>FALSE</td>
<td>fixed SYSDATE value</td>
</tr>
<tr>
<td>gcs_server_processes</td>
<td>0</td>
<td>FALSE number of background gcs_server processes to start</td>
</tr>
<tr>
<td>global_names</td>
<td>FALSE</td>
<td>FALSE enforce that database links have same name as remote database</td>
</tr>
<tr>
<td>global_txn_processes</td>
<td>1</td>
<td>FALSE number of background global transaction processes to start</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>hash_area_size</td>
<td>131072</td>
<td>FALSE size of in-memory hash work area</td>
</tr>
<tr>
<td>heat_map</td>
<td>OFF</td>
<td>FALSE ILM Heatmap Tracking</td>
</tr>
<tr>
<td>hi_shared_memory_address</td>
<td>0</td>
<td>FALSE SGA starting address (high order 32-bits on 64-bit platforms)</td>
</tr>
<tr>
<td>hs_autoregister</td>
<td>TRUE</td>
<td>FALSE enable automatic server DD updates in HS agent self registration</td>
</tr>
<tr>
<td>ifile</td>
<td></td>
<td>FALSE include file in init.ora</td>
</tr>
<tr>
<td>inmemory_ado_enabled</td>
<td>FALSE</td>
<td>FALSE Enable inmemory ADO</td>
</tr>
<tr>
<td>inmemory_clause_default</td>
<td></td>
<td>FALSE Default in-memory clause for new tables</td>
</tr>
<tr>
<td>inmemory_expressions_capture</td>
<td>DISABLE</td>
<td>FALSE Controls detection of frequently used costly expressions</td>
</tr>
<tr>
<td>inmemory_expressions_usage</td>
<td>ENABLE</td>
<td>FALSE Controls which In-Memory Expressions are populated in-memory</td>
</tr>
<tr>
<td>inmemory_force</td>
<td>DEFAULT</td>
<td>FALSE Force tables to be in-memory or not</td>
</tr>
<tr>
<td>inmemory_max_populate_servers</td>
<td>C</td>
<td>FALSE maximum inmemory populate servers</td>
</tr>
<tr>
<td>inmemory_query</td>
<td>ENABLE</td>
<td>FALSE Specifies whether in-memory queries are allowed</td>
</tr>
<tr>
<td>inmemory_size</td>
<td>C</td>
<td>FALSE size in bytes of in-memory area</td>
</tr>
<tr>
<td>inmemory_trickle_repopulate_server_1_s_percent</td>
<td></td>
<td>FALSE inmemory trickle repopulate servers percent</td>
</tr>
<tr>
<td>inmemory_virtual_columns</td>
<td>MANUAL</td>
<td>FALSE Controls which user-defined virtual columns are stored in-memory</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>instance_abort_delay_time</td>
<td>0</td>
<td>FALSE time to delay an internal initiated abort (in seconds)</td>
</tr>
<tr>
<td>instance_groups</td>
<td></td>
<td>FALSE list of instance group names</td>
</tr>
<tr>
<td>instance_mode</td>
<td>READ-WRITE</td>
<td>FALSE indicates whether the instance read-only or read-write or read-mostly</td>
</tr>
<tr>
<td>instance_name</td>
<td>orcl</td>
<td>FALSE instance name supported by the instance</td>
</tr>
<tr>
<td>instance_number</td>
<td>0</td>
<td>FALSE instance number</td>
</tr>
<tr>
<td>instance_type</td>
<td>RDBMS</td>
<td>FALSE type of instance to be executed</td>
</tr>
<tr>
<td>instant.restore</td>
<td>FALSE</td>
<td>FALSE instant repopulation of datafiles</td>
</tr>
<tr>
<td>java_jit_enabled</td>
<td>TRUE</td>
<td>FALSE Java VM JIT enabled</td>
</tr>
<tr>
<td>java_max_sessionspace_size</td>
<td>0</td>
<td>FALSE max allowed size in bytes of a Java sessionspace</td>
</tr>
<tr>
<td>java_pool_size</td>
<td>0</td>
<td>FALSE size in bytes of java pool</td>
</tr>
<tr>
<td>java_restrict</td>
<td>none</td>
<td>FALSE Restrict Java VM Access</td>
</tr>
<tr>
<td>java_soft_sessionspace_limit</td>
<td>0</td>
<td>FALSE warning limit on size in bytes of a Java sessionspace</td>
</tr>
<tr>
<td>job_queue_processes</td>
<td>1000</td>
<td>FALSE maximum number of job queue slave processes</td>
</tr>
<tr>
<td>large_pool_size</td>
<td>0</td>
<td>FALSE size in bytes of large pool</td>
</tr>
<tr>
<td>ldap_directory_access</td>
<td>NONE</td>
<td>FALSE RDBMS's LDAP access option</td>
</tr>
<tr>
<td>ldap_directory_sysauth</td>
<td>no</td>
<td>FALSE OID usage parameter</td>
</tr>
<tr>
<td>license_max_sessions</td>
<td>0</td>
<td>FALSE maximum number of non-system user sessions allowed</td>
</tr>
<tr>
<td>Variable</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>license_max_users</td>
<td>0</td>
<td>FALSE maximum number of named users that can be created in the database</td>
</tr>
<tr>
<td>license_sessions_warning</td>
<td>0</td>
<td>FALSE warning level for number of non-system user sessions</td>
</tr>
<tr>
<td>listener_networks</td>
<td></td>
<td>FALSE listener registration networks</td>
</tr>
<tr>
<td>local_listener</td>
<td></td>
<td>FALSE local listener</td>
</tr>
<tr>
<td>lock_name_space</td>
<td></td>
<td>FALSE lock name space used for generating lock names for standby/clone database</td>
</tr>
<tr>
<td>lock_sga</td>
<td>FALSE</td>
<td>FALSE Lock entire SGA in physical memory</td>
</tr>
<tr>
<td>log_archive_config</td>
<td></td>
<td>FALSE log archive config</td>
</tr>
<tr>
<td>log_archive_dest</td>
<td></td>
<td>FALSE archival destination text string</td>
</tr>
<tr>
<td>log_archive_dest_1</td>
<td></td>
<td>FALSE archival destination #1 text string</td>
</tr>
<tr>
<td>log_archive_dest_10</td>
<td></td>
<td>FALSE archival destination #10 text string</td>
</tr>
<tr>
<td>log_archive_dest_11</td>
<td></td>
<td>FALSE archival destination #11 text string</td>
</tr>
<tr>
<td>log_archive_dest_12</td>
<td></td>
<td>FALSE archival destination #12 text string</td>
</tr>
<tr>
<td>log_archive_dest_13</td>
<td></td>
<td>FALSE archival destination #13 text string</td>
</tr>
<tr>
<td>log_archive_dest_14</td>
<td></td>
<td>FALSE archival destination #14 text string</td>
</tr>
<tr>
<td>log_archive_dest_15</td>
<td></td>
<td>FALSE archival destination #15 text string</td>
</tr>
<tr>
<td>log_archive_dest_16</td>
<td></td>
<td>FALSE archival destination #16 text string</td>
</tr>
<tr>
<td>log_archive_dest_17</td>
<td></td>
<td>FALSE archival destination #17 text string</td>
</tr>
<tr>
<td>log_archive_dest_5</td>
<td>enable</td>
<td>FALSE archival destination #5 state text string</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>log_archive_dest_6</td>
<td>enable</td>
<td>FALSE archival destination #6 state text string</td>
</tr>
<tr>
<td>log_archive_dest_7</td>
<td>enable</td>
<td>FALSE archival destination #7 state text string</td>
</tr>
<tr>
<td>log_archive_dest_8</td>
<td>enable</td>
<td>FALSE archival destination #8 state text string</td>
</tr>
<tr>
<td>log_archive_dest_9</td>
<td>enable</td>
<td>FALSE archival destination #9 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_1</td>
<td>enable</td>
<td>FALSE archival destination #1 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_10</td>
<td>enable</td>
<td>FALSE archival destination #10 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_11</td>
<td>enable</td>
<td>FALSE archival destination #11 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_12</td>
<td>enable</td>
<td>FALSE archival destination #12 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_13</td>
<td>enable</td>
<td>FALSE archival destination #13 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_14</td>
<td>enable</td>
<td>FALSE archival destination #14 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_15</td>
<td>enable</td>
<td>FALSE archival destination #15 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_16</td>
<td>enable</td>
<td>FALSE archival destination #16 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_17</td>
<td>enable</td>
<td>FALSE archival destination #17 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_18</td>
<td>enable</td>
<td>FALSE archival destination #18 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_19</td>
<td>enable</td>
<td>FALSE archival destination #19 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_2</td>
<td>enable</td>
<td>FALSE archival destination #2 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state</td>
<td>enable</td>
<td>Archival Destination</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
<td>----------------------</td>
</tr>
<tr>
<td>log_archive_dest_state_20</td>
<td>enable</td>
<td>FALSE archival destination #20 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_21</td>
<td>enable</td>
<td>FALSE archival destination #21 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_22</td>
<td>enable</td>
<td>FALSE archival destination #22 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_23</td>
<td>enable</td>
<td>FALSE archival destination #23 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_24</td>
<td>enable</td>
<td>FALSE archival destination #24 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_25</td>
<td>enable</td>
<td>FALSE archival destination #25 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_26</td>
<td>enable</td>
<td>FALSE archival destination #26 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_27</td>
<td>enable</td>
<td>FALSE archival destination #27 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_28</td>
<td>enable</td>
<td>FALSE archival destination #28 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_29</td>
<td>enable</td>
<td>FALSE archival destination #29 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_3</td>
<td>enable</td>
<td>FALSE archival destination #3 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_30</td>
<td>enable</td>
<td>FALSE archival destination #30 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_31</td>
<td>enable</td>
<td>FALSE archival destination #31 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_4</td>
<td>enable</td>
<td>FALSE archival destination #4 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_5</td>
<td>enable</td>
<td>FALSE archival destination #5 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_6</td>
<td>enable</td>
<td>FALSE archival destination #6 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_7</td>
<td>enable</td>
<td>FALSE archival destination #7 state text string</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>log_archive_dest_state_8</td>
<td>enable</td>
<td>FALSE archival destination #8 state text string</td>
</tr>
<tr>
<td>log_archive_dest_state_9</td>
<td>enable</td>
<td>FALSE archival destination #9 state text string</td>
</tr>
<tr>
<td>log_archive_duplex_dest</td>
<td></td>
<td>FALSE duplex archival destination text string</td>
</tr>
<tr>
<td>log_archive_format</td>
<td>%t_%s_%r.d</td>
<td>FALSE archival destination format</td>
</tr>
<tr>
<td>log_archive_max_processes</td>
<td>4</td>
<td>FALSE maximum number of active ARCH processes</td>
</tr>
<tr>
<td>log_archive_min_succeed_dest</td>
<td>1</td>
<td>FALSE minimum number of archive destinations that must succeed</td>
</tr>
<tr>
<td>log_archive_start</td>
<td>FALSE</td>
<td>FALSE start archival process on SGA initialization.</td>
</tr>
<tr>
<td>log_archive_trace</td>
<td>0</td>
<td>FALSE Establish archive log operation tracing level</td>
</tr>
<tr>
<td>log_buffer</td>
<td>3735552</td>
<td>FALSE redo circular buffer size</td>
</tr>
<tr>
<td>log_checkpoint_interval</td>
<td>0</td>
<td>FALSE # redo blocks checkpoint threshold</td>
</tr>
<tr>
<td>log_checkpoint_timeout</td>
<td>1800</td>
<td>FALSE Maximum time interval between checkpoints in seconds</td>
</tr>
<tr>
<td>log_checkpoints_to_alert</td>
<td>FALSE</td>
<td>FALSE log checkpoint begin/end to alert file</td>
</tr>
<tr>
<td>log_file_name_convert</td>
<td></td>
<td>FALSE logfile name convert patterns and strings for standby/clone db</td>
</tr>
<tr>
<td>max_dispatchers</td>
<td></td>
<td>FALSE max number of dispatchers</td>
</tr>
<tr>
<td>max_dump_file_size</td>
<td>unlimited</td>
<td>FALSE Maximum size (in bytes) of dump file</td>
</tr>
<tr>
<td>Variable</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>max_iops</td>
<td>0</td>
<td>FALSE MAX IO per second</td>
</tr>
<tr>
<td>max_mbps</td>
<td>0</td>
<td>FALSE MAX MB per second</td>
</tr>
<tr>
<td>max_shared_servers</td>
<td>0</td>
<td>FALSE max number of shared servers</td>
</tr>
<tr>
<td>max_string_size</td>
<td>STANDARD</td>
<td>FALSE controls maximum size of VARCHAR2, NVARCHAR2, and RAW types in SQL</td>
</tr>
<tr>
<td>memory_max_target</td>
<td>0</td>
<td>FALSE Max size for Memory Target</td>
</tr>
<tr>
<td>memory_target</td>
<td>0</td>
<td>FALSE Target size of Oracle SGA and PGA memory</td>
</tr>
<tr>
<td>nls_calendar</td>
<td></td>
<td>FALSE NLS calendar system name</td>
</tr>
<tr>
<td>nls_comp</td>
<td>BINARY</td>
<td>FALSE NLS comparison</td>
</tr>
<tr>
<td>nls_currency</td>
<td></td>
<td>FALSE NLS local currency symbol</td>
</tr>
<tr>
<td>nls_date_format</td>
<td></td>
<td>FALSE NLS Oracle date format</td>
</tr>
<tr>
<td>nls_date_language</td>
<td></td>
<td>FALSE NLS date language name</td>
</tr>
<tr>
<td>nls_dual_currency</td>
<td></td>
<td>FALSE Dual currency symbol</td>
</tr>
<tr>
<td>nls_iso_currency</td>
<td></td>
<td>FALSE NLS ISO currency territory name</td>
</tr>
<tr>
<td>nls_language</td>
<td>AMERICAN</td>
<td>FALSE NLS language name</td>
</tr>
<tr>
<td>nls_length_semantics</td>
<td>BYTE</td>
<td>FALSE create columns using byte or char semantics by default</td>
</tr>
<tr>
<td>nls_nchar_conv_excnp</td>
<td>FALSE</td>
<td>FALSE NLS raise an exception instead of allowing implicit conversion</td>
</tr>
<tr>
<td>nls_numeric_characters</td>
<td></td>
<td>FALSE NLS numeric characters</td>
</tr>
<tr>
<td>nls_sort</td>
<td></td>
<td>FALSE NLS linguistic definition name</td>
</tr>
<tr>
<td>nls_territory</td>
<td>AMERICA</td>
<td>FALSE NLS territory name</td>
</tr>
<tr>
<td>nls_time_format</td>
<td></td>
<td>FALSE time format</td>
</tr>
<tr>
<td>nls_time_tz_format</td>
<td></td>
<td>FALSE time with timezone format</td>
</tr>
<tr>
<td>nls_timestamp_format</td>
<td></td>
<td>FALSE time stamp format</td>
</tr>
<tr>
<td>nls_timestamp_tz_format</td>
<td></td>
<td>FALSE timestamp with timezone format</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>noncdb_compatible</td>
<td>FALSE</td>
<td>FALSE Non-CDB Compatible</td>
</tr>
<tr>
<td>object_cache_max_size_percent</td>
<td>10</td>
<td>FALSE percentage of maximum size over optimal of the user session's object cache</td>
</tr>
<tr>
<td>object_cache_optimal_size</td>
<td>102400</td>
<td>FALSE optimal size of the user session's object cache in bytes</td>
</tr>
<tr>
<td>ofa_threads</td>
<td>4</td>
<td>FALSE Number of OFS threads</td>
</tr>
<tr>
<td>olap_page_pool_size</td>
<td>0</td>
<td>FALSE size of the olap page pool in bytes</td>
</tr>
<tr>
<td>one_step_plugin_for_pdb_with_tde</td>
<td>FALSE</td>
<td>FALSE Facilitate one-step plugin for PDB with TDE encrypted data</td>
</tr>
<tr>
<td>open_cursors</td>
<td>300</td>
<td>FALSE max # cursors per session</td>
</tr>
<tr>
<td>open_links</td>
<td>4</td>
<td>FALSE max # open links per session</td>
</tr>
<tr>
<td>open_links_per_instance</td>
<td>4</td>
<td>FALSE max # open links per instance</td>
</tr>
<tr>
<td>optimizer_adaptive_features</td>
<td>TRUE</td>
<td>FALSE controls adaptive features</td>
</tr>
<tr>
<td>optimizer_adaptive_reporting_only</td>
<td>FALSE</td>
<td>FALSE use reporting only mode for adaptive optimizations</td>
</tr>
<tr>
<td>optimizer_capture_sql_plan_baselines</td>
<td>FALSE</td>
<td>FALSE automatic capture of SQL plan baselines for repeatable statements</td>
</tr>
<tr>
<td>optimizer_dynamic_sampling</td>
<td>2</td>
<td>FALSE optimizer dynamic sampling</td>
</tr>
<tr>
<td>optimizer_features_enable</td>
<td>12.2.0.1</td>
<td>FALSE optimizer plan: compatibility parameter</td>
</tr>
<tr>
<td>optimizer_index_caching</td>
<td>0</td>
<td>FALSE optimizer percent index caching</td>
</tr>
<tr>
<td>optimizer_index_cost_adj</td>
<td>100</td>
<td>FALSE optimizer index cost adjustment</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>optimizer_inmemory_aware</td>
<td>TRUE</td>
<td>FALSE optimizer in-memory columnar awareness</td>
</tr>
<tr>
<td>optimizer_mode</td>
<td>RULE</td>
<td>FALSE optimizer mode</td>
</tr>
<tr>
<td>optimizer_secure_view_merging</td>
<td>TRUE</td>
<td>FALSE optimizer secure view merging and predicate pushdown/moveround</td>
</tr>
<tr>
<td>optimizer_use_invisible_indexes</td>
<td>FALSE</td>
<td>FALSE Usage of invisible indexes (TRUE/FALSE)</td>
</tr>
<tr>
<td>optimizer_use_pending_statistics</td>
<td>FALSE</td>
<td>FALSE Control whether to use optimizer pending statistics</td>
</tr>
<tr>
<td>optimizer_use_sql_plan_baselines</td>
<td>TRUE</td>
<td>FALSE use of SQL plan baselines for captured sql statements</td>
</tr>
<tr>
<td>os_authent_prefix</td>
<td>ops$</td>
<td>FALSE prefix for auto-logon accounts</td>
</tr>
<tr>
<td>os_roles</td>
<td>FALSE</td>
<td>FALSE retrieve roles from the operating system</td>
</tr>
<tr>
<td>outbound_dblink_protocols</td>
<td>ALL</td>
<td>FALSE Outbound D2LINK Protocols allowed</td>
</tr>
<tr>
<td>parallel_adaptive_multi_user</td>
<td>FALSE</td>
<td>FALSE enable adaptive setting of degree for multiple user streams</td>
</tr>
<tr>
<td>parallel_degree_limit</td>
<td>CPU</td>
<td>FALSE limit placed on degree of parallelism</td>
</tr>
<tr>
<td>parallel_degree_policy</td>
<td>MANUAL</td>
<td>FALSE policy used to compute the degree of parallelism (MANUAL/LIMITED/AUTO/ADAPTIVE)</td>
</tr>
<tr>
<td>parallel_execution_message_size</td>
<td>16384</td>
<td>FALSE message buffer size for parallel execution</td>
</tr>
<tr>
<td>parallel_force_local</td>
<td>FALSE</td>
<td>FALSE force single instance execution</td>
</tr>
<tr>
<td>parallel_instance_group</td>
<td>FALSE</td>
<td>FALSE instance group to use for all parallel operations</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>parallel_max_servers</td>
<td>40</td>
<td>FALSE maximum parallel query servers per instance</td>
</tr>
<tr>
<td>parallel_min_percent</td>
<td>0</td>
<td>FALSE minimum percent of threads required for parallel query</td>
</tr>
<tr>
<td>parallel_min_servers</td>
<td>4</td>
<td>FALSE minimum parallel query servers per instance</td>
</tr>
<tr>
<td>parallel_min_time_threshold</td>
<td>AUTO</td>
<td>FALSE threshold above which a plan is a candidate for parallelization (in seconds)</td>
</tr>
<tr>
<td>parallel_servers_target</td>
<td>16</td>
<td>FALSE instance target in terms of number of parallel servers</td>
</tr>
<tr>
<td>parallel_threads_per_cpu</td>
<td>2</td>
<td>FALSE number of parallel execution threads per CPU</td>
</tr>
<tr>
<td>pdb_file_name_convert</td>
<td></td>
<td>FALSE PDB file name convert patterns and strings for create cdb/pdb</td>
</tr>
<tr>
<td>pdb_lockdown</td>
<td></td>
<td>FALSE pluggable database lockdown profile</td>
</tr>
<tr>
<td>pdb_os_credential</td>
<td></td>
<td>FALSE pluggable database OS credential to bind</td>
</tr>
<tr>
<td>permit_92_wrap_format</td>
<td>TRUE</td>
<td>FALSE allow 9.2 or older wrap format in PL/SQL</td>
</tr>
<tr>
<td>pga_aggregate_limit</td>
<td>2147483648</td>
<td>FALSE limit of aggregate PGA memory for the instance or PDB</td>
</tr>
<tr>
<td>pga_aggregate_target</td>
<td>262144000</td>
<td>FALSE Target size for the aggregate PGA memory consumed by the instance</td>
</tr>
<tr>
<td>pga_aggregate_xmem_limit</td>
<td>0</td>
<td>FALSE limit of aggregate PGA XMEM memory consumed by the instance</td>
</tr>
</tbody>
</table>
plscope_settings
S: NONE
controls the compile time collection, cross reference, and storage of PL/SQL source code identifier and SQL statement data.
plsql_ccflags
plsql_code_type
INTERPRET
false
PL/SQL ccflags
PL/SQL code-type
plsql_debug
false
PL/SQL debug
plsql_optimize_level
2
PL/SQL optimize level
plsql_v2_compatibility
false
PL/SQL version 2.x compatibility flag
plsql_warnings
DISABLE: ALL
false
PL/SQL compiler warnings settings
pre_page_sga
true
false
pre-page sga for process
processes
300
false
user processes
processor_group_name
false
Name of the processor group that this instance should run in.
query_rewrite_enabled
true
false
allow rewrite of queries using materialized views if enabled
query_rewrite_integrity
enforced
false
perform rewrite using materialized views with desired integrity
rdbms_server_dn
false
RDBMS's Distinguished Name
read_only_open_delayed
false
false if TRUE delay opening of read only files until first access
recovery_parallelism
0
false
number of server processes to use for parallel recovery
<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>recyclebin</td>
<td>on</td>
<td>FALSE recyclebin processing</td>
</tr>
<tr>
<td>redo_transport_user</td>
<td></td>
<td>FALSE Data Guard transport user when using password file</td>
</tr>
<tr>
<td>remote_dependencies_mode</td>
<td>TIMESTAMP</td>
<td>FALSE remote-procedure-call dependencies mode parameter</td>
</tr>
<tr>
<td>remote_listener</td>
<td></td>
<td>FALSE remote listener</td>
</tr>
<tr>
<td>remote_login_passwordfile</td>
<td>EXCLUSIVE</td>
<td>FALSE password file usage parameter</td>
</tr>
<tr>
<td>remote_os_authent</td>
<td>FALSE</td>
<td>FALSE allow non-secure remote clients to use auto-logon accounts</td>
</tr>
<tr>
<td>remote_os_roles</td>
<td>FALSE</td>
<td>FALSE allow non-secure remote clients to use os roles</td>
</tr>
<tr>
<td>remote_recovery_file_dest</td>
<td></td>
<td>FALSE default remote database recovery file location for refresh/relocate</td>
</tr>
<tr>
<td>replication_dependency_tracking</td>
<td>TRUE</td>
<td>FALSE tracking dependency for Replication parallel propagation</td>
</tr>
<tr>
<td>resource_limit</td>
<td>TRUE</td>
<td>FALSE master switch for resource limit</td>
</tr>
<tr>
<td>resource_manager_cpu_allocation</td>
<td>1</td>
<td>FALSE Resource Manager CPU allocation</td>
</tr>
<tr>
<td>resource_manager_plan</td>
<td>SCHEDULER:[DB 0X4BFF]:DB FAULT_MAIN TENANCE_PLAN</td>
<td>FALSE resource mgr top plan</td>
</tr>
<tr>
<td>result_cache_max_result</td>
<td>5</td>
<td>FALSE maximum result size as percent of cache size</td>
</tr>
<tr>
<td>result_cache_max_size</td>
<td>5373952</td>
<td>FALSE maximum amount of memory to be used by the cache</td>
</tr>
<tr>
<td>result_cache_mode</td>
<td>MANUAL</td>
<td>FALSE result cache operator usage mode</td>
</tr>
<tr>
<td>Variable</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>result_cache_remoteExpiration</td>
<td>0</td>
<td>FALSE maximum life time (min) for any result using a remote object</td>
</tr>
<tr>
<td>resumableTimeout</td>
<td>0</td>
<td>FALSE set resumableTimeout</td>
</tr>
<tr>
<td>rollback_segments</td>
<td></td>
<td>FALSE undo segment list</td>
</tr>
<tr>
<td>sec_case_sensitive_logon</td>
<td>TRUE</td>
<td>FALSE case sensitive password enabled for logon</td>
</tr>
<tr>
<td>sec_max_failed_login_attempts</td>
<td>3</td>
<td>FALSE maximum number of failed login attempts on a connection</td>
</tr>
<tr>
<td>sec_protocol_errorFurtherAction</td>
<td>(DROP, 3)</td>
<td>FALSE TTC protocol error continue action</td>
</tr>
<tr>
<td>sec_protocol_errorTraceAction</td>
<td>TRACE</td>
<td>FALSE TTC protocol error action</td>
</tr>
<tr>
<td>sec_return_serverReleaseBanner</td>
<td>FALSE</td>
<td>FALSE whether the server returns the complete version information</td>
</tr>
<tr>
<td>serialReuse</td>
<td>disable</td>
<td>FALSE reuse the frame segments</td>
</tr>
<tr>
<td>serviceNames</td>
<td>orcl</td>
<td>FALSE service names supported by the instance</td>
</tr>
<tr>
<td>sessionCachedCursors</td>
<td>50</td>
<td>FALSE Number of cursors to cache in a session.</td>
</tr>
<tr>
<td>sessionMaxOpenFiles</td>
<td>10</td>
<td>FALSE maximum number of open files allowed per session</td>
</tr>
<tr>
<td>sessions</td>
<td>472</td>
<td>FALSE user and system sessions</td>
</tr>
<tr>
<td>sgaMaxSize</td>
<td>1073741824</td>
<td>FALSE maximum total SGA size</td>
</tr>
<tr>
<td>sgaMinsize</td>
<td>0</td>
<td>FALSE Minimum, guaranteed size of PDE's SGA</td>
</tr>
<tr>
<td>sgaTarget</td>
<td>1073741824</td>
<td>FALSE Target size of SGA</td>
</tr>
<tr>
<td>shadowCoreDump</td>
<td>partial</td>
<td>FALSE Core Size for Shadow Processes</td>
</tr>
<tr>
<td>sharedMemoryAddress</td>
<td>0</td>
<td>FALSE SGA starting address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(low order 32-bits on 64-bit platforms)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>shared_pool_reserved_size</td>
<td>12373196</td>
<td>FALSE size in bytes of reserved area of shared pool</td>
</tr>
<tr>
<td>shared_pool_size</td>
<td>0</td>
<td>FALSE size in bytes of shared pool</td>
</tr>
<tr>
<td>shared_server_sessions</td>
<td></td>
<td>FALSE max number of shared server sessions</td>
</tr>
<tr>
<td>shared_servers</td>
<td>1</td>
<td>FALSE number of shared servers to start up</td>
</tr>
<tr>
<td>skip_unusable_indexes</td>
<td>TRUE</td>
<td>FALSE skip unusable indexes if set to TRUE</td>
</tr>
<tr>
<td>smtp_out_server</td>
<td></td>
<td>FALSE utl_smtp server and port configuration parameter</td>
</tr>
<tr>
<td>sort_area_retained_size</td>
<td>0</td>
<td>FALSE size of in-memory sort work area retained between fetch calls</td>
</tr>
<tr>
<td>sort_area_size</td>
<td>65536</td>
<td>FALSE size of in-memory sort work area</td>
</tr>
<tr>
<td>spatial_vector_acceleration</td>
<td>FALSE</td>
<td>FALSE enable spatial vector acceleration</td>
</tr>
<tr>
<td>spfile</td>
<td></td>
<td>FALSE server parameter file</td>
</tr>
<tr>
<td></td>
<td></td>
<td>/u01/app/oracle/product/12.2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>/dbhome_1/dbs/apfile/orcl.ora</td>
</tr>
<tr>
<td>sql92_security</td>
<td>TRUE</td>
<td>FALSE require select privilege for searched update/delete</td>
</tr>
<tr>
<td>sql_trace</td>
<td>FALSE</td>
<td>FALSE enable SQL trace</td>
</tr>
<tr>
<td>sqltune_category</td>
<td>DEFAULT</td>
<td>FALSE Category qualifier for applying hintcots</td>
</tr>
<tr>
<td>standby_archive_dest</td>
<td>?&gt;/db/arc/archivelog destination text string&quot;</td>
<td>FALSE standby database</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>----------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>standby_db_keep_sessions</td>
<td>FALSE</td>
<td>KEEP session cross standby role transition</td>
</tr>
<tr>
<td>standby_file_management</td>
<td>MANUAL</td>
<td>FALSE if auto then files are created/dropped automatically on standby</td>
</tr>
<tr>
<td>star_transformation_enabled</td>
<td>FALSE</td>
<td>FALSE enable the use of star transformation</td>
</tr>
<tr>
<td>statistics_level</td>
<td>TYPICAL</td>
<td>FALSE statistics level</td>
</tr>
<tr>
<td>streams_pool_size</td>
<td>0</td>
<td>FALSE size in bytes of the streams pool</td>
</tr>
<tr>
<td>tape_async_io</td>
<td>TRUE</td>
<td>FALSE Use async I/O requests for tape devices</td>
</tr>
<tr>
<td>target_pdb</td>
<td>0</td>
<td>FALSE Parameter is a hint to adjust certain attributes of the CDB</td>
</tr>
<tr>
<td>temp_undo_enabled</td>
<td>FALSE</td>
<td>FALSE is temporary undo enabled</td>
</tr>
<tr>
<td>thread</td>
<td>0</td>
<td>FALSE Redo thread to mount</td>
</tr>
<tr>
<td>threaded Execution</td>
<td>FALSE</td>
<td>FALSE Threaded Execution Mode</td>
</tr>
<tr>
<td>timed_os_statistics</td>
<td>0</td>
<td>FALSE internal os statistic gathering interval in seconds</td>
</tr>
<tr>
<td>timed_statistics</td>
<td>TRUE</td>
<td>FALSE maintain internal timing statistics</td>
</tr>
<tr>
<td>trace_enabled</td>
<td>TRUE</td>
<td>FALSE enable in memory tracing</td>
</tr>
<tr>
<td>tracefile_identifier</td>
<td></td>
<td>FALSE trace file custom identifier</td>
</tr>
<tr>
<td>transactions</td>
<td>519</td>
<td>FALSE max. number of concurrent active transactions</td>
</tr>
<tr>
<td>transactions_per_rollback_segment</td>
<td>5</td>
<td>FALSE number of active transactions per rollback segment</td>
</tr>
</tbody>
</table>
### Listing of Undocumented Initialization Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>undo_management</td>
<td>AUTO</td>
<td>FALSE instance runs in SMU mode if TRUE, else in RBJ mode</td>
</tr>
<tr>
<td>undo_retention</td>
<td>900</td>
<td>FALSE undo retention in seconds</td>
</tr>
<tr>
<td>undo_tablespace</td>
<td>UNDOTBS1</td>
<td>FALSE use/switch undo tablespace</td>
</tr>
<tr>
<td>unified_audit_sga_queue_size</td>
<td>1048576</td>
<td>FALSE Size of Unified audit SGA Queue</td>
</tr>
<tr>
<td>uniform_log_timestamp_format</td>
<td>TRUE</td>
<td>FALSE use uniform timestamp formats vs pre-12.2 formats</td>
</tr>
<tr>
<td>use_dedicated_broker</td>
<td>FALSE</td>
<td>FALSE Use dedicated connection broker</td>
</tr>
<tr>
<td>use_indirect_data_buffers</td>
<td>FALSE</td>
<td>FALSE Enable indirect data buffers (very large SGA on 32-bit platforms)</td>
</tr>
<tr>
<td>use_large_pages</td>
<td>TRUE</td>
<td>FALSE Use large pages if available (TRUE/FALSE/ONLY)</td>
</tr>
<tr>
<td>user_dump_dest</td>
<td>/u01/app/o racle/product/12.2.0/dhome_1/rdbms/log</td>
<td>FALSE User process dump directory</td>
</tr>
<tr>
<td>utl_file_dir</td>
<td></td>
<td>FALSE utl file accessible directories list</td>
</tr>
<tr>
<td>workarea_size_policy</td>
<td>AUTO</td>
<td>FALSE policy used to size SQL working areas (MANUAL/AUTO)</td>
</tr>
<tr>
<td>xml_db_events</td>
<td>enable</td>
<td>FALSE are XML DB events enabled</td>
</tr>
</tbody>
</table>
Using these parameters is not supported by Oracle, and I do not recommend using them on a production system. Use them only if you are directed to use them by Oracle Support and have thoroughly tested them on your crash-and-burn system. Undocumented initialization parameters can lead to database corruption (although a few of them can get your database back up when it becomes corrupted). Use at your own risk. The following query retrieves the undocumented parameters (4237 of them in 12cR2). No output is displayed due to space considerations.

```
select a.kspplim_name, b.kspstvl.value, b.kspstdf.default1, a.kspdesc
desc1
from x$ksppli a, x$ksppcv b
where a.index = b.index
and substr(kspplim,1,1) = '_'
order by kspplim;
```

