Lecture 1:

Oracle Database 12c Architecture Part 1

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http://www.ildba.co.il/author/cimid/
http://www.sqlserver.co.il/?cat=940

Global Hebrew Virtual PASS Chapter:
https://www.youtube.com/watch?v=x4hGjYGbfkc
https://www.youtube.com/watch?v=eJO8G9if3EY

SqlSaturday Israel 2016:
Agenda

- RDBMS
- Oracle Database 12c Objects
- Interacting with Oracle Database 12
- DBA Tasks
- Schema
- Physical Storage Structures
- Logical Storage Structures
- Database Architecture: Databases and Instances
- Memory Architecture
- Multitenant Architecture
- Oracle Database as a Service
- Extra Reading
- Review Questions
Reference and Credits

Oracle® Database

Part I Oracle Relational Data Structures
  1 Introduction to Oracle Database

Part IV Oracle Database Storage Structures
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Part V Oracle Instance Architecture
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  14 Memory Architecture
  15 Process Architecture
  16 Application and Networking Architecture

Part VI Multitenant Architecture

Oracle Open World 2016

https://www.oracle.com/openworld/index.html
RDBMS

- Relational database management system (RDBMS)
- Most Common
- Different RDBMS have different architecture
- Basic storage of data in RDBMS is a table. Relations are implemented in tables, where data is stored in rows and columns.
<table>
<thead>
<tr>
<th>Object Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table</td>
<td>Basic form of data storage. A table has columns and stores rows of data.</td>
</tr>
<tr>
<td>View</td>
<td>A stored query. No data-storage space is occupied for view data.</td>
</tr>
<tr>
<td>Index</td>
<td>An optional structure that is useful for fetching data faster.</td>
</tr>
<tr>
<td>Materialized view</td>
<td>Used to summarize and store data. They are similar to views but take up storage space to store data</td>
</tr>
<tr>
<td>Index-organized table</td>
<td>Stores the table data along with the index, instead of storing table and index separately</td>
</tr>
<tr>
<td>Cluster</td>
<td>A group of tables sharing a common column. The cluster stores the rows of the tables together with the common columns stored once.</td>
</tr>
<tr>
<td>Constraint</td>
<td>A stored rule to enforce data integrity.</td>
</tr>
<tr>
<td>Sequence</td>
<td>A sequence provides a mechanism for the continuous generation of numbers.</td>
</tr>
<tr>
<td>Synonym</td>
<td>Alias for a database schema object</td>
</tr>
</tbody>
</table>
# Oracle Database 12c Objects

<table>
<thead>
<tr>
<th>Object Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger</td>
<td>A PL/SQL program unit that is executed when an event occurs.</td>
</tr>
<tr>
<td>Stored function</td>
<td>A PL/SQL programs that can be used to create user-defined functions to return a value.</td>
</tr>
<tr>
<td>Stored procedure</td>
<td>A PL/SQL programs to define a business process.</td>
</tr>
<tr>
<td>Package</td>
<td>A collection of procedures, functions, and other program constructs.</td>
</tr>
<tr>
<td>Java</td>
<td>Stored Java procedures can be created in Oracle to define business processes.</td>
</tr>
<tr>
<td>Database link</td>
<td>Database links are used to communicate between databases to share data.</td>
</tr>
<tr>
<td>.Net Extension</td>
<td>Stored .Net procedures and functions can be created in Oracle on windows platforms only.</td>
</tr>
</tbody>
</table>

Use SQL to create database objects and to interact with application data
Interacting with Oracle Database 12c

• SQL is the language used to interact with Oracle Database 12c.

• common tools for DBA to administer Oracle Database 12c:
  – SQL*Plus command-line interface utility
  – A New Command Line Interface, SQLcl
  – SQL Developer: a GUI tool to manage DB & Develop
  – Oracle Enterprise Manager Database Express 12c, a GUI tool for database administration
  – Oracle Enterprise Manager Cloud Control 12c
SQL*Plus

- SQL*Plus is the primary tool for an Oracle DBA to administer the database using SQL commands.

- Before you can run SQL statements, you must connect to Oracle Database 12c.

