Oracle Database 11g/12c

To Amazon Aurora with PostgreSQL Compatibility (9.6.x)

Migration Playbook

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Written by: David Yahalom, Nimrod Keinan

Notices

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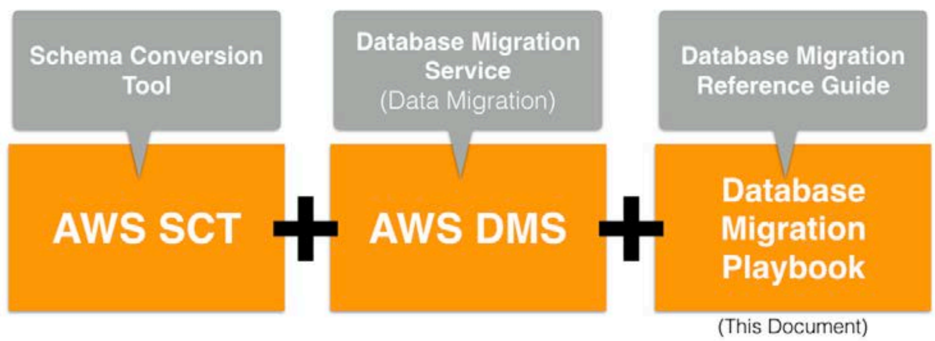
Introduction

To migrate an Oracle database to Amazon Aurora with PostgreSQL Compatibility, you usually need to perform both automated and manual tasks. The automated tasks involve data migration and schema conversion using the AWS Database Migration Service (AWS DMS) and AWS Schema Conversion Tool (AWS SCT). The manual tasks involve post-migration “touch-ups” for certain database objects that can’t be migrated automatically.

This whitepaper primarily focuses on the manual aspects of database migration and includes step-by-step instructions that you can adapt for your own requirements. In this document, we focus on how to manually migrate specific Oracle database objects and features to Amazon Aurora with PostgreSQL Compatibility equivalents. We also include a brief overview that explains how to use the AWS Schema Conversion Tool (AWS SCT) for automatic migrations of schema objects. You can use this document as a supplementary guide for your database migrations – both as a guide to expand your PostgreSQL competency if you come from an Oracle database background and as a reference to help build Oracle-comparable functionality in Amazon Aurora with PostgreSQL compatibility



This document does not yet cover all Oracle Database features and capabilities from a migration perspective. For the first release, we focus on some of the most important features and will continue to expand the Playbook document over time. Not all Oracle features have direct and fully compatible equivalents in PostgreSQL. In these cases, we present our recommendations for the best-possible equivalent features in Amazon Aurora with PostgreSQL compatibility.

We also plan to expand this document in the future and add new chapters specifically dedicated to advanced topics such as Oracle security, High Availability and Disaster Recovery, Performance Tuning, and more.

Disclaimer

The various code snippets, commands, guides, best practices, and scripts included in this document should be used for reference only and are provided as-is without warranty. Please be sure to test all of the code, commands, best practices, and scripts outlined in this document in a non-production environment first. Amazon and its affiliates are not responsible for any direct or indirect damage that can occur from the information contained in this document.

Automatic Schema Migration

	Help Section
Link	Using the AWS Schema Conversion Tool for automatic schema conversion

SQL & PL/SQL (Manual)

	Oracle Feature	Aurora PostgreSQL Feature	Compatibility
Link	Anonymous Block	Do	Yes
Link	Execute Immediate	Execute & Prepare	Yes
Link	DBMS_RANDOM	random()	Yes*
Link	DBMS_OUTPUT	RAISE	Yes
Link	Procedures & Functions	Functions	Yes*
Link	User Defined Functions (UDFs)	Functions	Yes*
Link	UTL_FILE	N/A	None
Link	JSON Document Support	JSON Document Support	Yes*
Link	OLAP Functions	Window Functions	Yes
Link	PL/SQL Cursors	Cursors	Yes
Link	Single Row & Aggregate Functions	Single Row & Aggregate Functions	Yes
Link	Merge	SQL Merge	Yes
Link	Create Table As Select (CTAS)	Create Table As Select (CTAS)	Yes
Link	Common Table Expression (CTE)	Common Table Expression (CTE)	Yes
Link	Insert From Select	Insert From Select	Yes
Link	Inline Views	Inline Views	Yes
Link	DB Hints	Query Planning	Yes*

Tables & Indexes (Manual)

	Oracle Feature	Aurora PostgreSQL Feature	Compatibility
Link	Index Organized Tables (IOTs)	PostgreSQL "Cluster" Tables	Yes*
Link	Common Data Types	Common Data Types	Yes
Link	Table Constraints	Table Constraints	Yes
Link	Table Partitioning including: RANGE, LIST, HASH, COMPOSITE, Automatic LIST	Table Partitioning including: RANGE, LIST	Yes*
Link	Exchange and Split Partitions	N/A	None
Link	Temporary Tables	Temporary Tables	Yes*
Link	Unused Columns	ALTER TABLE DROP COLUMN	Yes
Link	Virtual Columns	Views and/or Function as a Column	Yes*
Link	User Defined Types (UDTs)	User Defined Types (UDTs)	Yes
Link	Read Only Tables and Table Partitions	Read Only Roles and/or Triggers	Yes*
Link	Index Types	Index Types	Yes*
Link	B-Tree Indexes	B-Tree Indexes	Yes
Link	Composite Indexes	Multi-Column Indexes	Yes
Link	BITMAP Indexes	BRIN Indexes	Minimal
Link	Function-Based Indexes	Expression Indexes	Yes
Link	Local and Global Partitioned Indexes	Partitioned Indexes	Yes*
Link	Identity Columns	Serial Data Type	Yes*
Link	MVCC (Table and Row Locks)	MVCC (Table and Row Locks)	Yes*
Link	Character Sets	Encoding	Yes*
Link	Transaction Model	Transactional Model	Yes*
Link	LOBs and SecureFile LOBs	LOBs	Yes*

Database Objects (Manual)

	Oracle Feature	Aurora PostgreSQL Feature	Compatibility
Link	Materialized Views	Materialized Views	Yes*
Link	Common Data Types	Common Data Types	Yes
Link	Oracle Triggers	PostgreSQL Trigger Procedure	Yes*
Link	Views	Views	Yes
Link	Sequences	Sequences	Yes

Link	Database Links	PostgreSQL DBLink and FDWrapper	**Yes***

Database Administration (Manual)

	Oracle Feature	Aurora PostgreSQL Feature	Compatibility
Link	Recovery Manager (RMAN)	Amazon Aurora Snapshots	Yes
Link	Flashback Database	Amazon Aurora Snapshots	Yes
Link	12c Multi-Tenant Architecture: PDBs and CDB	Databases	Yes*
Link	Tablespaces and DataFiles	Tablespaces	Yes*
Link	Data Pump	pg_dump and pg_restore	Yes
Link	Resource Manager	Separate Amazon Aurora Clusters	Yes
Link	Database Users	Database Roles	Yes
Link	Database Roles	Database Roles	Yes
Link	SGA & PGA Memory	Memory Buffers	Yes
Link	V$ Views & the Data Dictionary	System Catalog Tables, Statistics Collector, Amazon Aurora Performance Insights	Yes*
Link	Log Miner	Logging Options	Yes
Link	Instance & Database Parameters (SPFILE)	Amazon Aurora Parameter Groups	Yes
Link	Session Parameters	Session Parameters	Yes
Link	Alert.log (error log)	Error Log via AWS Management Console	Yes
Link	Automatic and Manual Statistics Collection	Automatic and Manual Statistics Collection	Yes
Link	Viewing Execution Plans	Viewing Execution Plans	Yes

Automatic Migration of Oracle Schema Objects Using the AWS Schema Conversion Tool

Automatic Schema Migration

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This section provides a step-by-step process for using the AWS Schema Conversion Tool (AWS SCT) to migrate an Oracle database to an Aurora with PostgreSQL compatibility database cluster. Amazon SCT can automatically migrate most of the database objects.

While this document primarily covers the best practices, feature-parity aspects of manual database migrations, and Oracle to Amazon Aurora with PostgreSQL compatibility migration best practices, we recommend using AWS SCT as the first step of the process.

AWS SCT is a downloadable Java utility that runs locally on your computer. It connects to the source and target databases, scans the source database schema objects (tables, views, indexes, procedures, etc.), and converts them to the target database objects.

For more information, see
http://docs.aws.amazon.com/SchemaConversionTool/latest/userguide/Welcome.html

Download AWS SCT and Install JDBC Drivers

JDBC drivers are required for database connectivity to both the source and target databases.

1. Download **SCT**: http://docs.aws.amazon.com/SchemaConversionTool/latest/userguide/CHAP_SchemaConversionTool.Installing.html

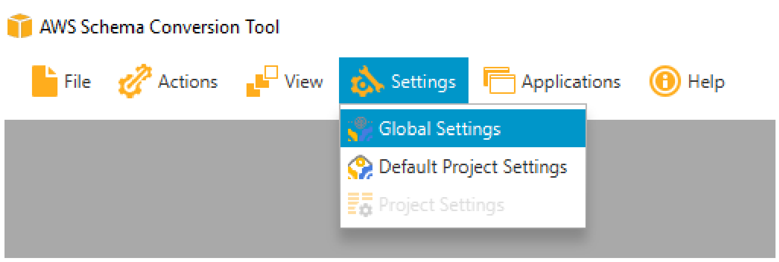
2. Download the **Oracle JDBC Driver** (ojdbc7.jar): http://www.oracle.com/technetwork/database/features/jdbc/jdbc-drivers-12c-download-1958347.html

3. Download the **PostgreSQL JDBC Driver** (postgresql-9.4-1204.jdbc42.jar): https://jdbc.postgresql.org/download.html

Configure SCT for Database Migration

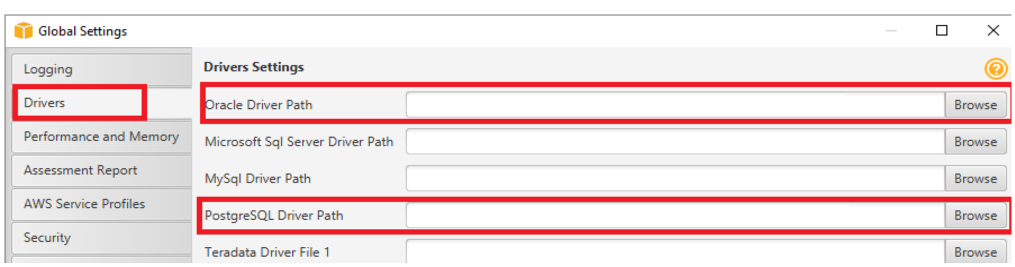
1. Launch **SCT**.

2. Choose the JAR files path under SCTs **Global Settings**



3. Click **Global Settings > Drivers**

4. Add the file path to the Oracle and the PostgreSQL JDBC drivers



5. Use the following filenames:

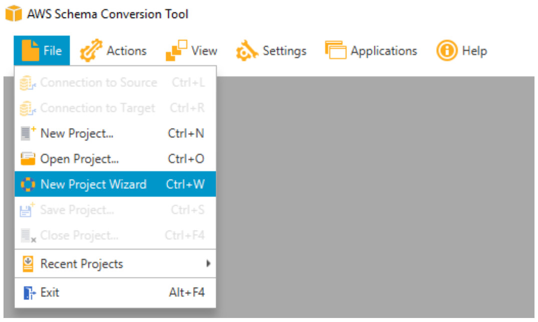
   Oracle JDBC JAR - `ojdbc7.jar`
   PostgreSQL JDBC JAR - `postgresql-9.4-1204.jdbc42.jar`

6. Click OK.

AWS SCT – Database Migration Project Configuration

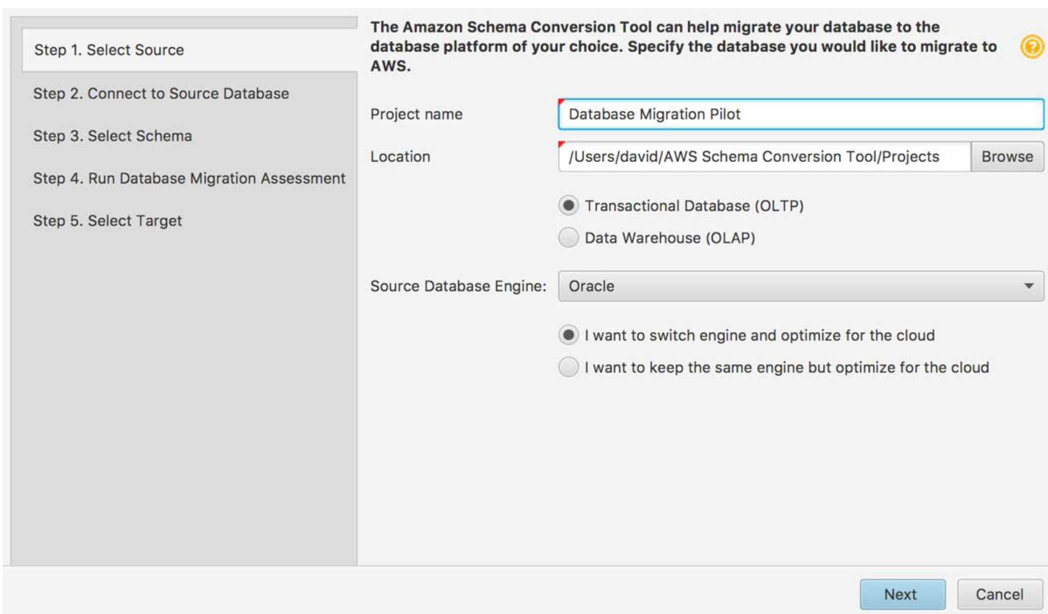
Create a new SCT project which will guide you, step-by-step, through the schema conversion process.

1. Click **SCT > File > New Project Wizard**

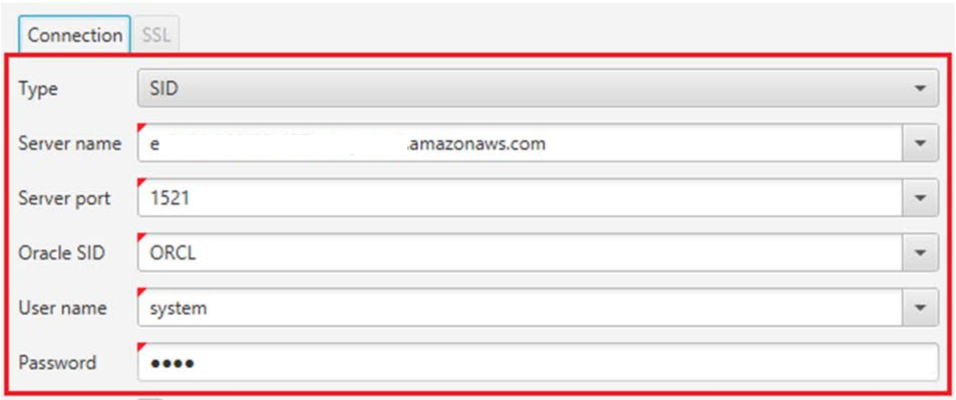


2. Select a source database for migration (the Oracle Database to migrate to Aurora with PostgreSQL Compatibility).

3. Enter a project name, specify the location of the SCT project files, choose the source database workload characteristics (OLTP or OLAP), and select the source database engine (Oracle).

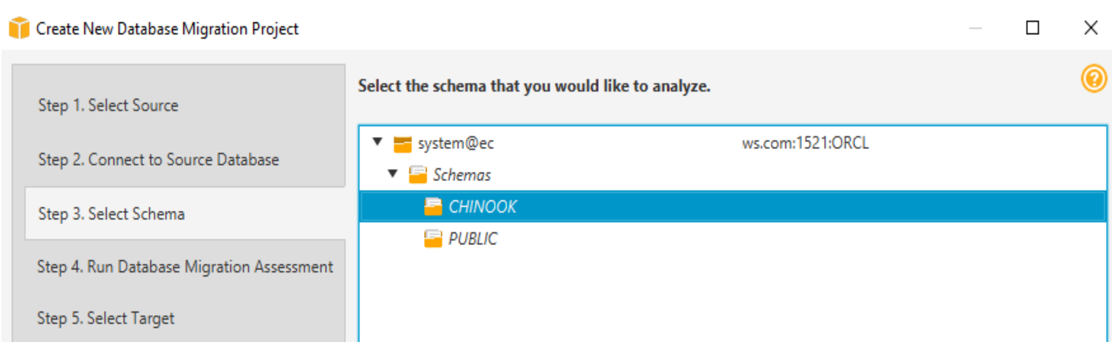


4. Configure the source database connection properties:
    - Server hostname
    - Oracle Net Listener port number
    - Oracle Database SID
    - Privileged username and password. For example, the Oracle `system` user.

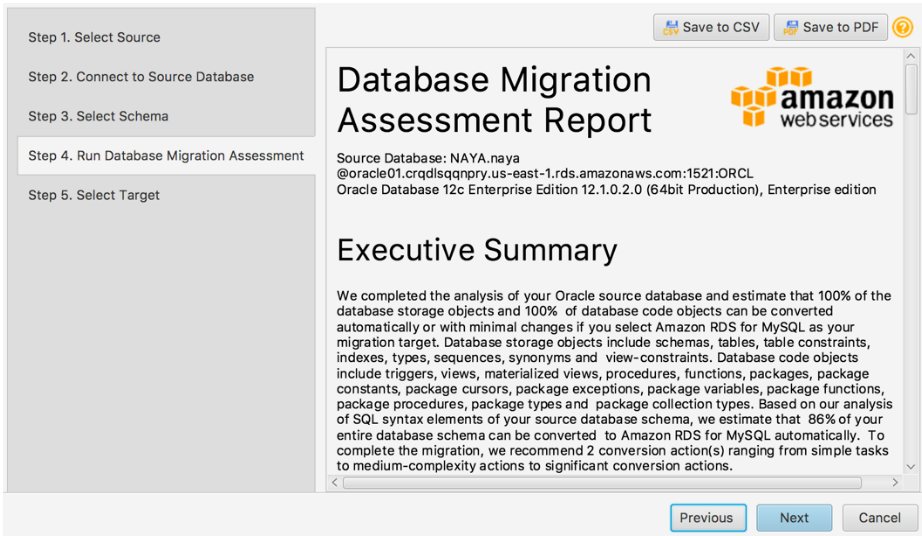


5. Click **Next**.

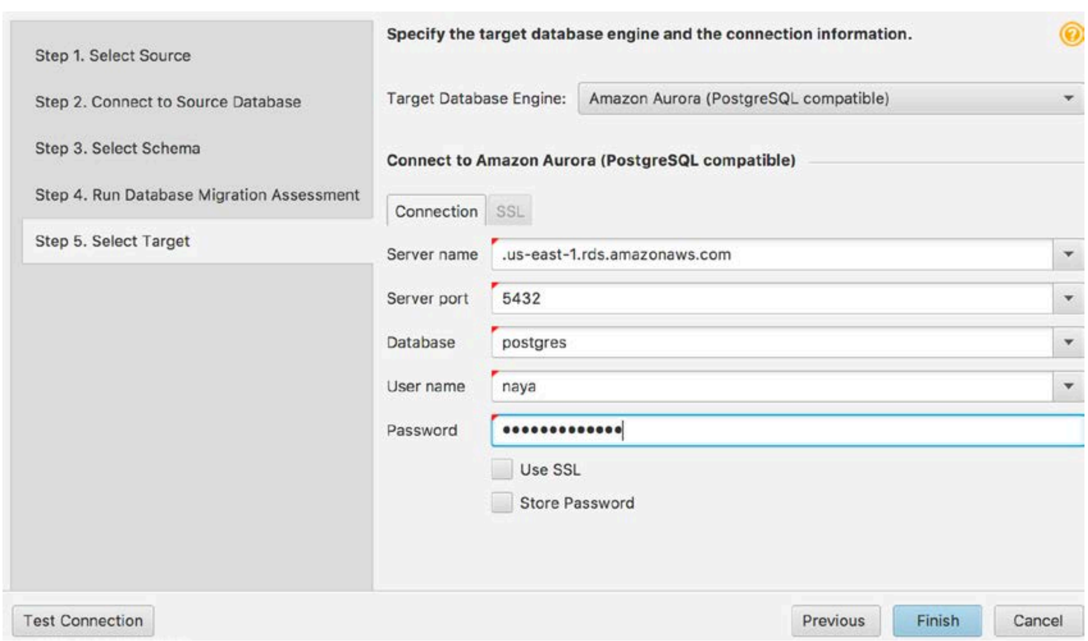
6. Select the source Oracle schema for migration.



7. SCT analyzes the source database schema objects and produces the Database Migration Assessment report. Review the report.

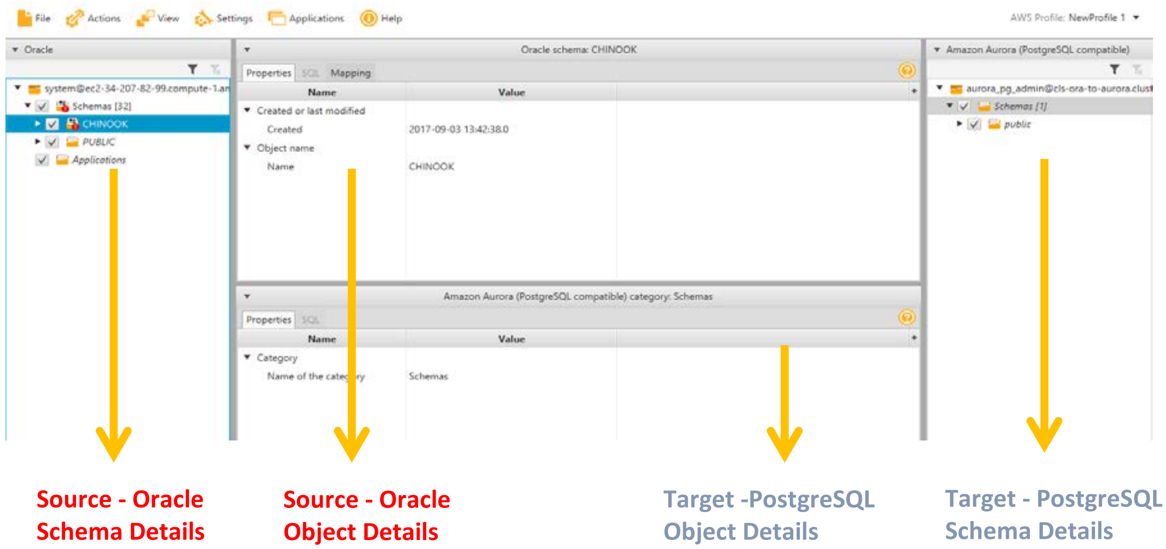


8. Specify the target database configuration:
   - Target Database Engine: Amazon Aurora (PostgreSQL compatible).
   - Server hostname: Aurora ***Cluster*** Endpoint.
   - Server port number: 5432 (default PostgreSQL network port).
   - Database: The name of the target database that will store the migrated schema objects.
   - The privileged target database username and password. Deployment of the converted schema in the target database will use these credentials.



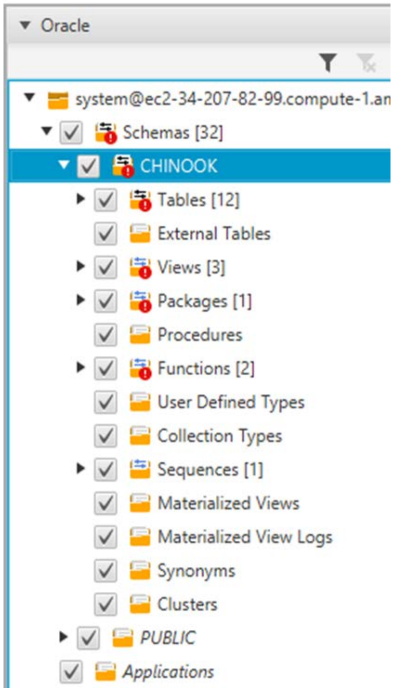
9. Click **Finish** when you are done. Note that at this stage in the process the migrated target schema ***has not*** yet been deployed to your target database.

10. Explore the AWS SCT Project Main Page and the other information pages. Select Oracle schema objects from the left Oracle pane to view the Oracle syntax.

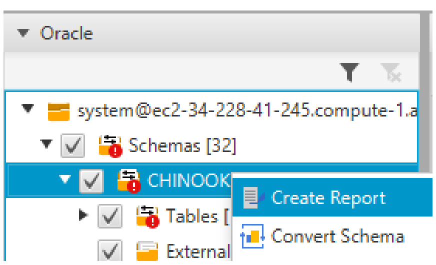


AWS SCT – Database Migration Assessment

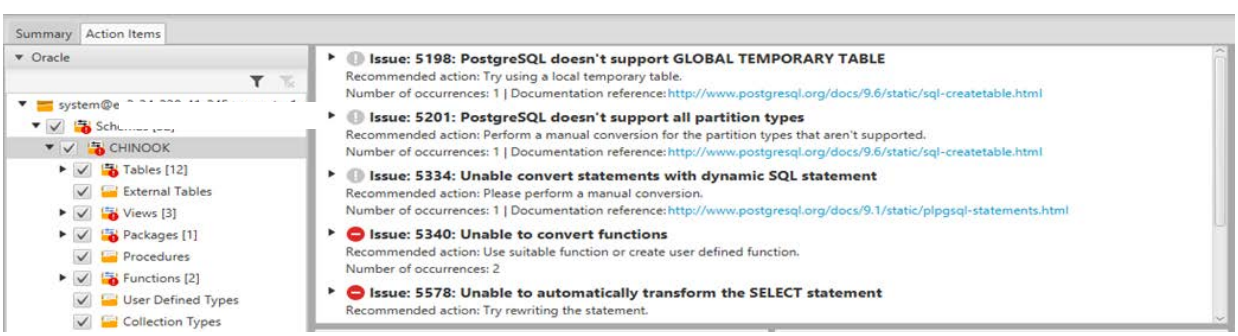
1. Explore the objects in your source database and be sure to note any database objects that SCT cannot automatically migrate to your target database syntax. SCT flags objects with potential migration issues with a **RED** exclamation mark. These objects require manual intervention for successful migration.



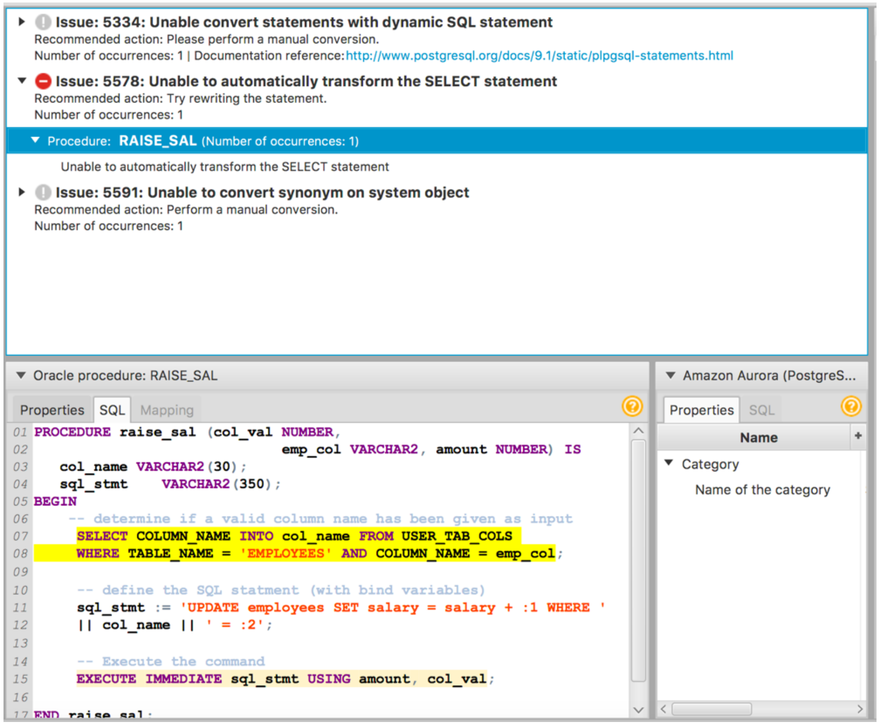
2. Right click the Oracle schema for migration and select **Create Report** to view the complete Database Migration Assessment report.



3. Click the **Action Items** tab**.** This section of the report provides information about potential migration issues.



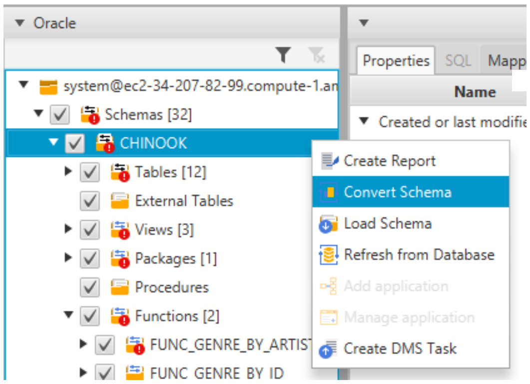
4. Click the migration **issues** highlighted by SCT to view a detailed overview of the exact source syntax that failed the automatic migration process.



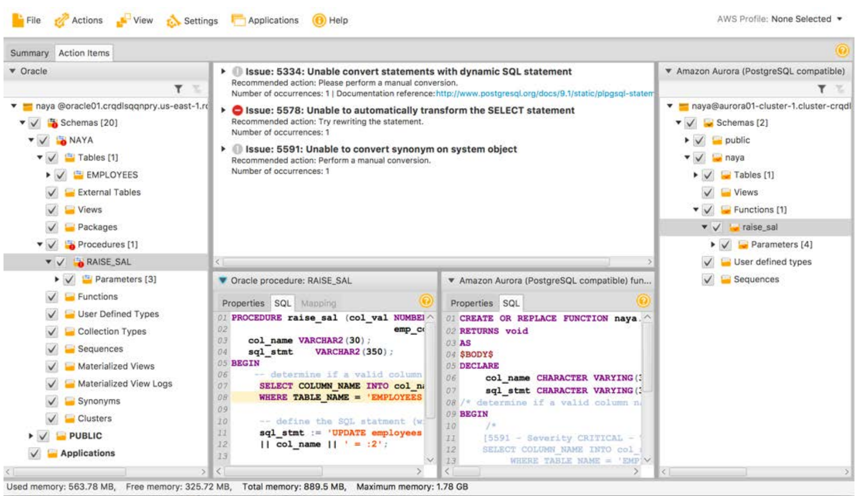
AWS SCT – Convert Source to Target Database Syntax

This step converts the source database schema objects to your target database using target database syntax.

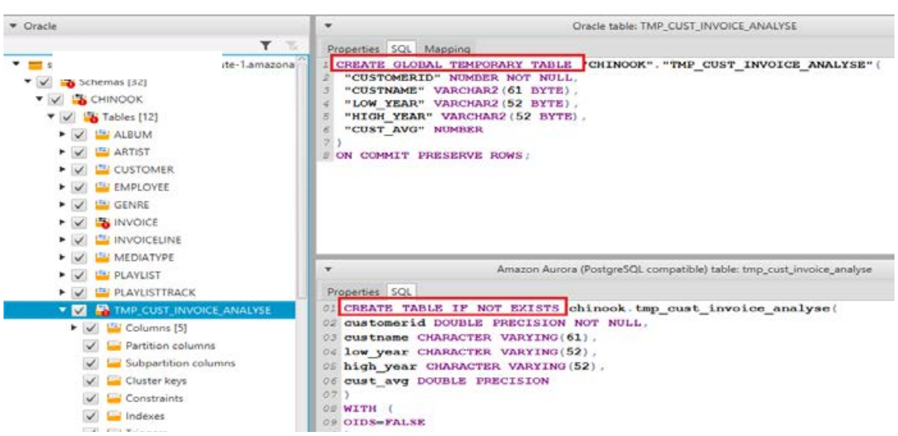
1. Right click the Oracle Schema and select **Convert Schema.**



2. The new schema and objects appear in the right-side pane under the target database. Compare the source database objects (left-side pane) to the converted target database objects (right-side pane). Note that the converted schema has **not yet been deployed** to the target PostgreSQL database.



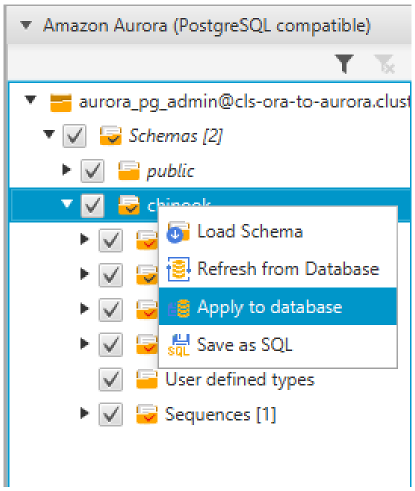
3. Examine any gaps in objects that AWS SCT could not automatically convert.



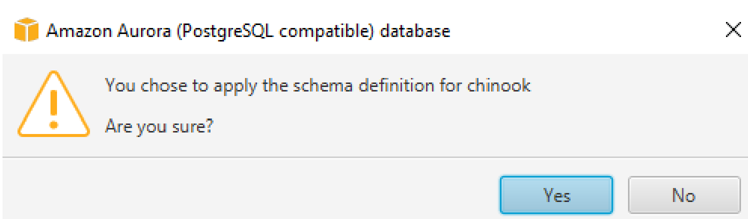
AWS SCT – Deploy the Converted Schema to the Target Database

1. In the right-side **Target Database** pane, right click the PostgreSQL schema corresponding to the source database schema name.

2. Select **Apply to database**.



3. Click **Yes** to continue. **This step creates the new schema in the target database.**



Manual Migration and Best Practices of Oracle Schema Objects and Database Features

Migrating from: Oracle Anonymous Block

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Overview

Oracle's PL/SQL is a procedural extension of SQL. The PL/SQL program structure divides the code into blocks that can be distinguished by the following keywords: `DECLARE`, `BEGIN`, `EXCEPTION`, and `END`.

An unnamed PL/SQL code block (code not stored in the database as a procedure, function, or package) is known as an ***anonymous block.*** An anonymous block serves as the basic unit of Oracle PL/SQL and contains the following code sections:

- **The Declarative Section** (Optional)
  Contains variables (names, data types, and initial values).

- **The Executable Section** (Mandatory)
  Contains executable statements (each block structure must contain at least one executable PL/SQL statement).

- **The Exception-Handling Section** (Optional)
  Contains elements for handling exceptions or errors in the code.

Examples

Simple structure of an Oracle Anonymous Block:

```
SQL> SET SERVEROUTPUT ON;
SQL> BEGIN
      DBMS_OUTPUT.PUT_LINE('hello world');
     END;
/
hello world

PL/SQL procedure successfully completed.
```

Oracle PL/SQL Anonymous blocks can contain advanced code elements such as functions, cursors, dynamic SQL, and conditional logic. The following anonymous block uses a cursor, conditional logic, and exception-handling:

```
SQL> SET SERVEROUTPUT ON;
SQL> DECLARE
     v_sal_chk        NUMBER;
     v_emp_work_years NUMBER;
     v_sql_cmd        VARCHAR2(2000);
     BEGIN
      FOR v IN (SELECT EMPLOYEE_ID, FIRST_NAME||' '||LAST_NAME AS
                       EMP_NAME, HIRE_DATE, SALARY FROM EMPLOYEES)
      LOOP
      v_emp_work_years:=EXTRACT(YEAR FROM SYSDATE) - EXTRACT (YEAR FROM
v.hire_date);

      IF v_emp_work_years>=10 and v.salary <= 6000 then
       DBMS_OUTPUT.PUT_LINE('Consider a Bonus for: '||v.emp_name);
      END IF;
     END LOOP;
     EXCEPTION WHEN OTHERS THEN
      DBMS_OUTPUT.PUT_LINE('CODE ERR: '||sqlerrm);
     END;
/
```

The above example calculates the years each employee has worked based on the `HIRE_DATE` column of the `EMPLOYEES` table. If the employee has worked for ten or more years and has a salary of $6000 or less, the system prints the message “Consider a Bonus for: <*employee name*>”.

For additional details:
https://docs.oracle.com/cd/B28359_01/appdev.111/b28370/controlstructures.htm#CJAEDEIH

Migration to: PostgreSQL DO

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Overview

PostgreSQL version 9.6 supports capabilities similar to Oracle's anonymous blocks. In PostgreSQL, you can execute PL/pgSQL code that is not stored in the database as an independent code segment using a PL/pgSQL DO statement.

PL/pgSQL is a PostgreSQL extension to the ANSI SQL and has many similar elements to Oracle PL/SQL. PostgreSQL DO uses a similar code structure to an Oracle anonymous block:

- **Declarative Section** (Optional)
- **Executable Section** (Mandatory)
- **Exception-Handling Section** (Optional)

Examples

PostgreSQL DO simple structure:

```
psql=> SET CLIENT_MIN_MESSAGES = 'debug';
-- Equivalent To Oracle SET SERVEROUTPUT ON

psql=> DO $$
       BEGIN
            RAISE DEBUG USING MESSAGE := 'hello world';
       END $$;

DEBUG:  hello world
DO
```

The PostgreSQL PL/pgSQL DO statement supports the use of advanced code elements such as functions, cursors, dynamic SQL, and conditional logic.

The following example is a more complex PL/pgSQL DO code structure converted from Oracle's "employee bonus" PL/SQL anonymous block example presented in the previous section:

```
psql=> DO $$
       DECLARE
            v_sal_chk DOUBLE PRECISION;
            v_emp_work_years DOUBLE PRECISION;
            v_sql_cmd CHARACTER VARYING(2000);
            v RECORD;
       BEGIN
       FOR v IN
       SELECT employee_id, CONCAT_WS('', first_name, ' ', last_name) AS
              emp_name, hire_date, salary
       FROM employees
       LOOP
        v_emp_work_years := EXTRACT (YEAR FROM now()) - EXTRACT (YEAR FROM
v.hire_date);

         IF v_emp_work_years >= 10 AND v.salary <= 6000 THEN
            RAISE DEBUG USING MESSAGE := CONCAT_WS('', 'Consider a Salary
            Raise for: ', v.emp_name);
         END IF;
        END LOOP;
       EXCEPTION
        WHEN others THEN
            RAISE DEBUG USING MESSAGE := CONCAT_WS('', 'CODE ERR: ',
            SQLERRM);
       END $$;
```

For additional information on PostgreSQL DO:
https://www.postgresql.org/docs/current/static/sql-do.html

Migrating from: Oracle EXECUTE IMMEDIATE

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Overview

Oracle's EXECUTE IMMEDIATE statement can be used to parse and execute a dynamic SQL statement or an anonymous PL/SQL block. It also supports bind variables.

Example

Run a dynamic SQL statement from within a PL/SQL procedure:

1. Create a PL/SQL procedure named `raise_sal`.

2. **Define a SQL Statement** with a dynamic value for the column name included in the where statement.

3. **Use the** EXECUTE IMMEDIATE command supplying the two bind variables to be used as part of the SELECT statement:
   - `amount`
   - `col_val`

```
CREATE OR REPLACE PROCEDURE raise_sal (col_val NUMBER,
                             emp_col VARCHAR2, amount NUMBER) IS
   col_name VARCHAR2(30);
   sql_stmt    VARCHAR2(350);
BEGIN
    -- determine if a valid column name has been given as input
     SELECT COLUMN_NAME INTO col_name FROM USER_TAB_COLS
     WHERE TABLE_NAME = 'EMPLOYEES' AND COLUMN_NAME = emp_col;

     -- define the SQL statment (with bind variables)
     sql_stmt := 'UPDATE employees SET salary = salary + :1 WHERE '
     || col_name || ' = :2';

     -- Execute the command
     EXECUTE IMMEDIATE sql_stmt USING amount, col_val;

END raise_sal;
/
```

4. Run the DDL operation from within an EXECUTE IMMEDIATE command:

```
EXECUTE IMMEDIATE 'CREATE TABLE link_emp (idemp1 NUMBER, idemp2 NUMBER)';
EXECUTE IMMEDIATE 'ALTER SESSION SET SQL_TRACE TRUE';
```

5. Run an anonymous block with bind variables using EXECUTE IMMEDIATE:

```
EXECUTE IMMEDIATE 'BEGIN raise_sal (:col_val, :col_name, :amount); END;'
USING 134, 'EMPLOYEE_ID', 10;
```

For additional details:
https://docs.oracle.com/database/121/LNPLS/dynamic.htm#LNPLS01115

Migration to: PostgreSQL PL/pgSQL Execute & Prepare

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Overview

The PostgreSQL EXECUTE command prepares and executes commands dynamically. The EXECUTE command can also run DDL statements and retrieve data using SQL commands. Similar to Oracle, the PostgreSQL EXECUTE command can be used with bind variables.

Example

1. Execute a SQL SELECT query with the table name as a dynamic variable using bind variables. This query returns the number of employees under a manager with a specific ID.

```
DO $$DECLARE
      Tabname      varchar(30) := 'employees';
      num         integer := 1;
       cnt        integer;
BEGIN
      EXECUTE format('SELECT count(*) FROM %I WHERE manager = $1', tabname)
      INTO cnt
      USING num;
      RAISE NOTICE 'Count is % int table %', cnt, tabname;
END$$;
;
```

2. Execute a DML command – first with no variables and then with variables:

```
DO $$DECLARE
BEGIN
      EXECUTE 'INSERT INTO numbers (a) VALUES (1)';
      EXECUTE format('INSERT INTO numbers (a) VALUES (%s)', 42);
END$$;
;
```

Notes

- **%s** formats the argument value as a simple string. A null value is treated as an empty string.
- %I treat the argument value as an SQL identifier and double-quoting it if necessary. It is an error for the value to be null.

3. Execute a DDL command:

```
DO $$DECLARE
BEGIN
      EXECUTE 'CREATE TABLE numbers (num integer)';
END$$;
;
```

For additional details:
https://www.postgresql.org/docs/9.3/static/functions-string.html

PostgreSQL Prepare

Using a PREPARE statement can improve performance for reusable SQL statements.

The PREPARE command can receive a SELECT, INSERT, UPDATE, DELETE, or VALUES statement and parse it with a user-specified qualifying name so the EXECUTE command can be used later without the need to re-parse the SQL statement on each execution.

- When using PREPARE to create a prepared statement, it will be viable for the scope of the current session.
- If a DDL command is executed on a database object referenced by the prepared SQL statement, the next EXECUTE command requires a hard parse of the SQL statement.

Example

Use PREPARE and EXECUTE commands in tandem:

The SQL command is prepared with a user-specified qualifying name.

The SQL command is executed several times, without the need for re-parsing.

```
PREPARE numplan (int, text, bool) AS
    INSERT INTO numbers VALUES($1, $2, $3);

EXECUTE numplan(100, 'New number 100', 't');
EXECUTE numplan(101, 'New number 101', 't');
EXECUTE numplan(102, 'New number 102', 'f');
EXECUTE numplan(103, 'New number 103', 't');
```

PL/pgSQL EXECUTE vs. Oracle implicit cursor

Functionality	PostgreSQL - EXECUTE	Oracle – EXECUTE IMMEDIATE
Execute SQL with results and bind variables	`EXECUTE format('select salary from employees WHERE %I = $1', col_name) INTO amount USING col_val;`	`EXECUTE IMMEDIATE 'select salary from employees WHERE ' || col_name || ' = :1' INTO amount USING col_val;`
Execute DML with variables and bind variables	`EXECUTE format('UPDATE employees SET salary = salary + $1 WHERE %I = $2', col_name) USING amount, col_val;`	`EXECUTE IMMEDIATE 'UPDATE employees SET salary = salary + :1 WHERE '  || col_name || ' = :2' USING amount, col_val;`
Execute DDL	`EXECUTE 'CREATE TABLE link_emp (idemp1 integer, idemp2 integer)';`	`EXECUTE IMMEDIATE 'CREATE TABLE link_emp (idemp1 NUMBER, idemp2 NUMBER)';`
Execute Anonymous block	`DO $$DECLARE BEGIN ... END$$;`	`EXECUTE IMMEDIATE ‘BEGIN DBMS_OUTPUT.PUT_LINE(‘’Anonymous Block’’); END;’;`

For additional details:

https://www.postgresql.org/docs/current/static/plpgsql-statements.html

Migrating From: Oracle DBMS_RANDOM

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Overview

Oracle's DBMS_RANDOM package enables you to generate a random number or string as part of a SQL statement or PL/SQL procedure.

DBMS_RANDOM Package Stored Procedures include:

1. **NORMAL** – returns random numbers in a standard normal distribution.
2. **SEED** – resets the seed that generates random numbers or strings.
3. **STRING** – returns a random string.
4. **VALUE** – returns a number that is greater than or equal to 0 and less than 1 with 38 digits to the right of the decimal. Alternatively, you could get a random Oracle number that is greater than or equal to a low parameter and less than a high parameter.

Notes:

- DBMS_RANDOM.RANDOM produces integers in [-2^^31, 2^^31).
- DBMS_RANDOM.VALUE produces numbers in [0,1] with 38 digits of precision.

Example

1. Generate a random number:

```
SQL> select dbms_random.value() from dual;

DBMS_RANDOM.VALUE()
-------------------
         .859251508

SQL> select dbms_random.value() from dual;

DBMS_RANDOM.VALUE()
-------------------
         .364792387
```

2. Generate a random string. The **first character** determines the returned string type and the **number** specifies the length:

```
SQL> select dbms_random.string('p',10) from dual;

DBMS_RANDOM.STRING('P',10)
-------------------------------------------------------
la'?z[Q&/2

SQL> select dbms_random.string('p',10) from dual;

DBMS_RANDOM.STRING('P',10)
-------------------------------------------------------
t?!Gf2M60q
```

For additional details:
https://docs.oracle.com/database/121/ARPLS/d_random.htm

Migration To: PostgreSQL random()

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Overview

PostgreSQL does not provide a dedicated package equivalent to Oracle `DBMS_RANDOM` – a 1:1 migration is not possible. However, other PostgreSQL functions can be used as workarounds *under certain conditions.* For example, generating random numbers can be performed using the `random()` function. For generating random strings, you can use the value returned from the `random()` function coupled with an `md5()` function.

Example

1. Generate a random number:

```
mydb=> select random();
      random
-------------------
 0.866594325285405
(1 row)

mydb=> select random();
      random
-------------------
 0.524613124784082
(1 row)
```

2. Generate a random string:

```
mydb=> select md5(random()::text);
               md5
----------------------------------
 f83e73114eccfed571b43777b99e0795
(1 row)

mydb=> select md5(random()::text);
               md5
----------------------------------
 d46de3ce24a99d5761bb34bfb6579848
(1 row
```

Oracle `dbms_random` **vs. PostgreSQL** `random()`

Description	Oracle	PostgreSQL
Generate a random number	`select dbms_random.value() from dual;`	`select random();`
Generate a random number between 1 to 100	`select dbms_random.value(1,100) from dual;`	`select random()*100;`
Generate a random string	`select dbms_random.string('p',10) from dual;`	`select md5(random()::text);`
Generate a random string in upper case	`select dbms_random.string('U',10) from dual;`	`select upper(md5(random()::text));`

For additional details:
https://www.postgresql.org/docs/current/static/functions-math.html
https://www.postgresql.org/docs/current/static/functions-string.html

Migrating from: Oracle DBMS_OUTPUT

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Overview

Oracle's DBMS_OUTPUT package is typically used for debugging or for displaying output messages from PL/SQL procedures.

Example

In the following example, DBMS_OUTPUT with PUT_LINE is used with a combination of bind variables to dynamically construct a string and print a notification to the screen from within an Oracle PL/SQL procedure.

In order to display notifications on to the screen, you must configure the session with SET SERVEROUPUT ON.

```
SET SERVEROUTPUT ON

DECLARE
  CURSOR c1 IS
    SELECT last_name, job_id FROM employees
    WHERE REGEXP_LIKE (job_id, 'S[HT]_CLERK')
    ORDER BY last_name;
  v_lastname  employees.last_name%TYPE;  -- variable to store last_name
  v_jobid     employees.job_id%TYPE;     -- variable to store job_id
BEGIN
  OPEN c1;
  LOOP  -- Fetches 2 columns into variables
    FETCH c1 INTO v_lastname, v_jobid;
    DBMS_OUTPUT.PUT_LINE ('The employee id is:' || v_jobid || ' and his
        last name is:' || v_lastname);
    EXIT WHEN c1%NOTFOUND;
  END LOOP;
  CLOSE c1;
END;
```

In addition to the output of information on the screen, the PUT and PUT_LINE procedures in the DBMS_OUTPUT package enable you to place information in a buffer that can be read later by another PL/SQL procedure or package. You can display the previously buffered information using the GET_LINE and GET_LINES procedures.

For additional details:
https://docs.oracle.com/database/121/ARPLS/d_output.htm#ARPLS036

Migration to: PostgreSQL RAISE

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Overview

The PostgreSQL RAISE statement can be used as an alternative to DBMS_OUTPUT. You can combine RAISE with several levels of severity including:

Severity	Usage
DEBUG1..DEBUG5	Provides successively-more-detailed information for use by developers.
INFO	Provides information implicitly requested by the user
NOTICE	Provides information that might be helpful to users
WARNING	Provides warnings of likely problems
ERROR	Reports an error that caused the current command to abort.
LOG	Reports information of interest to administrators, e.g., checkpoint activity.
FATAL	Reports an error that caused the current session to abort.
PANIC	Reports an error that caused all database sessions to abort.

Examples

1. Use RAISE DEBUG (where DEBUG is the configurable severity level) for similar functionality as Oracle's DBMS_OUTPUT.PUT_LINE feature.

```
psql=> SET CLIENT_MIN_MESSAGES = 'debug';
-- Equivalent To Oracle SET SERVEROUTPUT ON

psql=> DO $$
       BEGIN
            RAISE DEBUG USING MESSAGE := 'hello world';
       END $$;

DEBUG:  hello world
DO
```

2. Use the client_min_messages parameter to control the level of message **sent to the client.** The default is NOTICE. Use the log_min_messages parameter to control which message levels are written to the **server log.** The default is WARNING.

```
SET CLIENT_MIN_MESSAGES = 'debug';
```

For additional details:
https://www.postgresql.org/docs/current/static/plpgsql-errors-and-messages.html

For additional details:
https://www.postgresql.org/docs/current/static/runtime-config-logging.html#GUC-LOG-MIN-MESSAGES

Oracle DBMS_OUTPUT.PUT_LINE vs. PostgreSQL RAISE

Feature	Oracle	PostgreSQL
Disables message output **Enables message output**	DISABLE ENABLE	Configure "`client_min_message`" or "`log_min_message`" for the desired results
Retrieves one line from buffer **Retrieves an array of lines from buffer**	GET_LINE GET_LINES	Consider storing messages in an array or temporary table so that you can retrieve them from another procedure or package

Terminates a line created with PUT
Places a partial line in the buffer
	PUT + NEW_LINE
	BEGIN
	DBMS_OUTPUT.PUT ('1,');
	DBMS_OUTPUT.PUT('2,');
	DBMS_OUTPUT.PUT('3,');
	DBMS_OUTPUT.PUT('4');
	DBMS_OUTPUT.NEW_LINE();
	END;
	/
		Store and concatenate the message string in a varchar variable before raising
		
		do $$
		DECLARE
		 message varchar :='';
		begin
		   message := message \|\| '1,';
		   message := message \|\| '2,';
		   message := message \|\| '3,';
		   message := message \|\| '4';
		   RAISE NOTICE '%', message;
		END$$;

Places line in buffer	PUT_LINE DBMS_OUTPUT.PUT_LINE ('The employee id is:' || v_jobid || ' and his last name is:' || v_lastname);	RAISE RAISE NOTICE 'The employee id is: % and his last name is: %', v_jobid, v_lastname;

Returns the number code of the most recent exception
Returns the error message associated with its error-number argument.
	SQLCODE + SQLERRM
	
	DECLARE
	Name employees.last_name%TYPE;
	BEGIN
	   SELECT last_name INTO name
	     FROM employees WHERE
	      employee_id = -1;
	   EXCEPTION
	      WHEN OTHERS then
	DBMS_OUTPUT.PUT_LINE('Error code ' || SQLCODE || ': ' || sqlerrm);
	END;
	/
		SQLSTATE + SQLERRM
		
		do $$
		declare
		   Name employees%ROWTYPE;
		BEGIN
		   SELECT last_name INTO name
		     FROM employees WHERE
		      employee_id = -1;
		   EXCEPTION
		      WHEN OTHERS then
		            RAISE NOTICE 'Error code %: %', sqlstate, sqlerrm;
		end$$;

For additional details:
https://www.postgresql.org/docs/9.6/static/errcodes-appendix.html

Migrating from: Oracle Procedures and Functions

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Overview

Oracle PL/SQL is Oracle's built-in database programming language providing several methods to store and execute reusable business logic from within the database. Procedures and functions are reusable snippets of code created using the `CREATE PROCEDURE` and the `CREATE FUNCTION` statements.

Stored Procedures and Stored Functions are PL/SQL units of code consisting of SQL and PL/SQL statements that solve specific problems or perform a set of related tasks.

- Procedure – used to perform database actions with PL/SQL.
- Function – used to perform a calculation and return a result.

Privileges for Creating Procedures and Functions

- To create procedures and functions in their own schema, Oracle database users must have the `CREATE PROCEDURE` system privilege.
- To create procedures or functions in other schemas, the database user must have the `CREATE ANY PROCEDURE` privilege.
- To execute a procedure or function, the database user must have the `EXECUTE` privilege.

Package and Package Body

In addition to stored procedures and functions, Oracle also provides "Packages" that encapsulate related procedures, functions, and other program objects.

- Package: declares and describes all the related PL/SQL elements.
- Package body: contains the executable code.

To execute a stored procedure or function created inside a package, the ***package name*** and the ***stored procedure or function*** name must be specified.

```
SQL> EXEC PKG_EMP.CALCULTE_SAL('100');
```

Examples

1. Create an Oracle stored procedure using the CREATE OR REPLACE PROCEDUER statement. The optional OR REPLACE clause overwrites an existing stored procedure with the same name, if exists.

```
SQL> CREATE OR REPLACE PROCEDURE EMP_SAL_RAISE
     (P_EMP_ID IN NUMBER, SAL_RAISE IN NUMBER)
      AS
      V_EMP_CURRENT_SAL NUMBER;
      BEGIN
        SELECT SALARY INTO V_EMP_CURRENT_SAL FROM EMPLOYEES WHERE
        EMPLOYEE_ID=P_EMP_ID;

          UPDATE EMPLOYEES
          SET SALARY=V_EMP_CURRENT_SAL+SAL_RAISE
          WHERE EMPLOYEE_ID=P_EMP_ID;

        DBMS_OUTPUT.PUT_LINE('New Salary For Employee ID: '||P_EMP_ID||' Is
        '||(V_EMP_CURRENT_SAL+SAL_RAISE));

        EXCEPTION WHEN OTHERS THEN
            RAISE_APPLICATION_ERROR(-20001,'An error was encountered -
            '||SQLCODE||' -ERROR- '||SQLERRM);
            ROLLBACK;

        COMMIT;
      END;
/

-- Execute

SQL> EXEC EMP_SAL_RAISE(200, 1000);
```

2. Create a function using the CREATE OR REPLACE FUNCTION statement:

```
SQL> CREATE OR REPLACE FUNCTION EMP_PERIOD_OF_SERVICE_YEAR
      (P_EMP_ID NUMBER)
      RETURN NUMBER
      AS
      V_PERIOD_OF_SERVICE_YEARS NUMBER;
      BEGIN
        SELECT EXTRACT(YEAR FROM SYSDATE) - EXTRACT(YEAR FROM TO_DATE(HIRE_DATE))
      INTO V_PERIOD_OF_SERVICE_YEARS
        FROM EMPLOYEES
        WHERE EMPLOYEE_ID=P_EMP_ID;

        RETURN V_PERIOD_OF_SERVICE_YEARS;
      END;
/

SQL> SELECT EMPLOYEE_ID,
       FIRST_NAME,
       EMP_PERIOD_OF_SERVICE_YEAR(EMPLOYEE_ID) AS PERIOD_OF_SERVICE_YEAR
     FROM EMPLOYEES;

SQL> EMPLOYEE_ID FIRST_NAME           PERIOD_OF_SERVICE_YEAR
     ----------- -------------------- ----------------------
        174 Ellen                                  13
        166 Sundar                                  9
        130 Mozhe                                  12
        105 David                                  12
        204 Hermann                                15
        116 Shelli                                 12
        167 Amit                                    9
        172 Elizabeth                              10
…
```

3. Create a Package using the CREATE OR REPLACE PACKAGE statement:

```
SQL> CREATE OR REPLACE PACKAGE PCK_CHINOOK_REPORTS
     AS
       PROCEDURE GET_ARTIST_BY_ALBUM(P_ARTIST_ID ALBUM.TITLE%TYPE);
       PROCEDURE CUST_INVOICE_BY_YEAR_ANALYZE;
END;
```

4. Create a new Package using the CREATE OR REPLACE PACKAGE BODY statement:

```
SQL> CREATE OR REPLACE PACKAGE BODY PCK_CHINOOK_REPORTS
      AS
      PROCEDURE GET_ARTIST_BY_ALBUM(P_ARTIST_ID ALBUM.TITLE%TYPE)
      IS
            V_ARTIST_NAME ARTIST.NAME%TYPE;
      BEGIN
            SELECT ART.NAME INTO V_ARTIST_NAME
            FROM ALBUM ALB JOIN ARTIST ART USING(ARTISTID)
            WHERE ALB.TITLE=P_ARTIST_ID;

            DBMS_OUTPUT.PUT_LINE('ArtistName: '||V_ARTIST_NAME);
      END;

      PROCEDURE CUST_INVOICE_BY_YEAR_ANALYZE
      AS
            V_CUST_GENRES VARCHAR2(200);
      BEGIN
            FOR V IN(SELECT CUSTOMERID, CUSTNAME, LOW_YEAR, HIGH_YEAR, CUST_AVG
            FROM TMP_CUST_INVOICE_ANALYSE)
            LOOP
              IF SUBSTR(V.LOW_YEAR, -4) > SUBSTR(V.HIGH_YEAR , -4) THEN

                  SELECT LISTAGG(GENRE, ',') WITHIN GROUP (ORDER BY
                  GENRE) INTO V_CUST_GENRES
                  FROM (SELECT DISTINCT
                        FUNC_GENRE_BY_ID(TRC.GENREID) AS GENRE
                        FROM TMP_CUST_INVOICE_ANALYSE TMPTBL JOIN INVOICE INV
                        USING(CUSTOMERID)
                  JOIN INVOICELINE INVLIN
                  ON INV.INVOICEID = INVLIN.INVOICEID
                  JOIN TRACK TRC
                  ON TRC.TRACKID = INVLIN.TRACKID
                  WHERE CUSTOMERID=V.CUSTOMERID);

                DBMS_OUTPUT.PUT_LINE('Customer: '||UPPER(V.CUSTNAME)||' -
                Offer a Discount According To Preferred Genres:
               '||UPPER(V_CUST_GENRES));
              END IF;
            END LOOP;
          END;
      END;


SQL> EXEC PCK_CHINOOK_REPORTS.GET_ARTIST_BY_ALBUM();
SQL> EXEC PCK_CHINOOK_REPORTS.CUST_INVOICE_BY_YEAR_ANALYZE;
```

The above examples demonstrate basic Oracle PL/SQL procedure and function capabilities. Oracle PL/SQL provides a vast number of features and capabilities that are not within the scope of this document.

For additional details:
https://docs.oracle.com/cd/E18283_01/appdev.112/e17126/create_procedure.htm
https://docs.oracle.com/database/121/LNPLS/create_procedure.htm
https://docs.oracle.com/cd/E18283_01/appdev.112/e17126/create_function.htm
https://docs.oracle.com/database/121/LNPLS/create_function.htm#LNPLS01370
https://docs.oracle.com/database/121/LNPLS/create_package.htm#LNPLS01371

Migration to: PostgreSQL Functions

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Overview

PostgreSQL version 9.6 provides support for both stored procedures and stored functions using the CREATE FUNCTION statement. To emphasize, the procedural statements used by PostgreSQL version 9.6 support the CREATE FUNCTION statement only. The CREATE PROCEDURE statement is ***not compatible with this PostgreSQL version.***

PL/pgSQL is the main database programming language used for migrating from Oracle's PL/SQL code. PostgreSQL support additional programming languages, also available in Amazon Aurora PostgreSQL:

- *PL/pgSQL*
- *PL/Tcl*
- *PL/Perl*

Use the `psql=> show.rds.extensions` command to view all available extensions for Amazon Aurora.

Interchangeability Between Oracle PL/SQL and PostgreSQL PL/pgSQL

PostgreSQL's PL/pgSQL language is often considered the ideal candidate to migrate from Oracle's PL/SQL code because many of the Oracle PL/SQL syntax elements are supported by PostgreSQL PL/pgSQL code.

For example, Oracle's CREATE OR REPLACE PROCEDURE statement ***is supported*** by PostgreSQL PL/pgSQL. Many other PL/SQL syntax elements are also supported making PostgreSQL and PL/pgSQL natural alternatives when migrating from Oracle.

PostgreSQL create function privileges

To create a function, a user must have USAGE privilege on the language. When creating a function, a language parameter can be specified as shown in the examples.

Examples

Converting Oracle Stored Procedures and Functions to PostgreSQL PL/pgSQL:

1. Use the PostgreSQL CREATE FUNCTION command to create a new function named **FUNC_ALG**:

```
psql=> CREATE OR REPLACE FUNCTION FUNC_ALG(P_NUM NUMERIC)
       RETURNS NUMERIC
       AS $$
       BEGIN
            RETURN P_NUM * 2;
       END; $$
       LANGUAGE PLPGSQL;
```

- Using a CREATE OR REPLACE statement creates a new function, or replaces an *existing* function, with these limitations:
  - You cannot change the function name or argument types.
  - The statement does not allow changing the existing function return type.
  - The user must own the function to replace it.

- `INPUT parameter (P_NUM)` is implemented similarly to Oracle's PL/SQL INPUT parameter.
- The `$$` signs are used to prevent the need to use single-quoted string escape elements. With the `$$` sign, there is no need to use escape characters in the code when using single quotation marks ('). The `$$` sign appears after the keyword AS and after the function keyword END.
- Use the `LANGUAGE PLPGSQL` parameter to specify the language for the created function.