**TIP**

Undocumented initialization parameters often show a glimpse of things coming in the next version of Oracle (or things going away from the last version). However, some of them don’t work or could cause severe problems.

**Additional Oracle Applications Notes**

In Chapter 4 you received tips for sizing the Oracle Applications database. This section covers some additional notes about Oracle Applications, including tips related to concurrent managers, module-specific patches, Oracle E-Business Suite (EBS) modules, web server tuning, timeouts, and database initialization parameter sizing.

**Concurrent Managers**

There are multiple different ways concurrent managers (CMs) can be deployed in an EBS implementation. In the simple case of one application server running all the application tier processes, pay attention to all the default managers that are defined as part of the implementation. If the default seems to be high for a simple implementation, you can reduce the number of standard
managers and create specialized managers with different work shifts. For example, you can assign Order Management–related batch jobs to a specialized manager that runs only in the night so that accidental execution of these programs during the peak hours can be avoided.

While reducing the standard managers, you can create custom “slow queue” and “fast queue” concurrent managers by defining two of those entries from the Concurrent Manager | Define screen by appropriately configuring the sleep time. For slow queues, set the sleep time to a higher number of seconds (160 seconds), and for fast queues, set the sleep time to a low value (30 seconds).

The other important parameter related to concurrent managers is the cache size, which determines how many requests a CM tries to execute upon each pass. If the cache size is set too low, then the CM is polling the queue table fnd_concurrent_requests too frequently. If it is set too high, then the CM is repeatedly trying to execute upon requests already serviced by another CM. The rule of thumb for tuning the cache size is

\[
\text{# of CM Processes} \times \text{Desired Cache size per CM Process}
\]

For example, if you want to have 4 requests cached, then set the value to 200 for 50 target processes, and set it to 120 for 30 target processes.

The proper tuning of the sleep and cache size parameters will play a great role if and when parallel concurrent processing (PCP) is used along with the RAC databases. Parallel concurrent processing is a deployment option for larger environments where more than one application server is being used. In this setup, a primary node and a secondary node are defined for every concurrent manager queue. PCP is activated by tuning the AutoConfig variable appldcp. When the concurrent managers are started using `adcmctl.sh`, the internal concurrent manager is started on the primary node and will constantly poll the secondary node via tns. If it does not hear back from the other node, then concurrent managers would be failed to start in the primary node.

In RAC nodes where the interconnect bandwidth is low, an improper setting of the cache size and sleep time can cause “gc latch waits” in the database. Because these two parameters determine how often the SELECT FOR UPDATE query against fnd_concurrent_requests needs to be executed based on the STATUS_CODE and PHASE_CODE columns of this table, there could be hot blocks needed at the same time by various nodes across the RAC. The concurrency goes “critical” when Oracle RAC loses track of the current ownership of the block and is therefore not able to complete the block request from the other nodes (Dynamic Block Re-mastering—DRM). When multiple nodes require the same blocks of data/modified data for concurrency, you will run into “gc latch waits”—global cache concurrency waits that could bring down the entire EBS system to its knees.

In some implementations, either the development/implementation team or the DBA team tends to create custom triggers on the fnd_concurrent_requests table. Any trigger has an overhead of executing the code in it when it is fired. If you put that in the context of fnd_concurrent_requests having millions of rows with improper sleep time and cache values for the concurrent managers in a RAC environment, the gc latch waits issue would be even worse. So, if the triggers are not adding any value, disable them or revisit the purpose of why they were created in the first place. The same scenario of fnd_concurrent_requests and gc latches holds true for any other cohesive processes such as Pick, Release, Order, Import functionalities. By nature, these two can stress the “interconnect” by competing for the hot blocks in the Order Entry–related tables.

For very large environments, the concurrent managers can be tuned further by doing what is known
as CM affinity. It is controlled by the AutoConfig variable s_cp_twotask in the concurrent manager nodes. This variable can be set to a specific tns value or to a CRS service value that can pin all of the manager’s process from this particular concurrent manager to a specific instance in the RAC. There might be concurrent programs where the trace is enabled by default. `SELECT * FROM FND_CONCURRENT_PROGRAMS WHERE ENABLE_TRACE='Y'` can list all the concurrent programs for which trace is enabled. Revisit the list and take appropriate action. Usually for a specific issue, Oracle Support would ask you to turn on the trace, and people tend to forget to turn off the trace after the issue is resolved. Verify that the “Purge Concurrent Programs Request Logs” is scheduled to run. Frequency may vary depending on the site-specific and legislative requirements, but not running or running for anything more than 60 days would cause fnd_concurrent_requests and other related objects to grow substantially.

Workflow needs to be part of the discussion of concurrent managers. The Workflow Engine plays a major role in Oracle EBS. It has business events defined for various business functionalities that move the work from one place to the next. Work with the business analysts and/or functional folks to determine whether all the default business events are required for the current installation. There are numerous events that are turned on by default. When these events are on, they create workflow records in the Workflow tables, causing excessive growth in these tables. From time to time, run the EBS Workflow Analyzer Report as per “EBS Workflow (WF) Analyzer” (Doc ID 1369938.1). This HTML report will provide a clear picture of the state of the Workflow Engine, with different sections such as Workflow Administration, Workflow Footprint, Workflow Concurrent Programs, Workflow Notification Mailer, etc. Any check that’s not passed needs to be looked into.

For example, if the Workflow Administration section shows there are a huge number of workflows that are in “stuck” status, they need to be cleaned up. Or if the Workflow Patch Levels section indicates patch levels are not up to the latest and greatest, these need to be worked on and cleaned up. Even after executing the recommendations from the Workflow Analyzer Report, if you see more volume in the WF tables, then consider adding dedicated WF agent listeners for sales orders/purchase orders and for generic deferred events to process heavy WF items through the Oracle Access Manager (OAM) screens. In addition, take a look at “Troubleshooting Workflow Data Growth Issues” (Doc ID 298550.1) for details on how to purge and delete the unwanted workflow data.

Applications—Finding Module-Specific Patches

There are module-specific performance issues and fixes available depending on what modules are being primarily used on your current production instances. However, there is a one-stop shop to find all the patches related to performance, from RDBMS to ATG to Financials and other major modules. This is documented in “Oracle E-Business Suite Recommended Performance Patches” (Doc ID 244040.1) and is very frequently updated for the newly identified and bug-fixed patches. If you are an Apps DBA, bookmark this page (it will come in handy at the time of need) and consult this document during the design/preparation stage of your next patching cycle.

Diagnostics Data Collection: EBS Analyzers
Over the years, EBS and its related support methodologies for day-to-day smooth operation have matured. As of this writing, there is an analyzer tool for most of the modules in EBS. Each of these tools is very valuable in terms of troubleshooting a module-specific problem, data discrepancy issues, an Accounts Payable (AP) problem, a concurrent manager issue, etc. Similar to the output described for the Workflow Analyzer Report in the “Concurrent Managers” section, all other analyzers produce a nice HTML-formatted report that can be used for in-house maintenance purposes or can be used at the time of troubleshooting or working with Oracle Support. The EBS analyzers are minimally invasive, and do not perform any INSERTs, UPDATEs, or DELETEs in the database. Instead, they just collect data to do a health check for a specific module. They review the overall footprint for a given module, review its configuration details, and provide recommendations based on best practices. Currently, the following analyzers are available to download from the Oracle Support website:

1. Workflow (WF) Analyzer
2. Concurrent Processing (CP) Analyzer
3. Reports & Printing Analyzer
4. Clone Log Parser Utility
5. Database Parameter Settings Analyzer
6. BI Publisher (BIP) Analyzer
7. Cash Management Transaction Analyzer
8. Oracle Receivables Adjustment Analyzer
9. Oracle Receivables AutoAccounting Analyzer
10. Oracle Receivables AutoInvoice Analyzer
11. Oracle Receivables Period Close Analyzer
12. Oracle Receivables Transaction Analyzer
13. R12: Master GDF Diagnostic (MGD) to Validate Data Related to Invoices, Payments, Accounting, Suppliers and EBTax
14. Payables Create Accounting Analyzer
15. Payables Period Close Analyzer
16. AP, AR, and EBTax Setup/Data Integrity Analyzer
17. Payables Trial Balance Analyzer
18. Oracle Payments (IBY) Funds Disbursement Analyzer
19. Oracle Public Sector Accounting (PSA) Data Validation Analyzer
20. Internet Expenses (OIE) Analyzer
21. Inventory Consignment Analyzer
22. Inventory Transaction Analyzer
23. Order Management Sales Order Analyzer
24. R12: Order Management (ONT) Analyzer Diagnostic Script
The analyzers can be installed separately on an as-needed basis or can be downloaded as a bundle via the EBS Support Analyzer Bundle Menu Tool, a Perl-based menu system that you can download from Oracle Support Note 1939637.1.

**Web Server Tuning**

EBS 11i and R12.1.x run on Oracle Internet Application Server (iAS). Standard Apache performance tuning guidelines apply to these versions. You can enable verbose garbage collection methodologies, rotate the Apache logs for readability at certain sizes, increase/decrease the log levels, etc. The application is deployed based on the Java virtual machines (JVMs) for OACore, FormsGroup, oafm group, etc. These JVMs are the basic engines to serve the web traffic from the browsers/applications.
and can be tuned depending on the footprint of the installations. Oracle recommends one oacore JVM per 100 active/concurrent users. Typically, one CPU core can support one JVM, so if you have a dual quad core system (2*4=8 CPUs), it can support eight JVMs. But the numbers can vary according to the chip architecture. You can conservatively place four JVMs in a dual quad core system, or one JVM per two CPUs. On the other hand, the forms group can support up to 100 to 250 Oracle Forms users. But the number depends on what kind of forms the users are opening. More complex forms would require more resources. So, conservatively, we can say that one forms JVM can service around 125 Oracle Forms users.

Once you determine the active users in the EBS system, you can determine the number of JVMs required based on the given hardware according to the formulas in the previous paragraph. However, within a JVM, memory parameters play a crucial role in terms of garbage collection, minimum value of the starting footprint, and so on. The minimum and maximum memory per JVM are configurable. Some Java versions will not allow more than a 2GB footprint, but later versions from 1.6/1.7 onward allow a bigger footprint. So, the total memory needed should be calculated meticulously for a given web server so that the OS does not do excessive swapping.

For example, if you have two oacore JVMs with -Xmx1024M and one forms group with -Xmx1024M, that’s 3GB of total memory requirement just for this particular web server. At the OS level, the server should have enough memory to support this configuration. For a larger environment, if you have more than a few hundred users—for example, if you are using Oracle EBS mainly for HCM with thousands of employees who would be using the iExpenses modules—then it is safe to assume that, at the expense report submitting deadlines, there would be around 500 concurrent users in the system. For this scenario, consider having more than one web/middle tier in a load-balanced environment. Each middle tier can have multiple oacore JVMs to support this kind of huge load. According to the expected end-user volume, the database-side processes/sessions parameters and other SGA-related memory parameters need to be increased/tuned as well.

All of the JVMs and their memory parameters are controlled by the AutoConfig variables oacore_nprocs, frmsrv_nprocs, forms_nprocs, oacore_jvm_start_options, oafm_jvm_start_options, and forms_jvm_start_option. Once these variables are properly adjusted in the context file, AutoConfig should be run for the new values to take effect.

Timeouts

There are numerous timeout variables that determine when to terminate an idle EBS connection. Timeout variables play an important role in the stability of an EBS system. Idle or runaway user connections will consume the resources on the web server JVMs, OS memory, database connections and database memory, and so forth. For larger environments, these variables need to be more carefully calibrated in order to avoid memory/CPU problems across the tech stack. These variables range from database to web server variables to application profiles. The following table was originally put forth by Greg Kitzmiller, and was later enhanced by TUSC. This is not complete by any means, but it is a good starting point on where and how to find out the actual values set across the tech stack of an EBS system.
<table>
<thead>
<tr>
<th>Timeout Variable</th>
<th>Unit</th>
<th>Recom. Value</th>
<th>Metalink Notes</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQLNET.INBOUND_CONNECT_TIMEOUT</td>
<td>sec</td>
<td>60</td>
<td></td>
<td>Specifies the time for client to connect with the database server and provide necessary authentication information. If client fails to connect and complete authentication in the time specified, then the database server disconnects the connection. For slower networks, use a higher value, but not using this parameter at all will result in denial-of-service attacks where malicious clients can attempt to flood the database with a huge number of connect requests at the same time.</td>
</tr>
<tr>
<td>SQLNET.EXPIRE_TIME = 20</td>
<td>min</td>
<td>10</td>
<td></td>
<td>Specifies a time interval to send a probe and verify whether the client/server connections are still active. Keep it under the ICX: Session Timeout value. This will allow the database to clean up inactive DB sessions.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Unit</td>
<td>Value</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------</td>
<td>-------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>ICX: Session Timeout</td>
<td>min</td>
<td>30</td>
<td>Set by s_sesstimeout_self-service. This AutoConfig variable controls the ICX Session Timeout profile and s_sesstimeout/s_oc4j_timeout from R12 onward. So, the actual value in the context file is specified in milliseconds but agwebprf.sql will convert this value into minutes and update the find_profile tables. You can manually update the profile from the apps but the next AutoConfig run will wipe out that settings. 30 minutes is the recommended value for a high performance system.</td>
<td></td>
</tr>
<tr>
<td>ICX: Limit Time</td>
<td>hrs</td>
<td>12</td>
<td>This profile controls the total time a forms session can be logged in. After this many number of hours you will get a pop-up warning window irrespective of the activity being done at that time.</td>
<td></td>
</tr>
<tr>
<td>ICX: Limit Connect</td>
<td># of requests</td>
<td>2000</td>
<td>The maximum number of connection requests an user can make in a single session.</td>
<td></td>
</tr>
<tr>
<td>JTF_INACTIVE_SESSION_TIMEOUT</td>
<td>min</td>
<td>30</td>
<td>Should be the same as ICX: Session Timeout.</td>
<td></td>
</tr>
<tr>
<td>s_sesstimeout</td>
<td>ms</td>
<td>1800000</td>
<td>Sets initial value of ICX: Session Timeout. This should be set to default, which is 1800000. Anything higher can result in performance and out-of-memory errors.</td>
<td></td>
</tr>
<tr>
<td>s_f60time/s_formstime</td>
<td>min</td>
<td>5</td>
<td>Environment variable. The higher this variable is set, the longer the Forms processes will take to be cleaned up. Any dead connections older than 5 minutes would be cleaned up.</td>
<td></td>
</tr>
</tbody>
</table>
### Database Initialization Parameter Sizing

This material is also part of Note 396009.1, and I think it is an excellent guideline! The following table should be used to size the relevant parameters to size the memory of an EBS database. See Chapter 4 for related information on this table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$OA_HTML/bin/appsweb.cfg-Heartbeat</td>
<td>min</td>
<td>2</td>
<td>Forms client pings the server via a heartbeat message every 2 minutes by default. This heartbeat interval can be used to keep the connection alive if, e.g., the proxy or firewall has an inactivity timeout. If the server does not hear from the client for more than the heartbeat interval, it assumes that the client is gone and terminates that session. It should be less than s_f60time.</td>
</tr>
<tr>
<td>s_fmNetworkRetries</td>
<td># of tries</td>
<td>30</td>
<td>Number of times the client should attempt to connect to the server if the network is interrupted.</td>
</tr>
<tr>
<td>s_oc4j_sesstimeout</td>
<td>min</td>
<td>30</td>
<td>Should match ICX: Session Timeout.</td>
</tr>
<tr>
<td>session.timeout</td>
<td>ms</td>
<td>600000</td>
<td>$APACHE_TOP/Apache/Jserv/etc/zone.properties; longer idle sessions will cause out-of-memory errors.</td>
</tr>
</tbody>
</table>
Also part of Note 396009.1 are parameters from your database initialization parameters file that should be removed. Please see the note for that list. (My personal feeling is that some of these should be used to enhance performance, but many are not set because they feel that the DEFAULT is the correct setting … please test carefully!)

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Development or Test Instance</th>
<th>11–100 Users</th>
<th>101–500 Users</th>
<th>501–1000 Users</th>
<th>1001–2000 Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes</td>
<td>200</td>
<td>200</td>
<td>800</td>
<td>1200</td>
<td>2500</td>
</tr>
<tr>
<td>Sessions</td>
<td>400</td>
<td>400</td>
<td>1600</td>
<td>2400</td>
<td>5000</td>
</tr>
<tr>
<td>sga_target</td>
<td>1G</td>
<td>1G</td>
<td>2G</td>
<td>3G</td>
<td>14G</td>
</tr>
<tr>
<td>shared_pool_size (csp)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1800M</td>
<td>3000M</td>
</tr>
<tr>
<td>shared_pool_reserved_size (csp)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>180M</td>
<td>300M</td>
</tr>
<tr>
<td>shared pool size (no csp)</td>
<td>400M</td>
<td>600M</td>
<td>800M</td>
<td>1000M</td>
<td>2000M</td>
</tr>
<tr>
<td>shared_pool_reserved_size (no csp)</td>
<td>40M</td>
<td>60M</td>
<td>80M</td>
<td>100M</td>
<td>100M</td>
</tr>
<tr>
<td>pga_aggregate_target</td>
<td>1G</td>
<td>2G</td>
<td>4G</td>
<td>10G</td>
<td>20G</td>
</tr>
<tr>
<td>Total Memory Required</td>
<td>~2 GB</td>
<td>~3 GB</td>
<td>~6 GB</td>
<td>~13 GB</td>
<td>~34 GB</td>
</tr>
</tbody>
</table>

Also part of Note 396009.1 are parameters from your database initialization parameters file that should be removed. Please see the note for that list. (My personal feeling is that some of these should be used to enhance performance, but many are not set because they feel that the DEFAULT is the correct setting … please test carefully!)

Top 10 Reasons *Not* to Write a Book

1. You like sleep and caffeine-enhanced water clogs your coffee maker.
2. You have enough trouble getting the time to read books, let alone write one.
3. You enjoy getting together with your family from time to time.
4. You’re tired of being the first one in the office (actually, you’ve been there all night).
5. Your hobby is golf and you never play.
6. You enjoy noticing the world around you rather than feeling a “purple haze all through your mind.”
7. Kevin Loney will write on that subject eventually … you’ll wait for his book.
8. You don’t want to “show off” how much you know … you’re far too humble.
9. Your PC is out of disk space already, although you’ve just loaded Windows 99.1415926.
10. You just got your *life* back after the last Oracle upgrade—no way!
TIP

Retirement is a good time to write a book, not during the fastest tech growth cycles in history (starting to get faster than pre-2000) followed by the Great Recession. Perhaps when the 2000-year bull market ends somewhere between 2018 and 2020 (good time to get out of the market in my opinion) that might be a better time.

Tips Review

- Setting certain initialization parameters correctly could be the difference between a report taking two seconds and two hours. Test changes on a test system thoroughly before implementing those changes in a production environment.
- Oracle includes some excellent options. Unfortunately, some of them do not work unless you have the initialization parameter set correctly.
- Undocumented initialization parameters can corrupt your database! Some of them can help you salvage a corrupted database. Try to use these only when all other choices have failed and with the help of Oracle Support.
- Undocumented initialization parameters often show a glimpse of things coming in the next version of Oracle (or things going away from the last version). However, some of them don’t work or could cause severe problems.
- Retirement is a good time to write a book, not during the fastest tech growth cycles in history (starting to get faster than pre-2000) followed by the Great Recession. Perhaps when the 2000-year bull market ends somewhere between 2018 and 2020 (good time to get out of the market in my opinion) that might be a better time.

References

Metalink Notes: 22908.1, 216205.1, 316889.1, 396009.1.
Various Oracle Support Notes and Documentation Manuals on Oracle Applications
*Oracle Database Performance Tuning Guide*, versions 11g and 12c (Oracle Corporation).

Thanks to Lucas Niemiec for testing the queries and providing the new listings for 11gR2. Thanks to Palani Kasi for new information on Oracle Applications. Thanks also to Brad Brown, Joe Trezzo, Randy Swanson, Sean McGuire, Greg Pucka, Mike Broulette, and Kevin Loney for their contributions to this chapter.
The V$ Views (DBA and Developer)

The V$ views are very helpful in analyzing database issues. There are 746 V$ views in 12cR2 (there were 525 in 11gR2). This appendix lists all views and creation scripts used to actually build the V$ and GV$ views. The V$ views vary in structure and number, depending on the database version and release used. Run the queries on your version of the database to get the number of views and structure for your specific version. The topics covered in this appendix include the following:

- Creation of V$ and GV$ views and X$ tables
- A list of all Oracle 12cR2 V$ views
- Oracle 12c script listing of the X$ tables used in the creation of the V$ views

NOTE

V$ to X$ and X$ to V$ cross-references can be found in Appendix C.