- Start SQL*Plus using $ORACLE_HOME/bin/sqlplus executable on Unix/Linux/windows platform.
Oracle SQL Developer

SQL Developer 4.1.5

Oracle SQL Developer is a free integrated development environment that simplifies the development and management of Oracle Database in both traditional and Cloud deployments. SQL Developer offers complete end-to-end development of your PL/SQL applications, a worksheet for running queries and scripts, a DBA console for managing the database, a reports interface, a complete data modeling solution, and a migration platform for moving your 3rd party databases to Oracle.

We are very pleased at the massive adoption of Oracle SQL Developer. SQL Developer has been embraced by the developer community as de-facto standard database IDE for designing, developing, and DBA activities. Don't let the dot 1 version fool you, this release is loaded full of good stuff.” - Michael J. Hitcha, Vice President of Oracle Database Tools
SQLcl: A Modern Command Line Interface to the Oracle DB

- Free command line interface for Oracle DB
- 16 MB Download
- Extract & Run, no clients required!
- Key features:
  - In-Line Editor
  - Command History
  - Completion Insight
  - New Commands
  - Client Side Scripting
  - SQL*Plus Support

```
SQL> set sqlformat ansicone
SQL> select * from hr.departments;

<table>
<thead>
<tr>
<th>DEPARTMENT_ID</th>
<th>DEPARTMENT_NAME</th>
<th>MANAGER_ID</th>
<th>LOCATION_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Administration</td>
<td>200</td>
<td>1,700</td>
</tr>
<tr>
<td>20</td>
<td>Marketing</td>
<td>201</td>
<td>1,800</td>
</tr>
<tr>
<td>30</td>
<td>Purchasing</td>
<td>114</td>
<td>1,700</td>
</tr>
<tr>
<td>40</td>
<td>Human Resources</td>
<td>281</td>
<td>2,400</td>
</tr>
<tr>
<td>50</td>
<td>Shipping</td>
<td>121</td>
<td>1,500</td>
</tr>
<tr>
<td>60</td>
<td>IT</td>
<td>103</td>
<td>1,400</td>
</tr>
<tr>
<td>70</td>
<td>Public Relations</td>
<td>204</td>
<td>2,700</td>
</tr>
<tr>
<td>80</td>
<td>Sales</td>
<td>145</td>
<td>2,500</td>
</tr>
<tr>
<td>90</td>
<td>Executive</td>
<td>100</td>
<td>1,700</td>
</tr>
<tr>
<td>100</td>
<td>Finance</td>
<td>100</td>
<td>1,700</td>
</tr>
<tr>
<td>110</td>
<td>Accounting</td>
<td>205</td>
<td>1,700</td>
</tr>
<tr>
<td>120</td>
<td>Treasury</td>
<td>1,700</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>Corporate Tax</td>
<td>1,700</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>Control And Credit</td>
<td>1,700</td>
<td></td>
</tr>
</tbody>
</table>

SQL> select first_name, last_name, salary, department_id from hr.employees fetch first 5 rows only;

<table>
<thead>
<tr>
<th>FIRST_NAME</th>
<th>LAST_NAME</th>
<th>SALARY</th>
<th>DEPARTMENT_ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donald</td>
<td>O'Connell</td>
<td>2,600</td>
<td>58</td>
</tr>
<tr>
<td>Douglas</td>
<td>Grant</td>
<td>2,600</td>
<td>58</td>
</tr>
<tr>
<td>Jennifer</td>
<td>Ulion</td>
<td>4,400</td>
<td>10</td>
</tr>
<tr>
<td>Michael</td>
<td>Hartstein</td>
<td>13,000</td>
<td>20</td>
</tr>
<tr>
<td>Pat</td>
<td>Fay</td>
<td>6,000</td>
<td>20</td>
</tr>
</tbody>
</table>
```

SQL>
Oracle Enterprise Manager Express

- Enables you to perform administrative tasks such as managing user security and managing database memory and storage.
- View performance and status information about your database.
Oracle Enterprise Manager Cloud Control 13c
SQL Developer Data Modeler

- Free tool for DB design
- Logical, relational, physical models, DDLs, ...
- Multidimensional models (DW), Data Flows etc.
- For designing and documenting the data architecture and the database
- Support for all the phases in database design and easy moving from one to another, support for reverse engineering
- Support for version control and multi user environment
Schema