2. Convert the Oracle EMP_SAL_RAISE PL/SQL function to PostgreSQL PL/pgSQL:

```
psql=> CREATE OR REPLACE FUNCTION EMP_SAL_RAISE
       (IN P_EMP_ID DOUBLE PRECISION, IN SAL_RAISE DOUBLE PRECISION)
        RETURNS VOID
        AS $$
        DECLARE
           V_EMP_CURRENT_SAL DOUBLE PRECISION;
        BEGIN
           SELECT SALARY INTO STRICT V_EMP_CURRENT_SAL
           FROM EMPLOYEES WHERE EMPLOYEE_ID = P_EMP_ID;

           UPDATE EMPLOYEES
           SET SALARY = V_EMP_CURRENT_SAL + SAL_RAISE
           WHERE EMPLOYEE_ID = P_EMP_ID;

            RAISE DEBUG USING MESSAGE := CONCAT_WS('', 'NEW SALARY FOR EMPLOYEE ID: ', P_EMP_ID, ' IS
            ', (V_EMP_CURRENT_SAL + SAL_RAISE));

           EXCEPTION
               WHEN OTHERS THEN
                   RAISE USING ERRCODE := '20001', MESSAGE :=
        CONCAT_WS('', 'AN ERROR WAS ENCOUNTERED - ', SQLSTATE, ' -ERROR-
        ', SQLERRM);
        END; $$
        LANGUAGE  PLPGSQL;

       psql=> select emp_sal_raise(200, 1000);
```

3. Convert the Oracle EMP_PERIOD_OF_SERVICE_YEAR PL/SQL function to PostgreSQL PL/pgSQL:

```
psql=> CREATE OR REPLACE FUNCTION EMP_PERIOD_OF_SERVICE_YEAR
       (IN P_EMP_ID DOUBLE PRECISION)
        RETURNS DOUBLE PRECISION
        AS $$
       DECLARE
            V_PERIOD_OF_SERVICE_YEARS DOUBLE PRECISION;
        BEGIN
            SELECT
               EXTRACT (YEAR FROM NOW()) - EXTRACT (YEAR FROM (HIRE_DATE))
               INTO STRICT V_PERIOD_OF_SERVICE_YEARS
               FROM EMPLOYEES
               WHERE EMPLOYEE_ID = P_EMP_ID;
            RETURN V_PERIOD_OF_SERVICE_YEARS;
        END; $$
        LANGUAGE  PLPGSQL;

psql=> SELECT EMPLOYEE_ID,
         FIRST_NAME,
         EMP_PERIOD_OF_SERVICE_YEAR(EMPLOYEE_ID) AS
                 PERIOD_OF_SERVICE_YEAR
        FROM EMPLOYEES;
```

Oracle Packages and Package Bodies

PostgreSQL version 9.6 does not support Oracle Packages and Package Bodies. All PL/SQL objects must be converted to PostgreSQL functions. The following examples describe how the Amazon Schema Conversion Tool (SCT) handles Oracle Packages and Package Body names:

Oracle:

- Package Name: PCK_CHINOOK_REPORTS
- Package Body: GET_ARTIST_BY_ALBUM

```
SQL> EXEC PCK_CHINOOK_REPORTS.GET_ARTIST_BY_ALBUM('');
```

PostgreSQL (converted using Amazon SCT):

- The $ sign separates the package and the package name.

```
psql=> SELECT PCK_CHINOOK_REPORTS$GET_ARTIST_BY_ALBUM('');
```

Examples

Convert an Oracle Package and Package Body to PostgreSQL PL/pgSQL:

1. Oracle Package - PCK_CHINOOK_REPORT, Oracle Package Body - GET_ARTIST_BY_ALBUM:

```
psql=> CREATE OR REPLACE FUNCTION
       chinook."PCK_CHINOOK_REPORTS$GET_ARTIST_BY_ALBUM"
       (p_artist_id text)
       RETURNS void
       LANGUAGE plpgsql
       AS $function$
       DECLARE
           V_ARTIST_NAME CHINOOK.ARTIST.NAME%TYPE;
       BEGIN
           SELECT
               art.name
               INTO STRICT V_ARTIST_NAME
               FROM chinook.album AS alb
               JOIN chinook.artist AS art
               USING (artistid)
               WHERE alb.title = p_artist_id;
           RAISE DEBUG USING MESSAGE := CONCAT_WS('', 'ArtistName: ',
           V_ARTIST_NAME);
       END;
       $function$;

-- Procedures (Packages) Verification
psql=> set client_min_messages = 'debug';
-- Equivalent to Oracle SET SERVEROUTPUT ON

psql=> select chinook.pck_chinook_reports$get_artist_by_album(' Fireball’);
```

2. Oracle Package - `PCK_CHINOOK_REPORTS`, Oracle Package Body - `CUST_INVOICE_BY_YEAR_ANALYZE`:

```
psql=> CREATE OR REPLACE FUNCTION
 chinook."pck_chinook_reports$cust_invoice_by_year_analyze"()
 RETURNS void
 LANGUAGE plpgsql
 AS $function$
 DECLARE
    v_cust_genres CHARACTER VARYING(200);
    v RECORD;
 BEGIN
    FOR v IN
    SELECT
        customerid, custname, low_year, high_year, cust_avg
        FROM chinook.tmp_cust_invoice_analyse
    LOOP
        IF SUBSTR(v.low_year, - 4) > SUBSTR(v.high_year, - 4) THEN

 -- Altering Oracle LISTAGG Function With  PostgreSQL STRING_AGG
    Function
            select string_agg(genre, ',') into v_cust_genres
                      from (
                      select distinct
                             chinook.func_genre_by_id(trc.genreid)
                             as genre
                      from chinook.tmp_cust_invoice_analyse tmptbl
                      join chinook.INVOICE inv using(customerid)
                      join chinook.INVOICELINE invlin
                      on inv.invoiceid = invlin.invoiceid
                      join chinook.TRACK trc
                      on trc.trackid = invlin.trackid
                      where customerid=v.CUSTOMERID) a;

 -- PostgreSQL Equivalent To Oracle DBMS_OUTPUT.PUT_LINE()
    RAISE DEBUG USING MESSAGE := CONCAT_WS('', 'Customer: ',
    UPPER(v.custname), ' - Offer a Discount According To Preferred
    Genres: ', UPPER(v_cust_genres));
        END IF;
    END LOOP;
 END;
 $function$;

-- Executing
psql=> SELECT chinook.pck_chinook_reports$cust_invoice_by_year_analyze();
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createfunction.html
https://www.postgresql.org/docs/9.6/static/plpgsql.html
https://www.postgresql.org/docs/9.6/static/xplang.html
https://www.postgresql.org/docs/9.6/static/xfunc-sql.html

Migrating from: Oracle UDFs

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Overview

You can create an Oracle User-Defined Function (UDF) using PL/SQL, Java, or C. UDFs are useful for providing functionality not available in SQL or SQL built-in functions. They can appear in your SQL statements wherever built-in SQL functions appear.

UDFs Usage:

- Can be used to return a single value from a `SELECT` statement (scalar function).
- Can be used while performing DML operations.
- Can be used in `WHERE, GROUP BY, ORDER BY, HAVING, CONNECT BY,` and `START WITH` clauses.

Example

Create a simple Oracle UDF that receives each employee's `HIRE_DATE` and `SALARY` values as INPUT parameters and calculates the overall salary over the employee's years of service for the company.

```
SQL> CREATE OR REPLACE FUNCTION TOTAL_EMP_SAL_BY_YEARS
     (p_hire_date DATE, p_current_sal NUMBER)
       RETURN NUMBER
AS
v_years_of_service NUMBER;
v_total_sal_by_years NUMBER;
BEGIN
  SELECT EXTRACT(YEAR FROM SYSDATE) - EXTRACT(YEAR FROM to_date(p_hire_date))
         INTO v_years_of_service FROM dual;

  v_total_sal_by_years:=p_current_sal*v_years_of_service;
  RETURN v_total_sal_by_years;
END;
/

-- Verifying
SQL> SELECT EMPLOYEE_ID,
       FIRST_NAME,
       TOTAL_EMP_SAL_BY_YEARS(HIRE_DATE, SALARY)AS TOTAL_SALARY
     FROM EMPLOYEES;  2    3    4

EMPLOYEE_ID FIRST_NAME           TOTAL_SALARY
----------- -------------------- ------------
        100 Steven                     364000
        101 Neena                      204000
        102 Lex                        272000
        103 Alexander                   99000
        104 Bruce                       60000
        105 David                       57600
        …
```

For additional details:

https://docs.oracle.com/cd/E24693_01/server.11203/e17118/functions256.htm

Migration to: PostgreSQL User-Defined Functions

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Overview

PostgreSQL supports the creation of User-Defined Functions using the `CREATE FUNCTION` statement. The PostgreSQL extended SQL language, **PL/pgSQL**, is the primary language to use while migrating from Oracle's PL/SQL User-Defined Functions.

PostgreSQL Create Function Privileges

To create a function, a user must have USAGE privilege on the language.

Example

Convert the Oracle User-Defined Function from the previous Oracle section to a PostgreSQL PL/pgSQL function:

```
psql=> CREATE OR REPLACE FUNCTION total_emp_sal_by_years
        (P_HIRE_DATE DATE, P_CURRENT_SAL NUMERIC)
        RETURNS NUMERIC
        AS
        $BODY$
        DECLARE
        V_YEARS_OF_SERVICE NUMERIC;
        V_TOTAL_SAL_BY_YEARS NUMERIC;
        BEGIN
         SELECT EXTRACT(YEAR FROM NOW()) - EXTRACT(YEAR FROM
        (P_HIRE_DATE)) INTO V_YEARS_OF_SERVICE;

         V_TOTAL_SAL_BY_YEARS:=P_CURRENT_SAL*V_YEARS_OF_SERVICE;
         RETURN V_TOTAL_SAL_BY_YEARS;
       END;
       $BODY$
       LANGUAGE  PLPGSQL;


psql=> SELECT EMPLOYEE_ID,
         FIRST_NAME,
         TOTAL_EMP_SAL_BY_YEARS(HIRE_DATE, SALARY)AS TOTAL_SALARY
        FROM EMPLOYEES;

        employee_id | first_name  | total_salary
       -------------+-------------+--------------
                100 | Steven      |    364000.00
                101 | Neena       |    204000.00
                102 | Lex         |    272000.00
                103 | Alexander   |     99000.00
                104 | Bruce       |     60000.00
                105 | David       |     57600.00
                106 | Valli       |     52800.00
                107 | Diana       |     42000.00
       …
```

For additional details:

https://www.postgresql.org/docs/current/static/xfunc.html
https://www.postgresql.org/docs/9.6/static/sql-createfunction.html
http://docs.aws.amazon.com/SchemaConversionTool/latest/userguide/Welcome.html

Migrating from: Oracle UTL_FILE

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Overview

Oracle's UTL_FILE PL/SQL package enables you to read and write files stored outside of the database server, such as files stored on the O/S, your database server, or a connected storage volume. The UTL_FILE.FOPEN, UTL_FILE.GET_LINE, and UTL_FILE .PUT_LINE are procedures within the UTL_FILE package used to open, read, and write files.

Example

Run an anonymous PL/SQL block that reads a single line from file1 and writes it to file2.

- Use **UTL_FILE.FILE_TYPE** to create a handle for the file.
- Use **UTL_FILE.FOPEN** to open streamable access to the file and specify:
  - The logical Oracle directory object that was created pointing to the O/S folder where the file resides.
  - The file name.
  - The file access mode:
    - A: append mode.
    - W: write mode.
- Use **UTL_FILE.GET_LINE** to read a line from the input file into a variable.
- Use **UTL_FILE.PUT_LINE** to write a single line to the output file.

```
DECLARE
  strString1 VARCHAR2(32767);
  fileFile1 UTL_FILE.FILE_TYPE;
BEGIN
  fileFile1 := UTL_FILE.FOPEN('FILES_DIR','File1.tmp','R');
  UTL_FILE.GET_LINE(fileFile1,strString1);
  UTL_FILE.FCLOSE(fileFile1);
  fileFile1 := UTL_FILE.FOPEN('FILES_DIR','File2.tmp','A');
  utl_file.PUT_LINE(fileFile1,strString1);
  utl_file.fclose(fileFile1);
END;
/
```

For additional details:
https://docs.oracle.com/database/121/ARPLS/u_file.htm

Migration to:

Amazon Aurora PostgreSQL does not support a direct comparable alternative for Oracle UTL_FILE.

Migrating from: Oracle JSON Document Support

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Overview

JSON documents are based on JavaScript syntax and allow serialization of objects. Oracle support for JSON document storage and retrieval enables you to extend the database capabilities beyond purely relational use-cases and allows the Oracle database to support semi-structured data. Oracle JSON support also includes full-text search and several other functions dedicated to querying JSON documents.

Additional details:
http://www.oracle.com/technetwork/database/soda-wp-2531583.pdf

Examples

Create a table to store a JSON document in a `data` column and insert a JSON document into the table:

```
CREATE TABLE json_docs (
  id    RAW(16) NOT NULL,
  data  CLOB,
  CONSTRAINT json_docs_pk PRIMARY KEY (id),
  CONSTRAINT json_docs_json_chk CHECK (data IS JSON)
);
INSERT INTO json_docs (id, data)
VALUES (SYS_GUID(),
        '{
          "FName"      : "John",
          "LName"       : "Doe",
         "Address"        : {
                              "Street"   : "101 Street",
                              "City"     : "City Name",
                              "Country"  : "US",
                              "Pcode" : "90210"
                             }
         }');
```

Unlike XML data, which is stored using the SQL data type XMLType, JSON data is stored in an Oracle Database using the SQL data types VARCHAR2, CLOB, and BLOB. Oracle recommends that you always use an **is_json** check constraint to ensure the column values are valid JSON instances. Or, add a constraint at the table-level (`CONSTRAINT json_docs_json_chk CHECK (data IS JSON)`).

You can query a JSON document directly from a SQL query without the use of special functions. Querying without functions is called *Dot Notation*.

```
SELECT a.data.FName,
       a.data.LName,
       a.data.Address.Pcode AS Postcode
FROM   json_docs a;


FNAME          LNAME          POSTCODE
--------------- --------------- ----------
John            Doe             90210


1 row selected.
```

In addition, Oracle provides multiple SQL functions that integrate with the SQL language and enable querying JSON documents (such as **IS JSON**, **JSON_VAUE**, **JSON_EXISTS** , **JSON_QUERY** , and **JSON_TABLE**).

For additional details:
http://docs.oracle.com/database/121/ADXDB/json.htm#ADXDB6246

Migration to: PostgreSQL JSON Support

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Overview

PostgreSQL provides native JSON Document support using the JSON data types JSON and JSONB**.**

JSON: Stores an exact copy of the input text, which processing functions must reparse on each execution. It also preserves semantically-insignificant white space between tokens and the order of keys within JSON objects.

JSONB: Stores data in a decomposed binary format causing slightly slower input performance due to added conversion to binary overhead. But, it is significantly faster to process since no reparsing is needed on reads.

- Does not preserve white space.
- Does not preserve the order of object keys.
- Does not keep duplicate object keys. If duplicate keys are specified in the input, only the last value is retained.

Most applications store JSON data as JSONB unless there are specialized needs.

For additional information about the differences between JSON and JSOB datatypes:
https://www.postgresql.org/docs/9.6/static/datatype-json.html

In order to adhere to the full JSON specification, database encoding must be set to UTF8. If the database codepage is set to non-UTF8, characters that can be represented in the database encoding, but not in UTF8, are allowed. This condition is not desirable.

Creating JSON Tables in PostgreSQL and Inserting Data:

1. Create a PostgreSQL table named json_docs with a single JSON column:

```
CREATE TABLE json_docs (data jsonb);
```

2. Create a PostgreSQL table named employees with two scalar datatype columns and a single JSON column:

```
CREATE TABLE employees (emp_id int, emp_name varchar(100), emp_data jsonb);
```

3. Insert JSON data into the table:

```
INSERT INTO employees VALUES (1, 'First Employee',
'{ "address": "1234 First Street, Capital City", "phone numbers": { "home":
"123456789", "mobile": "98765431" } }');
```

Oracle uses VARCHAR/BLOB/CLOB data types to store JSON data, but PostgreSQL uses the special JSON and JSONB data types. Validations of proper JSON formats are performed during insert. You cannot store invalid JSON in a JSON/JSONB data type.

Query JSON/JSONB data with operators

Querying JSON data in PostgreSQL uses different query syntax from Oracle – you must change application queries. Examples of PostgreSQL-native JSON query syntax are provided below:

1. Return the JSON document stored in the `emp_data` column associated with `emp_id=1`:

```
SELECT emp_data FROM employees WHERE emp_id = 1;
```

2. Return all JSON documents stored in the `emp_data` column having a **key** named `address`:

```
SELECT emp_data FROM employees WHERE emp_data ? ' address';
```

3. Return all JSON items that have an `address` key **or** a `hobbies` key:

```
SELECT * FROM employees WHERE emp_data ?| array['address', 'hobbies'];
```

4. Return all JSON items that have both an `address` key **and** a `hobbies` key:

```
SELECT * FROM employees WHERE emp_data ?& array['a', 'b'];
```

5. Return the **value** of `home` **key** in the `phone numbers` array:

```
SELECT emp_data ->'phone numbers'->>'home' FROM employees;
```

6. Return all JSON documents where the `address` **key** is equal to a specified value and return all JSON documents where `address` **key** contains a specific string (using `like`):

```
SELECT * FROM employees WHERE emp_data->>'address' = '1234 First Street,
Capital City';

SELECT * FROM employees WHERE emp data->>'address' like '%Capital City%';
```

For additional details:
https://www.postgresql.org/docs/9.6/static/functions-json.html

Oracle vs. PostgreSQL JSON Support

Feature	Oracle (Dot-Notation)	PostgreSQL
Return the full JSON document / all JSON documents	`emp_data` is a column that stores json documents: `SELECT emp_data FROM employees;`	`emp_data` is a column that stores JSON documents: `SELECT emp_data FROM employees;`

Return a specific element from a JSON document	Return only the address property:
	
	`SELECT e.emp_data.address`
	`FROM employees e;`
		Return only the address property, for emp_id 1 from the emp_data JSON column in the employees table:
		
		`select emp_data->>'address'`
		`from employees`
		`where emp_id = 1;`

Return JSON documents matching a pattern in any field	Return the JSON based on a search of on all JSON properties. Could be returned even if element is equal to the pattern
	
	`SELECT e.emp_data FROM employees e`
	`WHERE e.emp_data like '%patten%';`
		Either use jsonb_pretty to flatten the JSON and search or, preferably, convert it to text and make like search on value
		
		`select *`
		`from`
		`(select jsonb_pretty(emp_data) as raw_data`
		`from employees) raw_jason`
		`where raw_data like '%1234%';`
		
		`SELECT key, value FROM card, lateral jsonb_each_text(data)`
		`WHERE value LIKE '%pattern%';`

Return JSON documents matching a pattern in specific fields (root level)	`SELECT e.emp_data.name`
	`FROM employees e`
	`WHERE e.data.active = 'true';`
		Only return results where the "finished" property in the JSON document is true:
		
		`SELECT * FROM employees`
		`WHERE emp_data->>'active' = 'true';`

Define a column in a table that supports JSONB documents	1. Create a table with a CLOB column.
	2. Define an "IS JSON" constraint on the column.
	
	`CREATE TABLE json_docs`
	`(id RAW(16) NOT NULL,`
	`data  CLOB,`
	`CONSTRAINT json_docs_pk PRIMARY KEY (id),`
	`CONSTRAINT json_docs_json_chk CHECK (data IS JSON)`
	`);`
		1. Create a table with a column defined as JSON:
		
		`CREATE TABLE json_docs (`
		`id integer NOT NULL,`
		`data jsonb`
		`);`

Indexing and Constraints with JSONB Columns

You can use the `CREATE UNIQUE INDEX` statement to enforce constraints on values inside JSON documents stored in PostgreSQL. For example, you can create a unique index that forces **values** of the `address` **key** to be unique.

```
CREATE UNIQUE INDEX employee_address_uq ON employees( (emp_data->>'address') ) ;
```

This index allows the first SQL insert statement to work and causes the second to fail:

```
INSERT INTO employees VALUES (2, 'Second Employee',
'{ "address": "1234 Second Street, Capital City"}');

INSERT INTO employees VALUES (3, 'Third Employee',
'{ "address": "1234 Second Street, Capital City"}');

ERROR: duplicate key value violates unique constraint "employee_address_uq" SQL
state: 23505 Detail: Key ((emp_data ->> 'address'::text))=(1234 Second Street,
Capital City) already exists.
```

For JSON data, PostgreSQL Supports B-Tree, HASH, and GIN indexes (Generalized Inverted Index). A GIN index is a special inverted index structure that is useful when an index must map many values to a row (such as indexing JSON documents).

When using GIN indexes, you can efficiently and quickly query data using **only the following JSON operators:** `@>, ?, ?&, ?|`

Without indexes, PostgreSQL is forced to perform a full table scan when filtering data. This condition applies to JSON data and will most likely have a negative impact on performance since Postgres has to step into each JSON document.

1. Create an index on the address key of `emp_data`:

```
CREATE  idx1_employees ON employees ((emp_data->>'address'));
```

2. Create a GIN index on a specific key or the entire `emp_data` column:

```
CREATE INDEX idx2_employees ON cards USING gin ((emp_data->'tags'));

CREATE INDEX idx3 employees ON employees USING gin (emp data);
```

For additional details:
https://www.postgresql.org/docs/9.6/static/datatype-json.html
https://www.postgresql.org/docs/9.6/static/functions-json.html

Migrating from: Oracle OLAP Functions

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Overview

Oracle OLAP functions extend the functionality of standard SQL analytic functions by providing capabilities to compute aggregate values based on a group of rows. You can apply the OLAP functions to logically "partitioned" sets of results within the scope of a single query expression. OLAP functions are usually used in combination with Business Intelligence reports and analytics. They can help boost query performance – an alternative to achieving the same result using more complex non-OLAP SQL code.

Common Oracle OLAP Functions:

Function Type	Related Functions
Aggregate	average_rank, avg, count, dense_rank, max, min, rank ,sum
Analytic	average_rank, avg, count, dense_rank, lag, lag_variance, lead_variance_percent, max, min, rank, row_number, sum, percent_rank, cume_dist, ntile, first_value, last_value
Hierarchical	hier_ancestor, hier_child_count,, hier_depth, hier_level, hier_order, hier_parent, hier_top
Lag	lag, lag_variance, lag_variance_percent, lead, lead_variance, lead_variance_percent
OLAP DML	olap_dml_expression
Rank	average_rank ,dense_rank, rank, row_number

For additional details:
https://docs.oracle.com/cd/E11882_01/olap.112/e23381/olap_functions.htm#OLAXS169
https://docs.oracle.com/database/121/OLAXS/olap_functions.htm#OLAXS174

Migration to: PostgreSQL Window Functions

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Overview

PostgreSQL refers to ANSI SQL analytical functions as "Window Functions". They provide the same core functionality as SQL Analytical Functions and Oracle extended OLAP functions. Window functions in PostgreSQL operate on a logical "partition" or "window" of the result set and return a value for rows in that "window".

From a database migration perspective, you should examine PostgreSQL Window Functions by type and compare them with the equivalent Oracle's OLAP functions to verify compatibility of syntax and output.

Note: Even if a PostgreSQL window function provides the same functionality of a specific Oracle OLAP function, the returned data type may be different and require application changes.

PostgreSQL provides support for two main types of Window Functions:

- Aggregation functions.
- Ranking functions.

PostgreSQL Window Functions by Type:

Function Type	Related Functions
Aggregate	avg, count, max, min, sum, string_agg
Ranking	row_number, rank, dense_rank, percent_rank, cume_dist, ntile, lag, lead, first_value, last_value, nth_value

Oracle's OLAP Functions vs. PostgreSQL Window Functions:

Oracle OLAP Function	Returned Data Type	PostgreSQL Window Function	Returned Data Type	Compatible Syntax
count	number	count	bigint	**Yes**
max	number	max	numeric, string, date/time, network or enum type	**Yes**
min	number	min	numeric, string, date/time, network or enum type	**Yes**
avg	number	avg	numeric, double, otherwise same datatype as the argument	**Yes**
sum	number	sum	bigint, otherwise same datatype as the argument	**Yes**
rank()	number	rank()	bigint	**Yes**
row_number()	number	row_number()	bigint	**Yes**
dense_rank()	number	dense_rank()	bigint	**Yes**
percent_rank()	number	percent_rank()	double	**Yes**
cume_dist()	number	cume_dist()	double	**Yes**
ntile()	number	ntile()	integer	**Yes**
lag()	same type as value	lag()	same type as value	**Yes**

Oracle OLAP Function	Returned Data Type	PostgreSQL Window Function	Returned Data Type	Compatible Syntax
`lead()`	same type as value	`lead()`	same type as value	**Yes**
`first_value()`	same type as value	`first_value()`	same type as value	**Yes**
`last_value()`	same type as value	`last_value()`	same type as value	**Yes**

Example

The Oracle `rank()` function & PostgreSQL `rank()` function providing the same results

Oracle:

```
SQL> SELECT department_id, last_name, salary, commission_pct,
     RANK() OVER (PARTITION BY department_id
     ORDER BY salary DESC, commission_pct) "Rank"
     FROM employees WHERE department_id = 80;

     DEPARTMENT_ID LAST_NAME                        SALARY COMMISSION_PCT       Rank
     ------------- ------------------------- ---------- -------------- ----------
                80 Russell                         14000             .4          1
                80 Partners                        13500             .3          2
                80 Errazuriz                       12000             .3          3
…
```

PostgreSQL:

```
hr=# SELECT department_id, last_name, salary, commission_pct,
     RANK() OVER (PARTITION BY department_id
     ORDER BY salary DESC, commission_pct) "Rank"
     FROM employees WHERE department_id = 80;

    DEPARTMENT_ID LAST_NAME                        SALARY COMMISSION_PCT       Rank
    ------------- ------------------------- ---------- -------------- ----------
               80 Russell                      14000.00           0.40          1
               80 Partners                     13500.00           0.30          2
               80 Errazuriz                    12000.00           0.30          3…
```

Note: The returned formatting for certain numeric data types is different.

Oracle CONNECT BY Equivalent in PostgreSQL:

PostgreSQL provides two workarounds as alternatives to Oracle's hierarchical statements such as the `CONNECT BY` function:

- Use PostgreSQL `generate_series` function.
- Use PostgreSQL recursive views.

  For more information:
  https://www.postgresql.org/docs/9.6/static/sql-createview.html

Example

PostgreSQL `generate_series` function:

```
demo=> SELECT "DATE"
       FROM generate_series(timestamp '2010-01-01',
                            timestamp '2017-01-01',
                            interval '1 day') s("DATE");

              DATE
      ---------------------
       2010-01-01 00:00:00
       2010-01-02 00:00:00
       2010-01-03 00:00:00
       2010-01-04 00:00:00
       2010-01-05 00:00:00
      …
```

For additional details:
https://www.postgresql.org/docs/9.6/static/functions-window.html
https://www.postgresql.org/docs/9.6/static/functions-aggregate.html

Extended Support for Analytic Queries and OLAP

For advanced analytic purposes and use cases, consider using **Amazon Redshift** as a purpose-built data warehouse cloud solution. You can run complex analytic queries against petabytes of structured data using sophisticated query optimization, columnar storage on high-performance local disks, and massive parallel query execution. Most results are returned in seconds.

Amazon Redshift is specifically designed for online analytic processing (OLAP) and business intelligence (BI) applications, which require complex queries against large datasets. Because it addresses very different requirements, the specialized data storage schema and query execution engine that Amazon Redshift uses is completely different from the PostgreSQL implementation. For example, Amazon Redshift stores data in ***columns***, also known as a columnar-store database.

Amazon Redshift Window functions by type:

Function Type	Related Functions
Aggregate	AVG COUNT CUME_DIST FIRST_VALUE LAG LAST_VALUE LEAD MAX MEDIAN MIN NTH_VALUE PERCENTILE_CONT PERCENTILE_DISC RATIO_TO_REPORT STDDEV_POP STDDEV_SAMP (synonym for STDDEV) SUM VAR_POP VAR_SAMP (synonym for VARIANCE)
Ranking	DENSE_RANK NTILE PERCENT_RANK RANK ROW_NUMBER

For additional details:
http://docs.aws.amazon.com/redshift/latest/dg/c_Window_functions.html
http://docs.aws.amazon.com/redshift/latest/dg/r_Window_function_examples.html

Migrating from: Oracle PL/SQL Cursors

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Overview

PL/SQL cursors are pointers to data sets on which application logic can iterate. A PL/SQL cursor holds the rows returned by a SQL statement. Using cursors, PL/SQL code can iterate over the rows and execute business logic one row at a time. You can refer to the active data set in *named* cursors from inside a program.

There are two types of cursors in PL/SQL:

1. **Implicit Cursors** – Session cursors constructed and managed by PL/SQL automatically without being created or defined by the user. PL/SQL opens an implicit cursor each time you run a SELECT or DML statement. Implicit cursors are also called “SQL Cursors”.

2. **Explicit Cursors** – Session cursors created, constructed, and managed by a user. You declare and define an explicit cursor giving it a name and associating it with a query. Unlike an implicit cursor, you can reference an explicit cursor using its name. An explicit cursor or cursor variable is called a “named cursor”.

When migrating Oracle PL/SQL Cursors to PostgreSQL, most of the focus is on application-controlled (or programmatically-controlled) cursors, which are Explicit Cursors.

Examples

1. Define an **explicit** PL/SQL cursor named `c1`.
2. The cursor executes an SQL statement to return rows from the database.
3. The PL/SQL Loop reads data from the cursor, row by row, and stores the values into two variables:
    - `v_lastname`
    - `v_jobid`
4. The loop terminates when the last row is read from the database using the `%NOTFOUND` attribute.

```
DECLARE
  CURSOR c1 IS
    SELECT last_name, job_id FROM employees
    WHERE REGEXP_LIKE (job_id, 'S[HT]_CLERK')
    ORDER BY last_name;
  v_lastname  employees.last_name%TYPE;  -- variable to store last_name
  v_jobid     employees.job_id%TYPE;     -- variable to store job_id
BEGIN
  OPEN c1;
  LOOP  -- Fetches 2 columns into variables
    FETCH c1 INTO v_lastname, v_jobid;
    EXIT WHEN c1%NOTFOUND;
  END LOOP;
  CLOSE c1;
END;
```

1. Define an **implicit** PL/SQL Cursor using a FOR Loop.
2. The cursor executes a query and stores values returned into a record.
3. A loop iterates over the Cursor data set and prints the result.

```
BEGIN
  FOR item IN (
    SELECT last_name, job_id
    FROM employees
    WHERE job_id LIKE '%MANAGER%'
    AND manager_id > 400
    ORDER BY last_name
  )
  LOOP
    DBMS_OUTPUT.PUT_LINE
      ('Name = ' || item.last_name || ', Job = ' || item.job_id);
  END LOOP;
END;
/
```

For additional details:
https://docs.oracle.com/database/121/LNPLS/explicit_cursor.htm#LNPLS01313
https://docs.oracle.com/database/121/LNPLS/static.htm#GUID-596C1961-5A94-40ED-9920-668BB05632C5

Migration to: PostgreSQL PL/pgSQL Cursors

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Overview

Similar to Oracle PL/SQL Cursors, PostgreSQL has PL/pgSQL cursors that enable you to iterate business logic on rows read from the database. They can encapsulate the query and read the query results a few rows at a time. All access to cursors in PL/pgSQL is performed through cursor variables, which are always of the `refcursor` data type.

Create a PL/pgSQL cursor by declaring it as a variable of type `refcursor`.

Example: Declare a Cursor

1. Declare a Cursor in PL/pgSQL to be used with any query:

```
DECLARE
      c1 refcursor;
```

   The variable `c1` is *unbound* since it is not bound to any particular query.

2. Declare a Cursor in PL/pgSQL with a bound query:

```
DECLARE
      c2 CURSOR FOR SELECT * FROM employees;
```

   `FOR` can be replaced by `IS` for Oracle compatibility:

```
DECLARE
      c2 CURSOR IS SELECT * FROM employees;
```

3. Declare a Cursor in PL/pgSQL with a *parameterized* bound query:

```
DECLARE
      c3 CURSOR (var1 integer) FOR SELECT * FROM employees where id = var1;
```

   - The `id` variable is replaced by an integer parameter value when the cursor is opened.
   - When declaring a Cursor with `SCROLL` specified, the Cursor can scroll backwards.
   - If `NO SCROLL` is specified, backward fetches are rejected.

4. Declare a backward-scrolling compatible Cursor using the `SCROLL` option:

```
DECLARE
      c3 SCROLL CURSOR FOR SELECT id, name FROM employees;
```

   Notes:
   - `SCROLL` specifies that rows can be retrieved backwards. `NO SCROLL` specifies that rows cannot be retrieved backwards.
   - Depending upon the complexity of the execution plan for the query, `SCROLL` might create performance issues.
   - Backward fetches are not allowed when the query includes `FOR UPDATE` or `FOR SHARE`.

Example: Open a Cursor
You must open a cursor before you can use it to retrieve rows.

1. *Open a Cursor variable* ***that was declared as Unbound*** *and specify the query to execute:*

```
BEGIN
      OPEN c1 FOR SELECT * FROM employees WHERE id = emp_id;
```

2. Open a Cursor variable ***that was declared as Unbound*** and specify the query to execute as a string expression. This approach provides greater flexibility.

```
BEGIN
    OPEN c1 FOR EXECUTE format('SELECT * FROM %I WHERE col1 =
$1',tabname) USING keyvalue;
```

Parameter values can be inserted into the dynamic command using `format()` and `USING`. For example, the table name is inserted into the query using `format()`. The comparison value for `col1` is inserted using a `USING` parameter.

3. Open a Cursor that was **bound to a query** when the Cursor was declared and that was **declared to take arguments.**

```
DO $$
DECLARE
      c3 CURSOR (var1 integer) FOR SELECT * FROM employees where id = var1;
BEGIN
      OPEN c3(var1 := 42);
END$$;
```

For the `c3` Cursor, supply the argument value expressions.

If the Cursor was not declared to take arguments, the arguments can be specified outside the Cursor:

```
DO $$
DECLARE
      var1 integer;
      c3 CURSOR FOR SELECT * FROM employees where id = var1;
BEGIN
      var1 := 1;
      OPEN c3;
END$$;
```

Example: Fetch a Cursor

The PL/pgSQL FETCH command retrieves the next row from the Cursor into a variable.

1. Fetch the values returned from the c3 Cursor into a **row variable**:

```
DO $$
DECLARE
      c3 CURSOR FOR SELECT * FROM employees;
      rowvar employees%ROWTYPE;
BEGIN
    OPEN c3;
    FETCH c3 INTO rowvar;
END$$;
```

2. Fetch the values returned from the c3 Cursor into two scalar datatypes:

```
DO $$
DECLARE
      c3 CURSOR FOR SELECT id, name FROM employees;
      emp_id integer;
      emp_name varchar;
BEGIN
    OPEN c3;
    FETCH c3 INTO emp_id, emp_name;
END$$;
```

3. PL/pgSQL supports a special direction clause when fetching data from a Cursor using the NEXT, PRIOR, FIRST, LAST, ABSOLUTE count, RELATIVE count, FORWARD, or BACKWARD arguments. Omitting direction is equivalent to as specifying NEXT. For example, fetch the last row from the Cursor into the declared variables:

```
DO $$
DECLARE
      c3 CURSOR FOR SELECT id, name  FROM employees;
      emp_id integer;
      emp_name varchar;
BEGIN
    OPEN c3;
    FETCH LAST FROM c3 INTO emp_id, emp_name;
END$$;
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-fetch.html

Example: Close a Cursor

Close a PL/pgSQL cursor using the `close` command:

```
DO $$
DECLARE
    c3 CURSOR FOR SELECT id, name  FROM employees;
    emp_id integer;
    emp_name varchar;
BEGIN
    OPEN c3;
    FETCH LAST FROM c3 INTO emp_id, emp_name;
    close c3;
END$$;
```

Example: Iterating Through a Cursor

PL/pgSQL supports detecting when a cursor has no more data to return and can be combined with loops to iterate over all rows of a Cursor reference.

The following PL/pgSQL code uses a loop to fetch all rows from the Cursor and then exit after the last record is fetched (using `EXIT WHEN NOT FOUND`):

```
DO $$
DECLARE
      c3 CURSOR FOR SELECT * FROM employees;
      rowvar employees%ROWTYPE;
BEGIN
      OPEN c3;
      LOOP
            FETCH FROM c3 INTO rowvar;
            EXIT WHEN NOT FOUND;
      END LOOP;
      CLOSE c3;
END$$;
```

Example: Move Cursor Without Fetching Data

`MOVE` repositions a cursor without retrieving any data and works exactly like the `FETCH` command, except it only repositions the cursor in the dataset and does not return the row to which the cursor is moved. The special variable `FOUND` can be checked to determine if there is a next row.

1. Move to the last row (null or no data found) for cursor `c3`:

   ```
   MOVE LAST FROM c3;
   ```

2. Move the Cursor two records back:

   ```
   MOVE RELATIVE -2 FROM c3;
   ```

3. Move the `c3` Cursor two records forward.

   ```
   MOVE FORWARD 2 FROM c3;
   ```

Example: Update/Delete Current

When a cursor is positioned on a table row, that row can be updated or deleted. There are restrictions on what the cursor's query can select for this type of DML to succeed.

For example, the current row to which the C3 Cursor is pointed to is updated:

```
UPDATE employee SET salary = salary*1.2 WHERE CURRENT OF c3;
```

Example: Use an Implicit Cursor (FOR Loop Over Queries)

```
DO $$
DECLARE
        item RECORD;
BEGIN
  FOR item IN (
    SELECT last_name, job_id
    FROM employees
    WHERE job_id LIKE '%MANAGER%'
    AND manager_id > 400
    ORDER BY last_name
  )
  LOOP
    RAISE NOTICE 'Name = %, Job=%', item.last_name, item.job_id;
  END LOOP;
END $$;
```

Comparing Oracle PL/SQL and PostgreSQL PL/pgSQL syntax:

Action	PostgreSQL PL/pgSQL	Oracle PL/SQL
Declare a bound explicit cursor	`c2 CURSOR FOR SELECT * FROM employees;`	`CURSOR c1 IS SELECT * FROM employees;`
Open a cursor	`OPEN c2;`	`OPEN c1;`
Move Cursor to next row and fetch into a record variable (rowvar was declared in the DECLARE section)	`FETCH c2 INTO rowvar;`	`FETCH c1 INTO rowvar;`
Move Cursor to next row and fetch into multiple scalar data types (emp_id, emp_name, salary was declared in the DECLARE section)	`FETCH c2 INTO emp_id, emp_name, salary;`	`FETCH c1 INTO emp_id, emp_name, salary;`
Iterate through an Implicit Cursor via a Loop	**`FOR item IN ( SELECT last_name, job_id FROM employees`**	**`FOR item IN ( SELECT last_name, job_id FROM employees`**

Action	PostgreSQL PL/pgSQL	Oracle PL/SQL

	WHERE job_id LIKE '%CLERK%'
	AND manager_id > 120
	ORDER BY last_name
	)
	LOOP
	`<< do something >>`
	`END LOOP;`
		WHERE job_id LIKE '%CLERK%'
		AND manager_id > 120
		ORDER BY last_name
		)
		LOOP
		`<< do something >>`
		`END LOOP;`

Declare a cursor with variables	`C2 CURSOR (key integer) FOR SELECT * FROM employees WHERE id = key;`	`CURSOR c1 (key NUMBER) IS SELECT * FROM employees WHERE id = key;`
Open a cursor with variables	`OPEN c2(2);` **or** `OPEN c2(key := 2);`	`OPEN c1(2);`
Exit a loop after no data found	`EXIT WHEN NOT FOUND;`	`EXIT WHEN c1%NOTFOUND;`
Detect if a Cursor has rows remaining in its dataset	`FOUND`	`%FOUND`
Determine how many rows were affected from any DML statement	Not Supported but you can run with every DML `GET DIAGNOSTICS integer_var = ROW_COUNT;` and save the results in an array	`%BULK_ROWCOUNT`
Determine which DML execution failed with the relevant error code	-	`%BULK_EXCEPTIONS`
Detect if the Cursor is open	-	`%ISOPEN`
Detect if a Cursor has *no* rows remaining in its dataset	`NOT FOUND`	`%NOTFOUND`
Returns the number of rows affected by a Cursor	`GET DIAGNOSTICS integer_var = ROW_COUNT;`	`%ROWCOUNT`

For additional information on PostgreSQL Pl/pgSQL:
https://www.postgresql.org/docs/current/static/plpgsql-cursors.html
https://www.postgresql.org/docs/current/static/plpgsql-statements.html

Migrating from: Oracle Single-Row and Aggregative Functions

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Overview

Oracle provides two main categories of built-in SQL functions based on the amount of rows used as input and generated as output.

- **Single-row functions** (also known as Scalar Functions) return a single result for each row of the queried table or view. The implementation of single-row functions can be performed with a `SELECT` statement in the `WHERE` clause, the `START WITH` clause, the `CONNECT BY` clause, and the `HAVING` clause.

  The single-row functions are divided into groups according to the datatypes, such as:

  - `NUMERIC` functions.
  - `CHAR` functions.
  - `DATETIME` functions.

- **Aggregative functions** (also known as Group functions) are used to summarize a group of values into a single result. Examples include: `AVG, MIN, MAX, SUM, COUNT, LISTAGG, FIRST,` and `LAST.`

See the next section for a comparison of Oracle and PostgreSQL single-row functions.

For additional details:
https://docs.oracle.com/database/121/SQLRF/functions002.htm#SQLRF20031
https://docs.oracle.com/database/121/SQLRF/functions003.htm#SQLRF20035

Migration to: PostgreSQL Single-Row and Aggregative Functions

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Overview

PostgreSQL provides an extensive list of single-row and aggregative functions. Some functions are similar to their Oracle counterparts (by name and functionality, or under a different name but with similar functionality). Other functions can have identical names to their Oracle counterparts but offer different functionality. The "Equivalent" column in the table below indicates functional equivalency.

Oracle Function	Function Definition	PostgreSQL Function	Function Definition	Equivalent
		NUMERIC FUNCTIONS		
ABS	Absolute value of n: `abs (-11.3) --> 11.3`	ABS(n)	Absolute value of n: `abs (-11.3) --> 11.3`	Yes
CEIL	Returns the smallest integer that is greater than or equal to n: `ceil (-24.9) --> -24`	CEIL / CEILING	Returns the nearest integer greater than or equal to argument: `ceil (-24.9) --> -24`	Yes
FLOOR	Returns the largest integer equal to or less than n: `floor (-43.7) --> -44`	FLOOR	Returns nearest integer less than or equal to argument: `floor (-43.7) --> -44`	Yes
MOD	Remainder of n2 divided by n1: `mod(10,3) --> 1`	MOD	Remainder of y/x: `mod (10,3) --> 1`	Yes
ROUND	Returns n rounded to integer places to the right of the decimal point: `round (3.49, 1) --> 3.5`	ROUND	Round to nearest integer: `round (3.49, 1) --> 3.5`	Yes
TRUNC (Number)	Returns n1 truncated to n2 decimal places: `trunc(13.5) --> 13`	TRUNC (Number)	Truncate to s decimal places: `trunc (13.5) --> 13`	Yes
		CHARACTER FUNCTIONS		
CONCAT	Returns char1 concatenated with char2: `concat('a', 1) --> a1`	CONCAT	Concatenate the text representations of all the arguments: `concat('a', 1) --> a1` Also, can use the (||) operators: `select 'a' ||' '|| 'b' --> a b`	Partly
LOWER / UPPER	Returns char, with all letters lowercase or uppercase: `lower ('MR. Smith') --> mr. smith`	LOWER / UPPER	Convert string to lower or upper case: `lower ('MR. Smith') --> mr. smith`	Yes

LPAD / RPAD	Returns expr1, left or right padded to length n characters with the sequence of characters in expr2: `LPAD('Log-1',10,'*') --> *****Log-1`	LPAD	Fill up the string to length by prepending the characters fill left or right: `LPAD('Log-1',10,'*') --> *****Log-1`	Yes
REGEXP_REPLACE	Search a string for a regular expression pattern: `regexp_replace('John', '[hn].', '1') --> Jo1`	REGEXP_REPLACE	Replace substring(s) matching a POSIX regular expression: `regexp_replace('John', '[hn].', '1') --> Jo1`	Yes
REGEXP_SUBSTR	Extends the functionality of the SUBSTR function by searching a string for a regular expression pattern: `REGEXP_SUBSTR('http://www.aws.com/products','http://([[:alnum:]]+\.?){3,4}/?') --> http://www.aws.com/`	REGEXP_MATCHES OR SUBSTRING	Return all captured substrings resulting from matching a POSIX regular expression against the string: `REGEXP_MATCHES ('http://www.aws.com/products', '(http://[[:alnum:]]+.*/)') --> {http://www.aws.com/}` **OR** `SUBSTRING ('http://www.aws.com/products', '(http://[[:alnum:]]+.*/)') --> http://www.aws.com/`	No
REPLACE	Returns char with every occurrence of search string replaced with a replacement string: `replace ('abcdef', 'abc', '123') --> 123def`	REPLACE	Replace all occurrences in string of substring from with substring to: `replace ('abcdef', 'abc', '123') --> 123def`	Yes
LTRIM / RTRIM	Removes from the left or right end of char all of the characters that appear in set: `ltrim('zzzyaws', 'xyz') --> aws`	LTRIM / RTRIM	Remove the longest string containing only characters from characters (a space by default) from the start of string: `ltrim('zzzyaws', 'xyz') --> aws`	Yes
SUBSTR	Return a portion of char, beginning at character position, substring length characters long:	SUBSTRING	Extract substring: `substring ('John Smith', 6 ,1) --> S`	No

	`substr('John Smith', 6 ,1) --> S`			
TRIM	Trim leading or trailing characters (or both) from a character string: `trim (both 'x' FROM 'xJohnxx') --> John`	TRIM	Remove the longest string containing only characters from characters (a space by default) from the start, end, or both ends: `trim (both from 'yxJohnxx', 'xyz') --> John`	Partly
ASCII	Returns the decimal representation in the database character set of the first character of char: `ascii('a') --> a`	ASCII	ASCII code of the first character of the argument: `ascii('a') --> a`	Yes
INSTR	Search string for substring	N/A	Oracle's INSTR function can be simulated using PostgreSQL built-in function.	No
LANGTH	Return the length of char: `length ('John S.') --> 7`	LANGTH	Number of characters in string: `length ('John S.')  --> 7`	Yes
REGEXP_COUNT	Returning the number of times, a pattern occurs in a source string.	N/A	The REGEXP_COUNT function can be used with Amazon Redshift if necessary.	No
REGEXP_INSTR	Search a string position for a regular expression pattern.	N/A	The REGEXP_INSTR function can be used with Amazon Redshift if necessary.	No
		DATETIME FUNCTIONS		
ADD_MONTHS	Returns the date plus integer months: `add_months( sysdate, 1)`		PostgreSQL can implement the same functionality using the '<date>+ interval month' statement: `now () + interval '1 month'`	No
CURRENT_DATE	Returns the current date in the session time zone: `select current_date from dual --> 2017-01-01 13:01:01`	CURRENT_DATE	PostgreSQL CURRENT_DATE will return date with no time, use the now() or the current_timestamp function to achieve the same results: `select current_timestamp --> 2017-01-01 13:01:01`	Partly

CURRENT_TIMESTAMP	Returns the current date and time in the session time zone: select current timestamp from dual; `--> 2017-01-01 13:01:01`	CURRENT_TIMESTAMP	Current date and time: `select current_timestamp; --> 2017-01-01 13:01:01`	Yes
EXTRACT (date part)	Returns the value of a specified datetime field from a datetime or interval expression: `EXTRACT (YEAR FROM DATE '2017-03-07') --> 2017`	EXTRACT (date part)	Retrieves subfields such as year or hour from date/time values: `EXTRACT (YEAR FROM DATE '2017-03-07') --> 2017`	Yes
LAST_DAY	Returns the date of the last day of the month that contains date	N/A	The LAST_DAY function can be used with Amazon Redshift if necessary or can be created using PostgreSQL built-in functions.	No
MONTHS_BETWEEN	Returns number of months between dates date1 and date2: `MONTHS_BETWEEN ( sysdate, sysdate-100) --> 3.25`	N/A	As an alternative solution create a function from PostgreSQL built-in functions to achieve the same functionality. Example for a possible solution without decimal values: `DATE_PART ('month', now()) - DATE_PART('month', now()- interval '100 days')--> 3`	No
SYSDATE	Returns the current date and time set for the operating system on which the database server resides: `select sysdate from dual --> 2017-01-01 13:01:01`	NOW()	Current date and time including fractional seconds and time zone: `select now () --> 2017-01-01 13:01:01.123456+00`	No
SYSTIMESTAMP	Returns the system date, including fractional seconds and time zone: `Select systimestamp from dual --> 2017-01-01 13:01:01.123456 PM +00:00`	NOW()	Current date and time including fractional seconds and time zone: select now () --> `2017-01-01 13:01:01.123456+00`	No
LOCALTIMESTAMP	Returns the current date and time in the session time zone in a value of data type TIMESTAMP:	LOCALTIMESTAMP	Current date and time: `select localtimestamp --> 2017-01-01 10:01:10.123456`	Yes

	`select localtimestamp from dual --> 01-JAN-17 10.01.10.123456 PM`			
TO_CHAR (datetime)	Converts a datetime or timestamp to data type to a value of VARCHAR2 data type in the format specified by the date format: `to_char(sysdate, 'DD-MON-YYYY HH24:MI:SS') --> 01-JAN-2017 01:01:01`	TO_CHAR (datetime)	Convert time stamp to string: TO_CHAR(now(), 'DD-MON-YYYY HH24:MI:SS') --> `01-JAN-2017 01:01:01`	Yes
TRUNC (date)	Returns date with the time portion of the day truncated to the unit specified by the format model: `trunc(systimestamp) --> 2017-01-01 00:00:00`	DATE_TRUNC	Truncate to specified precision: `date_trunc('day', now()) --> 2017-01-01 00:00:00`	No
		ENCODING AND DECODING FUNCTIONS		
DECODE	Compares expr to each search value one by one using the functionality of an IF-THEN-ELSE statement	DECODE	PostgreSQL Decode function acts differently from Oracle's, PostgreSQL decode binary data from textual representation in string and does not have the functionality of an IF-THEN-ELSE statement	No
DUMP	Returns a VARCHAR2 value containing the data type code, length in bytes, and internal representation of expr.	N/A	N/A	No
ORA_HASH	Computes a hash value for a given expression.	N/A	N/A	No
		NULL FUNCTIONS		
CASE	The CASE statement chooses from a sequence of conditions and runs a corresponding statement: `CASE WHEN condition THEN result`	CASE	The PostgreSQL CASE expression is a generic conditional expression, similar to if/else statements in other programming languages:	Yes

	`[WHEN ...]`
	`[ELSE result]`
	`END`
			`CASE WHEN condition THEN result`
			`[WHEN ...]`
			`[ELSE result]`
			`END`	

COALESCE	Returns the first non-null expr in the expression list: `coalesce (null, 'a', 'b') --> a`	COALESCE	Returns the first of its arguments that is not null: `coalesce (null, 'a', 'b') --> a`	Yes
NULLIF	Compares expr1 and expr2. If they are equal, then the function returns null. If they are not equal, then the function returns expr1: `NULLIF('a', 'b') --> a`	NULLIF	Returns a null value if value1 equals value2 otherwise it returns value1: `NULLIF ('a', 'b') --> a`	Yes
NVL	Replace null (returned as a blank) with a string in the results of a query: `NVL (null, 'a') --> a`	COALESCE	Returns the first of its arguments that is not null: `coalesce (null, 'a') --> a`	No
NVL2	Determine the value returned by a query based on whether a specified expression is null or not null.	N/A	Can use the CASE statement instead.	No
ENVIRONMENT AND IDENTIFIER FUNCTIONS				
SYS_GUID	Generates and returns a globally unique identifier (RAW value) made up of 16 bytes: `select sys_guid() from dual --> 5A280ABA8C76201EE0530100007FF691`	UUID_GENERATE_V1()	Generates a version 1 UUID: `select uuid_generate_v1() --> 90791a6-a359-11e7-a61c-12803bf1597a`	No
UID	Returns an integer that uniquely identifies the session user (the user who logged on): `select uid from dual --> 84`	N/A	Consider using the PostgreSQL current_user function along with other PostgreSQL buit-in function to generate a UID.	No

USER	Returns the name of the session user:
	`select user from dual`
		USER
		SESSION_USER
		CURRENT_USER
		CURRENT_SCHEMA()
			User name or schema of current execution context:
			`Select user;`
			`or`
			`select current_schema();`
				No

USERENV	Returns information about the current session using parameters: `SELECT USERENV('LANGUAGE') "Language" FROM DUAL`	N/A	Please refer to the PostgreSQL documentation for a list of all system functions: https://www.postgresql.org/docs/9.1/static/functions-info.html	No
		CONVERSION FUNCTIONS		
CAST	Converts one built-in data type or collection-typed value into another built-in data type or collection-typed value: `cast ('10' as int) + 1 --> 11`	CAST	Converting one data type into another: `cast ('10' as int) + 1 --> 11`	Yes
CONVERT	Converts a character string from a one-character set to another: `select convert ('Ä Ê Í Õ Ø A B C D E ', 'US7ASCII', 'WE8ISO8859P1') from dual`	N/A	N/A	No
TO_CHAR (string / numeric)	Converts NCHAR, NVARCHAR2, CLOB, or NCLOB data to the database character set: `select to_char('01234') from dual --> 01234`	TO_CHAR	Converts the first argument to the second argument: `select to_char(01234, '00000') --> 01234`	No
TO_DATE	Converts char of CHAR, VARCHAR2, NCHAR, or NVARCHAR2 data type to a value of DATE data type: `to_date('01Jan2017', 'DDMonYYYY') --> 01-JAN-17`	TO_DATE	Convert string to date: `to_date('01Jan2017', 'DDMonYYYY') --> 2017-01-01`	Partly

TO_NUMBER	Converts expr to a value of NUMBER data type:
	`to_number('01234') --> 1234`
	or
	`to_number('01234', '99999') --> 1234`
		TO_NUMBER	Convert string to numeric:
			`to_number('01234', '99999') --> 1234`
				Partly

		AGGREGATE FUNCTIONS		
AVG	AVG returns average value of expr: `select avg(salary) from employees`	AVG	Average (arithmetic mean) of all input values: `select avg(salary) from employees`	Yes

COUNT	Returns the number of rows returned by the query: `select count(*) from employees`	COUNT	The number of input rows: `select count(*) from employees`	Yes
LISTAGG	Orders data within each group specified in the ORDER BY clause and then concatenates the values of the measure column: `select listagg(firstname, ' ,') within group (order by customerid) from customer`	STRING_AGG	Input values concatenated into a string, separated by delimiter: `select string_agg(firstname, ' ,') from customer order by 1;`	No
MAX	Returns maximum value of expr: `select max(salary) from employees`	MAX	Maximum value of expression across all input values: `select max(salary) from employees`	Yes
MIN	Returns minimum value of expr: `select min(salary) from employees`	MIN	Minimum value of expression across all input values: `select min(salary) from employees`	Yes
SUM	Returns the sum of values of expr: `select sum(salary) from employees`	SUM	Sum of expression across all input values: `select sum(salary) from employees`	Yes
		Top-N Query Oracle 12c		
FETCH	Retrieves rows of data from the result set of a multi-row query: `select * from customer fetch first 10 rows only`	FETCH OR LIMIT	Retrieve just a portion of the rows that are generated by the rest of the query: `select * from customer fetch first 10 rows only`	Yes

For additional details:
https://www.postgresql.org/docs/current/static/functions.html
https://www.postgresql.org/docs/current/static/functions-math.html
https://www.postgresql.org/docs/current/static/functions-string.html
https://www.postgresql.org/docs/current/static/uuid-ossp.html

Migrating from: Oracle Merge SQL Syntax

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Overview

The MERGE statement provides a way to specify single SQL statements that can conditionally perform INSERT, UPDATE, or DELETE operations on the target table – a task that would otherwise require multiple logical statements. The MERGE statement selects record(s) from the source table and then, by specifying a logical structure, automatically performs multiple DML operations on the target table. Its main advantage is to help avoid the use of multiple inserts, updates or deletes. It is important to note that MERGE is a deterministic statement. That is, once a row has been processed by the MERGE statement, it cannot be processed again using the same MERGE Statement. MERGE is also sometimes known as UPSERT.

Example

Using Oracle MERGE to insert or update employees who are entitled to a bonus (by year):

```
SQL> CREATE TABLE EMP_BONUS
    (
     EMPLOYEE_ID NUMERIC,
     BONUS_YEAR VARCHAR2(4),
     SALARY NUMERIC,
     BONUS NUMERIC,
     PRIMARY KEY (EMPLOYEE_ID, BONUS_YEAR)
    );

SQL> MERGE INTO EMP_BONUS E1
     USING (SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
            FROM EMPLOYEES) E2
     ON (E1.EMPLOYEE_ID = E2.EMPLOYEE_ID)
     WHEN MATCHED THEN
          UPDATE SET E1.BONUS = E2.SALARY * 0.5
     DELETE WHERE (E1.SALARY >= 10000)
     WHEN NOT MATCHED THEN
       INSERT (E1.EMPLOYEE_ID, E1.BONUS_YEAR, E1.SALARY , E1.BONUS)
       VALUES (E2.EMPLOYEE_ID, EXTRACT(YEAR FROM SYSDATE), E2.SALARY,
               E2.SALARY * 0.5)
       WHERE (E2.SALARY < 10000);

SQL> SELECT * FROM EMP_BONUS;

EMPLOYEE_ID BONU     SALARY      BONUS
----------- ---- ---------- ----------
        103 2017       9000       4500
        104 2017       6000       3000
        105 2017       4800       2400
        106 2017       4800       2400
        107 2017       4200       2100
        109 2017       9000       4500
        110 2017       8200       4100
        111 2017       7700       3850
        112 2017       7800       3900
        113 2017       6900       3450
        115 2017       3100       1550
```

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28286/statements_9016.htm#SQLRF01606

Migration to: PostgreSQL Merge SQL Syntax

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Overview

Currently, PostgreSQL version 9.6 does not support the use of the MERGE SQL command. As an alternative, consider using the `INSERT… ON CONFLICT` clause, which can handle cases where insert clauses might cause a conflict, and then redirect the operation as an update.

Example

Using the `ON ONFLICT` clause to handle a similar scenario as shown for the Oracle MERGE command:

```
demo=> CREATE TABLE EMP_BONUS (
       EMPLOYEE_ID NUMERIC,
       BONUS_YEAR VARCHAR(4),
       SALARY NUMERIC,
       BONUS NUMERIC,
       PRIMARY KEY (EMPLOYEE_ID, BONUS_YEAR));

demo=> INSERT INTO EMP_BONUS (EMPLOYEE_ID, BONUS_YEAR, SALARY)
       SELECT EMPLOYEE_ID,
              EXTRACT(YEAR FROM NOW()),
              SALARY
       FROM   EMPLOYEES
       WHERE  SALARY < 10000
       ON CONFLICT (EMPLOYEE_ID, BONUS_YEAR)
       DO UPDATE SET BONUS = EMP_BONUS.SALARY * 0.5;

demo=> SELECT * FROM EMP_BONUS;

 employee_id | bonus_year | salary  |  bonus
-------------+------------+---------+----------
         103 | 2017       | 9000.00 | 4500.000
         104 | 2017       | 6000.00 | 3000.000
         105 | 2017       | 4800.00 | 2400.000
         106 | 2017       | 4800.00 | 2400.000
         107 | 2017       | 4200.00 | 2100.000
         109 | 2017       | 9000.00 | 4500.000
         110 | 2017       | 8200.00 | 4100.000
         111 | 2017       | 7700.00 | 3850.000
         112 | 2017       | 7800.00 | 3900.000
         113 | 2017       | 6900.00 | 3450.000
         115 | 2017       | 3100.00 | 1550.000
         116 | 2017       | 2900.00 | 1450.000
         117 | 2017       | 2800.00 | 1400.000
         118 | 2017       | 2600.00 | 1300.000
…
```

Running the same operation multiple times using the `ON CONFLICT` clause does not generate an error because the existing records are redirected to the update clause.

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-insert.html
https://www.postgresql.org/docs/9.6/static/unsupported-features-sql-standard.htm

Migrating from: Oracle Create Table as Select (CTAS)

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Overview

To create a new table based on an existing table, use the Create Table As Select (CTAS) statement. The CTAS statement copies the table DDL definitions (column names and column datatypes) and the data to a new table. The new table is populated from the columns specified in the `SELECT` statement, or all columns if you use `SELECT * FROM`. You can filter specific data using the `WHERE` and `AND` statements. Additionally, you can create a new table having a different structure using joins, `GROUP BY`, and `ORDER BY`.

Example

Oracle Create Table As Select (CTAS):

```
SQL> CREATE TABLE EMPS
     AS
     SELECT * FROM EMPLOYEES;
```

```
SQL> CREATE TABLE EMPS
     AS
     SELECT EMPLOYEE_ID, FIRST_NAME, SALARY FROM EMPLOYEES
     ORDER BY 3 DESC;
```

Migration to: PostgreSQL Create Table As Select (CTAS)

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Overview

PostgreSQL conforms to the ANSI/SQL standard for CTAS functionality and is compatible with an Oracle CTAS statement. For PostgreSQL, the following CTAS standard elements are optional:

- The standard requires parentheses around the `SELECT` statement; PostgreSQL does not.
- The standard requires the `WITH [ NO ]` DATA clause; PostgreSQL does not.

PostgreSQL CTAS Synopsis

```
CREATE
[ [ GLOBAL | LOCAL ] { TEMPORARY | TEMP } | UNLOGGED ] TABLE [ IF NOT EXISTS ]
table_name
    [ (column_name [, ...] ) ]
    [ WITH ( storage_parameter [= value] [, ... ] ) |
WITH OIDS | WITHOUT OIDS ]
    [ ON COMMIT { PRESERVE ROWS | DELETE ROWS | DROP } ]
    [ TABLESPACE tablespace_name ]
    AS query
    [ WITH [ NO ] DATA ]
```

Examples

1. PostgreSQL CTAS:

```
pg_demo=> CREATE TABLE EMPS
          AS
          SELECT * FROM EMPLOYEES;
```

```
pg_demo=> CREATE TABLE EMPS
          AS
          SELECT EMPLOYEE_ID, FIRST_NAME, SALARY FROM EMPLOYEES
          ORDER BY 3 DESC;
```

2. PostgreSQL CTAS with no data:

```
pg_demo=> CREATE TABLE EMPS
          AS
          SELECT * FROM EMPLOYEES
          WITH NO DATA; -- optionally
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createtableas.html

Migrating from: Oracle Common Table Expression (CTE)

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Overview

Common Table Expressions provide a way to implement the logic of sequential code or to reuse code. You can define a named subquery and then use it multiple times in different parts of a query statement. CTE is implemented using a `WITH` clause, which is part of the ANSI SQL-99 standard and has existed in Oracle since version 9.2. CTE usage is similar to an inline view or a temporary table. Its main purpose is to reduce query statement repetition and make complex queries simpler to read and understand.

CTE General Syntax

```
WITH <subquery name> AS (
<subquery code>)
[...]
SELECT <Select list> FROM <subquery name>;
```

Example

Create a subquery of the employee count for each department and then use the result set of the CTE in a query:

```
SQL> WITH DEPT_COUNT
          (DEPARTMENT_ID, DEPT_COUNT) AS
     (
       SELECT DEPARTMENT_ID, COUNT(*)
       FROM   EMPLOYEES
       GROUP BY DEPARTMENT_ID
      )

     SELECT E.FIRST_NAME ||' '|| E.LAST_NAME AS EMP_NAME,
            D.DEPT_COUNT AS EMP_DEPT_COUNT
     FROM   EMPLOYEES E JOIN DEPT_COUNT D
     USING  (DEPARTMENT_ID)
     ORDER BY 2;
```

Migration to: PostgreSQL Common Table Expression (CTE)

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Overview

PostgreSQL confirms to the ANSI SQL-99 standard. Implementing CTEs in PostgreSQL is done in a similar way to Oracle as long as you are not using native Oracle elements (for example, `connect by`).

Example

A PostgreSQL CTE:

```
SQL> WITH DEPT_COUNT
          (DEPARTMENT_ID, DEPT_COUNT) AS
     (
       SELECT DEPARTMENT_ID, COUNT(*)
       FROM   EMPLOYEES
       GROUP BY DEPARTMENT_ID
      )

     SELECT E.FIRST_NAME ||' '|| E.LAST_NAME AS EMP_NAME,
            D.DEPT_COUNT AS EMP_DEPT_COUNT
     FROM   EMPLOYEES E JOIN DEPT_COUNT D
     USING  (DEPARTMENT_ID)
     ORDER BY 2;
```

PostgreSQL provides an additional feature when using CTE as a recursive modifier. The following example uses a recursive `WITH` clause to access its own result set:

```
demo=> WITH RECURSIVE t(n) AS (
       VALUES (0)
       UNION ALL
       SELECT n+1 FROM t WHERE n < 5
       )
       SELECT * FROM t;

WITH RECURSIVE t(n) AS (
    VALUES (0)
  UNION ALL
    SELECT n+1 FROM t WHERE n < 5
)
SELECT * FROM t;

 n
---
 0
 1
 2
 3
 4
 5
```

For additional details:
https://www.postgresql.org/docs/9.6/static/queries-with.html

Migrating from: Oracle Insert From Select

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Overview

You can insert multiple records into a table from another table using the `INSERT FROM SELECT` statement. The `INSERT FROM SELECT` statement is a derivative of the basic `INSERT` statement. The column ordering and data types must match between the target and the source tables.

Example

Simple `INSERT FROM SELECT` (Explicit):

```
SQL> INSERT INTO EMPS (EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID)
     SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
     FROM EMPLOYEES
     WHERE SALARY > 10000;
```

Simple `INSERT FROM SELECT` (Implicit):

```
SQL> INSERT INTO EMPS
     SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
     FROM EMPLOYEES
     WHERE SALARY > 10000;
```

The following example produces the same effect as the preceding example using a subquery in the DML_table_expression_clause:

```
SQL> INSERT INTO
     (SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID FROM EMPS)
     VALUES (120, 'Kenny', 10000, 90);
```

Logging Errors Using Oracle *error_logging_clause:*

```
SQL> ALTER TABLE EMPS ADD CONSTRAINT PK_EMP_ID PRIMARY KEY(employee_id);

SQL> EXECUTE DBMS_ERRLOG.CREATE_ERROR_LOG('EMPS', 'ERRLOG');

SQL> INSERT INTO EMPS
     SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
     FROM EMPLOYEES
     WHERE SALARY > 10000
     LOG ERRORS INTO errlog ('Cannot Perform Insert') REJECT LIMIT 100;

0 rows inserted
```

When inserting an existing `EMPLOYEE_ID` into the `EMPS` table, the insert does not fail because the invalid records are redirected to the `ERRLOG` table.

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28286/statements_9014.htm#SQLRF01604

Migration to: PostgreSQL Insert From Select

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Overview

PostgreSQL INSERT FROM SELECT syntax is mostly compatible with the Oracle syntax, except for a few Oracle-only features such as the *conditional_insert_clause* (ALL|FIRST|ELSE). Also, PostgreSQL does not support the Oracle *error_logging_clause*. As an alternative, PostgreSQL provides the ON CONFLICT clause to capture errors, perform corrective measures, or log errors.

PostgreSQL Insert Synopsis

```
[ WITH [ RECURSIVE ] with_query [, ...] ]
INSERT INTO table_name [ AS alias ] [ ( column_name [, ...] ) ]
    { DEFAULT VALUES | VALUES ( { expression | DEFAULT } [, ...] ) [, ...] | query
}
    [ ON CONFLICT [ conflict_target ] conflict_action ]
    [ RETURNING * | output_expression [ [ AS ] output_name ] [, ...] ]

where conflict_target can be one of:

    ( { index_column_name | ( index_expression ) } [ COLLATE collation ] [ opclass
] [, ...] ) [ WHERE index_predicate ]
    ON CONSTRAINT constraint_name

and conflict_action is one of:

    DO NOTHING
    DO UPDATE SET { column_name = { expression | DEFAULT } |
                    ( column_name [, ...] ) = ( { expression | DEFAULT } [, ...] )
|
                    ( column_name [, ...] ) = ( sub-SELECT )
                  } [, ...]
              [ WHERE condition ]
```

Example

1. Simple INSERT FROM SELECT (Explicit):

```
demo=> INSERT INTO EMPS (EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID)
       SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
       FROM EMPLOYEES
       WHERE SALARY > 10000;
```

2. Simple `Insert from Select` (Implicit):

```
demo=> INSERT INTO EMPS
       SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
       FROM EMPLOYEES
       WHERE SALARY > 10000;
```

3. The following example **is not compatible** with the supported syntax PostgreSQL:

```
demo=> INSERT INTO
       (SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID FROM EMPS)
       VALUES (120, 'Kenny', 10000, 90);
```

4. Using the PostgreSQL `ON CONFLICT` clause:

```
demo=> ALTER TABLE EMPS ADD CONSTRAINT PK_EMP_ID PRIMARY KEY(employee_id);

demo=> INSERT INTO EMPS
       SELECT EMPLOYEE_ID, FIRST_NAME, SALARY, DEPARTMENT_ID
       FROM EMPLOYEES
       WHERE SALARY > 10000
       ON CONFLICT on constraint PK_EMP_ID DO NOTHING;

INSERT 0
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-insert.html

Migrating from: Oracle Index-Organized Table (IOT)

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Overview

Oracle's Index-Organized Table (IOT) is a special type of index/table hybrid that *physically* controls how data is stored at the table and index level. A common table, or heap-organized table, stores the data unsorted (as a heap). In an Index-Organized Table, the actual table data is stored in a B-tree index structure sorted by the row's primary key. Each leaf block in the index structure stores both the primary key and non-key columns.