Creation of V$ and GV$ Views and X$ Tables

To understand the creation of X$ tables, knowing the V$ and data dictionary views can be crucial. And both are critical to comprehending fully the intricacies of Oracle. While knowledge of the views and tables is critical to your career, their creation has, however, remained somewhat of a vexing mystery. Figure 1 illustrates the creation of the underlying tables and the data dictionary views, whereas Figure 2 illustrates the creation of the X$ tables and the V$ views.
A List of Oracle 12c (12.2.0.0.1) GV$ Views

NOTE
The Oracle 12c V$ views are about the same as the GV$ views, minus the instance ID.
Here is the Oracle 12c query to obtain the listing of all the GV$ views (709 views):

```
set pagesize 1000

select name
from v$fixed_table
where name like 'GV%'
order by name;
```

A List of Oracle 12c (12.2.0.0.1) V$ Views

Here is the Oracle 12c query to get the listing of V$ views (746 views):

```
set pagesize 1000

select name
from v$fixed_table
where name like 'V%'
order by name;
```

The listing itself follows:
V$ACTIVE_INSTANCES
V$ACTIVE_SERVICES
V$ACTIVE_SESSION_HISTORY
V$ACTIVE_SESS_POOL_MTH
V$ADVISOR_CURRENT_SQLPLAN
V$ADVISOR_PROGRESS
V$ALERT_TYPES
V$AQ1
V$AQBACKGROUND_COORDINATOR
V$AQ_BMA2_NONDUR_SUBSCRIBERS
V$AQ CROSS_INSTANCE_JOBS
V$AQ DEQUEUE_TRANSACTIONS
V$AQ JOB COORDINATOR
V$AQ MESSAGE CACHE
V$AQ MESSAGE_CACHE_ADVICE
V$AQ MSGRM
V$AQ NONDUR_REGISTRATIONS
V$AQ NONDUR_SUBSCRIBER
V$AQ NONDUR_SUBSCRIBER_LWM
V$AQ_NOTIFICATION_CLIENTS
V$AQ_OPT_CACHED_SUBSHARD
V$AQ_OPT_INACTIVE_SUBSHARD
V$AQ_OPT_STATISTICS
V$AQ_OPT_UNCACHED_SUBSHARD
V$AQ_REMOTE_DDQURIEAFFINTITY
V$AQ_SERVER_POOL
V$AQ SHARED_SUBSCRIBER_STAT
V$AQ SUBSCRIBER_LOAD
V$ARCHIVE
V$ARCHIVED_LOG
V$ARCHIVE_DEST
V$ARCHIVEDEST_STATUS
V$ARCHVR_GAP
V$ARCHIVEPROCESSES
V$ASE_INFO
V$ASM_ACFSREPL
V$ASM_ACFSREPLTAG
V$ASM_ACFSNAPSHOTS
V$ASM_ACFSSTAG
V$ASM_ACFSVOLUMES
V$ASM_ACFS_ENCRYPTION_INFO
V$ASM_ACFS_SECURITY_INFO
V$ASM_ACFS_SEC_ADMIN
V$ASM_ACFS_SEC_CMDRULE
V$ASM_ACFS_SEC_REALM
V$ASM_ACFS_SEC_REALM_FILTER
V$ASM_ACFS_SEC_REALM_GROUP
V$ASM_ACFS_SEC_REALM_USER
V$ASM_ACFS_SEC_RULE
V$ASM_ACFS_SEC_RULESET
V$ASM_ACFS_SEC_RULESET_RULE
V$ASM_ALIAS
V$ASM_ATTRIBUTE
V$ASM_AUDIT_CLEANUP_JOBS
V$ASM_AUDIT_CLEAN_EVENTS
V$ASM_AUDIT_CONFIG_PARAMS
V$ASM_AUDIT_LASTARCH_TS
V$ASM_CLIENT
V$ASM_DISK
V$ASM_DISKGROUP
V$ASM_DISKGROUP_SPARSE
V$ASM_DISKGROUP_STAT
V$ASM_DISK_IOSAT
V$ASM_DISK_IOSAT_SPARSE
V$ASM_DISK_SPARS
V$ASM_DISK_SPARSE_STAT
V$ASM_DISK_STAT
V$ASM_ESTIMATE
V$ASM_FILE
V$ASM_FILEGROUP
V$ASM_FILEGROUP_FILE
V$ASM_FILEGROUP_PROPERTY
V$ASM_FILESYSTEM
V$ASM_OPERATION
V$ASM_QUOTAGROUP
V$ASM_TEMPLATE
V$ASM_USER
V$ASM_USERGROUP
V$ASM_USERGROUP_MEMBER
V$ASM_VOLUME
V$ASM_VOLUME_STAT
V$ASMVOL_ALLOCATE_OP
V$ASMVOL_ALLOCATE_OP
V$ASMVOL_CALC
V$ASMVOL_LONGOPS
V$ASMVOL_OI
V$ASMVOL_SESSION_INFO
V$BACKUP
V$BACKUP_ARCHIVELOG_DETAILS
V$BACKUP_ARCHIVELOG_SUMMARY
V$BACKUP_ASYNC_IO
V$BACKUP_COMPRESSION_PROGRESS
V$BACKUP_CONTROLFILE_DETAILS
Oracle 12c Scripts for the X$ Tables Used to Create the V$ Views

Because of the number of views in 12c, it’s no longer possible to list all queries in this book. To give you a sampling of what’s available, this section list scripts for a few dozen views that pertain to performance tuning so you can see the results. You can run your own query to see a specific one. The most common new columns that you’ll see in the 12c of the views are CON_ID (Container ID), with the advent of pluggable databases, and Adaptive Query Optimization columns. Here is the Oracle 12cR2 query to get a listing of all X$ queries for the V$ views (it will return 1457 rows in 12cR2; V$ and GV$ are returned):

```sql
V$SYSTEM_EVENT
V$SYSTEM_FIX_CONTROL
V$SYSTEM_PARAMETER
V$SYSTEM_PARAMETER2
V$SYSTEM_PARAMETER4
V$SYSTEM_RESET_PARAMETER
V$SYSTEM_RESET_PARAMETER2
V$SYSTEM_WAIT_CLASS
V$SYS_OPTIMIZER_ENV
V$SYS_REPORT_REQUESTS
V$SYS_REPORT_STATS
V$SYS_TIME_MODEL
V$TABLESPACE
V$TEMPFILE
V$TEMPFILE_INFO_INSTANCE
V$TEMPORARY_LOBS
V$TEMPSAT
V$TEMPSUNDOSTAT
V$TEMP_CACHE_TRANSFER
V$TEMP_EXTENT_MAP
V$TEMP_EXTENT_POOL
V$TEMP_PING
V$TEMP_SPACE_HEADER
V$THREAD
V$THRESHOLD_TYPES
V$TIMER
V$TIMEZONE_FILE
V$TIMEZONE_NAMES
V$TOPELEVELCALL
V$TRANSACTION
V$TRANSACTION_ENQUER
V$TRANSPORTABLE_PLATFORM
V$TSDP_SUPPORTED_FEATURE
V$TSM_SESSIONS
V$TYPE_SIZE
V$UNDOSTAT
V$UNIFIED_AUDIT_RECORD_FORMAT
V$UNIFIED_AUDIT_TRAIL
V$UNUSABLE_BACKUPFILE_DETAILS
V$VERSION
V$VPD_POLICY
V$WAITCLASSMETRIC
V$WAITCLASSMETRIC_HISTORY
V$WAITSTAT
V$WAIT_CHAINS
V$WALLET
V$WLM_DB_MODE
V$WLM_FCMETRIC
V$WLM_FCMETRIC_HISTORY
V$WLM_PC_STATS
V$WORKLOAD_REPLAY_THREAD
V$XML_AUDIT_TRAIL
V$XSTREAM_APPLY_COORDINATOR
V$XSTREAM_APPLY_READER
V$XSTREAM_APPLY_RECEIVER
V$XSTREAM_APPLY_SERVER
V$XSTREAM_CAPTURE
V$XSTREAM_MESSAGE_TRACKING
V$XSTREAM_OUTBOUND_SERVER
V$XSTREAM_TABLE_STATS
V$XSTREAM_TRANSACTION
V$XS_SESSIONS
V$XS_SESSION_NS_ATTRIBUTE
V$XS_SESSION_ROLE
V$ZONEMAP_USAGE_STATS
V$LOCK
V$LOCK1
V$SEQUENCES
746 rows selected.
```
View Name: GV$BH (New in 12c Bolded)

```sql
select 'View Name: ' || view_name,
       substr(substr(view_definition,1,3990),1,(instr(view_definition,'from') - 1)),
       substr(substr(view_definition,1,3990),(instr(view_definition,'from') + 1)),
       defa2 from v$fixed_view_definition
order by view_name;
```

View Name: V$BH (New in 12c Bolded)

```sql
select bl.inst_id, file#, dbid, class, decode(state,3,'free',1,'xcur',2,
       'scur',3,'cr',4,'rdr',5,'mrec',6,'trec',7,'wtrc',8,'pl',
       9,'memory',10,'mwrite',11,'donated',12,'protected',13,'securefile',
       14,'size',15,'flockpt',16,'flashfree',17,'flashcur',18,'flashna'),
       0, 0, 0, bh.lo_addr, le_id1, le_id2, decode(bitand(flag,1), 0, 'N', 'Y'),
       decode(bitand(flag,16), 0, 'N', 'Y'), decode(bitand(flag,1536), 0, 'N', 'Y'),
       decode(bitand(flag,16384), 0, 'N', 'Y'),
       decode(bitand(flag,65536), 0, 'N', 'Y'), obj, lsh, lobid, bitand(CBC_FLAG, 240)/16,
       decode(bitand(CBC_FLAG, 48)/16, 1, 'KEEP', 2, 'NONE', 'DEFAULT'),
       decode(bitand(CBC_FLAG, 192)/64, 1, 'KEEP', 2, 'NONE', 'DEFAULT'), bh.con_id
from x$ih bh, x$lo lu
where bh.lo_addr = lo.lo_addr ()
```

View Name: GV$CELL

```sql
select inst_id, cellpath_cellrow, cellhashval_cellrow,
       con_id, celltype_cellrow
from x$cell name;
```

View Name: V$CELL
select cell_path, cell_hashval, con_id, cell_type
from gv$cell
where inst_id = userenv('Instance');

View Name: GV$CELL_DISK

select c.cellpath_cellrow, cd.cell_hash, cd.incarnation_num, cd.metric_timestamp,
    cd.disk, cd.disk_id, cd.metric_id, md.metric_name, cd.metric_value,
    md.metric_type, cd.inst_id, cd.con_id
from x$kxdom disk cd, x$kxdom metric doco md,x$kcell name c
where cd.metric_id = md.metric_id
and cd.cell_hash = c.cellhashval_cellrow and cd.inst_id = md.inst_id
and cd.con_id = md.con_id and cd.con_id = c.con_id;

View Name: V$CELL_DISK

select cell name, cell hash, incarnation num, metric timestamp, disk name,
    disk_id, metric id, metric name, metric value, metric type, con id
from gv$cell_disk
where inst_id = userenv('Instance');

View Name: GV$CONTAINERS

select inst_id, con_id, dbid, con_nid, guid, name,
    decode(state, 0, 'MOUNTED', 1, 'READ WRITE', 2, 'READ ONLY',
    3, 'MIGRATE'), decode(restricted, 0, 'NO', 1, 'YES'), stime,
    create_con, total_size, block_size, decode(recovery_status, 0,
    'DISABLED', 1, 'DISABLED'), snapshot_parent_con_id, decode(app_root,
    1, 'YES', 'NO'), decode(app_root_con_id, NULL, 'NO', 'YES'),
    decode(app_scocd, 1, 'YES', 'NO'), app_root_con_id, decode(app_root_clons,
    1, 'YES', 'NO'), decode(proxy pdb, 1, 'YES', 'NO') from x$kcon

View Name: V$CONTAINERS
View Name: GV$INMEMORY_AREA

```sql
select inst_id, pool, allocated_len, used_len, status, con_id
from x$ktsimau;
```

View Name: V$INMEMORY_AREA

```sql
select pool, alloc_bytes, used_bytes, populate_status, con_id
from gv$inmemory_area
where inst_id = USERENV('instance');
```

View Name: GV$LATCH

```sql
select lt inst_id, lt.kalltaddr, lt.kalltmem, lt.kalltlnv, lt.kalltnam, lt.kallthls,
    lt.kalltwh, lt.kallthls, lt.kallthls0, lt.kallthls1, lt.kallthls2, lt.kallthls3,
    lt.kallthls4, lt.kallthls5, lt.kallthls6, lt.kallthls7, lt.kallthls8,
    lt.kallthls9, lt.kallthls10, lt.kallthls11, lt.kalltwh., lt.con_id
from x$kalltr lt;
```

View Name: V$LATCH

```sql
select addr, latch#, level#, name, hash, gets, misses, sleeps, immediate_gets,
    immediate_misses, waiters woken, waits holding latch, spin
gets, sleep1, sleep2,
    sleep3, sleep4, sleep5, sleep6, sleep7, sleep8, sleep9, sleep10, sleep11,
    wait_time, con_id
from gv$latch
where inst_id = USERENV('Instance');
```
View Name: GV$LATCHHOLDER

```sql
SELECT inst_id, kauprpid, kauprsid, kauprlat, kauprlnm, ksulagte, con_id
FROM x$kauprlat;
```

View Name: V$LATCHHOLDER

```sql
SELECT pid, sid, laddr, name, gets, con_id
FROM gv$latchholder
WHERE inst_id = userenv('Instance');
```

View Name: GV$LATCHNAME

```sql
SELECT inst_id, indx, ksllidnam, kslliddsp, ksllidhsh, con_id
FROM x$ksllid;
```

View Name: V$LATCHNAME

```sql
SELECT latch#, name, display_name, hash, con_id
FROM gv$latchname
WHERE inst_id = userenv('Instance');
```

View Name: GV$LATCH_CHILDREN

```sql
SELECT t.instd, t.kalltaddr, t.kalltmnm, t.kalltdcm, t.kalltlu1, t.kalltmnam,
       t.kalltth1, t.kalltwgt, t.kalltwft, t.kalitwai, t.kalltn1, t.kalltmsa,
       t.kalitw1, t.kallthst1, t.kallthst2, t.kallthst3, t.kallthst4, t.kallthst5,
       t.kallthst6, t.kallthst7, t.kallthst8, t.kallthst9, t.kallthst10, t.kallthst11, t.kalltwft, t.con_id
FROM x$kslltcr children: t;
```

View Name: V$LATCH_CHILDREN
**View Name: GV$LATCH_MISSES**

```sql
select addr,latch#,child#,level#,name,hash,gets,misses,sleeps,immediate_gets,
immediate_misses,waiters,woaken,waits,holding latch,spin gets,sleep1,sleep2,
sleep3,sleep4,sleep5,sleep6,sleep7,sleep8,sleep9,sleep10,sleep11,
wait_time,con_id
from qm$latch_children
where inst_id = USERENV('Instance');
```

**View Name: V$LATCH_MISSES**

```sql
select t1.inst_id,t1.kallnam,t2.kallnam,t1.kainwt,t1.kalsleep,t1.kalsct,
       t1.klwacwac1,t2.kalkww,t1.con_id
from x$kallw t2,x$kswac t1
where t2.index = t1.klwacwhere;
```

**View Name: GV$LIBRARYCACHE**

```sql
select inst_id,kglstdac,kglstgt,kglstg,decode(kglstgt,0,1,kglstg/kglstgt),kglstpin,kglstph,decode(kglstpin,0,1,kglstph/kglstpin),kglstlrd,kglstinv,kglstlq,kglstprq,kglstprq,kglstmiv,kglstmiv,con_id
from x$kglst
where kglsttyp = 'NAMESPACE'
and kglstgt != 0
and LENGTH(kglstdac) <= 15 ;
```

**View Name: V$LIBRARYCACHE**

```sql
```
select namespace, gets, gethits, gethitratio, pins, pinhits, pinhitratio, reloads, invalidations, dlm_lock_requests, dlm_pin_requests, dlm_pin_releases, dlm_invalidation_requests, dlm_invalidations, con_id
from gv$librarycache
where inst_id = USERENV('Instance');

**View Name: GV$MUTEX_SLEEP**

```
select inst_id, mutex_type, location, sleeps, wait_time, con_id
from x$mutex_sleep;
```

**View Name: V$MUTEX_SLEEP**

```
select mutex_type, location, sleeps, wait_time, con_id
from gv$mutex_sleep
where inst_id = USERENV('Instance');
```

**View Name: GV$PDBS**

```
select inst_id, con_id, dbid, con_uid, guid, name, decode(state, 0, 'MOUNTED', 1, 'READ WRITE', 2, 'READ ONLY', 3, 'MIGRATE', 4, 'DISMOUNTED'), decode(restricted, 0, 'NO', 1, 'YES'), atime, create SCN, total size, block size, decode(recovery status, 0, 'ENABLED', 1, 'DISABLED'), snapshot parent con id, decode(app_root, 1, 'YES', 'NO'), decode(app_root con id, NULL, 'NO', 'YES'), decode(app seed, 1, 'YES', 'NO'), app_root con id, decode(app_root clone, 1, 'YES', 'NO'), decode(proxy pdb, 1, 'YES', 'NO')
from x$con
where con id > 1;
```

**View Name: V$PDBS**

```
select con_id, dbid, con_uid, guid, name, open mode, restricted, open_time, create SCN, total size, block size, recovery status, snapshot parent con id, application root, application pdb, application seed, application root con id, application root con id, application root clone, proxy pdb
from gv$pdb
where inst id = USERENV('Instance');
```
View Name: GV$SESSION_LONGOPS

```sql
SELECT inst_id, kaulosno, kaulosrn, kaulopna, kaulotna, kaulotde, kaulosfr, kaulotot, kaulouni, TO_DATE(kaulostm, 'MM/DD/RR HH24:MI:SS', 'NLS_DATE_FORMAT=YYYY-MM-DD HH24:MI:SS'), TO_DATE(kaulolut, 'MM/DD/RR HH24:MI:SS', 'NLS_DATE_FORMAT=YYYY-MM-DD HH24:MI:SS'), TO_DATE(kauloinft, 'MM/DD/RR HH24:MI:SS', 'NLS_DATE_FORMAT=YYYY-MM-DD HH24:MI:SS'), decode(kaulopna, 'Advisor', kaulocif2), decode(sign(kaulotot-kaulosfr), -1, to_number(NULL)), decode(kaulosfr, 0, to_number(NULL)), round(kauloetm*(kaulotot-kaulosfr)/kaulosfr)), kauloetm, kauloctx, kaulomsg, kaulounn, kaulosql, kaulosgb, kaulosqgph, kaulosgqnta, decode(kaulosgqid, 0, to_number(NULL)), kaulosqgqnta, decode(kaulosgqplid, 0, to_number(NULL)), kaulosgqplid), kaulosgqplop, kaulosgqplnm, kaulogid, con_id FROM x$kaulop;
```

View Name: V$SESSION_LONGOPS

```sql
SELECT sid, serial#, opname, target, target_desc,sofar, totalwork, units, start_time, last_update_time, timestamp, time_remaining, elapsed_seconds, context, message, username, sql_address, sql_hash_value, sql_id, sql_plan_hash_value, sql_exec_start, sql_exec_id, sql_plan_line_id, sql_plan_operation, sql_plan_options, qcsid, con_id FROM gv$session longops WHERE inst_id = USERENV('Instance');
```

View Name: GV$SQL (New in 12c Bolded)
View Name: V$SQL (New in 12c Bolded)
select inst_id, kglnaobj, kglfnobj, kgllocht3, kgllobhs0+kgllobhs1, kgllobhs2+kgllobhs3+kgllobhs4+kgllobhs5+kgllobhs6, kgllobt08+kgllobt11, kgllobt10, kgllobt01, kgllobcc, kgllobclc, kglhldmd, kglhldlkc, kgllobt04, kgllobt05, kgllobt48, kgllobt35, kgllobt6, kglhldlc, substr(to_char(kglnatim,'YYY-MM-DD/HH24:MI:SS'),1,19), kglhdive, kgllobt12, kgllobt13, kgllobdw, kgllobt14, kgllobwad, kgllobwcc, kgllobwcl, kgllobwul, kgllobt42, kgllobt43, kgllobt15, kgllobt02, decode(kgllobt32, 0, 'NONE', 1, 'ALL_ROWS', 2, 'FIRST_ROWS', 3, 'RULE', 4, 'CHOOSE', 'UNKNOWN'), kgllobt00, kgllobcc, kgllobccch, kgllobt17, kgllobt18, kgllopts4, kglhdcmk, kglhdpap, kgllobh, kgllobh46, kgllopts0, kgllopts19, kgllopts1, kgllopts29, kgllopts21, kgllopts06, kgllopts07, decode(kgllopts28, 0, NULL, kgllopts28), kglhdadr, decode(bitand(kgllopts03, 64), 64, 'Y', 'N'), decode(kgllopta, 1, 'VALID', 2, 'VALID_AUTH_ERROR', 3, 'VALID_COMPILE_ERROR', 4, 'VALID_UNAUTH', 5, 'INVALID_UNAUTH', 6, 'INVALID'), kgllobt31, kgllobt0, decode(kgllopts33, 1, 'Y', 'N'), decode(bitand(kgllocta, 1), 1, 'Y', 'N'), kglhdcit, kgllopta3, kgllopts7, kgllopts6, kgllopts44, kgllopts45, kgllopts47, kgllopts49, kgllobc1a, kgllobc1c, kgllobt22, kgllopts52, kgllopts53, kgllopts54, kgllopts55, kgllopts56, kgllopts57, kgllopts58, kglloptc, kgllopts59, kgllopts53 - (kgllopts55+kgllopts57) - kgllopts52, con_id, decode(bitand(kglloqap, 1), 1, decode(bitand(kglloqap, 2), 2, 'R', 'Y'), 'N'), decode(bitand(kglloqap, 4), 4, decode(bitand(kglloqap, 8), 8, 'Y', 'N'), 'Y') from x$kglcursor_child_sqlid
where kgllopt02 != 0;

View Name: GV$SQLAREA (New in 12c Bolded)
select sql_text, sql_fulltext, sql_id, sharable_mom, persistent_mom, runtime_mem, sorts, version_count, loaded_versions, open_versions, users_opening, fetches, executions, px_servers_executions, end_of_fetch_count, users_executing, Loads, first_load_time,
invalidations, parse_calls, disk_reads, direct_writes, buffer_gets, application_wait_time, concurrency_wait_time, cluster_wait_time, user_io_wait_time, plsql_exec_time, java_exec_time, rows_processed, command_type, optimizer_mode, optimizer_cost, optimizer_env, optimizer_env_hash_value, parsing_user_id, parsing_schema_id, parsing_schema_name, kept_versions, address, hash_value, old_hash_value, plan_hash_value, module_name, module_hash, action, action_hash, serializable_aborts, outline_category, cpu_time, elapsed_time, outline_sid, last_active_child_address, remote, object_status, literal_hash_value, last_load_time, is_obsolete, is_sensitive, is_bind_sensitive, is_bind_aware, child_latch, sql_profile, sql_patch, sql_plan_baseline, program_id, program_line#, exact_matching_signature, force_matching_signature, last_active_time, bind_data, typecheck_mem, ic_cell_offload_eligible_bytes, io_interconnect_bytes, physical_read_requests, physical_read_bytes, physical_write_requests, physical_write_bytes, optimized_phy_read_requests, locked_total, pinned_total, ic_cell_uncompressed_bytes, io_cell_offload_returned_bytes, con_id, is_reoptimizable, is_resolved_adaptive_plan
from GV$SQLAREA
where inst_id = USERENV('Instance');

View Name: GV$SQLTEXT

select inst_id, kglhddadr, kglnahsh, kglnasqrid, kgloboct, piece, name
from x$kglna
where kgloboct != 0;

View Name: V$SQLTEXT

select address, hash_value, sql_id, command_type, piece, sql_text, con_id
from gv$sqltext
where inst_id = USERENV('Instance');

View Name: GV$SQL_CURSOR
select inst_id, kxsecocur, kxsecocfl, decode(kxsecocsta, 0, 'CURNULL', 1, 'CURSYNTAX', 1, 'CURPARSE', 3, 'CURBOUND', 4, 'CURFETCH', 5, 'CURROW', 'ERROR'), kxsecphd, kxsecplk, kxsecplk, kxsecoppn, kxsecbkm, kxsecotwm, kxsecotv, kxsecotdv, kxsecbdf, kxseclig, xsecclg, xsecclg2, kxsecclg, con_id
from x$kxsec;

View Name: V$SQL_CURSOR

select curno, flag, status, parent_handle, parent_lock, child_lock, child_pin, pers_heap_mem, work_heap_mem, bind_vars, define_vars, bind_mem_loc, inst_flag, inst_flag2, child_handle, con_id
from gv$sql_cursor
where inst_id = USERENV('Instance');

View Name: GV$SYSSTAT

select inst_id, indx, ksusdnam, ksusdcis, ksusgstv, ksusdhsh, con_id
from x$kususgsta;

View Name: V$SYSSTAT

select statistic#, name, class, value, stat_id, con_id
from gv$sysstat
where inst_id = USERENV('Instance');
The X$ Tables (DBA)

The X$ tables are usually not mentioned or talked about in many Oracle books or even in the Oracle user community. For this reason, I am including them in this book as one of the few references available (Chapter 13 contains many X$ queries). There are 1312 X$ tables in 12cR2. There were 945 X$ tables in 11gR2 (11.2.0.1.0), 613 X$ tables in 10gR2 (10.2.0.1), and only 394 in Oracle9i Release 2 (9.2.0.1.0). The X$ tables vary in structure and number, depending on the database version and release used. Run the queries on your version of the database to get the number of views and structure for your specific version. Areas covered in this appendix include

- A list of all Oracle 12cR2 (12.2.0.0.2) X$ tables (1312 total)
- Query to list the Oracle 12cR2 (12.2.0.0.2) X$ indexed columns (1312 total)
- Some of the Oracle 12cR2 (12.2.0.0.2) V$ views cross-referenced to the X$ tables

Oracle 12cR2 X$ Tables Ordered by Name

Here is the Oracle 12cR2 query to get the following listing:
Here are the entire 1312 X$ tables in Oracle 12cR2, ordered by name:

<table>
<thead>
<tr>
<th>NAME</th>
<th>NAME</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>X$ABSTRACT_LOB</td>
<td>X$CONTEXT</td>
<td>X$DBKH_CHECK_PARAM</td>
</tr>
<tr>
<td>X$ACTIVE_EKPT</td>
<td>X$CON_KENMDREK</td>
<td>X$DBKINMETCFSG</td>
</tr>
<tr>
<td>X$AQ_MESSAGE_CACHE_ADVICE</td>
<td>X$CON_KENMDRV</td>
<td>X$DBKINMETINFO</td>
</tr>
<tr>
<td>X$AQ_OPT_CACHED_SUBSHARD</td>
<td>X$CON_KENSTSYV</td>
<td>X$DBKNTCNMTSUMMARY</td>
</tr>
<tr>
<td>X$AQ_OPT_INACTIVE_SUBSHARD</td>
<td>X$CON_KSELEI</td>
<td>X$DBKINFO</td>
</tr>
<tr>
<td>X$AQ_OPT_STATS</td>
<td>X$CON_KSLCS</td>
<td>X$DBKRECO</td>
</tr>
<tr>
<td>X$AQ_OPT_UNCACHED_SUBSHARD</td>
<td>X$CON_KUSGSTA</td>
<td>X$DBKRUN</td>
</tr>
<tr>
<td>X$AQ_REMOTE_DROAPP</td>
<td>X$DBCALERTTEXT</td>
<td>X$DBHRNPLAY_PATCH_INFO</td>
</tr>
<tr>
<td>X$AQ_SUBSCRIBER_LOAD</td>
<td>X$DBGATFLIST</td>
<td>X$DLFPARAM</td>
</tr>
<tr>
<td>X$AQ_SUBTRANS</td>
<td>X$DBGDIREXT</td>
<td>X$DLXDAT</td>
</tr>
<tr>
<td>X$ASH</td>
<td>X$DBGLOGEXT</td>
<td>X$DIAL_ACL_CONTROL</td>
</tr>
<tr>
<td>X$AUD_DRAPI_ACTIONS</td>
<td>X$DBGKCCX</td>
<td>X$DIAL_ACL_CONTROL_AUX</td>
</tr>
<tr>
<td>X$AUD_DP_ACTIONS</td>
<td>X$DBGKIFX</td>
<td>X$DIAL_ACL_INVALIDATION</td>
</tr>
<tr>
<td>X$AUD_DV_OBJ_EVENTS</td>
<td>X$DBGRIKX</td>
<td>X$DIAL_ALERT_EXT</td>
</tr>
<tr>
<td>X$AUD_OBJ_ACTIONS</td>
<td>X$DBGRIKX</td>
<td>X$DIAL_AWS_XACTION</td>
</tr>
<tr>
<td>X$AUD_OLS_ACTIONS</td>
<td>X$DBGSTFLIST</td>
<td>X$DIAL_DUE_USER_ACTION</td>
</tr>
<tr>
<td>X$AUD_XS_ACTIONS</td>
<td>X$DBGSTFOPTT</td>
<td>X$DIAL_DUE_USER_ACTION_DEF</td>
</tr>
<tr>
<td>X$SH</td>
<td>X$DBGSTFOPTT</td>
<td>X$DIAL_DUE_USR_ACT_PARAM</td>
</tr>
<tr>
<td>X$IMAPNODURSUBL</td>
<td>X$DBGSTQQLT</td>
<td>X$DIAL_DUE_USR_ACT_PARAM_DEF</td>
</tr>
<tr>
<td>X$BUFFER</td>
<td>X$DBGTFNULLT</td>
<td>X$DIAL_DUE_USR_INC_ACT_MAP</td>
</tr>
<tr>
<td>X$BUFFER2</td>
<td>X$DBGTFSQLT</td>
<td>X$DIAL_DUE_USR_INC_TYPE</td>
</tr>
<tr>
<td>X$BUFFERED_PUBLISHERS</td>
<td>X$DBGTFVIEWK</td>
<td>X$DIAL_DFW_CONFIG_CAPTURE</td>
</tr>
<tr>
<td>X$BUFFERED_QUEUES</td>
<td>X$DBKCE</td>
<td>X$DIAL_DFW_CONFIG_ITEM</td>
</tr>
<tr>
<td>X$BUFFERED_SUBSCRIBERS</td>
<td>X$DBKFAPC</td>
<td>X$DIAL_DFW_PATCH_CAPTURE</td>
</tr>
<tr>
<td>X$CDBWS</td>
<td>X$DBKFDDEAPC</td>
<td>X$DIAL_DFW_PATCH_ITEM</td>
</tr>
<tr>
<td>X$CELL_NAME</td>
<td>X$DBKFDEAPC</td>
<td>X$DIAL_DFW_PURGE_ITEM</td>
</tr>
<tr>
<td>X$CKPTBUF</td>
<td>X$DBKFEFPC</td>
<td>X$DIAL_DIAL_INCIDENT</td>
</tr>
<tr>
<td>X$COMVWS</td>
<td>X$DBKFFEPC</td>
<td>X$DIAL_DIR_EXT</td>
</tr>
<tr>
<td>X$CON</td>
<td>X$DBKFDG</td>
<td></td>
</tr>
</tbody>
</table>
Oracle 12cR2 X$ Indexes
To get the 799 X$ indexed columns in Oracle 12cR2, run the following query:

```
select    table_name, column_name, index_number
from       v$indexed_fixed_column
order by   table_name, index_number;
```

...799 rows selected.