• A database **schema** is a logical container for data structures, called schema objects. Example: tables, indexes, PL/SQL packages.
• You create and manipulate schema objects with SQL.
• A database user account has a password and specific database privileges. Each user account owns a single schema, which has the same name as the user.
• The schema contains the data for the user owning the schema.
• Example: **HR.EMPLOYEES**, **SALES.ORDERS** tables.
• Within a schema, each schema object of a particular type has a unique name.
Physical Storage Structures

- **An Oracle database** is a set of files that store Oracle data in persistent disk storage.
- **A data file**
  Every Oracle DB has one or more physical data files. Data of logical DB structures, (tables, indexes, etc.) is physically stored in the data files.
- **A temp file**
  Data file that belongs to a temporary tablespace for sorting and temporary object.
- **Control files**
  Every Oracle database has a control file. A control file contains metadata specifying the physical structure of the database, including the database name and the names and locations of the database files. Information required to recover DB including checkpoints (SCN).
- **Online redo log (ORL) files**
  Every Oracle Database has an online redo log, which is a set of two or more online redo log files. An online redo log is made up of redo entries (also called redo log records), which record all changes made to data.

- **A database instance** is a set of memory structures that manage database files.
Logical Storage Hierarchy

- **Data blocks**: Smallest units of storage that Oracle DB can use or allocate. One data block corresponds to a specific number of bytes on disk. For example, 2 KB.

- **Extents**: An extent is a set of logically contiguous data blocks allocated for storing a specific type of information. Ex: 24 KB extent has 12 data blocks, while the 72 KB extent has 36 data blocks.

- **Segments**: A segment is a set of extents allocated for a user object (table, index ...), undo data, or temporary data. Every DB object that consumes storage consists of a single segment.

- **Tablespaces**: DB is divided into logical storage units called tablespaces. A tablespace is the logical container for a segment. Each tablespace consists of at least one data file.

Each segment belongs to one and only one tablespace. Thus, all extents for a segment are stored in the same tablespace. Within a tablespace, a segment can include extents from multiple data files.
Logical Storage Structures

- Oracle Database allocates logical space for all data in database.
- Logical units of database space allocation are **data blocks, extents, segments, and tablespaces**.
- At a physical level, the data is stored in data files on disk.

![Diagram of logical and physical storage structures](image-url)
Data Files Structure

- The data file header contains metadata about the data file such as its size and checkpoint SCN.
- Each header contains an absolute file number, which uniquely identifies the data file within the database, and a relative file number, which uniquely identifies a data file within a tablespace.
- When Oracle Database first creates a data file, the allocated disk space is formatted but contains no user data. However, the database reserves the space to hold the data for future segments of the associated tablespace.
- As the data grows in a tablespace, Oracle Database uses the free space in the data files to allocate extents for segment.
Overview of Data Files

• Each **tablespace** consists of one or more data files.
• The data for a database is collectively stored in the data files.
• A **segment** can span one or more data files, but it cannot span multiple tablespaces.
• A database must have the **SYSTEM** and **SYSAUX** tablespaces.
• **SYSTEM** tablespace contains the data dictionary, a set of tables that contains database metadata.
• **DB** also has an **undo tablespace** and a **temporary tablespace** (**TEMP**).
Data Blocks and Operating System Blocks

• An operating system block is the minimum unit of data that the OS can read or write.

• Oracle block is a logical storage structure whose size and structure are not known to OS.

• The database requests data in multiples of data blocks, not OS blocks.

• Applications do not need to determine the physical addresses of data on disk.

• Database data can be striped or mirrored on multiple physical disks.
Block size range from 2K to 32K
  - 8K is typical

Block header
  - Block Type Information in (like disk address and segment type).
  - For blocks that are transaction-managed, block header contains active and historical transaction information.
  - A transaction entry is required for every transaction that updates the block.

Table directory
  - For a heap-organized table contains metadata about tables whose rows are stored in this block

Row directory
  - For a heap-organized table, this directory describes the location of rows in the data portion of the block.

Row Data
  - Free Space allow for insertion of new rows
  - Some free space left at the end of each row
Types of Processes

1. **A client process** runs application or Oracle tool code.

2. **An Oracle process**
   - **A background process** perform maintenance tasks like: instance recovery, cleaning up processes.
   - **A server process** communicate with client processes and interact with Oracle DB to fulfill requests.
   - **Dedicated server VS Shared server**.