Index-Organized Table benefits include:

- The table records are sorted (clustered) using the primary key, which provides performance benefits. Accessing data using the primary key is faster because the key and data are located physically in the same structure.
- The total size of storage is reduced because primary key duplication is prevented.

Example

Create an Oracle Index-Organized Table storing "ordered" table data based on the PK_EVENT_ID primary key:

```
SQL> CREATE TABLE SYSTEM_EVENTS (
      EVENT_ID NUMBER,
      EVENT_CODE VARCHAR2(10) NOT NULL,
      EVENT_DESCIPTION VARCHAR2(200),
      EVENT_TIME DATE NOT NULL,
      CONSTRAINT PK_EVENT_ID PRIMARY KEY(EVENT_ID))
      ORGANIZATION INDEX;

SQL> INSERT INTO SYSTEM_EVENTS VALUES(9, 'EVNT-A1-10', 'Critical', '01-JAN-2017');
SQL> INSERT INTO SYSTEM_EVENTS VALUES(1, 'EVNT-C1-09', 'Warning',  '01-JAN-2017');
SQL> INSERT INTO SYSTEM_EVENTS VALUES(7, 'EVNT-E1-14', 'Critical', '01-JAN-2017');

SQL> SELECT * FROM SYSTEM_EVENTS;

  EVENT_ID EVENT_CODE EVENT_DESCIPTION               EVENT_TIM
---------- ---------- ------------------------------ ---------
         1 EVNT-C1-09 Warning                        01-JAN-17
         7 EVNT-E1-14 Critical                       01-JAN-17
         9 EVNT-A1-10 Critical                       01-JAN-17
```

Note: The EVENT_ID records are sorted in the reverse order from which they were inserted.

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28310/tables012.htm#ADMIN11684
https://docs.oracle.com/database/121/CNCPT/indexiot.htm#CNCPT721

Migration to: PostgreSQL “Cluster” Table

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Overview

PostgreSQL does not support IOTs directly, but offers partially similar functionality using the CLUSTER feature. The PostgreSQL CLUSTER statement specifies table sorting based on an index already associated with the table. When using the PostgreSQL CLUSTER command, the data in the table is physically sorted based on the index, possibly using a primary key column.

Note: Unlike an Oracle Index-Organized Table which is defined during table creation and persists data sorting (the IOT will always remain sorted), the PostgreSQL CLUSTER **does not** provide persistent sorting; it is a one-time operation. When the table is subsequently updated, the changes are not clustered/sorted.

The CLUSTER statement can be used as needed to re-cluster the table.

Example

Using the PostgreSQL CLUSTER command:

```
demo=> CREATE TABLE SYSTEM_EVENTS (
        EVENT_ID NUMERIC,
        EVENT_CODE VARCHAR(10) NOT NULL,
        EVENT_DESCIPTION VARCHAR(200),
        EVENT_TIME DATE NOT NULL,
        CONSTRAINT PK_EVENT_ID PRIMARY KEY(EVENT_ID));

demo=> INSERT INTO SYSTEM_EVENTS VALUES(9, 'EV-A1-10', 'Critical', '01-JAN-
2017');
demo=> INSERT INTO SYSTEM_EVENTS VALUES(1, 'EV-C1-09', 'Warning', '01-JAN-
2017');
demo=> INSERT INTO SYSTEM_EVENTS VALUES(7, 'EV-E1-14', 'Critical', '01-JAN-
2017');

demo=> CLUSTER SYSTEM_EVENTS USING PK_EVENT_ID;
demo=> SELECT * FROM SYSTEM_EVENTS;

 event_id | event_code | event_desciption | event_time
----------+------------+------------------+------------
        1 | EVNT-C1-09 | Warning          | 2017-01-01
        7 | EVNT-E1-14 | Critical         | 2017-01-01
        9 | EVNT-A1-10 | Critical         | 2017-01-01

demo=> INSERT INTO SYSTEM_EVENTS VALUES(2, 'EV-E2-02', 'Warning', '01-JAN-
2017');
demo=> SELECT * FROM SYSTEM_EVENTS;

 event_id | event_code | event_desciption | event_time
----------+------------+------------------+------------
        1 | EVNT-C1-09 | Warning          | 2017-01-01
        7 | EVNT-E1-14 | Critical         | 2017-01-01
        9 | EVNT-A1-10 | Critical         | 2017-01-01
        2 | EVNT-E2-02 | Warning          | 2017-01-01

demo=> CLUSTER SYSTEM_EVENTS USING PK_EVENT_ID; -- Run CLUSTER again to re-
cluster
demo=> SELECT * FROM SYSTEM_EVENTS;

 event_id | event_code | event_desciption | event_time
----------+------------+------------------+------------
        1 | EVNT-C1-09 | Warning          | 2017-01-01
        2 | EVNT-E2-02 | Warning          | 2017-01-01
        7 | EVNT-E1-14 | Critical         | 2017-01-01
        9 | EVNT-A1-10 | Critical         | 2017-01-01
```

For additional details:

https://www.postgresql.org/docs/current/static/sql-cluster.html

https://www.postgresql.org/docs/9.6/static/sql-createindex.html#SQL-CREATEINDEX-CONCURRENTLY

Migrating from: Oracle Common Data Types

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Overview

Oracle provides a set of primitive data types that can be used for table columns or PL/SQL code variables. The assigned data types for table column or PL/SQL code (such as stored procedures and triggers) define valid values that each column or argument can store.

Oracle Data Types vs. PostgreSQL Data Types

Oracle Data Type Family	Oracle Data Type	Oracle Data Type Characteristic	PostgreSQL Identical Compatibility	PostgreSQL Corresponding Data Type
Character Data Types	CHAR(*n*)	Maximum size of 2000 bytes	√	CHAR(*n*)
	CHARACTER(*n*)	Maximum size of 2000 bytes	√	CHARACTER(**n**)
	NCHAR(*n*)	Maximum size of 2000 bytes	☒	CHAR(*n*)
	VARCHAR(**n**)	Maximum size of 2000 bytes	√	VARCHAR(*n*)
	NCHAR VARYING(**n**)	Varying-length UTF-8 string Maximum size of 4000 bytes	☒	CHARACTER VARYING(*n*)
	VARCHAR2(**n**) 11g	Maximum size of 4000 bytes Maximum size of 32KB in PL/SQL	☒	VARCHAR(**n**)
	VARCHAR2(**n**) 12g	Maximum size of 32767 bytes MAX_STRING_SIZE= EXTENDED	☒	VARCHAR(**n**)
	NVARCHAR2(*n*)	Maximum size of 4000 bytes	☒	VARCHAR(**n**)
	LONG	Maximum size of 2GB	☒	TEXT
	RAW(*n*)	Maximum size of 2000 bytes	☒	BYTEA
	LONG RAW	Maximum size of 2GB	☒	BYTEA
Numeric Data Types	NUMBER	Floating-point number	☒	DOUBLE PRECISION
	NUMBER(*)	Floating-point number	☒	DOUBLE PRECISION
	NUMBER(*p,s*)	Precision can range from 1 to 38 Scale can range from -84 to 127	☒	DECIMAL(*p,s*)
	NUMERIC(*p,s*)	Precision can range from 1 to 38	√	NUMERIC(*p,s*)
	FLOAT(*p*)	Floating-point number	☒	DOUBLE PRECISION
	DEC(**p,s**)	Fixed-point number	√	DEC(**p,s**)
	DECIMAL(**p,s**)	Fixed-point number	√	DECIMAL(**p,s**)
	INT	38 digits integer	√	INTEGER / NUMERIC(38,0)
	INTEGER	38 digits integer	√	INTEGER / NUMERIC(38,0)
	SMALLINT	38 digits integer	√	SMALLINT
	REAL	Floating-point number	☒	DOUBLE PRECISION
	DOUBLE PRECISION	Floating-point number	√	DOUBLE PRECISION
Date &Time Data Types	DATE	DATE data type stores date and time data (year, month, day, hour, minute and second)	√	TIMESTAMP(0)

Oracle Data Type Family	Oracle Data Type	Oracle Data Type Characteristic	PostgreSQL Identical Compatibility	PostgreSQL Corresponding Data Type
	TIMESTAMP(**p**)	Date and time with fraction	√	TIMESTAMP(**p**)
	TIMESTAMP(**p**) WITH TIME ZONE	Date and time with fraction and time zone	√	TIMESTAMP(**p**) WITH TIME ZONE
	INTERVAL YEAR(**p**) TO MONTH	Date interval	√	INTERVAL YEAR TO MONTH
	INTERVAL DAY(**p**) TO SECOND(**s**)	Day and time interval	√	INTERVAL DAY TO SECOND(**s**)
LOB Data Types	BFILE	Pointer to binary file Maximum file size of 4G	☒	VARCHAR (255) / CHARACTER VARYING (255)
	BLOB	Binary large object Maximum file size of 4G	☒	BYTEA
	CLOB	Character large object Maximum file size of 4G	☒	TEXT
	NCLOB	Variable-length Unicode string Maximum file size of 4G	☒	TEXT
ROWID Data Types	ROWID	Physical row address	☒	CHARACTER (255)
	UROWID(**n**)	Universal row id Logical row addresses	☒	CHARACTER VARYING
XML Data Type	XMLTYPE	XML data	☒	XML
Logical Data Type	BOOLEAN	Values TRUE / FALSE and NULL Cannot be assign to a database table column	√	BOOLEAN
Spatial Types	SDO_GEOMETRY	The geometric description of a spatial object	☒	-
	SDO_TOPO_GEOMETRY	Describes a topology geometry	☒	-
	SDO_GEORASTER	A raster grid or image object is stored in a single row	☒	-
Media Types	ORDDicom	Supports the storage and management of audio data	☒	-
	ORDDicom	Supports the storage and management of Digital Imaging and Communications in Medicine (DICOM),	☒	-
	ORDDoc	Supports storage and management of any type of media data	☒	-
	ORDImage	Supports the storage and management of image data	☒	-
	ORDVideo	Supports the storage and management of video data	☒	-

Note: *The "PostgreSQL Identical Compatibility" column indicates if you can use the exact Oracle data type syntax when migrating to Amazon Aurora PostgreSQL.*

Oracle Character Column Semantics

Oracle supports both **BYTE** and **CHAR** semantics for column size, which determines the amount of storage allocated for CHAR and VARCHAR columns.

- If you define a field as `VARCHAR2(10 BYTE)`, Oracle can use up to 10 bytes for storage. However, based on your database codepage and NLS settings, you may not be able to store 10 *characters* in that field because the physical size of some non-English characters exceeds one byte.
- If you define a field as `VARCHAR2(10 CHAR)`, Oracle can store 10 characters no matter how many bytes are required to store each non-English character.

```
CREATE TABLE table1 (col1 VARCHAR2(10 CHAR),
col2 VARCHAR2(10 BYTE));
```

By default, Oracle will use **BYTE** semantics. When using a multi-byte character set such as UTF8, you must do one of the following:

- Use the CHAR modifier in the VARCHAR2/CHAR column definition
- Modify the session or system parameter `NLS_LENGTH_SEMANTICS` to change the default from BYTE to CHAR:

```
ALTER system SET nls_length_semantics=char scope=both;
ALTER system SET nls_length_semantics=byte scope=both;

ALTER session SET nls_length_semantics=char;
ALTER session SET nls_length_semantics=byte;
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e41084/sql_elements001.htm#SQLRF0021
https://docs.oracle.com/database/121/SQLRF/sql_elements001.htm#SQLRF30020

Migration to: PostgreSQL Common Data Types

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Overview

PostgreSQL provides multiple data types which are equivalent to certain Oracle data types. The following table provides the full list of PostgreSQL datatypes:

PostgreSQL Data Type Family	PostgreSQL Data Type	PostgreSQL Data Type Characteristic
Character Data Types	CHAR	Stores a single character
	CHARACTER	Stores a single character
	CHAR(*n*)	Stores exactly (n) characters
	VARCHAR(*N*)	Stores a variable number of characters, up to a maximum of n characters
	TEXT	Specific variant of varchar, which does not require you to specify an upper limit on the number of characters
Numeric Data Types	NUMERIC (P, S)	Exact numeric of selectable precision
	REAL	Single precision floating-point number (4 bytes)
	DOUBLE PRECISION	Double precision floating-point number (8 bytes)
	INT	A signed 4-byte integer that can store –2147483648 to +2147483647
	INTEGER	A signed 4-byte integer that can store –2147483648 to +2147483647
	SMALLINT	A signed 2-byte integer that can store –32768 to +32767
	BIGINT	A signed 8-byte integer, giving approximately 18 digits of precision
	BIT	Stores a single bit, 0 or 1
	BIT VARYING	Stores a string of bits
	MONEY	Equivalent to NUMERIC (9,2), storing 4 bytes of data. Its use is discouraged
Date &Time Data Types	TIMESTAMP	Stores dates and times from 4713 BC to 1465001 AD, with a resolution of 1 microsecond - 8 bytes
	INTERVAL	Stores an interval of approximately +/– 178,000,000 years, with a resolution of 1 microsecond - 16 bytes
	DATE	Stores dates from 4713 BC to 32767 AD, with a resolution of 1 day - 4 bytes
	TIME	Stores a time of day, from 0 to 23:59:59.99, with a resolution of 1 microsecond - 8 bytes with no timezone, 12 bytes with timezone
Logical Data Type	BOOLEAN	Holds a truth value. Will accept values such as TRUE, 't','true', 'y', 'yes', and '1' as true. Uses 1 byte of storage, and can store NULL. This type can be used upon table creation
XML Data Type	XML	XML data
Geometric Data Types	POINT	An x,y value
	LINE	A line (pt1, pt2)
	LSEG	A line segment (pt1, pt2)

PostgreSQL Data Type Family	PostgreSQL Data Type	PostgreSQL Data Type Characteristic
	BOX	A box specified by a pair of points
	PATH	A sequence of points, which may be closed or open
	POLYGON	A sequence of points, effectively a closed path
	CIRCLE	A point and a length, which specify a circle
PostgreSQL Data Types	SERIAL	A numeric column in a table that increases each time a row is added
	OID	An object identifier. Internally, PostgreSQL adds, by default, a hidden oid to each row, and stores a 4-byte integer
	CIDR	Stores a network address of the form x.x.x.x/y where y is the netmask
	INET	Similar to cidr, except the host part can be 0
	MACADDR	MAC (Media Access Control) address
	JSON	Textual JSON data
	JSONB	Binary JSON data, decomposed
	PG_LSN	PostgreSQL Log Sequence Number
	BYTEA	Binary data ("byte array")
	TSQUERY	Text search query
	TSVECTOR	Text search document
	TXID_SNAPSHOT	User-level transaction ID snapshot
	UUID	Universally unique identifier

PostgreSQL Character Column Semantics

PostgreSQL only supports **CHAR** for column size semantics. If you define a field as VARCHAR `(10)`, PostgreSQL can store 10 characters regardless of how many bytes it takes to store each non-English character. VARCHAR`(n)` stores strings up to ***n*** characters (not bytes) in length.

Migration of Oracle Datatypes to PostgreSQL datatypes

Automatic migration and conversion of Oracle Tables and Data Types can be performed using Amazon's Schema Conversion Tool (Amazon SCT).

Examples

To demonstrate SCT's capability for migrating Oracle tables to their PostgreSQL equivalents, a table containing columns representing the majority of Oracle data types was created and converted using Amazon SCT.

Source Oracle compatible DDL for creating the DATATYPES table:

```
CREATE TABLE "DATATYPES"(
 "BFILE"                       BFILE,
 "BINARY_FLOAT"                BINARY_FLOAT,
 "BINARY_DOUBLE"               BINARY_DOUBLE,
 "BLOB"                        BLOB,
 "CHAR"                        CHAR(10 BYTE),
 "CHARACTER"                   CHAR(10 BYTE),
 "CLOB"                        CLOB,
 "NCLOB"                       NCLOB,
 "DATE"                        DATE,
 "DECIMAL"                     NUMBER(3,2),
 "DEC"                         NUMBER(3,2),
 "DOUBLE_PRECISION"            FLOAT(126),
 "FLOAT"                       FLOAT(3),
 "INTEGER"                     NUMBER(*,0),
 "INT"                         NUMBER(*,0),
 "INTERVAL_YEAR"               INTERVAL YEAR(4) TO MONTH,
 "INTERVAL_DAY"                INTERVAL DAY(4) TO SECOND(4),
 "LONG"                        LONG,
 "NCHAR"                       NCHAR(10),
 "NCHAR_VARYING"               NVARCHAR2(10),
 "NUMBER"                      NUMBER(9,9),
 "NUMBER1"                     NUMBER(9,0),
 "NUMBER(*)"                   NUMBER,
 "NUMERIC"                     NUMBER(9,9),
 "NVARCHAR2"                   NVARCHAR2(10),
 "RAW"                         RAW(10),
 "REAL"                        FLOAT(63),
 "ROW_ID"                      ROWID,
 "SMALLINT"                    NUMBER(*,0),
 "TIMESTAMP"                   TIMESTAMP(5),
 "TIMESTAMP_WITH_TIME_ZONE"    TIMESTAMP(5) WITH TIME ZONE,
 "UROWID"                      UROWID(10),
 "VARCHAR"                     VARCHAR2(10 BYTE),
 "VARCHAR2"                    VARCHAR2(10 BYTE),
 "XMLTYPE"                     XMLTYPE
);
```

Target PostgreSQL compatible DDL for creating the DATATYPES table migrated from Oracle with Amazon SCT.

```
CREATE TABLE IF NOT EXISTS datatypes(
bfile                        character varying(255) DEFAULT NULL,
binary_float                 real DEFAULT NULL,
binary_double                double precision DEFAULT NULL,
blob                         bytea DEFAULT NULL,
char                         character(10) DEFAULT NULL,
character                    character(10) DEFAULT NULL,
clob                         text DEFAULT NULL,
nclob                        text DEFAULT NULL,
date                         TIMESTAMP(0) without time zone DEFAULT NULL,
decimal                      numeric(3,2) DEFAULT NULL,
dec                          numeric(3,2) DEFAULT NULL,
double_precision             double precision DEFAULT NULL,
float                        double precision DEFAULT NULL,
integer                      numeric(38,0) DEFAULT NULL,
int                          numeric(38,0) DEFAULT NULL,
interval_year                interval year to month(6) DEFAULT NULL,
interval_day                 interval day to second(4) DEFAULT NULL,
long                         text DEFAULT NULL,
nchar                        character(10) DEFAULT NULL,
nchar_varying                character varying(10) DEFAULT NULL,
number                       numeric(9,9) DEFAULT NULL,
number1                      numeric(9,0) DEFAULT NULL,
"number(*)"                  double precision DEFAULT NULL,
numeric                      numeric(9,9) DEFAULT NULL,
nvarchar2                    character varying(10) DEFAULT NULL,
raw                          bytea DEFAULT NULL,
real                         double precision DEFAULT NULL,
row_id                       character(255) DEFAULT NULL,
smallint                     numeric(38,0) DEFAULT NULL,
timestamp                    TIMESTAMP(5) without time zone DEFAULT NULL,
timestamp_with_time_zone TIMESTAMP(5) with time zone DEFAULT NULL,
urowid                       character varying DEFAULT NULL,
varchar                      character varying(10) DEFAULT NULL,
varchar2                     character varying(10) DEFAULT NULL,
xmltype                      xml DEFAULT NULL
)
WITH (
OIDS=FALSE
);
```

Note: While most of the datatypes were converted successfully, a few exceptions were raised for datatypes that Amazon SCT is unable to automatically convert and where SCT recommended manual actions:

- **PostgreSQL does not have a BFILE data type**
  BFILEs are pointers to binary files.

  Recommended actions: either store a named file with the data and create a routine that retrieves the file from the file system or store the data inside a blob datatype in your table.

- **PostgreSQL doesn't have a ROWID data type**
  ROWIDs are physical row addresses inside Oracle's storage subsystems. The `ROWID` datatype is primarily used for values returned by the `ROWID` pseudocolumn.

  Recommended actions: while PostgreSQL contains a `ctid` column that is the physical location of the row version within its table, it does not have a comparable data type. However, you can use CHAR as a partial datatype equivalent. Note: If you are using ROWID datatypes in your code, modifications may be necessary.

- **PostgreSQL does not have a UROWID data type**
  Universal rowid, or `UROWID`, is a single Oracle datatype that supports both logical and physical rowids of foreign table rowids such as non-Oracle tables accessed through a gateway.

  Recommended actions: PostgreSQL does not have a comparable data type. You can use `VARCHAR(n)` as a partial datatype equivalent. However, if you are using `UROWID` datatypes in your code, modifications may be necessary.

For additional details:
https://www.postgresql.org/docs/current/static/ddl-system-columns.html
https://www.postgresql.org/docs/current/static/datatype.html
https://aws.amazon.com/documentation/SchemaConversionTool

Migrating from: Oracle Table Constraints

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Overview

The Oracle database provides six types of constraints to enforce data integrity on table columns. Constraints ensure that data inserted into tables is controlled and satisfies logical requirements.

Oracle integrity constraint types:

- Primary key: enforces that row values in a specific column are unique and not null.
- Foreign key: enforces that values in the current table exist in the referenced table.
- Unique: prevents data duplication on a column, or combination of columns, and allows one null value.
- Check: enforces that values comply with a specific condition.
- Not null: enforces that null values cannot be inserted into a specific column.
- REF: references an object in another object type or in a relational table.

Constraint Creation

Oracle allows to create new constraints in two ways:

- Inline: Defines a constraint as part of a table column declaration:

```
SQL> CREATE TABLE EMPLOYEES (
       EMP_ID NUMBER PRIMARY KEY,
       …);
```

- Out-Of-Line: Defines a constraint as part of the table DDL during table creation:

```
SQL> CREATE TABLE EMPLOYEES (
       EMP_ID NUMBER,
       …,
       CONSTRAINT PK_EMP_ID PRIMARY KEY(EMP_ID));
```

  Note: *NOT NULL constraints must be declared using the inline method.*

Oracle constraints can be specified with the following syntax:

- `CREATE / ALTER TABLE`
- `CREATE / ALTER VIEW`

  Note: *Views have only a primary key, foreign key, and unique constraints*.

Major Constraint Types

PRIMARY KEY Constraint

A unique identifier for each record in a database table can appear only once and cannot contain NULL values. A table can only have one primary key.

When creating a primary key constraint inline, you can specify only the `PRIMARY KEY` keyword. When you create the constraint out-of-line, you must specify one column or combination of columns.

Creating a new primary key constraint will also implicitly create a unique index on the primary key column if no such index already exists. When dropping a primary key constraint, the system generated index is also dropped. If a user defined Index was used, the index is not dropped.

Limitations

- Primary keys cannot be created on columns defined with the following data types: `LOB, LONG, LONG RAW, VARRAY, NESTED TABLE, BFILE, REF, TIMESTAMP WITH TIME ZONE`. Note: The data type `TIMESTAMP WITH LOCAL TIME ZONE` is allowed as primary key.
- Primary keys can be created from multiple columns (composite PK), limited to a total of 32 columns.
- Defining the same column as both a primary key and as a unique constraint is not allowed.

Examples

1. Create an Inline primary key using a system-generated primary key constraint name:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID NUMBER PRIMARY KEY,
      FIRST_NAME  VARCHAR2(20),
      LAST_NAME   VARCHAR2(25),
      EMAIL       VARCHAR2(25));
```

2. Create an inline primary key using a user-specified primary key constraint name:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID NUMBER CONSTRAINT PK_EMP_ID PRIMARY KEY,
      FIRST_NAME  VARCHAR2(20),
      LAST_NAME   VARCHAR2(25),
      EMAIL       VARCHAR2(25));
```

3. Create an out-of-line primary key:

```
SQL> CREATE TABLE EMPLOYEES(
      EMPLOYEE_ID NUMBER,
      FIRST_NAME  VARCHAR2(20),
      LAST_NAME   VARCHAR2(25),
      EMAIL       VARCHAR2(25));
      CONSTRAINT PK_EMP_ID PRIMARY KEY (EMPLOYEE_ID));
```

4. Add a primary key to an existing table:

```
SQL> ALTER TABLE SYSTEM_EVENTS
      ADD CONSTRAINT PK_EMP_ID PRIMARY KEY (EVENT_CODE, EVENT_TIME);
```

FOREIGN KEY Constraint

Foreign key constraints identify the relationship between column records defined with a foreign key constraint and a referenced primary key or a unique column. The main purpose of a foreign key is to enforce that the values in table A also exist in table B, as referenced by the foreign key.

A referenced table is known as a parent table while the table on which the foreign key was created is known as a child table. Foreign keys created in child tables generally reference a primary key constraint in a parent table.

Limitations

- Foreign keys cannot be created on columns defined with the following data types: `LOB, LONG, LONG RAW, VARRAY, NESTED TABLE, BFILE, REF, TIMESTAMP WITH TIME ZONE`.
- Composite Foreign key constraints, comprised from multiple columns, cannot have more than 32 columns.
- Foreign key constraints cannot be created in a `CREATE TABLE` statement with a subquery clause.
- A referenced primary key or unique constraint on a parent table must be created before the foreign key creation command.

ON DELETE Clause

The `ON DELETE` clause specifies the effect of deleting values from a parent table on the referenced records of a child table. If the `ON DELETE` clause is not specified, Oracle does not allow deletion of referenced key values in a parent table that has dependent rows in the child table.

- `ON DELETE CASCADE`: Any dependent foreign key values in a child table are removed along with the referenced values from the parent table.
- `ON DELETE NULL`: Any dependent foreign key values in a child table are updated to NULL.

Examples

1. Create an inline foreign key with a user-defined constraint name:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20),
      LAST_NAME     VARCHAR2(25),
      EMAIL         VARCHAR2(25) ,
      DEPARTMENT_ID REFERENCES DEPARTMENTS(DEPARTMENT_ID));
```

2. Create an Out-Of-Line foreign key with a system-generated constraint name:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20),
      LAST_NAME     VARCHAR2(25),
      EMAIL         VARCHAR2(25),
      DEPARTMENT_ID NUMBER,
      CONSTRAINT FK_FEP_ID
        FOREIGN KEY(DEPARTMENT_ID) REFERENCES DEPARTMENTS(DEPARTMENT_ID));
```

3. Create a foreign key using the `ON DELETE CASCADE` clause:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20),
      LAST_NAME     VARCHAR2(25),
      EMAIL         VARCHAR2(25),
      DEPARTMENT_ID NUMBER,
      CONSTRAINT FK_FEP_ID
        FOREIGN KEY(DEPARTMENT_ID) REFERENCES DEPARTMENTS(DEPARTMENT_ID)
        ON DELETE CASCADE);
```

4. Add a foreign key to an existing table:

```
SQL> ALTER TABLE EMPLOYEES
      ADD CONSTRAINT FK_FEP_ID
                      FOREIGN KEY(DEPARTMENT_ID)
                      REFERENCES DEPARTMENTS(DEPARTMENT_ID);
```

UNIQUE Constraint

A unique constraint is similar to a primary key constraint. A unique constraint specifies that the values in a single column, or combination of columns, must be unique and cannot repeat in multiple rows.

The main difference from primary key constraint is that the unique constraint can contain NULL values. NULL values in multiple rows are also supported provided the combination of values is unique.

Limitations

- A unique constraint cannot be created on columns defined with the following data types: `LOB, LONG, LONG RAW, VARRAY, NESTED TABLE, BFILE, REF, TIMESTAMP WITH TIME ZONE`
- A unique constraint comprised from multiple columns cannot have more than 32 columns.
- Primary key and unique constraints cannot be created on the same column or columns.

Example

Create an inline unique Constraint:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20),
      LAST_NAME     VARCHAR2(25),
      EMAIL         VARCHAR2(25) CONSTRAINT UNIQ_EMP_EMAIL UNIQUE,
      DEPARTMENT_ID NUMBER);
```

Check Constraint

Check constraints are used to validate that values in specific columns meet specific criteria or conditions. For example, a check constraint on an EMPLOYEE_EMAIL column can be used to validate that each record has an "@aws.com" suffix, if a record fails the "check" validation, an error is raised and the record is not inserted.

Using a check constraint can help transfer some of the logical integrity validation from the application to the database.

In-Line vs. Out-Of-Line

When creating a check constraint as inline, it can only be defined on a specific column. When using the out-of-line method, the check constraint can be defined on multiple columns.

Limitations

- Check constraints cannot perform validation on columns of other tables.
- Check constraints cannot work with functions that not deterministic (e.g. CURRENT_DATE).
- Check constraints cannot work with user-defined functions.
- Check constrains cannot work with pseudo columns such as: CURRVAL, NEXTVAL, LEVEL, or ROWNUM.

Example

Create an inline check constraint that uses a regular expression to validate that the email suffix of inserted rows contains "@aws.com".

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20),
      LAST_NAME     VARCHAR2(25),
      EMAIL         VARCHAR2(25)
                    CHECK(REGEXP_LIKE (EMAIL, '^[A-Za-z]+@aws.com?{1,3}$')),
      DEPARTMENT_ID NUMBER);
```

Not Null Constraint

The not null constraint prevents a column from containing any null values. In order to enable the not null constraint, the keywords NOT NULL must be specified during table creation (inline only). Permitting null values is the default if NOT NULL is not specified.

Example

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20) NOT NULL,
      LAST_NAME     VARCHAR2(25) NOT NULL,
      EMAIL         VARCHAR2(25),
      DEPARTMENT_ID NUMBER);
```

REF Constraint

REF constraints define a relationship between a column of type REF and the object it references. The REF constraint can be created both inline and out-of-line. Both methods permit you to define a scope constraint, a rowid constraint, or a referential integrity constraint based on the REF column.

Example

1. Create a new Oracle type object:

```
SQL> CREATE TYPE DEP_TYPE AS OBJECT (
      DEP_NAME    VARCHAR2(60),
      DEP_ADDRESS VARCHAR2(300));
```

2. Create a table based on the previously created type object:

```
SQL> CREATE TABLE DEPARTMENTS_OBJ_T OF DEP_TYPE;
```

3. Create the EMPLOYEES table with a reference to the previously created DEPARTMENTS table that is based on the DEP_TYPE object:

```
SQL> CREATE TABLE EMPLOYEES (
      EMP_NAME   VARCHAR2(60),
      EMP_EMAIL  VARCHAR2(60),
      EMP_DEPT   REF DEPARTMENT_TYP REFERENCES DEPARTMENTS_OBJ_T);
```

Special Constraint States

Oracle provides granular control of database constraint enforcement. For example, you can disable constraints temporarily while making modifications to table data.

Constraint states can be defined using the CREATE TABLE / ALTER TABLE statements. The following constraint states are supported:

- **DEFERRABLE:** Enables the use of the SET CONSTRAINT clause in subsequent transactions until a COMMIT statement is submitted.
- **NOT DEFERRABLE:** Disables the use of the SET CONSTRAINT clause.
- **INITIALLY IMMEDIATE:** Checks the constraint at the end of each subsequent SQL statement (this state is the default).
- **INITIALLY DEFERRED:** Checks the constraint at the end of subsequent transactions.
- **VALIDATE | NO VALIDATE:** These parameters depend on whether the constraint is ENABLED or DISABLED.
- **ENABLE | DISABLE:** Specifies if the constraint should be enforced after creation (ENABLE by default). Several options are available when using ENABLE | DISABLE:
    - **ENABLE VALIDATE:** Enforces that the constraint applies to all existing and new data.
    - **ENABLE NOVALIDATE:** Only new data complies with the constraint.
    - **DISABLE VALIDATE:** A valid constraint is created in disabled mode with no index.

- **DISABLE NOVALIDATE:** The constraint is created in disabled mode without validation of new or existing data.

Example

1. Create a unique constraint with a state of DEFERRABLE:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID   NUMBER PRIMARY KEY,
      FIRST_NAME    VARCHAR2(20),
      LAST_NAME     VARCHAR2(25),
      EMAIL         VARCHAR2(25) CONSTRAINT UNIQ_EMP_EMAIL UNIQUE DEFERRABLE,
      DEPARTMENT_ID NUMBER);
```

2. Modify the state of the constraint to ENABLE NOVALIDATE:

```
SQL> ALTER TABLE EMPLOYEES
      ADD CONSTRAINT CHK_EMP_NAME CHECK(FIRST_NAME LIKE 'a%')
       ENABLE NOVALIDATE;
```

Using Existing Indexes to Enforce Constraint Integrity (*using_index_clause*)
Primary key and unique constraints can be created based on an existing index to enforce the constraint integrity instead of implicitly creating a new index during constraint creation.

Example
Create a unique constraint based on an existing index:

```
SQL> CREATE UNIQUE INDEX IDX_EMP_ID ON EMPLOYEES(EMPLOYEE_ID);

SQL> ALTER TABLE EMPLOYEES
      ADD CONSTRAINT PK_CON_UNIQ
       PRIMARY KEY(EMPLOYEE_ID) USING INDEX IDX_EMP_ID;
```

Required Privileges for Creating Constraints
You must have privileges on the table in which constrains are created and, in case of foreign key constraints, you must have the REFERENCES privilege on the referenced table.

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28286/clauses002.htm#SQLRF52163
https://docs.oracle.com/database/121/SQLRF/clauses002.htm#SQLRF52180

Migration to: PostgreSQL Table Constraints

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Overview

PostgreSQL supports the following types of table constraints:

- PRIMARY KEY
- FOREIGN KEY
- UNIQUE
- CHECK
- NOT NULL
- EXCLUDE (specific to PostgreSQL)

Note: PostgreSQL ***does not*** support Oracle's REF constraint.

Similar to constraint deceleration in Oracle, PostgreSQL allows creating constraints in-line or out-of-line during table column specification.

PostgreSQL constraints can be specified using CREATE / ALTER TABLE. Views are not supported.

Privileges

You must have privileges on the table in which constrains will be created. With foreign key constraints, you must also have the REFERENCES privilege.

Primary Key Constraint

- Uniquely identifies each record and cannot contain a NULL value.
- Uses the same ANSI SQL syntax as Oracle.
- Can be created on a single column or on multiple columns ("composite primary keys") as the only PRIMARY KEY in a table.
- Create a PRIMARY KEY constraint creates a unique B-Tree index automatically on the column or group of columns marked as the primary key of the table.
- Constraint names can be generated automatically by PostgreSQL or explicitly specified during constraint creation.

Examples

1. Create an inline primary key constraint with a system-generated constraint name:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID NUMERIC PRIMARY KEY,
        FIRST_NAME  VARCHAR(20),
        LAST_NAME   VARCHAR(25),
        EMAIL       VARCHAR(25));
```

2. Create an inline primary key constraint with a user-specified constraint name:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID NUMERIC CONSTRAINT PK_EMP_ID PRIMARY KEY,
        FIRST_NAME  VARCHAR(20),
        LAST_NAME   VARCHAR(25),
        EMAIL       VARCHAR(25));
```

3. Create an out-of-line primary key constraint:

```
demo=> CREATE TABLE EMPLOYEES(
        EMPLOYEE_ID NUMERIC,
        FIRST_NAME  VARCHAR(20),
        LAST_NAME   VARCHAR(25),
        EMAIL       VARCHAR(25));
        CONSTRAINT PK_EMP_ID PRIMARY KEY (EMPLOYEE_ID));
```

4. Add a primary key constraint to an existing table:

```
demo=> ALTER TABLE SYSTEM_EVENTS
        ADD CONSTRAINT PK_EMP_ID PRIMARY KEY (EVENT_CODE, EVENT_TIME);
```

5. Drop the primary key:

```
demo=> ALTER TABLE SYSTEM_EVENTS
        DROP CONSTRAINT PK_EMP_ID;
```

Foreign Key Constraint

- Enforces referential integrity in the database. Values in specific columns or group of columns must match the values from another table (or column).
- Creating a FOREIGN KEY constraint in PostgreSQL uses the same ANSI SQL syntax as Oracle.
- Can be created in-line or out-of-line during table creation.
- Use the REFERENCES clause to specify the table referenced by the foreign key constraint.
- When specifying REFERENCES in absence of a column list in the referenced table, the PRIMARY KEY of the referenced table is used as the referenced column or columns.
- A table can have multiple FOREIGN KEY constraints to describe its relationships with other tables.
- Use the ON DELETE clause to handle cases of FOREIGN KEY parent records deletions (such as cascading deletes).
- Foreign key constraint names are generated automatically by the database or specified explicitly during constraint creation.

Foreign Key and the ON DELETE clause

PostgreSQL provides three main options to handle cases where data is deleted from the parent table and a child table is referenced by a FOREIGN KEY constraint. By default, without specifying any additional options, PostgreSQL will use the NO ACTION method and raise an error if the referencing rows still exist when the constraint is verified.

- ON DELETE CASCADE
  Any dependent foreign key values in the child table are removed along with the referenced values from the parent table.

- `ON DELETE RESTRICT`
  Prevents the deletion of referenced values from the parent table and the deletion of dependent foreign key values in the child table.

- `ON DELETE NO ACTION`
  Performs no action (the default action). The fundamental difference between `RESTRIC` and `NO ACTION` is that `NO ACTION` allows the check to be postponed until later in the transaction; `RESTRICT` does not.

Foreign Key and the `ON UPDATE` clause
Handling updates on `FOREIGN KEY` columns is also available using the `ON UPDATE` clause, which shares the same options as the `ON DELETE` clause:

- `ON UPDATE CASCADE`
- `ON UPDATE RESTRICT`
- `ON UPDATE NO ACTION`

Note: Oracle does not provide an `ON UPDATE` clause.

Examples

1. Create an inline foreign key with a user-specified constraint name:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID   NUMERIC PRIMARY KEY,
        FIRST_NAME    VARCHAR(20),
        LAST_NAME     VARCHAR(25),
        EMAIL         VARCHAR(25),
        DEPARTMENT_ID NUMERIC REFERENCES DEPARTMENTS(DEPARTMENT_ID));
```

**PostgreSQL foreign key columns must have a specified data type while Oracle doesn't*

2. Create an out-of-line foreign key constraint with a system-generated constraint name:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID   NUMERIC PRIMARY KEY,
        FIRST_NAME    VARCHAR(20),
        LAST_NAME     VARCHAR(25),
        EMAIL         VARCHAR(25),
        DEPARTMENT_ID NUMERIC,
        CONSTRAINT FK_FEP_ID
        FOREIGN KEY(DEPARTMENT_ID) REFERENCES DEPARTMENTS(DEPARTMENT_ID));
```

3. Create a foreign key using the `ON DELETE CASCADE` clause:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID   NUMERIC PRIMARY KEY,
        FIRST_NAME    VARCHAR(20),
        LAST_NAME     VARCHAR(25),
        EMAIL         VARCHAR(25),
        DEPARTMENT_ID NUMERIC,
        CONSTRAINT FK_FEP_ID
        FOREIGN KEY(DEPARTMENT_ID) REFERENCES DEPARTMENTS(DEPARTMENT_ID)
        ON DELETE CASCADE);
```

4. Add a foreign key to an existing table:

```
demo=> ALTER TABLE EMPLOYEES
        ADD CONSTRAINT FK_FEP_ID
                       FOREIGN KEY(DEPARTMENT_ID)
                       REFERENCES DEPARTMENTS(DEPARTMENT ID);
```

UNIQUE Constraints

- Ensures that a value in a column, or a group of columns, is unique across the entire table.
- PostgreSQL UNIQUE constraint syntax is ANSI SQL compatible.
- Automatically creates a B-Tree index on the respective column, or a group of columns, when creating a UNIQUE constraint.
- If duplicate values exist in the column(s) on which the constraint was defined during UNIQUE constraint creation, the UNIQUE constraint creation fails, returning an error message.
- UNIQUE constraints in PostgreSQL will accept multiple NULL values (similar to Oracle).
- UNIQUE constraint naming can be system-generated or explicitly specified.

Example

Create an inline unique constraint ensuring uniqueness of values in the email column:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID   NUMERIC PRIMARY KEY,
        FIRST_NAME    VARCHAR(20),
        LAST_NAME     VARCHAR(25),
        EMAIL         VARCHAR(25) CONSTRAINT UNIQ_EMP_EMAIL UNIQUE,
        DEPARTMENT_ID NUMERIC);
```

CHECK Constraint

- CHECK constraints enforce that values in a column satisfy a specific requirement.
- CHECK constraints in PostgreSQL use the same ANSI SQL syntax as Oracle.
- Can only be defined using a ***Boolean data type*** to evaluate the values of a column.
- CHECK constraints naming can be system-generated or explicitly specified by the user during constraint creation.

Example

Create an inline CHECK constraint, using a regular expression, to enforce that the email column contains email addresses with an "@aws.com" suffix.

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID   NUMERIC PRIMARY KEY,
        FIRST_NAME    VARCHAR(20),
        LAST_NAME     VARCHAR(25),
        EMAIL         VARCHAR(25) CHECK(EMAIL ~ '(^[A-Za-z]+@aws.com$)'),
        DEPARTMENT_ID NUMERIC);
```

NOT NULL Constraints

- `NOT NULL` constraints enforce that a column *cannot* accept NULL values. This behavior is different from the default column behavior in PostgreSQL where columns *can* accept NULL values.
- `NOT NULL` constraints can only be defined inline, during table creation (similar to Oracle).
- `NOT NULL` constraints in PostgreSQL use the same ANSI SQL syntax as Oracle.
- You can explicitly specify names for `NOT NULL` constraints when used with a `CHECK` constraint.

Example

Define two not null constraints on the `FIRST_NAME` and `LAST_NAME` columns. Define a check constraint (with an explicitly user-specified name) to enforce not null behavior on the `EMAIL` column.

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID NUMERIC PRIMARY KEY,
        FIRST_NAME  VARCHAR(20) NOT NULL,
        LAST_NAME   VARCHAR(25) NOT NULL,
        EMAIL       VARCHAR(25) CONSTRAINT CHK_EMAIL
                     CHECK(EMAIL IS NOT NULL));
```

Constraint States

Similarly to Oracle, PostgreSQL provides controls for certain aspects of constraint behavior:

- `DEFERRABLE | NOT DEFERRABLE`
  Using the PostgreSQL `SET CONSTRAINTS` statement, constraints can be defined as:

  - `DEFERRABLE`
    Allows you to use the `SET CONSTRAINTS` statement to set the behavior of constraint checking within the current transaction until transaction commit.

  - `IMMEDIATE`
    Constraints are enforced only at the end of each statement.
    Note: Each constraint has its own `IMMEDIATE` or `DEFERRED` mode (same as Oracle)

  - `NOT DEFERRABLE`
    This statement always runs as `IMMEDIATE` and is not affected by the `SET CONSTRAINTS` command.

PostgreSQL SET CONSTRAINTS Synopsis

```
SET CONSTRAINTS { ALL | name [, ...] } { DEFERRED | IMMEDIATE }
```

- `VALIDATE CONSTRAINT | NOT VALID`

  - `VALIDATE CONSTRAINT`
    Validates foreign key or check constraints (only) that were previously created as `NOT VALID`. This action performs a validation check by scanning the table to ensure that all records satisfy the constraint definition.

- `NOT VALID`
  Can be used only for foreign key or check constraints. When specified, new records are not validated with the creation of the constraint. Only when the `VALIDATE CONSTRAINT` state is applied does the constraint state is enforced on all records.

Example

```
demo=> ALTER TABLE EMPLOYEES ADD CONSTRAINT FK_DEPT
        FOREIGN KEY (department_id)
        REFERENCES DEPARTMENTS (department_id) NOT VALID;

demo=> ALTER TABLE EMPLOYEES VALIDATE CONSTRAINT FK_DEPT;
```

Using Existing Indexes During Constraint Creation (*table_constraint_using_index*)
PostgreSQL can add a new primary key or unique constraints based on an existing unique Index . All the index columns are included in the constraint. When creating constraints using this method, the index is owned by the constraint. When dropping the constraint, the index is also dropped.

Example
Use an existing unique Index to create a primary key constraint:

```
demo=> CREATE UNIQUE INDEX IDX_EMP_ID ON EMPLOYEES(EMPLOYEE_ID);

demo=> ALTER TABLE EMPLOYEES
        ADD CONSTRAINT PK_CON_UNIQ PRIMARY KEY USING INDEX IDX_EMP_ID;
```

Oracle Constraints Comparison to PostgreSQL

Oracle Constraint / Parameter	PostgreSQL Constraint / Parameter
PRIMARY KEY	PRIMARY KEY
FOREIGN KEY	FOREIGN KEY
UNIQUE	UNIQUE
CHECK	CHECK
NOT NULL	NOT NULL
REF	Not Supported
DEFERRABLE	DEFERRABLE
NOT DEFERRABLE	NOT DEFERRABLE
SET CONSTRAINTS	SET CONSTRAINTS
INITIALLY IMMEDIATE	INITIALLY IMMEDIATE
INITIALLY DEFERRED	INITIALLY DEFERRED
ENABLE	Default, not supported as keyword
DISBALE	Not supported as keyword, NOT VALID can use instead
ENABLE VALIDATE	Default, not supported as keyword
ENABLE NOVALIDATE	NOT VALID
DISABLE VALIDATE	Not supported
DISABLE NOVALIDATE	Not supported
USING_INDEX_CLAUSE	table_constraint_using_index
View Constraints	Not Supported
Metadata:	Metadata:
DBA_CONSTRAINTS	PG_CONSTRAINT

For additional details:
https://www.postgresql.org/docs/9.6/static/ddl-constraints.html
https://www.postgresql.org/docs/9.6/static/sql-set-constraints.html
https://www.postgresql.org/docs/9.6/static/sql-altertable.html

Migrating from: Oracle Table Partitioning

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Overview

The purpose of database partitioning is to provide support for very large tables and indexes by splitting them into smaller pieces, known as partitions. Each partition has its own name and definitions and can be managed separately from other partitions, or collectively as one object. From an application perspective, partitions are transparent - partitioned tables act the same as non-partitioned tables allowing your applications to access a partitioned table using unmodified SQL statements. Table partitioning provides several benefits:

- **Performance improvement**
  Table partitions help improve query performance by accessing a subset of a partitions instead of scanning a larger set of data. Additional performance improvements can also be achieved when using partitions and parallel query execution for DML and DDL operations.

- **Data Management**
  Table partitions facilitate easier data management operations (such as data migration), index management (creation, dropping, or rebuilding indexes), and backup/recovery. These operations are also referred to as “Information Lifecycle Management” (ILM) activities.

- **Maintenance Operations**
  Table partitions can significantly reduce downtime caused by table maintenance operations.

Oracle basic Table Partitioning methods

- **Hash Table Partitioning**
  When a partition key is specified (for example, a table column with a number data type), Oracle applies a hashing algorithm to evenly distribute the data (records) among all defined partitions (partitions have approximately the same size).

  Example

  Create a hash-partitioned Table:

```
SQL> CREATE TABLE SYSTEM_LOGS
     (EVENT_NO    NUMBER NOT NULL,
      EVENT_DATE  DATE   NOT NULL,
      EVENT_STR   VARCHAR2(500),
      ERROR_CODE  VARCHAR2(10))
     PARTITION BY HASH (ERROR_CODE)
     PARTITIONS 3
     STORE IN (TB1, TB2, TB3);
```

- **List Table Partitioning**
  You can specify a list of discrete values for the table partitioning key in the description of each partition. This type of table partitioning enables control over partition organization using explicit values. For example, partition "events" by error code values.

  Example
  Create a list-partition table:

```
SQL> CREATE TABLE SYSTEM_LOGS
     (EVENT_NO    NUMBER NOT NULL,
      EVENT_DATE  DATE   NOT NULL,
      EVENT_STR   VARCHAR2(500),
      ERROR_CODE  VARCHAR2(10))
     PARTITION BY LIST (ERROR_CODE)
     (PARTITION warning VALUES ('err1', 'err2', 'err3') TABLESPACE TB1,
      PARTITION critical VALUES ('err4', 'err5', 'err6') TABLESPACE TB2);
```

- **Range Table Partitioning**
  Partition a table based on a *range* of values. The Oracle database assigns rows to table partitions based on column values falling within a given range. Range table partitioning is one of the most frequently used type of partitioning in the Oracle database, primarily with date values. Range table partitioning can also be implemented with numeric ranges (1-10000, 10001- 20000…).

  Example
  Create a range-partitioned table:

```
SQL> CREATE TABLE SYSTEM_LOGS
     (EVENT_NO    NUMBER NOT NULL,
      EVENT_DATE  DATE   NOT NULL,
      EVENT_STR   VARCHAR2(500))
     PARTITION BY RANGE (EVENT_DATE)
     (PARTITION EVENT_DATE VALUES LESS THAN (TO_DATE('01/01/2015',
      'DD/MM/YYYY')) TABLESPACE TB1,
     PARTITION EVENT_DATE VALUES LESS THAN (TO_DATE('01/01/2016',
      'DD/MM/YYYY')) TABLESPACE TB2,
     PARTITION EVENT_DATE VALUES LESS THAN (TO_DATE('01/01/2017',
      'DD/MM/YYYY')) TABLESPACE TB3);
```

Composite Table Partitioning
With composite partitioning, a table can be partitioned by one data distribution method and then each partition can be further subdivided into sub-partitions using the same, or different, data distribution method(s). For example:

- Composite list-range partitioning
- Composite list-list partitioning
- Composite range-hash partitioning

Partitioning Extensions

Oracle provides additional partitioning strategies that enhance the capabilities of basic partitioning. These partitioning strategies are:

- Manageability extensions
  - Interval partitioning
  - Partition advisor

- Partitioning key extensions
  - Reference partitioning
  - Virtual column-based partitioning

Examples

Split and exchange partitions:

- **Split Partitions**
  The `SPLIT PARTITION` statement can be used to redistribute the contents of one partition or sub-partition into multiple partitions or sub-partitions:

```
SQL> ALTER TABLE SPLIT PARTITION p0 INTO
     (PARTITION P01 VALUES LESS THAN (100),
     PARTITION p02);
```

- **Exchange Partitions**
  The `EXCHANGE PARTITION` statement is useful to exchange table partitions in, or out, of a partitioned table.

```
SQL> ALTER TABLE orders
     EXCHANGE PARTITION p_ord3 WITH TABLE orders_year_2016;
```

Sub-Partitioning Tables

Sub-Partitions are created within partitions to further split the parent partition:

```
SQL> PARTITION BY RANGE(department_id)
     SUBPARTITION BY HASH(last_name)
     SUBPARTITION TEMPLATE
         (SUBPARTITION a TABLESPACE ts1,
          SUBPARTITION b TABLESPACE ts2,
          SUBPARTITION c TABLESPACE ts3,
          SUBPARTITION d TABLESPACE ts4
         )
    (PARTITION p1 VALUES LESS THAN (1000),
     PARTITION p2 VALUES LESS THAN (2000),
     PARTITION p3 VALUES LESS THAN (MAXVALUE)
    `
```

For additional information on Oracle Partitioning:
https://docs.oracle.com/cd/E11882_01/server.112/e25523/partition.htm
https://docs.oracle.com/database/121/VLDBG/GUID-C121EA1B-2725-4464-B2C9-EEDE0C3C95AB.htm
https://docs.oracle.com/database/121/VLDBG/GUID-01C14320-0D7B-48BE-A5AD-003DDA761277.htm
https://docs.oracle.com/database/121/VLDBG/GUID-E08650B4-06B1-43F9-91B0-FBF685A3B848.htm#VLDBG1156

Automatic List Partitioning (Oracle 12c only)
Automatic-list partitioning is an enhancement of Oracle list partitioning. Automatic-list partitioning enables the automatic creation of new partitions for new values inserted into the list-partitioned table. An automatic list-partitioned table is created with only one partition. The database creates the additional table partitions automatically.

Example
Create an automatic list-partitioned table:

```
SQL> CREATE TABLE SYSTEM_LOGS
     (EVENT_NO    NUMBER NOT NULL,
      EVENT_DATE  DATE   NOT NULL,
      EVENT_STR   VARCHAR2(500),
      ERROR_CODE  VARCHAR2(10))
     PARTITION BY LIST (ERROR_CODE) AUTOMATIC
     (PARTITION warning VALUES ('err1', 'err2', 'err3'))
```

For additional information on Oracle Automatic List Partitioning:
http://www.oracle.com/technetwork/database/options/partitioning/partitioning-wp-12c-1896137.pdf

Migration to: PostgreSQL Table Inheritance

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Overview

The table partitioning mechanism in PostgreSQL differs from Oracle. Partitioning in PostgreSQL is implemented using "table inheritance". Each *table partition* is represented by a *child table* referenced to a single *parent table.* The *parent table* should be empty and is only used to represent the entire table data set (as a metadata dictionary and as a query source).

Partitioning management operations are performed directly on the *child tables*. Querying is performed directly on the *parent table*.

For additional information on PostgreSQL Table Inheritance, see:
https://www.postgresql.org/docs/9.6/static/ddl-inherit.html

Implementing List "Table Partitioning"

1. Create a *parent table* ("master table") from which all child tables ("partitions") will inherit.
2. Create *child tables* (which act similar to Table Partitions) that inherit from the *parent table*, the *child tables* should have and identical structure to the *parent table*.
3. Create Indexes on each *child table*. Optionally, add constraints (for example, primary keys or check constraints) to define allowed values in each table.
4. Create a database trigger to redirect data inserted into the parent table to the appropriate *child table*.
5. Ensure the PostgreSQL `constraint_exclusion` parameter is enabled and set to `partition`. This parameter insures that the queries are optimized for working with table partitions.

```
demo=# show constraint_exclusion;
 constraint_exclusion
----------------------
 partition
```

For additional information on PostgreSQL constraint_exclusion parameter:
https://www.postgresql.org/docs/9.6/static/runtime-config-query.html#GUC-CONSTRAINT-EXCLUSION

PostgreSQL 9.6 does not support "declarative partitioning" as well as several of the table partitioning features available in Oracle. Alternatives, such as for replacing Oracle's interval table partitioning, include using application-centric methods using PL/pgSQL or other programing languages.

Notes:

- PostgreSQL 9.6 Table Partitioning does not support the creation of foreign keys on the *parent table*. Alternative solutions include application-centric methods such as using triggers/functions.
- PostgreSQL 9.6 does not support sub-partitions and does not support `SPLIT` and EXCHANGE of table partitions.

Oracle versus PostgreSQL Partitioning Comparison Table

Oracle Table Partition Type	Build-In PostgreSQL Support	Link To Example
List	Yes	PostgreSQL List Partitioning
Range	Yes	PostgreSQL Range Partitioning
Hash	No	-
Composite Partitioning	No	-
Interval Partitioning	No	-
Partition Advisor	No	-
Reference Partitioning	No	-
Virtual Column Based Partitioning	No	-
Automatic List Partitioning	No	-
Sub Partitioning	No	-
Split / Exchange Partitions	No	-

For additional details:
https://www.postgresql.org/docs/9.6/static/ddl-partitioning.html

Example

Steps for creating a PostgreSQL "list-partitioned table":

1. Create the parent table:

```
demo=# CREATE TABLE SYSTEM_LOGS
       (EVENT_NO    NUMERIC NOT NULL,
        EVENT_DATE  DATE    NOT NULL,
        EVENT_STR   VARCHAR(500),
        ERROR_CODE VARCHAR(10));
```

2. Create child tables ("partitions") with check constraints:

```
demo=# CREATE TABLE SYSTEM_LOGS_WARNING (
            CHECK (ERROR_CODE IN('err1', 'err2', 'err3')))
            INHERITS (SYSTEM_LOGS);

demo=# CREATE TABLE SYSTEM_LOGS_CRITICAL (
            CHECK (ERROR_CODE IN('err4', 'err5', 'err6')))
            INHERITS (SYSTEM_LOGS);
```

3. Create indexes on each of the child tables ("partitions"):

```
demo=# CREATE INDEX IDX_SYSTEM_LOGS_WARNING ON
            SYSTEM_LOGS_WARNING(ERROR_CODE);

demo=# CREATE INDEX IDX_SYSTEM_LOGS_CRITICAL ON
            SYSTEM_LOGS_CRITICAL(ERROR_CODE);
```

4. Create a function to redirect data inserted into the *Parent Table*:

```
demo=# CREATE OR REPLACE FUNCTION SYSTEM_LOGS_ERR_CODE_INS()
       RETURNS TRIGGER AS
       $$
       BEGIN
            IF (NEW.ERROR_CODE IN('err1', 'err2', 'err3')) THEN
            INSERT INTO SYSTEM_LOGS_WARNING VALUES (NEW.*);
       ELSIF (NEW.ERROR_CODE IN('err4', 'err5', 'err6')) THEN
            INSERT INTO SYSTEM_LOGS_CRITICAL VALUES (NEW.*);
       ELSE
            RAISE EXCEPTION 'Value out of range, check
                             SYSTEM_LOGS_ERR_CODE_INS () Function!';
            END IF;
       RETURN NULL;
       END;
       $$
       LANGUAGE plpgsql;
```

5. Attach the trigger function created above to log to the table:

```
demo=# CREATE TRIGGER SYSTEM_LOGS_ERR_TRIG
       BEFORE INSERT ON SYSTEM_LOGS
       FOR EACH ROW EXECUTE PROCEDURE SYSTEM_LOGS_ERR_CODE_INS();
```

6. Insert data directly into the parent table:

```
demo=# INSERT INTO SYSTEM_LOGS VALUES(1, '2015-05-15', 'a...', 'err1');
demo=# INSERT INTO SYSTEM_LOGS VALUES(2, '2016-06-16', 'b...', 'err3');
demo=# INSERT INTO SYSTEM_LOGS VALUES(3, '2017-07-17', 'c...', 'err6');
```

7. View results from across all the different child tables:

```
demo=# SELECT * FROM SYSTEM_LOGS;
       event_no | event_date | event_str
      ----------+------------+-----------
              1 | 2015-05-15 | a...
              2 | 2016-06-16 | b...
              3 | 2017-07-17 | c...

demo=# SELECT * FROM SYSTEM_LOGS_WARNING;
       event_no | event_date | event_str | error_code
      ----------+------------+-----------+------------
              1 | 2015-05-15 | a...      | err1
              2 | 2016-06-16 | b...      | err3


demo=# SELECT * FROM SYSTEM_LOGS_CRITICAL;
       event_no | event_date | event_str | error_code
      ----------+------------+-----------+------------
              3 | 2017-07-17 | c...      | err6
```

Example

Steps for creating a PostgreSQL “range-partitioned table”:

1. Create the parent table:

```
demo=# CREATE TABLE SYSTEM_LOGS
       (EVENT_NO    NUMERIC NOT NULL,
        EVENT_DATE  DATE    NOT NULL,
        EVENT_STR   VARCHAR(500));
```

2. Create the child tables (“partitions”) with check constraints:

```
demo=# CREATE TABLE SYSTEM_LOGS_2015 (
            CHECK (EVENT_DATE >= DATE '2015-01-01'
                   AND EVENT_DATE < DATE '2016- 01-01')
            ) INHERITS (SYSTEM_LOGS);

demo=# CREATE TABLE SYSTEM_LOGS_2016 (
            CHECK (EVENT_DATE >= DATE '2016-01-01'
                   AND EVENT_DATE < DATE '2017-01-01')
            ) INHERITS (SYSTEM_LOGS);

demo=# CREATE TABLE SYSTEM_LOGS_2017 (
            CHECK (EVENT_DATE >= DATE '2017-01-01'
                   AND EVENT_DATE <= DATE '2017-12-31')
            ) INHERITS (SYSTEM_LOGS);
```

3. Create indexes on each child table (“partitions”):

```
demo=# CREATE INDEX IDX_SYSTEM_LOGS_2015 ON
SYSTEM_LOGS_2015(EVENT_DATE);
demo=# CREATE INDEX IDX_SYSTEM_LOGS_2016 ON
SYSTEM_LOGS_2016(EVENT_DATE);
demo=# CREATE INDEX IDX_SYSTEM_LOGS_2017 ON
SYSTEM_LOGS_2017(EVENT_DATE);
```

4. Create a function to redirect data inserted into the parent table:

```
demo=# CREATE OR REPLACE FUNCTION SYSTEM_LOGS_INS ()
       RETURNS TRIGGER AS
       $$
       BEGIN
           IF (NEW.EVENT_DATE >= DATE '2015-01-01' AND NEW.EVENT_DATE <
       DATE '2016-01-01') THEN
             INSERT INTO SYSTEM_LOGS_2015 VALUES (NEW.*);
          ELSIF (NEW.EVENT_DATE >= DATE '2016-01-01' AND NEW.EVENT_DATE <
       DATE '2017-01-01') THEN
             INSERT INTO SYSTEM_LOGS_2016 VALUES (NEW.*);
          ELSIF (NEW.EVENT_DATE >= DATE '2017-01-01' AND NEW.EVENT_DATE <=
       DATE '2017-12-31') THEN
             INSERT INTO SYSTEM_LOGS_2017 VALUES (NEW.*);
          ELSE
             RAISE EXCEPTION 'Date out of range. check SYSTEM_LOGS_INS ()
       function!';
         END IF;
         RETURN NULL;
       END;
       $$
       LANGUAGE plpgsql;
```

5. Attach the trigger function created above to log to the SYSTEM_LOGS table:

```
demo=# CREATE TRIGGER SYSTEM_LOGS_TRIG
       BEFORE INSERT ON SYSTEM_LOGS
       FOR EACH ROW EXECUTE PROCEDURE SYSTEM_LOGS_INS ();
```

6. Insert data directly to the parent table:

```
demo=# INSERT INTO SYSTEM_LOGS VALUES (1, '2015-05-15', 'a...');
demo=# INSERT INTO SYSTEM_LOGS VALUES (2, '2016-06-16', 'b...');
demo=# INSERT INTO SYSTEM_LOGS VALUES (3, '2017-07-17', 'c...');
```

7. Test the solution by selecting data from the parent and child tables:

```
demo=# SELECT * FROM SYSTEM_LOGS;
       event_no | event_date | event_str
      ----------+------------+-----------
              1 | 2015-05-15 | a...
              2 | 2016-06-16 | b...
              3 | 2017-07-17 | c...

demo=# SELECT * FROM SYSTEM_LOGS_2015;
       event_no | event_date | event_str
      ----------+------------+-----------
              1 | 2015-05-15 | a...
```

Migrating from: Oracle Temporary Tables

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Overview

Oracle enables you to create temporary tables for storing data that should exist only for the duration of a session or transaction.