Oracle 12cR2 V$ Views Cross-Referenced to the X$ Tables
This section presents some of the X$ tables mapped back to the V$ views. Because of the large number of views in 12cR2, it’s no longer possible to list all cross-references here. I have, however, listed several that pertain primarily to performance tuning. You can run your own query to see a specific query associated with the GV$ or V$ views, as shown in Appendix B. You must go through the GV$ view to make this inference. Here are some of the referenced X$ tables, ordered by the selected V$ view names:
Fixed View

VSBH
VSBUFFER_POOL
VSBUFFER_POOL_STATISTICS
VSDATABASE
VSDATAFILE
VSDB_CACHE_ADVICE
VSDB_OBJECT_CACHE
VSDLM_ALL_LOCKS
VSDLM_LATCH
VSDLM_LOCKS
VSENQUEUE_LOCK
VSENQUEUE_STAT
VSEVENT_NAME
VSEXECUTION
VFILESTAT
VFILE_CACHE_TRANSFER
VFIXED_TABLE
VFIXED_VIEW_DEFINITION
VSGES_BLOCKING_ENQUEUE
VSGES_ENQUEUE

Underlying Base X$ Tables and/or Fixed Views

x$bh, x$le
x$kcwbwpd
x$kcwbwd, kcbwds, x$kcwbwpd, kcbwpd
x$kcddi, x$kcddi2
x$kccke, x$kcce, x$kcfln, x$kcfln, x$kcfln
x$ksbwc, x$kcwbwpd
x$kglob
V$GES_ENQUEUE
V$LATCH
V$GES_BLOCKING_ENQUEUE
x$ksseq, x$ksuse, x$ksqrs
x$ksqst
x$ksled
x$ksste
x$kcffo, x$kcffee
x$kcffo, x$kcffee
x$ksqita, x$ksqivi, x$ksqft
x$ksqi, x$ksqivt
V$GES_BLOCKING_ENQUEUE
x$skjik, x$skjbl
Thanks to Jacob Niemiec for testing the queries and providing the new listings.
Please note that index links point to page beginnings from the print edition. Locations are approximate in e-readers, and you may need to page down one or more times after clicking a link to get to the indexed material.

Symbols

$DB_CACHE_ADVICE, 185–186
$LGWRIO_OUTLIER, 103
$RESULT_CACHE_DEPENDENCY view, PL/SQL, 512
$SESSION_EVENT view, 719

Numbers

30-Day Trial screen, Oracle Cloud, 13, 600–601
50-50 index split, 62
80/20 Rule, indexes, 356–357
90-10 index split, 62

A

access
  to V$ views, 673–675
  to X$ tables, 734
access method hints, 310
Account, Cloud, 601
ACMS (Atomic Controlfile to Memory Service), RAC, 629
action name, DBMS_MONITOR, 266, 268–269
Active Data Guard, 24, 25, 30–31
Active Session History (ASH) Report, 241, 897–898
active transaction management, 573–574
+ADAPTIVE format parameter, DBMS_XPLAN, 387–388
adaptive plans
  Adaptive Query Optimization, 382–389
  SQL Plan Management, 294–301
Adaptive Query Optimization
adaptive statistics, 389–394
overview of, 383–389
tuning changes, 18–19, 381–382
adaptive statistics, 389–394
ADAPTIVE_PLAN hint, 341
ADD PARTITION option, 147
ADDM (Automatic Database Diagnostic Monitor)
  ADDM Report, 893–898
  Real-Time ADDM, 233–237
tune Oracle Database, 222
admrpt.sql script, ADDM Report, 893–898
Administration menu. See OEM Administration menu
ADO (Automatic Data Optimization)
  12c Heat Map and, 22–23, 101–102
global index maintenance and, 146
  initialization parameters, 166
  manage In-Memory column store, 27
Advanced Compression, Heat Map/ADO, 102
Advanced Queuing, 726, 792
advanced tuning
  from 14 hours to 30 seconds with EXISTS, 471–472
  block level, 473–485
  Database Replay, 417–422
distributed queries, 462–463
external tables, 465–469
overview of, 416–417
pattern interpretation, 493–498
review tips, 499–500
set event to dump every wait, 469–471
simple mathematical techniques for, 485–499
Snapshot Too Old error, 469
SQL Performance Analyzer, 423–427
  table joins. See table joins
  third-party products, 458–462
  view data dictionary after tuning, 464
Advisor Tasks, query in SPA, 425
advisors, V$ views for, 722
AFTER clause, ADO, 22–23, 102
aliases, using hints for, 314, 342
all Flash Cache option, Exadata X6, 609
all flash storage, Exadata, 609, 610
ALL_EXECUTIONS value, PLAN_STAT, 266
ALL_IND_COLUMNS, 46
ALL_ROWS hint, 316
ALL_ROWS optimizer mode, 204–205, 373–375
ALTER DATABASE ADD LOGFILE, redo logs, 155
ALTER DATABASE BACKUP CONTROLFILE, disks, 157
ALTER DISKGROUP operations, ASM, 121–124
ALTER INDEX statement
  drop index, 364–365
  fast index rebuild, 79
  invisible indexes, 47–49
  partition options, 148
  using indexes, 706–708
ALTER PLUGGABLE DATABASE, PDBs, 88, 89
ALTER SESSION command
  PL/SQL tracing, 773–774
  SQL TRACE, 257
  STORED OUTLINES, 284
ALTER SESSION FORCE PARALLEL command, 651
ALTER SYSTEM commands
  modify initialization parameters, 179–180, 753
  at PDB level, 92
  set events, 773–774
  SQL TRACE set up, 257
  switch log files, 156, 753
  write to SPFILE only, 177
ALTER TABLE command
  ADO policies, 102
  Flash Cache, 614
  invisible columns, 6
  PARALLEL/NOPARALLEL clauses, 651
ALWAYS option, forcing identity, 519–520
Amazon Cloud, 596
AMM (Automatic Memory Management)
  initialization parameters, 107, 167
  shared pool size, 555
  V$MEMORY_TARGET_ADVICE view, 687–688
analysis task, SPA, 424–426
ANALYZE command, table management, 926
AND-EQUAL operation, merge indexes, 374
APM (Application Performance Monitoring)
within Oracle Management Cloud, 16–17
pinpoint problems at every tier, 599, 606–608
view customer web pages, 251–252
APPEND hint, 333–334
application servers, monitoring, 250–252
approximate query processing, new 12cR2 features, 29–30
architecture, Real Application Cluster, 627–629
Archive High, HCC, 619–620
archive log files
directory location for copy of, 156
as fine-grained, 98
new 12cR2 features for, 33
turn off for DML statement, 340
view with ARCHIVE LOG LIST, 681
written for redo logs, 156
X$ table groups for, 786
ARCHIVE LOG LIST command, 681
Archive Low, HCC, 619–620
arithmetic, number vs. hardware, 551
ASH (Active Session History) Report, 241, 897–898
+ASM (ASM instance), 106
ASM (Automatic Storage Management)
bigfiles and, 137
communication across IT roles, 105–106
disk scrubbing, 119–121
fast filter driver, 124–132
fast mirror resync, 123–124
initialization parameters, 107
installation in 12c, 107–115
instances, 106–107
introduction to, 104–105
and multipathing, 136–137
and privileges, 132–136
rebalance enhancements, 121–123
review tips, 159–161
separate key datafiles, Disk Performance Index, 926
srvcct enhancements, 115–119
tables/indexes separated to decrease file I/O, 925
V$ views for, 722
ASM Filter Driver (ASMFD), 124–132
asmca command, 115
ASMCMD command-line
   for administrators not familiar with SQL, 104
ASM Filter Driver configuration, 124–129
Flex ASM configuration, 109, 114
view ASM attribute settings, 121
view ASM disk scrubbing, 121
ASMDBA, 132
ASM_DISKSTRING parameter, 128
ASMM (Automatic Shared Memory Management)
   initialization parameters, 167–168
   and MEMORY_TARGET, 687
   use SGA_TARGET, 208
ASSM (Automatic Segment Space Management)
   avoid row chaining, 150, 152
   create index, 360
   performance/segment management with, 152–153
   query buffer cache, 765
   table management, 925–926
   use big file tablespaces, 103
associative arrays, PL/SQL, 562–565
async disk I/O wait event, 848
Atomic Controlfile to Memory Service (ACMS), RAC, 629
AU extents, ASM, 97–98
AUM (automatic undo management), DPI, 574, 926–928
AUs (allocation units), ASM, 97–98
Automatic Database Diagnostic Monitor. See ADDM (Automatic Database Diagnostic Monitor)
   automatic reoptimization, 390–392
Automatic Shared Memory Management. See ASMM (Automatic Shared Memory Management)
Automatic Storage Management. See ASM (Automatic Storage Management)
Automatic Tuning Optimizer mode, 381
automatic undo management (AUM), DPI, 574, 926–928
AUTOPURGE, SPM, 286
AUTO_REOPTIMIZE hint, 341
AUTOTRACE
   generate EXPLAIN PLAN, 275–276
   set autotrace on/off command, 658–660
   specify hints, 312
availability
   disk arrays improve, 94
   new 12cR2 features for, 30–32
   version comparison chart for, 38
view information on host, 250
AWR (Automatic Workload Repository)

display stored SQL statements, 282–283
in OEM Performance menu, 238–241
view available snapshots, 222, 355
view RAC wait events, 633–636, 639

AWR Report

ASH Report at end of, 897–898
automated snapshots, 826
AWR and, 824–825
manually managing AWR, 825–826
as next generation of Statspack Report, 816, 824
overview of, 816–817
query wait events, 718
run in OEM Cloud Control, 828–831
running, 240–241
snapshot reports, 826–828
tips for review, 900–902
what’s new, 817

AWR Report output

additional Memory Statistics, 865–871
Dictionary and Library Cache Statistics, 886–887
header information and Cache Sizes, 832–833
Instance Activity Statistics, 856–861
Instance Efficiency, 835–837
Latch and Mutex Statistics, 872–882
Load Profile, 833–834
Nondefault Initialization Parameters, 889–890
Oracle bugs, 851–852
RAC Statistics, 852–854
Segment Statistics, 864–866
SGA Memory Statistics, 888–889
Shared Pool Statistics, 838
SQL Statistics, 853–856
Tablespace and File I/O Statistics, 861–864
top 15 things to look for, 889–890
Top Wait Events, 838–851
tuning and viewing at block level, 883–886
UNDO segment statistics, 871–872
awrrpti.sql, AWR report, 826
awrrpt.sql, AWR report, 826–827
b-tree indexes
  bitmap indexes vs., 69–71
  index-organized tables and, 72
  overview of, 68–69
  partitioning of, 75–78
  restrictions, 50
  use INDEX hint for, 320
background processes
  ASM, 133–135
  new 12cR2 features, 34–35
  new in 12.2 Statspack/AWR report, 817
Background Wait Events, AWR Report/Statspack, 838, 840–841
backup
  disk I/O, 157
  RMAN cross-platform (12cR1), 24
  Statspack table, 892
  system information list, 936
  V$ views for, 722
  X$ table groups for, 789
bad indexes, 362–364
baseline AWR snapshots, AWR Report, 827–831
batch processing, 157, 316
best practices, Exadata, 622–623
Big Data Appliance X6-2, Oracle, 625
big data, new 12cR2 features, 33
big table caching, automatic (12cR1), 28
bigfiles, 103, 137
binary height of index, 60–62
bind variables, 864–865, 872
BITMAP AND operation, bitmap indexes, 70
bitmap indexes
  block dumps of, 483–484
  INDEX_COMBINE hint for, 320–321
  overview of, 69–71
  partitioning, 75–78
  restrictions, 71, 453–454
  understanding, 452–453
bitmap join indexes
  best uses, 455–458
caveats of, 456–457
defined, 452
examples, 454–455
overview of, 78–79
understanding, 452–458
blackouts, 224–225
BLEVEL, 60–64
block buffers, 760–766
block comments, 312
block for last UNDO entry (UBLK), block dump, 480
block range granules, 649
block tuning
data section of block dump, 477–483
flag section of block dump, 477
index block dumps, 483–485
ITL section of block dump, 476–477
overview of, 473–476
and viewing (advanced), 883–886
BLOCKSIZE, BLEVEL/index height and, 64
Bloom filters, 27, 207, 614
BOOLEAN type, 522–523
buffer busy waits, 842–844, 848, 853
buffer cache
check with sar -b command, 947–948
flushing, 188
hit ratio, 859, 914–916
hot data blocks/wait events in, 761–763
latch contention/wait events in, 763–766
latch/mutex waits in, 872–873
LRU chain, 881–882
segments occupying block buffers, 760–761
view state of buffers, 758–759
X$ tables used, 757, 795
Buffer Pool Advisory, AWR Report/Statspack, 867–868
buffer pools, 201–203
bundled writes, RAID 5, 97
business intelligence, version comparison chart, 37–38
BWnn (database writer) background process, 35
BY DEFAULT clause, Identity Columns, 519–520
BY DEFAULT ON NULL clause, Identity Columns, 520
BYTES column, PLAN_TABLE, 281–282, 302–303
cache advisors, V$ views for, 722
cache buffers chains (CBC) latch, 473, 880–881, 883
cache buffers lru chain latch, 881
Cache Fusion, in RAC
   cluster interconnect tuning, 644
   overview of, 630–631
   reads and writes, 640–641
   V$ views for, 723
CACHE hint, 334–335
CACHE (NOCACHE) hint, Flash Cache, 615
Cache Sizes section, AWR Report/Statspack, 831–833
caching/pinning
   all packages, 556–557
   automatic big table (12cR1), 28
   full database (12cR1), 28
   identify PL/SQL objects that need, 557
Memory Performance Index, 921–922
PL/SQL Function Result Cache, 505–515
PL/SQL object statements into memory, 555–556
resize data cache (V$DB_CACHE_ADVICE), 693
   small, often-used tables in memory, 369–371
   understanding pinning, 875
   V$ views for, 723
capture/replay. See Database Replay
CAQP (Continuous Adaptive Query Plans), 12cR2, 18–19
cardinality, 69–71, 110–111
CARDINALITY hint (undocumented), 331, 342
CASCADE parameter, 827
case sensitivity
   passwords, 166, 818–819
   SQL, 192
CAST function, SQL and PL/SQL, 29–30
catalog.sql script, 673, 736
catldr.sql script, create $V views, 673
CBC (cache buffers chains) latch, 473, 880–881, 883
CDB (container database)
   Disk Performance Index, 928–930
   move between containers, 88–89
   with multiple PDBs, 9–11
new in 12.2 Statspack/AWR report, 817
objects created by, 86–87
start up, 89–90
CDB_view, 680
CELL_FLASH_CACHE storage clause, 615
CELL_OFFLOAD_PROCESSING parameter, Exadata, 207
CELLSRV (cell storage server), Flash Cache, 615–616
CHAINED_ROWS table, 152, 925–926
chaining, 151–152
checkpoints, modify log file size, 153–155
CHOOSE OPTIMIZER_MODE, 204–205, 381
class, create PDB, 93
client identifier, DBMS_MONITOR, 266–268
clients, execute PL/SQL objects on, 571–572
clones, block, 473–474, 881
cloning PDBs
    create PDB via, 87
    source no longer needs to be read-only when, 11, 93
subsets, 29
Cloud Account, 601
Cloud at the Customer, 598
cluster interconnect, RAC, 628–629, 633, 641–645
cluster IPs, installation of ASM, 108–109
CLUSTER joins, 429–430
clustering factor, indexes, 59–60
CLUSTER_INTERCONNECTS parameter, 644
clusters, hash indexes require hash, 71–72
collection tables, Statspack
    gathering statistics, 820–822
    post-installation, 819–820
collisions, as drawback of hash indexes, 71–72
columns
    B-tree indexes and, 68–69
    based on sequence (12cR1), 20
    bitmap indexes and, 69–71
    bitmap join indexes and, 454–456
    check table for current indexes, 360–361
    create tables with virtual, 378–379
    Identity, 519–521
    invisible, 6
    multiple types of indexes on same, 7–8, 50–53
partition tables using multiple, 141
PLAN_TABLE, 280–282
query if properly indexed, 361–362
suppression of indexes when modifying query, 375–377
commands
  hints vs., 308
  redo log, 155–156
comments, undocumented hints vs., 341–342
commit operations, trace file, 783
COMMITs, limit amount of data manipulated, 574
communication across IT roles, ASM, 105–106
Compare Explain Plan tool, OEM, 237, 253
compare tool, Data Guard Database as, 31
COMPATIBLE parameter, parallel operations, 660
compile-time warnings, 528–530, 535–536
compiler directive hints, 308
composite indexes. See concatenated (composite) indexes
composite partitioning, 140–141
compression
  ADO policies for data, 102
  advanced index, 28
  change at import time, 18
  In-Memory options, 27, 174–175
  new 12cR2 features, 33
    Oracle database storage and, 613
compression units (CUs), 337, 618–620
compute nodes, Exadata, 609
compute servers, Exadata, 611
COMPUTE statistics clause, indexes, 55
concatenated (composite) indexes
  on columns in SELECT and WHERE, 367
determine selectivity, 59
  overview of, 53–54
  skip-scans using, 66–67
    third-party product tuning via, 459–462
conditional compilation, suppress debug in PL/SQL, 581–586
configuration information file, modify with /etc/system file, 967
Configuration Topology screen, Oracle Database menu, 248
conflict management, new 12cR2 features for, 31
CON_ID, X$ table naming conventions with, 812
consistent gets, AWR Report/Statspack, 859
consumer groups, 246–247, 797
containers, 88–89, 696–697
CONTAINERS hint, 339
CONTENT.CHECK attribute, ASM, 121
contention, shared pool, 745–747
context switching, CPU scheduler, 952–953
contexts, X$ table groups for, 798
CONTINUE statement, loops, 525–528
Continuous Adaptive Query Plans (CAQP), 12cR2, 18–19
control files
  Flash Cache caching and, 615
  storage of multiple, 157
  V$ views for, 723
  X$ table groups for, 787
CONTROL_MANAGEMENT_PACK_ACCESS parameter, MONITOR hint, 340
copy, seed PDB to create PDB, 87
cost
  benefits of cloud, 597
  of disk arrays that mirror data, 98–99
  Exadata scalability, 610–611
  new 12cR2 features for managing, 30
  of parallel execution, 646
cost-based optimizer
  concurrent statistics (12cR1), 21
  determine whether to parallelize statement, 647
  effectiveness of, 204
  how it looks at data, 204–205
  NORMAL and TUNING mode in 12c, 381
  two table INDEXED joins, 439–443
  two table joins, 435–439, 447–450
COST column, PLAN_TABLE, 281–282, 303
count, for all V$ views, 676–677
CPU cores, Exadata, 609
CPUs
  check usage of, 953
  disk I/O precautions and tips, 157
  downside of parallel operations, 666
  find which process uses most with ps, 957–959
  good idle percentage for, 952
  identify bottlenecks with mpstat, 956
  identify disk I/O bottlenecks using iostat, 959–962
monitor load with uptime, 955–956
monitor memory use on Windows with Task Manager, 959
monitor usage with sar, 943–948
scheduler and context switching, 952–953
system information list, 935
tuning system, 968

CR versions for given block
  find, 884–885
  overview of, 881
  query first time, 473

CREATE CONTROLFILE statement, 157
Create Database Cloud Service Instance wizard, 603–605
CREATE INDEX statement, 47, 55, 652–653
CREATE PLUGGABLE DATABASE, clone PDBs, 11, 88
CREATE TABLE AS (CTAS) operation, 12c statistics gathering, 394
CREATE TABLE statement
  ADO policies, 102
  Flash Cache, 614
  log timing statistics into tables, 542
  tune external tables, 466
CREATE UNIQUE INDEX command, 54
CREATE_EVOLVE_TASK function, SPM, 396
CRITICAL priority, In-Memory database, 26–27, 174
cron program, monitor disk free space, 964
crsctl eval command, 119
CTAS (CREATE TABLE AS) operation, 12c statistics gathering, 394
cube joins, 341
CURRENT block, DML transactions, 473–474
CURRENT version, tuning and viewing blocks, 883–885
cursor pin mutex, 876–878
cursor: pin S wait event, 845, 851
cursor: pin S wait on X event, 845, 851
cursors
  read long trace files and, 779–781
  use rollback segments to open large, 572–573
V$ views for, 723
CURSOR_SHARING parameter
  how to use, 208
  library cache memory, 747–750
  query parse activity, 750
  stored procedures for shared SQL area, 191–193
CURSOR_SHARING_EXACT hint, 336
CUs (compression units), 337, 618–620
customer experience, view in Database Cloud Service, 608

D

data
- process large quantities of, 573–574
- store in separate location from index files, 99

data blocks
- buffer busy waits on, 844
- multiple sizes allowed for, 871
- X$ tables for queries on, 757–758

data buffers
- query for free, 919–920
- query if system needs more, 692
- query number of dirty, 859
- query percentage still free, 919–920
- statistics for each type of call, 262

data cache hit ratios. See hit ratio(s)

data dictionary
- access information on block dumps, 476
- AWR Report/Statspack, statistics, 886–887
- AWR Report/Statspack, Top SQL section, 855
- determine memory for, 693–694
- view after all tuning is done, 464

data dictionary cache
- keeping objects cached in, 193–194
- as part of shared pool, 191
- set SHARED_POOL_SIZE, 191
- size of, 199

Data Guard
- improvements (12cR1), 24
- new 12cR2 features, 31–32
- V$ views for, 726

data integrity, RAC, 631

data loads, compression, 620

data-partitioning model, parallel database, 626

data reads, DB_BLOCK_SIZE, 189–190

data redaction for testing, new in 12cR2, 32

data section, block dump, 477–483
data types
  compare mismatched, 58–59
  ensure comparison operations use same, 548–550
  max size increase to 32k for some, 521–522
  PL/SQL-only, bind to SQL statements, 522–523

data warehousing
  bitmap indexes ideal for, 69–71
  bitmap join indexes in, 78–79
  Exadata speed vs. that of, 609–610
  version comparison chart for, 37–38

Database Administration Tab, OEM Administration menu, 242–247
Database as a Service (DBaaS). See also Database Cloud Service, 11–13, 608
Database Cloud Service
  in 12cR1, 11–17
    Application Performance Monitoring, 606–608
    building first, 603–605
    create first instance, 599–600
    EM Console, 605–607
    free 30-Day Trial button, 600–601
    Get Started, 601–602
    launch Oracle Management Cloud, 606–607
    sign into Oracle Cloud, 601–602
    sign up for Oracle Public Cloud services, 601
    view customer experience, 608

Database Configuration Assistant (DBCA), 626
Database Files Metrics in Cloud Control, I/O disk contention, 99–100
Database in the Cloud. See Database Cloud Service
Database menu, OEM, 247–248
Database Replay, 252–253, 417–421
Database Resource Manager (DBRM), 622, 648
Database tab, Oracle Database menu, 247–248
Database Vault, 32
database writer (BWnn) background process, 35

databases
  number of writers, 156
  V$ views for basic information, 681
  version comparison chart, 38–39
  X$ table groups for links, 788
datafiles
  ASM disk scrubbing to repair ASM, 120–121
  bigfiles reduce number of, 137
as coarse-grained, 98
map PDBs to, 90
online (12cR1), 23
plan location for parallel data access, 666
separate key, Disk Performance Index, 926
store in filesystems to prevent disk contention, 99–100
XS table groups for, 786

DATE data type, use time component with, 568–570
date, reduce calls to SYSDATE, 552–553
DB block gets, AWR Report/Statspack, 859
db file parallel write wait event, 847, 849
db file scattered read wait event, 841–842, 848
db file sequential read wait event, 842, 848
db path read, wait event, 847–848
DBA knowledge rating, system information list, 937–938