   - system global area (SGA) and background processes using dedicated server connections.
   - For each user connection, a client process runs the application. Each client process is associated with its own server process, which has its own program global area (PGA).
Dedicated Server Architecture

- Server process created on behalf of each client process is called a dedicated server process separate from the client process.
- A one-to-one ratio exists between the client processes and server processes.
- Sometimes result in inefficient use of operating system resources. Ex: order entry system.

![Diagram of Dedicated Server Architecture](image-url)
Shared Server Architecture

- Dispatcher directs multiple incoming network session requests to a pool of shared server processes, eliminating the need for a dedicated server process for each connection. An idle shared server process from the pool picks up a request from a common queue.

Advantages:
- Reduces the number of resources on the OS
- Reduces instance PGA memory
- Increases application scalability and number of clients that can simultaneously connect to the database
- May be faster than dedicated server when the rate of client connections and disconnections is high
Overview of Oracle Networking Architecture

- Oracle Net Listener (Listener)
  1. A client process or another database requests a connection.
  2. Listener selects an appropriate service handler to service the client request and forwards the request to the handler.
  3. Client process connects directly to the service handler. The listener is no longer involved in the communication.
The Oracle Net Listener

1. Server-side process that accepts incoming client connection requests and forwards them to the database

2. LREG background process manages the listener’s activity

3. Service name: Logical name for an Oracle database service

4. Service ID (SID): Unique name of a specific Oracle database

5. One SID > multiple service names

6. Dedicated vs. shared server mode
Basic Memory Structures

1. **System global area (SGA)**
   Data and control information for one Oracle DB. All server and background processes share the SGA. Ex: cached data blocks and shared SQL areas.

2. **Program global area (PGA)**
   Nonshared memory region that contains data and control information exclusively for use by an Oracle process. Oracle Database creates the PGA when an Oracle process starts. One PGA exists for each server process and background process. The collection of individual PGAs is instance PGA.

3. **Software code areas** used to store code that is being run or can be run.

4. **User global area (UGA)**
   Memory associated with a user session.
Program Global Area (PGA)

- Memory assigned to process when it connects to Oracle that contains session-dependent variables required by a dedicated or shared server process.
- Instance PGA (collection of all PGAs) for an instance that is not configured for shared servers.
- SQL Work Area
  - Sorting Data
  - Creating hash tables for hash joins
- Private SQL Area
  - Value of bind variables
  - Query execution state information
- Because PGA is process-specific, it is never allocated in the SGA.
Database Buffer Cache

- Largest components of SGA
- All SQL Statement need to access blocks of data

Goals
- Used to cache data blocks (both table and index) from disk
- Reading from memory much faster than disk
- Keep frequently accessed blocks in the buffer cache and write infrequently accessed blocks to disk

Buffer Replacement Algorithms
- LRU-based, block-level replacement algorithm
- Temperature-based, object-level replacement algorithm

Reading Blocks into buffer Cache

Buffer Search

buffer cache hit ratio
Measure of how often the database found a requested block in the buffer cache without needing to read it from disk.
Shared pool

- Caches various types of program data. EX: stores parsed SQL, PL/SQL code, system parameters, and data dictionary information.
- Involved in almost every operation that occurs in the database.
- Divided into several subcomponents
  - Data Dictionary Cache.
    - Database object definitions & Object Permissions
  - Shared SQL Area
    - Cached SQL statements and execution plans
  - Reserved Pool
    - Borrows memory for short term operations
1. New pool in SGA: Column store
2. BOTH row and column formats for same table
   – Simultaneously active and consistent
3. OLTP uses existing row format
4. Analytics uses new In-Memory Column format
5. Seamlessly built into Oracle Database
6. Huge performance boost for full table scans and analytics queries.
Redo Log Buffer

- A **circular** buffer in SGA that stores redo entries describing changes made to DB.

- A redo record is a data structure that contains the information necessary to reconstruct, or redo, changes made to the database by DML or DDL operations.

- DB recovery applies redo entries to data files to reconstruct lost changes.

- DB processes copy redo entries from the user memory space to the redo log buffer in the SGA.

- Redo entries take up continuous, sequential space in the buffer.
Q&A