Oracle uses the `CREATE GLOBAL TEMPORARY TABLE` statement to create a temporary table. This type of table has a persistent DDL structure, but not persistent data, and does not generate redo during DML. Two of the primary use-cases for temporary tables include:

- Processing many rows as part of a batch operation while requiring staging tables to store intermediate results.
- Data is required only for the duration of a specific session. When the session ends, the session data should be cleared.

When using temporary tables, the data is visible only to the session that inserts the data into the table.

Oracle Global Temporary Tables Notes:

- Global Temporary Tables store data inside the Oracle Temporary Tablespace.
- DDL operations on a temporary table are permitted including: `ALTER TABLE, DROP TABLE, CREATE INDEX`.
- Temporary tables cannot be partitioned, clustered, or created as Index-Organized Tables. Also, they do not support parallel `UPDATE`, `DELETE` and `MERGE`.
- Foreign key constraints cannot be created on temporary tables.
- Processing DML operations on a Temporary Table does not generate Redo Data. However, Undo Data for the rows and Redo Data for the Undo Data itself are generated.
- Indexes can be created for a Temporary Table and are treated as Temporary Indexes. Temporary Tables also support Triggers.
- Temporary Tables cannot be named after an existing table object and cannot be dropped while containing records, even from another session.

Session-specific and Transaction-specific Temporary Table syntax:

- **ON COMMIT**
  This clause is associated only with Temporary Tables. It specifies whether the temporary table data persists for the duration of a transaction or a session.

  - **PRESERVE ROWS**
    When the session ends, all data is truncated but persists beyond the end of the transaction.

  - **DELETE ROWS**
    The default behavior. Data is truncated after each commit.

Oracle 12c Temporary Table enhancements:

- **Global Temporary Table statistics**
  Prior to Oracle 12c, statistics on temporary tables were common to all sessions.
  Oracle 12c introduces session-specific statistics for Temporary Tables. Statistics can be configured using the DBMS_STATS preference `GLOBAL_TEMP_TABLE_STATS`, which can be set to SHARED or `SESSION`.

- **Global Temporary Table Undo**
  Performing DML operations on a Temporary Table does not generate Redo data, but does generate Undo Data that eventually, by itself, will generate Redo records. Oracle 12c provides an option to store the temporary Undo Data in the Temporary Tablespace itself. This feature is configured using the `temp_undo_enabled` parameter with the options TRUE or FALSE.

  For additional details:
  https://docs.oracle.com/database/121/REFRN/GUID-E2A01A84-2D63-401F-B64E-C96B18C5DCA6.htm#REFRN10326

Examples

Create an Oracle Global Temporary Table (with `ON COMMIT PRESERVE ROWS`):

```
SQL> CREATE GLOBAL TEMPORARY TABLE EMP_TEMP (
       EMP_ID        NUMBER PRIMARY KEY,
       EMP_FULL_NAME VARCHAR2(60) NOT NULL,
       AVG_SALARY    NUMERIC NOT NULL)
       ON COMMIT PRESERVE ROWS;

SQL> CREATE INDEX IDX_EMP_TEMP_FN ON EMP_TEMP(EMP_FULL_NAME);

SQL> INSERT INTO EMP_TEMP VALUES(1, 'John Smith', '5000');

SQL> COMMIT;

SQL> SELECT * FROM SCT.EMP_TEMP;

    EMP_ID EMP_FULL_NAME        AVG_SALARY
---------- -------------------- ----------
         1 John Smith                 5000
```

Create an Oracle Global Temporary Table (with `ON COMMIT DELETE ROWS`):

```
SQL> CREATE GLOBAL TEMPORARY TABLE EMP_TEMP (
       EMP_ID        NUMBER PRIMARY KEY,
       EMP_FULL_NAME VARCHAR2(60) NOT NULL,
       AVG_SALARY    NUMERIC NOT NULL)
       ON COMMIT DELETE ROWS;

SQL> INSERT INTO EMP_TEMP VALUES(1, 'John Smith', '5000');

SQL> COMMIT;

SQL> SELECT * FROM SCT.EMP_TEMP;
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_7002.htm#SQLRF01402
https://docs.oracle.com/database/121/SQLRF/statements_7002.htm

Migration to: PostgreSQL Temporary Tables

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Overview

PostgreSQL Temporary Tables share many similarities with Oracle Global Temporary Tables.
From a syntax perspective, PostgreSQL Temporary Tables are referred to as "Temporary Tables" (without Oracle's *Global* definition). The implementation is mostly identical.

In terms of differences, Oracle stores the temporary table structure (DDL) for repeated use – even after a database restart – but does not store rows persistently. PostgreSQL implements temporary tables differently: the table structure (DDL) is not stored in the database. When a session ends, the temporary table is dropped.

- **Session-specific** - In PostgreSQL, every session is required to create its own Temporary Tables. Each session can create its own "private" Temporary Tables, using identical table names.

- **`LOCAL` / `GLOBAL` syntax** - PostgreSQL temporary tables do not support cross-session data access. PostgreSQL does not distinguish between "`GLOBAL`" and "`LOCAL`" temporary tables. The use of these keywords *is permitted* in PostgreSQL, but they have *no effect* because PostgreSQL creates Temporary Tables as local and session-isolated tables.

  Note: use of the `GLOBAL` keyword is deprecated.

- In the Oracle Database, the default behavior when the `ON COMMIT` clause is omitted is `ON COMMIT DELETE ROWS`. In PostgreSQL, the default is `ON COMMIT PRESERVE ROWS.`

PostgreSQL Temporary Tables `ON COMMIT` clause:

- **ON COMMIT**

The clause specifies the state of the data as it persists for the duration of a transaction or a session.

  - **PRESERVE ROWS**
    The PostgreSQL default. When a session ends, all data is truncated but persists beyond the end of the transaction.

  - **DELETE ROWS**
    The data is truncated after each commit.

Examples

1. Create a use a Temporary Table, with `ON DELTE PRESERVE ROWS`:

```
demo=> CREATE GLOBAL TEMPORARY TABLE EMP_TEMP (
        EMP_ID        NUMERIC PRIMARY KEY,
        EMP_FULL_NAME VARCHAR(60) NOT NULL,
        AVG_SALARY    NUMERIC NOT NULL)
        ON COMMIT PRESERVE ROWS;

demo=> CREATE INDEX IDX_EMP_TEMP_FN ON EMP_TEMP(EMP_FULL_NAME);

demo=> INSERT INTO EMP_TEMP VALUES(1, 'John Smith', '5000');

demo=> COMMIT;

demo=> SELECT * FROM SCT.EMP_TEMP;

 emp_id | emp_full_name | avg_salary
--------+---------------+------------
      1 | John Smith    |       5000

demo=> DROP TABLE EMP_TEMP;
DROP TABLE
```

2. Create and use a Temporary Table, with `ON COMMIT DELETE ROWS`:

```
demo=> CREATE GLOBAL TEMPORARY TABLE EMP_TEMP (
        EMP_ID        NUMERIC PRIMARY KEY,
        EMP_FULL_NAME VARCHAR(60) NOT NULL,
        AVG_SALARY    NUMERIC NOT NULL)
        ON COMMIT DELETE ROWS;

demo=> INSERT INTO EMP_TEMP VALUES(1, 'John Smith', '5000');

demo=> COMMIT;

demo=> SELECT * FROM SCT.EMP_TEMP;

 emp_id | emp_full_name | avg_salary
--------+---------------+------------
(0 rows)

demo=> DROP TABLE EMP_TEMP;
DROP TABLE
```

Oracle Global Temporary Tables vs. PostgreSQL Temporary Tables:

	Oracle Temporary Tables	PostgreSQL Temporary Tables
Semantic	Global Temporary Table	Temporary Table / Temp Table

Create table	`CREATE GLOBAL TEMPORARY…`	`CREATE GLOBAL TEMPORARY…`
		`CREATE TEMPORARY…`
		`CREATE TEMP…`

Accessible from multiple sessions	Yes	No
Temp table DDL persist after session end / database restart	Yes	No (dropped at the end of the session)
Create index support	Yes	Yes
Foreign key support	Yes	Yes
ON COMMIT default	`COMMIT DELETE ROWS`	`ON COMMIT PRESERVE ROWS`
ON COMMIT PRESERVE ROWS	Yes	Yes
ON COMMIT DELETE ROWS	Yes	Yes
Alter table support	Yes	Yes
Gather statistics	`dbms_stats.gather_table_stats`	`ANALYZE`
Oracle 12c GLOBAL_TEMP_TABLE_STATS	`dbms_stats.set_table_prefs`	`ANALYZE`

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createtable.html

Migrating from: Oracle Unused Columns

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Overview

Oracle provides a method to mark columns as "unused". Unused columns are not physically dropped, but are treated as if they were dropped. Unused columns cannot be restored. Select statements do not retrieve data from columns marked as unused and are not displayed when executing a DESCRIBE table command.

The main advantage of setting a column to UNUSED is to reduce possible high database load when dropping a column from a large table. To overcome this issue, a column can be marked as unused and then be physically dropped later.

To set a column as unused, use the SET UNUSED clause.

Example

```
SQL> ALTER TABLE EMPLOYEES SET UNUSED (COMMISSION_PCT);
SQL> ALTER TABLE EMPLOYEES SET UNUSED (JOB_ID, COMMISSION_PCT);
```

Display unused columns:

```
SQL> SELECT * FROM USER_UNUSED_COL_TABS;

TABLE_NAME                          COUNT
------------------------------ ----------
EMPLOYEES                               3
```

Drop the Column Permanently (physically drop the column):

```
SQL> ALTER TABLE EMPLOYEES DROP UNUSED COLUMNS;
```

For additional details:

https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_3001.htm

http://docs.oracle.com/database/121/SQLRF/statements_3001.htm

Migration to: PostgreSQL Alter Table

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Overview

PostgreSQL does not support marking table columns as “unused”. However, when executing the ALTER TABLE… DROP COLUMN command, the drop column statement does not physically remove the column; it only makes it invisible to SQL operations. As such, dropping a column is a “fast” action, but does not reduce the on-disk size of your table immediately because the space occupied by the dropped column is not reclaimed.

The unused space is reclaimed by new DML actions, as they use the space that once was occupied by the dropped column. To force an immediate reclamation of storage space, the VACUUM FULL command should be used. Alternatively, execute an ALTER TABLE statement to forces a rewrite.

Example

1. PostgreSQL “crop column” statement:

```
demo=> ALTER TABLE EMPLOYEES DROP COLUMN COMMISSION_PCT;
```

2. Verify the operation:

```
demo=> SELECT TABLE_NAME, COLUMN_NAME
       FROM INFORMATION_SCHEMA.COLUMNS
       WHERE TABLE_NAME = 'emps1' AND COLUMN_NAME=LOWER('COMMISSION_PCT');

 table_name | column_name
------------+-------------
(0 rows)
```

3. Use the VACUUM FULL command to reclaim unused space from storage:

```
demo=> VACUUM FULL EMPLOYEES;
```

4. Run the VACUUM FULL statement with the VERBOSE option to display an activity report of the vacuum process that includes the tables vacuumed and the time taken to perform the vacuum operation:

```
demo=> VACUUM FULL VERBOSE EMPLOYEES;
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-altertable.html
https://www.postgresql.org/docs/9.6/static/sql-vacuum.html

Migrating from: Oracle Virtual Columns

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Overview

Oracle Virtual Columns appear as normal columns but their values are calculated instead of being stored in the database. Virtual Columns cannot be created based on other Virtual Columns and can only reference columns from the same table. When creating a Virtual Column, you can explicitly specify the datatype or let the database choose the datatype based on the expression.

Notes

- Virtual Columns can be used with Constraints, Indexes, Table Partitioning, and Foreign Keys.
- Functions in expressions must be deterministic at the time of table creation.
- Virtual Columns cannot be manipulated by DML operations.
- Virtual Columns can be used in a `WHERE` clause and as part of DML commands.
- When creating an index on a virtual column, a Function Based Index is created.
- Virtual columns do not support Index-Organized Tables, external, objects, Clusters, or Temporary Tables.
- The output of a Virtual Column expression must be a Scalar value.
- The Virtual Column keyword `GENERATED ALWAYS AS` and `VIRTUAL` are not mandatory and provided for clarity only.

```
COLUMN_NAME [datatype] [GENERATED ALWAYS] AS (expression) [VIRTUAL]
```

- The keyword AS after the column name can indicate the column is created as a Virtual Column.
- A Virtual Column does not need to be specified in an `INSERT` statement.

Example

1. Create a table that includes two Virtual Columns:

```
SQL> CREATE TABLE EMPLOYEES (
      EMPLOYEE_ID NUMBER,
      FIRST_NAME   VARCHAR2(20),
      LAST_NAME    VARCHAR2(25),
      USER_NAME    VARCHAR2(25),
      EMAIL        AS (LOWER(USER_NAME) || '@aws.com'),
      HIRE_DATE    DATE,
      BASE_SALARY  NUMBER,
      SALES_COUNT  NUMBER,
      FINEL_SALARY NUMBER GENERATED ALWAYS AS
      (CASE WHEN SALES_COUNT >= 10 THEN BASE_SALARY + (BASE_SALARY *
      (SALES_COUNT * 0.05)) END) VIRTUAL);
```

2. Insert a new record into the table without specifying values for the Virtual Column:

```
SQL> INSERT INTO EMPLOYEES
      (EMPLOYEE_ID, FIRST_NAME, LAST_NAME, USER_NAME, HIRE_DATE,
       BASE_SALARY, SALES_COUNT)
      VALUES(1, 'John', 'Smith', 'jsmith', '17-JUN-2003', 5000, 21);
```

3. Select the `email` Virtual Column from the table:

```
SQL> SELECT email FROM EMPLOYEES;

EMAIL                FINEL_SALARY
-------------------- ------------
jsmith@aws.com              10250
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_7002.htm#SQLRF01402
https://docs.oracle.com/database/121/SQLRF/statements_7002.htm#SQLRF01402

Migration to: PostgreSQL Virtual Columns

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Overview

PostgreSQL does not provide a feature that is directly equivalent to a Virtual Column in Oracle. However, there are workarounds to emulate similar functionality.

Alternatives for Virtual Columns:

- **Views**
  Create a View using the function for the "Virtual Column" as part of the View syntax.

- **Function as a column**
  Create a function that receives column values from table records (as parameters) and returns a modified value according to a specific expression. The function serves as a Virtual Column equivalent. You can create a **PostgreSQL Expression Index** (*equivalent to Oracle's Function Based index*) that is based on the function.

Example

The email address for a user is calculated based on the USER_NAME column that is a physical property of the table.

1. Create a table that includes a USER_NAME column but does not include an email address column:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID NUMERIC PRIMARY KEY,
        FIRST_NAME   VARCHAR(20),
        LAST_NAME    VARCHAR(25),
        USER_NAME    VARCHAR(25));
```

2. Create a PL/pgSQL function which receives the USER_NAME value and return the full email address:

```
demo=> CREATE OR REPLACE FUNCTION USER_EMAIL(EMPLOYEES)
       RETURNS text AS $$
       SELECT (LOWER($1.USER_NAME) || '@aws.com')
       $$ STABLE LANGUAGE SQL;
```

3. Insert data to the table, including a value for USER_NAME. During insert, no reference to the USER_EMAIL function is made:

```
demo=> INSERT INTO EMPLOYEES
       (EMPLOYEE_ID, FIRST_NAME, LAST_NAME, USER_NAME)
       VALUES(1, 'John', 'Smith', 'jsmith'),
             (2, 'Steven', 'King', 'sking');
```

4. Use the USER_EMAIL function as part of a SELECT statement:

```
demo=> SELECT EMPLOYEE_ID,
              FIRST_NAME,
              LAST_NAME,
              USER_NAME,
              USER_EMAIL(EMPLOYEES)
       FROM EMPLOYEES;

 employee_id | first_name | last_name | user_name |   user_email
-------------+------------+-----------+-----------+----------------
           1 | John       | Smith     | jsmith    | jsmith@aws.com
           2 | Steven     | King      | sking     | sking@aws.com
```

5. Create a view that incorporates the USER_EMAIL function:

```
demo=> CREATE VIEW employees_function AS
SELECT EMPLOYEE_ID,
              FIRST_NAME,
              LAST_NAME,
              USER_NAME,
              USER_EMAIL(EMPLOYEES)
       FROM EMPLOYEES;
```

6. Create an *Expression Based Index* on the USER_EMAIL column for improved performance:

```
demo=> CREATE INDEX IDX_USER_EMAIL ON
EMPLOYEES(USER_EMAIL(EMPLOYEES));
```

7. Verify the Expression Based Index with EXPLAIN:

```
demo=> SET enable_seqscan = OFF;

demo=> EXPLAIN
       SELECT * FROM EMPLOYEES
       WHERE USER_EMAIL(EMPLOYEES) = 'jsmith@aws.com';

                              QUERY PLAN
----------------------------------------------------------------------
Index Scan using idx_user_email on employees  (cost=0.13..8.14 rows=1
width=294)
Index Cond: ((lower((user_name)::text) || '@aws.com'::text) =
'jsmith@aws.com'::text)
```

DML Support

Using triggers, you can populate column values automatically as “Virtual Columns”. For this approach, create two PostgreSQL objects:

- Create a function containing the data modification logic based on table column data.
- Create a trigger to use the function and execute it as part of the DML.

Example

In the following example, the FULL_NAME column s automatically populated by the values using data from the FIRST_NAME and LAST_NAME columns.

1. Create the table:

```
demo=> CREATE TABLE EMPLOYEES (
        EMPLOYEE_ID NUMERIC PRIMARY KEY,
        FIRST_NAME   VARCHAR(20),
        LAST_NAME    VARCHAR(25),
        FULL_NAME    VARCHAR(25));
```

2. Create a function to concatenate the FIRST_NAME and LAST_NAME columns:

```
demo=> CREATE OR REPLACE FUNCTION FUNC_USER_FULL_NAME ()
       RETURNS trigger as '
       BEGIN
       NEW.FULL_NAME = NEW.FIRST_NAME || '' '' || NEW.LAST_NAME;
       RETURN NEW;
       END;
      ' LANGUAGE plpgsql;
```

3. Create a trigger that uses the function created in the previous step. The function will execute before an insert:

```
demo=> CREATE TRIGGER TRG_USER_FULL_NAME BEFORE INSERT OR UPDATE
        ON EMPLOYEES FOR EACH ROW
        EXECUTE PROCEDURE FUNC_USER_FULL_NAME();
```

4. Verify the functionality of the trigger:

```
demo=> INSERT INTO EMPLOYEES (EMPLOYEE_ID, FIRST_NAME, LAST_NAME)
       VALUES(1, 'John', 'Smith'),(2, 'Steven', 'King');

demo=> SELECT  * FROM EMPLOYEES;

 employee_id | first_name | last_name |  full_name
-------------+------------+-----------+-------------
           1 | John       | Smith     | John Smith
           2 | Steven     | King      | Steven King
```

5. Create an Index based on the "virtual" FULL_NAME column:

```
demo=> CREATE INDEX IDX_USER_FULL_NAME
        ON EMPLOYEES(FULL_NAME);
```

6. Verify the Expression Based Index with EXPLAIN:

```
demo=> SET enable_seqscan = OFF;

demo=> EXPLAIN
       SELECT * FROM EMPLOYEES
       WHERE FULL_NAME = 'John Smith';

                             QUERY PLAN
---------------------------------------------------------------------
 Index Scan using idx_user_full_name on employees  (cost=0.13..8.14 rows=1
width=226)
   Index Cond: ((full_name)::text = 'John Smith'::text)
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createtrigger.html

Migrating from: Oracle User Defined Types

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Overview

Oracle refers to User Defined Types (UDTs) as OBJECT TYPES. They are managed using PL/SQL.
User Defined Types enable you to create application-dedicated, complex data types that are based on, and extend, the built-in Oracle data types.

The CREATE TYPE statement supports creating:

- Objects Types
- Varying Array (varray) types
- Nested Table types
- Incomplete Types
- Additional types such as an SQLJ object type (Java class mapped to SLQ user defined type)

Examples

1. Create an Oracle Object Type to store an employee phone number:

```
SQL> CREATE OR REPLACE TYPE EMP_PHONE_NUM AS OBJECT (
      PHONE_NUM VARCHAR2(11));

SQL> CREATE TABLE EMPLOYEES (
      EMP_ID    NUMBER PRIMARY KEY,
      EMP_PHONE EMP_PHONE_NUM NOT NULL);

SQL> INSERT INTO EMPLOYEES VALUES(1, EMP_PHONE_NUM('111-222-333'));

SQL> SELECT a.EMP_ID, a.EMP_PHONE.PHONE_NUM FROM EMPLOYEES a;

    EMP_ID EMP_PHONE.P
---------- -----------
         1 111-222-333
```

2. Create an Oracle Object Type as a “collection of attributes” for the employees table:

```
SQL> CREATE OR REPLACE TYPE EMP_ADDRESS AS OBJECT (
       STATE    VARCHAR2(2),
       CITY     VARCHAR2(20),
       STREET   VARCHAR2(20),
       ZIP_CODE NUMBER);

SQL> CREATE TABLE EMPLOYEES (
       EMP_ID      NUMBER PRIMARY KEY,
       EMP_NAME    VARCHAR2(10) NOT NULL,
       EMP_ADDRESS EMP_ADDRESS NOT NULL);

SQL> INSERT INTO EMPLOYEES
       VALUES(1, 'John Smith',
       EMP_ADDRESS('AL', 'Gulf Shores', '3033 Joyce Street', '36542'));

SQL> SELECT a.EMP_ID,
            a.EMP_NAME,
            a.EMP_ADDRESS.STATE,
            a.EMP_ADDRESS.CITY,
            a.EMP_ADDRESS.STREET,
            a.EMP_ADDRESS.ZIP_CODE
     FROM EMPLOYEES a;

EMP_ID EMP_NAME    STATE  CITY         STREET             ZIP_CODE
------ ----------- ------ ------------ ------------------ ------
1      John Smith  AL     Gulf Shores  3033 Joyce Street  36542
```

For additional details:
http://docs.oracle.com/cloud/latest/db112/SQLRF/statements_8001.htm#SQLRF01506
http://docs.oracle.com/cloud/latest/db112/LNPLS/create_type.htm#LNPLS01375

Migration to: PostgreSQL User Defined Types

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Overview

Similar to Oracle, PostgreSQL enables creation of User Defined Types using the CREATE TYPE statement. A User Defined Type is owned by the user who creates it. If a schema name is specified, the type is created under the specified schema.

PostgreSQL supports the creation of several different User Defined Types:

- **Composite Types**
  Stores a single named attribute that is attached to a data type or multiple attributes as an attribute collection. In PostgreSQL, you can also use the CREATE TYPE statement standalone with an association to a table.

- **Enumerated Types** (enum)
  Stores a static ordered set of values. For example, product categories:

```
demo=> CREATE TYPE PRODUCT_CATEGORT AS ENUM
        ('Hardware', 'Software', 'Document');
```

- **Range Types**
  Stores a range of values, for example, a range of timestamps used to represent the ranges of time of when a course is scheduled.

```
demo=> CREATE TYPE float8_range AS RANGE
        (subtype = float8, subtype_diff = float8mi);
```

  For more information on PostgreSQL Range Types:
  https://www.postgresql.org/docs/9.6/static/rangetypes.html

- **Base Types**
  These types are the system core types (abstract types) and are implemented in a low-level language such as C.

- **Array Types**
  Support definition of columns as multidimensional arrays. An array column can be created with a built-in type or a user-defined base type, enum type, or composite.

```
demo=> CREATE TABLE COURSE_SCHEDULE (
        COURSE_ID        NUMERIC PRIMARY KEY,
        COURSE_NAME      VARCHAR(60),
        COURSE_SCHEDULES text[]);
```

For additional details:
https://www.postgresql.org/docs/9.1/static/arrays.html

PostgreSQL CREATE TYPE Synopsis

```
CREATE TYPE name AS RANGE (
    SUBTYPE = subtype
    [ , SUBTYPE_OPCLASS = subtype_operator_class ]
    [ , COLLATION = collation ]
    [ , CANONICAL = canonical_function ]
    [ , SUBTYPE_DIFF = subtype_diff_function ]
)

CREATE TYPE name (
    INPUT = input_function,
    OUTPUT = output_function
    [ , RECEIVE = receive_function ]
    [ , SEND = send_function ]
    [ , TYPMOD_IN = type_modifier_input_function ]
    [ , TYPMOD_OUT = type_modifier_output_function ]
    [ , ANALYZE = analyze_function ]
    [ , INTERNALLENGTH = { internallength | VARIABLE } ]
    [ , PASSEDBYVALUE ]
    [ , ALIGNMENT = alignment ]
    [ , STORAGE = storage ]
    [ , LIKE = like_type ]
    [ , CATEGORY = category ]
    [ , PREFERRED = preferred ]
    [ , DEFAULT = default ]
    [ , ELEMENT = element ]
    [ , DELIMITER = delimiter ]
    [ , COLLATABLE = collatable ]
)
```

PostgreSQL syntax differences from Oracle's CREATE TYPE Statement:

- PostgreSQL does not support: `CREATE OR REPLACE TYPE`.
- PostgreSQL does not accept: `AS OBJECT`.

Examples

1. Create a User Define Type as a dedicated type for storing an employee phone number:

```
demo=> CREATE TYPE EMP_PHONE_NUM AS (
        PHONE_NUM VARCHAR(11));

demo=> CREATE TABLE EMPLOYEES (
        EMP_ID    NUMERIC PRIMARY KEY,
        EMP_PHONE EMP_PHONE_NUM NOT NULL);

demo=> INSERT INTO EMPLOYEES VALUES(1, ROW('111-222-333'));

demo=> SELECT a.EMP_ID, (a.EMP_PHONE).PHONE_NUM FROM EMPLOYEES a;

 emp_id |  phone_num
--------+-------------
      1 | 111-222-333
(1 row)
```

2. Create a PostgreSQL Object Type as a collection of Attributes for the employees table:

```
demo=> CREATE OR REPLACE TYPE EMP_ADDRESS AS OBJECT (
        STATE    VARCHAR(2),
        CITY     VARCHAR(20),
        STREET   VARCHAR(20),
        ZIP_CODE NUMERIC);

demo=> CREATE TABLE EMPLOYEES (
        EMP_ID      NUMERIC PRIMARY KEY,
        EMP_NAME    VARCHAR(10) NOT NULL,
        EMP_ADDRESS EMP_ADDRESS NOT NULL);

demo=> INSERT INTO EMPLOYEES
        VALUES(1, 'John Smith',
        ('AL', 'Gulf Shores', '3033 Joyce Street', '36542'));

demo=> SELECT a.EMP_NAME,
             (a.EMP_ADDRESS).STATE,
             (a.EMP_ADDRESS).CITY,
             (a.EMP_ADDRESS).STREET,
              (a.EMP_ADDRESS).ZIP_CODE
       FROM EMPLOYEES a;

  emp_name  | state |    city     |      street       | zip_code
------------+-------+-------------+-------------------+----------
 John Smith | AL    | Gulf Shores | 3033 Joyce Street |    36542
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createtype.html
https://www.postgresql.org/docs/9.6/static/rowtypes.htm

Migrating from: Oracle Read-Only Tables & Partitions

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Overview

Beginning with Oracle 11g, tables can be marked as "read-only", which prevents DML operations from altering table data.

Prior to Oracle 11g, the only way to set a table to "read only" mode was by limiting table privileges to SELECT. The table owner was still able to perform read and write operations. Starting with Oracle 11g, users can execute an ALTER TABALE statement and change the table mode to either READ ONLY or READ WRITE.

Oracle 12c Release 2 introduces greater granularity for read-only objects and supports "read only" table partitions. Any attempt to perform a DML operation on a partition, or sub-partition, set to READ ONLY in Oracle 12.2 results in an error.

Notes:

- SELECT FOR UPDATE statements are not allowed.
- DDL operations are permitted if they do not modify table data.
- Operations on indexes are allowed on tables set to READ ONLY mode.

Example

Oracle READ ONLY and READ WRITE Modes:

```
SQL> CREATE TABLE EMP_READ_ONLY (
      EMP_ID        NUMBER PRIMARY KEY,
      EMP_FULL_NAME VARCHAR2(60) NOT NULL);

SQL> INSERT INTO EMP_READ_ONLY VALUES(1, 'John Smith');
1 row created

SQL> ALTER TABLE EMP_READ_ONLY READ ONLY;

SQL> INSERT INTO EMP_READ_ONLY VALUES(2, 'Steven King');
ORA-12081: update operation not allowed on table "SCT"."TBL_READ_ONLY"

SQL> ALTER TABLE EMP_READ_ONLY READ WRITE;

SQL> INSERT INTO EMP_READ_ONLY VALUES(2, 'Steven King');
1 row created

SQL> COMMIT;

SQL> SELECT * FROM EMP_READ_ONLY;

    EMP_ID EMP_FULL_NAME
---------- --------------------
         1 John Smith
         2 Steven King
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_3001.htm
http://docs.oracle.com/database/121/SQLRF/statements_3001.htm
https://docs.oracle.com/database/122/VLDBG/release-changes.htm#GUID-387B86B7-DBE7-440D-9BCA-E5469E7AE88B__READ-ONLYPARTITIONS-5B55A563

Migration to: PostgreSQL "Read Only" Roles/DB/Triggers

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Overview

PostgreSQL does not provide an equivalent to the READ ONLY mode supported in Oracle.

The following alternatives could be used as workarounds:

- "Read-only" User or Role.
- "Read-only" database.
- Creating a "read-only" database trigger or a using a "read-only" constraint.

PostgreSQL "read-only" User or Role

To achieve some degree of protection from unwanted DML operations on table for a specific Database User, you can grant the user only the `SELECT` privilege on the table and set the user `default_transaction_read_only` parameter to `ON`.

Example

Create a PostgreSQL User with `READ ONLY` privileges:

```
demo=> CREATE TABLE EMP_READ_ONLY (
        EMP_ID        NUMERIC PRIMARY KEY,
        EMP_FULL_NAME VARCHAR(60) NOT NULL);

demo=> CREATE USER aws_readonly PASSWORD 'aws_readonly';
CREATE ROLE

demo=> ALTER USER aws_readonly SET DEFAULT_TRANSACTION_READ_ONLY=ON;
ALTER ROLE

demo=> GRANT SELECT ON EMP_READ_ONLY TO aws_readonly;
GRANT
       -- Open a new session with user "aws_readonly"
demo=> SELECT * FROM EMP_READ_ONLY;

 emp_id | emp_full_name
--------+---------------
(0 rows)

demo=> INSERT INTO EMP_READ_ONLY VALUES(1, 'John Smith');
ERROR:  cannot execute INSERT in a read-only transaction
```

PostgreSQL “read-only” database

As an alternative solution for restricting write operations on database objects, a dedicated “read-only” PostgreSQL database can be created to store all “read-only” tables. PostgreSQL supports multiple databases under the same database instance. Adding a dedicated “read-only” database is a simple and straightforward solution.

- Set the `DEFAULT_TRANSACTION_READ_ONLY` to `ON` for a database. If a session attempts to perform DDL or DML operations, and error will be raised.
- The database can be altered back to `READ WRITE` mode when the parameter is set to “`OFF`”.

Example

Create a PostgreSQL `READ ONLY` database:

```
demo=> CREATE DATABASE readonly_db;
CREATE DATABASE

demo=> ALTER DATABASE readonly_db SET DEFAULT_TRANSACTION_READ_ONLY=ON;
ALTER DATABASE

       -- Open a new session connected to the “readonly_db” database

demo=> CREATE TABLE EMP_READ_ONLY (
        EMP_ID        NUMERIC PRIMARY KEY,
        EMP_FULL_NAME VARCHAR(60) NOT NULL);
ERROR:  cannot execute CREATE TABLE in a read-only transaction

       -- In case of an existing table

demo=> INSERT INTO EMP_READ_ONLY VALUES(1, 'John Smith');
ERROR:  cannot execute INSERT in a read-only transaction
```

“Read-only” Database Trigger

An `INSTEAD OF` trigger can by created to prevent data modifications on a specific table, such as restricting `INSERT, UPDATE, DELETE and TRUNCATE.`

Example

1. Create PostgreSQL function which contains the logic for restricting to “read-only” operations:

```
demo=> CREATE OR REPLACE FUNCTION READONLY_TRIGGER_FUNCTION()
       RETURNS
       TRIGGER AS $$
       BEGIN
            RAISE EXCEPTION 'THE "%" TABLE IS READ ONLY!',
            TG_TABLE_NAME using hint = 'Operation Ignored';
       RETURN NULL;
       END;
       $$ language 'plpgsql';
```

2. Create a trigger which will execute the function that was previously created:

```
demo=> CREATE TRIGGER EMP_READONLY_TRIGGER
       BEFORE INSERT OR UPDATE OR DELETE OR TRUNCATE
       ON EMP_READ_ONLY FOR EACH STATEMENT
       EXECUTE PROCEDURE READONLY TRIGGER FUNCTION();
```

3. Test DML & truncate commands against the table with the new trigger:

```
demo=> INSERT INTO EMP_READ_ONLY VALUES(1, 'John Smith');
       ERROR:  THE "EMP_READ_ONLY" TABLE IS READ ONLY!
       HINT:  Operation Ignored
       CONTEXT:  PL/pgSQL function readonly_trigger_function() line 3 at
       RAISE

demo>= TRUNCATE TABLE SRC;
       ERROR:  THE " EMP_READ_ONLY" TABLE IS READ ONLY!
       HINT:  Operation Ignored
       CONTEXT:  PL/pgSQL function readonly_trigger_function() line 3 at
       RAISE
```

For additional details:
https://www.postgresql.org/docs/9.6/static/ddl-priv.html
https://www.postgresql.org/docs/9.6/static/sql-grant.html
https://www.postgresql.org/docs/9.6/static/runtime-config-client.html

Migration to: PostgreSQL Indexes

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Overview

PostgreSQL supports multiple types of Indexes using different indexing algorithms that can provide performance benefits for different types of queries. The built-in PostgreSQL Index types include:

- **B-Tree**
  Default indexes that can be used for equality and range for the majority of queries.
  These indexes can operate against all datatypes and can be used to retrieve NULL values.
  B-Tree index values are sorted in ascending order by default.

- **Hash**
  Hash Indexes are practical for equality operators. These types of indexes are rarely used because they are not transaction-safe. They need to be rebuilt manually in case of failures.

- **GIN (Generalized Inverted Indexes)**
  GIN indexes are useful when an index needs to map a large amount of values to one row, while B-Tree indexes are optimized for cases when a row has a single key value. GIN indexes work well for indexing full-text search and for indexing array values.

- **GiST (Generalized Search Tree)**
  GiST indexes are not viewed as a single type of index but rather as an index infrastructure; a base to create different indexing strategies. GiST indexes enable building general B-Tree structures that can be used for operations more complex than equality and range comparisons. They are mainly used to create indexes for geometric data types and they support full-text search indexing.

- **BRIN (Block Range Indexes)**
  BRIN Indexes store summary data for values stored in sequential physical table block ranges. A BRIN index contains only the minimum and maximum values contained in a group of database pages. Its main advantage is that it can rule out the presence of certain records and therefore reduce query run time.

Additional PostgreSQL indexes (such as SP-GiST) exist but are currently not supported because they require a loadable extension not currently available in Amazon Aurora PostgreSQL.

PostgreSQL CREATE INDEX Synopsis

```
CREATE [ UNIQUE ] INDEX [ CONCURRENTLY ] [ [ IF NOT EXISTS ] name ]
ON table_name [ USING method ]
    ( { column_name | ( expression ) } [ COLLATE collation ] [ opclass ]
[ ASC | DESC ] [ NULLS { FIRST | LAST } ] [, ...] )
    [ WITH ( storage_parameter = value [, ... ] ) ]
    [ TABLESPACE tablespace_name ]
    [ WHERE predicate ]
```

By default, the CREATE INDEX statement creates a **B-Tree** index.

Examples

Oracle CREATE/DROP Index:

```
SQL> CREATE UNIQUE INDEX IDX_EMP_ID ON EMPLOYEES (EMPLOYEE_ID DESC);
SQL> DROP INDEX IDX_EMP_ID;
```

PostgreSQL CREATE/DROP Index:

```
demo=> CREATE UNIQUE INDEX IDX_EMP_ID ON EMPLOYEES (EMPLOYEE_ID DESC);
demo=> DROP INDEX IDX_EMP_ID;
```

Oracle ALTER INDEX - RENAME:

```
SQL> ALTER INDEX IDX_EMP_ID RENAME TO IDX_EMP_ID_OLD;
```

PostgreSQL ALTER INDEX - RENAME:

```
demo=> ALTER INDEX IDX_EMP_ID RENAME TO IDX_EMP_ID_OLD;
```

Oracle ALTER INDEX - TABLESPACE:

```
SQL> ALTER INDEX IDX_EMP_ID REBUILD TABLESPACE USER_IDX;
```

PostgreSQL ALTER INDEX - TABLESPACE:

```
demo=> CREATE TABLESPACE PGIDX LOCATION '/data/indexes';
demo=> ALTER INDEX IDX_EMP_ID SET TABLESPACE PGIDX;
```

Oracle REBUILD INDEX:

```
SQL> ALTER INDEX IDX_EMP_ID REBUILD;
```

PostgreSQL REINDEX (REBUILD) INDEX:

```
demo=> REINDEX INDEX IDX_EMP_ID;
```

Oracle REBUILD INDEX ONLINE:

```
SQL> ALTER INDEX IDX_EMP_ID REBUILD ONLINE;
```

PostgreSQL REINDEX (REBUILD) INDEX ONLINE:

```
demo=> CREATE INDEX CONCURRENTLY IDX_EMP_ID1 ON EMPLOYEES(EMPLOYEE_ID);
demo=> DROP INDEX CONCURRENTLY IDX_EMP_ID;
```

For additional information on PostgreSQL Indexes:
https://www.postgresql.org/docs/9.6/static/sql-createindex.html#SQL-CREATEINDEX-CONCURRENTLY
https://www.postgresql.org/docs/9.6/static/sql-alterindex.html
https://www.postgresql.org/docs/current/static/sql-reindex.html

Oracle vs. PostgreSQL Indexes

Oracle Indexes Types / Features	PostgreSQL Compatibility	PostgreSQL Equivalent
B-Tree Index	Supported	B-Tree Index
Index-Organized Tables	Supported	PostgreSQL CLUSTER
Reverse key indexes	Not supported	-
Descending indexes	Supported	ASC (default) / DESC
B-tree cluster indexes	Not supported	-
Unique / non-unique Indexes	Supported	Syntax is identical
Function-Based Indexes	Supported	PostgreSQL Expression Indexes
Application Domain indexes	Not supported	-
BITMAP Index / Bitmap Join Indexes	Not supported	Consider BRIN index*
Composite Indexes	Supported	Multicolumn Indexes
Invisible Indexes	Not supported	Extension “hypopg” is not currently supported*
Local and Global Indexes	Not supported	-
Partial Indexes for Partitioned Tables (Oracle 12c)	Not supported	-
CREATE INDEX… / DROP INDEX…	Supported	High percentage of syntax similarity
ALTER INDEX… (General Definitions)	Supported	-
ALTER INDEX… REBUILD	Supported	REINDEX
ALTER INDEX… REBUILD ONLINE	Limited support	CONCURRENTLY
Index Metadata	PG_INDEXES (Oracle USER_INDEXES)	-
Index Tablespace Allocation	Supported	SET TABLESPACE
Index Parallel Operations	Not supported	-
Index Compression	Not direct equivalent to Oracle index key compression or advanced index compression	-

Migrating from: Oracle B-Tree Indexes

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Overview

B-Tree indexes ("B" stands for balanced), are the most common index type in Relational Database and are used for a variety of common query performance enhancing tasks. B-Tree indexes can be defined as an ordered list of values divided into ranges. They provide superior performance by associating a key with a row or range of rows.

B-Tree indexes contain two types of blocks: branch blocks for searching and leaf blocks for storing values. The branch blocks also contain the root branch, which points to lower-level index blocks in the B-Tree index structure.

B-Tree indexes are useful for Primary Keys and other high-cardinality columns. They provide excellent data access performance for a variety of query patterns such as exact match searches and range searches. B-Tree indexes serve as the default index type when creating a new index.

Example

Creating an Oracle B-Tree Index:

```
SQL> CREATE INDEX IDX_EVENT_ID ON SYSTEM_LOG(EVENT_ID);
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e40540/indexiot.htm#CNCPT721

Migration to: PostgreSQL B-Tree Indexes

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Overview

When creating an Index in PostgreSQL, a B-Tree Index is created by default, similarly to the behavior in the Oracle Database. PostgreSQL B-Tree indexes have the same characteristics as Oracle and these types of indexes can handle equality and range queries on data. The PostgreSQL optimizer considers using B-Tree indexes especially when using one or more of the following operators in queries: `>, >=, <, <=, =`

In addition, performance improvements can be achieved when using `IN, BETWEEN, IS NULL or IS NOT NULL.`

Example

Create a PostgreSQL B-Tree Index:

```
demo=> CREATE INDEX IDX_EVENT_ID ON SYSTEM_LOG(EVENT_ID);
     OR
demo=> CREATE INDEX IDX_EVENT_ID1 ON SYSTEM_LOG USING BTREE (EVENT_ID);
```

Migrating from: Oracle Composite Indexes

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Overview

An index that is created on multiple table columns is known as a multi-column, concatenated or Composite Index. The main purpose of these indexes is to improve the performance of data retrieval for SELECT statements when filtering on all or some of the Composite Index columns. When using Composite Indexes, it is beneficial to place the most restrictive columns at the first position of the index to improve query performance. Column placement order is crucial when using Composite Indexes as the most prevalent columns are accessed first.

Example

Create a Composite Index on the HR.EMPLOYEES table:

```
CREATE INDEX IDX_EMP_COMPI
  ON EMPLOYEES (FIRST_NAME, EMAIL, PHONE_NUMBER);
```

Drop a Composite Index:

```
DROP INDEX IDX_EMP_COMPI;
```

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28274/data_acc.htm#i2773
https://docs.oracle.com/database/121/CNCPT/indexiot.htm#CNCPT88833

Migration to: PostgreSQL Multi-Column Indexes

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Overview

PostgreSQL Multi-Column Indexes are similar to Oracle Composite Indexes.

- Currently, only B-tree, GiST, GIN, and BRIN support Multi-Column Indexes.
- 32 columns can be specified when creating a Multi-Column Index.

PostgreSQL uses the exact same syntax as Oracle to create Multi-Column Indexes.

Example

Create a Multi-Column Index on the `EMPLOYEES` table:

```
CREATE INDEX IDX_EMP_COMPI
  ON EMPLOYEES (FIRST_NAME, EMAIL, PHONE_NUMBER);
```

Drop a Multi-Column Index:

```
DROP INDEX IDX_EMP_COMPI;
```

For additional details:
https://www.postgresql.org/docs/9.6/static/indexes-multicolumn.html

Migrating from: Oracle BITMAP Indexes

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Overview

BITMAP indexes are task-specific indexes that are best suited for providing fast data retrieval for OLAP workloads. BITMAP Indexes are generally very fast for read-mostly scenarios. BITMAP indexes do not perform well in heavy-DML or OLTP-type workloads.

Unlike B-Tree Indexes where an index entry points to a specific table row, when using BITMAP Indexes, the index stores a BITMAP for each index key.

BITMAP Indexes are ideal for low-cardinality data filtering, where the number of distinct values in a column is relatively small.

Example

Create an Oracle BITMAP Index:

```
SQL> CREATE BITMAP INDEX IDX_BITMAP_EMP_GEN ON EMPLOYEES(GENDER);
```

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28286/statements_5011.htm#SQLRF01209
https://docs.oracle.com/database/121/SQLRF/statements_5013.htm#SQLRF01209

Migration to: PostgreSQL BRIN Indexes

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PostgreSQL Index Overview

PostgreSQL does not provide native support for BITMAP indexes. However, a BRIN index, which splits table records into block ranges with MIN/MAX summaries, can be used as a ***partial*** alternative for ***certain*** analytic workloads. For example, BRIN indexes are suited for queries that rely heavily on aggregations to analyze large numbers of records.

However, Oracle BITMAP indexes and PostgreSQL BRIN indexes are not implemented in the same way and cannot be used as direct equivalents.

Example

PostgreSQL BRIN Index Creation:

```
demo=> CREATE INDEX IDX_BRIN_EMP ON EMPLOYEES USING BRIN(salary);
```

For additional details:
https://www.postgresql.org/docs/9.6/static/indexes-types.html
https://www.postgresql.org/docs/9.6/static/sql-createindex.html#SQL-CREATEINDEX-CONCURRENTLY

Migrating from: Oracle Function-Based Indexes

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Overview

Function-Based Indexes allow functions to be used in the WHERE clause of queries on indexes columns. Function-Based Indexes store the output of a Function applied on the values of a table column. The Oracle Query Optimizer will only use a Function-Based Index when the function itself is used in the query itself. To maintain Function-Based Indexes updated, when the Oracle Database processes DML operations it will also evaluate the output of the Function on updated column values.

Example

Creation of a Function-Based Index:

```
SQL> CREATE TABLE SYSTEM_EVENTS(
       EVENT_ID NUMERIC PRIMARY KEY,
       EVENT_CODE VARCHAR2(10) NOT NULL,
       EVENT_DESCIPTION VARCHAR2(200),
       EVENT_TIME TIMESTAMPNOT NULL);

SQL> CREATE INDEX EVNT_BY_DAY ON SYSTEM_EVENTS(EXTRACT(DAY FROM EVENT_TIME));
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e40540/indexiot.htm#CNCPT721
https://docs.oracle.com/database/121/SQLRF/statements_5013.htm#SQLRF01209

Migration to: PostgreSQL Expression Indexes

Overview

PostgreSQL supports Expression Indexes which are similar to Function-Based Indexes in Oracle.

Examples

1. Creating an Expression Index in PostgreSQL:

```
demo=> CREATE TABLE SYSTEM_EVENTS(
         EVENT_ID NUMERIC PRIMARY KEY,
         EVENT_CODE VARCHAR(10) NOT NULL,
         EVENT_DESCIPTION VARCHAR(200),
         EVENT_TIME TIMESTAMP NOT NULL);

Demo=> CREATE INDEX EVNT_BY_DAY ON SYSTEM_EVENTS(EXTRACT(DAY FROM EVENT_TIME));
```

2. Inserting records to the SYSTEM_EVENTS table, gathering table statistics using the ANALYZE statement and verifying that the Expression Index ("EVNT_BY_DAY") is being used for data access.

```
demo=> INSERT INTO SYSTEM_EVENTS
        SELECT ID AS event_id,
        'EVNT-A'||ID+9||'-'||ID AS event_code,
        CASE WHEN mod(ID,2) = 0 THEN 'Warning' ELSE 'Critical' END AS
event_desc,
        now() + INTERVAL '1 minute' * ID AS event_time
       FROM
       (SELECT generate_series(1,1000000) AS ID) A;
INSERT 0 1000000

demo=> ANALYZE SYSTEM_EVENTS;
ANALYZE

demo=> EXPLAIN
       SELECT * FROM SYSTEM_EVENTS
       WHERE EXTRACT(DAY FROM EVENT_TIME) = '22';

                                    QUERY PLAN
----------------------------------------------------------------------------------
 Bitmap Heap Scan on system_events  (cost=729.08..10569.58 rows=33633 width=41)
   Recheck Cond: (date_part('day'::text, event_time) = '22'::double precision)
   ->  Bitmap Index Scan on evnt_by_day  (cost=0.00..720.67 rows=33633 width=0)
         Index Cond: (date_part('day'::text, event_time) = '22'::double precision)
```

Partial Indexes

PostgreSQL also offers "partial indexes", which are indexes that use a WHERE clause when created. The biggest benefit of using "partial indexes" is reduction of the overall subset of indexed data allowing users to index relevant table data only. "Partial indexes" can be used to increase efficiency and reduce the size of the index.

Example

Create a PostgreSQL "partial Index":

```
demo=> CREATE TABLE SYSTEM_EVENTS(
       EVENT_ID NUMERIC PRIMARY KEY,
       EVENT_CODE VARCHAR(10) NOT NULL,
       EVENT_DESCIPTION VARCHAR(200),
       EVENT_TIME DATE NOT NULL);

Demo=> CREATE INDEX IDX_TIME_CODE ON SYSTEM_EVENTS(EVENT_TIME)
                                       WHERE EVENT_CODE like '01-A%';
```

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createindex.html#SQL-CREATEINDEX-CONCURRENTLY

Migrating from: Oracle Local and Global Partitioned Indexes

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Overview

Local and Global Indexes are used for Partitioned Tables:

- **Local Partitioned Index**
  Maintain a one-to-one relationship between the Index Partitions and the Table Partitions. For each Table Partition, a separate Index Partition will be created. This type of index is created using the `LOCAL` clause. Because each Index Partition is independent, index maintenance operations are easier and can be performed independently. Local Partitioned Indexes are managed automatically by the Oracle Database during creation or deletion of Table Partitions.

- **Global Partitioned Index**
  Each Global Index contains keys from multiple table partitions in a single index partition. This type of index is created using the `GLOBAL` clause during index creation. A Global index can be partitioned or non-partitioned (default).

  Certain restrictions exist when creating Global Partitioned Indexes on Partitioned Tables, specifically for index management and maintenance. For example, dropping a Table Partition causes the Global Index to become unusable without an index rebuild.

Example

Create a Local and Global Index on a Partitioned Table:

```
SQL> CREATE INDEX IDX_SYS_LOGS_LOC ON SYSTEM_LOGS (EVENT_DATE)
      LOCAL
      (PARTITION EVENT_DATE_1,
       PARTITION EVENT_DATE_2,
       PARTITION EVENT_DATE_3);
```

```
SQL> CREATE INDEX IDX_SYS_LOGS_GLOB ON SYSTEM_LOGS (EVENT_DATE)
     GLOBAL PARTITION BY RANGE (EVENT_DATE) (
     PARTITION EVENT_DATE_1 VALUES LESS THAN
(TO_DATE('01/01/2015','DD/MM/YYYY')),
     PARTITION EVENT_DATE_2 VALUES LESS THAN
(TO_DATE('01/01/2016','DD/MM/YYYY')),
     PARTITION EVENT_DATE_3 VALUES LESS THAN
(TO_DATE('01/01/2017','DD/MM/YYYY')),
     PARTITION EVENT_DATE_4 VALUES LESS THAN (MAXVALUE);
```

For additional details:
https://docs.oracle.com/cd/E18283_01/server.112/e16541/partition.htm
https://docs.oracle.com/database/121/VLDBG/GUID-81DD6045-A269-4BD2-9EBF-E430F8C3E51B.htm#VLDBG1354

Migration to: PostgreSQL Partitioned Indexes

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Overview

The Table Partitioning mechanism in PostgreSQL is different when compared to Oracle. There is no direct equivalent for Oracle Local and Global Indexes. The implementation of partitioning in PostgreSQL ("Table Inheritance") includes the use of a Parent Table with Child Tables used as the table partitions.

- Indexes created on the Child Tables behave similarly to Local Indexes in the Oracle database, with per-table indexes ("partitions").
- Creating an index on the parent table, similar to a Global Indexes in Oracle, has no effect.

Example

1. Create the Parent Table:

```
demo=# CREATE TABLE SYSTEM_LOGS
       (EVENT_NO    NUMERIC NOT NULL,
        EVENT_DATE  DATE    NOT NULL,
        EVENT_STR   VARCHAR(500),
        ERROR_CODE VARCHAR(10));
```

2. Create Child Tables ("partitions") with a Check Constraint:

```
demo=# CREATE TABLE SYSTEM_LOGS_WARNING (
            CHECK (ERROR_CODE IN('err1', 'err2', 'err3')))
            INHERITS (SYSTEM_LOGS);

demo=# CREATE TABLE SYSTEM_LOGS_CRITICAL (
            CHECK (ERROR_CODE IN('err4', 'err5', 'err6')))
            INHERITS (SYSTEM_LOGS);
```

3. Create Indexes on each Child Table ("partitions")

```
demo=# CREATE INDEX IDX_SYSTEM_LOGS_WARNING ON
            SYSTEM_LOGS_WARNING(ERROR_CODE);

demo=# CREATE INDEX IDX_SYSTEM_LOGS_CRITICAL ON
            SYSTEM_LOGS_CRITICAL(ERROR_CODE);
```

PostgreSQL does not have direct equivalents for Local and Global indexes in Oracle. However, indexes that have been created on the Child Tables behave *similarly* to Local Indexes in Oracle.

For additional details:
https://www.postgresql.org/docs/9.6/static/ddl-partitioning.html

Migrating from: Oracle Identity Columns

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Overview

Oracle 12c introduced support for automatic generation of values to populate columns in database tables. The `IDENTITY` type generates a sequence and associates it with a table column *without* the need to manually create a separate Sequence object. The `IDENTITY` type relies (internally) on Sequences, which can also be manually configured.

Example

1. Create a table with an Oracle 12c Identity Column:

```
SQL> CREATE TABLE IDENTITY_TST (
      COL1 NUMBER GENERATED BY DEFAULT AS IDENTITY
                                          (START WITH 100
                                           INCREMENT BY 10),
      COL2 VARCHAR2(30));
```

2. Insert data into the table. The Identity Column automatically generates values for `COL1`.

```
SQL> INSERT INTO IDENTITY_TST(COL2) VALUES('A');
SQL> INSERT INTO IDENTITY_TST(COL1, COL2) VALUES(DEFAULT, 'B');
SQL> INSERT INTO IDENTITY_TST(col1, col2) VALUES(NULL, 'C');

SQL> SELECT * FROM IDENTITY_TST;
      COL1 COL2
---------- ------------------------------
       100 A
       110 B
```

For additional details:
https://docs.oracle.com/database/121/SQLRF/statements_6017.htm#SQLRF01314
http://www.oracle.com/technetwork/issue-archive/2013/13-sep/o53asktom-1999186.html

Migration to: PostgreSQL SERIAL Type

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Overview

PostgreSQL enables you to create a Sequence that is similar to the AUTO_INCREMENT property supported by Oracle 12c's Identity column feature. When creating a new table using the SERIAL pseudo-type, a Sequence is created. Additional types from the same family are SMALLSERIAL and BIGSERIAL.

By assigning a SERIAL type to a column as part of table creation, PostgreSQL creates a Sequence using default configuration and adds the NOT NULL constraint to the column. The new Sequence can be altered and configured as a regular Sequence.

Example

Using the PostgreSQL SERIAL pseudo-type (with a Sequence that is created implicitly):

```
psql=> CREATE TABLE SERIAL_SEQ_TST(
       COL1 SERIAL PRIMARY KEY,
       COL2 VARCHAR(10));

psql=> \ds

 Schema |          Name          |   Type   | Owner
--------+------------------------+----------+-------
 public | serial_seq_tst_col1_seq | sequence | pg_tst_db

psql=> ALTER SEQUENCE SERIAL_SEQ_TST_COL1_SEQ RESTART WITH 100
       INCREMENT BY 10;

psql=> INSERT INTO SERIAL_SEQ_TST(COL2) VALUES('A');
psql=> INSERT INTO SERIAL_SEQ_TST(COL1, COL2) VALUES(DEFAULT, 'B');

psql=> SELECT * FROM SERIAL_SEQ_TST;

 col1 | col2
------+------
  100 | A
  110 | B
```

For additional details:

https://www.postgresql.org/docs/9.6/static/sql-createsequence.html
https://www.postgresql.org/docs/9.6/static/functions-sequence.html
https://www.postgresql.org/docs/9.6/static/datatype-numeric.html

Migrating from: Oracle MVCC

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Overview

Two *primary* lock types exist in the Oracle database: *exclusive locks* and *share locks* which implement the following high-level locking semantics:

- Writers *never* block readers.
- Readers *never* block writers.
- Oracle *never* escalates locks from row to page and table level, which reduces potential deadlocks.
- Oracle allows the user to issue an explicit lock on a specific table using the `LOCK TABLE` statement.

Lock types can be divided into four categories:

- **DML Locks**
  Preserving data integrity accessed concurrently by multiple users, DML statements acquire locks automatically both on row and table levels.

  - **Row Locks (TX)** – obtained on a single row of a table by one the following statements: `INSERT, UPDATE, DELETE, MERGE, and SELECT ... FOR UPDATE`.
    If a transaction obtains a row lock, a table lock is also acquired to prevent DDL modifications to the table that might cause conflicts. The lock exists until the transaction ends with a `COMMIT` or `ROLLBACK`.

  - **Table Locks (TM)** - When performing one of the following DML operations: `INSERT, UPDATE, DELETE, MERGE, and SELECT ... FOR UPDATE,` a transaction automatically acquires a table lock to prevent DDL modifications to the table that might cause conflicts if the transaction did not issue a `COMMIT` or `ROLLBACK`.

The following table provides additional information regarding row and table locks:

Statement	Row Locks	Table Lock Mode	RS	RX	S	SRX	X
SELECT … FROM *table...*	—	none	Y	Y	Y	Y	Y
INSERT INTO *table*…	Yes	SX	Y	Y	N	N	N
UPDATE *table* …	Yes	SX	Y	Y	N	N	N
MERGE INTO *table* …	Yes	SX	Y	Y	N	N	N
DELETE FROM *table*…	Yes	SX	Y	Y	N	N	N
SELECT … FROM *table* FOR UPDATE OF…	Yes	SX	Y	Y	N	N	N
LOCK TABLE *table* IN…	—						
ROW SHARE MODE		SS	Y	Y	Y	Y	N
ROW EXCLUSIVEMODE		SX	Y	Y	N	N	N
SHARE MODE		S	Y	N	Y	N	N
SHARE ROWEXCLUSIVE MODE		SSX	Y	N	N	N	N
EXCLUSIVE MODE		X	N	N	N	N	N

- **DDL Locks**
  The main purpose of a DDL lock is to protect the definition of a schema object while it is modified by an ongoing DDL operation such as `ALTER TABLE EMPLOYEES ADD <COLUMN>`.

- **Explicit (Manual) Data Locking**
  The user has the ability to explicitly create a lock to achieve transaction-level read consistency for when an application requires transactional exclusive access to a resource without waiting for other transactions to complete. Explicit data locking can be done at the transaction level or the session level:

  Transaction Level:
  - `SET TRANSACTION ISOLATION LEVEL`
  - `LOCK TABLE`
  - `SELECT … FOR UPDATE`

  Session Level:
  - `ALTER SESSION SET ISOLATION LEVEL`

- **System Locks**
  Oracle lock types such as Latches, Mutexes, and internal locks.

Examples

Explicit data lock using the LOCK TABLE command:

```
-- Session 1
SQL> LOCK TABLE EMPLOYEES IN EXCLUSIVE MODE;

-- Session 2
SQL> UPDATE EMPLOYEES
     SET SALARY=SALARY+1000
     WHERE EMPLOYEE_ID=114;

-- Session 2 waits for session 1 to COMMIT or ROLLBACK
```

Explicit data lock using the SELECT… FOR UPDATE command. Oracle obtains exclusive row-level locks on all the rows identified by the SELECT FOR UPDATE statement:

```
-- Session 1
SQL> SELECT * FROM EMPLOYEES WHERE EMPLOYEE_ID=114 FOR UPDATE;

-- Session 2
SQL> UPDATE EMPLOYEES
     SET SALARY=SALARY+1000
     WHERE EMPLOYEE_ID=114;

-- Session 2 waits for session 1 to COMMIT or ROLLBACK
```

For additional details:
https://docs.oracle.com/cloud/latest/db112/SQLRF/statements_9015.htm#SQLRF01605
http://docs.oracle.com/cd/E18283_01/server.112/e17118/ap_locks002.htm
https://docs.oracle.com/database/121/SQLRF/ap_locks001.htm#SQLRF55502
https://docs.oracle.com/database/121/SQLRF/ap_locks003.htm#SQLRF55513
https://docs.oracle.com/database/121/SQLRF/ap_locks002.htm#SQLRF55509

Migration to: PostgreSQL MVCC

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Overview

PostgreSQL provides various lock modes to control concurrent access to data in tables. Data consistency is maintained using a Multi-Version Concurrency Control (MVCC) mechanism. Most PostgreSQL commands automatically acquire locks of appropriate modes to ensure that referenced tables are not dropped or modified in incompatible ways while the command executes.

The MVCC mechanism prevents viewing inconsistent data produced by concurrent transactions performing updates on the same rows. MVCC in PostgreSQL provides strong *transaction isolation* for each database session and minimizes lock-contention in multiuser environments.

- Similarly, to Oracle, MVCC locks acquired for querying (reading) data do not conflict with locks acquired for writing data. **Reads will never block writes and writes never blocks reads.**

- Similarly to Oracle, Postgres ***does not escalate locks to table-level,*** such as where an entire table is locked for writes when a certain threshold of row locks is exceeded.

Implicit and Explicit Transactions (Auto-Commit Behavior)

Unlike Oracle, PostgreSQL uses auto-commit for transactions by default. However, there are two options to support explicit transactions, which are similar to the default behavior in Oracle (non-auto-commit):

- Use the `START TRANSACTION` (or `BEGIN TRANSACTION`) statements and then `COMMIT` or `ROLLBACK`.

- Set `AUTOCOMMIT` to OFF at the session level:

```
psql=> \set AUTOCOMMIT off
```

With explicit transactions:

- Users can explicitly issue a lock similar to the `LOCK TABLE` statement in Oracle.

- `SELECT… FOR UPDATE` is supported.

Similarly to Oracle, PostgreSQL automatically acquires the necessary locks to control concurrent access to data. PostgreSQL implements the following types of locks:

1. **Table-level Locks**:

Requested Lock Mode VS current	ACCESS SHARE	ROW SHARE	ROW EXCLUSIVE	SHARE UPDATE EXCLUSIVE	SHARE	SHARE ROW EXCLUSIVE	EXCLUSIVE	ACCESS EXCLUSIVE
ACCESS SHARE								X
ROW SHARE							X	X
ROW EXCLUSIVE					X	X	X	X
SHARE UPDATE EXCLUSIVE				X	X	X	X	X
SHARE			X	X		X	X	X
SHARE ROW EXCLUSIVE			X	X	X	X	X	X
EXCLUSIVE		X	X	X	X	X	X	X
ACCESS EXCLUSIVE	X	X	X	X	X	X	X	X

2. **Row-level Locks**:

Requested Lock Mode VS current	FOR KEY SHARE	FOR SHARE	FOR NO KEY UPDATE	FOR UPDATE
`FOR KEY SHARE`				X
`FOR SHARE`			X	X
`FOR NO KEY UPDATE`		X	X	X
`FOR UPDATE`	X	X	X	X

3. **Page-level Locks:** Shared/Exclusive locks used to control read or write access to table pages in the shared buffer pool. They are released immediately after a row is fetched or updated.

4. **Deadlocks:** Occur when two or more transactions are waiting for one another to release each lock.

Transaction-level locking:
PostgreSQL does not support session isolation levels, although it can be controlled via transactions:

- `SET TRANSACTION ISOLATION LEVEL`
- `LOCK TABLE`
- `SELECT … FOR UPDATE`

PostgreSQL LOCK TABLE Synopsis

```
LOCK [ TABLE ] [ ONLY ] name [ * ] [, ...] [ IN lockmode MODE ] [ NOWAIT ]

where lockmode is one of:
    ACCESS SHARE | ROW SHARE | ROW EXCLUSIVE | SHARE UPDATE EXCLUSIVE
    | SHARE | SHARE ROW EXCLUSIVE | EXCLUSIVE | ACCESS EXCLUSIVE
```

Notes:

- If `ONLY` and `[*]` are specified, the command aborts with an error.
- There is no `UNLOCK TABLE` command. Locks are always released at the end of a transaction (`COMMIT / ROLLBACK`).
- The `LOCK TABLE` command can be used inside a transaction and should appear after the `START TRANSACTION` statement.

Examples

1. Obtain an explicit lock on a table using the `LOCK TABLE` command:

```
-- Session 1
psql=> START TRANSACTION;
psql=> LOCK TABLE EMPLOYEES IN EXCLUSIVE MODE;

-- Session 2
psql=> UPDATE EMPLOYEES
       SET SALARY=SALARY+1000
       WHERE EMPLOYEE_ID=114;

-- Session 2 waits for session 1 to COMMIT or ROLLBACK
```

2. Explicit lock via the `SELECT… FOR UPDATE` command. PostgreSQL obtains exclusive row-level locks on rows referenced by the `SELECT FOR UPDATE` statement. Must be executed inside a transaction.