DBA_ADVISOR_TASKS view, SPA, 425
DBA_APPLY_EXCEPTIONS view, new in 12cR2, 31
DBaaS (Database as a Service). See also Database Cloud Service, 11–13, 599, 608
DBA_DATA_FILES view, disk I/O issues, 713–714
DBA_DEPENDENCIES view, PL/SQL objects, 567
DBA_ENABLED_AGGREGATIONS view, DBMS_MONITOR, 269
DBA_ENABLED_TRACES view, DBMS_MONITOR, 269
DBA_HIST_SNAPSHOT view, AWR, 355
DBA_HIST_SQL_PLAN view, EXPLAIN PLAN, 358–359
DBA_HIST_SQLSTAT view, find worst queries, 355–357
DBA_HIST_WR_CONTROL view, AWR, 825–826
DBA_IND_COLUMNS view, indexes, 46–47, 360–361
DBA_INDEXES view, partitioned indexes, 149
DBA_IND_INDEXES view, 46–47, 49
DBA_OBJECT_SIZE view, 558–559
DBA_PART_TABLES view, partitions, 139–140
DBA_ROLLBACK_SEGS view, open large cursors, 572–573
DBA_SEGMENTS view, extents, 151
DBA_SOURCE view, query SQL source code, 565–567
DBA_SQL_PLAN_BASELINES, SPM, 287–288, 396
DBA_SQL_PLAN_DIRECTIVES table, SQL plan directives, 392
DBA_SQL_PLAN_DIR_OBJECTS table, SQL plan directives, 392
DBA_TABSET_REFERENCES view, active SQL Tuning Set, 426
DBA_TABLESPACES view, current UNDO retention period, 572
DBA_TRIGGERS view, 561–562, 567
DBA_views, underlying objects in, 678–680
DB_BLOCK_BUFFERS, deprecated, 182
DB_BLOCK_SIZE parameter, 189–190, 927–928
DBCA (Database Configuration Assistant), 626
DB_CACHE_SIZE parameter
  block tuning, 473
  db file sequential read wait events and, 842
  importance of, 207
  pools/allocate memory for data, 201
  set SGA_MAX_SIZE parameter, 190
  set SHARED_POOL_SIZE for, 193
  tune to increase performance, 182–185
  tune with $DB_CACHE_ADVICE, 185–186
DB_FILE_MULTIBLOCK_READ_COUNT parameter
  db file scattered read wait events and, 841
  importance of, 209
  increase for larger DB_BLOCK_SIZE, 189–190, 219
  in parallel operations, 660
  set for SORT-MERGE joins, 434
  set in SPFILE to improve read time, 862
DB_KEEP_CACHE_SIZE parameter, 168, 201, 209
DB_KEEP_RECYCLE_SIZE parameter, 168, 209
DBMS_APPLICATION_INFO package, 539–541, 782
DBMS_DATAPUMP package, compression at import time, 18
DBMS_DB_VERSION package, PL/SQL debug, 580–586
DBMS_INMEMORY_ADMIN package, 176
DBMS_JOB package, 566–567
DBMS_METADATA package, 577–580
DBMS_MONITOR
  disable tracing when done, 269, 302
  end-to-end application tracing with, 266
  replaces SQL TRACE, 256
  setting application tracing with, 267–270
DBMS_OUTPUT package, PL/SQL, 544–546, 582
dbmspool.sql script, cache PL/SQL objects, 555–556
DBMS_PREPROCESSOR package, PL/SQL debug, 583
DBMS_PROFILER package, PL/SQL, 543, 571
DBMS_REDACT package, new in 12cR2, 32
DBMS_RESULT_CACHE package, 510–512
DBMS_RESULT_CACHE.FLUSH package, 921
DBMS_ROWID PL/SQL package, 765
DBMS_RULE package, 565–566
DBMS_SESSION package, replaces SQL TRACE, 256
DBMS_SHARED_POOL.KEEP procedure, 556–557, 921
DBMS_SHARED_POOL.SIZES package, 557–558
DBMS_SPACE package, block dumps, 476
DBMS_SPD package, SQL plan directives, 394
DBMS_SQL package, dynamic SQL, 574–575
DBMS_SQLPA package, remove SPA task, 426
DBMS_STATS package, 28, 314, 682
DBMS_SUPPORT package, 769, 774
DBMS_SYSTEM package, invoke trace, 768, 769–770
DBMS_TRACE package, PL/SQL, 772–773
DBMS_UTILITY.COMPILE_SCHEMA package, 560
DBMS_UTILITY.EXPAND_SQL_TEXT, 20
DBMS_WORKLOAD_REPOSITORY package, AWR, 825
DBMS_XPLAN package
  display EXPLAIN PLAN, 358
  EXPLAIN PLAN vs., 289
  specify hints correctly, 312
  using, 282–283
  view adaptive plans, 387
DB_nK_CACHE_SIZE, 189
DB_PERFORMANCE_PROFILE, PDB, 93
DB_RECYCLE_CACHE_SIZE parameter, 201
DBRM (Database Resource Manager), 622, 648
DBUA (Database Upgrade Assistant), upgrade to 12c, 165–166
DBWR_IO_SLAVES, online redo log files, 156
  _DB_WRITER_FLUSH_IMU parameter, IMU, 473
DB_WRITER_PROCESSES, online redo log files, 156
DDL commands
  do not let statements fail, 206
  new features in 12cR2, 31
  new online capability commands (12cR1), 23
  NOLOGGING hint for, 340
  parallel, 647–648
  pipelined table function, 576–577
DDL_LOCK_TIMEOUT parameter, 206
debug commands, PL/SQL, 580–586
DEBUG_PKG package, PL/SQL, 581–586
decision support systems (DSSs), use bitmap indexes, 69–71
degree of parallelism. See DOP (degree of parallelism)
DELETE statements
data section of block dump, 480
effects on index, 63
FIRST_ROWS hint ignored in, 315
increase log file size to speed up, 154–155
for index-organized tables, 73
index using WHERE clause with, 45–46
parallelized via PARALLEL hint, 331
use rollback segments for large, 572
dependencies, find PL/SQL object, 567
descending indexes, 322
design, fix first before using hints, 308–309
destinations, X$ table groups for, 786
developer products, tracing in, 279–280
df command, monitor disk space with, 965
DIAGNOSTIC_DEST parameter, 257, 774
dictionary cache hit ratio, Memory Performance Index, 916–917
dictionary objects, In-Memory Database, 176
direct path operations
  direct path writes wait event, 848, 849
  V$ views, 724
  X$ table groups, 798
directives, SQL plan, 392–394
directory, for external tables, 465–466
dirty buffers, AWR Report/Statspack, 859
disk contention, avoid, 99–100, 137–139
disk free space, monitor, 964–966
disk I/O
  find problems with sar -d, 944–947
  identify bottlenecks with iostat, 959–962
  precautions and tips, 157–158
  SORT-MERGE joins can lead to extra, 428
disk implementation methodology
  12c Heat Map and ADO, 101–102
  12c I/O performance tracking views, 102–103
  ASM disk scrubbing to repair, 120–121
  ASM striping and mirroring, 97–98
  bigfile tablespaces, 103
disk arrays, 94–95
disk I/O precautions and tips, 157–158
eliminate fragmentation, 150–153
I/O disk contention avoidance, 99–100
improve performance/protect data with, 99
increase log file size/speed, 153–156
manage with ASM. See ASM (Automatic Storage Management)
number of disks needed, 95
planning stage issues, 158
RAID, 94–97
review tips, 159–161
setup/maintenance of traditional filesystem, 98–99
solid-state disks, 97
store data/index files in separate locations, 99
store multiple control files on different disks/controllers, 157
use partitions. See partitions
Disk Performance Index. See DPI (Disk Performance Index)
disk scrubbing, ASM, 23, 119–121
disk space
APPEND hint wasting, 334
check with RMAN, 32
monitor free space, 964–965
monitor with df command, 965
monitor with du command, 966
disk storage, Exadata, 609
diskfreespace.sh program, monitor disk free space, 964
diskgroup, ASM disk scrubbing, 120–121
DISK_REPAIR_TIME attribute, ASM, 123
disks
find high reads without TRACE, 278–279
system information list, 935
tuning tips, 968–969
dispatchers, create enough, 205–206
DISPLAY function, DBMS_XPLAN, 282
DISPLAY_AWR function, DBMS_XPLAN, 282
DISPLAY_CURSOR function, DBMS_XPLAN, 282, 387–388
DISPLAY_SQLSET, DBMS_XPLAN, 282
distinct (unique) keys, determine index selectivity, 59
distributed queries, tuning, 462–463
Distributed Services, V$ views for, 724
distributed transactions, 30, 39
DML transactions
CURRENT version of block for, 883
disk I/O, 157
not allowed on X$ tables, 734
parallel, 647–648
rebuild indexes online during, 79–80
require CURRENT version of block, 473
sizing Oracle Applications Database, 217
too many indexes create slow, 50
turn off archive logging, 340
DML_LOCKS parameter, parallel operations, 660
documentation
RAC, 627
save time in complex code, 381
use Oracle online, 666
DOP (degree of parallelism)
calculate from initialization parameters, 651, 667
determine with cost-based optimizer, 647
inter- and intra-operation parallelization, 649–651
PARALLEL hint for table overriding, 654
parallel operations on partitions and, 649
performance feedback and, 391
understand, 645
DPI (Disk Performance Index)
automatic undo management, 926–928
how to receive perfect score, 922
mission-critical table management, 925–926
separate key Oracle files, 926
separate tables/indexes or use ASM, 925
top “disk-read abusers,” 922–924
use PDBs effectively, 928–930
driving order for query, ORDERED hint, 323
driving table, force join methods, 428–429, 444–450
DRIVING_SITE hint, 325–326
drop
all migrated stored outlines, 294
index, 364–365
SPM plan, 292
SQL Tuning Set, 426
DROP PARTITION, 147
drop PDB commands, 88
DROP PLUGGABLE DATABASE command, 88
DROP_UNUSED procedure, STORED OUTLINES, 285
driving order for query, ORDERED hint, 323
driving table, force join methods, 428–429, 444–450
DRIVING_SITE hint, 325–326
drop
du command, monitor disk space, 966
dumps
  event, set for every wait, 469–471
  to trace files for analysis, 774–775
dumps, block
  data section, 477–483
  flag section, 477
  index, 483–485
  ITL section, 476–477
  overview of, 474–476
DUPPLICATE command, 32, 172–173
Dynamic Buffer Cache Advisory, 185
dynamic cache management, RAID 5, 96
dynamic SQL, limit use of, 574–575
dynamic statistics, 389–390
DYNAMIC_SAMPLING hint, 340

E

E-Business Suite (EBS) database, size memory, 213–218
Edit Settings, AWR, 239, 829
Education Performance Index (EPI), 907–909
EF (Extreme Flash) storage, Exadata, 611–613
EHCC (Exadata Hybrid Columnar Compression), 618–621
eighth rack, Exadata, 610, 612
elastic configuration, Exadata, 610, 611
EM Console, Database Cloud Service, 605–607
EM (Enterprise Manager). See OEM (Oracle Enterprise Manager)
EMP table, indexes, 46–47, 53–54
EMP1, 884
encryption
  FIPS 140 parameter, 28
  new 12cR2 features, 34
end-to-end application tracing. See DBMS_MONITOR
Enqueue Activity Section, AWR Report, 850
enqueue waits
  AWR Report/Statspack, 860
  GES in RAC managing, 630
  potential fix, 846, 848–849
  X$ table groups for, 796
Enterprise drop-down menu, 224
Enterprise Manager. See OEM (Oracle Enterprise Manager)
Enterprise Summary window, OEM 12c, 227–229
Enterprise tab, OEM, 224
EPI (Education Performance Index), 907–909
equations, tuning via Simple Mathematical Techniques, 487–493
equijoins, 429–431
errors
  failure to extend rollback segment, 572
  not enough memory in shared pool, 555
  solving with TRACE, 283
  in trace files, 784
estimator, SQL default execution plan, 383
/etc/system file, monitor configuration, 967
Ethernet, Exadata 6 ports/interfaces, 609
ETL (extract, transform, load) process, external tables for, 465
-eval option, srvctl, 116
events
  10046, 471, 774
  capture information to trace files, 773–774
  set to dump every wait, 469–471
  tracing, 284
EVICT hint, Flash Cache, 615
evolution report, SPM, 396–397
Exadata Deployment Assistant, 36
Exadata (Exadata Database Machine)
  best practices, 622–623
  change compression at import time, 18
  disk I/O, 157
  initialization parameters, 207
Oracle Database Appliance vs., 624
other Oracle hardware vs., 625–626
as paradigm shift, 623–624
security advantages of, 622
simulation, SQL Performance Analyzer, 232–233
SPARC SuperCluster M7 chip, 624–625
statistics, 610–612
Storage Server software, 613
terminology, 609–610
versions of, 610
Exadata Hybrid Columnar Compression (EHCC), 618–621
Exadata PCIe card Smart Flash Cache, 614, 617
Exadata Storage Expansion Rack

Flush Cache, 614–617

Hybrid Columnar Compression, 618–621

I/O Resource Management, 621–622

overview of, 612–613

release of, 610

Smart Scans, 614

storage indexes, 617–618

EXECUTE IMMEDIATE command, 574–575, 768

EXECUTE_EVOLVE_TASK function, SPM, 396

execution errors, trace files, 784

execution path hints, 309–310

execution plan

force specific join method, 443–445

graph pattern interpreting, 496

tune external tables with join, 468

using INDEX_DESC hint, 322

view from DBA_HIST_SQL_PLAN, 358

EXISTS function, 380

EXISTS operator, change 14 hours to 30 seconds with, 471–472

EXPLAIN PLAN

important columns in PLAN_TABLE, 280–282

for parallelized query, 655–658

reading, 274–275

run DBMS_XPLAN after running, 282–283

select query from DBA_HIST_SQL_PLAN, 358–359

set autotrace on/off, 275–276

set autotrace on/off command, 659–660

simple query example, 273–274

specify hints correctly, 312

three-table joins, 451–452

two-table joins, 447–450

use alone, 271–273

use DBMS_XPLAN vs., 289

use instead of TRACE, 278–279, 302

use partitions with, 276–278

EXPLAIN PLAN section, TKPROF, 263

Explain Plans comparison, Real-Time ADDM, 236

EXPLAIN WORK SQL statement, ASM rebalance, 121–123

exporting partitions, 150

extended character data type, max size, 521–522
failover capability, 12cR2 Data Guard, 31
fast full scans
   db file scattered read wait event in, 841–842
   of indexes, 65–66
   with INDEX_FFS hint, 322–323, 367–368
   with PARALLEL_INDEX hint, 333
fast mirror resync, ASM, 123–124
FDA (Flashback Data Archive), 28
Federal Information Processing Standards (FIPS), encryption, 28
Fetch Across Commit, Snapshot Too Old error, 469
fetch first x rows, 12cR1, 8–9
FIFO (first in, first out), 846, 875
File I/O Statistics section, AWR Report/Statspack, 863–864
file mapping, V$ views for, 724
FILE parameter, direct writes from data loads, 663
filesystems
   managing with ASM, 104
   RAID 5 for read or read-only, 96
   setup/maintenance of traditional, 98–99
   store datafiles in, 99
Findings tab, Real-Time ADDM, 234–235
FIPS (Federal Information Processing Standards), encryption, 28
FIRST_ROWS hint, 315–316
FIRST_ROWS optimizer mode, 204–205, 373–375
FIXED SQL Plan Baselines, 291–292
fixed tables, X$ tables as, 733, 735–736
flags
   block dumps, 476, 477
   SPM, 286
Flash Cache, Exadata Storage Server software, 614–617
Flashback Data Archive (FDA), 28
flashback PDB, 11, 93–94
Flex ASM, Grid Infrastructure installation, 107, 109–115
Flex Cluster, Grid Infrastructure installation, 107, 115
Flex disk group quota management, ASM, 34
FOR loop, optimize compiler, 535–538
FORCE option, ASM disk scrubbing, 120–121
forcing specific join method, 443–445
Foreground Processes, new in 12.2 Statspack/AWR report, 817
Foreground Wait Events, AWR Report/Statspack, 839–841
FORMAT_NAME function, SQL function calls, 524–525
fragmentation
  avoid chaining with PCTFREE, 151–152
  overview of, 150–151
  query shared pool issues, 745–747
  use ASSM, 152–153
  use correct extent size, 151
free buffer inspected, AWR Report/Statspack, 860
Frequency histogram, 394
FROM clause
  bitmap join indexes, 78–79
  expected order of table access in, 323–324, 452
  two table INDEXED join, 440–442
  two table joins, 436–439, 447–450
  use first table as driving table, 443
FSTAT system call, ASM and multipathing, 137
full database caching, in 12cR1, 28
FULL hint, 316–317
full rack, Exadata, 610–612
full table scans
  CACHE hint causing caching of, 334–335
  db file scattered read wait event in, 841–842
  effect of compression on, 621
  fast full scan require fewer IOs than, 66
  functions causing, 58
  as inefficient, 301
Instance Activity Statistics section, AWR Report/Statspack, 857
mismatched data types causing, 58–59
with parallel execution, 645–646
PARALLEL_INDEX hint for, 333
problems in TKPROF output caused by, 265
read every row in table via, 45
on specified table with FULL hint, 316–317
two table joins: equal-sized tables, 436–438
function-based indexes
applying functions in, 58
create, 377–378
for multiple types of indexes, 50–53
overview of, 73–74
using with DATE, 570

functions
  build complex results sets with pipelined table, 575–580
  creating tables with virtual columns, 378–379
  example in PL/SQL, 588
  execute GET_CUST_NAME function, 588
  PL/SQL Function Result Cache, 505–515
Fusion Middleware products, use TRACE within, 280
GATHER_OPTIMIZER_STATISTICS hint, 341
gc (global cache) wait events, RAC, 635, 847, 853–854
GCS (Global Cache Service), RAC, 629–630, 633–634
general information, V$ views for, 724
GES (Global Enqueue Service), RAC, 630, 633, 639–640
Get Started, Database Cloud Service, 601–602
gethit ratio, Library Cache, 887
GI (Grid Infrastructure) installation in 12c, 107–115
Global Cache Service processes (LMSn), RAC, 629
Global Enqueue Service Daemon (LMD), RAC, 629
Global Enqueue Service Monitor (LMON), RAC, 629
global hints, 342
global index maintenance: drop and truncate, 23, 146
global partitioned indexes
  hash partitioning, 141
  index partitioning, 149
  non-prefixed (not supported), 78
  overview of, 76–77
  prefixed, 77
global transactions, X$ table groups for, 792
GNS (Grid Naming Service), Flex ASM, 108–109
gold image homes, 29, 34
Golden Gate, new replication features, 31
Google Cloud, 596
GOTO statement, simplify loops, 525–528
graphing performance metrics, 493–498
GRD (Global Resource Directory), RAC, 630–631, 633
Grid Control, enhancements to, 626
Grid Infrastructure (GI) installation in 12c, 107–115
Grid Naming Service (GNS), Flex ASM, 108–109
grouping statements, 315
GTX0-j (Global Transaction Process), RAC, 629
GUI monitoring tools, 955
Guided Workflow, SQL Performance Analyzer, 230–231
GV$ views
  $V views created from, 674
  listing of all, 737
  V$ views vs., 677, 737
GV$PQ_SESSTAT view, parallel statistics, 665
GV$PQ_SYSSTAT view, parallel statistics, 665
GV$RESOURCE_LIMIT view, global resources, 645
GV$SESSION view, RAC session waits, 636–639
GV$SESSION_WAIT view, RAC waits, 633–634

H

Hadoop Distributed File System (HDFS), 33
half rack, Exadata, 610, 612
hardware
  arithmetic, 551
    Exadata. See Exadata (Exadata Database Machine)
  other Oracle, 625–626
hash chains, block tuning, 473
hash indexes, 71–72, 75
HASH joins
  forcing, 445
    initialization parameters, 434–435
    overview of, 430–431
  two table INDEXED joins, 440–443
  two table joins, 436–439
    USE_HASH hint, 328–329
hash partitioning, 141–142
HBA drivers, ASM and multipathing, 136–137
HC (High Capacity) storage, Exadata, 611–613
HCC (Hybrid Columnar Compression), Exadata, 33, 618–621
HDFS (Hadoop Distributed File System), 33
header information section, AWR Report/Statspack, 831–833
Heat Map, 12c, 22, 101–102, 926
height-balanced histograms, 64–65, 394–395
Help, OEM online, 225–226
  -help option, srvctl, 117–119
heterogeneous services, X$ table groups for, 798
High Capacity (HC) storage, Exadata, 611–613
HIGH compression option, indexes, 33
HIGH priority, In-Memory database, 26, 174
hints
  use with external tables, 468
  use with X$ tables and indexes, 741–742
hints, basic syntax
  access method hints, 310
    ALL_ROWS hint, 316
  APPEND hint, 333–334
CACHE hint, 334–335
CONTAINERS hint, 339
CURSOR_SHARING_EXACT hint, 336
DRIVING_SITE hint, 325–326
evaluation path hints, 309–310
FIRST_ROWS hint, 315–316
fix design first, 308–309
FULL hint, 316–317
at a glance, 344
INDEX hint, 317–319
INDEX_ASC hint, 321
INDEX_COMBINE hint, 320–321
INDEX_DESC hint, 322
INDEX_FFS hint, 322–323
INDEX_JOIN hint, 320
INMEMORY, NO_INMEMORY, and other IM hints, 337
join operation hints, 311
LEADING hint, 324–325
miscellaneous, 339–341
NOAPPEND hint, 334
NOCACHE hint, 335
NO_EXPAND hint, 325
NO_INDEX hint, 319–320
NO_PARALLEL hint, 332
Oracle demo sample HR schema, 314–315
ORDERED hint, 323–324
other, 311–312
overview of, 306–307
parallel execution hints, 311
PARALLEL hint, 331–332
PARALLEL_INDEX hint, 333
WITH_PL/SQL hint, 339
problems with, 343
PUSH_SUBQ hint, 330–331
QB_NAME hint, 329–330
query transformation hints, 310–311
RESULT_CACHE hint, 335–336
review tips, 345–347
specifying, 312–313
specifying multiple, 313
specifying when using alias, 314
STORED OUTLINES, 284, 343
Top Hints list, 307–308
undocumented, 341–342
use sparingly, 308
USE_HASH hint, 328–329
USE_INVISIBLE_INDEXES hint, 338–339
USE_MERGE hint, 326–327
USE_NL hint, 327–328
using with views, 342
hint_string, pass hints to PDBs, 339
histograms
  AWR Report/Statspack statistics, 849–850
defined, 64
  height-balanced, 64–65, 394–395
  using for tables or indexes, 64–65
hit ratio(s)
  as barometer of system health, 837
  buffer cache, 859, 914–916
  data cache, 183–186
  data dictionary cache, 193–194, 916–917
  find bad queries via, 186–189
  library cache, 195–197, 917
  monitor Instance Efficiency for, 836–838
hosting IT, history of push towards, 596
Hosts tab, OEM, monitoring hosts, 248–250
hot blocks
  latch and mutex waits related to, 872
  latch issues, 881
  tuning and viewing, 883–886
hot cloning, PDB, 11
hot data, Flash Cache caching, 614–615
HTML format, AWR Report in 2.2, 826
Hub Nodes, Oracle Flex Cluster, 115
HW enqueue waits, 846
hybrid cloud, 598
Hybrid Columnar Compression (HCC), Exadata, 33, 618–621
Hybrid Hash, in 12c, 388–389
Hybrid histogram, 12c, 394–396
I/O

ASM, multipathing and, 136–137
AWR Report/Statspack for, 861–864
binary height of index and, 60–62
bottlenecks in parallel operations, 652–653, 666
distortion of, 189
distribute processes over multiple slaves, 156
in fast full scans vs. full table scans, 66
find problems with sar -d command, 944–947
handling RAID 5 heavy, 96
hash index collisions increasing, 71–72
precautions/tips for disk, 157–158
reduce to avoid disk contention, 99–100
reduce with partitioned indexes, 75
separate tables/indexes to decrease file, 925
tracking views (outliers) in 12c, 102–103
V$ views for, 724

I/O Resource Management (IORM), Exadata, 621–622
I/O Stats section, Statspack/AWR report, 817
IAS (INSERT AS SELECT, 12c statistics, 394
Identity Columns, create table/alter column, 517–519
idle wait events, 848–850
IF statements, ordering PL/SQL, 550–551
IFACE column values, cluster interconnect, 643
ilm_clause, Automatic Data Optimization, 22–23, 102
ILOM (Integrated Lights Out Management), remote Exadata, 609
IM (In-Memory) column store
  ADO managing in 12cR2, 102
  configure Database Cloud Service, 16
  features, 25–28
  hints, 337
  initialization parameters, 165–166
INMEMORY_SIZE parameter and, 17, 93, 171–176
overview of, 170–171
using with PDBs, 93
V$ views for, 722
IMCU (In-Memory Compression Unit), 27
impdp command, 18
IMPLEMENT_EVOLVE_TASK function, SPM, 396
import time, change compression at, 18
IMU (in-memory undo) statistics, 473, 855–856, 883
_IMU_POOLS parameter, IMU, 473
IN clauses, distributed queries, 463
IN function, query tuning via EXISTS vs., 380
In-Memory Central, OEM Administration menu, 244
In-Memory column store. See IM (In-Memory) column store
In-Memory Compression Unit (IMCU), 27
In-Memory Expressions, 176
In-Memory latches section, AWR Report, 874
in-memory undo (IMU) statistics, 473, 855–856, 883
index blocks
  buffer busy waits on, 844
dumps, 483–485
index-by tables, as PL/SQL associative arrays, 562–565
INDEX hint
  basic syntax, 317–319
  INDEX_ASC hint does same thing as, 321
  third-party product tuning via, 458–459
INDEX-MERGE joins, 432–434
index-organized tables, 72–73
index-organized tables (IOTs), restrictions, 50
INDEX_ASC hint, 321
INDEX_COMBINE hint, 320–321
INDEX_DESC hint, 322
indexes
  advanced compression in 12c R1, 28
cautions when dropping, 364–365
check table for current, 360–361
on columns used in SELECT and WHERE, 365–367
create, 360
create bad, 362–364
create with parallel operations, 652–653
db file scattered read wait events and, 841–842
distortion of, 189
Exadata storage, 617–618
fast full scan of, 367–368
find out if index is being used, 706–708
get listing of all X$ table, 740–741
graph pattern interpreting, 495–496
hints, use with X$ table, 741–742
Instance Activity Statistics section, AWR Report/Statspack, 857–858
merging two, 373–375
multiple, on same column(s), 7–8  
new 12cR2 compression features, 33  
parallel data loading and, 663  
parallel index builds, 665  
PARALLEL_INDEX hint for scanning, 333  
partial, 5  
partition, 149  
perform count of bitmap index, 457–458  
separate from tables to decrease file I/O, 925  
storage, IMCU, 27  
store data in separate location from, 99  
suppressing, 375–377  
third-party product tuning via, 458–462  
using, 356–357  
when you forget to provide, 359–360  
indexes, basics  
  basic concepts, 45–47  
  binary height, 60–62  
  BLEVEL and Index Height details, 62–64  
  clustering factor, 59–60  
  comparing mismatched data types, 58–59  
  concatenated indexes, 53–54  
  fast full scans, 65–66  
  invisible indexes, 47–49  
  multiple, on same column(s), 50–53  
  overview of, 44–45  
  rebuild fast, 79  
  rebuild online, 79–80  
  review tips, 80–82  
  selectivity, 59  
  skip-scans, 66–67  
  suppressing indexes, 54–55  
  use functions, 58  
  use histograms, 64–65  
  use IS NULL or IS NOT NULL, 55–56  
  use LIKE, 57  
  use NOT EQUAL operators: <>, !-, 55  
indexes, types of  
  B-tree indexes, 68–69  
  bitmap indexes, 69–71  
  bitmap join indexes, 78–79
function-based indexes, 73–74
hash indexes, 71–72
index-organized tables, 72–73
overview of, 67–68
partitioned indexes (local and global), 74–78
reverse key indexes, 73
INDEX_FFS hint, 322–323, 367–368, 434
INDEXING clause, partial indexes, 6, 143–144
INDEX_JOIN hint, 320, 374
INDEX_SS hint, 340
INDEX_SS_ASC hint, 340
INDEX_SS_DESC hint, 340
inequalities, SORT-MERGE for, 429
InfiniBand switches, X6-2 Exadata, 611
information integration, version comparison chart, 38
information lifecycle management, ilm_clause in ADO, 22–23, 102
information section, TKPROF, 263
initialization parameters
  ASM, 107
    get current values for, 690–691
    modify at PDB level, 91
  parallel execution, 660–662, 665
    setting, 753–757
  Statspack/AWR report, 817, 889–890
  table joins, 434–439
  undocumented TRACE, 283–284
  X$ tables relevant to, 756–757
Initialization Parameters, Administration menu, 244–246
initialization parameters, tune database
  avoid paging/swapping, 204
  change without database restart, 176–180
  create enough dispatchers, 205–206
  for crucial memory, 166–170
  DDL statements, do not let fail, 206
  Exadata only, 207
  find undocumented, 210–211
  have enough open cursors, 206
  insight into, 181
  modify at PDB level, 180–181, 691
  modify LRU algorithm, 202
  monitor data dictionary cache, 193–194
monitor library cache reload/hit ratios, 195–197
monitor V$SQLAREA for bad queries, 186–189
over the years, 207–210
overview of, 164–165
at PDB level, 170
review tips, 218–220
set cache and share pool sizes, 199
set DB_BLOCK_SIZE, 189–190
set SGA_MAX_SIZE, 190
setup In-Memory database (INMEMORY_SIZE), 170–176
SHARED_POOL_SIZE and memory for statements, 202–203
SHARED_POOL_SIZE correct settings, 197–198
SHARED_POOL_SIZE set to fully use DB_CACHE_SIZE, 193
sizing Oracle Applications database, 213–218
top twenty-five, 207–210
tune DB_CACHE_SIZE, 182–186
tune PGA_AGGREGATE_TARGET/PGA_AGGREGATE_LIMIT, 203
tune SHARED_POOL_SIZE, 191
and typical server, 211–213
understand Oracle Optimizer, 204–205
upgrade to 12c and, 165–166
use Oracle multiple buffer pools, 201
use SEC_CASE_SENSITIVE_LOGON, 166
use stored procedures for shared SQL area, 191–193
use X$KSMSP table for details on shared pool, 198–199
view with Enterprise Manager, 181–182
waits and, 200
init.ora, 257, 690–691
INLINE pragma, 538–539
INMEMORY attribute, IM column store, 173
INMEMORY hint, 337
INMEMORY scans, 45
_IN_MEMORY_ UNDO=TRUE parameter, IMU, 473
INMEMORY V$ views, 812
INMEMORY_PRUNING hint, 337
INMEMORY_QUERY parameter, 171
INMEMORY_SIZE parameter
  how to use, 208
  IM Database setup, 170–176
new (12cR1), 25–28
query V$IM_SEGMENTS after setting, 685–686
upgrade to 12c, 166
inner table, NESTED LOOPS joins, 428–429
inquiry directives, conditional compilation, 581, 584
INSERT AS SELECT (IAS) operation, 12c statistics, 394
INSERT statements
  APPEND hint improves performance of, 333–334
  bitmap vs. b-tree indexes for, 69–71
  data section of block dump, 480
  increase log file size to speed up, 154–155
  log timing statistics into database tables, 541–543
  parallelized via PARALLEL hint, 331
  use rollback segments for large, 572
installation
  ASM, 107–109
  Flex ASM, 109–115
  Statspack, 818–820
  Statspack deinstallation, 893
  X$ table groups for, 785
Instance Activity Statistics section, AWR Report/Statspack, 855–861
Instance Efficiency section, AWR Report/Statspack, 836–838
Instance Enqueue Process (LCK0), RAC, 629
Instance Recovery Stats section, AWR Report/Statspack, 869
instances
  ASM, 106–107
  obtain information on, 766–767
  V$ views for, 723
  X$ table groups for, 785
instant recovery repopulation daemon (RPOP), 35
integer operations, PLS_INTEGER PL/SQL data type for, 551–552
Integrated Lights Out Management (ILOM), remote Exadata, 609
Intelligent Data Placement, ASM disks, 156
interconnect statistics, RAC wait events and, 635–641
interested transaction list (ITL), 473, 476–477
interoperation parallelization, 649–653
interval partitioning, avoid disk contention via, 139
intra-operation parallelization, 649–653
intrapartition parallelism, 647
invalid objects, find in PL/SQL code, 559–561
Inventory and Usage pane, Enterprise Summary, 227
invisible columns, 6
invisible indexes
create or alter existing index to, 360
force use of, 338–339
for multiple types of indexes on same column(s), 50–53
overview of, 47–49
_IO_OUTLIER_THRESHOLD parameter, 103
IORM (I/O Resource Management), Exadata, 621–622
iostat command, disk performance, 945, 959–962
IOTs (index-organized tables), restrictions, 50
ipcrm command, shared memory, 962–963
ipcs command, shared memory, 962–963
IS NOT NULL, suppress indexes, 55–56
IS NULL, suppress indexes, 55–56
I_SNAP_LEVEL parameter, Statspack, 821–822
IS_REOPTIMIZABLE column, Adaptive Query Optimization, 384–386
IS_RESOLVED_ADAPTIVE_PLAN column, Adaptive Query Optimization, 384–386
IT Analytics, Oracle Management Cloud, 606
IT operations, cloud services lower cost of, 597
iterations
reduce time for PL/SQL program, 544–546
use ROWID for, 546–548
ITL (interested transaction list), 473, 476–477