```
-- Session 1
psql=> START TRANSACTION;
psql=> SELECT * FROM EMPLOYEES WHERE EMPLOYEE_ID=114 FOR UPDATE;

-- Session 2
psql=> UPDATE EMPLOYEES
       SET SALARY=SALARY+1000
       WHERE EMPLOYEE_ID=114;

-- Session 2 waits for session 1 to COMMIT or ROLLBACK
```

PostgreSQL Deadlocks

Deadlocks occur when two or more transactions acquired locks on each other's process resources (table or row). PostgreSQL can detect Deadlocks automatically and resolve the event by aborting one of the transactions, allowing the other transaction to complete.

Example

Simulating a Deadlock:

Session 1	Session 2

Step1:
`UPDATE accounts SET balance = balance + 100.00 WHERE acctnum = 11111;`
 	
Step4:
`UPDATE accounts SET balance = balance - 100.00 WHERE acctnum = 22222;`
	Step2:
	`UPDATE accounts SET balance = balance + 100.00 WHERE acctnum = 22222;`
	
	Step3:
	`UPDATE accounts SET balance = balance - 100.00 WHERE acctnum = 11111;`

Session 1 is waiting for Session 2 and Session 2 is waiting for Session 1 = deadlock.

Real-time Monitoring of Locks using Catalog Tables

- `pg_locks`
- `pg_stat_activity`

Examples

1. Monitor locks using a SQL query:

```
psql=> SELECT
            block.pid                        AS block_pid,
            block_stm.usename                AS blocker_user,
            block.mode                       AS block_mode,
            block.locktype                   AS block_locktype,
            block.relation::regclass         AS block_table,
            block_stm.query                  AS block_query,
            block.GRANTED                    AS block_granted,
            waiting.locktype                 AS waiting_locktype,
            waiting_stm.usename                AS waiting_user,
            waiting.relation::regclass       AS waiting_table,
            waiting_stm.query                AS waiting_query,
            waiting.mode                     AS waiting_mode,
            waiting.pid                      AS waiting_pid
      from pg_catalog.pg_locks AS waiting JOIN
      pg_catalog.pg_stat_activity AS waiting_stm
      ON (waiting_stm.pid = waiting.pid)
      join pg_catalog.pg_locks AS block
      ON ((waiting."database" = block."database"
            AND waiting.relation  = block.relation)
            OR waiting.transactionid = block.transactionid)
      join pg_catalog.pg_stat_activity AS block_stm
      ON (block_stm.pid = block.pid)
      where NOT waiting.GRANTED
      and waiting.pid <> block.pid;
```

2. Generate an explicit lock using the `SELECT… FOR UPDATE` statement:

```
-- Session 1
psql=> START TRANSACTION;
psql=> SELECT * FROM EMPLOYEES WHERE EMPLOYEE_ID=114 FOR UPDATE;

-- Session 2
psql=> UPDATE EMPLOYEES
       SET SALARY=SALARY+1000
       WHERE EMPLOYEE_ID=114;

-- Session 2 waits for session 1 to COMMIT or ROLLBACK
```

3. Run the SQL query from step #1 monitoring locks while distinguishing between the "blocking" and "waiting" session:

```
-[ RECORD 1 ]----+---------------------------------------------------------
block_pid        | 31743
blocker_user     | aurora_admin
block_mode       | ExclusiveLock
block_locktype   | transactionid
block_table      |
block_query      | SELECT * FROM EMPLOYEES WHERE EMPLOYEE_ID=114 FOR UPDATE;
block_granted    | t
waiting_locktype | transactionid
waiting_user     | aurora_admin
waiting_table    |
waiting_query    | UPDATE EMPLOYEES
                 |      SET SALARY=SALARY+1000
                 |      WHERE EMPLOYEE_ID=114;
waiting_mode     | ShareLock
waiting_pid      | 31996
```

Comparing "Locks", Oracle vs. PostgreSQL

Description	Oracle	PostgreSQL

"Dictionary" tables to obtain information about locks	`v$lock;`
	`v$locked_object;`
	`v$session_blockers;`
		`pg_locks`
		`pg_stat_activity`

Lock a table	`BEGIN;` `LOCK TABLE employees IN SHARE ROW EXCLUSIVE MODE;`	`LOCK TABLE employees IN SHARE ROW EXCLUSIVE MODE`
Explicit Locking	`SELECT * FROM employees WHERE employee_id=102 FOR UPDATE;`	`BEGIN;` `SELECT * FROM employees WHERE employee_id=102 FOR UPDATE;`

Explicit Locking , options	`SELECT…FOR UPDATE`	`SELECT … FOR…`
		`KEY SHRE`
		`SHARE`
		`NO KEY UPDATE`
		`UPDATE`

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-lock.html
https://www.postgresql.org/docs/9.6/static/explicit-locking.html

Migrating from: Oracle Character Sets

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Overview

Oracle supports most national and international encoded character set standards including extensive support for Unicode character sets.

Oracle provides two scalar string-specific data types:

1. **VARCHAR2**: stores variable-length character strings with a string length between 1 and 4000 bytes. The Oracle database can be configured to use the VARCHAR2 data type to store either Unicode or Non-Unicode characters.

2. **NVARCHAR2**: scalar data type used to store Unicode data. Supports AL16UTF16 or UTF8, specified during database creation.

Character sets in the Oracle database are defined at Instance (Oracle 11g) or Pluggable Database level (Oracle 12c R2) level. In Pre-12cR2 Oracle databases, the character set for the root Container and all Pluggable Databases were required to be identical.

UTF8 Unicode

Oracle's implementation is done using the AL32UTF8 Character Set and offers encoding of ASCII characters as single-byte for Latin characters, two-bytes for some European and Middle-Eastern languages, and three-bytes for certain South and East-Asian characters. Therefore, Unicode storage requirements are usually higher when compared non-Unicode character sets.

Character Set Migration

Two options exist for modifying existing Instance-level or database-level character sets:

1. Export/Import from the source Instance/PDB to a new Instance/PDB with a modified CS.
2. Database Migration Assistant for Unicode (DMU) which simplifies the migration process to the Unicode CS.

As of 2012, using the CSALTER utility for CS migrations is *deprecated*.

Notes:

1. Oracle Database 12c Release 1 (12.1.0.1) complies with version 6.1 of the Unicode Standard.
2. Oracle Database 12c Release 2 (12.1.0.2) extends the compliance to version 6.2 of the Unicode standard.
3. UTF-8 is supported through the AL32UTF8 CS and is valid as both the client and database character sets.
4. UTF-16BE is supported through AL16UTF16 and is valid as the national (NCHAR) character set.

For additional details:
https://docs.oracle.com/database/121/SQLRF/ap_standard_sql015.htm#SQLRF55539
https://docs.oracle.com/database/121/NLSPG/applocaledata.htm#NLSPG584
https://docs.oracle.com/database/121/NLSPG/ch11charsetmig.htm

Migration to: PostgreSQL Encoding

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Overview

PostgreSQL supports a variety of different character sets, also known as encoding, including support for both single-byte and multi-byte languages. The default character set is specified when initializing your PostgreSQL database cluster with `initdb`. Each individual database created on the PostgreSQL cluster supports individual character sets defined as part of database creation.

Notes:

1. All supported character sets can be used by clients. However, some client-side only characters are not supported for use within the server.
2. Unlike Oracle, PostgreSQL *does not* natively support an NVARHCHAR data type and *does not* offer support for UTF-16.

Type	Function	Implementation Level
Encoding	Defines the basic rules on how alphanumeric characters are represented in binary format, for example – Unicode Encoding.	Database
Locale	Superset which include LC_COLLATE and LC_CTYPE, among others. For example, LC_COLLATE defines how strings are sorted and needs to be a subset supported by the database Encoding.	Table-Column

Example

1. Create a database named `test01` which uses the Korean EUC_KR Encoding the and the `ko`_KR locale.

```
CREATE DATABASE test01 WITH ENCODING 'EUC_KR' LC_COLLATE='ko_KR.euckr'
LC_CTYPE='ko_KR.euckr' TEMPLATE=template0;
```

2. View the character sets configured for each database by querying the System Catalog:

```
select datname, datcollate, datctype from pg_database;
```

Changing Character Sets / Encoding

In-place modification of the database encoding is not recommended nor supported. You must export all data, create a new database with the new encoding, and import the data.

Example

1. Export the data using the `pg_dump` utility:

```
pg_dump mydb1 > mydb1_export.sql
```

2. Rename (or delete) your current database:

```
ALTER DATABASE mydb1 TO mydb1_backup;
```

3. Create a new database using the modified encoding:

```
CREATE DATABASE mydb1_new_encoding WITH ENCODING 'UNICODE'
TEMPLATE=template0;
```

4. Import the data using the `pg_dump` file previously created. Verify that you set your client encoding to the encoding of your "old" database.

```
PGCLIENTENCODING=OLD_DB_ENCODING psql -f mydb1_export.sql
mydb1_new_encoding
```

Note: Using the `client_encoding` parameter overrides the use of `PGCLIENTENCODING`.

Client/Server Character Set Conversions

PostgreSQL supports conversion of character sets between server and client for *specific* character set combinations as described in the `pg_conversion` system catalog.

PostgreSQL includes predefined conversions, for a complete list:
https://www.postgresql.org/docs/current/static/multibyte.html#MULTIBYTE-TRANSLATION-TABLE

You can create a new conversion using the SQL command `CREATE CONVERSION.` By using `CREATE CONVERSION`.

Examples

1. Create a conversion from UTF8 to LATIN1 using a custom-made `myfunc1` function:

```
CREATE CONVERSION myconv FOR 'UTF8' TO 'LATIN1' FROM myfunc1;
```

2. Configure the PostgreSQL client character set:

```
Method 1
========
psql \encoding SJIS

Method 2
========
SET CLIENT_ENCODING TO 'value';
```

3. View the client character set and reset it back to the default value.

```
SHOW client_encoding;

RESET client_encoding;
```

Table Level Collation

PostgreSQL supports specifying the sort order and character classification behavior on a per-column level.

Example

Specify specific collations for individual table columns:

```
CREATE TABLE test1 (
    col1 text COLLATE "de_DE",
    col2 text COLLATE "es_ES");
```

Oracle vs. PostgreSQL Character Sets

	Oracle	PostgreSQL
View database character set	`SELECT * FROM NLS_DATABASE_PARAMETERS;`	`select datname, pg_encoding_to_char(encoding), datcollate, datctype from pg_database;`
Modify the database character set	1. Full Export/Import. 2. When converting to Unicode, use the Oracle DMU utility.	• Export the database. • Drop or rename the database. • Re-create the database with the desired new character set. • Import database data from the exported file into the new database.
Character set granularity	Instance (11g + 12cR1) Database (Oracle 12cR2)	Database
UTF8	Supported via VARCHAR2 and NVARCHAR data types	Supported via VARCHAR datatype
UTF16	Supported via NVARCHAR2 datatype	Not Supported
NCHAR/NVARCHAR data types	Supported	Not supported

For additional details:
https://www.postgresql.org/docs/9.6/static/multibyte.html

Migrating from: Oracle Transaction Model

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Overview

Database transactions are a logical, atomic units of processing that contains one or more SQL statements and may run concurrently alongside other transactions. The primary purpose of a transaction is to ensure the **ACID** model is enforced, including:

- **Atomicity**
  Every statement in a transaction is processed as one logical unit or none are processed. If a single part of a transaction fails, the entire transaction is aborted and no changes are persisted ("all or nothing").

- **Consistency**
  All data integrity constraints are checked and all triggers are processed before a transaction is processed. If any of the constraint are violated, the entire transaction fails.

- **Isolation**
  One transaction is not affected by the behavior of other concurrently-running transactions. The effect of a transaction is not visible to other transactions until the transaction is committed.

- **Durability**
  Once a transaction commits, its results will not be lost, regardless of subsequent failures.
  After a transaction completes, changes made by committed transactions are permanent. The database ensures that committed transactions cannot be lost.

Database Transaction Isolation Levels

Four levels of isolation are defined by the ANSI/ISO SQL standard (SQL92). Each level offers a different approach to handle the concurrent execution of database transactions. Transaction isolation levels are meant to manage the visibility of the changed data, as seen by other running transactions. In addition, when accessing the same data with several concurrent transactions, the selected level of transaction isolation affects the way different transactions interact with each other.

Example
If a bank account is shared by two individuals, what will happen if both parties attempt to perform a transaction on the shared account at the same time? One checks the account balance while the other withdraws money.

- **Read Uncommitted Isolation Level**
  A currently processed transaction can see uncommitted data made by the other transaction. If a rollback is performed, all data is restored to its previous state.

- **Read Committed Isolation Level**
  A currently processed transaction only sees data changes that were committed; "dirty reads" (uncommitted changes) are not possible.

- **Repeatable Read Isolation Level**
  A currently processed transaction can view changes made by the other transaction only after both transactions issue a Commit or both are rolled-back.

- **Serializable Isolation Level**
  The strictest isolation level. Any concurrent execution of a set of serializable transactions is guaranteed to produce the same effect as running them, one at a time, in the same order.

Using different isolation levels will affect the following in terms of database behavior:

- **Dirty Reads**
  A transaction can read data that was written by another transaction, but is not yet committed.

- **Non-Repeatable (fuzzy) Reads**
  When reading the same data several times, a transaction can find that the data has been modified by another transaction that has just committed. The same query executed twice can return different values for the same rows.

- **Phantom Reads**
  Similar to a non-repeatable read, but it is related to new data created by another transaction. The same query executed twice can return a different numbers of records.

Isolation level	Dirty read	Non-repeatable read	Phantom read
Read Uncommitted	Permitted	Permitted	Permitted
Read Committed	Not permitted	Permitted	Permitted
Repeatable Read	Not permitted	Not permitted	Permitted
Serializable	Not permitted	Not permitted	Not permitted

Isolation Levels Supported by the Oracle Database

Oracle supports the *Read Committed* and *Serializable* isolation levels. Oracle also provides a *Read-Only* isolation level which is not a part of the ANSI/ISO SQL standard (SQL92). *Read Committed* is the default isolation level in the Oracle Database.

- **Read Committed**
  Default transaction isolation level in the Oracle database. Each query, executed inside a transaction, only sees data that was committed before the query itself. The Oracle database will never allow reading "dirty pages" and uncommitted data.

- **Serializable**
  Serializable transactions do not experience non-repeatable reads or phantom reads because they are only able to "see" changes that were committed at the time the transaction began, in addition to the changes made by the transaction itself performing DML operations.

- **Read-Only**
  As implemented, the read-only isolation level does not allow any DML operations during the transaction and only sees data committed at the time the transaction began.

Oracle Multiversion Concurrency Control (MVCC)

Oracle uses the MVCC mechanism to provide automatic read consistency across the entire database and all sessions. Using MVCC, database sessions "see" data based on a single point in time, ensuring that only committed changes is viewable. Oracle relies on using the SCN (System Change Number) of the current transaction to obtain a consistent view of the database. Therefore, every database query only returns data which was committed with respect to the SCN that is taken at the time of query execution.

Setting Isolation Levels in Oracle

Oracle database isolation levels can be altered. The isolation level can be changed at the transaction-level and at the session-level.

Example

Altering the isolation-level at the transaction-level:

```
SQL> SET TRANSACTION ISOLATION LEVEL READ COMMITTED;
SQL> SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
SQL> SET TRANSACTION READ ONLY;
```

Altering the isolation-level at a session-level:

```
SQL> ALTER SESSION SET ISOLATION_LEVEL = SERIALIZABLE;
SQL> ALTER SESSION SET ISOLATION_LEVEL = READ COMMITTED;
```

For additional details:
http://docs.oracle.com/cd/E25054_01/server.1111/e25789/transact.htm
https://docs.oracle.com/database/121/CNCPT/transact.htm#CNCPT041

Migration to: PostgreSQL Transaction Model

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Overview

The same ANSI/ISO SQL (SQL92) isolation levels apply to PostgreSQL, with several similarities and some differences:

Isolation Level	Dirty Reads	Non-Repeatable Reads	Phantom Reads
Read Uncommitted	Permitted but not implemented in PostgreSQL	Permitted	Permitted
Read Committed	Not permitted	Permitted	Permitted
Repeatable Read	Not permitted	Not permitted	Permitted but not implemented in PostgreSQL
Serializable	Not permitted	Not permitted	Not permitted

PostgreSQL technically supports the use of any of the above four transaction isolation levels, but only three can practically be used. The Read-Uncommitted isolation level serves as Read-Committed.

The way the Repeatable-Read isolation-level is implemented does not allow for phantom reads, which is similar to the Serializable isolation-level. The primary difference between Repeatable-Read and Serializable is that Serializable guarantees that the result of concurrent transactions will be precisely the same as if they were executed serially, which is not always true for Repeatable-Reads.

Isolation Levels Supported by PostgreSQL

PostgreSQL supports the Read-Committed, Repeatable-Reads, and Serializable isolation levels. Read-Committed is the default isolation level (similar to the default isolation level in the Oracle database).

- **Read-Committed**
  The default PostgreSQL transaction isolation level. Preventing sessions from “seeing” data from concurrent transactions until it is committed. Dirty reads are not permitted.

- **Repeatable-Read**
  Queries can only see rows committed before the first query or DML statement was executed in the transaction.

- **Serializable**
  Provides the strictest transaction isolation level. The Serializable isolation level assures that the result of the concurrent transactions will be the same as if they were executed serially. This is not always the case for the Repeatable-Read isolation level.

Multiversion Concurrency Control (MVCC)
PostgreSQL implements a similar MVCC mechanism when compared to Oracle. In PostgreSQL, the MVCC mechanism allows transactions to work with a consistent snapshot of data ignoring changes made by other transactions which have not yet committed or rolled back. Each transaction "sees" a snapshot of accessed data accurate to its execution start time, regardless of what other transactions are doing concurrently.

Setting Isolation Levels in Aurora PostgreSQL
Isolation levels can be configured at several levels:
- Session level.
- Transaction level.
- Instance level using Aurora "Parameter Groups".

Example
Configure the isolation level for a specific transaction:
```
Demo=> SET TRANSACTION ISOLATION LEVEL READ COMMITTED;
Demo=> SET TRANSACTION ISOLATION LEVEL REPEATABLE READ;
Demo=> SET TRANSACTION ISOLATION LEVEL SERIALIZABLE;
```

Configure the isolation level for a specific session:
```
Demo=> SET SESSION CHARACTERISTICS AS TRANSACTION ISOLATION LEVEL READ COMMITTED;
Demo=> SET SESSION CHARACTERISTICS AS TRANSACTION ISOLATION LEVEL REPEATABLE READ;
Demo=> SET SESSION CHARACTERISTICS AS TRANSACTION ISOLATION LEVEL REPEATABLE READ;
```

View the current isolation level:
```
Demo=> SELECT CURRENT_SETTING('TRANSACTION_ISOLATION'); -- Session
Demo=> SHOW DEFAULT_TRANSACTION_ISOLATION;              -- Instance
```

Modifying instance-level parameters for Aurora PostgreSQL is done using "Parameter Groups". For example altering the `default_transaction_isolation` parameter using the AWS Console or the AWS CLI.

For additional details:
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_WorkingWithParamGroups.html#USER_WorkingWithParamGroups.Modifying

PostgreSQL Transaction Synopsis
```
SET TRANSACTION transaction_mode [...]
SET TRANSACTION SNAPSHOT snapshot_id
SET SESSION CHARACTERISTICS AS TRANSACTION transaction_mode [...]

where transaction_mode is one of:

ISOLATION LEVEL {
SERIALIZABLE | REPEATABLE READ | READ COMMITTED | READ UNCOMMITTED
}
      READ WRITE | READ ONLY [ NOT ] DEFERRABLE
```

Database Feature	Oracle	PostgreSQL	Comments
AutoCommit	Off	On	Can be set to `OFF`
MVCC	Yes	Yes	
Default Isolation Level	Read Committed	Read Committed	
Supported Isolation Levels	Serializable Read-only	Repeatable Reads Serializable Read-only	
Configure Session Isolation Levels	Yes	Yes	
Configure Transaction Isolation Levels	Yes	Yes	
Nested Transaction Support	Yes	No	Consider using `SAVEPOINT` instead
Support for Transaction SAVEPOINTs	Yes	Yes	

Example

Read-Committed Isolation Level

TX1	TX2	Comment
select employee_id, salary from EMPLOYEES where employee_id=100; employee_id	salary ------------+---------- 100	24000.00	select employee_id, salary from EMPLOYEES where employee_id=100; employee_id	salary ------------+---------- 100	24000.00	Same results returned from both sessions

begin;
update employees set
salary=27000 where
employee_id=100;
	begin;
	set transaction isolation
	level read committed;
		TX1 starts a transaction; performs an update.
		TX2 starts a transaction with read-committed isolation level

select employee_id, salary from EMPLOYEES where employee_id=100; employee_id	salary ------------+---------- 100	27000.00	select employee_id, salary from EMPLOYEES where employee_id=100; employee_id	salary ------------+---------- 100	24000.00	**TX1** will “see” the modified results (27000.00) while **TX2** “sees” the original data (24000.00)
	update employees set salary=29000 where employee_id=100;	Waits as **TX2** is blocked by **TX1**
Commit;		**TX1** issues a commit, and the lock is released
	Commit;	**TX2** issues a commit
select employee_id, salary from EMPLOYEES where employee_id=100; employee_id	salary ------------+---------- 100	29000.00	select employee_id, salary from EMPLOYEES where employee_id=100; employee_id	salary ------------+---------- 100	29000.00	Both queries return the value - 29000.00

Example

Serializable Isolation Level

<table>
<tr><th>TX1</th><th>TX2</th><th>Comment</th></tr>
<tr><td>select employee_id, salary
from EMPLOYEES
where employee_id=100;

employee_id | salary
------------+----------
100 | 24000.00</td><td>select employee_id, salary
from EMPLOYEES
where employee_id=100;

employee_id | salary
------------+----------
100 | 24000.00</td><td>Same results returned from both sessions</td></tr>
<tr><td>begin;
update employees set
salary=27000 where
employee_id=100;</td><td>begin;
set transaction isolation
level serializable;</td><td>TX1 starts a transaction; performs an update.
TX2 starts a transaction with isolation level of read committed</td></tr>
<tr><td>select employee_id, salary
from EMPLOYEES
where employee_id=100;

employee_id | salary
------------+----------
100 | 27000.00</td><td>select employee_id, salary
from EMPLOYEES
where employee_id=100;

employee_id | salary
------------+----------
100 | 24000.00</td><td>TX1 will “see” the modified results (27000.00) while TX2 “sees” the original data (24000.00)</td></tr>
<tr><td></td><td>update employees set
salary=29000 where
employee_id=100;</td><td>Waits as TX2 is blocked by TX1</td></tr>
<tr><td>Commit;</td><td></td><td>TX1 issues a commit, and the lock is released</td></tr>
<tr><td></td><td>ERROR: could not serialize
access due to concurrent
update</td><td>TX2 received an error message</td></tr>
<tr><td></td><td>Commit;

ROLLBACK</td><td>TX2 trying to issue a commit but receives a rollback message, the transaction failed due to the serializable isolation level</td></tr>
<tr><td>select employee_id, salary
from EMPLOYEES
where employee_id=100;

employee_id | salary
------------+----------
100 | 27000.00</td><td>select employee_id, salary
from EMPLOYEES
where employee_id=100;

employee_id | salary
------------+----------
100 | 27000.00</td><td>Both queries will return the data updated according to TX1</td></tr>
</table>

For additional details:
https://www.postgresql.org/docs/9.6/static/tutorial-transactions.html
https://www.postgresql.org/docs/9.6/static/transaction-iso.html
https://www.postgresql.org/docs/9.6/static/sql-set-transaction.htm

Migrating from: Oracle Materialized Views

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Overview

Oracle Materialized Views (also known as MViews) are table segments where the contents are periodically refreshed based on the results of a stored query. Oracle Materialized Views are defined with a specific user-supplied query and can be manually or automatically refreshed based on user-supplied configuration. A Materialized View will run its associated query and store the results as a table segment.

Oracle Materialized Views are especially useful for:

- Replication of data across multiple databases.
- Data warehouse use-cases.
- Performance enhancements by persistently storing the results of complex queries, as database tables.

Like ordinary views, Materialized Views are created with a `SELECT` query. The `FROM` clause of the MView query can reference other tables, views, and other Materialized Views. The source objects the Mview uses as data sources are also called “master tables” (replication terminology) or “detail tables” (data warehouse terminology).

Examples

1. Create a simple Materialized View named `mv1` which executes a simple `SELECT` statement on the `employees` table:

```
CREATE MATERIALIZED VIEW mv1 AS SELECT * FROM hr.employees;
```

2. Create a more complex Materialized View using a Database Link (`remote`) to obtain data from a table located in a remote database. This Materialized View also contains a subquery. The `FOR UPDATE` clause enables the Materialized View to be updated.

```
CREATE MATERIALIZED VIEW foreign_customers FOR UPDATE
        AS SELECT * FROM sh.customers@remote cu
        WHERE EXISTS (SELECT * FROM sh.countries@remote co
                        WHERE co.country_id = cu.country_id);
```

Immediate vs. Deferred Refresh

When creating Materialized Views, the `BUILD IMMEDIATE` option can be specified to instruct Oracle to immediately update the contents of the Materialized View by running the underlying query. This is different from the `deferred` update where the Materialized View is populated only on the first requested refresh.

Fast and Complete Refresh

1. REFRESH FAST – incremental data refresh. Only updates rows that have changed since the last refresh of the Materialized View instead of performing a complete refresh. This type of refresh fails if Materialized View Logs have not been created.
2. COMPLETE - the table segment used by the Materialized View is truncated (data is cleared) and repopulated entirely by running the associated query.

Materialized View Logs

When creating Materialized Views, a Materialized View Log can be used to instruct Oracle to store any changes performed by DML commands on the "master tables" that are used to refresh the Materialized View thus providing faster Materialized View refreshes. Without Materialized View Logs, Oracle must re-execute the query associated with the Materialized View each time (also known as a "complete refresh"). This process is slower compared with using Materialized View Logs.

Materialized View Refresh Strategy

1. ON COMMIT – refreshes the Materialized View upon any commit made on the underlying associated tables.
2. ON DEMAND – the refresh is initiated via a scheduled task or manually by the user.

Example

1. Create a Materialized View on two source tables – *times* and *products*. This approach enables FAST refresh of the Materialized View instead of the slower COMPLETE refresh.
2. Create a new Materialized View named sales_mv which will be refreshed inclemently (REFRESH FAST) each time changes in data are detected (ON COMMIT) on one, or more, of the tables associated with the Materialized View query.

```
CREATE MATERIALIZED VIEW LOG ON times
   WITH ROWID, SEQUENCE (time_id, calendar_year)
   INCLUDING NEW VALUES;

CREATE MATERIALIZED VIEW LOG ON products
   WITH ROWID, SEQUENCE (prod_id)
   INCLUDING NEW VALUES;

CREATE MATERIALIZED VIEW sales_mv
   BUILD IMMEDIATE
   REFRESH FAST ON COMMIT
   AS SELECT t.calendar_year, p.prod_id,
      SUM(s.amount_sold) AS sum_sales
      FROM times t, products p, sales s
      WHERE t.time_id = s.time_id AND p.prod_id = s.prod_id
      GROUP BY t.calendar_year, p.prod_id;
```

For additional details:
https://docs.oracle.com/database/121/DWHSG/basicmv.htm
https://docs.oracle.com/database/121/REPLN/repmview.htm#REPLN003

Migration to: PostgreSQL Materialized Views

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Overview

PostgreSQL supports Materialized Views with associated queries similar to the Oracle implementation. The query associated with the Materialized View is executed and used to populate the Materialized View at the time the REFRESH command is issued. The PostgreSQL implementation of Materialized Views has three primary limitations when compared to Oracle Materialized Views:

1. PostgreSQL Materialized Views may be refreshed either manually or using a job running the `REFRESH MATERIALIZED VIEW` command. Automatic refresh of Materialized Views require the creation of a trigger.

2. PostgreSQL Materialized Views only support complete (full) refresh.

3. DML on Materialized Views is not supported.

Examples

1. Create a materialized view named `sales_summary` using the sales table as the source for the Materialized View:

```
CREATE MATERIALIZED VIEW sales_summary AS
  SELECT
      seller_no,
      sale_date,
      sum(sale_amt)::numeric(10,2) as sales_amt
    FROM sales
    WHERE sale_date < CURRENT_DATE
    GROUP BY
      seller_no,
      sale_date
    ORDER BY
      seller_no,
      sale_date;
```

2. Execute a manual refresh of the Materialized View:

```
REFRESH MATERIALIZED VIEW sales summary;
```

Note: The Materialized View data will not be refreshed automatically if changes occur to its underlying tables. For automatic refresh of materialized view data, a trigger on the underlying tables must be created.

Creating a Materialized View

When you create a Materialized View in PostgreSQL, it uses a regular database table underneath. You can create database indexes on the Materialized View directly and improve performance of queries that access the Materialized View.

Example

Create an index on the `sellerno` and `sale_date` columns of the `sales_summary` Materialized View.

```
CREATE UNIQUE INDEX sales_summary_seller
  ON sales_summary (seller_no, sale_date);
```

Oracle vs. PostgreSQL Materialized Views

	ORACLE	PostgreSQL
Create Materialized View	`CREATE MATERIALIZED VIEW mv1 AS SELECT * FROM employees;`	`CREATE MATERIALIZED VIEW mv1 AS SELECT * FROM employees;`
Manual refresh of a Materialized View	`DBMS_MVIEW.REFRESH('mv1', 'cf');` The`--cf` parameter configured the refresh method: **c** is complete and **f** is fast	`REFRESH MATERIALIZED VIEW mv1;`

Online refresh of a Materialized View	`CREATE MATERIALIZED VIEW mv1` **`REFRESH FAST ON COMMIT`** `AS SELECT * FROM employees;`	Create a trigger that will initiate a refresh after every DML command on the underlying tables:
		
		`CREATE OR REPLACE FUNCTION refresh_mv1()`
		`returns trigger language plpgsql`
		`as $$`
		`begin`
		`    refresh materialized view mv1;`
		`    return null;`
		`end $$;`
		
		`create trigger refresh_ mv1`
		`after insert or update or delete or truncate`
		`on employees for each statement`
		`execute procedure refresh_mv1();`

Automatic incremental refresh of a Materialized View	**`CREATE MATERIALIZED VIEW LOG`** `ON employees…`
	`INCLUDING NEW VALUES;`
	
	`CREATE MATERIALIZED VIEW mv1`
	`REFRESH FAST AS SELECT * FROM employees;`
		Not Supported

DML on Materialized View data	Supported	Not Supported

For additional information on PostgreSQL materialized views:
https://www.postgresql.org/docs/current/static/rules-materializedviews.htm

Migrating from: Oracle Triggers

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Overview

A trigger in Oracle is a "named program" written in PL/SQL that is stored in the database and fired (or executed) when a specified event occurs. The associated event that causes a trigger to execute can either be tied to a specific database table, database view, database schema, or the database itself.

Triggers can be executed after:

- Data Manipulation Language (DML) statements (`DELETE`, `INSERT`, or `UPDATE`).
- Data Definition Language (DDL) statements (`CREATE`, `ALTER`, or `DROP`).
- Certain database events and operations (`SERVERERROR`, `LOGON`, `LOGOFF`, `STARTUP`, or `SHUTDOWN`).

Oracle trigger types:

1. **DML Trigger** – can be created on Tables or Views. The trigger fires when one of the following events occur on the object on which the trigger was created: inserting data, updating data, and deleting data.
   a. Triggers can be fired **before** or **after** a DML command occurred.

2. **INSTED OF Trigger** – a special type of DML trigger that is created on a non-editable view. INSTEAD OF triggers provide an application-transparent method to modify views that cannot be modified via DML statements.

3. **SYSTEM Event Triggers –** these are defined at the database level or schema level. These include triggers that fire after specific events:
   a. User logon and logoff.
   b. Database events (startup/shutdown), DataGuard events, server errors.

Examples

1. Create a trigger that is executed after a row is deleted from the `PROJECTS` table or if the primary key of a project is updated:

```
SQL> CREATE OR REPLACE TRIGGER PROJECTS_SET_NULL
     AFTER DELETE OR UPDATE OF PROJECTNO ON PROJECTS
     FOR EACH ROW
     BEGIN
        IF UPDATING AND :OLD.PROJECTNO != :NEW.PROJECTNO OR DELETING THEN
              UPDATE EMP SET EMP.PROJECTNO = NULL
              WHERE EMP.PROJECTNO = :OLD.PROJECTNO;
        END IF;
     END;
/

Trigger created.

SQL> DELETE FROM PROJECTS WHERE PROJECTNO=123;
SQL> SELECT PROJECTNO FROM EMP WHERE PROJECTNO=123;

PROJECTNO
----------
NULL
```

2. Create a SYSTEM/Schema trigger on a table. The trigger fires if a DDL DROP command is executed for an object in the HR schema and prevents dropping of the object while raising an application error.

```
SQL> CREATE OR REPLACE TRIGGER PREVENT_DROP_TRIGGER
     BEFORE DROP ON HR.SCHEMA
      BEGIN
            RAISE_APPLICATION_ERROR (
            num => -20000,
            msg => 'Cannot drop object');
      END;
/

Trigger created.

SQL> DROP TABLE HR.EMP

ERROR at line 1:
ORA-00604: error occurred at recursive SQL level 1
ORA-20000: Cannot drop object
ORA-06512: at line 2
```

For additional details:
https://docs.oracle.com/database/121/LNPLS/create_trigger.htm#LNPLS01374

Migration to: PostgreSQL Trigger Procedure

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Overview

PostgreSQL triggers can be associated with a specific table, view, or foreign table and will invoke execution of a function when a certain events occur. DML triggers in PostgreSQL share much of the functionality that exists in Oracle triggers.

1. DML triggers (triggers that fire based on table related events such as DML).
2. Event triggers (triggers that fire after certain database events such as running DDL commands).

Unlike Oracle triggers, PostgreSQL triggers must call a function and do not support anonymous blocks of PL/pgSQL code as part of the trigger body. The user-supplied function is declared with no arguments and has a return type of **trigger**.

PostgreSQL DML Triggers

1. PostgreSQL triggers can run **BEFORE** or **AFTER** a DML operation.
    a. Fire before the operation is attempted on a row.
        i. Before constraints are checked and the `INSERT`, `UPDATE`, or `DELETE` is attempted.
        ii. If the trigger fires before or instead of the event, the trigger can skip the operation for the current row or change the row being inserted (for `INSERT` and `UPDATE` operations only).
    b. After the operation was completed, after constraints are checked and the `INSERT, UPDATE`, or `DELETE` command completed.
        i. If the trigger fires after the event, all changes, including the effects of other triggers, are "visible" to the trigger.
2. PostgreSQL triggers can run **INSTEAD OF** a DML command when created on views.
3. PostgreSQL triggers can run **FOR EACH ROW** affected by the DML statement or **FOR EACH STATEMENT** running only once as part of a DML statement.

When Fired	Database Event	Row-Level Trigger (FOR EACH ROW)	Statement-Level Trigger (FOR EACH STATEMENT)
BEFORE	`INSERT, UPDATE, DELETE`	Tables and foreign tables	Tables, views, and foreign tables
	`TRUNCATE`	—	Tables
AFTER	`INSERT, UPDATE, DELETE`	Tables and foreign tables	Tables, views, and foreign tables
	`TRUNCATE`	—	Tables
INSTEAD OF	`INSERT, UPDATE, DELETE`	Views	—
	`TRUNCATE`	—	—

PostgreSQL Event Triggers

An event trigger executes when a specific event that is associated with the trigger occurs in the database. Supported events include: `ddl_command_start, ddl_command_end, table_rewrite` and `sql_drop`.

1. **`ddl_command_start`** - occurs before the execution of a `CREATE, ALTER, DROP, SECURITY LABEL, COMMENT, GRANT, REVOKE` or `SELECT INTO` command.
2. **`ddl_command_end`** **–** occurs after the command completed and before the transaction commits.
3. **`sql_drop`** **–** fired only for the DROP DDL command. Fires before `ddl_command_end` trigger fire.

Full list of supported PostgreSQL event trigger types:
https://www.postgresql.org/docs/9.6/static/event-trigger-matrix.html

Example

Create a DML trigger:

1. In order to create an equivalent version of the Oracle DML trigger in PostgreSQL, first create a function trigger which will store the execution logic for the trigger:

```
psql=> CREATE OR REPLACE FUNCTION PROJECTS_SET_NULL()
       RETURNS TRIGGER
       AS $$
       BEGIN
            IF TG_OP = 'UPDATE' AND OLD.PROJECTNO != NEW.PROJECTNO OR
              TG_OP = 'DELETE' THEN
                  UPDATE EMP
                  SET PROJECTNO = NULL
                  WHERE EMP.PROJECTNO = OLD.PROJECTNO;
            END IF;

            IF TG_OP = 'UPDATE' THEN RETURN NULL;
                  ELSIF TG_OP = 'DELETE' THEN RETURN NULL;
            END IF;
       END; $$
       LANGUAGE  PLPGSQL;

CREATE FUNCTION
```

2. Create the trigger itself:

```
psql=> CREATE TRIGGER TRG_PROJECTS_SET_NULL
       AFTER UPDATE OF PROJECTNO OR DELETE
       ON PROJECTS
       FOR EACH ROW
       EXECUTE PROCEDURE PROJECTS_SET_NULL();

CREATE TRIGGER
```

3. Test the trigger by deleting a row from the PROJECTS table:

```
psql=> DELETE FROM PROJECTS WHERE PROJECTNO=123;
psql=> SELECT PROJECTNO FROM EMP WHERE PROJECTNO=123;

 projectno
-----------
(0 rows)
```

Example

Create a DDL trigger:

1. In order to create an equivalent version of the Oracle DDL System/Schema level triggers, such as a trigger that prevent running a DDL DROP on objects in the HR schema: first create an event trigger function. Note that trigger functions are created with no arguments and must have a return type of TRIGGER or EVENT_TRIGGER:

```
psql=> CREATE OR REPLACE FUNCTION ABORT_DROP_COMMAND()
       RETURNS EVENT_TRIGGER
       AS $$
       BEGIN
            RAISE EXCEPTION 'The % Command is Disabled', tg_tag;
       END; $$
       LANGUAGE PLPGSQL;

CREATE FUNCTION
```

2. Create the event trigger, which will fire before the start of a DDL DROP command:

```
psql=> CREATE EVENT TRIGGER trg_abort_drop_command
       ON DDL_COMMAND_START
       WHEN TAG IN ('DROP TABLE', 'DROP VIEW', 'DROP FUNCTION', 'DROP
                    SEQUENCE', 'DROP MATERIALIZED VIEW', 'DROP TYPE')
       EXECUTE PROCEDURE abort_drop_command();
```

3. Test the trigger by attempting to drop the EMPLOYEES table:

```
psql=> DROP TABLE EMPLOYEES;

ERROR:  The DROP TABLE Command is Disabled
CONTEXT:  PL/pgSQL function abort_drop_command() line 3 at RAISE
```

For additional details:
https://www.postgresql.org/docs/9.6/static/plpgsql-trigger.html

Oracle vs. PostgreSQL Triggers Comparison

<table>
<tr><th></th><th>Oracle</th><th>PostgreSQL</th></tr>
<tr><td>“Before update” trigger, row level</td><td>CREATE OR REPLACE TRIGGER
check_update
  BEFORE UPDATE ON projects
  FOR EACH ROW
BEGIN
/*Trigger body*/
END;
/</td><td>CREATE TRIGGER check_update
    BEFORE UPDATE ON
employees
    FOR EACH ROW
    EXECUTE PROCEDURE
myproc();</td></tr>
<tr><td>“Before update” trigger, statement level</td><td>CREATE OR REPLACE TRIGGER
check_update
  BEFORE UPDATE ON projects
BEGIN
/*Trigger body*/
END;
/</td><td>CREATE TRIGGER check_update
    BEFORE UPDATE ON
employees
    FOR EACH STATEMENT
    EXECUTE PROCEDURE
myproc();</td></tr>
<tr><td>System / event trigger</td><td>CREATE OR REPLACE TRIGGER
drop_trigger
  BEFORE DROP ON hr.SCHEMA
  BEGIN
    RAISE_APPLICATION_ERROR (
      num => -20000,
      msg => 'Cannot drop
object');
  END;
/</td><td>CREATE EVENT TRIGGER
trg_drops
   ON ddl_command_start
   EXECUTE PROCEDURE
trg_drops();</td></tr>
<tr><td>Referencing :old and :new values in triggers</td><td>Use ":NEW" and ":OLD" in trigger body:

CREATE OR REPLACE TRIGGER
UpperNewDeleteOld
BEFORE INSERT OR UPDATE OF
first_name ON employees
FOR EACH ROW
BEGIN
  :NEW.first_name :=
UPPER(:NEW.first_name);

  :NEW.salary := :OLD.salary;
END;
/</td><td>Use ".NEW" and ".OLD" in trigger Procedure body:

CREATE OR REPLACE FUNCTION
log_ emp_name_upd()
 RETURNS trigger
 LANGUAGE plpgsql
  AS $$
BEGIN
       IF NEW.last_name <>
OLD.last_name THEN
             INSERT INTO
employee_audit
(employee_id,last_name,chan
ged_on)
VALUES(OLD.id,OLD.last_name
,now());
       END IF;
RETURN NEW;
END;
$$

CREATE TRIGGER
last_name_change_trg
BEFORE UPDATE
ON employees
FOR EACH ROW
EXECUTE PROCEDURE
log_last_emp_name_upd();</td></tr>
<tr><td>Database event level trigger</td><td>CREATE TRIGGER
register_shutdown
  ON DATABASE
  SHUTDOWN
    BEGIN
    Insert into logging values
(‘DB was</td><td>N/A</td></tr>
</table>

	Oracle	PostgreSQL

	shutdown’, sysdate);
	    commit;
	    END;
	/	

Drop a trigger	DROP TRIGGER last_name_change_trg ;	DROP TRIGGER last_name_change_trg on employees;

Modify logic executed by a trigger	Can be used with create or replace
	
	CREATE OR REPLACE TRIGGER
	UpperNewDeleteOld
	BEFORE INSERT OR UPDATE OF
	first_name ON employees
	FOR EACH ROW
	BEGIN
	  <<NEW CONTENT>>
	END;
	/
		Use CREATE OR REPLACE on the called function in the trigger (trigger stay the same)
		
		CREATE or replace FUNCTION
		UpperNewDeleteOld() RETURNS
		trigger AS
		$UpperNewDeleteOld$
		BEGIN
		<<NEW CONTENT>>
		END;
		$UpperNewDeleteOld$
		LANGUAGE plpgsql;

Enable a trigger	ALTER TRIGGER UpperNewDeleteOld ENABLE;	alter table employees enable trigger UpperNewDeleteOld;
Disable a trigger	ALTER TRIGGER UpperNewDeleteOld DISABLE;	alter table employees disable trigger UpperNewDeleteOld;

Migrating from: Oracle Views

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Overview

Database Views store a named SQL query in the Oracle Data Dictionary with a predefined structure. A view does not store actual data and may be considered as a "virtual table" or a "logical table" and is based on the data from one or more "physical" database tables.

Oracle view main privileges as a prerequisite for Creation

- A user must have the `CREATE VIEW` privilege to create a view in their own schema.
- A user must have the `CREATE ANY VIEW` privilege to create a view in any schema.
- The owner of a view must have all the necessary privileges on the source tables or views on which the view is based (`SELECT` or DML privileges).

Oracle views CREATE (OR REPLACE) statements

- `CREATE VIEW` to create a new view.
- `CREATE OR REPLACE` to overwrite an existing view and change the view definition without having to manually drop and re-create the original view and without deleting the previously granted privileges.

Example:

```
CREATE VIEW "HR"."EMP_DETAILS_VIEW"…

CREATE OR REPLACE VIEW "HR"."EMP_DETAILS_VIEW"…
```

Oracle common view parameters

Oracle View Parameter	Description	PostgreSQL Compatible
`CREATE OR REPLACE`	Re-create an existing view (if one exists) or create a new view.	Yes
`FORCE`	Create the view regardless the existence of the source tables or views and regardless to view privileges.	No
`VISIBLE | INVISIBLE`	Specify if a column based on the view will be visible or invisible.	No
`WITH READ ONLY`	Disable DML commands.	No
`WITH CHECK OPTION`	Specifies the level of enforcement when performing DML commands on the view	Yes

Running DML Commands On views

Views are classified as follows:

- **Simple View**
  A view having a single source table with no aggregate functions.
  DML operations can be performed on simple views and affect the base table(s).

  Example: Simple view + update operation

```
SQL> CREATE OR REPLACE VIEW VW_EMP
     AS
     SELECT EMPLOYEE_ID, LAST_NAME, EMAIL, SALARY
     FROM EMPLOYEES
     WHERE DEPARTMENT_ID BETWEEN 100 AND 130;

     UPDATE VW_EMP
     SET EMAIL=EMAIL||'.org'
     WHERE EMPLOYEE_ID=110;

     1 rows updated.
```

- **Complex View**
  A view with several source tables or views containing joins, aggregate (group) functions, or an order by clause. Performing DML operations on complex views cannot be done directly, but `INSTEAD OF` triggers can be used as a workaround.

  Example: Complex view + update operation

```
SQL> CREATE OR REPLACE VIEW VW_DEP
     AS
     SELECT B.DEPARTMENT_NAME, COUNT(A.EMPLOYEE_ID) AS CNT
     FROM EMPLOYEES A JOIN DEPARTMENTS B USING(DEPARTMENT_ID)
     GROUP BY B.DEPARTMENT_NAME;

     UPDATE VW_DEP
     SET CNT=CNT +1
     WHERE DEPARTMENT_NAME=90;

ORA-01732: data manipulation operation not legal on this view
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_8004.htm#SQLRF01504
https://docs.oracle.com/database/121/SQLRF/statements_8004.htm

Migration to: PostgreSQL Views

[Back to TOC]

Overview

PostgreSQL views share functionality with Oracle views. Creating a view defines a stored query based on one or more physical database tables which executes every time the view is accessed.

PostgreSQL View Synopsis

```
CREATE [ OR REPLACE ] [ TEMP | TEMPORARY ] [ RECURSIVE ] VIEW name [ (
column_name [, ...] ) ]
    [ WITH ( view_option_name [= view_option_value] [, ... ] ) ]
    AS query
    [ WITH [ CASCADED | LOCAL ] CHECK OPTION ]
```

PostgreSQL View Privileges

A Role or user must be granted SELECT and DML privileges on the bases tables or views in order to create a view.

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-grant.html

PostgreSQL View Parameters

- **CREATE [OR REPLACE] VIEW**
  Similar to the Oracle syntax. Note that when re-creating an existing view, the new view must have the same column structure as generated by the original view (column names, column order and data types). As such, it is sometimes preferable to drop the view and use the CREATE VIEW statement instead.

```
hr=# CREATE [OR REPLACE] VIEW VW_NAME AS
     SELECT COLUMNS
     FROM TABLE(s)
     [WHERE CONDITIONS];
```

```
hr=# DROP VIEW [IF EXISTS] VW_NAME;
```

** The IF EXISTS parameter is optional*

* **`WITH [ CASCADED | LOCAL ] CHECK OPTION`**
  DML `INSERT` and `UPDATE` operations are verified against the view based tables to ensure that new rows satisfy the original structure conditions or the view-defining condition. If a conflict is detected, the DML operation fails.

  `CHECK OPTION`
  - **LOCAL** - Verifies against the view without a hierarchical check.
  - **CASCADED** - Verifies all underlying base views using a hierarchical check.

* **Executing DML Commands On views**
  PostgreSQL simple views are automatically updatable. Unlike Oracle views, no restrictions exist when performing DML operations against views. An updatable view may contain a combination of *updatable* and *non-updatable* columns. A column is updatable if it references an updatable column of the underlying base table. If not, the column is read-only and an error is raised if an `INSERT` or `UPDATE` statement is attempted on the column.

  Example 1
  Creating and updating a view without the `CHECK OPTION` parameter:

```
hr=# CREATE OR REPLACE VIEW VW_DEP AS
     SELECT DEPARTMENT_ID, DEPARTMENT_NAME, MANAGER_ID, LOCATION_ID
     FROM DEPARTMENTS
     WHERE LOCATION_ID=1700;

view VW_DEP created.

hr=# UPDATE VW_DEP
     SET LOCATION_ID=1600;

21 rows updated.
```

  Example 2
  Creating and updating a view with the `LOCAL CHECK OPTION` parameter:

```
hr=# CREATE OR REPLACE VIEW VW_DEP AS
     SELECT DEPARTMENT_ID, DEPARTMENT_NAME, MANAGER_ID, LOCATION_ID
     FROM DEPARTMENTS
     WHERE LOCATION_ID=1700
     WITH LOCAL CHECK OPTION;

view VW_DEP created.

hr=# UPDATE VW_DEP
     SET LOCATION_ID=1600;

SQL Error: ERROR: new row violates check option for view "vw dep"
```

For additional details:
https://www.postgresql.org/docs/9.6/static/tutorial-views.html
https://www.postgresql.org/docs/9.6/static/sql-createview.html

Migrating from: Oracle Sequences

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Overview

Sequences are database objects that serve as a unique identity value generators, such as for automatically generating primary key values. Oracle treats sequences as independent objects and the same sequence can generate values for multiple tables.

Sequences can be configured with multiple parameters which control their value-generating behavior. For example, the `INCREMENT BY` sequence parameter defines the interval between each generated sequence value. If more than one database user is generating incremented values from the same sequence, each user may encounter gaps in the generated values that are visible to them.

Oracle Sequence Options

By default, the initial and increment values for a sequence are both 1, with no upper limit.

- **`INCREMENT BY`**
  Controls the sequence interval value of the increment or decrement (if a negative value is specified). If the `INCREMENT BY` parameter is not specified during sequence creation, the value is set to 1. The increment cannot be assigned a value of 0.

- **`START WITH`**
  Defines the initial value of a sequence. The default value is 1.

- **`MAXVALUE | NOMAXVALUE`**
  Allows controlling the maximum limit for values generated by a sequence. Must be equal or greater than the `START WITH` parameter and must be greater in value than the `MINVALUE` parameter. The default for `NOMAXVALUE` is 10^{27} for an ascending sequence.

- **`MINVALUE | NOMINVALUE`**
  Allows controlling the minimum limit for values generated by a sequence. Must be less than or equal to the `START WITH` parameter and must be less than the `MAXVALUE` parameter. The default for `NOMINVALUE` is -10^{26} for a descending sequence.

- **`CYCLE | NOCYCLE`**
  Instructs a sequence to continue generating values despite reaching the maximum value or the minimum value. If the sequence reaches one of the defined ascending limits, it generates a new value according to the minimum value. If it reaches a descending limit, it generates a new value according to the maximum value. `NOCYCLE` is the default.

- **CACHE | NOCACHE**
  The CACHE parameter enables controlling the number of sequence values to keep cached in memory for improved performance. CACHE has a minimum value of “2”.

  Using the NOCACHE parameter will cause a sequence not to cache any values in memory. Specifying neither CACHE or NOCACHE will cache 20 values to memory. In the event of a database failure, all cached sequence values that have not been used, will be lost and gaps in sequence values may occur.

Example
Creating a sequence:

```
SQL> CREATE SEQUENCE SEQ_EMP
     START WITH 100
     INCREMENT BY 1
     MAXVALUE 99999999999
     CACHE 20
     NOCYCLE;
```

Dropping a sequence:

```
SQL> DROP SEQUENCE SEQ_EMP;
```

Viewing sequences created for the current schema/user:

```
SQL> SELECT * FROM USER_SEQUENCES;
```

Using sequence as part of an `INSERT INTO` statement:

```
SQL> CREATE TABLE EMP_SEQ_TST (
     COL1 NUMBER PRIMARY KEY,
     COL2 VARCHAR2(30));

SQL> INSERT INTO EMP_SEQ_TST VALUES(SEQ_EMP.NEXTVAL, 'A');

      COL1 COL2
---------- ------------------------------
       100 A
```

Query the current value of a sequence:

```
SQL> SELECT SEQ_EMP.CURRVAL FROM DUAL;
```

Manually increment the value of a sequence, according to the `INCREMENT BY` specification:

```
SQL> SELECT SEQ_EMP.NEXTVAL FROM DUAL;
```

Altering an existing sequence:

```
SQL> ALTER SEQUENCE SEQ_EMP MAXVALUE 1000000;
```

Oracle 12c Default Values Using Sequences

Starting with Oracle 12c, you can assign a sequence to a table column with the CREATE TABLE statement and specify the NEXTVAL configuration of the sequence during table creation.

Example

Generating DEFAULT values using sequences in Oracle 12c:

```
SQL> CREATE TABLE SEQ_TST (
     COL1 NUMBER DEFAULT SEQ_1.NEXTVAL PRIMARY KEY,
     COL2 VARCHAR(30));

SQL> INSERT INTO SEQ_TST(COL2) VALUES('A');

SQL> SELECT * FROM SEQ_TST;

      COL1 COL2
---------- ------------------------------
       100 A
```

Oracle 12c Session Sequences (Session/Global)

Starting with Oracle 12c, sequences can be created as session-level or global-level sequences. By adding the SESSION parameter to CREATE SEQUENCE, the sequence will be created as a session-level sequence. Optionally, the GLOBAL keyword can be used to create a sequence as a global sequence to provide consistent results across sessions in the database. Global sequences are the default. Session sequences return a unique range of sequence numbers only within a session.

Example

Oracle 12c SESSION and GLOBAL sequences:

```
SQL> CREATE SEQUENCE SESSION_SEQ SESSION;
SQL> CREATE SEQUENCE SESSION_SEQ GLOBAL;
```

Oracle 12c Identity Columns

Sequences can be used as an IDENTITY type, which automatically creates a sequence and associates it with the table column. The main difference is that there is no need to create a sequence manually; the IDENTITY type does that for you. An IDENTITY type is a sequence that can be configured.

Example

Oracle 12c Identity Columns:

Inserting records using an Oracle 12c IDENTITY column explicitly/implicitly:

```
SQL> INSERT INTO IDENTITY_TST(COL2) VALUES('A');
SQL> INSERT INTO IDENTITY_TST(COL1, COL2) VALUES(DEFAULT, 'B');
SQL> INSERT INTO IDENTITY_TST(col1, col2) VALUES(NULL, 'C');

SQL> SELECT * FROM IDENTITY_TST;
      COL1 COL2
---------- ------------------------------
       120 A
       130 B
```

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28286/statements_6015.htm#SQLRF01314
https://docs.oracle.com/database/121/SQLRF/statements_6017.htm#SQLRF01314
http://www.oracle.com/technetwork/issue-archive/2013/13-sep/o53asktom-1999186.html

Migration to: PostgreSQL Sequences

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Overview

The PostgreSQL CREATE SEQUENCE command is mostly compatible with the Oracle CREATE SEQUENCE command. Sequences in PostgreSQL serve the same purpose as in Oracle; they generate numeric identifiers automatically. A sequence object is owned by the user that created it.

PostgreSQL Sequence Synopsis

```
CREATE [ TEMPORARY | TEMP ] SEQUENCE [ IF NOT EXISTS ] name
[ INCREMENT [ BY ] increment ]
[ MINVALUE minvalue | NO MINVALUE ] [ MAXVALUE maxvalue | NO MAXVALUE ]
[ START [ WITH ] start ] [ CACHE cache ] [ [ NO ] CYCLE ]
 [ OWNED BY { table_name.column_name | NONE } ]
```

Most Oracle CREATE SEQUENCE parameters are compatible with PostgreSQL. Similar to Oracle 12c, in PostgreSQL you can create a sequence and use it directly as part of a CREATE TABLE statement.

Sequence Parameters

- **TEMPORARY or TEMP**
  PostgreSQL can create a temporary sequence within a session. Once the session ends, the sequence is automatically dropped.

- **`IF NOT EXISTS`**
  Creates a sequence even if a sequence with an identical name already exists. Replaces the existing sequence.

- **`INCREMENT BY`**
  Optional parameter with a default value of 1. Positive values generate sequence values in ascending order. Negative values generate sequence values in descending sequence.

- **`START WITH`**
  The same as Oracle. This is an optional parameter having a default of 1. It uses the MINVALUE for ascending sequences and the MAXVALUE for descending sequences.

- **`MAXVALUE | NO MAXVALUE`**
  Defaults are between 2^{63} for ascending sequences and -1 for descending sequences.

- **`MINVALUE | NO MINVALUE`**
  Defaults are between 1 for ascending sequences and -2^{63} for descending sequences.

- **`CYCLE | NO CYCLE`**
  If the sequence value reaches MAXVALUE or MINVALUE, the CYCLE parameter instructs the sequence to return to the initial value (MINVALUE or MAXVALUE). The default is NO CYCLE.

- **`CACHE`**
  Note that in PostgreSQL, the NOCACHE is not supported. By default, when not specifying the CACHE parameter, no sequence values will be pre-cached into memory, which is equivalent to the Oracle NOCACHE parameter. The minimum value is 1.

- **`OWNED BY | OWNBY NON`**
  Specifies that the sequence object is to be associated with a specific column in a table, which is not supported by Oracle. When dropping this type of sequence, an error will be returned because of the sequence/table association.

Example

Create a sequence:

```
demo=> CREATE SEQUENCE SEQ_1
       START WITH 100
       INCREMENT BY 1
       MAXVALUE 99999999999
       CACHE 20
       NO CYCLE;
```

** Identical to Oracle syntax, except for the whitespace in the NO CYCLE parameter.*

Drop a sequence:

```
demo=> DROP SEQUENCE SEQ_1;
```

View sequences created in the current schema and sequence specifications:

```
demo=> SELECT * FROM INFORMATION_SCHEMA.SEQUENCES;
OR
demo=> \ds
```

Use a PostgreSQL sequence as part of a CREATE TABLE and an INSERT statement:

```
demo=> CREATE TABLE SEQ_TST (
       COL1 NUMERIC DEFAULT NEXTVAL('SEQ_1') PRIMARY KEY,
       COL2 VARCHAR(30));

demo=> INSERT INTO SEQ_TST (COL2) VALUES('A');

demo=> SELECT * FROM SEQ_TST;

 col1 | col2
------+------
  100 | A
```

Use the OWNED BY parameter to associate the sequence with a table:

```
demo=> CREATE SEQUENCE SEQ_1
       START WITH 100
       INCREMENT BY 1
       OWNED BY SEQ_TST.COL1;
```

Query the current value of a sequence:

```
demo=> SELECT CURRVAL('SEQ_1);
```

Manually increment a sequence value according to the INCREMENT BY value:

```
demo=> SELECT NEXTVAL('SEQ_1');
OR
demo=> SELECT SETVAL('SEQ_1', 200);
```

Alter an existing sequence:

```
demo=> ALTER SEQUENCE SEQ_1 MAXVALUE 1000000;
```

Generating Sequence by SERIAL Type

PostgreSQL enables you to create a sequence that is similar to the AUTO_INCREMENT property supported by identity columns in Oracle 12c. When creating a new table, the sequence is created through the SERIAL pseudo-type. Other types from the same family are SMALLSERIAL and BIGSERIAL.

By assigning a SERIAL type to a column on table creation, PostgreSQL creates a sequence using the default configuration and adds a NOT NULL constraint to the column. The newly created sequence behaves as a regular sequence.

Example

Using a SERIAL Sequence:

```
demo=> CREATE TABLE SERIAL_SEQ_TST(
        COL1 SERIAL PRIMARY KEY,
        COL2 VARCHAR(10));

demo=> INSERT INTO SERIAL_SEQ_TST(COL2) VALUES('A');

demo=> SELECT * FROM SERIAL_SEQ_TST;

 col1 | col2
------+------
    1 | A

demo=> \ds

 Schema |          Name          |   Type   | Owner
--------+------------------------+----------+-------
 public | serial_seq_tst_col1_seq | sequence | pg_tst_db
```

Oracle Sequences vs. PostgreSQL Sequences:

Parameter/Feature	Compatibility with PostgreSQL	Comments
Create sequence syntax	Full, with minor differences	See Exceptions
INCREMENT BY	Full	
START WITH	Full	
MAXVALUE | NOMAXVALUE	Full	Use "NO MAXVALUE"
MINVALUE | NOMINVALUE	Full	Use "NO MINVALUE"
CYCLE | NOCYCLE	Full	USE "NO CYCLE"
CACHE | NOCACHE	PostgreSQL does not support the NOCACHE parameter but the default behavior is identical. The CACHE parameter is compatible with Oracle.	
Default values using sequences (Oracle 12c)	Supported by PostgreSQL	CREATE TABLE TBL(COL1 NUMERIC DEFAULT NEXTVAL('SEQ_1')…
Session sequences (session / global), Oracle 12c	Supported by PostgreSQL by using the TEMPORARY sequence parameter to Oracle SESSION sequence	
Oracle 12c identity columns	Supported by PostgreSQL by using the SERIAL data type as sequence	

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createsequence.html
https://www.postgresql.org/docs/9.6/static/functions-sequence.html
https://www.postgresql.org/docs/9.6/static/datatype-numeric.html

Migrating from: Oracle Database Links

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Overview

Database Links are schema objects that are used to interact with remote database objects such as tables. Common use cases for database links include selecting data from tables that reside in a remote database.

Note: To use database links, Oracle net services must be installed on both the local and remote database servers to facilitate communications.

Example:

1. Create a database link named **`remote_db`**. When creating a database link, you have the option to either specify the remote database destination using a TNS Entry or specify the full TNS Connection string.

```
CREATE DATABASE LINK remote_db
   CONNECT TO username IDENTIFIED BY password
   USING 'remote';

CREATE DATABASE LINK remotenoTNS
   CONNECT TO username IDENTIFIED BY password
   USING '(DESCRIPTION=(ADDRESS_LIST=(ADDRESS = (PROTOCOL = TCP)(HOST
=192.168.1.1)(PORT = 1521)))(CONNECT_DATA =(SERVICE_NAME = orcl)))';
```

2. After the database link is created, you can use the database link directly as part of a SQL query using the database link name (`@remote_db`) as a postfix to the table name.

```
SELECT * FROM employees@remote_db;
```

3. Database links also support DML commands:

```
INSERT INTO employees@remote_db
   (employee_id, last_name, email, hire_date, job_id)
   VALUES (999, 'Claus', 'sclaus@example.com', SYSDATE, 'SH_CLERK');

UPDATE jobs@remote_db SET min_salary = 3000
   WHERE job_id = 'SH_CLERK';

DELETE FROM employees@remote_db
   WHERE employee_id = 999;
```

For additional details:
https://docs.oracle.com/database/121/SQLRF/statements_5006.htm#SQLRF01205

Migration to: PostgreSQL DBLink and FDWrapper

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Overview

Querying data in remote databases in PostgreSQL is available via two primary options:

1. `dblink` database link function.
2. `postgresql_fdw` (Foreign Data Wrapper, FDW) extension.

The Postgres foreign data wrapper extension is new to PostgreSQL and offers functionality that is similar to `dblink`. However, the Postgres foreign data wrapper aligns closer with the SQL standard and can provide improved performance.

Example using the `dblink` function

1. Load the `dblink` extension into PostgreSQL:

```
CREATE EXTENSION dblink;
```

2. Create a persistent connection to a remote PostgreSQL database using the `dblink_connect` function specifying a connection name (`myconn`), database name (`postgresql`), port (`5432`), host (`hostname`), user (`username`) and password (`password`).

```
SELECT dblink_connect('myconn', 'dbname=postgres port=5432
                       host=hostname user=username password=password');
```

   The connection can be used to execute queries against the remote database.

3. Execute a query using the previously created connection (`myconn`) via the `dblink` function.
   The query returns the `id` and `name` columns from the `employees` table. On the remote database, you must specify the connection name and the SQL query to execute as well as parameters and datatypes for selected columns (`id` and `name` in this example).

```
SELECT *
from dblink('myconn', 'SELECT id, name FROM EMPLOYEES')
    AS p(id int,fullname text);
```

4. Close the connection using the `dblink_disconnect` function.

```
SELECT dblink_disconnect('myconn');
```

5. Alternatively, you can use the `dblink` function specifying the full connection string to the remote PostgreSQL database, including: database name, port, hostname, username, and password. This can be done instead of using a previously defined connection. You must also specify the SQL query to execute as well as parameters and datatypes for the selected columns (`id` and `name`, in this example).

```
SELECT *
from dblink('dbname=postgres port=5432
                      host=hostname user=username password=password',
                      'SELECT id, name FROM EMPLOYEES')
    AS p(id int,fullname text);
```

6. DML commands are supported on tables referenced via the `dblink` function. For example, you can insert a new row and then delete it from the remote table.

```
SELECT * FROM dblink('myconn',$$INSERT into employees VALUES (3,'New
Employees No. 3!')$$) AS t(message text);

SELECT * FROM dblink('myconn',$$DELETE FROM employees WHERE id=3$$) AS
t(message text);
```

7. Create a new local table (`new_employees_table`) by querying data from a remote table.

```
SELECT emps.* INTO new_employees_table FROM dblink('myconn','SELECT *
FROM employees') AS emps(id int, name varchar);
```

8. Join remote data with local data.

```
SELECT local_emps.id , local_emps.name, s.sale_year, s.sale_amount,
FROM local_emps INNER JOIN dblink('myconn','SELECT * FROM
working_hours') AS s(id int, hours_worked int) ON
local_emps.id = s.id;
```

9. Execute DDL statements in the remote database.

```
SELECT * FROM dblink('myconn',$$CREATE table new_remote_tbl
                              (a int, b text)$$) AS t(a text);
```

For additional details:
https://www.postgresql.org/docs/9.6/static/dblink.html

Example using the PostgreSQL Foreign Data Wrapper

1. Load the `fdw` Extension into PostgreSQL.

```
CREATE EXTENSION postgres_fdw;
```

2. Create a connection to the remote PostgreSQL database specifying the remote server (`hostname`), database name (`postgresql`) and the port (`5432`).

```
CREATE SERVER remote_db
FOREIGN DATA WRAPPER postgres_fdw
OPTIONS (host 'hostname', dbname 'postgresql', port '5432');
```

3. Create the user mapping, specifying:

    - The `local_user` is a user with permissions in the *current* database.
    - Specify the server connection created in the previous command (`remote_db`).
    - The `user` and `password` arguments specified in the options clause must have the required permissions in the *remote* database.

```
CREATE USER MAPPING FOR local_user
SERVER remote_db
OPTIONS (user 'remote_user', password 'remote_password');
```

After the connection with login credentials for the remote database was created, we can either import individual tables or the entire schema containing all, or some, of the tables and views.

4. Create a `FOREIGN TABLE` named `foreign_emp_tbl` using the `remote_db` remote connection created earlier specifying both the schema name and table name in the remote database to be queried. For example, the `hr.employees` table.

```
CREATE FOREIGN TABLE foreign_emp_tbl (
        id int, name text)
        SERVER remote_db
        OPTIONS (schema_name 'hr', table_name 'employees');
```

5. Queries running on the local `foreign_emp_tbl` table will actually query data directly from the remote `hr.employees` table.

```
SELECT * FROM foreign_emp_tbl;
```

6. You can also "import" an entire schema, or specific tables, without specifying a specific table name:

```
IMPORT FOREIGN SCHEMA hr LIMIT TO (employees)
    FROM SERVER remote_db INTO local_hr;
```

Notes:

1. Both `dblink` and `FDW` store the remote database username and password as plain-text, in two locations:
   a. The `pg_user_mapping` view, accessible only to "super users" in the database.
   b. When using the `dblink` function, passwords can be stored in your code or procedures inside the database.

2. Any changes to PostgreSQL user passwords require changing the `FDW/dblink` specifications as well.

3. When using `FDW`, if columns in the remote tables have been dropped or renamed, the queries will fail. The `FDW` tables must be re-created.

   For additional details:
   https://www.postgresql.org/docs/current/static/postgres-fdw.html

Oracle Database Links vs. PostgreSQL DBLink

Description	Oracle	PostgreSQL DBlink

Create a permanent "named" database link	`CREATE DATABASE LINK remote`
	`   CONNECT TO username IDENTIFIED BY password`
	`   USING 'remote';`
		Not Supported.
		
		You have to manually open the connection to the remote database in your sessions / queries:
		
		`SELECT dblink_connect('myconn', 'dbname=postgres port=5432`
		
		`host=hostname user=username password=password');`

Query using a database link	`SELECT * FROM employees@remote;`	`SELECT * FROM dblink('myconn','SELECT * FROM employees') AS p(id int,fullname text, address text);`

DML using database link	`INSERT INTO employees@remote`
	`   (employee_id, last_name, email, hire_date, job_id)`
	`   VALUES (999, 'Claus', 'sclaus@example.com', SYSDATE, 'SH_CLERK');`
		`SELECT * FROM dblink('myconn',$$INSERT into employees VALUES (45,'Dan','South side 7432, NY')$$) AS t(id int, name text, address text);`

Heterogeneous database link connections, such as Oracle to	Supported.	`create extension oracle_fdw` not supported by Amazon RDS.

Description	Oracle	PostgreSQL DBlink
PostgreSQL or vice-versa		
Run DDL via a database link	Not supported directly, but you can run a procedure or create a job on the remote database and executes the desired DDL commands. `dbms_job@remote.submit( l_job, 'execute immediate ''create table t ( x int )''' ); commit;`	`SELECT * FROM dblink('myconn',$$CREATE table my_remote_tbl (a int, b text)$$) AS t(a text);`
Delete a database link	`drop database link remote;`	Not supported. Close the DBLink connection instead. `SELECT dblink_disconnect('myconn');`

PostgreSQL DBLink vs. FDW

Description	PostgreSQL DBlink	PostgreSQL FDW
Create a permanent reference to a remote table using a database link	Not supported	After creating: - DFW Server definition. - User Mapping. - Run: `CREATE FOREIGN TABLE foreign_emp_tbl (id int, name text, address text ) SERVER foreign_server OPTIONS (schema_name 'hr', table_name 'employees');`
Query remote data	`SELECT * FROM dblink('myconn','SELECT * FROM employees') AS p(id int,fullname text, address text);`	`SELECT * FROM foreign_emp_tbl;`
DML on remote data	`SELECT * FROM dblink('myconn',$$INSERT into employees VALUES (45,'Dan','South side 7432, NY')$$) AS t(id int, name text, address text);`	`INSERT into foreign_emp_tb VALUES (45,'Dan','South side 7432, NY');` (Regular DML)
Run DDL on remote objects	`SELECT * FROM dblink('myconn',$$CREATE table my_remote_tbl`	Not Supported

	(a int, b text)$$) AS t(a text);	

Migrating from: Oracle Inline Views

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Overview

Inline views refer to a SELECT statement located in the FROM clause of secondary (or more) SELECT statement. Inline views can help make complex queries simpler by removing compound calculations or eliminating join operations while condensing several separate queries into a single simplified query.

Example

Inline View in the Oracle database:

```
SELECT A.LAST_NAME, A.SALARY, A.DEPARTMENT_ID, B.SAL_AVG
  FROM EMPLOYEES A,
       (SELECT DEPARTMENT_ID, ROUND(AVG(SALARY)) AS SAL_AVG
         FROM EMPLOYEES
         GROUP BY DEPARTMENT_ID)
WHERE A.DEPARTMENT_ID = B.DEPARTMENT_ID;
```

The SQL statement marked in red represents the inline view code. In our example above, the query will return each employee matched to their salary and department id. In addition, the query will return the average salary for each department, using the inline view column - SAL_AVG.

Migration to: PostgreSQL Inline Views

Overview

PostgreSQL semantics may refer to inline views as "Subselect" or as "Subquery". In either case, the functionality is the same. Running the Oracle inline view example above, as is, will result in an error: *"ERROR: subquery in FROM must have an alias".* This is because Oracle supports omitting aliases for the inner statement while in PostgreSQL the use of aliases is mandatory. "B" will be used as an alias in the example provided below.

Mandatory aliases are the only major difference when migrating Oracle inline views to PostgreSQL.

Example

```
SELECT A.LAST_NAME, A.SALARY, A.DEPARTMENT_ID, B.SAL_AVG
  FROM EMPLOYEES A,
       (SELECT DEPARTMENT_ID, ROUND(AVG(SALARY)) AS SAL_AVG
         FROM EMPLOYEES
         GROUP BY DEPARTMENT_ID) B
WHERE A.DEPARTMENT_ID = B.DEPARTMENT_ID;
```

Migrating from: Oracle Database Hints

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Overview

Oracle provides users with the ability to influence how the query optimizer behaves and the decisions made to generate query execution plans. Controlling the behavior of a database optimizer is done via the use of special "Database Hints". These can be defined as a directive operation to the optimizer and as such, alter the decisions on how execution plans are generated.

The Oracle Database supports over 60 different database hints and each database hint can receive 0 or more arguments. Database hints are divided into different categories such as optimizer hints, join order hints, parallel execution hints, etc.

Note: Database hints are embedded directly into the SQL queries immediately following the `SELECT` keyword using the following format: `/* <DB_HINT> */`

Example

1. Force the Query Optimizer to use a specific index for data access using a database hint embedded into the query:

```
SQL> SELECT /* INDEX(EMP, IDX_EMP_HIRE_DATE)*/ * FROM EMPLOYEES EMP
     WHERE HIRE_DATE >= '01-JAN-2010';

Execution Plan
----------------------------------------------------------
Plan hash value: 3035503638

---------------------------------------------------------------------------------------------
| Id  | Operation                    | Name           | Rows   | Bytes | Cost (%CPU)| Time
|
---------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT             |                |      1 |    62 |      2   (0)| 00:00:01
|   1 |  TABLE ACCESS BY INDEX ROWID| EMPLOYEES      |      1 |    62 |      2   (0)| 00:00:01
|*  2 |   INDEX RANGE SCAN           | IDX_HIRE_DATE  |      1 |       |      1   (0)| 00:00:01
---------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - access("HIRE_DATE">=TO_DATE(' 2010-01-01 00:00:00', 'syyyy-mm-dd hh24:mi:ss'))
```

For additional details:

http://docs.oracle.com/cd/E25178_01/server.1111/e16638/hintsref.htm#CHDIDIDI

https://docs.oracle.com/database/121/TGSQL/tgsql_influence.htm#TGSQL246

Migration to: PostgreSQL DB Query Planning

[Back to TOC]

Overview

PostgreSQL does not support "database hints" to influence the behavior of the query planner and we cannot influence how execution plans are generated from within SQL queries. Although database hints are not directly supported, session parameters (also known as "Query Planning Parameters") can influence the behavior of the query optimizer *at a session level*.

Example

1. Set the query planner to use indexes instead of full table scans (disable SEQSCAN):

```
psql=> SET ENABLE_SEQSCAN=FALSE;
```

2. Sets the query planner's estimated "cost" of a disk page fetch that is part of a series of sequential fetches (SEQ_PAGE_COST) and set the planner's estimate of the cost of a non-sequentially-fetched disk page (RANDOM_PAGE_COST). Reducing the value of RANDOM_PAGE_COST relative to SEQ_PAGE_COST will cause the query planner to prefer index scans, while raising the value will make index scans more "expensive".

```
psql=> SET SEQ_PAGE_COST to 4;
psql=> SET RANDOM PAGE COST to 1;
```

3. Enables or disables the query planner's use of nested-loops when performing joins. While it is impossible to completely disable the usage of nested-loop joins, setting the ENABLE_NESTLOOP to an OFF value discourages the query planner from choosing nested-loop joins compared to alternative join methods.

```
psql=> SET ENABLE_NESTLOOP to FALSE;
```

For additional details:
https://www.postgresql.org/docs/9.6/static/runtime-config-query.html

Migrating from: Oracle Recovery Manager (RMAN)

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Overview

RMAN, or Oracle Recovery Manager, is Oracle's primary backup and recovery tool. RMAN provides its own scripting syntax, which can be used to take full or incremental backups of your Oracle database.

1. **Full RMAN backup** – you can take a full backup of an entire database or individual Oracle data files. For example, a level 0 full backup.
2. **Differential incremental RMAN backup** – performs a backup of all database blocks that have changed from the previous level 0 or 1 backup.
3. **Cumulative incremental RMAN backup** – perform a backup all of the blocks that have changed from the previous level 0 backup.

Notes

- RMAN supports online backups of your Oracle database if your database has been configured to run in Archived Log Mode.
- RMAN is used to take backups of the following files:
    - Database data files.
    - Database control file.
    - Database parameter file.
    - Database Archived Redo Logs.

Examples

1. Connect using the RMAN CLI to the Oracle database you wish to back-up:

```
export ORACLE_SID=ORCL
rman target=/
```

2. Perform a full backup of the database and the database archived redo logs:

```
BACKUP DATABASE PLUS ARCHIVELOG;
```

3. Perform an incremental level 0 or level 1 backup of the database:

```
BACKUP INCREMENTAL LEVEL 0 DATABASE;
BACKUP INCREMENTAL LEVEL 1 DATABASE;
```

4. Restore the database using RMAN:

```
RUN {
  SHUTDOWN IMMEDIATE;
  STARTUP MOUNT;
  RESTORE DATABASE;
  RECOVER DATABASE;
  ALTER DATABASE OPEN;
}
```

5. Restore a specific pluggable database (Oracle 12c):

```
RUN {
  ALTER PLUGGABLE DATABASE pdbA, pdbB CLOSE;
  RESTORE PLUGGABLE DATABASE pdbA, pdbB;
  RECOVER PLUGGABLE DATABASE pdbA, pdbB;
  ALTER PLUGGABLE DATABASE pdbA, pdbB OPEN;
}
```

6. Restore a database to a specific point in time:

```
RUN {
  SHUTDOWN IMMEDIATE;
  STARTUP MOUNT;
  SET UNTIL TIME "TO_DATE('20-SEP-2017 21:30:00','DD-MON-YYYY
HH24:MI:SS')";
  RESTORE DATABASE;
  RECOVER DATABASE;
  ALTER DATABASE OPEN RESETLOGS;
}
```

7. Report (list) on all current database backups created via RMAN:

```
LIST BACKUP OF DATABASE;
```

For additional details:
https://docs.oracle.com/database/121/BRADV/toc.htm

Migration to: Amazon Aurora Snapshots

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Overview

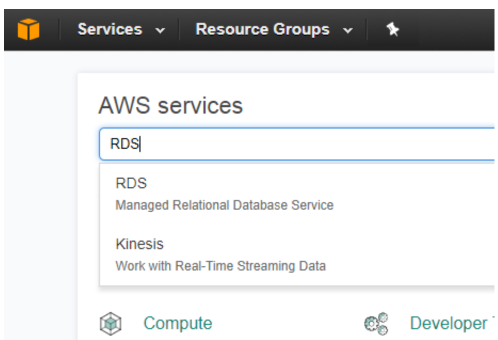
The primary backup mechanism for Amazon Aurora is using snapshots. Taking a snapshot is an extremely fast and non-intrusive operation for your database. Both taking snapshots and restoring your database from a snapshot can be done using the Amazon RDS Management Console or using the AWS CLI. Unlike RMAN, there is no need for incremental backups. You can choose to restore your database to the exact time when a snapshot was taken, or to any other point in time.

- **Automated backups**. Always enabled on Amazon Aurora. Backups do not impact database performance.
- **Manual backups**. You can create a snapshot at any given time. There is no performance impact when taking snapshots of your Aurora database. Restoring data from snapshots requires you to create a new instance. Up to 100 manual snapshots are supported per database.

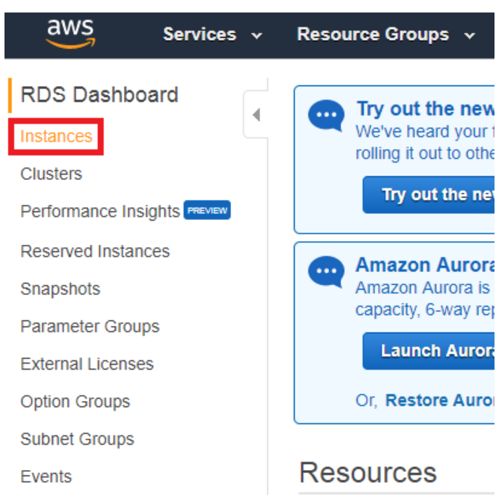
Example:

Enable Aurora automatic backups and configure the backup retention window as part of the database creation process. Doing this is equivalent to setting the Oracle RMAN backup retention policy (using the "`configure retention policy to recovery window of X days`" command).

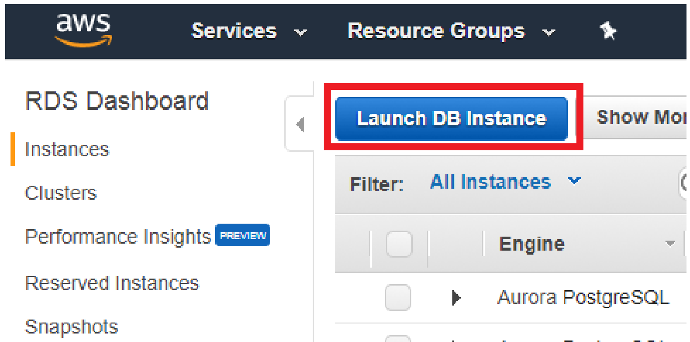
1. Go to the Amazon RDS page in your AWS Management Console:



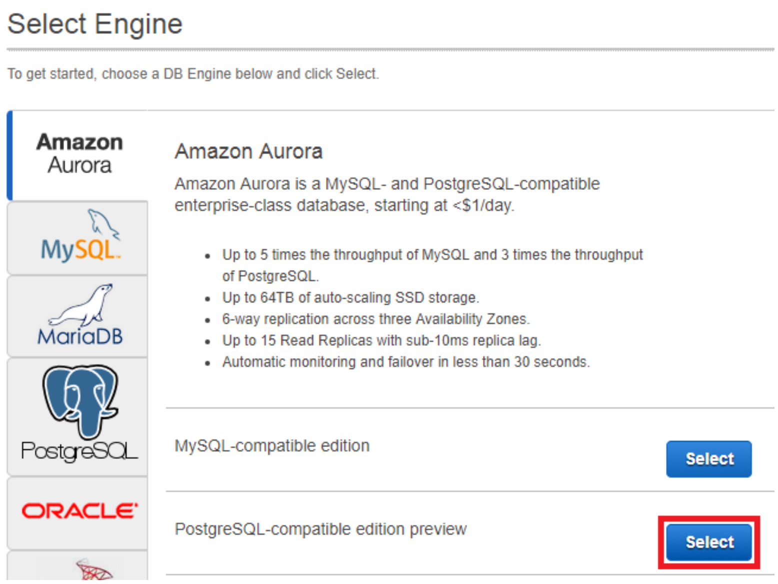
2. Click **Instances**



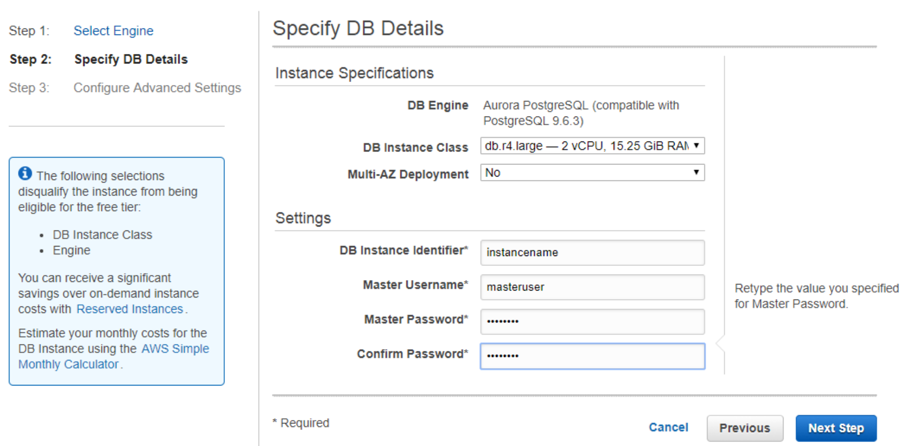
3. Select **Launch DB Instance.**



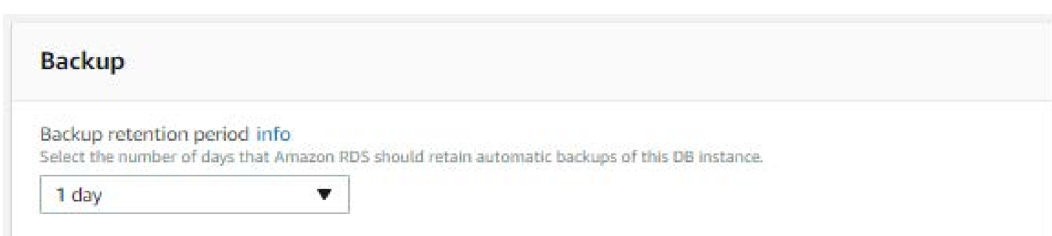
4. Select the **Aurora PostgreSQL-compatible** database engine.



5. Configure your database settings and parameters.



6. On the next page, you can configure a backup retention policy for your Aurora database, defined as the number of days for Amazon RDS to automatically to retain your snapshots:

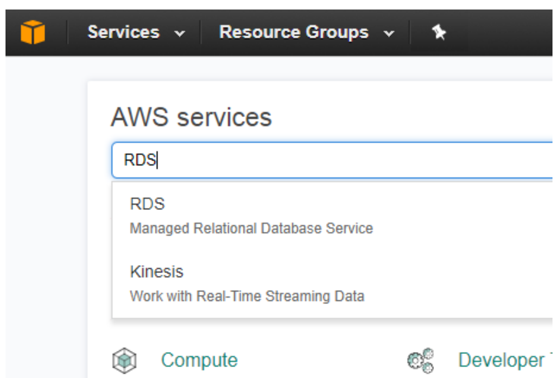


Region	Default Backup Window
US West (Oregon) Region	06:00–14:00 UTC
US West (N. California) Region	06:00–14:00 UTC
US East (Ohio) Region	03:00–11:00 UTC
US East (N. Virginia) Region	03:00–11:00 UTC
Asia Pacific (Mumbai) Region	16:30–00:30 UTC
Asia Pacific (Seoul) Region	13:00–21:00 UTC
Asia Pacific (Singapore) Region	14:00–22:00 UTC
Asia Pacific (Sydney) Region	12:00–20:00 UTC
Asia Pacific (Tokyo) Region	13:00–21:00 UTC
Canada (Central) Region	06:29–14:29 UTC
EU (Frankfurt) Region	20:00–04:00 UTC
EU (Ireland) Region	22:00–06:00 UTC
EU (London) Region	06:00–14:00 UTC
South America (São Paulo) Region	23:00–07:00 UTC
AWS GovCloud (US)	03:00–11:00 UTC

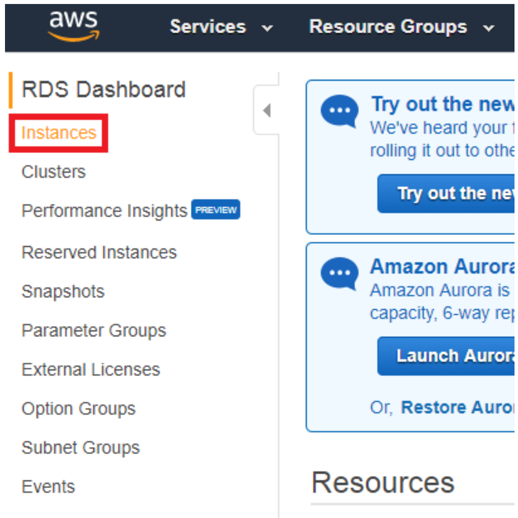
Example:

Perform a manual snapshot backup of your Aurora database, equivalent to creating a full Oracle RMAN backup (“`BACKUP DATABASE PLUS ARCHIVELOG`”).

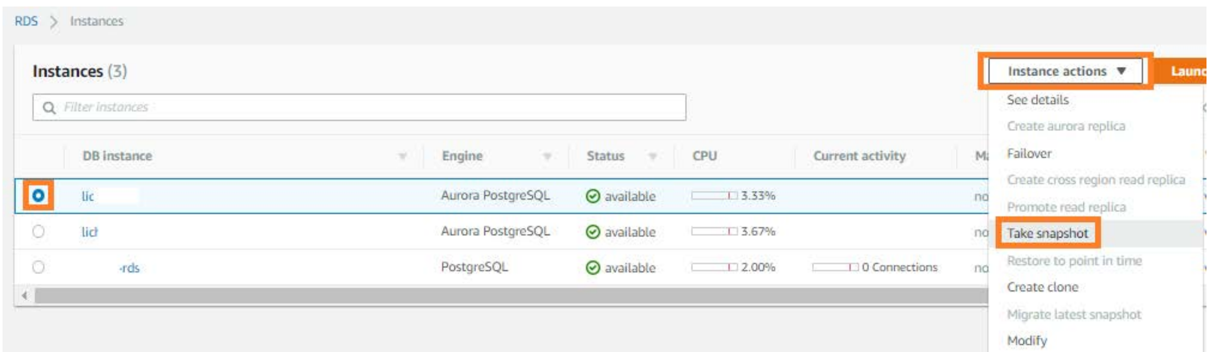
1. Go to the Amazon RDS page in your AWS Management Console:



2. Click **Instances.**



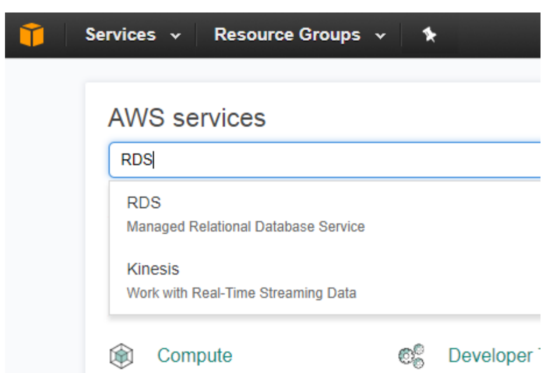
3. Select your Aurora PostgreSQL instance, click **Instance actions** and select **Take snaphot**:



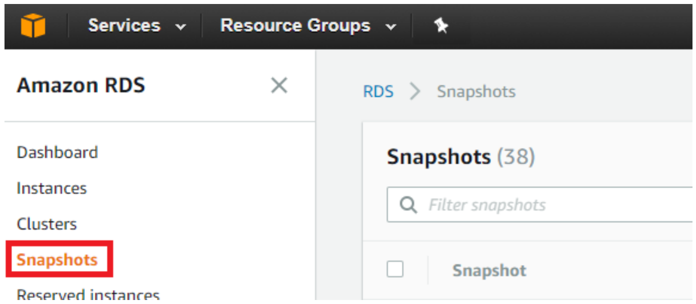
Example

Restore an Aurora database from a snapshot. Similar to Oracle RMAN “RESTORE DATABASE” and “RECOVER DATABASE” commands. However, note that instead of running in-place, restoring an Amazon Aurora database will create a new cluster.

1. Navigate to the Amazon RDS page in your AWS Management Console:



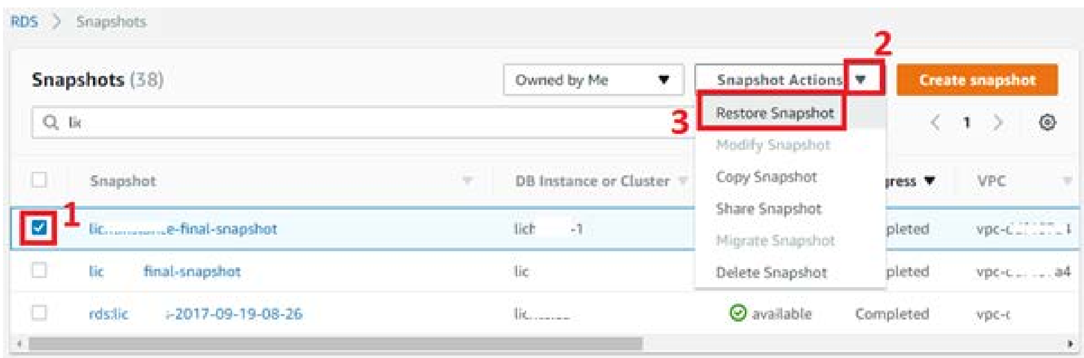
2. Click on the **Snapshots** link on the left-hand menu to see the list of snapshots you have available across your database instances.



3. Select **Snapshots**.

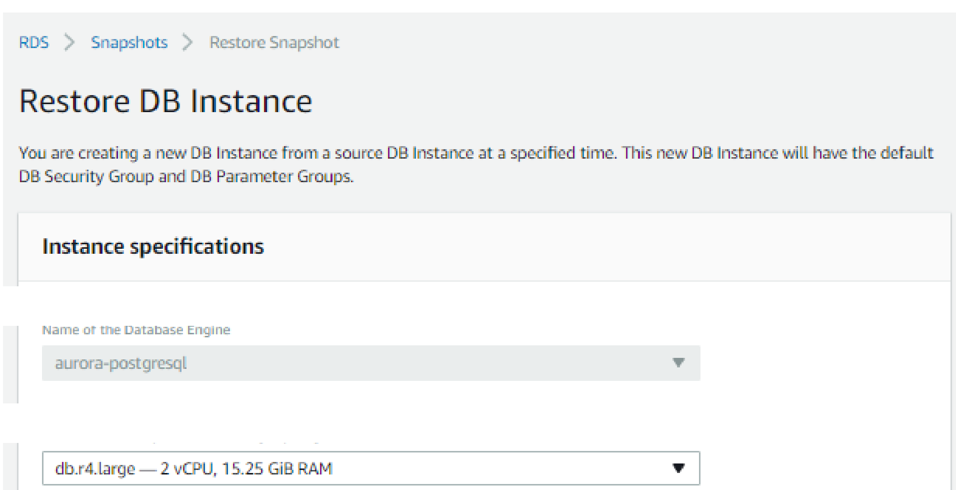
4. Select the snapshot to restore.

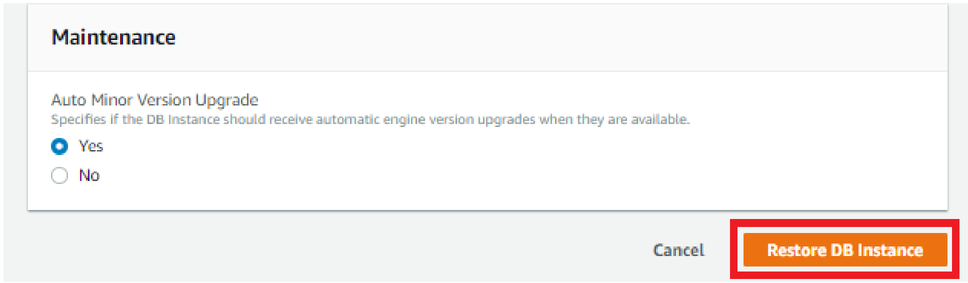
5. Click **Snapshot Actions** on the context menu and select **Restore snapshot**.

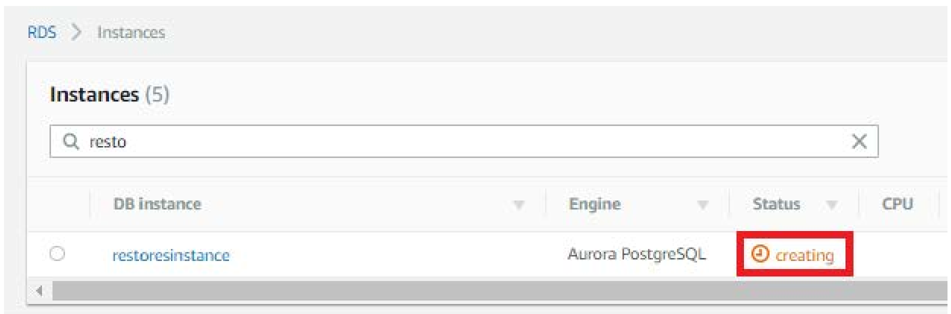


Note: *This creates a new instance.*

6. You will be presented with a wizard for creating your new Aurora database instance from the selected snapshot. Fill the required configuration options and click **Restore DB Instance**.



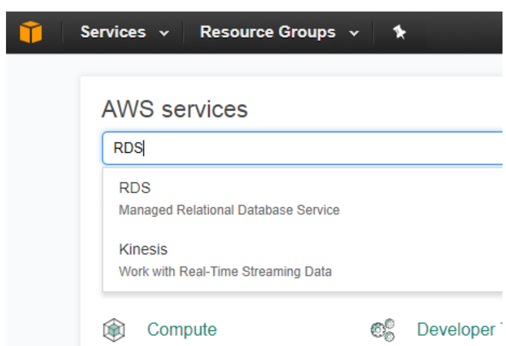




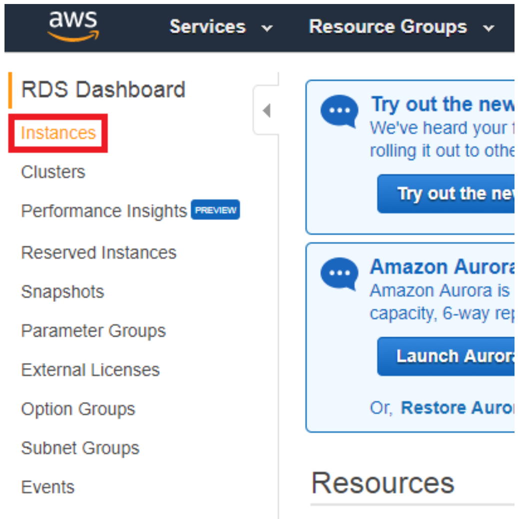
Example

Restore an Aurora PostgreSQL database backup to a specific previous point in time, similar to running an Oracle RMAN “`SET UNTIL TIME "TO_DATE('XXX')"` command, before running RMAN `RESTORE DATABASE` and `RECOVER DATABASE`.

1. Navigate to the Amazon RDS page in your AWS Management Console.

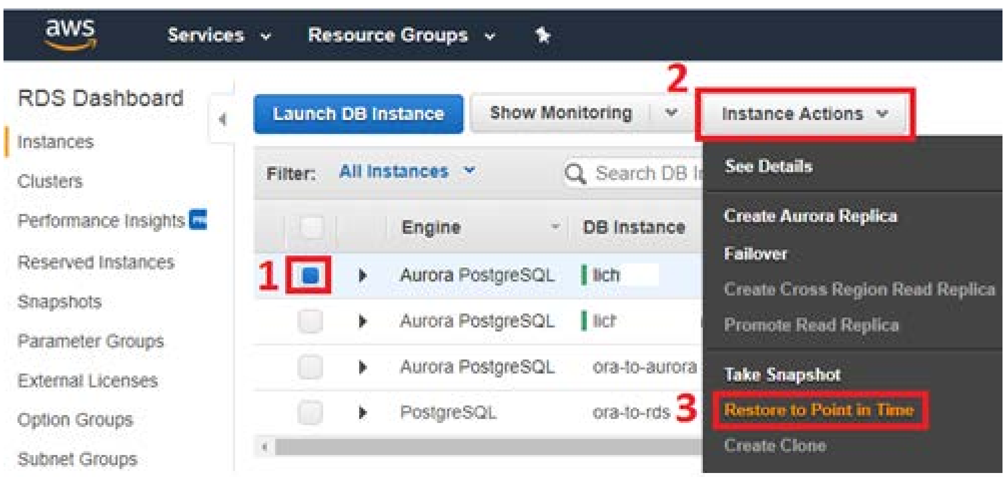


2. Click **Instances.**

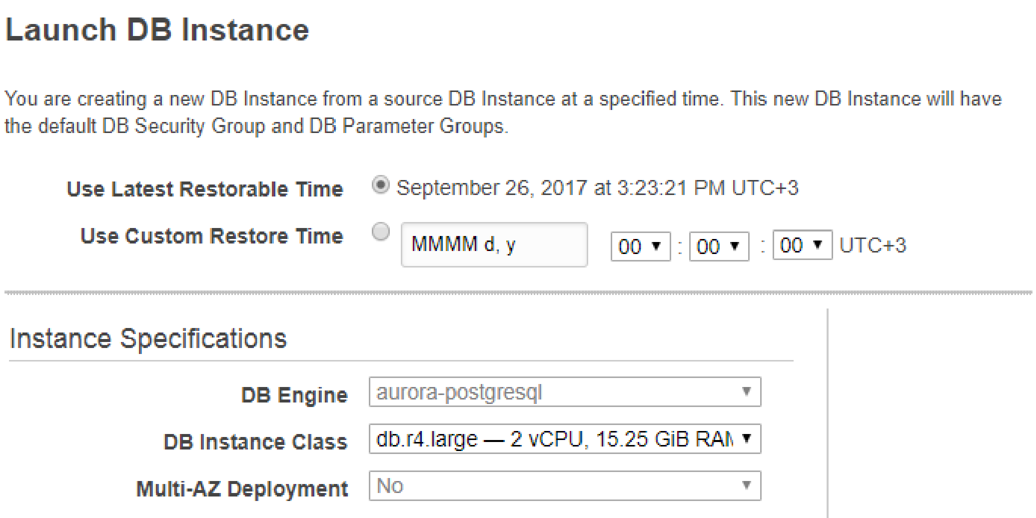


3. Select your Aurora instance and click **Instance Actions**.

4. Select **Restore to Point in Time** on the context menu.



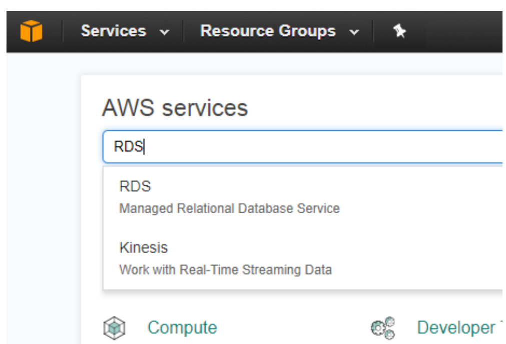
5. This process will launch a new instance. Select the date and time to which you want to restore your database. The selected date and time must be within the configured backup retention for this instance.



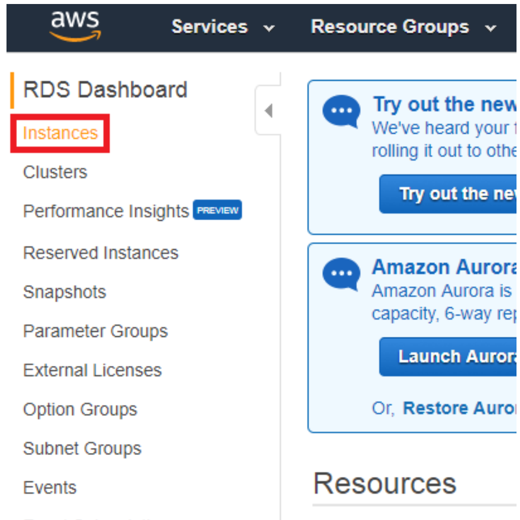
Example

Modify your Aurora backup retention policy after a database was already created. You need to configure how long your Aurora database backups should be stored. When restoring an Aurora database to a previous point in time, the selected time must be within the configured backup retention window.

1. Navigate to the Amazon RDS page in your AWS Management Console.

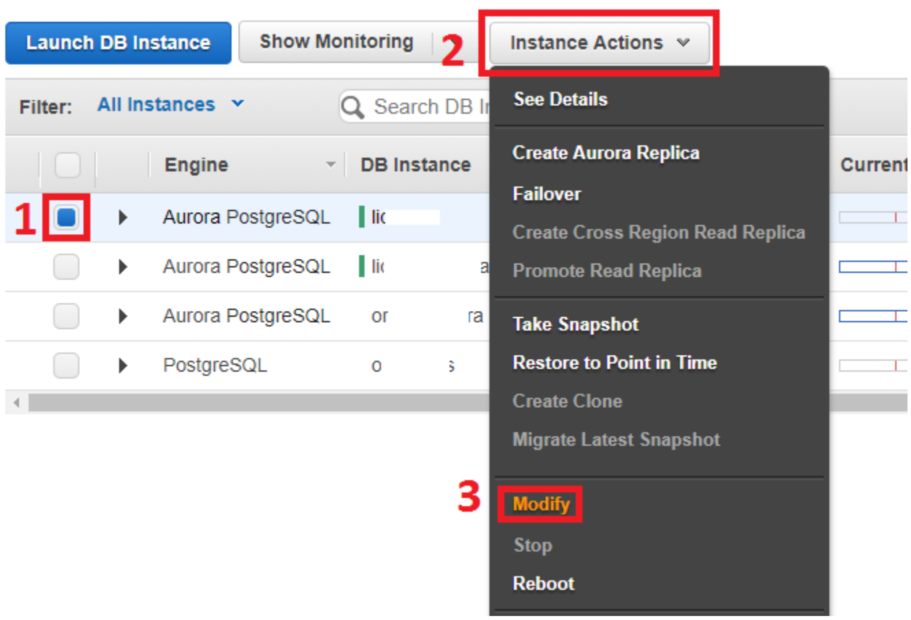


2. Click **Instances.**

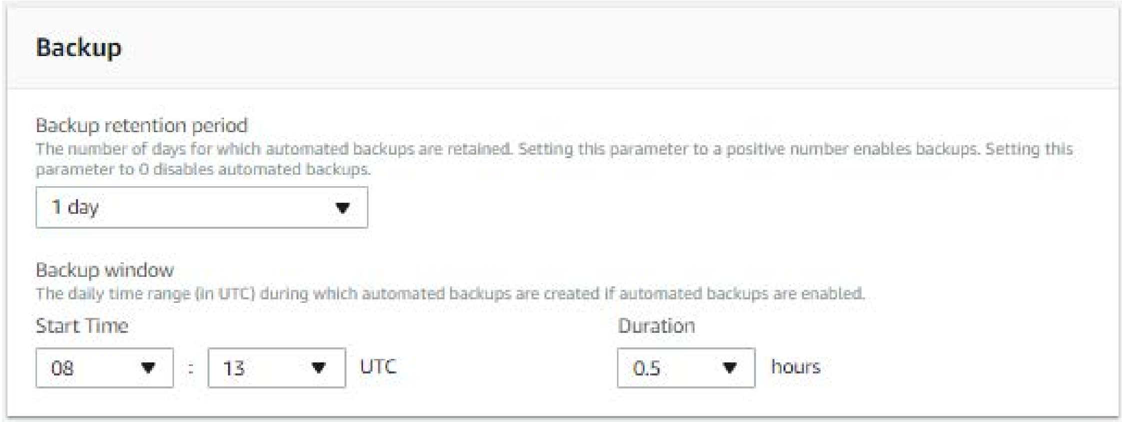


3. Select your Aurora instance, click **Instance Actions**.

4. Select **Modify** from the menu.



5. Configure the desired backup retention policy (maximum retention allowed is up to 35 days).



Using the AWS CLI for Amazon Aurora backup and restore operations

In addition to using the AWS web console user-interface to backup and restore your Aurora instance to a previous point in time or using a specific snapshot, you can also use the AWS CLI to perform the same actions. This is especially useful in case you need to convert your existing automated Oracle RMAN scripts to an Amazon Aurora environment.

Examples

1. Use `describe-db-cluster-snapshots` to view all current Aurora PostgreSQL snapshots.
2. Use `create-db-cluster-snapshot` to create a snapshot ("Restore Point").
3. Use `restore-db-cluster-from-snapshot` to restore a new cluster from an existing database snapshot.
4. Use `create-db-instance` to add new instances to the restored cluster.

```
aws rds describe-db-cluster-snapshots

aws rds create-db-cluster-snapshot --db-cluster-snapshot-iden
tifier Snapshot_name --db-cluster-identifier Cluster_Name

aws rds restore-db-cluster-from-snapshot --db-cluster-identifier
NewCluster --snapshot-identifier SnapshotToRestore --engine aurora-
postgresql

aws rds create-db-instance --region us-east-1 --db-subnet-group default -
-engine aurora-postgresql --db-cluster-identifier NewCluster --db-
instance-identifier newinstance-nodeA --db-instance-class db.r4.large
```

5. Use `restore-db-instance-to-point-in-time` to perform point-in-time recovery.

```
aws rds restore-db-cluster-to-point-in-time --db-cluster-identifier
clustername-restore --source-db-cluster-identifier clustername --restore-
to-time 2017-09-19T23:45:00.000Z

aws rds create-db-instance --region us-east-1 --db-subnet-group default -
-engine aurora-postgresql --db-cluster-identifier clustername-restore --
db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large
```

Oracle RMAN vs. Aurora snapshot backups

Description	Oracle	Amazon Aurora
Scheduled backups	Create DBMS_SCHEDULER job that will execute your RMAN script on a scheduled basis.	Automatic
Manual full database backups	`BACKUP DATABASE PLUS ARCHIVELOG;`	Use Amazon RDS dashboard or the AWS CLI command to take a snapshot on the cluster: `aws rds create-db-cluster-snapshot --db-cluster-snapshot-identifier Snapshot_name --db-cluster-identifier Cluster_Name`

Restore database	`RUN {`
	`  SHUTDOWN IMMEDIATE;`
	`  STARTUP MOUNT;`
	`  RESTORE DATABASE;`
	`  RECOVER DATABASE;`
	`  ALTER DATABASE OPEN;`
	`}`
		Create new cluster from a cluster snapshot:
		
		`aws rds restore-db-cluster-from-snapshot --db-cluster-identifier NewCluster --snapshot-identifier SnapshotToRestore --engine aurora-postgresql`
		
		Add a new instance to the new/restored cluster:
		
		`aws rds create-db-instance --region us-east-1 --db-subnet-group default --engine aurora-postgresql --db-cluster-identifier clustername-restore --db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large`

Incremental differential	`BACKUP INCREMENTAL LEVEL 0 DATABASE;` `BACKUP INCREMENTAL LEVEL 1 DATABASE;`	N/A
Incremental cumulative	`BACKUP INCREMENTAL LEVEL 0 CUMULATIVE DATABASE;` `BACKUP INCREMENTAL LEVEL 1 CUMULATIVE DATABASE;`	N/A

Restore database to a specific point-in-time	`RUN {`
	`  SHUTDOWN IMMEDIATE;`
	`  STARTUP MOUNT;`
	`  SET UNTIL TIME "TO_DATE('19-SEP-2017 23:45:00','DD-MON-YYYY HH24:MI:SS')";`
	`  RESTORE DATABASE;`
	`  RECOVER DATABASE;`
	`  ALTER DATABASE OPEN RESETLOGS;`
	`}`
		Create new cluster from a cluster snapshot by given custom time to restore:
		
		`aws rds restore-db-cluster-to-point-in-time --db-cluster-identifier clustername-restore --source-db-cluster-identifier clustername --restore-to-time 2017-09-19T23:45:00.000Z`
		
		Add a new instance to the new/restored cluster:

Description	Oracle	Amazon Aurora
		`aws rds create-db-instance --region us-east-1 --db-subnet-group default --engine aurora-postgresql --db-cluster-identifier clustername-restore --db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large`
Backup database Archive logs	`BACKUP ARCHIVELOG ALL;`	N/A
Delete old database Archive logs	`CROSSCHECK BACKUP;` `DELETE EXPIRED BACKUP;`	N/A

Restore a single Pluggable database (12c)	`RUN {`
	`  ALTER PLUGGABLE DATABASE pdb1, pdb2 CLOSE;`
	`  RESTORE PLUGGABLE DATABASE pdb1, pdb2;`
	`  RECOVER PLUGGABLE DATABASE pdb1, pdb2;`
	`  ALTER PLUGGABLE DATABASE pdb1, pdb2 OPEN;`
	`}`
		Create new cluster from a cluster snapshot:
		
		`aws rds` **`restore-db-cluster-from-snapshot`** `--db-cluster-identifier NewCluster --snapshot-identifier SnapshotToRestore --engine aurora-postgresql`
		
		Add a new instance to the new/restored cluster:
		
		`aws rds create-db-instance --region us-east-1 --db-subnet-group default --engine aurora-postgresql --db-cluster-identifier clustername-restore --db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large`
		
		Use **`pg_dump`** and **`pg_restore`** to copy the database to the original instance:
		
		`pgdump -F c -h hostname.rds.amazonaws.com -U username -d hr -p 5432 > c:\Export\hr.dmp`
		
		`pg_restore -h restoredhostname.rds.amazonaws.com -U hr -d hr_restore -p 5432 c:\Export\hr.dmp`
		
		Optionally, replace with the old database using `ALTER DATABASE RENAME`

For additional details:
http://docs.aws.amazon.com/cli/latest/reference/rds/index.html#cli-aws-rds
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_PIT.html
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_RestoreFromSnapshot.html

Migrating from: Oracle 12c PDBs & CDB

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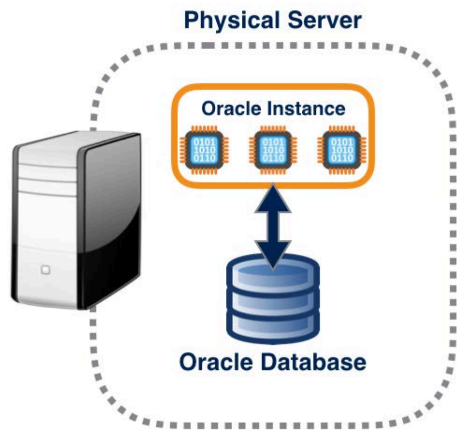
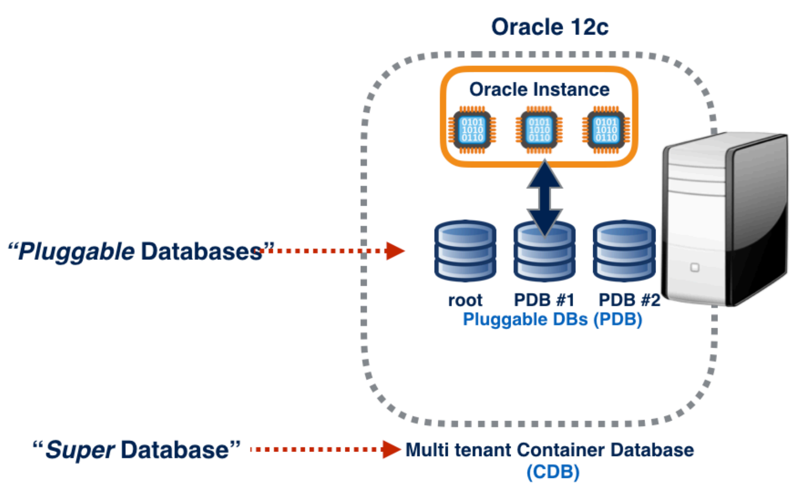
Overview

Oracle 12c introduces a new multitenant architecture which provides the ability to create additional independent “pluggable” databases under a single Oracle instance. Prior to Oracle 12c, a single Oracle database instance only supported running single Oracle database, as shown in the picture below.



The Pre-12c Oracle Database Architecture

Oracle 12c introduces a new multi-container database, or CDB, that supports one or more “Pluggable Databases”, or PDBs. The CDB can be thought of as a single “superset” database with multiple pluggable database. The relationship between The Oracle instance and databases is now 1:N.



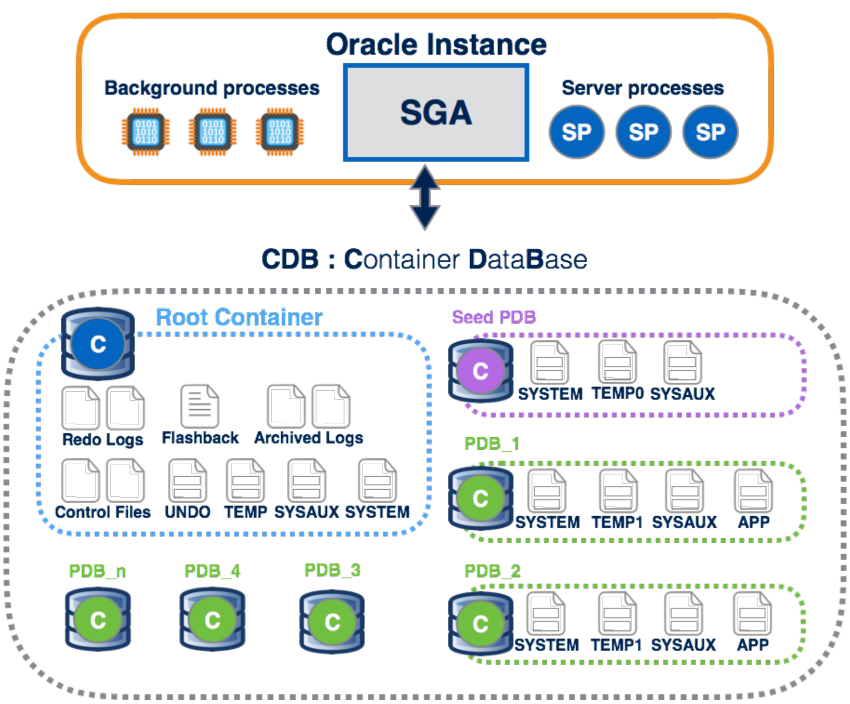
The Multitenant Oracle 12c Database Architecture

Advantages of the Oracle 12c multitenant architecture

- PDBs can be used to isolate applications from one another.
- PDBs can be used as portable collection of schemas.
- PDBs can cloned and transported to different CDBs/Oracle instances.
- Management of many databases (individual PDBs) as a whole.
- Separate security, users, permissions, and resource management per PDB provides greater application isolation.
- Enables a consolidated database model of many individual applications sharing a single Oracle server.
- Provide an easier way to patch and upgrade individual clients and/or applications, using PDBs.
- Backups are supported at both a multitenant container-level as well as at an individual PDB-level (both for physical and logical backups).

The Oracle multitenant architecture

- A multitenant Container Database (CDB) can support one or more "pluggable databases" (PDBs).
- Each pluggable database contains its own copy of SYSTEM and application tablespaces.
- The PDBs will share the Oracle Instance memory and background processes. The use of PDBs enables consolidation of many databases and applications into individual containers under the same Oracle instance.
- A single "Root Container" (or CDB$ROOT) exists in a CDB and contains the Oracle Instance Redo Logs, undo tablespace (unless Oracle 12.2 local undo mode is enabled) and control files.
- A single Seed PDB exists in a CDB and used as a template for creating new PDBs.



The Oracle Multitenant Oracle 12c Database Architecture

CDB & PDB Semantics

- **CDB (Container Database)**
  - A “Super” database that contains the Root Container – `cdb$root` (one per instance) and one or more Pluggable Databases (with user-provided naming).
  - Created as part of the Oracle 12c software installation.
  - Contains the Oracle control files, its own set of system tablespaces, the instance undo tablespaces (unless Oracle 12.2 local undo mode is enabled), and the instance redo logs.
  - Holds the data dictionary for the root container and for all of the PDBs.

- **PDB (Pluggable Database)**
  - Independent database that exists under a CDB. Also known as a “container”.
  - Used to store application-specific data.
  - Can be created from a the pdb$seed (template database) or as a clone of an existing PDB
  - Stores metadata information specific to its own objects (data-dictionary)
  - Has its own set of application and system data files and tablespaces along with temporary files to manage objects.

Examples

1. List existing PDBs created in an Oracle CDB instance:

```
SQL> SHOW PDBS;

    CON_ID CON_NAME                       OPEN MODE  RESTRICTED
---------- ------------------------------ ---------- ----------
         2 PDB$SEED                       READ ONLY  NO
         3 PDB1                           READ WRITE NO
```

2. Provisioning of a new PDB from the template `seed$pdb`:

```
SQL> CREATE PLUGGABLE DATABASE PDB2 admin USER ora_admin IDENTIFIED BY
     ora_admin FILE_NAME_CONVERT=('/pdbseed/','/pdb2/');
```

3. Alter a specific PDB to READ/WRITE and verify:

```
SQL> ALTER PLUGGABLE DATABASE PDB2 OPEN READ WRITE;

SQL> show PDBS;

    CON_ID CON_NAME                       OPEN MODE  RESTRICTED
---------- ------------------------------ ---------- ----------
         2 PDB$SEED                       READ ONLY  NO
         3 PDB1                           READ WRITE NO
         4 PDB2                           READ WRITE NO
```

4. Clone a PDB from an existing PDB:

```
SQL> CREATE PLUGGABLE DATABASE PDB3 FROM PDB2 FILE_NAME_CONVERT=
     ('/pdb2/','/pdb3/');

SQL> SHOW PDBS;
    CON_ID CON_NAME                       OPEN MODE  RESTRICTED
---------- ------------------------------ ---------- ----------
         2 PDB$SEED                       READ ONLY  NO
         3 PDB1                           READ WRITE NO
         4 PDB2                           READ WRITE NO
         5 PDB3                           MOUNTED
```

For additional details:
http://docs.oracle.com/database/122/CNCPT/overview-of-the-multitenant-architecture.htm#CNCPT89250
http://docs.oracle.com/database/122/ADMIN/managing-a-multitenant-environment.htm#ADMIN13506

Migration to: PostgreSQL Databases

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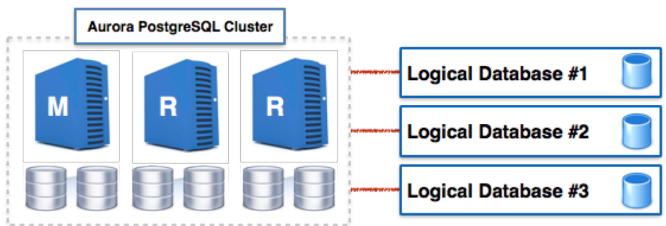
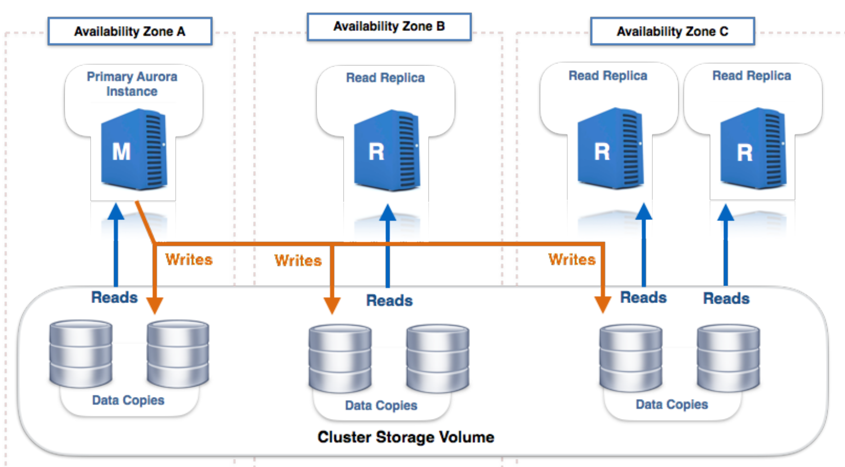
Overview

Amazon Aurora PostgreSQL offers a different and simplified architecture to manage and create a multitenant database environment. Using Aurora PostgreSQL, it is possible to provide levels of functionality similar (but not identical) to those offered by Oracle PDBs by creating multiple databases under the same Aurora PostgreSQL cluster and/or using separate Aurora clusters, when total isolation of workloads is required.

- Multiple PostgreSQL databases can be created under a single Amazon Aurora PostgreSQL Cluster.



- Each Amazon Aurora cluster contains a primary instance that can accept both reads and writes for all cluster databases.
- Up to 15 read-only nodes can be created which provide both scale-out functionality for application reads as well as for high availability proposes.



Amazon Aurora Database Cluster with Primary (Master) an Read replicas.

In theory, an Oracle *CDB/Instance* can be considered as the high-level equivalent to an Amazon Aurora *cluster*, and an Oracle Pluggable Database (PDB) would be equivalent to PostgreSQL database created inside the Amazon Aurora cluster. Not all features are comparable between Oracle 12c PDBs and Amazon Aurora.

Examples

1. Create a new database in PostgreSQL using the CREATE DATABASE statement:

```
psql=> CREATE DATABASE pg_db1;
CREATE DATABASE

psql=> CREATE DATABASE pg_db2;
CREATE DATABASE

psql=> CREATE DATABASE pg_db3;
CREATE DATABASE
```

2. List all databases created under an Amazon Aurora PostgreSQL cluster:

```
psql=> \l

    Name      |    Owner     | Encoding |   Collate    |    Ctype     |
-------------+-------------+----------+-------------+-------------+-----
--------------------------
 admindb     | rds_pg_admin | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 pg_db1      | rds_pg_admin | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 pg_db2      | rds_pg_admin | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 pg_db3      | rds_pg_admin | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 postgres    | rds_pg_admin | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 rdsadmin    | rdsadmin     | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 template0   | rdsadmin     | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
 template1   | rds_pg_admin | UTF8     | en_US.UTF-8 | en_US.UTF-8 |
```

Independent database backups in Amazon Aurora PostgreSQL

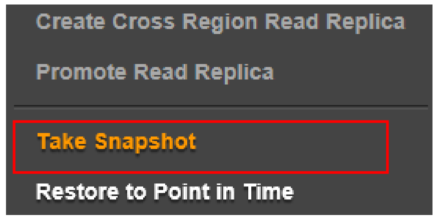
Oracle 12c provides the ability to perform both logical backups (via DataPump) and physical backups (via RMAN) at both CDB and PDB levels. Similarly, Amazon Aurora PostgreSQL provides the ability to perform logical backups on all or a specific database(s) using **pg_dump**. However, for physical backups when using snapshots, the entire cluster and all databases are included in the snapshot, backing up a specific database with in the cluster is not supported.

This is usually not a concern as volume snapshots are extremely fast operations that occur at the storage-infrastructure layer and thus incur minimal overhead and operate at extremely fast speeds. However, you the process of restoring a single PostgreSQL database from an Aurora snapshot requires additional steps, such as exporting the specific database after a snapshot restore and importing it back to the original Aurora cluster.

Examples

Physical backup: take an Amazon Aurora PostgreSQL snapshot.

1. On the AWS Management Console, navigate to **RDS > Instances > Instance Actions** and choose "Take Snapshot".



Logical backup: Use PostgreSQL `pg_dump` (installed on your client machine) to create a logical backup for a specific PostgreSQL database:

```
$ pg_dump -h hostname.rds.amazonaws.com -U username -d db_name
  -f dump_file_name.sql
```

For additional information on PostgreSQL databases:
https://www.postgresql.org/docs/current/static/sql-createdatabase.html

Migrating from: Oracle Tablespaces & Data Files

Overview

The storage structure of an Oracle database contains both physical and logical elements.

Type	Description
Tablespaces	Each Oracle database contains one or more *tablespaces*, which are logical storage groups, that are used as “containers” when creating new tables and indexes.
Data files	Each tablespace is made up of one or more *data files*, which are the physical elements that make up an Oracle database tablespace. Datafiles can be located on the local file system, raw partitions, managed by Oracle ASM or files located on network file system.

Storage Hierarchy

- **Database**: each Oracle database is composed from one or more tablespaces.
- **Tablespace**: each Oracle tablespace is composed from one or more datafiles. Tablespaces are logical entities that have no physical manifestation on the file system.
- **Data files**: physical files, located on a file-system. Each Oracle tablespace is made from one or more data files.
  Segments: each represents a single database object that consumes storage, such as tables, indexes, undo segments etc.
- **Extent**: each segment is made from one or more extents. Oracle uses extents as a form of allocating contiguous sets of database blocks on disk.
- **Block:** the smallest unit of I/O that can be used by a database for reads and writes. In case of blocks that store table data, each block can store one or more table rows.

Types of Oracle Database Tablespace

- **Permanent Tablespaces:** designated to store persistent schema objects for your applications.
- **Undo Tablespace :** a special type of system permanent tablespace that is used by Oracle to manage UNDO data when running the database in automatic undo management mode.
- **Temporary Tablespace:** contains schema objects that are valid for the duration of a session. It is also used for spilling sorts that cannot fit into memory.

Tablespace Privileges

In order to create a tablespace:

- The database user must have the `CREATE TABLESAPCE` system privilege.
- Create a database and the database must be in open mode.

Examples

1. Create the USERS tablespace comprised of a single **data file**.

```
SQL> CREATE TABLESPACE USERS
       DATAFILE '/u01/app/oracle/oradata/orcl/users01.dbf' SIZE 5242880
       AUTOEXTEND ON NEXT 1310720 MAXSIZE 32767M
       LOGGING ONLINE PERMANENT BLOCKSIZE 8192
       EXTENT MANAGEMENT LOCAL AUTOALLOCATE DEFAULT
       NOCOMPRESS SEGMENT SPACE MANAGEMENT AUTO;
```

Drop a tablespace:

```
SQL> DROP TABLESPACE USERS;
OR
SQL> DROP TABLESPACE USERS INCLUDING CONTENTS AND DATAFILES;
```

For additional details:
https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_7003.htm#SQLRF01403
https://docs.oracle.com/database/121/SQLRF/statements_7003.htm#SQLRF01403
https://docs.oracle.com/cd/E11882_01/server.112/e41084/clauses004.htm#SQLRF01602
https://docs.oracle.com/database/121/SQLRF/clauses004.htm#SQLRF01602
https://docs.oracle.com/cd/E11882_01/server.112/e41084/statements_9004.htm#SQLRF01807
https://docs.oracle.com/database/121/SQLRF/statements_9004.htm#SQLRF01807

Migration to: PostgreSQL Tablespaces & Data Files

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Overview

The logical storage structure in PostgreSQL shares similar concepts as Oracle, utilizing tablespaces for storing database objects. Tablespaces in PostgreSQL are made from datafiles and are used to store different databases and database object.

- **Tablespace** - the *directory* where datafiles are stored.
- **Data files** - file-system files that are placed inside a tablespace (directory) and are used to store database objects such as tables or indexes. Created automatically by PostgreSQL. Similar to how Oracle-Managed-Files (OMF) behave.

Notes:

- Unlike Oracle, a PostgreSQL tablespace does not have user-configured segmentation into multiple and separate data files. When you create the tablespace, PostgreSQL automatically creates the necessary files to store the data.
- Each table and index are stored in a separate O/S file, named after the table or index's ***filenode*** number.