J
jackknifing pattern, 497
Java pool, 747, 751–752
Java source, X$ table groups for, 799
JAVA_POOL_SIZE parameter
    cache sizes, 181
    defined, 209
    query ORA-04031 errors, 744
    set automatically with MEMORY_TARGET, 207
    unaffected by PGA_AGGREGATE_TARGET, 203
    usually sets minimum value, 168
Job Activity screen, Oracle Database, 247–248
join operations hints, 311
joins. See table joins
JSON (JavaScript Object Notification), 28

K
Label Security, new features in 12cR2, 32
Large Object (LOB) data types, 521
LARGE_POOL_SIZE parameter, 202–203, 209
Latch Activity section, AWR Report/Statspack, 873–875
Latch and Mutex Statistics, AWR Report/Statspack, 872–882
latch free wait events, 844–845, 848, 877
LATCH MISS section, Statspack/AWR report, 817
latch waits
  causes of, 763–766, 872
  pinning to reduce, 878
  potential fixes, 200
  query, 751–752
latches
  library cache pin/latch replaced by mutexes, 845
  and mutex statistics, 872–882
  not willing to wait, 873
  potential fix, 844–845
  V$ views for, 724
  X$ table groups for, 796
latency, tuning cluster interconnect, 641–642
LCK0 (Instance Enqueue Process), RAC, 629
LEADING hint, 324–325, 443
leaf blocks
  BLEVEL index depth and, 62–64
  in fast full scans of indexes, 65–66
  measure clustering factor of index, 60
Leaf Nodes, Oracle Flex Cluster, 115
Least Redo Block Address (LRBA), block dumps, 480–481
LGn (log writer) slave background process, 35
library cache
  cache size and, 199
  hit ratio, Memory Performance Index, 917
  query memory use, 747–750
  query mutex/latch waits and/or sleeps, 751–752
reload ratio and hit ratio settings, 195–197
reset X$KSMLRU table, 752
statistics, AWR Report/Statspack, 886–887
X$ table groups for, 793–794

library cache mutexes
- library cache pins/latches replaced by, 845–846
- limiting issues, 877–879
- potential fix for waits, 848
- related to Oracle bugs, 851–852

licensing
- AWR Report, 824
- Exadata, 610–611
LIKE, use with indexes, 57
linear equation determination, 487–488, 491–494
links, clone PDBs over, 88
list of V$ views, 677
listener registration (LREG) background process, 35
LMD (Global Enqueue Service Daemon), RAC, 629
LMON (Global Enqueue Service Monitor), RAC, 629
LMSn (Global Cache Service processes), RAC, 629
load-balancing, cluster interconnect tuning, 642
Load Profile section, AWR Report/Statspack, 830, 833–834
loader, X$ table groups for, 798
LOB (Large Object) data types, 521
local partitioned indexes
- example of, 149
- hash partitioning supporting, 141
- overview of, 75–76
- utilizing, 143
lock blockers, GES, 639–640
locks
- behavior, HCC during updates, 620
- enqueue protecting shared resource via, 846
- identify issues, 708–710
- ITL section of block dump, 476
- PERFSTAT account, 819
- V$ views for, 724
- X$ table groups for, 796
Log Analytics, Oracle Management Cloud, 606
log buffer space wait event, 846–847, 849
log file parallel write wait event, 847, 849
log file switch wait event, 846, 849
log file sync wait event, 847, 849
log files
determine if size is problem, 154
determine size of, 155
increase size for speed, 152–153
instance parameters, 156
other helpful commands, 155–156
of timing statistics into database tables, 541–543
Log Miner, V$ views for, 724
log writer (LGn) slave background process, 35
LOG_ARCHIVE_DUPLEX_DEST, 156
LOG_ARCHIVE_MIN_SUCCEED_DEST, 156
LOG_BUFFER parameter, 168, 209
LOG_CHECKPOINT_INTERVAL, 152–153
logical disk corruption, ASM disk scrubbing for, 119–121
logical replication, new 12cR2 features, 31
login screen, OEM, 223
LogMiner, X$ table groups for, 790–791
long tables, AWR Report/Statspack, 860
lookup tables, CACHE hint for, 334–335
loops
reduce PL/SQL program unit iterations, 544–546
simplify with CONTINUE statement, 525–528
LOW priority, In-Memory database, 26, 174
LRBA (Least Redo Block Address), block dumps, 480–481
LREG (listener registration) background process, 35
LRU algorithm, initialization parameters for, 202
LRU block, buffer headers, 474
LRU-W block, buffer headers, 474
LUN (logical unit number), RAID, 94
LVMs (logical volume managers), ASM vs., 97

M

materialized views
   REWRITE_OR_ERROR hint, 341
   V$ views for, 725
   X$ table groups for, 788
mathematics
techniques for tuning. See Simple Mathematical Techniques, for tuning
traditional mathematical analysis, 486
MAX_DUMP_FILE_SIZE, SQL TRACE, 257
maximum transmission unit (MTU), cluster interconnect, 643
MAX_MEMORY_TARGET, ASM, 107
MAXVALUE, partition tables using multiple columns, 141
MEDIUM priority, In-Memory database, 26, 174
MEMCOMPRESS, In-Memory option, 174–175
MEMCOMPRESS, In-Memory options, 27
memory
  caching small, often-used tables in, 369–371
crucial initialization parameters for, 166–170
DB_CACHE_SIZE and allocating, 201
disk I/O precautions and tips, 157
finding high reads without TRACE, 278–279
improve shared pool use by pinning PL/SQL objects into, 555–557
information in EM Console in Cloud, 606
MEMORY_TARGET setting SGA/PGA, 167–170
new in 12.2 Statspack/AWR report, 817
query shared/Java pools for low free, 747
query use of library cache, 747–750
reporting on free memory with sar -r, 950
reporting on resources with sar -wpgr, 950–951
setting for HASH joins, 435
SHARED_POOL_SIZE and, 202–203
SORT-MERGE joins and, 428
system information list for, 934–935
tuning system, 968
USE_HASH hint requirements, 328–329
X$ tables only reside in, 733
Memory Dynamic Components section, AWR Report/Statspack, 867
Memory Performance Index. See MPI (Memory Performance Index)
MEMORY_LIMIT parameter, PDB level, 17, 170
MEMORY_MAX_TARGET parameter, AMM, 167, 207
MEMORY_MINIMUM parameter, PDB level, 17, 170
MEMORY_TARGET advisor section, AWR Report/Statspack, 865–867
MEMORY_TARGET parameter
  accommodate INMEMORY_SIZE, 171–172
  ASM, 107
  as crucial new initialization parameter, 17, 166–170
  for HASH joins, 430, 434
  how to use, 207
In-Memory database and, 25, 27
as not modifiable, 181
PGA_AGGREGATE_LIMIT as part of, 204
PGA_AGGREGATE_TARGET as part of, 203
for Result Cache, 920
Statspack/AWR report, 817
tuning data cache hit ratio, 183–184
upgrade to 12c, 166
V$MEMORY_TARGET_ADVICE view, 687–688
MERGE JOIN operation, 326–327, 657–658
MERGE PARTITIONS option, 148
MERGE/SPLIT partitions, move online, 23
Message Passing Interface (MPI), RAC, 628
metrics, V$ views for, 724
Microsoft Cloud, 596
Microsoft Excel, graphing performance metrics, 493
migration, new RMAN features, 32
MINIMUM SIZE parameter, DBMS_SHARED_POOL.SIZES, 557–558
MINUS operator, tuning distributed queries, 463
mirrored disks, RAID, 95–96
mirroring, in ASM, 97
miscellaneous tables, X$ table groups for, 799
miscellaneous V$ views, 727
miss ratio, data dictionary cache, 197
mission-critical table management, Disk Performance Index, 925–926
M$LOG tables, 218
mobile applications, and cloud, 11–17, 596
MODEL_MIN_ANALYSIS hint, 340
MODIFY PARTITION option, 146
MODIFY_STATSPACK_PARAMETER procedure, 822–823
module information, trace file identifying, 782
module name, DBMS_MONITOR, 266, 268–269
MONITOR hint, 340
MOVE PARTITION option, 146–147
MPI (Memory Performance Index)
  buffer cache hit ratio, 914–916
dictionary cache hit ratio, 916–917
how to receive perfect score, 912
library cache hit ratio, 917
percentage of data buffers still free, 919–920
PGA memory sort ratio, 918–919
pinning/caching objects, 921–922

 top memory-abusers, 912–914

 using Result Cache, 920–921

 MPI (Message Passing Interface), RAC, 628

 mpstat command, 956

 MTU (maximum transmission unit), cluster interconnect, 643

 multicolon column range partitioning, 140–141

 multipathing, ASM and, 136–137

 multiple hints, 313


 multiple tables, bitmap join indexes on, 456

 multitable joins, 445–446, 471–472, 496

 multitenant databases. See PDBs (pluggable databases)

 multithreaded servers, V$ views for, 725

 Mutex Sleep Summary section, AWR Report, 874–876

 mutex waits, 872, 876–877

 mutexes

 defined, 845

 latches as, 844–845

 library cache pin/latch replaced by, 845–846, 872

 Oracle move from latches to, 874

 query, 751–752

 statistics for latches and, 872–882

 My Oracle Support (Metalink) Note 224176.1, 969

 N

 named notation, pass parameters to subroutine, 525

 named parameters, SQL function calls, 523–525

 naming conventions

 system information list, 937

 X$ table, 805–812

 National Language Support (NLS), X$ table groups for, 786

 native compilation

 defined, 530

 increase performance, 530–533

 optimize compiler for, 533–539

 NATIVE_FULL_OUTER_JOIN hint, 340

 NDVs (number of distinct values), histograms, 394

 nested loops, hints for, 327–328, 341

 NESTED LOOPS joins
CLUSTER joins as special, 429–430
forcing, 444
overview of, 428–429
two table INDEXED joins, 440–443
nested subquery, with EXISTS clause for speed, 381
netstat, 642–643, 966–967
networking
monitor performance with netstat, 966–967
network-enabled restore, RMAN, 24
tune distributed queries, 463
version comparison chart, 39–40
new features
Oracle 12cR1 (12.1.0.2), 4, 25–29, 36–40
overview, 2–5
new features, Oracle 12cR1 (12.1.0.1)
Adaptive Query Optimization, 18–19
ASM disk scrubbing, 23
Automatic Data Optimization, 22–23
change compression at import time, 18
columns based on sequence, 20
concurrent cost-based optimizer statistics, 21
concurrent execution for UNION/UNION ALL, 20
Data Guard improvements, 24
Database Cloud Service, 11–17
DBMS_UTILITY.EXPAND_SQL_TEXT, 20
drop and truncate partitions, 23
enhanced system statistics, 21
fetch first $x$ rows, 8–9
invisible columns, 6
known as PDB version, 5
multiple indexes on same column list, 7–8
multiple SSD devices for Smart Flash Cache, 20
NVARCHAR2 size limit increase, 5
online capability improvements, 23
overview of, 3–4
partial indexes, 5–6
PGA_AGGREGATE_LIMIT, 19
pluggable databases, 9–11
Resource Manager for runaway queries, 22
Results Cache for invoker rights, 20
RMAN improvements, 24
VARCHAR2 size limit increase, 5
version comparison chart, 36–40
new features, Oracle 12cR2 (12.2)
application development, 29–30
availability, 30–32
background processes, 34–35
big data, 33
compression and archiving, 34
Exadata X6, 35–36
Oracle RAC and grid infrastructure, 34
overview of, 4–5
PDB level: MEMORY_LIMIT and MEMORY_MINIMUM, 17
reduce costs/issues for migration to Oracle, 30
version comparison chart, 36–40
new systems, planning stage issues, 158
Newton's Divided Difference Interpolating Polynomial, 487–493
NLS (National Language Support), X$ table groups for, 786
NLS_DATE_FORMAT, 569
NO_MEMCOMPRESS, In-Memory option, 174
NO_ADAPTIVE_PLAN hint, 341
NOAPPEND hint, 333, 334
NO_AUTO_REOPTIMIZE hint, 341
NOCACHE hint, 335, 615
nodes, Oracle Flex Cluster, 115
NO_EXPAND hint, 325, 380
NO_GATHER_OPTIMIZER_STATISTICS hint, 341
NO_INDEX hint, 49, 319–320
NO_INMEMORY hint, 337
NO_INMEMORY_PRUNING hint, 337
NOLOGGING hint, 340
NOLOGGING option
  create table/index, 160
  create tables/indexes with parallel operations, 652
disable redo generation during MOVE, 147
new 12cR2 availability options, 31
NO_MONITOR hint, 340
non-CDBs, 9, 87
non-prefix local indexes, 76
non-V$ fixed view associations, and X$ tables, 801–803
Non-Volatile Memory Express (NVMe), Exadata, 610
NO_NATIVE_FULL_OUTER_JOIN hint, 340
NONE priority, 26, 174
nonprefixed global indexes, 78, 149
NOPARALLEL clause, ALTER TABLE command, 651
NO_PARALLEL hint, 332, 650–651
NO_PUSH_PRED hint, 340
NO_RESULT_CACHE hint, 336
NORMAL mode, cost-based optimizer, 381
NO_STATEMENT_QUEUING hint, 648
NOT EQUAL operators (<>!, =), suppress index usage 55
NOT NULL, 521
not willing to wait latches, 873
NO_USE_CUBE hint, 341
NO_USE_NL hint, 328
NULL values
   B-tree indexes, 68
   suppressing indexes with, 55, 56
number arithmetic, 551
number of distinct values (NDVs), histograms, 394
numeric data types, 551
NVARCHAR2, 5, 521
NVMe (Non-Volatile Memory Express), Exdata, 610
NVRAM, 947

O

objects
   cache all, 556–557
   find dependencies for PL/SQL, 567
   find invalid PL/SQL, 559–560
   find state of all PL/SQL schema, 560
   identify PL/SQL that need pinning, 557
   implications of location of PL/SQL, 571–572
   pinning/caching, Memory Performance Index, 921–922
   query SQL source code behind stored, 565–567
   V$ views for, 725
ODA (Oracle Database Appliance), 623
OEM Administration menu
   Initialization Parameters, 244–246
   In-Memory Central, 244
   monitor and tune via, 241–242
   Resource Manager/consumer groups, 246–247
   Storage | Tablespaces, 242–244
OEM (Oracle Enterprise Manager)
   for ASM, 104
   Express console, 224–225
   locate bad queries, 186–189
Online Help window, 225–226
Oracle Cloud Database, 15–16
query wait events, 718
view initialization parameters, 181–182

OEM (Oracle Enterprise Manager) Cloud Control
Administration menu, 241–248
basics/accessing via Oracle Cloud, 223–226
monitor and tune with, 222–223
monitor application servers/web applications, 250–252
monitor hosts, 248–250
Oracle Database menu, 247–248
Performance menu. See OEM Performance menu
Real Application Testing (Database Replay), 252–253
review tips, 253–254
run AWR Report, 828–831
set with all targets/other groupings, 227–229
use ADDM Report through, 893
view/monitor Smart Scan benefits, 614

OEM Performance menu
Access Advisor, 237
ASH Analytics, 241
AWR Administration, 238–241
Optimizer Statistics, 237–238
overview of, 229
Real-Time ADDM, 233–237
SQL Performance Analyzer, 230–233
Top Activity screen, 229–230

oerr command-line facility, 774
ols.pl Perl script, Flex ASM, 129–132
OLTP (online transaction processing)
bitmap indexes not used for, 69, 71
Exadata speed vs., 609
In-Memory Database and, 170–171
use hints sparingly, 308
OMF (Oracle Managed Files), 103–104
on-demand capacity licensing, Exadata, 611
ON NULL clause, Identity Columns, 519–520
online capability improvements
12cR1, 23
12cR2, 32
Online Database Relocation, RAC, 627
online services
    OEM help, 225–226
    Oracle Cloud, 599
    Oracle documentation, 666
    rebuild indexes, 79–80

online transaction processing. See OLTP (online transaction processing)
open cursors, 206
OPEN_CURSORS parameter, 181, 206, 210
OPERATION column, PLAN_TABLE, 280
OPS (Oracle Parallel Server). See also RAC (Real Application Clusters), 626
OPT_ESTIMATE hint, 391–392
optimization
    Adaptive Query Optimization. See Adaptive Query Optimization
    ADO. See ADO (Automatic Data Optimization)
    new 12cR2 features for big data, 33
optimizer
    automatic statistics collection in, 314
    some hints overridden by, 312
    X$ table groups for, 796
OPTIMIZER_ADAPTIVE_FEATURES parameter, 383–384
Optimizer Statistics, 21, 237–238
OPTIMIZER_ADAPTIVE_FEATURES parameter, 166
OPTIMIZER_ADAPTIVE_REPORTING_ONLY parameter, 166, 383–384, 387–388
OPTIMIZER_CAPTURE_PLAN_BASELINES, SPM, 287–289, 295–301
OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES parameter, 209
OPTIMIZER_DYNAMIC_SAMPLING parameter, 384, 389–390
OPTIMIZER_INDEX_COST_ADJ parameter, 190, 209, 862
OPTIMIZER_MODE = ALL_ROWS, 316
OPTIMIZER_MODE = FIRST_ROWS, 316
OPTIMIZER_MODE parameter, 166, 204–205, 208
OPTIMIZER_USE_INVISIBLE_INDEXES parameter
    create invisible index, 360
    force use of invisible index, 48–49, 338
    how to use, 209
    upgrade to 12c, 166
OPTIMIZER_USE_PENDING_STATISTICS parameter, 209
OPTIMIZER_USE_SQL_PLAN_BASELINES parameter, 209, 287–291, 295–301
OPTIONS column, PLAN_TABLE, 280
OPT_PARAM hint, 340
OR clause, improvements to, 380
OR expansion, NO_EXPAND hint prevents, 325
ORA-04031 errors, 743–747
Oracle 12cR1 (12.1.0.1). See new features, Oracle 12cR1 (12.1.0.1)
Oracle 12cR1 (12.1.0.2), new features, 4, 25–29, 36–40
Oracle 12cR2 (12.2). See new features, Oracle 12cR2 (12.2)
Oracle Big Data Appliance X6-2, 625
Oracle bugs, 851–852, 872
Oracle Cloud
  march to, 596–598
  My Services menu, 224–225
  overview of, 594–597
  review tips, 667–668
  sign in, 601–602
  working with, 599–608
Oracle Cluster Health Monitor (CHM), 969
Oracle Database Administrator’s Guide, 12c, 662
Oracle Database Appliance (ODA), 623, 624
Oracle Database Cloud Service
  access OEM Console from, 224–225
  overview of, 11–17
Oracle Database Data Warehousing Guide, 341
Oracle Database Exadata Express Cloud Service, 59, 599, 608
Oracle Database New Features Guide, 2
Oracle Database Performance Tuning Guide Automatic SQL Tuning, 381
Oracle Database SQL Language Reference, 309, 341
Oracle Database Upgrade Guide, 12c, 662
Oracle Developer distortion, 188
Oracle Enterprise Manager. See OEM (Oracle Enterprise Manager)
Oracle Intelligent Storage Protocol, ZFS Storage server, 625
Oracle internals topics. See trace, generate
Oracle Managed Files (OMF), 103–104
Oracle Management Cloud, 606–607
Oracle optimizer, 204–206
Oracle ORION Calibration Tool, 969
Oracle Parallel Server (OPS). See also RAC (Real Application Clusters), 626
Oracle Public Cloud services, sign up, 601
Oracle shadow process, 852
Oracle Virtual Machine (OVM), Exadata licensing, 611
ORADEBUG command
  invoke trace via, 768, 770
  set events in sessions other than current one, 774
  troubleshooting instance or sessions, 775–777
ORDERED hint
  basic syntax, 323–324
LEADING hint overridden by, 324–325
request specific join order for all tables, 443, 445
two table INDEXED join, 441–443
two table joins, 438–439, 448–450

OSASM role, ASM, 132–136
OSDBA group role, ASM, 132, 135
OTHER_TAG column, PLAN_TABLE, parallelized query, 656–658
outer joins, 340
outsourcing IT, history of, 596
Overview pane, Enterprise Summary, 227
OVM (Oracle Virtual Machine), Exadata licensing, 611

packages
  creating in PL/SQL, 588–589
  pinning all, 556–557
  query SQL source code behind, 565–567
paging
  modify size of SGA to avoid, 204
  monitor with sar and vmstat, 948–953
  viewing with vmstat, 964
PARALLEL clause
  ALTER TABLE command, 651
  CREATE/ALTER TABLE command, 662
  PARALLEL hint for tables created with, 331–332
parallel clustered databases, 626
parallel data loading, 662–663
parallel databases
  overview of, 626
  with RAC. See RAC (Real Application Clusters)
parallel execution hints, 311
Parallel Execution Option (PEO), 653
PARALLEL hint
  basic syntax, 331–332
  enable parallel operations for commands, 662
  NOAPPEND hint overriding, 334
  overrides DOP for table, 654
  parallelizing SQL statements, 650
parallel hints, 666
parallel index builds/rebuilds, 665–666
PARALLEL keyword, parallel data loading, 662
parallel operations
  basic concepts of, 645–646
  CREATE TABLE AS (CTAS), 665
  DML/DDL statements and, 647–648
  initialization parameters, 665
  inter- and intra-operation parallelization, 649–651
  monitor via V$ views, 653–655
  NO_PARALLEL hint disabling, 332
  objectives of, 664
  optimize in RAC, 664
  other notes, 666
  overview of, 645
  parallel execution/initialization parameters, 660–662
  PARALLEL hint, 331–332
  parallel index builds, 665–666
  parallel server resources/parallel statement queuing, 648
  PARALLEL_INDEX hint, 333
  partitions and, 649
  performance considerations, 666
  RAC parallel usage models, 664
  review tips, 667–668
  set autotrace on/off command, 658–660
  table and index examples, 652–653
  use EXPLAIN PLAN and AUTOTRACE on, 655–658
  use parallel data loading, 662–663
  V$ views for, 665, 725
  version comparison chart, 38
parallel queries, X$ table groups for, 797
parallel server resources, configure, 648
parallel servers, V$ views for, 725
parallel statement queuing, 648
parallel usage models, RAC, 664
PARALLEL_ADAPTIVE_MULTI_USER parameter, 648, 661
PARALLEL_DEGREE_LIMIT parameter, 660
PARALLEL_DEGREE_POLICY parameter, 28, 391, 648
PARALLEL_EXECUTION_MESSAGE_SIZE parameter, 661
PARALLEL_FORCE_LOCAL parameter, 661
PARALLEL_INDEX hint, 333
PARALLEL_MAX_SERVERS parameter, 647, 661, 665
PARALLEL_MIN_PERCENT parameter, 661
PARALLEL_MIN_SERVERS parameter, 661, 665
PARALLEL_MIN_TIME_THRESHOLD parameter, 391
PARALLEL_SERVERS_TARGET parameter, 648
PARALLEL_TARGET_PERCENTAGE directive, 648
PARALLEL_THREADS_PER_CPU parameter, 662
parameters, V$ views for, 725
parent-child relationship, reference partitioning, 144–145
PARENT_ID, PLAN_TABLE, 281, 303
parse activity, 750
parse count, AWR Report/Statspack, 860
parsing errors, in trace files, 784
partial indexes, 5–6, 143–144
PARTITION clause, 146
partition granules, parallelism and, 649
partition-wise joins, 145
partitioned indexes
example of, 149
global, 76–78
local, 75–76, 143
new features in 12cR2, 78
overview of, 74–75
partitions
avoid disk contention via, 137–139
change nonpartitioned tables to Golden Gate, 32
change nonpartitioned tables to partitioned, 23
composite, 141–142
disk scrubbing, 23
exporting, 150
getting more information about, 139–140
global index maintenance in 12c, 23, 146
hash, 141
list, 142–143
move online (12cR1), 23
multicolumn range, 140–141
new 12cR2 features for, 34
new 12cR2 features for big data, 33
other options, 146–148
parallelism and, 647, 649
partial indexes, 143–146
partial tables (12cR1), 5–6
reference partitioning, 144–145
viewed by EXPLAIN PLAN, 276–278, 302
passwords
   new 12cR2 Data Guard features, 31
   SEC_CASE_SENSITIVE_LOGON for, 166
Statspack installation, 818–819
past image (PI), RAC, 631
pattern interpretation
   in advanced tuning, 493–494
   indexing, 495–496
   jackknifing, 497
   linear and quadratic interpretations, 494–495
   multiple-table join statements, 496
   optimizer execution plan, 496
   riding quadratic curve, 497–498
   volatility effects, 498
PCle card Smart Flash Cache, Exadata, 614, 617
PCTFREE settings, avoid chaining via, 151–152
PDBs (pluggable databases)
   12cR1 support for, 28
   aggregate data across multiple, 339
   alter system while in, 92
   availability options (12cR2), 31
   CDB or PDB created objects, 86–87
   check history, 91
   cloning, 88
   detailed memory allocated for, 689–690
   Disk Performance Index for, 928–930
   identify services you have, 91
   information in EM Console in Cloud, 606
   MEMORY LIMIT and MEMORY_MINIMUM, 16–17, 170
   methods of creating, 87
   modify initialization parameters, 92, 179–180, 691
   move between containers (CDB/PDB), 88–89
   new features (12cR1), 9–11
   new features (12cR2), 93–94
   new features in Statspack/AWR report (12cR2), 817
   open and close, 89
   overview of, 84–85
   review tips, 159
RMAN commands for, 93
RMAN features (12cR2), 32
RMAN improvements (12cR1), 24
Root CDB_views of, 678
sharing in Oracle Cloud, 598
start up from CDB, 89, 90
subset cloning (12cR1), 29
subset standby feature, 94
track to datafiles, 90–91
unplug and drop, 88
use In-Memory with, 93, 172
V$ views for, 722
working with, 85–86