Tablespaces in Amazon Aurora PostgreSQL

After an Amazon Aurora PostgreSQL cluster is created, two system tablespaces are automatically provisioned and cannot be modified or dropped:

- **`pg_global` tablespace**
  - Used for the shared system catalogs.
  - Stores objects that are visible to all Cluster databases.

- **`pg_default` tablespace**
  - The default tablespace of the `template1` and `template0` databases.
  - Serves as the default tablespace for other databases, by default, unless a different tablespace was explicitly specified during database creation.

One of the main advantages when using Amazon Aurora PostgreSQL is the absence of complexity for storage management. Therefore, creating tablespaces in Aurora PostgreSQL is simplified and has several advantages over a "vanilla" PostgreSQL database deployment:

- When creating tablespaces, the superuser can specify an OS path (location) that does not currently exist. The directory will be implicitly created.

- A user-specified tablespace directory will be created under an embedded Amazon RDS/Aurora path. For example, every path specified in the `LOCATION` clause when creating a new tablespace will be created under the Amazon RDS path of: */rdsdbdata/tablespaces/*

- Amazon Aurora PostgreSQL leverages a unique self-managed shared storage architecture. The DBA does not need to micro-manage most storage aspects of the database.

Examples

1. Creating a Tablespace via Amazon Aurora PostgreSQL and view its associated directory:

```
demo=> CREATE TABLESPACE TBS_01 LOCATION '/app_data/tbs_01';
CREATE TABLESPACE

demo=> \du

    Name     |  Owner    |                    Location
------------+----------+-----------------------------------------------
 pg_default | rdsadmin |
 pg_global  | rdsadmin |
 tbs_01     | rdsadmin | /rdsdbdata/tablespaces/app_data/tbs_01
```

* Notice that the newly specified path was created under the embedded base path for Amazon Aurora: */rdsdbdata/tablespaces/*

2. View current tablespaces and associated directories:

```
select spcname, pg_tablespace_location(oid) from pg_tablespace;
```

3. Drop the PostgreSQL TBS_01 tablespace:

```
demo=> DROP TABLESPACE TBS_01;
DROP TABLESPACE
```

4. Alter a tablespace:

```
demo=> ALTER TABLESPACE TBS_01 RENAME TO IDX_TBS_01;
ALTER TABLESPACE

demo=> ALTER TABLESPACE TO IDX_TBS_01 OWNER TO USER1;
ALTER TABLESPACE
```

5. Assign a database with a specific tablespace:

```
demo=> CREATE DATABASE DB1 TABLESPACE TBS_01;
CREATE DATABASE

demo=> SELECT DATNAME, PG_TABLESPACE_LOCATION(DATTABLESPACE) FROM PG_DATABASE
         WHERE DATNAME='db1';

 datname |         pg_tablespace_location
---------+----------------------------------------
 db1     | /rdsdbdata/tablespaces/app_data/tbs_01
```

6. Assign a table with a specific tablespace:

```
demo=> CREATE TABLE TBL(
          COL1 NUMERIC, COL2 VARCHAR(10))
          TABLESPACE TBS_01;
CREATE TABLE

demo=> SELECT SCHEMANAME, TABLENAME, TABLESPACE FROM PG_TABLES
         WHERE TABLENAME='tbl';

 schemaname | tablename | tablespace
------------+-----------+------------
 public     | tbl       | tbs_01
```

7. Assign an index with a specific tablespace:

```
demo=> CREATE INDEX IDX_TBL ON TBL(COL1)
         TABLESPACE TBS_01;
CREATE INDEX

demo=> SELECT SCHEMANAME, TABLENAME, INDEXNAME, TABLESPACE FROM PG_INDEXES
         WHERE INDEXNAME='idx_tbl';

 schemaname | tablename | indexname | tablespace
------------+-----------+-----------+------------
 public     | tbl       | idx_tbl   | tbs_01
```

8. Alter a table to use a different tablespace:

```
demo=> ALTER TABLE TBL SET TABLESPACE TBS_02;
ALTER TABLE
```

Tablespace Exceptions

- `CREATE TABLESPACE` cannot be executed inside a transaction block.
- A tablespace cannot be dropped until all objects in all databases using the tablespace have been removed/moved.

Privileges

- The creation of a tablespace in the PostgreSQL database must be performed by a database superuser.
- Once a tablespace has been created, it can be used from any database, provided that the requesting user has sufficient privileges.

Tablespace Parameters

The `default_tablespace` parameter controls the system default location for newly created database objects. By default, this parameter is set to an empty value and any newly created database object will be stored in the default tablespace (`pg_default`).

The `default_tablespace` parameter can be altered by using the cluster parameter group.

To verify and to set the *default_tablespace* variable:

```
demo=> SHOW DEFAULT_TABLESPACE; -- No value
 default_tablespace
--------------------

demo=> SET DEFAULT_TABLESPACE=TBS_01;
demo=> SHOW DEFAULT_TABLESPACE;
 default_tablespace
--------------------
 tbs_01
```

Oracle vs. PostgreSQL tablespaces

Feature	Oracle	Aurora PostgreSQL
Tablespace	Exists as a logical object and made from one or more user-specified or system-generated data files.	Logical object that is tied to a specific directory on the disk where datafiles will be created.
Data file	1. Can be explicitly created and resized by the user. Oracle-Managed-Files (OMF) allows for automatically created data files. 2. Each data file can contain one or more tables and/or indexes.	Behavior is more akin to Oracle Managed Files (OMF). 1. Created automatically in the directory assigned to the tablespace. 2. Single data file stores information for a specific table or index. Multiple data files can exist for a table or index. Additional files are created: **1. Freespace map file** Exists in addition to the datafiles themselves. The free space map is stored as a file named with the filenode number plus the _fsm suffix. **2. Visibility Map File** Stored with the _vm suffix and used to track which pages are known to have no dead tuples.
Creates a new tablespace with system-managed datafiles	`CREATE TABLESPACE sales_tbs DATAFILE SIZE 400M;`	`create tablespace sales_tbs LOCATION '/postgresql/data';`
Create a new tablespace with user-managed datafiles	`CREATE TABLESPACE sales_tbs DATAFILE '/oradata/sales01.dbf' SIZE 1M AUTOEXTEND ON NEXT 1M;`	N/A
Alter the size of a datafile	`ALTER DATABASE DATAFILE '/oradata/sales01.dbf' RESIZE 100M;`	N/A

Feature	Oracle	Aurora PostgreSQL
Add a datafile to an existing tablespace	`ALTER TABLESPACE sales_tbs ADD DATAFILE '/oradata/sales02.dbf' SIZE 10M;`	N/A

Per-database tablespace	Supported as part of the Oracle 12c Multi-Tenant architecture. Different dedicated tablespaces can be created for different pluggable databases and set as the default tablespace for a PDB:
	
	`ALTER SESSION SET CONTAINER = 'sales';`
	
	`CREATE TABLESPACE sales_tbs DATAFILE '/oradata/sales01.dbf' SIZE 1M AUTOEXTEND ON NEXT 1M;`
	
	`ALTER DATABASE sales TABLESPACE sales_tds;`
		Tablespaces are shared across all databases but a default tablespace can be created and configured for the database:
		
		`create tablespace sales_tbs LOCATION '/postgresql/data';`
		
		`CREATE DATABASE sales OWNER sales_app` **`TABLESPACE sales_tbs;`**

Metadata tables	Data Dictionary tables are stored in the `SYSTEM` tablespace	System Catalog tables are stored in the `pg_global` tablespace
Tablespace data encryption	***Supported*** 1. Using transparent data encryption. 2. Encryption and decryption are handled seamlessly so the user does not have to modify the application to access the data.	***Supported*** 1. Encrypt using keys managed through KMS. 2. Encryption and decryption are handled seamlessly so the user does not have to modify the application to access the data 3.Enable encryption while deploying a new cluster via the AWS Management Console or API actions. *For additional details:* http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/Overview.Encryption.html

For additional details:
https://www.postgresql.org/docs/9.6/static/manage-ag-tablespaces.html
https://www.postgresql.org/docs/9.6/static/sql-createtablespace.html
https://www.postgresql.org/docs/9.6/static/storage-file-layout.html
https://www.postgresql.org/docs/9.6/static/storage-fsm.html
https://www.postgresql.org/docs/9.6/static/functions-info.html#FUNCTIONS-INFO-CATALOG-TABLE
https://www.postgresql.org/docs/9.6/static/sql-droptablespace.html
https://www.postgresql.org/docs/current/static/sql-altertablespace.html

Migrating from: Oracle Data Pump

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Overview

Oracle Data Pump is a utility for exporting/importing data from/to an Oracle database. Data Pump can be used to copy an entire database, an entire schema(s) or specific objects in a schema. Oracle Data Pump is commonly used as a part of backup strategy for restoring individual database objects (specific records, tables, views, stored procedures, etc.) as opposed to snapshots or Oracle RMAN, which provides backup and recovery capabilities at the database-level. By default, and without using the *sqlfile* parameter during export, the "dumpfile" generated by Oracle Data Pump is a binary file and cannot be opened using a text editor.

Oracle Data Pump Supports:

1. **Export of data from an Oracle database:**
   The Data Pump **EXPDP** command creates a binary dump file containing the exported database objects. Objects can be exported with data or, as an alternative, containing metadata only. Support for cross-object consistent exports can be accomplished by requesting the export to be done according to a specific timestamp or Oracle SCN.

2. **Import data to an Oracle database:**
   The Data Pump **IMPDP** command will import objects and data from specific dump file created with the **EXPDP** Data Pump command. The **IMPDP** command can filter on import (only import certain objects) and remap object and schema names during import.

Notes:

- The term "Logical backup" refers to a dump file created by Oracle Data Pump.
- Both EXPDP and IMPDP can only read/write "dumpfiles" from filesystem paths that were pre-configured in the Oracle database as "directories". During export/import, users will need to specify the logical "directory" name where the dumpfile should be created, and not the actual filesystem path.

Examples

Export - using **EXPDP** to export the Oracle HR schema:

```
$ expdp system/**** directory=expdp_dir schemas=hr dumpfile=hr.dmp
  logfile=hr.log
```

** The command contains the **credentials*** to run Data Pump*, logical Oracle **directory*** name for the dump file location (which maps in the database to a physical filesystem location)*, schema name to export and **dump file** and **log files** names*.

Import - Using the **IMPDP** to import the HR schema and rename to HR_COPY:

```
$ impdp system/**** directory=expdp_dir schemas=hr dumpfile=hr.dmp
  logfile=hr.log REMAP_SCHEMA=hr:hr_copy
```

** The command contains the database **credentials** to run Data Pump, logical Oracle **directory** for where the export dumpfile is located, dump file name, **schema** to export, name for the **dump file** and **log file** name and the **REMAP_SCHEMA** parameter.*

For additional details:
https://docs.oracle.com/cloud/latest/db112/SUTIL/part_dp.htm
https://docs.oracle.com/database/121/SUTIL/GUID-501A9908-BCC5-434C-8853-9A6096766B5A.htm

Migration to: PostgreSQL pg_dump & pg_restore

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Overview
PostgreSQL provides native utilities - **pg_dump** and **pg_restore** can be used to perform logical database exports and imports with a degree of comparable functionality to the Oracle Data Pump utility. Such as for moving data between two databases and creating logical database backups.

- **pg_dump** equivalent to Oracle **expdp**
- **pg_restore** equivalent to Oracle **impdp**

Amazon Aurora PostgreSQL supports data export and import using both pg_dump and pg_restore, but the binaries for both utilities will need to be placed on your local workstation or on an Amazon EC2 server as part of the PostgreSQL client binaries.

PostgreSQL dump files created using pg_dump can be copied, after export, to an Amazon S3 bucket as cloud backup storage or for maintaining the desired backup retention policy. Later, when dump files are needed for database restore, the dump files should be copied back to the desktop/server that has a PostgreSQL client (such as your workstation or an Amazon EC2 server) to issue the pg_restore command.

Notes:
- **pg_dump** will create consistent backups even if the database is being used concurrently.
- **pg_dump** does not block other users accessing the database (readers or writers).
- **pg_dump** only exports a single database, in order to backup global objects that are common to all databases in a cluster, such as roles and tablespaces, use **pg_dumpall**.
- Unlike Data Pump, PostgreSQL dump files **are plain-text files**.

Examples

1. Export data using **`pg_dump`**:
   Use a workstation or server with the PostgreSQL client installed in order to connect to the Aurora PostgreSQL instance in AWS; providing the hostname (-h), database user name (-U) and database name (-d) while issuing the `pg_dump` command:

```
$ pg_dump -h hostname.rds.amazonaws.com -U username -d db_name
  -f dump_file_name.sql
```

Note:
The output file, `dump_file_name.sql`, will be stored on the server where the `pg_dump` command executed. You can later copy the outfile file to an S3 Bucket, if needed.

2. Run `pg_dump` and copy the backup file to an Amazon S3 bucket using pipe and the AWS CLI:

```
$ pg_dump -h hostname.rds.amazonaws.com -U username -d db_name
  -f dump_file_name.sql | aws s3 cp - s3://pg-backup/pg_bck-$(date
  "+%Y-%m-%d-%H-%M-%S")
```

3. Restore data - `pg_restore`:
   Use a workstation or server with the PostgreSQL client installed to connect to the Aurora PostgreSQL instance providing the hostname (-h), database user name (-U), database name (-d) and the dump file to restore from while issuing the `pg_restore` command:

```
$ pg_restore -h hostname.rds.amazonaws.com -U username -d
  dbname_restore dump_file_name.sql
```

4. Copy the output file from the local server to an Amazon S3 Bucket using the AWS CLI:

   Upload the dump file to S3 bucket:

```
$ aws s3 cp /usr/Exports/hr.dmp s3://my-bucket/backup-$(date "+%Y-
  %m-%d-%H-%M-%S")
```

   * *Note that the {-$(date "+%Y-%m-%d-%H-%M-%S")} format will work only on Linux servers.*

   Download the output file from S3 bucket:

```
$ aws s3 cp s3://my-bucket/backup-2017-09-10-01-10-10
  /usr/Exports/hr.dmp
```

Note:
You can create a copy of an existing database without having to use `pg_dump` or `pg_restore`. Instead, use the `template` keyword to signify the database used as the source:

```
psql> CREATE DATABASE mydb_copy TEPLATE mydb;
```

Oracle Data Pump vs. PostgreSQL pg_dump and pg_restore

Description	Oracle data pump	PostgreSQL SQL Dump
Export data to a local file	`expdp system/**** schemas=hr dumpfile=hr.dmp logfile=hr.log`	`pgdump -F c -h hostname.rds.amazonaws.com -U username -d hr -p 5432 > c:\Export\hr.dmp`

Export data to a remote file	• Create Oracle directory on remote storage mount or NFS directory called EXP_DIR
	
	• Use export command: `expdp system/**** schemas=hr directory=EXP_DIR dumpfile=hr.dmp logfile=hr.log`
		Export-
		`pgdump -F c -h hostname.rds.amazonaws.com -U username -d hr -p 5432 > c:\Export\hr.dmp`
		
		Upload to S3-
		`aws s3 cp c:\Export\hr.dmp s3://my-bucket/backup-$(date "+%Y-%m-%d-%H-%M-%S")`

Import data to a new database with a new name	`impdp system/**** schemas=hr dumpfile=hr.dmp logfile=hr.log REMAP_SCHEMA=hr:hr_copy TRANSFORM=OID:N`	`pg_restore -h hostname.rds.amazonaws.com` **`-U hr -d hr_restore`** `-p 5432 c:\Expor\hr.dmp`

For additional details:
https://www.postgresql.org/docs/current/static/backup-dump.html
https://www.postgresql.org/docs/9.6/static/app-pgrestore.html

Migrating from: Oracle Resource Manager
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Overview
Oracle's Resource Manager enables enhanced management of multiple concurrent workloads running under a single Oracle database. Using Oracle Resource Manager, you can partition server resources for different workloads. Resource Manager helps with sharing server and database resources without causing excessive resource contention and helps to eliminate scenarios involving inappropriate allocation of resources across different database sessions.

Oracle Resource Manager enables you to:

- Guarantee a minimum amount of CPU cycles for certain sessions regardless of other running operations.
- Distribute available CPU by allocating percentages of CPU time to different session groups.
- Limit the degree of parallelism of any operation performed by members of a user group.
- Manage the order of parallel statements in the parallel statement queue.
- Limit the number of parallel execution servers that a user group can use.
- Create an active session pool. An active session pool consists of a specified maximum number of user sessions allowed to be concurrently active within a user group.
- Monitor used database/server resources by dictionary views.
- Manage runaway sessions or calls and prevent them from overloading the database.
- Prevent the execution of operations that the optimizer estimates will run for a longer time than a specified limit.
- Limit the amount of time that a session can be connected but idle, thus forcing inactive sessions to disconnect and potentially freeing memory resources.
- Allow a database to use different resource plans, based on changing workload requirements
- Manage CPU allocation when there is more than one instance on a server in an Oracle Real Application Cluster environment (also called instance caging).

Oracle Resource Manager introduces three concepts:

Consumer Group – A collection of sessions grouped together based on resource requirements. The Oracle Resource Manager allocates server resources to resource consumer groups, not to the individual sessions.
Resource Plan – Specifies how the database allocates its resources to different Consumer Groups. You will need to specify how the database allocates resources by activating a specific resource plan.
Resource Plan Directive – Associates a resource consumer group with a plan and specifies how resources are to be allocated to that resource consumer group.

Notes:
- Only one Resource Plan can be active at any given time.
- Resource Directives control the resources allocated to a Consumer Group belong to a Resource Plan
- The Resource Plan can refer to Subplans to create even more complex Resource Plans.

Example

Creating a Simple Resource Plan

1. To enable the Oracle Resource Manager, you need to assign a plan name to the RESOURCE_MANAGER_PLAN parameter. Using an empty string will disable the Resource Manager.

```
ALTER SYSTEM SET RESOURCE_MANAGER_PLAN = 'mydb_plan';

ALTER SYSTEM SET RESOURCE_MANAGER_PLAN = '';
```

Example

We can also create complex Resource Plans. A complex Resource Plan is one that is not created with the CREATE_SIMPLE_PLAN PL/SQL procedure and provides more flexibility and granularity.

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

For additional details:
https://docs.oracle.com/database/121/ADMIN/dbrm.htm#ADMIN027

Migration to: Dedicated Amazon Aurora Clusters

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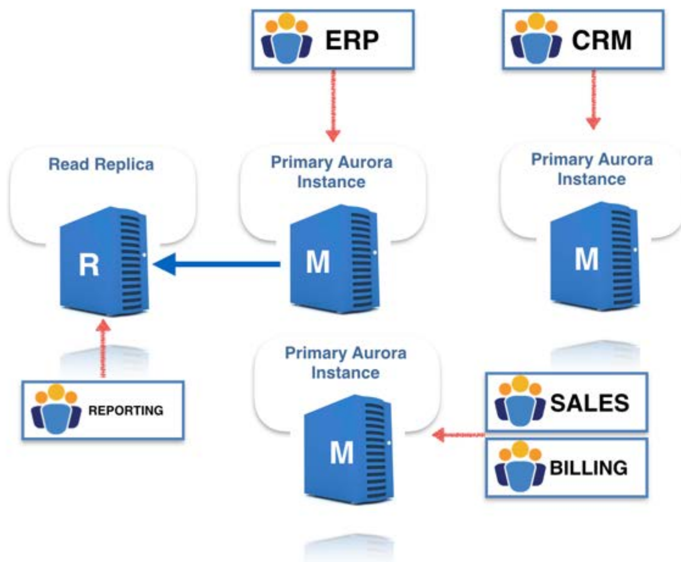
Overview

PostgreSQL does not have built-in resource management capabilities that are equivalent to the functionality provided by Oracle Resource Manager. However, due to the elasticity and flexibility provided by "cloud economics", workarounds could be applicable and such capabilities might not be as of similar importance to monolithic on-premises databases.

The Oracle Resource Manager primarily exists because traditionally, Oracle databases were installed on very powerful monolithic servers that powered multiple applications simultaneously. The monolithic model made the most sense in an environment where the licensing for the Oracle database was per-CPU and where Oracle databases were deployed on physical hardware. In these scenarios, it made sense to consolidate as many workloads as possible into few servers. In cloud databases, the strict requirement to maximize the usage of each individual "server" is often not as important and a different approach can be employed:

Individual Amazon Aurora clusters can be deployed, with varying sizes, each dedicated to a specific application or workload. Additional read-only Aurora Replica servers can be used to offload any reporting-style workloads from the master instance.

The traditional Oracle model where maximizing the usage of each physical Oracle server was essential due to physical hardware constraints and the per-CPU core licensing model.



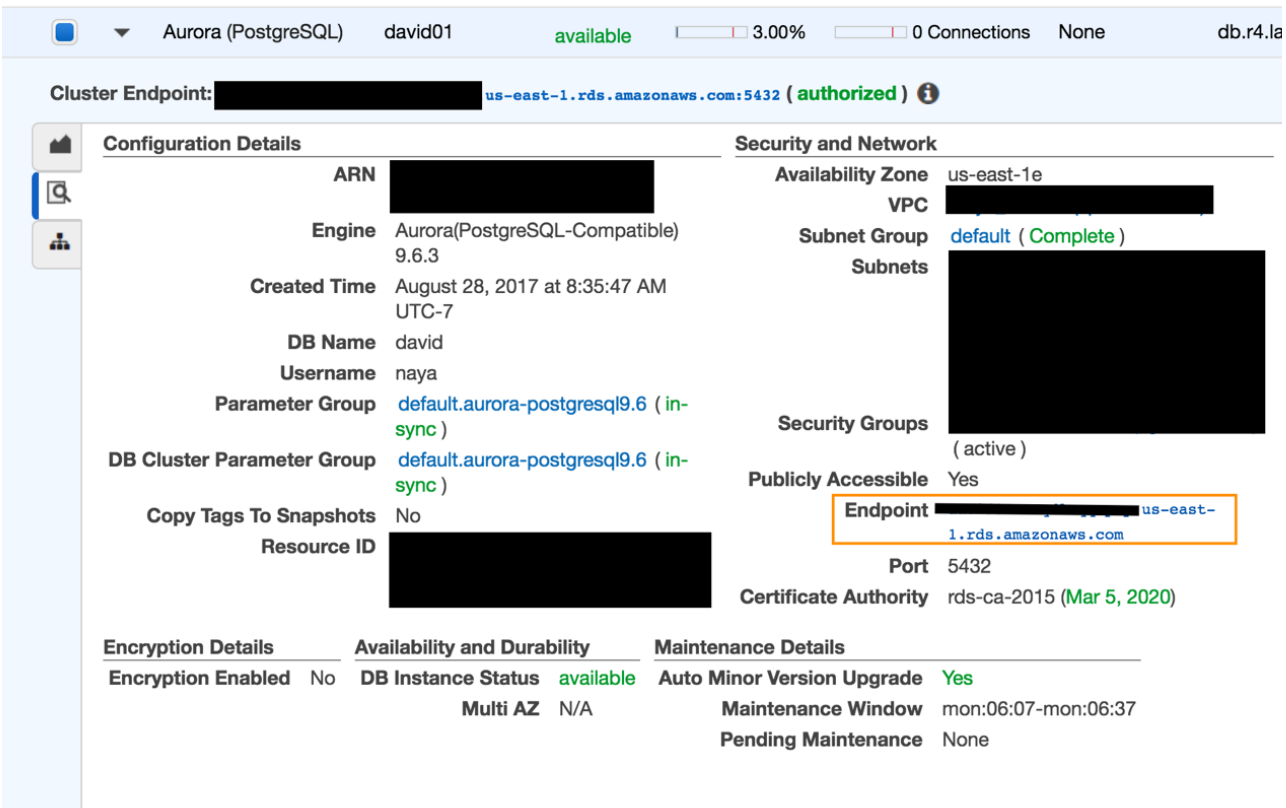
With Amazon Aurora, separate and dedicated database clusters can be deployed, each dedicated to a specific application/workload creating isolation between multiple connected sessions and applications.

Each Amazon Aurora instance (Primary/Replica) can scaled independently in terms of CPU and memory resources using the different “instance types”. Because multiple Amazon Aurora Instances can be instantly deployed and much less overhead is associated with the deployment and management of Aurora instances when compared to physical servers, separating different workloads to different instance classes could be a suitable solution for controlling resource management.

Instance Type	vCPU	Memory (GiB)	PIOPS-Optimized	Network Performance
Standard				
db.m4.large	2	8	Yes	Moderate
db.m4.xlarge	4	16	Yes	High
db.m4.2xlarge	8	32	Yes	High
db.m4.4xlarge	16	64	Yes	High
db.m4.10xlarge	40	160	Yes	10 Gigabit
db.m3.medium	1	3.75	-	Moderate
db.m3.large	2	7.5	-	Moderate
db.m3.xlarge	4	15	Yes	High
db.m3.2xlarge	8	30	Yes	High
Memory Optimized				
db.r3.large	2	15	-	Moderate
db.r3.xlarge	4	30.5	Yes	Moderate
db.r3.2xlarge	8	61	Yes	High
db.r3.4xlarge	16	122	Yes	High
db.r3.8xlarge	32	244	-	10 Gigabit
Micro instances				
db.t2.micro	1	1	-	Low
db.t2.small	1	2	-	Low

db.t2.medium	2	4	-	Moderate
db.t2.large	2	8	-	Moderate

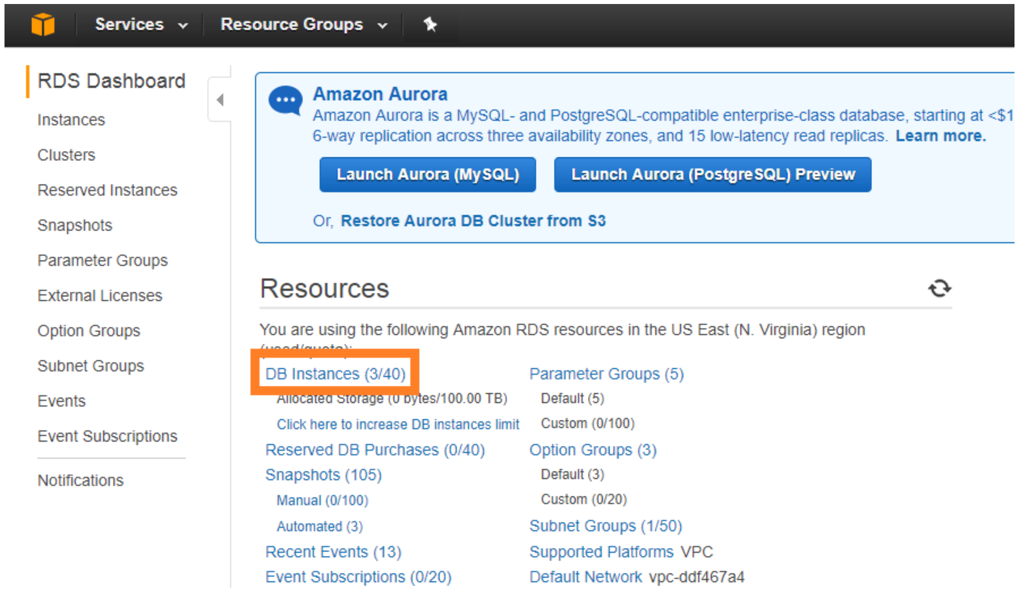
In addition, each Amazon Aurora primary/replica instance can also be directly accessed from your applications using its own endpoint. This capability is especially useful if you have multiple Aurora read-replicas for a given cluster and you wish to utilize different Aurora replicas to segment your workload.



Example

Suppose that you were using a single Oracle Database for multiple separate applications and used Oracle Resource Manager to enforce a workload separation, allocating a specific amount of server resources for each application. With Amazon Aurora, you might want to create multiple separate databases for each individual application. Adding additional replica instances to an existing Amazon Aurora cluster is easy.

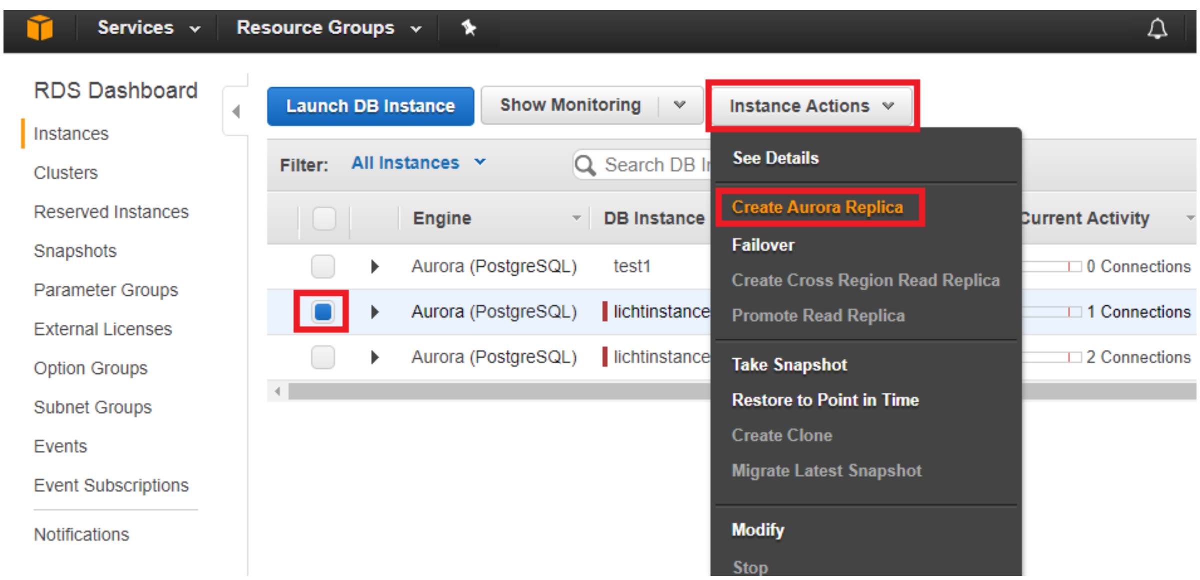
1. In the AWS Management Console, select the **Amazon RDS service** and click the **DB Instances** link from the Resources section of the RDS Dashboard window (highlighted).



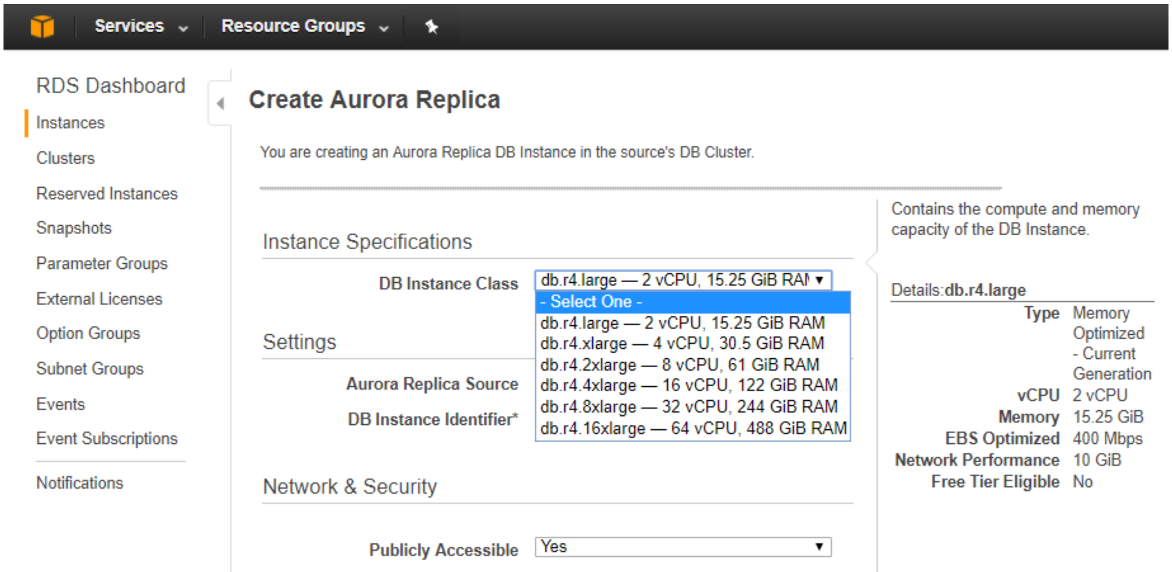
2. Select the Amazon Aurora cluster that you want to scale-out by adding an additional read Replica.

3. Click on the **Instance Actions** button.

4. Select **Create Aurora Replica**.



5. Select the instance class depending on the amount of compute resources your application requires.



6. Once completed, click **Create Aurora Replica.**

Oracle Resource Manager vs. Dedicated Aurora PostgreSQL Instances

Oracle Resource Manager	Amazon Aurora Instances
Set the maximum CPU usage for a resource group	Create a dedicated Aurora Instance for a specific application.
Limit the degree of parallelism for specific queries	`SET max_parallel_workers_per_gather TO x;` *Setting the PostgreSQL `max_parallel_workers_per_gather` parameter should be done as part of your application database connection.*
Limit parallel execution	`SET max_parallel_workers_per_gather TO 0;`

Limit the number of active sessions	Manually detect the number of connections that are open from a specific application and restrict connectivity either via database procedures or within the application DAL itself.
	
	`select pid from pg_stat_activity where usename in(`
	`select usename from pg_stat_activity where state = 'active'  group by usename having count(*) > 10) and state = 'active'`
	`order by query_Start;`

Restrict maximum runtime of queries	Manually terminate sessions that exceed the required threshold. You can detect the length of running queries using SQL commands and restrict max execution duration using either

Oracle Resource Manager	Amazon Aurora Instances

	database procedures or within the application DAL itself.
	
	`SELECT pg_terminate_backend(pid)`
	`FROM pg_stat_activity`
	`WHERE now()-pg_stat_activity.query_start >`
	`interval '5 minutes';`

Limit the maximum idle time for sessions	Manually terminate sessions that exceed the required threshold. You can detect the length of your idle sessions using SQL queries and restrict maximum execution using either database procedures or within the application DAL itself.
	
	`SELECT pg_terminate_backend(pid)`
	`    FROM pg_stat_activity`
	`    WHERE datname = 'regress'`
	`      AND pid <> pg_backend_pid()`
	`      AND state = 'idle'`
	`      AND state_change < current_timestamp -`
	`INTERVAL '5' MINUTE;`

Limit the time that an idle session holding open locks can block other sessions	Manually terminate sessions that exceed the required threshold. You can detect the length of blocking idle sessions using SQL queries and restrict max execution duration using either database procedures or within the application DAL itself.
	
	`SELECT`
	`pg_terminate_backend(blocking_locks.pid)`
	`FROM pg_catalog.pg_locks AS blocked_locks`
	`JOIN pg_catalog.pg_stat_activity AS`
	`blocked_activity`
	`    ON blocked_activity.pid =`
	`blocked_locks.pid`
	`JOIN pg_catalog.pg_locks AS blocking_locks`
	`    ON blocking_locks.locktype =`
	`blocked_locks.locktype`
	`        AND blocking_locks.DATABASE IS NOT`
	`DISTINCT FROM blocked_locks.DATABASE`
	`        AND blocking_locks.relation IS NOT`
	`DISTINCT FROM blocked_locks.relation`
	`        AND blocking_locks.page IS NOT`
	`DISTINCT FROM blocked_locks.page`
	`        AND blocking_locks.tuple IS NOT`
	`DISTINCT FROM blocked_locks.tuple`
	`        AND blocking_locks.virtualxid IS NOT`
	`DISTINCT FROM blocked_locks.virtualxid`
	`        AND blocking_locks.transactionid IS`
	`NOT DISTINCT FROM`
	`blocked_locks.transactionid`
	`        AND blocking_locks.classid IS NOT`
	`DISTINCT FROM blocked_locks.classid`

Oracle Resource Manager	Amazon Aurora Instances

	`AND blocking_locks.objid IS NOT DISTINCT FROM blocked_locks.objid`
	`AND blocking_locks.objsubid IS NOT DISTINCT FROM blocked_locks.objsubid`
	`AND blocking_locks.pid != blocked_locks.pid`
	`JOIN pg_catalog.pg_stat_activity AS blocking_activity`
	`ON blocking_activity.pid = blocking_locks.pid`
	`WHERE NOT blocked_locks.granted and blocked_activity.state_change < current_timestamp - INTERVAL '5' minute;`

Use "instance caging" in a multi-node Oracle RAC Environment	Similar capabilities can be achieved by separating different applications to different Aurora clusters or, for read-only workloads, separate Aurora read replicas within the same Aurora cluster.

For additional detail:
https://www.postgresql.org/docs/9.6/static/runtime-config-resource.html

Migrating from: Oracle Database Users

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Overview

Database user accounts are used for authenticating connecting sessions as well as authorizing access for individual users to specific database objects. The Database Administrator grants privileges to database user accounts that are used by applications to authenticate with the Oracle database.

Steps for Providing Database Access to Applications

1. Create a user account in the database, typically authenticated by using a password. Additional methods of authenticating users also exist.
2. Assign permissions to the database user account enabling access certain database objects and system permissions.
3. Connecting applications will use the database username and password combination to authenticate with the database.

Oracle Database Users Common Properties

1. Granting privileges or roles (collection of privileges) to the database user.
2. Defining the default database tablespace for the user.
3. Assigning tablespace quotas for the database user.
4. Configuring password policy, password complexity, lock or unlock the account.

Authentication Mechanisms

1. Username and password combination (default).
2. External - using OS or third-party (Kerberos).
3. Global - enterprise directory service (such as Active Directory or Oracle Internet Directory).

Oracle Schemas Compared to Users

In the Oracle database, a user equals a schema. This relationship is special because in Oracle, users and schemas are essentially the same thing. Consider an Oracle database user as the account you use to connect to a database while a database schema is the set of objects (tables, views, etc.) that belong to that account.

- You cannot create schemas and users separately. When you create a database user, you also create a database schema with the same name.
- When you run the CREATE USER command in Oracle, you create a user for login and a schema to store database objects in.
- The schema created will be initially empty, but objects, such tables, can be created inside it.

Database Users in Oracle 12c

Two kinds of users exist in the Oracle 12c database:

- Common users - created in all database containers, root and PDBs. Common user must have the C## prefix in the username.
- Local users – created only in a specific PDB. Different database users with identical usernames can be created in multiple PDBs.

Examples

1. Create a *common* database user, using the default tablespace.
2. Grant privileges and roles to the user.
3. Assign a profile to the user, unlock the account and force the user to change the password (`PASSWORD EXPIRE`).
4. Create a *local* database user in the `my_pdb1` pluggable database.

```
CREATE USER c##test_user IDENTIFIED BY password DEFAULT TABLESPACE
USERS;

GRANT CREATE SESSION TO c##test_user;

GRANT RESOURCE TO c##test_user;

ALTER USER c##test_user ACCOUNT UNLOCK;

ALTER USER c##test_user PASSWORD EXPIRE;

ALTER USER c##test_user PROFILE ORA_STIG_PROFILE;

ALTER SESSION SET CONTAINER = my_pdb1;
CREATE USER app_user1 IDENTIFIED BY password DEFAULT TABLESPACE USERS;
```

For additional details:
https://docs.oracle.com/database/121/DBSEG/users.htm

Migration to: PostgreSQL Roles

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Overview

In a PostgreSQL database, users and roles are identical. Roles with *connect permissions* are essentially database users.

- A role is a database entity that can own objects and have database privileges.
- A role can be considered a "user", a "group", or both depending on how it is used.
- Roles are defined at the root level and are valid in all databases in the Amazon Aurora cluster. In terms of database scope, roles in PostgreSQL can be compared to *common users* in Oracle 12c as they are global for all the databases and are not created in the individual scope of a specific database.
- Schemas are created separately from roles/users in PostgreSQL.

Oracle	**PostgreSQL**
Common database user (12c)	Database role ***with*** **Login**
Local database user (12c)	N/A
Database user (11g)	Database role ***with*** **Login**
Database role	Database role ***without*** **Login**
Database users are identical to schema	Database users and schemas are created separately

The `CREATE USER` command in PostgreSQL is an alias for the `CREATE ROLE` command with one important difference: the `CREATE USER` command it automatically adds the `LOGIN` argument so that the role can access the database and act as a “database user”.

Examples

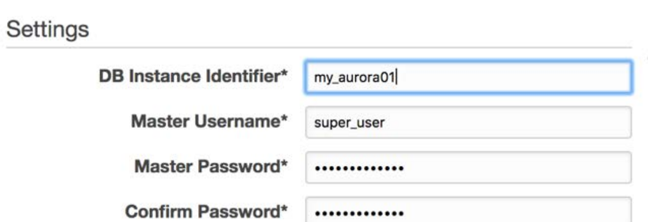
1. Create a role that can log-in to the database and specify a password:

```
CREATE USER test_user1 WITH PASSWORD 'password';

CREATE ROLE test user2 WITH LOGIN PASSWORD 'password';
```

Notes

- `CREATE USER` is identical to `CREATE ROLE`, except that it implies a log-in to the database.
- When we provision a new Amazon Aurora cluster, a master user is created as the most powerful user in the database:



2. Create a role that can log in to the database and assign a password that has an expiration date:

```
CREATE ROLE test_user3 WITH LOGIN PASSWORD 'password' VALID UNTIL
'2018-01-01';
```

3. Create a powerful role `db_admin` that will allow users to which this role is assigned to create new databases. Note that this role will not be able to log in to the database. Assign this role to the `test_user1` database user.

```
CREATE ROLE db_admin WITH CREATEDB;

GRANT db_admin TO test_user1;
```

4. Create a new schema `hello_world` and create a new table inside that schema:

```
CREATE SCHEMA hello_world;

CREATE TABLE hello_world.test_table1 (a int);
```

Oracle vs. PostgreSQL Database Users

Description	Oracle	Amazon Aurora PostgreSQL
List all database users	`SELECT * FROM dba_users;`	`SELECT * FROM pg_user;`
Create a database user	`CREATE USER c##test_user IDENTIFIED BY test_user;`	`CREATE ROLE test_user WITH LOGIN PASSWORD 'test_user';`
Change the password for a database user	`ALTER USER c##test_user IDENTIFIED BY test_user;`	`ALTER ROLE test_user WITH LOGIN PASSWORD 'test_user';`
External authentication	Supported via Externally Identified Users	Currently not supported; future support for AWS Identity and Access Management (IAM) users is possible
Tablespace quotas	`Alter User c##test_user QUOTA UNLIMITED ON TABLESPACE users;`	Not supported
Grant role to user	`GRANT my_role TO c##test_user;`	`GRANT my_role TO test_user;`
Lock user	`ALTER USER c##test_user ACCOUNT LOCK;`	`ALTER ROLE test_user WITH NOLOGIN;`
Unlock user	`ALTER USER c##test_user ACCOUNT UNLOCK;`	`ALTER ROLE test_user WITH LOGIN;`
Grant privileges	`GRANT CREATE TABLE TO c##test_user;`	`GRANT create ON DATABASE postgres to test_user;`
Default tablespace	`ALTER USER C##test_user default tablespace users;`	`ALTER ROLE test_user SET default_tablespace = 'pg_global';`
Grant select privilege on a table	`GRANT SELECT ON hr.employees to c##test_user;`	`GRANT SELECT ON hr.employees to test_user;`
Grant DML privileges on a table	`GRANT INSERT,DELETE ON hr.employees to c##test_user;`	`GRANT INSERT,DELETE ON hr.employees to test_user;`
Grant execute	`GRANT EXECUTE ON hr.procedure_name to c##test_user;`	`grant execute on function "newdate"() to test_user;` *Inside the brackets "()" - specify the arguments types for the function*
Limits user connection	`CREATE PROFILE app_users LIMIT SESSIONS_PER_USER 5;`	`ALTER ROLE test_user WITH CONNECTION LIMIT 5;`

	`ALTER USER C##TEST_USER PROFILE app_users;`	
Create a new database schema	`CREATE USER my_app_schema IDENTIFIED BY password;`	`CREATE SCHEMA my_app_schema;`

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createrole.html

Migrating from: Oracle SGA & PGA Memory Sizing

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Overview

The Oracle instance allocates several individual "pools" of server RAM used as various caches for the database. These include the Buffer Cache, Redo Buffer, Java Pool, Shared Pool, Large Pool and others. These caches are contained in the SGA, or System Global Area. These caches are shared across all Oracle sessions.

In addition to the SGA, each connecting Oracle session is granted an additional area of memory used for session-private operations (sorting, private SQL cursors elements, etc.) called PGA, or Private Global Area.

The size of the various caches is controlled via parameters, either individually on per-cache level or managed as a whole automatically by the Oracle database by setting a unified "memory size" parameter and allowing Oracle to take care of individual cache sizes.

- All Oracle memory parameters are set using an `ALTER SYSTEM` command.
- Some changes to memory parameters may require an instance restart.

Some of the common Oracle parameters that control memory allocations include:

- **`db_cache_size`** – size of the cache used for database data.
- **`log_buffer`** – cache used to store Oracle redo log buffers, until written to disk.
- **`shared_pool_size`** – cache used to store shared cursors, stored procedures, control structures, and other structures.
- **`large_pool_size`** – cached used for parallel queries and RMAN backup / restore operations.
- **`Java_pool_size`** – cached used to store Java code and JVM context.

While these parameters can be configured individually, most Database Administrators choose to let Oracle automatically manage available RAM. The Database Administrator configures the size of the overall size of the SGA only, and Oracle sizes individual caches based on workload characteristics.

- **`sga_max_size`** – specify the hard-limit, maximum size of the SGA as a whole.
- **`sga_target`** – sets the required soft-limit for the SGA and within it, the individual caches.

Oracle also grants control over how much private memory is dedicated for each connecting session. The Database Administrator will configure the total size of memory available for all connecting sessions, and Oracle will allocate individual dedicated "chunks" from the total amount of available memory for each session.

- **`pga_aggregate_target`** – a soft-limit controlling the total amount of memory available for all sessions, combined.
- **`pga_aggregate_limit`** – **(Oracle 12c only)** a hard-limit for the total amount of memory available for all sessions, combined.

In addition, instead of manually configuring the SGA and PGA memory areas, we can also configure one overall memory limit for *both* the SGA and PGA and let Oracle automatically balance memory between the various memory pools. This behavior can be enabled using the **`memory_target`** and **`memory_max_target`** parameters.

For additional details:
https://docs.oracle.com/database/121/ADMIN/memory.htm#ADMIN11198
https://docs.oracle.com/database/121/TGDBA/memory.htm

Migration to: PostgreSQL Memory Buffers

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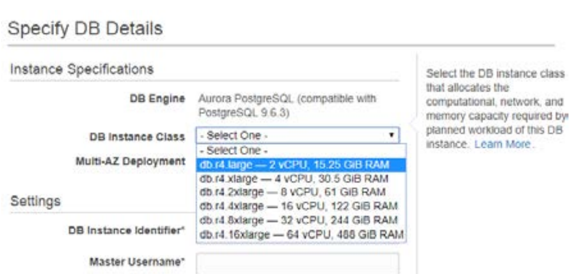
Overview

PostgreSQL provides us with control over how server RAM is allocated. Some of the most important PostgreSQL memory parameters include:

Memory Pool	Description
`shared_buffers`	Used to cache database data read from disk. *Approximate Oracle Database Buffer Cache equivalent.*
`wal_buffers`	Used to store WAL (Write-Ahead-Log) records before they are written to disk. *Approximate Oracle Redo Log Buffer equivalent.*
`work_mem`	Used for parallel queries and SQL sort operations. *Approximate Oracle PGA equivalent and/or the Large Pool (for parallel workloads)*
`maintenance_work_mem`	Memory used for certain backend database operations such as: `VACUUM, CREATE INDEX, ALTER TABLE ADD FOREIGN KEY`
`temp_buffers`	Memory buffers used by each database session for reading data from temporary tables.
Total memory available for PostgreSQL Cluster	Controlled by choosing the "DB Instance Class" during instance creation: 

Notes:

Cluster level parameters, such as `shared_buffers` and `wal_buffers`, are configured using "parameter groups" in the Amazon RDS Management Console.

Examples

1. View the configured value for database parameters:

```
show shared_buffers

show work_mem

show temp_buffers
```

2. View current configured values for all database parameters:

```
Select * from pg_settings;
```

3. Use of the SET SESSION command to modify the value of parameters that support session-specific settings. Changing the value using the SET SESSION command for one session will have no effect on other sessions.

```
SET SESSION work_mem='100MB';
```

Note
If a SET SESSION command is issued within a transaction that is aborted or rolled back, the effects of the SET SESSION command disappear. Once the transaction is committed, the effects will become persistent until the end of the session, unless overridden by another execution of SET SESSION.

4. Use of the SET LOCAL command to modify the current value of those parameters that can be set locally to a single transaction. Changing the value using the SET LOCAL command for one transaction will have no subsequent effect on other transactions from the same session. After issuing a COMMIT or ROLLBACK, the session-level settings will take effect.

```
SET LOCAL work_mem='100MB';
```

5. Reset a value of a run-time parameter to its default value:

```
RESET work_mem;
```

6. Changing parameter values can also be done via a direct update to the pg_settings table:

```
UPDATE pg_settings SET setting = '100MB' WHERE name = 'work_mem';
```

Common Oracle vs. PostgreSQL Memory Caches

Please note that the table provided below should be used as a general reference only and functionality might not be identical across Oracle and PostgreSQL.

Description	Oracle	PostgreSQL
Memory for caching table data	`db_cache_size`	`shared_buffers`
Memory for transaction log records	`log_buffer`	`wal_buffers`
Memory for parallel queries	`large_pool_size`	`work_mem`
Java code and JVM	`Java_pool_size`	N/A

Maximum amount of physical memory available for the Instance	`sga_max_size`
	or
	`memory_max_size`
		Configured via the Amazon RDS/Aurora Instance class
		
		For example:
		`db.r3.large: 15.25GB`
		`db.r3.xlarge: 30.5GB`
		Etc.

Total amount of private memory for all sessions	`pga_aggregate_target`
	+
	`pga_aggregate_limit`
		`temp_buffers`
		(for reading data from temp tables)
		
		`work_mem`
		(for sorts)

View values for all database parameters	`Select * from v$parameter;`	`Select * from pg_settings;`
Configure a session-level parameter	`ALTER SESSION SET ...`	`SET SESSION work_mem='100MB';`
Configure instance-level parameter	`ALTER SYSTEM SET ...`	Configured via “Parameter Groups” in the Amazon RDS Management Console.

For additional details:
https://www.postgresql.org/docs/current/static/runtime-config-resource.html
https://www.postgresql.org/docs/current/static/runtime-config-wal.html

Migrating from: Oracle Roles

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Overview

Oracle roles are groups of privileges that can be granted to database users. A database role can contain individual system and object permissions as well as other roles. Database roles enable you to grant multiple database privileges to users in one go. It is convenient to group permissions together to ease the management of privileges.

Oracle 12c introduces a new multi-tenant database architecture that supports the creation of both *common* as well as *local* roles:

1. **Common roles** – these are roles created at the container database (CDB) level. A common role is a database role that exists in the root and in every existing, and future, pluggable database (PDB) that will be created. Common roles are useful for cross-container operations, such as ensuring that a common user has a role in every container.

2. **Local roles** – these are roles created in a specific pluggable database (PDB). A local role exists only in a single pluggable database and can only contain roles and privileges that apply within the pluggable database in which the role exists.

Notes:

- Common role names must start with a `C##` prefix. Starting with Oracle 12.1.0.2, these prefixes can be change using the `COMMON_USER_PREFIX` parameter.
- A `CONTAINER` clause can be added to `CREATE ROLE` statement to choose the container applicable for the role.

Examples

1. Create a common role:

```
SQL> show con_name

CON_NAME
------------------------------
CDB$ROOT
SQL> CREATE ROLE c##common_role;

Role created.
```

2. Create a local role:

```
SQL> show con_name

CON_NAME
------------------------------
ORCLPDB


SQL> CREATE ROLE local_role;

Role created.
```

3. Grant privileges and roles to the `local_role` database role.

```
GRANT RESOURCE, ALTER SYSTEM, SELECT ANY DICTIONARY TO local_role;
```

   Any database user to which the `local_role` role will be granted, will now hold all privileges that were granted to the role.

4. Revoke privileges and roles from the `local_role` database role:

```
REVOKE RESOURCE, ALTER SYSTEM, SELECT ANY DICTIONARY FROM local_role;
```

For additional details:
https://docs.oracle.com/database/121/DBSEG/authorization.htm
https://docs.oracle.com/database/121/DBSEG/authorization.htm

Migration to: PostgreSQL Roles

[Back to TOC]

Overview

In PostgreSQL, roles *without login permissions* are similar to database roles in Oracle. PostgreSQL roles are most similar to common roles in Oracle 12c as they are global in scope for all the databases in the instance.

- Roles are defined at the database cluster level and are valid in all databases in the PostgreSQL cluster. In terms of database scope, roles in PostgreSQL can be compared to *common roles* in Oracle 12c as they are global for all the databases and are not created in the individual scope of each database.
- The `CREATE USER` command in PostgreSQL is an alias for the `CREATE ROLE` command with one important difference: when using `CREATE USER` command, it automatically adds `LOGIN` so the role can access to the database as a "database user". As such, for creating PostgreSQL roles that are similar in function to Oracle roles, be sure to use the `CREATE ROLE` command.

Example

Create a new database role called `myrole1` that will allow users (to which the role is assigned) to create new databases in the PostgreSQL cluster. Note that this role will not be able to login to the database and act as a "database user". In addition, grant `SELECT`, `INSERT` and `DELETE` privileges on the `hr.employees` table to the role:

```
CREATE ROLE hr_role;

GRANT SELECT, INSERT,DELETE on hr.employees to hr_role;
```

Typically, a role being used as a group of permissions would not have the `LOGIN` attribute, as with the example above.

Comparing Oracle to PostgreSQL database roles

Description	Oracle	PostgreSQL
List all roles	`SELECT * FROM dba_roles;`	`SELECT * FROM pg_roles;`

Create a new role	`CREATE ROLE c##common_role;`
	Or
	`CREATE ROLE local_role1;`
		`CREATE ROLE test_role;`

Grant one role privilege to another database role	`GRANT local_role1 TO local_role2;`	`grant myrole1 to myrole2;`
Grant privileges on a database object to a database role	`GRANT CREATE TABLE TO local_role;`	`GRANT create ON DATABASE postgresdb to test_user;`
Grant DML permissions on a database object to a role	`GRANT INSERT, DELETE ON hr.employees to myrole1;`	`GRANT INSERT, DELETE ON hr.employees to myrole1;`

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-createrole.html

Migrating from: Oracle V$ Views and the Data Dictionary

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Overview

Oracle provides several built-in views that are used to monitor the database and query its operational state. These views can be used to track the status of the database, view information about database schema objects and more.

The *data dictionary* is a collection of internal tables and views that supply information about the state and operations of the Oracle database including: database status, database schema objects (tables, views, sequences, etc.), users and security, physical database structure (datafiles), and more. The contents of the data dictionary are persistent to disk.

Examples for data dictionary views include:

- **DBA_TABLES –** information about all of the tables in the current database.
- **DBA_USERES –** information about all the database users.
- **DBA_DATA_FILES –** information about all of the physical datafiles in the database.
- **DBA_TABLESPACES –** information about all tablespaces in the database.
- **DBA_TABLES –** information about all tables in the database.
- **DBA_TAB_COLS –** information about all columns, for all tables, in the database.

Note: data dictionary view names can start with DBA_*, ALL_*, USER_* , depending on the level and scope of information presented (user-level versus database-level).

> *For the complete list of dba_* data dictionary views:*
> https://docs.oracle.com/database/121/nav/catalog_views-dba.htm

Dynamic performance views (V$ Views) are a collection of views that provide real-time monitoring information about the current state of the database instance configuration, runtime statistics and operations. These views are continuously updated while the database is running.
Information provided by the dynamic performance views includes session information, memory usage, progress of jobs and tasks, SQL execution state and statistics and various other metrics.

Common dynamic performance views include:

- **V$SESSION** – information about all current connected sessions in the instance.
- **V$LOCKED_OBJECT** – information about all objects in the instance on which active "locks" exist.
- **V$INSTANCE** – dynamic instance properties.
- **V$SESSION_LONG_OPS** – information about certain "long running" operations in the database such as queries currently executing.
- **V$MEMORY_TARGET_ADVICE** – advisory view on how to size the instance memory, based on instance activity and past workloads.

For additional details:
https://docs.oracle.com/database/121/nav/catalog_views.htm

Migration to: PostgreSQL System Catalog & The Statistics Collector

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Overview

PostgreSQL provides three different sets of metadata tables that are used to retrieve information about the state of the database and current activities. These tables are similar in nature to the Oracle data dictionary tables and V$ performance views. In addition, Amazon Aurora PostgreSQL provides a "Performance Insights" console for monitoring and analyzing database workloads and troubleshooting performance issues.

Category	Description
Statistic collection views	Subsystem that collects runtime dynamic information about certain server activities such as statistical performance information. *Some of these tables could be thought as comparable to Oracle V$ views.*
System catalog tables	Static metadata regarding the PostgreSQL database and static information about schema objects. *Some of these tables could be thought as comparable to Oracle DBA_* Data Dictionary tables.*
Information schema tables	Set of views that contain information about the objects defined in the current database. The information schema is specified by the SQL standard and as such, supported by PostgreSQL. *Some of these tables could be thought as comparable to Oracle USER_* Data Dictionary tables.*
Advance performance monitoring	Use the Performance Insights Console

2. **System Catalog Tables**

   These are a set of tables used to store dynamic and static metadata for the PostgreSQL database and can be thought of as the "data dictionary" for the database. These tables are used for internal "bookkeeping"-type activities. All System catalog tables start with the `pg_*` prefix and can be found in the `pg_catalog` schema. Both system catalog tables and statistics collector views can be found on the `pg_catalog` schema

Example

Display all tables in the `pg_catalog` schema:

```
select * from pg_tables where schemaname='pg_catalog';
```

Some of the common system catalog tables include:

Table name	Purpose
`pg_database`	Contains information and properties about each database in the PostgreSQL cluster, such as the database encoding settings as well as others.
`pg_tables`	Information about all tables in the database, such as indexes and the tablespace for each database table.
`pg_index`	Contains information about all indexes in the database
`pg_cursors`	List of currently available/open cursors

For additional details:
https://docs.oracle.com/database/121/nav/catalog_views.htm
https://www.postgresql.org/docs/current/static/catalogs.html

3. **Statistics Collector**
Special subsystem which collects runtime dynamic information about the current activities in the database instance. For example, statistics collector views are useful to determine how frequently a particular table is accessed and if the table is scanned or accessed using an index.

```
SELECT * FROM pg_stat_activity WHERE STATE = 'active';
```

Common statistics collector views include:

Table name	Purpose
pg_stat_activity	Statistics of currently sessions in the database. Useful for identifying long running queries
pg_stat_all_tables	Performance statistics on all tables in the database, such as identifying table size, write activity, full scans vs. index access, etc.
pg_statio_all_tables	Performance statistics and I/O metrics on all database tables
pg_stat_database	One row for each database showing database-wide statistics such as blocks read from the buffer cache vs. blocks read from disk (buffer cache hit ratio).
pg_stat_bgwriter	Important performance information on PostgreSQL checkpoints and background writes
pg_stat_all_indexes	Performance and usage statistics on indexes, for example, useful for identifying unused indexes

For additional details:
https://docs.oracle.com/database/121/nav/catalog_views.htm
https://www.postgresql.org/docs/9.6/static/monitoring-stats.html#MONITORING-STATS-DYNAMIC-VIEWS-TABLE

4. **Information Schema Tables**
The information schema consists of views which contain information about objects that were created in the current database.
    - The information schema is specified by the SQL standard and as such, supported by PostgreSQL.
    - The owner of this schema is the initial database user.
    - Since the information schema is defined as part of the SQL standard, it can be expected to remain stable across PostgreSQL versions. This is unlike the system catalog tables, which are specific to PostgreSQL, and subject to changes across different PostgreSQL versions.
    - The information schema views do not display information about PostgreSQL-specific features.

```
select * from information_schema.tables;
```

For additional details:
https://www.postgresql.org/docs/9.6/static/information-schema.html

Note
By default, all database users (*public*) can query both the system catalog tables, the statistics collector views and the information schema.

Common Oracle vs. PostgreSQL system metadata tables

Information	Oracle	PostgreSQL
Database properties	V$DATABASE	PG_DATABASE
Database sessions	V$SESSION	PG_STAT_ACTIVITY
Database users	DBA_USERS	PG_USER
Database tables	DBA_TABLES	PG_TABLES
Database roles	DBA_ROLES	PG_ROLES
Table columns	DBA_TAB_COLS	PG_ATTRIBUTE
Database locks	V$LOCKED_OBJECT	PG_LOCKS
Currently configured runtime parameters	V$PARAMETER	PG_SETTINGS
All system statistics	V$SYSSTAT	PG_STAT_DATABASE
Privileges on tables	DBA_TAB_PRIVS	TABLE_PRIVILEGES
Information about IO operations	V$SEGSTAT	PG_STATIO_ALL_TABLES

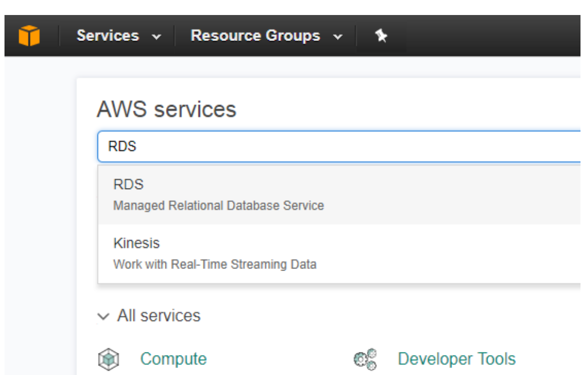
5. Amazon RDS performance Insights

In addition to monitoring database status and activity using queries on metadata tables, Aurora PostgreSQL provides a visual performance monitoring and status information via the "*Performance Insights*" feature accessible as part of the Amazon RDS Management Console.

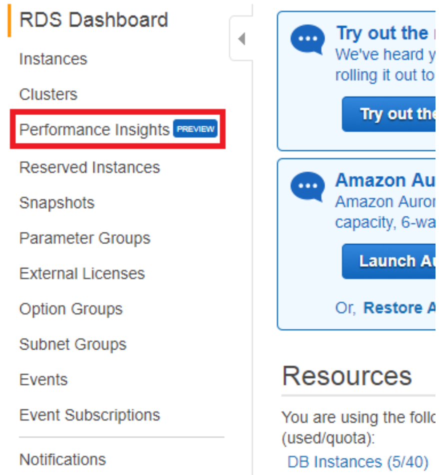
Performance insights monitors your Amazon RDS/Aurora databases and captures workloads so that you can analyze and troubleshoot database performance. Performance insights visualizes the database load and provides advanced filtering using various attributes such as: waits, SQL statements, hosts, or users.

Example
Accessing the Amazon Aurora Performance Insights Console

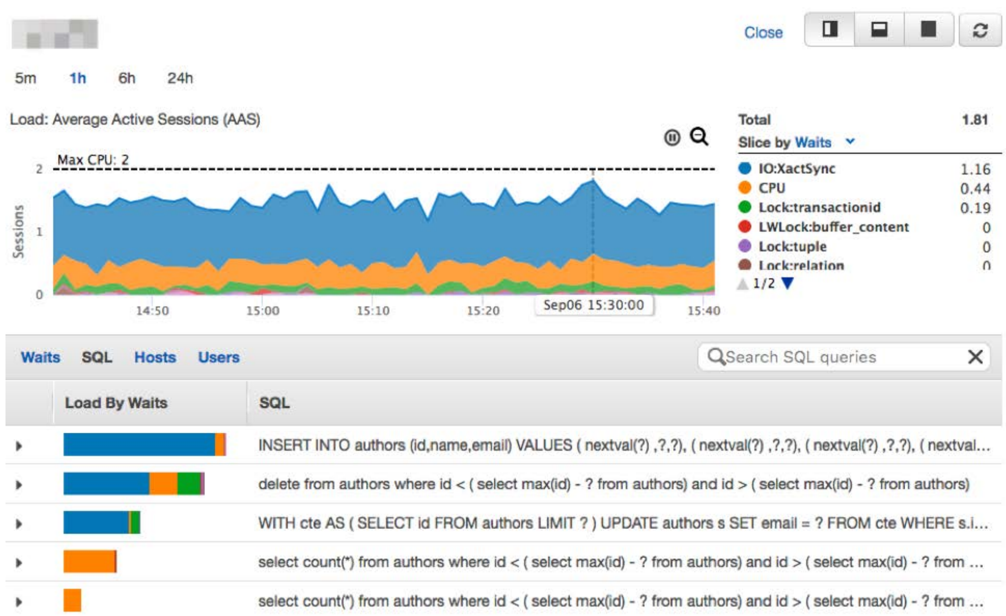
1. Navigate to the RDS section of the AWS Console.



- Select **Performance Insights**.