PEO (Parallel Execution Option), 653
performance feedback, automatic reoptimization, 391–392
PERFSTAT account, 818–819

PFILE
create from SPFILE, 177
setting initialization parameters, 753–755

PGA
managed by MEMORY_TARGET, 168–170
Memory Performance Index for, 918–919

PGA_AGGREGATE_LIMIT parameter
calculate PGA memory sort ratio, 918–919
how to use, 208
new in 12c, 19
set maximum for, 168–169
tuning, 204

USE_HASH hint requiring, 328–329

PGA_AGGREGATE_TARGET parameter
calculate PGA memory sort ratio, 918–919
how to use, 208
set for HASH joins, 430
set for SORT-MERGE joins, 434–435
set minimum for, 168–169
tuning, 203–204

PGA_AGGREGATE_TARGET section, AWR Report/Statspack, 868–869
physical reads, Instance Activity Statistics in AWR Report/Statspack, 859
PI (past image), RAC, 631
pinhit ratio, library cache, 197, 887
pinning. See caching/pinning
PIPE ROW statement, PL/SQL, 576–577
PIPELINED keyword, 576–580
pipelined table functions, 575–580
PL/SQL
  active transaction management, 573
  ADO functions, 102
  binding PL/SQL-only data types, 522–523
  compile-time warnings, 528–530
  data types in comparison operations, 548–550
  determine memory, 694–695
  example of code, 587
  find disabled triggers, 561–562
  find invalid objects, 559–561
  find/tune SQL when objects are used, 565–567
  Function Result Cache, 505–515
  get contiguous space in shared pool, 559
  identify objects for pinning, 557
  identity columns, 519–521
  leave debugging commands alone, 580–586
  limit use of dynamic SQL, 573–574
  log timing information in table, 541–543
  “look and feel” for beginners, 586–589
  Max Size increase for VARCHAR2, NVARCHAR2, and RAW data types, 521–522
  monitor via DBMS_APPLICATION_INFO, 539–541
  named parameters in SQL function calls, 523–525
  native compilation, 530–533
  new 12cR2 features, 29–30
  object location, 571–572
  optimizing compiler, 533–539
  order IF conditions, 550–551
  overview of, 504–505
  pin objects for shared pool use, 555–557
  pipelined table functions, 575–580
  PLS_INTEGER data type, 551–552
  query DBA_OBJECT_SIZE for object details, 558–559
  reduce calls to SYSDATE, 552–553
  reduce unit iterations/iteration time, 544–546
  reduce use of MOD function, 553–554
  reference sequences directly in expressions, 517–519
  reference table lookups with associative arrays, 562–565
  review tips, 589–591
rollback segments to open large cursors, 572–573
ROWID for iterative processing, 546–548
simplify loops with CONTINUE, 525–528
subprograms, 515–517
temporary database tables, 573
time component and DATE data types, 568–570
trace with DBMS_TRACE, 772–773
tune with PL/SQL, 570–571
use/modify DBMS_SHARED_POOL.SIZES, 557–558
XS table groups for, 798
PL/SQL Function Result Cache, 589–591
PL/SQL Tips and Techniques (McGraw-Hill, 1999), 586
plan capture, SPM, 286, 288
plan evolution, SPM, 286, 290
plan generator, SQL, 383
plan selection, SPM, 286
plan status, SPM, 286, 288–291
planning stage, issues to consider in, 158
PLAN_STAT parameter, 266
PLAN_TABLE
EXPLAIN example for simple query, 273–274
important columns in, 280–282
for parallelized query, 656–658
reading EXPLAIN PLAN based on query for, 274–275
set autotrace on/off command, 659–660
three-table joins, 450–452
using DBMS_XPLAN, 282–283
using EXPLAIN PLAN without TRACE, 271–273
using SPM, 289–291
viewing partitions in EXPLAIN PLAN in, 278
platform-specific, XS tables as, 733
PLS_INTEGER PL/SQL data type, 551–552
PLSQL compiler, 528–530, 533–539
PLSQL_CODE_TYPE parameter, 532
PLSQL_OPTIMIZE_LEVEL parameter, 533–539
PLSQL_WARNINGS parameter, 528–530, 535
PLUSTRACE role, AUTOTRACE, 275
policies, ADO data, 27–28, 102
POWER option, ASM disk scrubbing, 120
PRAGMA UDF, 516–517
predict command, srvctl, 117–118
preferences, OEM, 224, 226
prefixed global indexes, 78, 149
prefixed local indexes, 75–76
preserved snapshot sets, OEM, 828
PRIORITY keyword, In-Memory database, 26–27, 174
privileges
  ASM and, 132–136
  PERFSTAT account, 819
  V$ scripts that check for, 715–717
  V$ views for, 725
  X$ table groups for security, 797
procedures, PL/SQL, 570–571, 587–588
processes
  use vmstat to view blocked, 963–964
  X$ table groups for, 786, 791
PROCESS_TIMING_LOG table, 542–543
PROD_DB group, monitoring databases, 227–228
profiles, query for current, 712
profit margins, cloud companies, 597
programming mistakes, compile-time warnings, 528–530
prvtpool.plb script, 556
ps command, find memory-intensive jobs, 951, 957–959
public cloud option, 598
PUSH_PRED hint, 340
PUSH_SUBQ hint, 330–331

Q

QB_NAME hint, 329–330
quadratic curve, pattern interpretation of riding, 497–498
quadratic equation determination, 488–495
quarter rack, Exadata, 610, 612
queries
  Adaptive Query Optimization. See Adaptive Query Optimization
  Continuous Adaptive Query Plans, 19
  DBMS_UTILITY.EXPAND_SQL_TEXT, 20
  monitor V$SQLAREA view to locate bad, 186–189
  new 12cR2 features for big data, 33
  Resource Manager for runaway, 22
  steps for SQL TRACE with simple, 257
  tuning distributed, 462–463
use hints sparingly to tune, 308–309
use indexes to improve performance, 45–46
query blocks, specifying hints, 313, 329–330
Query High, HCC, 619–620
Query Low, HCC, 619–620
query transformation hints, 310–311
query transformer, SQL default execution plan, 383
query tuning
    Automatic SQL Tuning Adviser, 397–407
    cache table in memory, 369–371
    check if column is properly indexed, 361–362
    checking index on table, 360–361
    choose among multiple indexes, 372–373
    create bad index, 362–364
    create index, 360
    create invisible index, 360
    drop index with caution, 364–365
    EXISTS function/nested subquery for, 380–381
    fast full scan, 367–368
    find current resource-intensive sessions, 354–355
    find worst queries, 351–354
    function-based indexes, 377–378
    index columns in SELECT and WHERE, 365–367
    index merge, 373–375
    indexes that can get suppressed, 375–377
    make query run faster, 368–369
    overview of, 350–351
    Result Cache, 371
    review tips, 412–413
    select query EXPLAIN PLAN from DBA_HIST_SQL_PLAN view, 358–359
    select query text from DBA_HIST_SQLTEXT view, 357
    SQL and Grand Unified Theory, 381
    SQL Performance Analyzer for, 407–412
    table is actually a view, 381
    use OR clause, 379–380
    view available AWR snapshots, 355–356
    virtual columns, 378–379
    when index is forgotten, 359–360
    when to use indexes, 356–357
query tuning, changes in Oracle 12c
    Adaptive Query Optimization, 383–389
Adaptive Query Optimization statistics, 389–394
overview of, 382–383
SQL Plan Management, 395–397
statistics gathering, 394–396
QUERY_REWRITE_ENABLED, function-based indexes, 74
queuing, lock mechanism for, 846

R

RAC (Real Application Clusters)
arbarchitecture, 627–629
changing parameters in, 179
cluster interconnect tuning, 641–645
defining In-Memory column store for, 172–173
find wait events, 633–634
interconnect performance, 633
internal workings of, 629–632
One Node, 626
optimizing parallel operations in, 664
Oracle Parallel Server rebuilt as, 626
overview of, 595–598, 626–627
parallel usage models, 664
performance tuning overview, 632–633
tips for review, 667–668
unbreakability and, 631–632
V$ views for, 723
wait events and interconnect statistics, 635–641, 852–853
X$ table groups for, 793
RAC Statistics section, AWR Report, 853–854
RAID (Redundant Array of Independent/Inexpensive Disks)
ASM. See ASM (Automatic Storage Management)
disk-stripping software support for, 944
improved performance/availability, 94
number of disks needed, 95
overview of, 94
setup/maintenance of traditional filesystem, 98–99
tuning disk-bound systems, 946–947
types of, 95–97
range partitioning, 140–142
range scan, indexes, 54, 60, 333
Rapid Home Provisioning (RHP), 29
RAT masking (RM) slave background process, 35
ratings
  system information list, 934–938
  system reviews, 931–933
RAW data types, max size increase to 32k, 521
read-only, X$ tables as, 733
read or read-only, RAID 5, 96–97
reading
  EXPLAIN PLAN, 274–279
  trace files, 778–784
reads, Cache Fusion, 640–641
Real Application Clusters. See RAC (Real Application Clusters)
Real Application Testing. See Database Replay
Real-Time ADDM, OEM, 233–237
rebalance enhancements, ASM, 121–123
REBUILD ONLINE option, ALTER INDEX statement, 79–80
REBUILD option, ALTER INDEX statement, 79
REBUILD UNUSABLE LOCAL INDEXES, partition maintenance, 148
record number of block (UREC), data section of block dump, 480
record types, bind PL/SQL-only data types to, 522–523
recovery
  instant recovery repopulation daemon, 35
  RMAN table-level (12cR1), 24
  system information list for details on, 936
  V$ views for, 722
  X$ table groups for, 789
RECOVERY_PARALLELISM parameter, 662
recursion, reduce PL/SQL, 544–546
recursive calls
  AWR Report/Statspack, 860
  trace file identifying, 782
REDEFINITION.ROLLBACK (12cR2), 32
redo allocation latch, contention, 880
redo apply (12cR2), 30–31
redo copy latch, 880
REDO data
  block tuning and, 473–474
  latch and mutex waits related to, 872
  temporary database tables generating, 574
redo log files
  determine if size is a problem, 154
determine size of, 155
as fine-grained, 98
increase size for speed, 152–153
instance parameters, 156
NOLOGGING removes I/O bottleneck in, 652
obtain information about, 753
other helpful commands, 155–156
review tips, 159–161
V$ views for, 725
X$ table groups for, 787
redo transport, 12cR2 Data Guard features, 31
Redundant Array of Independent/Inexpensive Disks. See RAID (Redundant Array of Independent/Inexpensive Disks)
Redundant Interconnect Usage, cluster interconnects, 642
reference partitioning, 144–145
reference table lookups, PL/SQL associative arrays for, 562–565
relational databases, tune external tables, 465–469
RELOCATE command, Flex ASM, 112–113
Remote Slave Monitor (RMSN), RAC, 629
RENAME PARTITION, 146
REPAIR option, ASM disk scrubbing, 120
replication
    new 12cR2 features for, 31
    V$ views for, 725
    X$ table groups for, 789
REPORT_AUTO_EVOLVE_TASK, SPM, 396
REPORT_EVOLVE_TASK function, SPM, 397
REPORTING ONLY parameter, DBMS_XPLAN, 387
Resource Manager
    cost-based optimizer statistics in, 21
    runaway queries and, 22
    tune consumer groups, 246–247
    V$ views for, 725
resource modes, RAC, 630–631
resource roles, RAC, 630–631
resources
    cluster interconnect tuning, 644–645
    X$ table groups for, 797
    X$ table groups for managing, 792
response time
    affect on performance, 967
and wait events in trace file, 781–782
RESTORE TABLE, RMAN, 24
restricted parallel usage model, RAC, 664
Result Cache
  applying to invoker, 20
  Memory, 698–700
  PL/SQL Function, 505–515
  query tuning via, 371
  set SHARED_POOL_SIZE for, 191
  use effectively, Memory Performance Index, 920–921
result sets, pipelined table functions for, 575–580
RESULT_CACHE hint, 335–336, 371, 698
RESULT_CACHE keyword, 507
RESULT_CACHE_MAX_SIZE parameter, 698, 921
RESULT_CACHE_MODE parameter, 698, 921
Results screens, Real-Time ADDM, 233–234
RETURN statement, pipelined table function, 577
reverse key indexes, 73, 484–485, 844
REWRITE_OR_ERROR hint, materialized views, 341
RHP (Rapid Home Provisioning), 29
RM (RAT masking) slave background process, 35
RMAN
  commands for given PDB, 92
  improvements in 12c, 3, 24
  recovery server improvements, 32
  X$ table groups for, 790
RMSN (Remote Slave Monitor), RAC, 629
roles
  ASM, 132–136
  V$ scripts that check for, 715–717
  X$ table groups for security, 797
rollback segments
  for large quantities of data, 573–574
  open large cursors with, 572–573
  V$ views for, 725
  X$ table groups for, 788
root block, BLEVEL index depth and, 62
Root CDB_views, 678, 689–690
row cache
  objects latch contention, 880
  X$ table groups for, 795
ROWID
    access single row in tables, 45
    avoid hard-coding into specific code, 54
    B-tree indexes, 68
    binary height of index and I/O required for, 60–62
    bitmap join indexes compressing, 78–79
    for HCC-organized table, 619
    INDEX_JOIN hint faster than scanning with, 320
    for iterative processing, 546–548
    range scans access data via, 54
    read data from table by accessing, 151
    rows
        access data from table, 45
        avoid chaining using PCTFREE, 151–152
        fetch first x (12cR1), 8–9
    RPOP (instant recovery repopulation daemon), 35
    RSMN (Remote Slave Monitor), RAC, 629
    RULE hint, 341–342, 381
    RULE OPTIMIZER_MODE (deprecated in 12c), 204–205, 381
    Run AWR Report, 240–241
    Run Compare Periods Reports, AWR, 829
    Run Compare Reports, AWR, 240–241
    run queue, check with sar -q, 948
    runtime exceptions, 530

S

SAA (SQL Access Advisor), OEM Performance menu, 237
SAME (stripe-and-mirror-everything) methodology, ASM, 97, 105–106
SAnn (SG Allocator) background process, 35
sar command
    good idle percentage for CPU, 952
    monitor CPU usage, 943–947
    monitor paging and swapping, 948–951
    run at scheduled intervals throughout day, 952
scalability, 597–598, 610
scheduler, CPU, 952
SCNs (System Change Numbers)
    data section of block dump, 480
flag section of block dump, 477
ITL section of block dump, 476
perform Database Replay, 417, 420
RAC, 631
Snapshot Too Old error and, 469
in UNDO (ROLLBACK), 474
scripts
new in 12.2 Statspack/AWR report, 817–818
new in 12cR2, 898–900
SCSI inquiry command, multipaths, 136–137
SEC_CASE_SENSITIVE_LOGON parameter, 166, 208, 819
SEC_MAX_FAILED_LOGIN_ATTEMPTS parameter, 166, 208
secondary indexes, index-organized tables, 73
SECTION SIZE, RMAN improvements, 24
security
Exadata options, 622
external tables not subject to Oracle, 469
new 12cR2 features for, 34
PERFSTAT account, 818–819
system information list, 937
V$ views for, 725
version comparison chart, 40
X$ table groups for, 797
Security Technical Implementation Guide (STIG) Profile, 712
segment header, buffer busy waits on, 844
Segment Statistics, AWR Report/Statspack, 864–866
segments, X$ table groups for sort/temp, 787
SELECT statement
benefits of indexes for, 45
create PL/SQL subprogram inline, 515–517
discerning table from view, 381
index columns used in, 365–367
parallelized via PARALLEL hint, 331
SELECT_CATALOG_ROLE privilege, access to X$ tables, 736
selection directives, conditional compilation, 581, 585–586
selectivity, determine benefits of index, 59
sequences
default for columns based on (12cR1), 20
reference directly in PL/SQL expressions, 517–519
SERIAL#
invoke session trace, 768–770
trace in DBMS_MONITOR, 266–267
“serialized I/O” condition, RAID 5 and, 96
Server Control Utility (SVRCTL), RAC, 626
servers
execute PL/SQL objects on, 571–572
monitor application, 250–252
understand/model typical, 211–213
service name, trace in DBMS_MONITOR, 266, 268–269
services, V$ views for, 726
session ID (SID), and tracing, 266–267, 769
session parameters, OPT_PARAM hint for, 340
session waits, viewing RAC, 636–639
sessions
read traced, 778–884
tracing. See trace, generate
V$ views for, 726
X$ table groups for, 791
SET AUTOTRACE ON/OFF command, 658–660
SET SERVEROUTPUT ON command, 544–546
SET STATEMENT_ID, 272, 302
SET_SQL_TRACE_IN_SESSION, DBMS_SYSTEM, 768–769
seven-step methodology, traditional mathematical analysis, 486–487
SG Allocator (SAnn) background process, 35
SGA Memory Summary section, AWR Report/Statspack, 870, 888–889
SGA (System Global Area)

determine shared memory, 962–963
increase to accommodate INMEMORY_SIZE, 171
In-Memory database, 25–27
memory initialization parameters, 167–170
modify size to avoid paging/swapping, 204
SGA Target Advisory section, AWR Report/Statspack, 869–871
SGA_MAX_SIZE parameter, 167, 190, 208
SGA_TARGET parameter
as crucial memory initialization parameter, 167–170
enables ASMM, 167
how to use, 208
increase to accommodate INMEMORY_SIZE, 171–172
In-Memory database and, 25, 27
with Result Cache, 920
set for HASH joins, 430
tune data cache hit ratio, 183–184
tuning, 688
upgrade to 12c, 166
sharding, new 12cR2 features for, 32
shared memory
determine using ipcs, 962–963
XS table groups for, 794–795
shared-nothing model, parallel database, 626
shared pool
bind variables with dynamic SQL for, 575
determine memory left in, 197–198
dictionary cache/Result Cache as part of, 191
find all large pieces of PL/SQL in, 558
improve use by pinning PL/SQL objects, 555–557
monitor space allocations in, 742–743
NO_RESULT_CACHE hint for not caching in, 336
query fragmentation/contention issues, 745–747
query large allocations causing contention, 745
query library cache memory use, 747–750
query low free memory, 747
query mutex/latch waits and/or sleeps, 751–752
query ORA-04031 errors, 743
RESULT_CACHE hint caching results in, 335–336
set SGA_MAX_SIZE, 190
SQL plan directives managed in, 394
use library cache parameters to diagnose, 195–197
use/modify DBMS_SHARED_POOL.SIZES, 557–558
use stored procedures for shared SQL area, 193
use X$KSMSP table for detailed look at, 198–199
using SPM, 287
Shared Pool Advisory, AWR Report/Statspack, 869
shared pool latch, 877–879
Shared Pool Statistics, AWR Report/Statspack, 838
shared servers
query to monitor shared pool, 745
XS table groups for, 796
shared SQL area, stored procedures for, 191–193
SHARED_POOL_RESERVED_SIZE parameter, 744, 747, 749
SHARED_POOL_SIZE parameter
cache PL/SQL objects into memory, 555–556
defined, 555
determine memory left in shared pool, 197–198
how to use, 207–208
keep objects cached in data dictionary cache, 193–194
library cache reload/hit ratio settings and, 195–197
Library Cache statistics, 887
points to remember about cache size, 199
pools related to, 202–203
query library cache memory use, 749–750
query ORA-04031 errors, 744
set to fully use DB_CACHE_SIZE, 193
set to percentage of DB_CACHE_SIZE, 199
tune for optimal performance, 191
use Result Cache effectively, 920
shell script, tune external tables, 466–467
short tables, AWR Report/Statspack, 860
SHOW PARAMETER SPFILE command, 754
Show Tablespace Contents, OEM Administration menu, 243–244
SHRINK SPACE clause, ASSM, 152–153
SID (session ID), and tracing, 266–267, 769
sign in, Oracle Cloud, 601–602
Simple Mathematical Techniques, for tuning
  conclusions, 498–499
  example equations, 491–493
  overview of, 485
  seven-step methodology, 486–487
  simple linear equation determination, 487–488
  simple quadratic equation determination, 488–491
  traditional mathematical analysis, 486
SIMPLE_INTEGER PL/SQL data type, 551
size
  Oracle Applications Database, 213–218
  specify histogram, 64–65
*_SIZE parameters, PGA_AGGREGATE_TARGET, 203
skip-scans, 66–67, 340
SKIP_UNUSABLE_INDEXES, index partitions, 149
sleeping processes, 751–752, 872–876
SLOT (ROLLBACK segment’s transaction table), 480
_Small_TABLE_THRESHOLD parameter (undocumented), 861
Smart Flash Cache, 20
Smart Scans, Exadata, 207, 614
smartphone market, in cloud, 596
SMB (SQL Management Base), SPM, 286–287
SNAP procedure, gather statistics in Statspack, 820–823
SNAP_ID
  manually manage AWR, 826
  Statspack Report, 820, 822–824
Snapshot Too Old errors, 469, 574
snapshots, ADDM Report, 893–898
snapshots, AWR
  automated, 826
  manually manage AWR, 825–826
  run reports, 826–828
  run reports in OEM Cloud Control, 828–831
  screen, 239
snapshots, Statspack, 820–824
social media, benefits of cloud, 597
software, Exadata Storage Server, 613
solid-state disks (SSDs), 20, 21, 97
SORT JOIN, on parallel operations, 657–658
SORT-MERGE joins
  forcing, 444–445
  initialization parameters, 434–435
  overview of, 428–430
  two table joins: equal-sized tables, 436–439
  USE_MERGE hint causing, 327
sort/temp segments, X$ table groups for, 787
sorts, AWR Report/Statspack, 860
sorts (disk)
  AWR Report/Statspack, 857–859, 860
  V$ views for (check this), 726
SPA (SQL Performance Analyzer)
  cancel analysis task, 425
  create analysis task, 424
  create SQL Tuning Set, 423–424
  determine active SQL Tuning Sets, 426
  drop SQL Tuning Set, 427
  execute analysis task, 424–425
  overview of, 423
  query Advisor tasks, 425
  remove analysis task, 426
  remove SQL Tuning Set, 426–427
  screen, OEM Performance menu, 230–233, 237
spaces, separate multiple hints with, 313
SPARC SuperCluster M7 chip, 624–625
spcreate.sql, 818
spdrop.sql script, 893
specifying hints
  multiple, 313
  overview of, 312–313
  when using alias, 314
speed
  Exadata speed, 609–610
  increase log file size for, 152–153
SPFILE (server parameter file)
  Initialization Parameters screen, SPFile tab, 245–246
  setting initialization parameters, 753–757
  store dynamic changes in, 176–178
spfile.ora, 690–691
SPI (System Performance Index), 909–912
  _SPIN_COUNT parameter, latches, 873
Split Mirror, ASM (12cR2), 34
SPLIT PARTITION, 147–148
SPM (SQL Plan Management)
  adaptive plans and, 294–301
  convert STORED OUTLINES to, 292–294
  drop plan with SQL_HANDLE, 292
  example, 288–291
  fixed SQL Plan Baselines, 291–292
  Oracle 12c changes in, 395–397
  overview of, 285
  review tips, 301–302
  STORED OUTLINES replaced by, 284–285
  terms, 286–287
  using, 287–288
  using fixed SQL Plan Baselines, 291–292
sppurge script, purge old Statspack data, 892
spreadsheet analysis, MODEL_MIN_ANALYSIS hint, 340
sprecon.sql script, 872
spreport.sql script, 823–824, 852–853
sprepsql.sql script, 824
sptrunc.sql SQL*Plus script, 892
SQL
  limit use of dynamic, 574–575
  new 12cR2 features, 29–30, 33
SQL Access Advisor, 237
SQL Tuning Advisor, 234–237
use EXPLAIN PLAN alone. See EXPLAIN PLAN
use named parameters in function calls, 523–525
SQL Access Advisor (SAA), OEM Performance menu, 237
SQL hint, 650, 664
SQL Management Base (SMB), SPM, 286–287
SQL Performance Analyzer. See SPA (SQL Performance Analyzer)
SQL Plan Baselines, SPM, 286–287, 303, 343
SQL plan directives, adaptive statistics, 392–394
SQL plan history, SPM, 286–287
SQL statement section, TKPROF, 262
SQL statements
  bind PL/SQL-only data types to, 522–523
default execution plan, 383
define PL/SQL subprograms in, 515–517
determine memory for, 694–695
DOP for each parallelized, 666
find problem queries, 703–704
fix design first before using hints, 308–309
gathering statistics in Statspack, 821–823
logging timing statistics for, 541–543
manage parallel statement queuing, 648
native compilation performance increase and, 531–533
parallel operations in, 650–653
Top SQL section, AWR Report/Statspack, 853
tuning with SQL Tuning Advisor, 896
V$ views for, 723
SQL TABLE collection expression, pipelined table functions, 580
SQL TRACE
  find high disk/memory reads without, 278–279
  within Fusion Middleware products, 280
invoke trace via, 768
overview of, 256–257
problem queries in developer products, 279–280
setup and run, 257–261
TKPROF output, 263–265
TRACE output, 261–262
when to use EXPLAIN vs., 272
SQL Tuning Advisor, 234–237, 896
SQL Tuning Set, SPA, 423–427
SQL_HANDLE, drop SPM plan with, 292
SQL*Loader
  parallel data loading, 662
  V$ views for, 724
SQL*PLUS. See EXPLAIN PLAN
SQL*Plus Query, Flash Cache, 616
SQN (sequence number) column, block dump, 480
srvctl (Server Control Utility) commands, 115–119
SSD (flash), disk I/O, 157
SSDs (solid-state disks), 20, 21, 97
ST enqueue waits, 846
standard parallel usage model, RAC, 664
standby databases
  V$ views for, 726
  X$ table groups for, 790
startup, PDBs, 11, 89
STAT dumps, 770
STATEMENT_QUEUEING hint, 648
statements
  grouping, 315
  top memory-abuser, 912–914
statistics
  12c changes in gathering, 394–396
  AWR Report RAC, 635–636
cost-based optimizer, 21
create/analyze indexes in single step, 55
Exadata, 610–612
get detailed user information, 706
IMU, 473
Optimizer Statistics, 21
RAC wait events and interconnect, 635–641
Statspack. See Statspack Report
V$ views for, 726
statistics collector, SQL default execution plan, 383
statistics feedback, automatic reoptimization, 391–392
statistics section, TKPROF statement, 262–263
STATISTICS_LEVEL parameter, 209, 826
STATS$ tables, 821
Statspack Report
  choosing to run AWR and, 824–825
deinstalling, 893
gathering statistics, 820–822
installing, 818
managing data, 892
overview of, 816–817
post-installation, 819–820
query wait events, 718
RAC wait events, 633–635, 639
running statistics report, 822–824
security of PERFSTAT account, 818–819
tips for review, 900–902
upgrading old data to new version, 892–893

Statspack Report output
  additional Memory Statistics, 865–871
  Dictionary and Library Cache Statistics, 886–887
  header information and Cache Sizes, 832–833
  Instance Activity Statistics, 856–861
  Instance Efficiency, 835–837
  Latch and Mutex Statistics, 872–882, 883–886
  Load Profile, 833–834
  Nondefault Initialization Parameters, 889–890
  Oracle bugs, 852
  RAC Statistics, 852–854
  Segment Statistics, 864–865
  SGA Memory Statistics, 888–889
  Shared Pool Statistics, 838
  SQL Statistics, 853–856
  Tablespace and File I/O Statistics, 861–864
  top 15 things to look for, 890–892
  Top Wait Events, 838–851
  UNDO Statistics, 865–871

STATS$STATSPACK_PARAMETER, 821

STIG (Security Technical Implementation Guide) Profile, 712

storage
  Exadata, 36, 609, 611–612
  expanding Exadata. See Exadata Storage Expansion Rack
  manage with ASM. See ASM (Automatic Storage Management)
  manage with OMF, 103–104
  In-Memory indexes for, 175–176
  multiple control files, 157
  tablespaces in OEM, 242–244
  STORAGE clause, Flash Cache, 614
Storage Expansion Rack. See Exadata Storage Expansion rack
storage indexes, Exadata, 617–618
storage servers, Exadata, 611
StorageTek modular library system, 625–626
STORED OUTLINES, 284–285, 292–294, 343
stored procedures, shared SQL area, 191–193
streams, V$ views for, 726
stripe-and-mirror-everything (SAME) methodology, ASM, 97, 105–106
striped disks, RAID, 95–96
striping, in ASM, 97
subqueries
  APPEND hint for, 334
  change multitable joins with EXISTS into, 471–472
  PUSH_SUBQ hint for, 329–330
subroutine inlining, optimize compiler, 534–535, 538–539
subroutines, SQL function calls, 523–525
Sun ZFS Storage servers, 625
SuperCluster, M7 SPARC chip, 609, 624–625
suppressed indexes
  avoid when matching dates, 569–570
  db file scattered read wait events from, 841–842
  with function-based indexes, 377–378
  with IS NULL or IS NOT NULL, 55–56
  monitor V$SQLAREA to locate bad queries, 187
  with NOT EQUAL operators, 55
  overview of, 54–55
  query tuning and, 375–377
  when comparing mismatched data types, 59
SVRCTL (Server Control Utility), RAC, 626
SWAP_JOIN_INPUTS hint (undocumented), 329, 341
swapping
  modify size of SGA to avoid, 204
  queue lengths with sar -q, 948
  report activities with sar, 949–950
  view with vmstat, 964
synchronization, GES and GCS in RAC, 630
synonyms, V$ views accessed via, 732–733, 736
SYS user
  cluster interconnect tuning, 643
  create DBMS_SHARED_POOL as, 555–556
  get contiguous space in shared pool, 558
grant access to X$ tables, 734–735
monitor via DBMS_APPLICATION_INFO, 541
as only user of X$ tables, 733–734
pin all packages in shared pool as, 556
X$KSPPI table only accessed by, 283
SYSASM privileges, ASM, 132–136
SYS_AUTO_SPM_EVOLVE_TASK, 295, 396
SYSBACKUP privilege, ASM, 136
SYSDATE, 552–553, 568–569
SYSDBA privilege, ASM, 132–136
SYSDG privilege, ASM, 136
SYS.IDNSEQ$ table, 521
SYSKM privilege, ASM, 136
SYSOPER privilege, ASM, 135–136
System Change Numbers. See SCNs (System Change Numbers)
System Global Area. See SGA (System Global Area)
system information list, 934–938
system load, monitor using vmstat, 963–964
system management, version comparison chart, 40
system monitoring. See Unix utilities, system monitoring
system partitions, 145–146
system review, example
  item requiring immediate action, 933–934
  other items requiring action, 934
  overview of, 930–931
  rating categories, 931–933
  system information list, 934–938
system review, quick
  DPI. See DPI (Disk Performance Index)
  Education Performance Index, 907–909
  example rating scale, 930–933
  items requiring immediate action, 933–934
  MPI. See MPI (Memory Performance Index)
  other items requiring action, 934
  other items to consider, 938–939
  overview of, 906
  review tips, 939
  system information list, 934–938
  System Performance Index, 909–912
  Total Performance Index, 906–907, 930
system statistics, enhanced in 12cR1, 21
system, V$ views for, 725
table fetches, AWR Report/Statspack, 860

Table joins

- bitmap join indexes using, 452–458
- common X$, 803–805
- db file sequential read wait event, poor orders of, 842
- DRIVING_SITE hint for, 325–326
- eliminate join records in multitable joins, 445–446
- fix design first before using hints, 308–309
- initialization parameters, 434–439
- partition-wise, 145
- three-table, 450–452
- tune external tables, 467–468
- two-table INDEXED join, 439–443
- two-table joins of large and small table, 447–450

Table joins, methods

- CLUSTER joins, 429–430
- force specific method, 443–445
- HASH joins, 430–431
- INDEX-MERGE joins, 432–434
- NESTED LOOPS joins, 428–429
- overview, 427–428
- review tips, 499–500
- SORT-MERGE joins, 428–430

TABLE operator, 522–523

Table scans, AWR Report/Statspack, 857–860

TABLE_COMPRESSION_CLAUSE, at import time, 18

Tables

- AWR table names, 824–825
- create with Identity Columns, 519–521
- create with parallel operations, 652–653
- discerning views from, 381
- do not use INDEX_DESC hint for multiple, 322
- LEADING hint for, 324–325
- log timing information in, 541–543
- management of, 925–926
- ORDERED hint for, 322–323
- separate from indexes to decrease file I/O, 925
- Statspack collection, 819–820
- use temporary database, 574
- V$ views for, 724

Tablespace I/O Statistics section, AWR Report/Statspack, 861–863
tablespace(s) create prior to Statspack installation, 818
new 12cR2 features for RMAN, 32
new 12cR2 online improvements, 32
OEM Administration menu, Storage, 242–244
Oracle bigfile, 103
X$ table groups for, 787
Task Manager, CPU/memory monitoring on Windows with, 959
temp segments, X$ table groups for, 787
temporary database tables, 574
temporary objects, X$ table groups for, 788
terminology
Exadata, 609–610
SQL Plan Management, 286–287
testing
as benefit of cloud, 597
data redaction for (12cR2), 32
thin clients, execute PL/SQL objects on, 571–572
THIN_PROVISIONED attribute, ASM, 121
third-party product tuning, 458–462
three-table joins, 445–446, 450–452
thresholds, Statspack statistics, 821–823
throughput, affect on performance, 967
tiering_clause policy, ADO, 102
time
DATA datatype, 568–570
reduce calls to SYSDATE, 552–553
time zones, X$ table groups for, 786
TIMED_STATISTICS parameter
SQL TRACE, 257–258, 301
Statspack, 820
TKPROF utility
AUTOTRACE statistics for, 276
command-line options for, 259–260
example, 260–261
force specific join method, 444–445
interpret contents of trace, 770
problems to look for in output, 263–265
read trace file with, 778
review, 301
translates TRACE file to readable format, 258
tuning distributed queries, 463
top 10 “disk-read abusers” as percentage of all statements, DPI, 923–924
Top 10 Foreground Events by Total Wait Time section, AWR Report, 838–839
top 10 memory-abusers as percent of all statements, MPI, 914
top 25 “disk-read abuser” statements, DPI, 922–923
top 25 memory-abuser statements, MPI, 912–913
Top Activity report, Enterprise Manager, 186
Top Activity screen, OEM Performance menu, 229–230
top command, find worst user with, 954
Top Consumers screen, services, 247, 254
Top-Frequency histogram, 12c, 394–395
Top SQL section, AWR Report/Statspack, 853–856
Top Waits Events section, Statspack, 838–840
Total Performance Index (TPI), 906–907, 930, 938–939
TPI (Total Performance Index), 906–907, 930, 938–939
TRACE. See also SQL TRACE
  initialization parameters for undocumented, 283–284
  solving errors, 283–284
  use EXPLAIN PLAN without, 271–273
Trace Analyzer, 770–772, 778
trace, generate
  with DBMS_MONITOR. See DBMS_MONITOR
  with DBMS_TRACE, 772–774
  in developer tools, 279–280
dumps, 774–775
invoke, 768–772
with ORADEBUG, 775–777
reading trace file, 778–784
with SQL_TRACE. See SQL TRACE
with trcsess utility, 777–778
ditional mathematical analysis, 486
Transaction END (XCTEND) calls, 783
transaction ID (XID), block dump, 476
transaction management, active, 573–574
transactions
  V$ views for, 726
  X$ table groups for, 792
TRANSACTIONS parameter, parallel operations, 662
trcsess utility, 269–270, 777–778
trendline equations, Excel, 493
trickle repopulation, IM column store, 172
triggers
events as similar to system, 773–774
example using PL/SQL, 589
find disabled PL/SQL, 561–562
query SQL source code behind, 567
TRUNCATE PARTITION, 147
tuning. See advanced tuning
TUNING mode, cost-based optimizer, 381
two-table INDEXED join, 439–443
two-table join, between large and small table, 447–450
TX4 enqueue waits, 846

U

UBA (Undo Block Address), block dump, 476
UBLK (block for last UNDO entry), block dump, 480
UDF (user-defined function) pragma, PL/SQL subprograms, 516–517
UNDO
  automatic, Disk Performance Index, 926–928
  buffer busy waits on, 844
  data section of block dumps, 480
  segment statistics for AWR Report, 871–872
  Snapshot Too Old error, 469
  for temporary tables, 574
  tuning and viewing at block level, 883–884
  tuning at block level, 473
  use rollback segments to open large cursors, 572
  V$ views for, 725
  X$ table groups for segments, 788
Undo Block Address (UBA), block dump, 476
UNDO/ROLLBACK segments
  distortion, 188
  tuning DB_CACHE_SIZE, 186
  upgrade to Oracle Database 12c, 165
Undo Segment Number (USN), data section of block dump, 480
undocumented features, Oracle bugs, 851
undocumented hints
  CARDINALITY, 331, 342
  overview of, 341–342
  SWAP_JOIN_INPUTS, 329, 341
undocumented initialization parameters
alter LRU algorithm, 202
 can cause corruption, 211
 Exadata, 207
 finding, 210–211
 over the years, 210–211
 remedy performance problems, 752–753
 TRACE, 283–284
 X$ tables, 752
 UNDO_RETENTION parameter, 574, 927–928
 UNION operator, distributed queries, 463
 UNION/UNION ALL, concurrent execution (12cR1), 20
 unique (distinct) keys, determine index selectivity, 59
 unique scans, indexes, 54
 Unix utilities, system monitoring
 determine shared memory, 962–963
 find worst user, 954
 guidelines for GUI monitoring tools, 955
 identify CPU bottlenecks, 956
 identify disk I/O bottlenecks, 959–962
 and Linux utilities, 942
 list top CPU users, 957–959
 modify configuration information file, 967
 monitor CPU load, 955–956
 monitor CPU/memory use on Windows, 959
 monitor CPU usage, 943–948
 monitor disk free space, 964–966
 monitor network performance, 966–967
 monitor paging/swapping, 948–953
 monitor system load, 963–964
 Oracle Cluster Health Monitor, 969
 Oracle ORION Calibration Tool, 969
 Oracle Support (Metalink) Note 224176.1, 969
 other factors affecting performance, 967–969
 review tips, 969–970
 unmap operation, 783
 unplug PDB, 88
 UNRECOVERABLE, insert data into table without index, 663
 UNUSABLE LOCAL INDEXES, partition maintenance, 148
 UPDATE statements
 block dump data section and, 480
 effects on index, 63
FIRST_ROWS hint ignored in, 315
increase log file size to speed up, 154–155
in index-organized tables, 73
indexes use WHERE clause with, 45–46
PARALLEL hint applied to, 331
rollback segments for large, 572
ROWID for iterative processing, 546–548

updates
  automatic cloud, 597
  locking behavior of HCC during, 620
UPDATE_TOTAL nested procedure, optimize compiler, 536–537
Upgrade option, SQL Performance Analyzer, 232

upgrades
  initialization parameters for 12c, 165–166
  issues in planning stage, 158
  new 12cR2 features for, 32
  of old Statspack to new version, 892–893
  test index after, 45

uptime command, monitor CPU load, 955–956
UREC (record number of block), data section of block dump, 480

usage directive hints, 308
USE_CUBE hint, 341
USE_HASH hint, 328–329, 443, 445
USE_INVISIBLE_INDEXES hint, 48–49, 338–339
USE_MERGE hint
  basic syntax, 326–327
  request specific join method, 443, 445
  results of forcing, 437
USE_NL hint
  basic syntax, 327–328
  defined, 341
  request specific join method, 443, 445
USE_NL_WITH_INDEX hint, 328, 341

user-defined function (UDF) pragma, PL/SQL subprograms, 516–517
USER_ADVISOR_TASKS, SPA, 425
USER_DEPENDENCIES, PL/SQL objects, 567
USER_DUMP_DEST view, trace information, 774, 775
USER_IND_COLUMNS view, 46
USER_INDEXES view
  check for current indexes, 361
  check visibility of invisible index, 49
determine index selectivity, 59
retrieve index data for your schema, 46–47

USER_OUTLINE_HINTS, 343
USER_PLSQL_OBJECT_SETTINGS dictionary table, 532

users
find objects being accessed by, 705
find problem, 703–704
find worst user, 954

USER_SEGMENTS view, partitions, 139–140
USER_SOURCE view, SQL source code, 565, 567
USER.Tables view, 139–140, 176, 686

USER_TRIGGERS view, 561–562, 567

USN (Undo Segment Number), data section of block dump, 480

utlchain.sql script, 925
utlchn1.sql script, 925
utllockt.sql, 476
utlrp.sql script, 560–561
utlxplan.sql script, 271–273, 276, 656
utlxplp.sql script, EXPLAIN PLAN, 271, 273, 658

V

V$ views

AMM and MEMORY_TARGET, 687–688
basic AWR, 682
basic database, 681
basic licensing, 683
create/grant access to, 673–676
created on X$ tables, 735–736
current profiles, 712
DBA_views, 678–680
detailed memory allocated, 689–690
disk I/O issue, 713–714
find PL/SQL objects for pinning, 700
find problem queries, 701–704
find problem users/resources used, 704–705
find users with multiple sessions, 711
find which process uses most CPU, 957–959
get detailed user information, 706
get listing of all, 736
GV$ views vs., 737
identify locking issues, 708–710
if data is in memory, 692–693
indexes, 706–708
installed database options, 683–684
kill problem session, 710–711
list of GV$ and, 676–677
list of X$ tables, 677–678
listing of all, 737
major categories of, 721–727
memory allocated, 684–685
memory for data dictionary, 693–694
memory for shared SQL and PL/SQL, 694–695
modify initialization parameter at PDB level, 691
overview of, 672–673
for PDB information, 696–698
privileges and roles, 715–717
Result Cache, 698–700
review tips, 728–729
set INMEMORY_SIZE, 685–686
spfile.ora/init.ora settings, 690–691
Statspack post-installation, 819–820
tips for review, 728–729
wait events, 718–721
which objects user is accessing, 705
X$ table and non-V$ fixed view associations, 801–803
X$ tables comprising, 737–738
V$ACTIVE_SESSION_HISTORY view, 720–721
VARCHAR2, 5, 29–30, 521
V$ASM_CLIENT view, 112–113
V$ASM_OPERATION view, 121
V$ASM_ATTRIBUTE view, 121
V$ASM_OPERATION view, 124
V$BUFFER_POOL_STATISTICS view, 916
V$CONTAINERS view, 696–697, 738
V$CR_BLOCK_SERVER view, 635
V$DATABASE view, 681
V$DATAFILE view, 100, 713–714
V$DB_CACHE_ADVICE view, 693, 916
V$DB_OBJECT_CACHE view, 557, 701, 748–749
version(s)
  Exadata, 610
number of $V$ views/$X$ tables for all, 673
$V$VERSION view of, 681
$X$ table groups for, 785
$V$EVENT_NAME view, 719
$V$FILESTAT view, 100, 666, 713–714
$V$FIXED_TABLE view, 677, 738–739
$V$FIXED_VIEW_DEFINITION view, 678, 737–738
$V$HEAT_MAP_SEGMENT view, 101
View Tablespace screen, OEM, 243
$V$SIM_SEGMENTS view, 685–686
$V$INDEXED_FIXED_COLUMN view, 740–741
$V$INDEX_USAGE_INFO view, 55
$V$INMEMORY_AREA view, 737–738
$V$IO_OUTLIER view, 103
virtual columns, create tables with, 378–379
$V$KERNEL_IO_OUTLIER view, 103
VLAN tagging, Exadata, 36
$V$LATCH view, 751–752, 873
VLDBs (very large databases), bigfiles for, 137
$V$LIBRARYCACHE view, 195–197, 694–695, 748
$V$LICENSE view, 683
$V$LOCK view, 708–710
$V$LOCK_ELEMENT view, 635
$V$LOG_HISTORY view, 154, 753
$V$MEMORY_TARGET_ADVICE view, 687
vmstat command, 948–949, 963–964
$V$MUTEX_SLEEP view, 751–752
$V$OBJECT_USAGE view, 705, 707–708
$V$OBSOLETE_PARAMETER view, 757
volatility effects, pattern interpretation, 498
Volume Manager factors, 969
$V$OPTION view, 683–684
$V$PARAMETER view
get current values for initialization parameters, 690–691
key fields in, 179
nondefault initialization parameters, 889–890
parallel operations, 666
setting initialization parameters, 754–756
shared pool settings, 202–203
$V$PDBS view, 697–698, 738
$V$PGA_TARGET_ADVICE view, 203
V$PGA_TARGET_ADVICE_HISTOGRAM view, 203
V$PQ_SESSTAT view, 655
V$PQ_SYSSTAT view, 653–654
V$PQ_TQSTAT view, 666
V$PX_PROCESS view, 666
V$PX_SESSION view, 666
V$PX_SESSTAT view, 666
V$RESULT_CACHE_MEMORY view, 512
V$RESULT_CACHE_OBJECTS view, 512–515
V$RESULT_CACHE_STATISTICS view, 512–513
V$ROWCACHE view, 194, 693–694
V$SEGMENT_STATISTICS view, 864–866
V$SESS_IO view, 703–704
V$SESSION view
  find problem users/what they are executing, 703–704
  find SID and SERIAL# for session trace, 769
  find users with multiple sessions, 711
  kill problem session, 710–711
  real-time monitoring with DBMS_APPLICATION_INFO, 540–541
  view who is waiting now, 718
V$SESSION_LONGOPS view, 701–702
V$SESSION_WAIT view, 718–719
V$SESSION_WAIT_CLASS view, 719
V$SESSION_WAIT_HISTORY view, 719
V$SESSMETRIC view, 354–355
V$SESSTAT view, 655, 666
V$SGA view, 684–685, 688
V$SGASTAT, 480
V$SGASTAT view, 689–690
V$SQL view
  Adaptive Query Optimization, 384
  find worst queries, 353–354
  Flash Cache, 616–617
  log timing statistics for SQL, 542
  Top SQL section, AWR Report/Statspack, 855
V$SQLAREA view
  find problem queries, 703–704
  find worst queries, 186–189, 351–353
  query library cache memory use, 749
  statistics when tracing query, 278–279
V$SQL_BIND_CAPTURE view, 695
V$SQL_HINT view, 309
V$SQL_MONITOR view, 542, 701
V$SQL_PLAN_MONITOR view, 701
V$SQL_SHARED_CURSOR view, 386–387
V$SQLTEXT view, 703–704, 760, 763
V$SYSAUX_OCCUPANTS view, 682
V$SYSMETRIC view, 692–693, 695, 915
V$SYSSTAT view, 692–693, 855–861, 915–916, 953
V$SYSTEM_PARAMETER view, 756
V$SYSTEM_WAIT_CLASS view, 720
V$TEMPFILE view, 100
V$TEMPSTAT view, 100
V$TRANSACTION view, 709
V$UNDOSTAT view, 572
V$VERSION view, 681, 684
V$WAITSTAT view, 842–844

W

Wait Classes by Total Wait Time section, AWR Report, 838–839
Wait Event Histogram, Statspack, 849
wait events
  causes of buffer cache, 763–766
  find with V$ scripts, 718–721
  latch free, 877
  Oracle shadow process/where it lives, 852
  RAC, 633–634, 635–641
  related to initialization parameters, 200
  and response time in trace file, 781–782
  set event to dump on every wait, 469–471
wait events, AWR Report/Statspack
  async disk I/O, 848
  buffer busy wait, 842–844
  cursor, 845
  db file parallel write, 847
  db file scattered read, 841–842
  db file sequential read, 842
  db path read, 847–848
  direct path writes, 848
  enqueue, 846
  global cache cr request, 847
idle, 848–850
latch free, 844–845
library cache (mutex x), 845–846
log buffer space, 846–847
log file parallel write, 847
log file switch, 846
log file sync, 847
mutex, 875–876
Oracle bugs, 851–852
overview of, 838–841
RAC interconnect statistics, 852–853
reactive tuning by, 838–851
Top Wait Events section, 838–841
WAIT option, ASM disk scrubbing, 120
waiters, GES, 639–640
wc (word count) command -1, external tables, 467
web applications, monitor performance, 250–252
WHEN clause, CONTINUE statement with, 525–528
WHERE clause
  bitmap join indexes using, 78–79
  concatenated indexes using, 53–54
  function-based indexes using, 378
  index columns using, 365–367
  index suppression and, 375–377
  indexes UPDATE/DELETE using, 45–46
  IS NULL or IS NOT NULL in, 55–56
  NOT EQUAL operators in, 55
  PUSH_PRED hint for, 340
  willing to wait latches, 873
WITH clause, PL/SQL subprograms, 515–517
WITH_PL/SQL hint, 339
word count (wc) command -1, external tables, 467
WORKAREA_SIZE_POLICY, PGA_AGGREGATE_TARGET, 203
workload, and Database Replay, 418–422
WR identifier, AWR table names, 824
write operations, RAID 5, 96–97
write-through cache, Flash Cache, 614
writes, Cache Fusion, 640–641
Advanced Queuing, 792
archive log files/destinations/processes, 786
backup, 789
buffer cache, 795
contexts, 798
control files, 787
database links, 788
datafiles, 786
global transactions, 792
heterogeneous services, 798
instance/database, 785
Java source, 799
latches, 796
library cache, 793–794
loader/direct path API, 798
locks/enqueues, 796
LogMiner, 790–791
materialized views, 788
miscellaneous tables, 799
National Language Support, 786
optimizer, 796
other, 800–801
parallel query, 797
PL/SQL, 798
Real Application Clusters, 793
recovery, 789
redo log files, 787
replication, 788
resource/consumer groups, 797
resource management, 791
RMAN, 790
rollback/undo segments, 788
rowcache, 795
security privileges, roles, and policies, 797
session performance, 791
sessions/processes, 791
shared memory, 794–795
shared servers, 796
sort/temp segments, 787
standby databases, 790
tablespaces, 787
temporary objects, 788
time zones, 786
transactions, 792
version/installation, 785

X$ tables

buffer cache/data block, 757–761
common joins, 803–805
with CON_ID and MEMORY, 812
create V$ views and, 735–737
database- and instance-specific information, 766–767
effective use/strategy for, 767
future version impact in 12cR2, 813
get listing of all in 12c, 678, 738–739
get listing of all X$ indexes in 12c, 740–741
grant access to, 734–735
GV$ views created from, 674
hot buffer blocks/latch contention/wait events, 761–766
initialization parameters, 753–757
introduction to, 732–734
misconceptions, 734
monitor shared pool, 742–753
monitor space allocations in shared pool, 741–742
mutex/latch waits and/or sleeps, 751–752
naming conventions, 805–812
non-V$ fixed view associations and, 801–803
overview of, 732
parse activity, 750
redo log files, 753
tips for review, 813–814
underlying V$ views in, 677, 737–738
undocumented initialization parameters, 210–211
use hints with X$ indexes and, 741–742

X6-2 Exadata Rack, 609
X6-8 Exadata Rack, 609
X$BH table, 473, 480–481, 757–764, 883
X$CON, new in 12c, 739
XCTEND (Transaction END) calls, 783
XID (transaction ID), block dump, 476
X$KCCCP table, 753
X$KCCDI table, 766–767
X$KCCLE table, 753
X$KQFDT table, 738–739
X$KQFTA table, 738–739
X$KQFVI table, 737–738
X$KSMLRU table, 742–743, 752
X$KSMSP table, 742–743, 878
X$KSMSP table, 198–199, 558
X$KSPPCV table, 756
X$KSPPCV2 table, 756
X$KSPPI table, 283, 756
X$KSPPSV table, 756
X$KSPPSV2 table, 756
X$KSPSPFILE table, 756
X$KTSIMAU table, 737–738, 739
XML metadata files, create PDB, 87

Z

ZFS Storage servers, 625
Join the Largest Tech Community in the World

- Download the latest software, tools, and developer templates
- Get exclusive access to hands-on trainings and workshops
- Grow your professional network through the Oracle ACE Program
- Publish your technical articles – and get paid to share your expertise

Join the Oracle Technology Network
Membership is free. Visit community.oracle.com

@OracleOTN  facebook.com/OracleTechnologyNetwork

ORACLE
Climb the Career Ladder

Think about it—97 percent of the Fortune 500 companies run Oracle solutions. Why wouldn't you choose Oracle certification to secure your future? With certification through Oracle, your resume gets noticed, your chances of landing your dream job improve, you become more marketable, and you earn more money. It's simple. Oracle certification helps you get hired and get paid for your skills.

93% Hiring managers who say IT certifications are beneficial and provide value to the company

7% Salary growth for Oracle Certified professionals

70% Believe that Oracle certification improved their earning power

90% Say that Oracle certification gives them credibility when looking for a new job

68% Think that certification has made them more in demand

6x Increased LinkedIn profile views for people with certifications, boosting their visibility and career opportunities

Take the next step
http://education.oracle.com/certification/press

Push a Button
Move Your Java Apps to the Oracle Cloud

Same Java Runtime
Same Dev Tools
Same Standards
Same Architecture

... or Back to Your Data Center

ORACLE

cloud.oracle.com/java
Reach More than 640,000 Oracle Customers with Oracle Publishing Group

Connect with the Audience that Matters Most to Your Business

**Oracle Magazine**
The Largest IT Publication in the World
Circulation: 325,000
Audience: IT Managers, CIOs, Programmers, and Developers

**Profit**
Business Insight for Enterprise-Class Business Leaders to Help Them Build a Better Business Using Oracle Technology
Circulation: 92,000
Audience: Top Executives and Line of Business Managers

**Java Magazine**
The Essential Source on Java Technology, the Java Programming Language, and Java-Based Applications
Circulation: 295,000 and Growing Steady
Audience: Corporate and Independent Java Developers, Programmers, and Architects

For more information or to sign up for a FREE subscription: Scan the QR code to visit Oracle Publishing online.
Beta Test
Oracle Software

Get a first look at our newest products—and help perfect them. You must meet the following criteria:

- Licensed Oracle customer or Oracle PartnerNetwork member
- Oracle software expert
- Early adopter of Oracle products

Please apply at: pdpm.oracle.com/BPO/userprofile