- Once you have accessed the **Performance insights** console, you will be presented with a visualized dashboard of your current and past database performance metrics. You can choose the period of time of the displayed performance data (5m, 1h, 6h or 24h) as well as different criteria to filter and slice the information presented such as waits, SQL, Hosts or Users, etc.



Enabling Performance Insights

Performance Insights is enabled by default for Amazon Aurora clusters. If you have more than one database created in your Aurora cluster, performance data for all of the databases is aggregated. Database performance data is kept for 24 hours.

For additional details:
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_PerfInsights.html

Migrating from: Oracle Flashback Database

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Overview

Oracle flashback database is a special mechanism built into the Oracle database that can help protect against human errors by providing the capabilities to revert the entire database back to a previous point in time using SQL commands. Flashback database implements a self-logging mechanism that captures all the changes applied to the database and to data, essentially storing previous versions of database modifications in the configured database “fast recovery area” destination.

When using Oracle flashback database, you can choose to restore your entire database to either a user-created restore point, a timestamp value or to a specific Oracle System Change Number (SCN).

Examples

- Create a database restore point to which you can flashback your database to:

```
CREATE RESTORE POINT before_update GUARANTEE FLASHBACK DATABASE;
```

- Flashback your database to a previously created restore point:

```
SQL> shutdown immediate;
SQL> startup mount;
SQL> flashback database to restore point before_update;
```

- Flashback your database to a specific time:

```
SQL> shutdown immediate;
SQL> startup mount;
SQL> FLASHBACK DATABASE TO TIME "TO_DATE('01/01/2017','MM/DD/YY')";
```

For additional details:
https://docs.oracle.com/database/121/RCMRF/rcmsynta023.htm#RCMRF194

Migration to: Amazon Aurora Snapshots

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Overview

The primary backup mechanism for Amazon Aurora are *snapshots*. Taking a database snapshot is an extremely fast and non-intrusive operation for your database. Database *snapshots* can be used in a similar way to flashback database in Oracle.

Amazon Aurora provides two types of snapshots:

- **Automated** - enabled by default.
- **Manual** – User-initiated backup of the database which can be done at any given time.

Restoring a snapshot will result in creating a new database instance. Up to 100 manual snapshots are supported for each Amazon Aurora database.

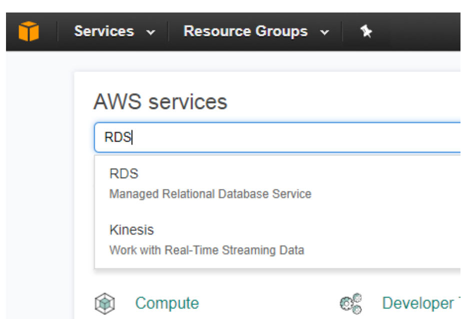
Similarly, to Oracle flashback, Amazon Aurora snapshots support two options for specifying how to restore your database:

1. Restore your database to a specific snapshot, similar to Oracle flashback database "restore points".
2. Restore your database to a previous point in time, similar to Oracle Flashback database "restore to timestamp".

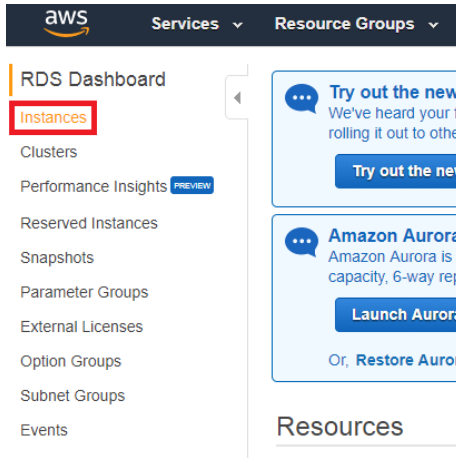
Example

Enable automatic snapshots for your Amazon Aurora database and set the backup retention window during database creation (equivalent to setting the DB_FLASHBACK_RETENTION_TARGET parameter in Oracle).

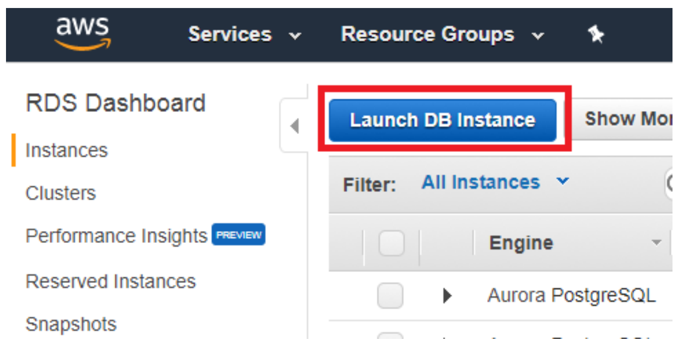
1. Navigate to the **Amazon RDS page** in your AWS console:



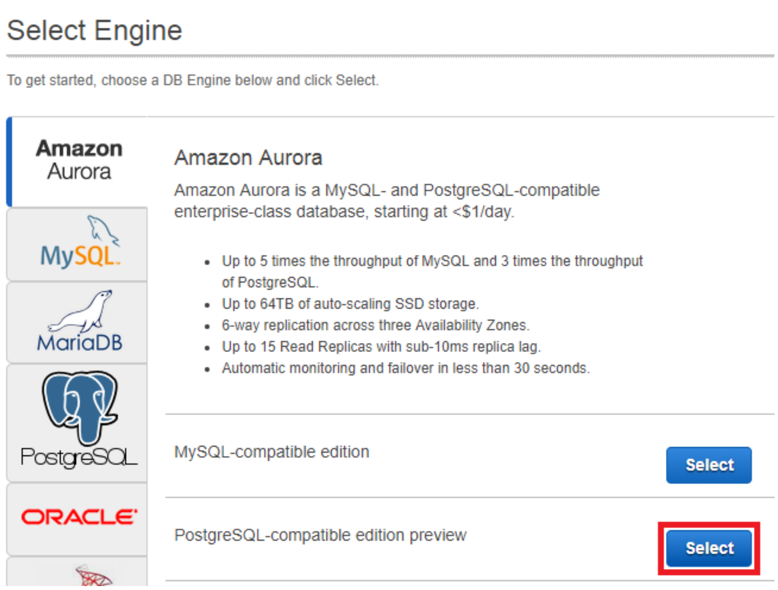
2. Select **Instances.**



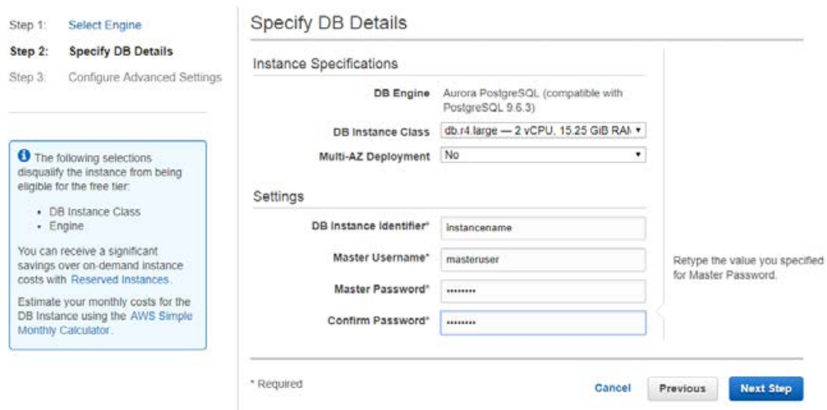
3. Click on **Launch DB Instance.**



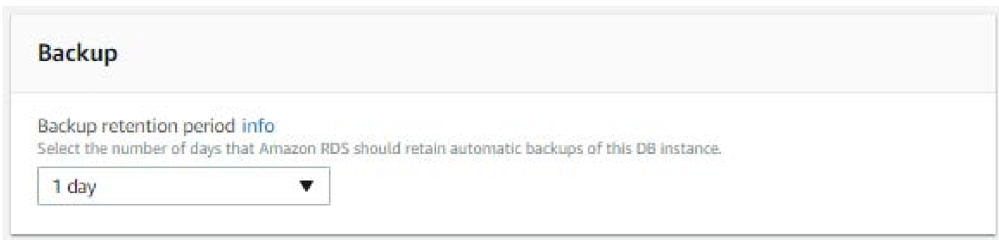
4. Select the **Amazon Aurora** with the **PostgreSQL** database engine.



5. Configure your database settings and parameters.



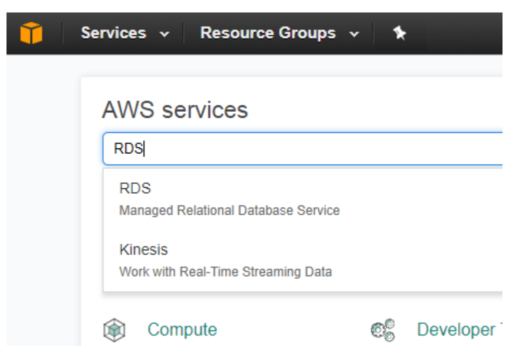
6. Configure your Amazon Aurora cluster backup retention policy as the number of days ("retention period") to automatically to store your snapshots:



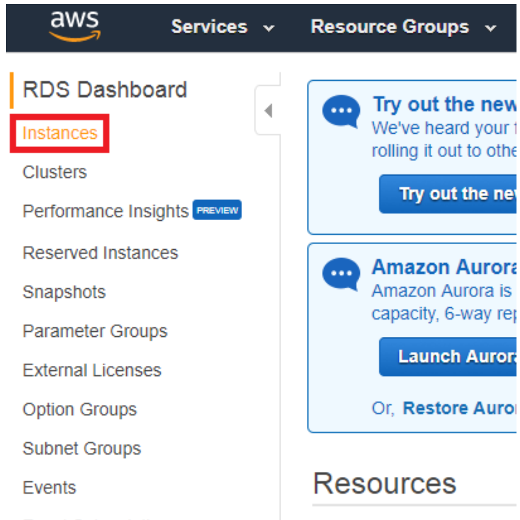
Example

Perform a manual snapshot backup of your database, equivalent to creating a "guaranteed flashback database restore point" in Oracle (`CREATE RESTORE POINT xxxx GUARANTEE FLASHBACK DATABASE;`).

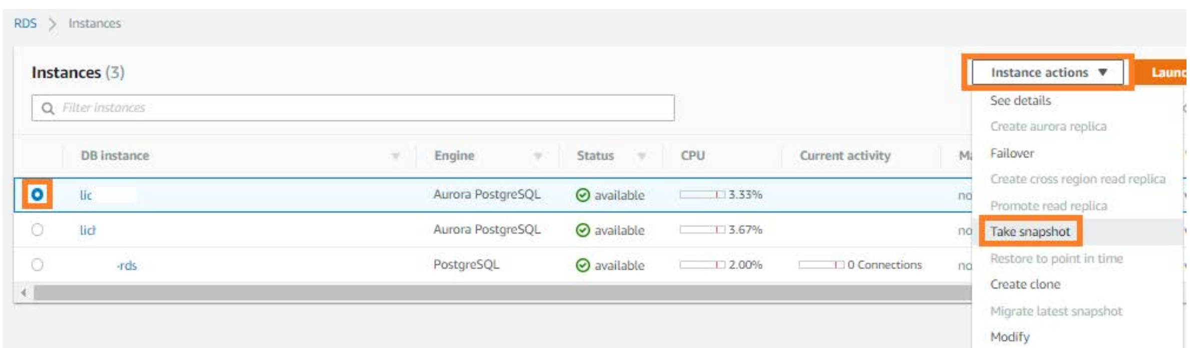
1. Navigate to the **Amazon RDS page** in your AWS Console:



2. Select **Instances.**



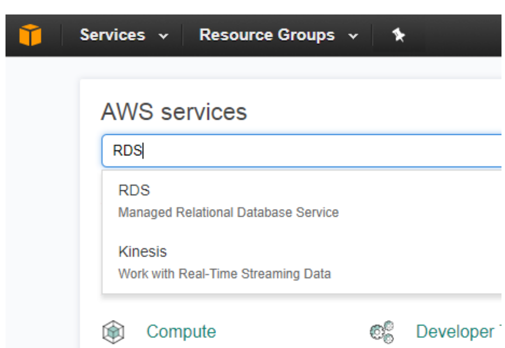
3. Select your **Amazon Aurora PostgreSQL** instance.
4. Click **Instance actions**.
5. Select **Take Snaphot** in the context menu.



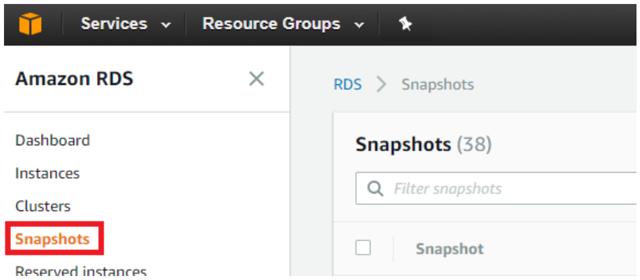
Example

Restore an Amazon Aurora database backup from an existing snapshot, similar to using "`flashback database to restore point xxx;`" in Oracle.

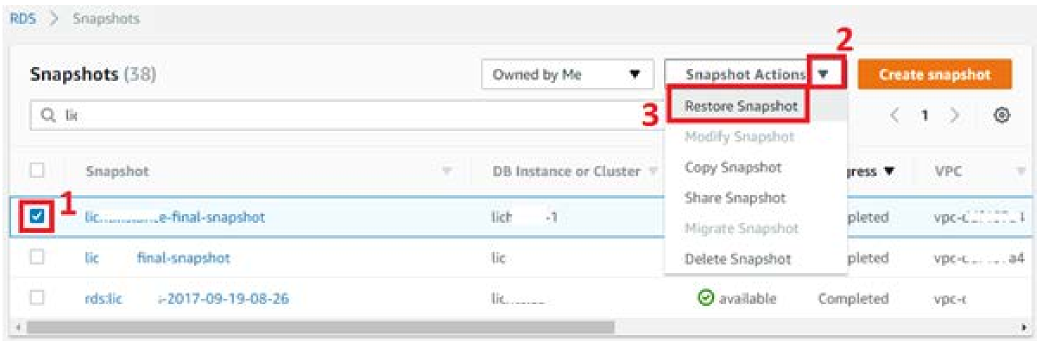
1. Navigate to the **Amazon RDS** page in your AWS Console:



2. Choose **Snapshots** on the left-hand menu to see the list of snapshots available for your database instances:



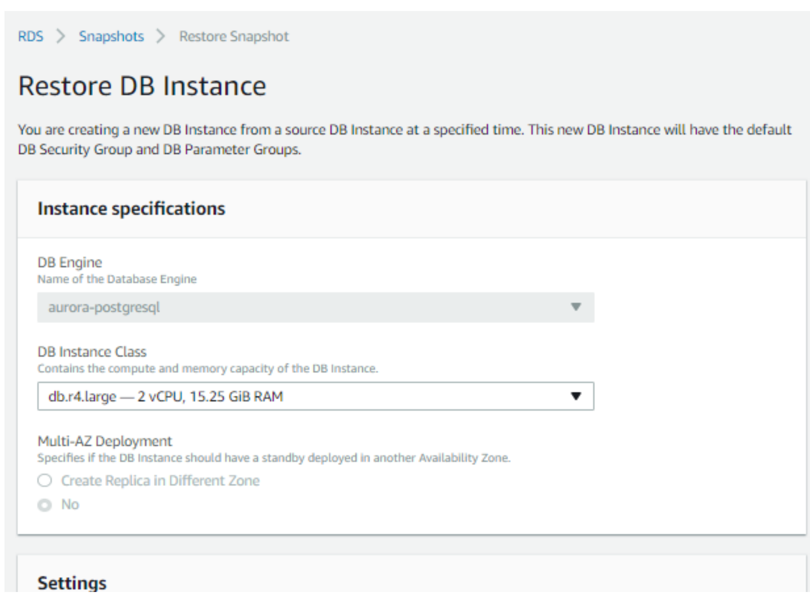
3. Select the **snapshot** to restore. Choose the snapshot, click on **Snapshot Actions** and select **Restore snapshot** in the context menu.

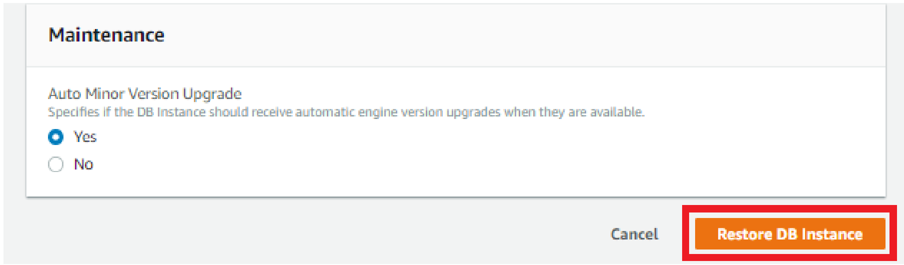


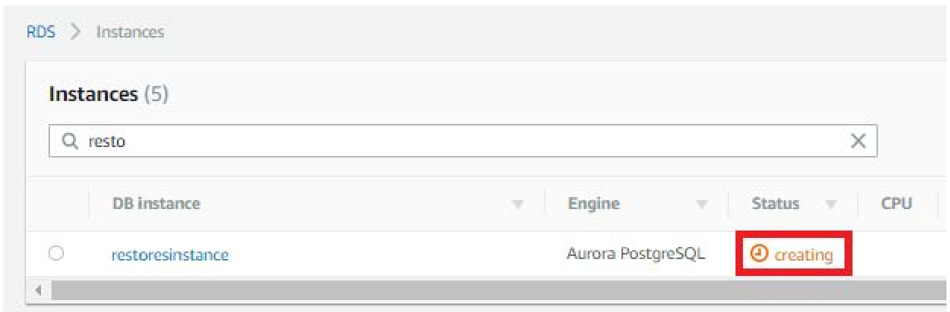
Note: The restore process will create a new instance.

4. You will be presented with a wizard for creating your *new* Amazon Aurora instance from the snapshot you selected. Complete all the required properties for creating your newly restored database instance.

5. Click **Restore DB Instance.**



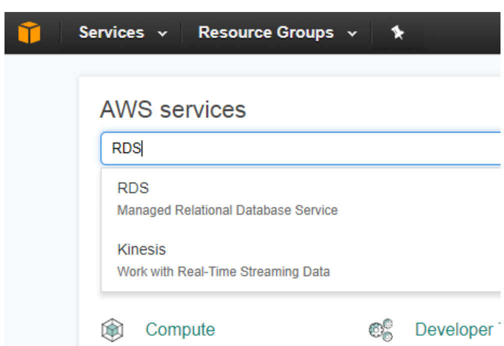




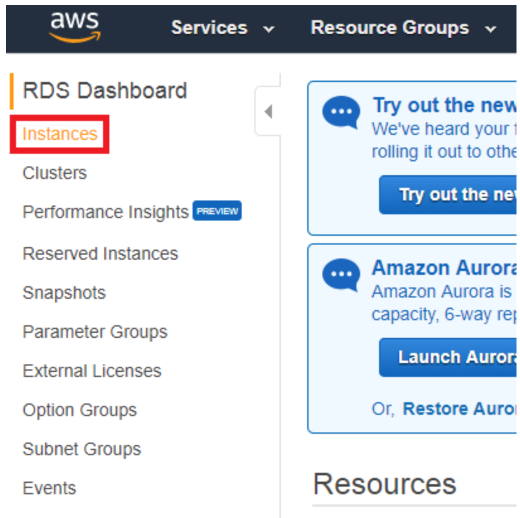
Example

Restore an Amazon Aurora database to a specific (previous) point in time, similar to the “FLASHBACK DATABASE TO TIME "TO_DATE('xxxx') “ command in Oracle.

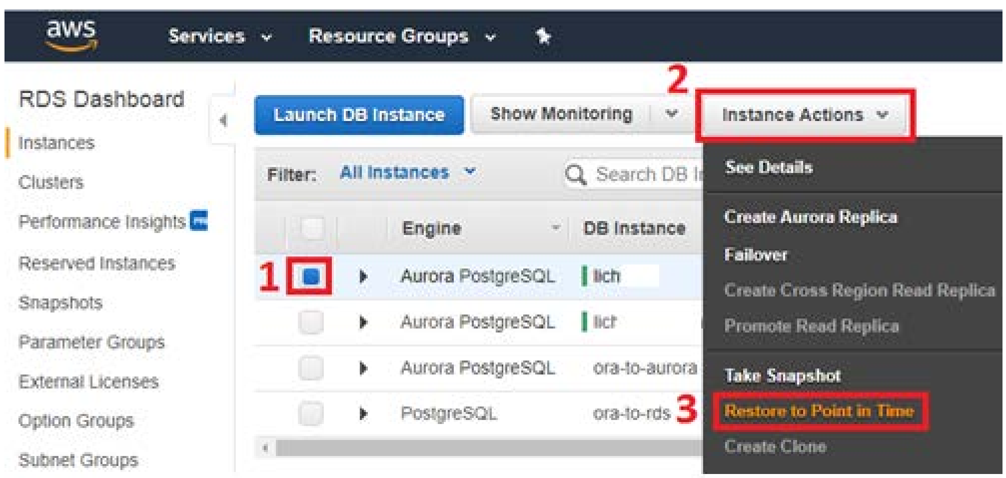
1. Navigate to the **Amazon RDS** page in your AWS Console.



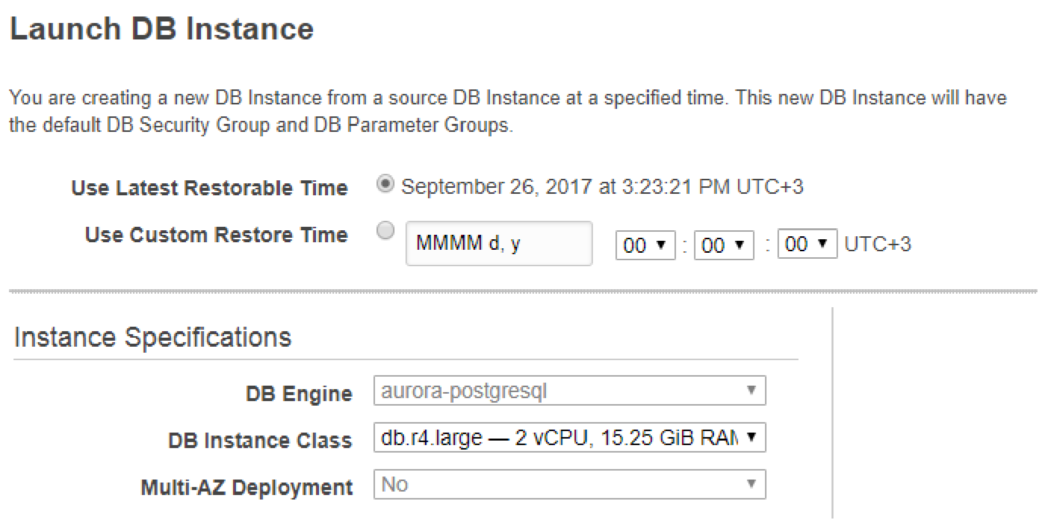
2. Click **Instances**.



4. Select your Amazon Aurora instance and click on **Instance Actions**. Select **Restore to Point in Time** on the context menu.



5. This process will launch a new instance. Select the **date and time** to which you want to restore your new instance. The selected time must be within the configured backup retention for this instance.

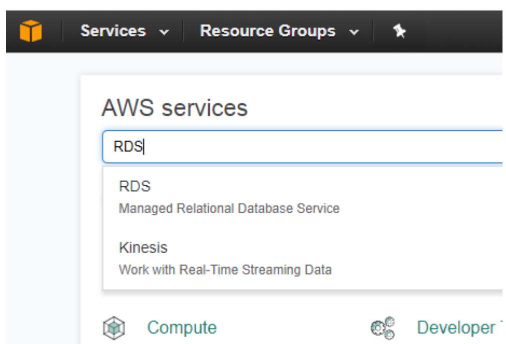


Example

Modify the backup retention policy for an Amazon Aurora database, after a database was created. This process is similar to setting the `DB_FLASHBACK_RETENTION_TARGET` parameter in Oracle.

This process allows you to control for how long your Aurora database snapshots will be retained. When restoring an Amazon Aurora database to a previous point in time, the specified date/time must be within the configured backup retention window.

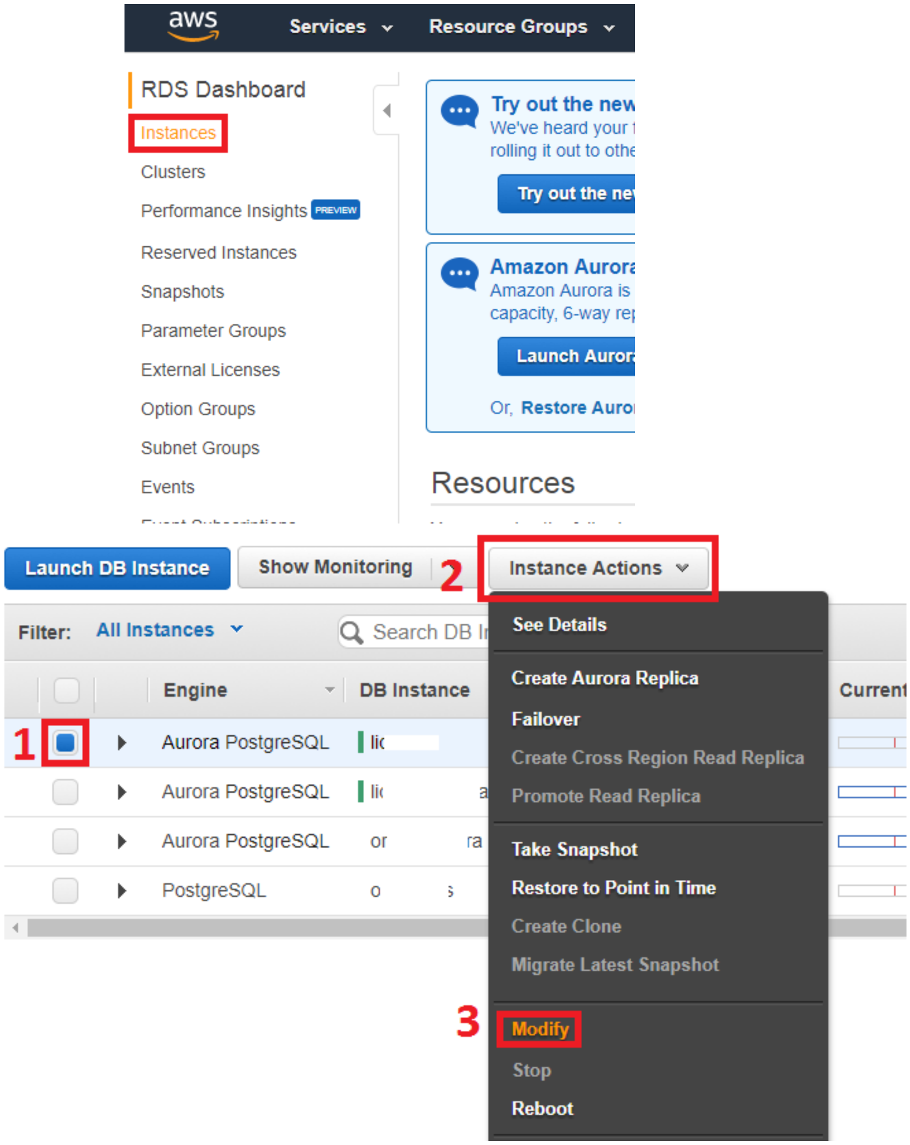
1. Navigate to the **Amazon RDS** page in your AWS Console.



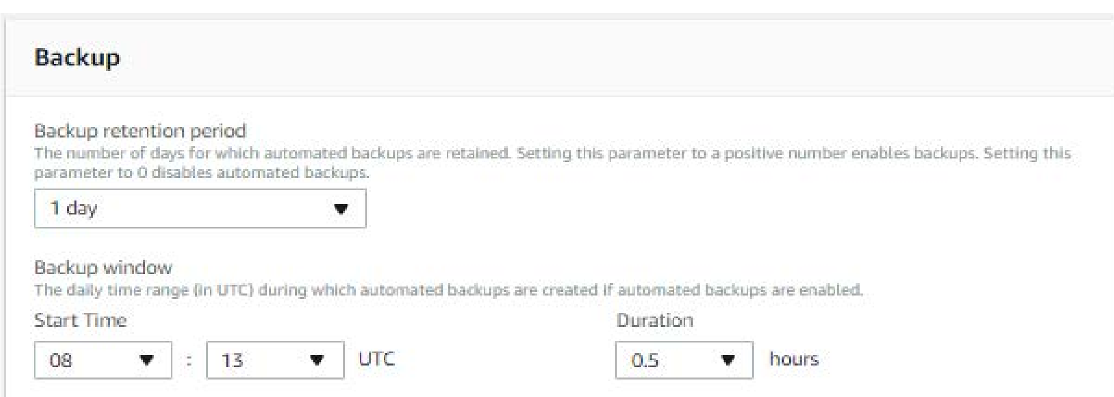
2. Click **Instances.**

3. Select your Aurora instance, click **Instance Actions**.

4. Select **Modify** in the context menu.



5. Configure the desired **backup retention period**. Maximum supported retention is 35 days.



AWS CLI commands for Aurora database backup and database restore

In addition to using the AWS management console to restore your Amazon Aurora database to a previous point in time or to a specific snapshot, you can also use the AWS CLI to perform the same actions. Some examples include:

1. Use `describe-db-cluster-snapshots` to view all current Amazon Aurora snapshots.
2. Use `create-db-cluster-snapshot` to create a new snapshot ("restore point").
3. Use `restore-db-cluster-from-snapshot` to restore a new cluster from an existing snapshot.
4. Use `create-db-instance` to add new instances to the newly restored Amazon Aurora cluster.

```
aws rds describe-db-cluster-snapshots

aws rds create-db-cluster-snapshot --db-cluster-snapshot-iden
tifier Snapshot_name --db-cluster-identifier Cluster_Name

aws rds restore-db-cluster-from-snapshot --db-cluster-identifier
NewCluster --snapshot-identifier SnapshotToRestore --engine aurora-
postgresql

aws rds create-db-instance --region us-east-1 --db-subnet-group default -
-engine aurora-postgresql --db-cluster-identifier NewCluster --db-
instance-identifier newinstance-nodeA --db-instance-class db.r4.large
```

5. Use `restore-db-instance-to-point-in-time` to perform point-in-time recovery.

```
aws rds restore-db-cluster-to-point-in-time --db-cluster-identifier
clustername-restore --source-db-cluster-identifier clustername --restore-
to-time 2017-09-19T23:45:00.000Z

aws rds create-db-instance --region us-east-1 --db-subnet-group default -
-engine aurora-postgresql --db-cluster-identifier clustername-restore --
db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large
```

Oracle Flashback database vs. Amazon Aurora Snapshots

	Oracle	Amazon Aurora
Create a "restore point"	`CREATE RESTORE POINT before_update GUARANTEE FLASHBACK DATABASE;`	`aws rds create-db-cluster-snapshot --db-cluster-snapshot-identifier Snapshot_name --db-cluster-identifier Cluster_Name`
Configure flashback "retention period"	`ALTER SYSTEM SET db_flashback_retention_target=2880;`	Configure the "Backup retention window" setting using the AWS management console or using the AWS CLI.

Flashback database to a previous "restore point"	`shutdown immediate;`
	`startup mount;`
	`flashback database to restore point before_update;`
		1. Create new cluster from a snapshot:
		`aws rds` **`restore-db-cluster-from-snapshot`** `--db-cluster-identifier NewCluster --snapshot-identifier`

	Oracle	Amazon Aurora

		`SnapshotToRestore --engine aurora-postgresql`
		
		2. Add new instance to the cluster:
		
		`aws rds create-db-instance --region us-east-1 --db-subnet-group default --engine aurora-postgresql --db-cluster-identifier clustername-restore --db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large`

Flashback database to a previous point in time	`shutdown immediate;`
	
	`startup mount;`
	
	`FLASHBACK DATABASE TO TIME "TO_DATE('01/01/2017','MM/DD/YY')";`
		1. Create a new cluster from a snapshot and provide a specific point in time:
		
		`aws rds` **`restore-db-cluster-to-point-in-time`** `--db-cluster-identifier clustername-restore --source-db-cluster-identifier clustername` **`--restore-to-time 2017-09-19T23:45:00.000Z`**
		
		2. Add a new instance to the cluster:
		
		`aws rds create-db-instance --region us-east-1 --db-subnet-group default --engine aurora-postgresql --db-cluster-identifier clustername-restore --db-instance-identifier newinstance-nodeA --db-instance-class db.r4.large`

For additional details:
http://docs.aws.amazon.com/cli/latest/reference/rds/index.html#cli-aws-rds
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_PIT.html
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_RestoreFromSnapshot.html

Migrating from: Oracle Log Miner

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Overview

Oracle Log Miner is a tool that enables you to query the database Redo Logs and the Archived Redo Logs using a SQL interface. Using Log Miner, you can analyze the content of database “transaction logs” (online and archived redo logs) and provide historical insight on past database activity, such as reviewing individual DML statements which have modified data in the database.

Examples

Use Log Miner to view DML statements executed on the `employees` table:

1. Find current redo log file to analyze:

```
SQL> SELECT V$LOG.STATUS, MEMBER
     FROM V$LOG, V$LOGFILE
     WHERE V$LOG.GROUP# = V$LOGFILE.GROUP#
     AND V$LOG.STATUS = 'CURRENT';

STATUS           MEMBER
---------------- --------------------------------------------------
CURRENT          /u01/app/oracle/oradata/orcl/redo02.log
```

2. Use the `DBMS_LOGMNR.ADD_LOGFILE` procedure, pass the file path as a parameter to the Log Miner API:

```
SQL> BEGIN
      DBMS_LOGMNR.ADD_LOGFILE('/u01/app/oracle/oradata/orcl/redo02.log');
     END;
/

PL/SQL procedure successfully completed.
```

3. Start Log Miner using the `DBMS_LOGMNR.START_LOGMNR` procedure:

```
SQL> BEGIN
      DBMS_LOGMNR.START_LOGMNR(options=>
                                dbms_logmnr.dict_from_online_catalog);
     END;
/

PL/SQL procedure successfully completed.
```

4. Run a DML statement as an example which we will analyze using Log Miner:

```
SQL> UPDATE HR.EMPLOYEES
     SET SALARY=SALARY+1000
     WHERE EMPLOYEE_ID=116;

COMMIT;
```

5. Querying the V$LOGMNR_CONTENTS table to view the DML commands captured using Log Miner:

```
SQL> SELECT TO_CHAR(TIMESTAMP,'mm/dd/yy hh24:mi:ss') TIMESTAMP,
     SEG_NAME, OPERATION, SQL_REDO, SQL_UNDO
     FROM V$LOGMNR_CONTENTS
     WHERE TABLE_NAME = 'EMPLOYEES'
     AND OPERATION = 'UPDATE';

TIMESTAMP         SEG_NAME   OPERATION  SQL_REDO                      SQL_UNDO
----------------- ---------- ---------- ----------------------------- -----------------------------
10/09/17 06:43:44 EMPLOYEES  UPDATE     update "HR"."EMPLOYEES" set "S update "HR"."EMPLOYEES" set "S
                                        ALARY" = '3900' where "SALARY" ALARY" = '2900' where "SALARY"
                                         = '2900' and ROWID = 'AAAViUA  = '3900' and ROWID = 'AAAViUA
                                        AEAAABVvAAQ';                 AEAAABVvAAQ';
```

For additional information on Oracle LogMiner:
https://docs.oracle.com/cd/E11882_01/server.112/e22490/logminer.htm#SUTIL019

Migration to: PostgreSQL Logging Options

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Overview

PostgreSQL does not provide a feature that is directly equivalent to Oracle Log Miner. However, several alternatives exist which allow viewing historical database activity in PostgreSQL.

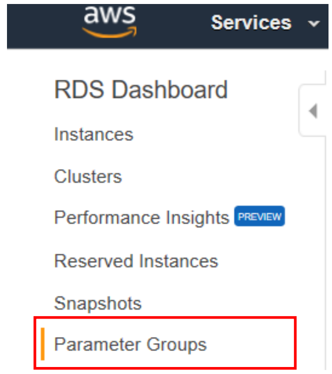
Using PG_STAT_STATEMENTS

Extension module for tracking query execution details with statistical information. The PG_STAT_STATEMENTS view presents a single row for each database operation that was logged, including information about the user, query, number of row retrieved by the query and more.

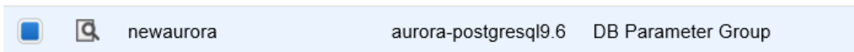
Examples

Configure and use PG_STAT_STATEMENTS to view past database activity:

1. On the AWS Management Console, navigate to **RDS > Parameter Groups.**

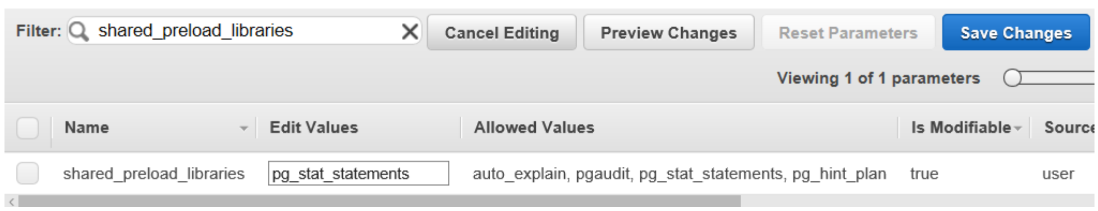


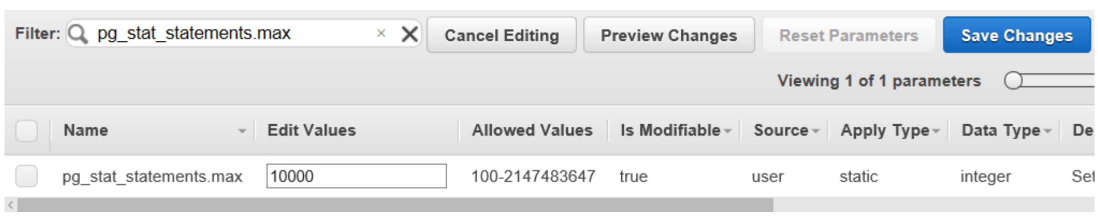
2. Select the current database parameter group:

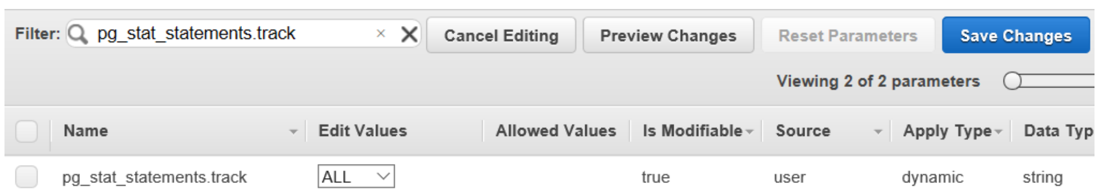


3. Set the following parameters:

```
shared_preload_libraries = 'pg_stat_statements'
pg_stat_statements.max = 10000
pg_stat_statements.track = all
```







Note: A database reboot may be required for the updated values to take effect.

4. Connect to the and run the following command:

```
psql=> CREATE EXTENSION PG_STAT_STATEMENTS;
```

5. Test the PG_STAT_STATEMENTS view to see captured database activity:

```
psql=> UPDATE EMPLOYEES
       SET SALARY=SALARY+1000
       WHERE EMPLOYEE_ID=116;

psql=> SELECT *
       FROM PG_STAT_STATEMENTS
       WHERE LOWER(QUERY) LIKE '%update%';

-[ RECORD 1 ]-------+---------------------------
userid              | 16393
dbid                | 16394
queryid             | 2339248071
query               | UPDATE EMPLOYEES            +
                    |          SET SALARY=SALARY+?+
                    |        WHERE EMPLOYEE_ID=?
calls               | 1
total_time          | 11.989
min_time            | 11.989
max_time            | 11.989
mean_time           | 11.989
stddev_time         | 0
rows                | 1
shared_blks_hit     | 15
shared_blks_read    | 10
shared_blks_dirtied | 0
shared_blks_written | 0
local_blks_hit      | 0
local_blks_read     | 0
local_blks_dirtied  | 0
local_blks_written  | 0
temp_blks_read      | 0
temp_blks_written   | 0
blk_read_time       | 0
blk_write_time      | 0
```

Note: PostgreSQL PG_STAT_STATEMENTS does not provide a feature that is equivalent to LogMiner's SQL_UNDO column.

DML / DDL Database Activity Logging

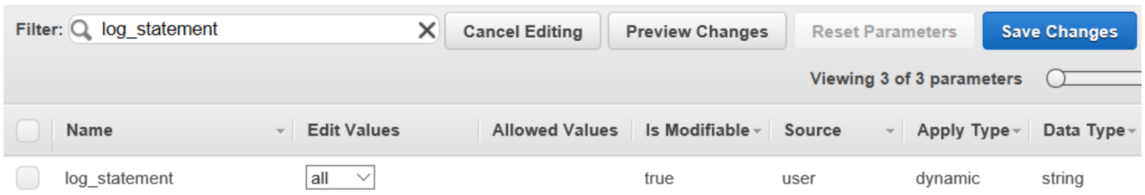
DML and DML operations can be tracked inside the PostgreSQL log file (`postgres.log`) and viewed using AWS console.

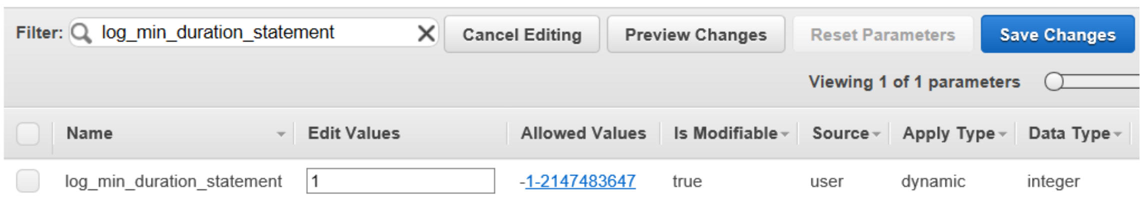
Example

1. On the AWS Console, navigate to **RDS > Parameter Groups**.

2. Set the following parameters:

```
log_statement = 'ALL'
log_min_duration_statement = 1
```

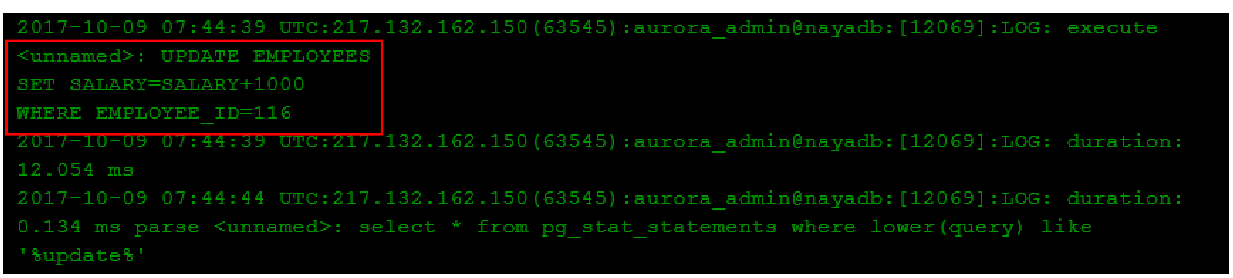




Note: A reboot may be required for the parameters to take effect.

3. Test DDL/DML logging:

- On the AWS Management Console, navigate to **RDS > Instances > Select Instance > Logs**
- Sort via the **Last Written** column to show recent logs (click on column header).
- Click **View** on the relevant log. For example, the PostgreSQL log file shown here with a logged UPDATE command:

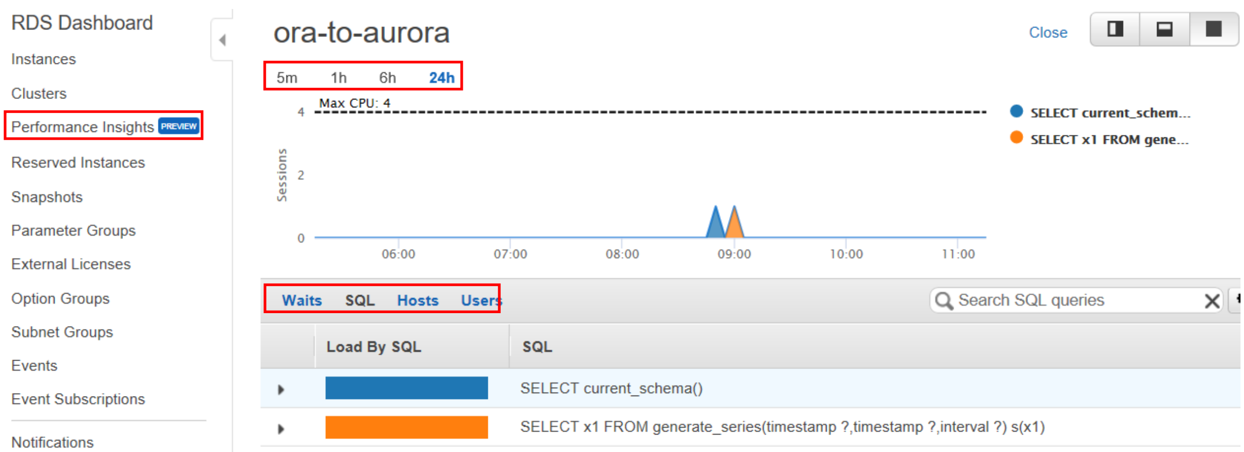


Amazon Aurora Performance Insights

The Amazon Aurora Performance Insights dashboard provides information about current and historical SQL statements, executions and workloads. Note, enhanced monitoring should be enabled during Amazon Aurora instance configuration.

Example

1. On the AWS Management Console, navigate to **RDS > Instances.**
2. Select the relevant instance and choose **Instance Actions > Modify.**
3. Ensure that **Enable Enhanced Monitoring** option is set to **Yes.**
4. Mark the checkbox for **Apply Immediately.**
5. Click **Continue.**
6. On the AWS Management Console, navigate to **RDS > Performance Insights**.
7. Select the relevant instance to monitor.
8. Select the timeframe and monitor scope (Waits, SQL, Hosts and Users).



For additional information:
https://www.postgresql.org/docs/9.6/static/runtime-config-logging.html
https://www.postgresql.org/docs/current/static/pgstatstatements.html
http://docs.aws.amazon.com/AmazonRDS/latest/UserGuide/USER_LogAccess.Concepts.PostgreSQL.html

Migrating from: Oracle Instance Parameters

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Overview

Oracle Instance and database-level parameters can be configured via `ALTER SYSTEM` commands. Certain parameters can be configured dynamically and take immediate effect, while other parameters require an instance restart.

1. All Oracle instance and database-level parameters are stored in a binary file known as the `SPFILE` (or **S**erver **P**arameter **FILE**).
2. The binary server parameter file (`SPFILE`) can be exported to a text file via the following command:
   `CREATE PFILE = 'my_init.ora' FROM SPFILE = 's_params.ora';`

When modifying parameters, the DBA can choose the persistency of the changed values with one of the three following options:

- Make the change applicable only after a restart by specifying `scope=spfile`.
- Make the change dynamically but not persistent after a restart by specifying `scope=memory`.
- Make the change both dynamically and persistent by specifying `scope=both`.

Example

Use the `ALTER SYSTEM SET` command for configuring a value for an Oracle parameter

```
ALTER SYSTEM SET QUERY_REWRITE_ENABLED = TRUE SCOPE=BOTH;
```

For additional details about Oracle initialize Parameters and ALTER SYSTEM command:
https://docs.oracle.com/database/121/ADMQS/GUID-EFF3CCE9-DD06-4755-B2DA-32CDD26F7A18.htm#ADMQS0511
https://docs.oracle.com/database/121/SQLRF/statements_2017.htm#SQLRF00902

Migration to: Amazon Aurora DB Parameter Groups

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Overview

When running your PostgreSQL databases as Amazon Aurora Clusters, changes to cluster-level and database-level parameters are performed via *Parameter Groups.*

Most of the PostgreSQL parameters are configurable in an Amazon Aurora PostgreSQL cluster, but some are disabled and non-modifiable. Since Amazon Aurora clusters restrict access to the underlying operating system, modification to PostgreSQL parameters are done using *parameter groups*.

Amazon Aurora is a cluster of DB instances and, as a direct result, some of the PostgreSQL parameters apply to the *entire cluster*, while other parameters apply only to a particular *database instance* in the cluster.

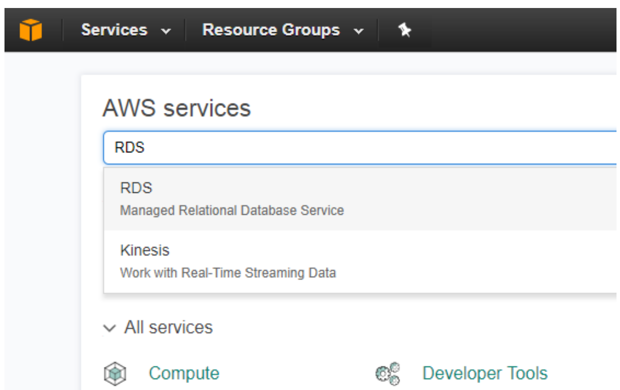
Aurora PostgreSQL Parameter Class	Controlled Via
Cluster-level parameters *Single cluster parameter group per Amazon Aurora Cluster*	Managed via *cluster parameter groups* For example: • The PostgreSQL **`wal_buffers`** parameter is controlled via a cluster parameter group. • The PostgreSQL **`autovacuum`** parameter is controlled via a cluster parameter group. • The **`client_encoding`** parameter is controlled via a cluster parameter group.
Database Instance-Level parameters *Every instance in your Amazon Aurora cluster can be associated with a unique database parameter group*	Managed via *database parameter groups* For example: • The PostgreSQL **`shared_buffers`** memory cache configuration parameter is controlled via a database parameter group with an AWS-optimized default value based on the configured database class: `{DBInstanceClassMemory/10922}` • The PostgreSQL **`max_connections`** parameter which controls maximum number of client connections allowed to the PostgreSQL instance, is controlled via a database parameter group. Default value is optimized by AWS based on the configured database class: `LEAST({DBInstanceClassMemory/9531392},5000)` • The PostgreSQL **`effective_cache_size`** which informs the query optimizer how much cache is present in the kernel and helps control how expensive large index scans will be, is controlled via a database level parameter group. The default value is optimized by AWS based on database class (RAM): `{DBInstanceClassMemory/10922}`

Aurora PostgreSQL Parameter Class	Controlled Via
	• The **`authentication_timeout`** parameter, which controls the maximum time to complete client authentication, in seconds, is controlled via a database parameter group. • The **`superuser_reserved_connections`** parameter which determines the number of reserved connection "slots" for PostgreSQL superusers, is configured via a database parameter group.

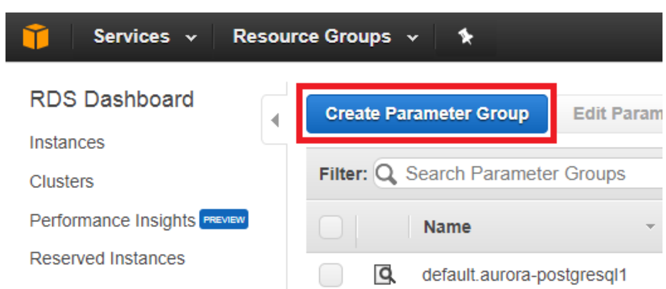
Examples

Create and configure the Amazon Aurora database and cluster parameter groups:

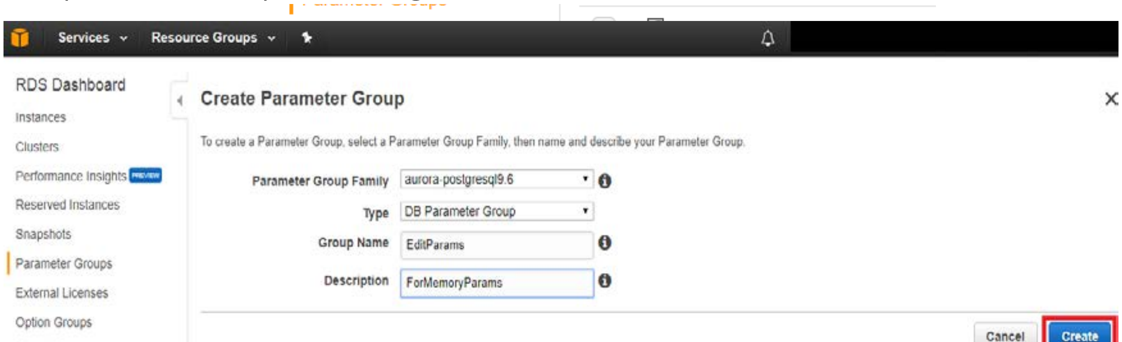
1. Navigate to the **RDS** Service section of the AWS Console.



2. Click **Parameters Group** on the left-hand navigation menu and select **Create Parameter Group**. **Note:** you *cannot* edit the default parameter group**,** you will need to create a custom parameter group to apply changes to your Amazon Aurora cluster and its database instances.

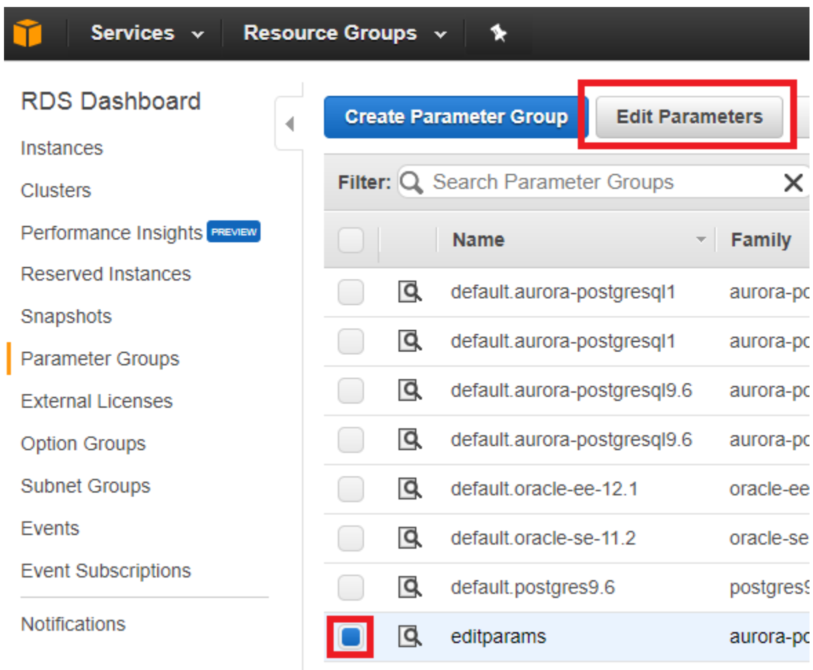


3. Complete all the required configuration and click **Create.**

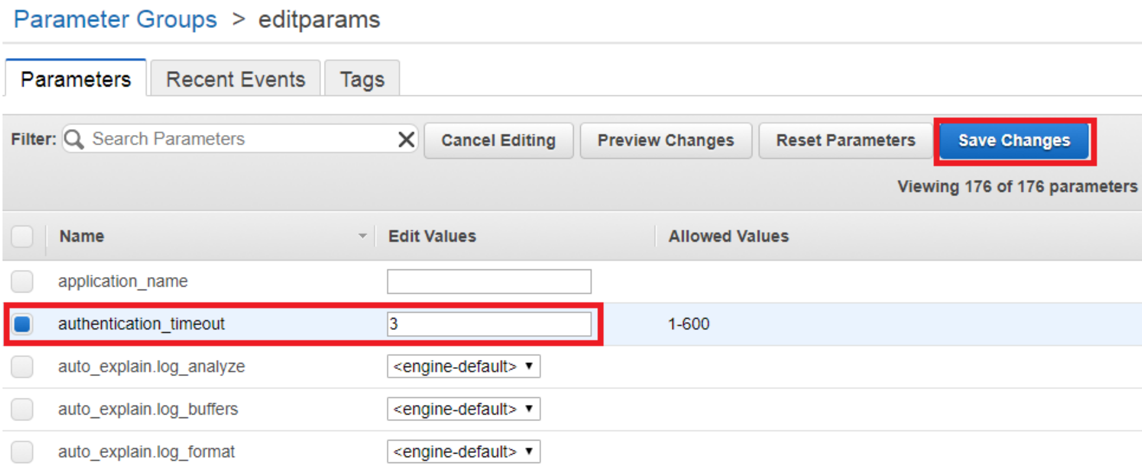


- Parameter group family – select the database engine type for this group. For example – "`aurora-postgresql9.6`" should be selected for Amazon Aurora PostgreSQL clusters.
- Type – cluster or database-level parameter group.
- Specify a custom name for your new parameter group.
- Specify a description for your parameter group.

4. Once the new parameter group is created, you can configure its parameters by clicking **Edit Parameters**:

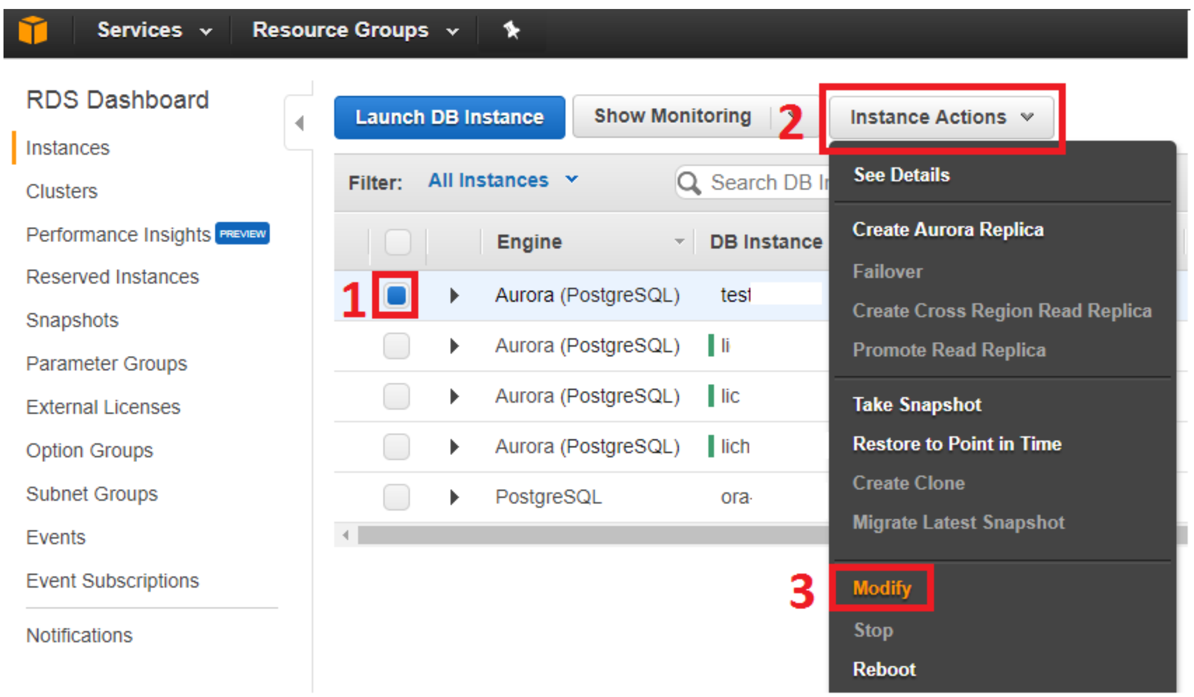


5. Setting the values for specific parameters inside the parameter groups is performed by searching for the parameter name (for example, the `authentication_timeout` parameter) and specifying a new value (for example, 3 minutes). Once the modification is complete, click **Save Changes.**

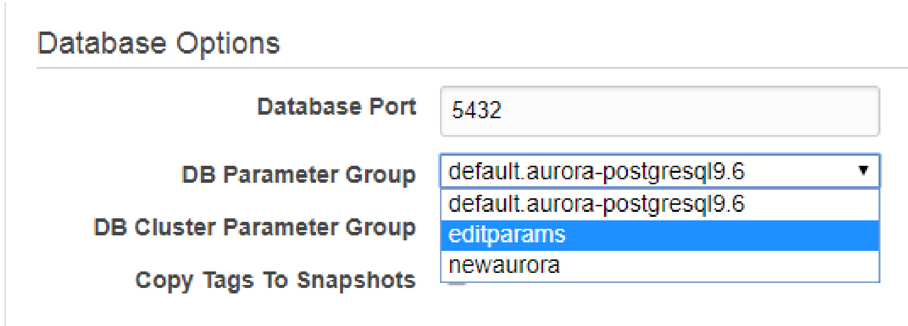


6. To associate an Aurora PostgreSQL Cluster with a specific parameter group, do the following:

- Navigate to the **Instances List** page.
- Select your desired Amazon Aurora instance.
- Click **Instance Actions.**
- In the context menu, click **Modify.**



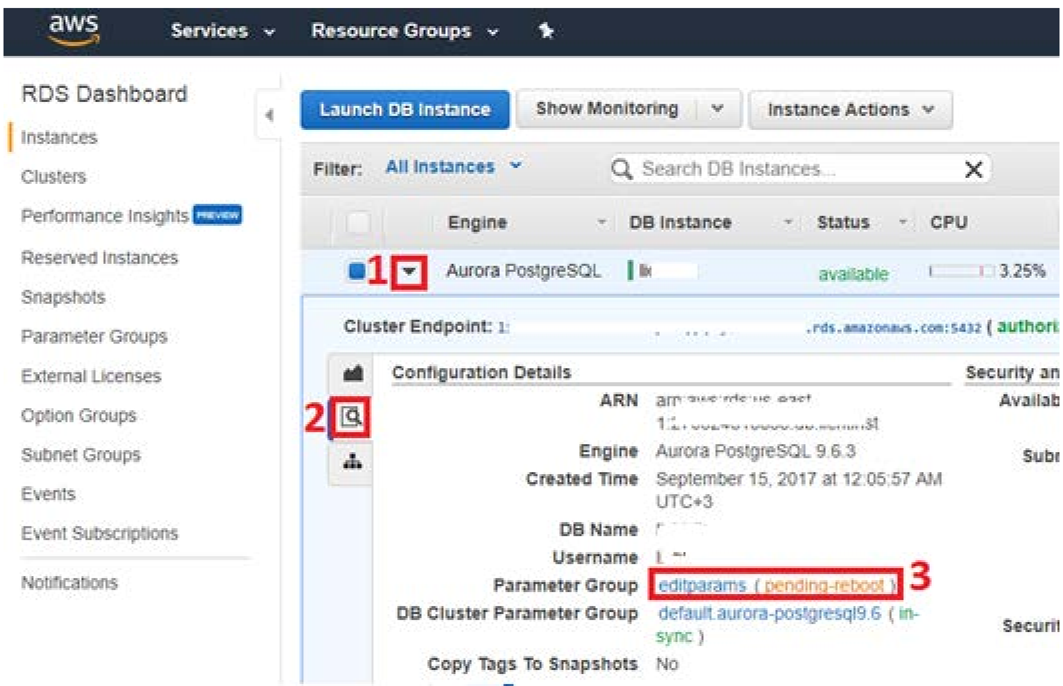
7. In the configuration page, select the desired parameter group.



Note: These changes will require an instance restart

8. To apply the changes:

- Navigate to the **Amazon Aurora** instance list page.
- Expand the instance properties (1).
- Click the **Details** button (2). If the parameter group is listed as "pending reboot", an instance restart is required.



9. To restart your Aurora instance, select **Instance Actions** and click **Reboot**.

Migrating from: Oracle Session Parameters

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Overview

Certain parameters and configuration options in the Oracle database are modifiable on a per-session level. This is accomplished using the `ALTER SESSION` command , which configures parameters for the scope of the connected session only.

Note:

Not all Oracle configuration options and parameters can be modified on a per-session basis. To view a list of all configurable parameters that can be set for the scope of a specific session, you will need to query the `v$parameter` view:

```
SELECT NAME, VALUE FROM V$PARAMETER WHERE ISSES_MODIFIABLE='TRUE';
```

Example

1. Change the `NLS_LANAUGE` (codepage) parameter of the current session using an `ALTER SESSION` command:

```
SQL> alter session set nls_language='SPANISH';

Sesi≤n modificada.

SQL> alter session set nls_language='ENGLISH';

Session altered.

SQL> alter session set nls_language='FRENCH';

Session modifiΘe.

SQL> alter session set nls_language='GERMAN';

Session wurde geΣndert.
```

2. Specify the format of dates values returned from the database using the `NLS_DATE_FORMAT` session parameter:

```
SQL> select sysdate from dual;
SYSDATE
---------
SEP-09-17

SQL> alter session set nls_date_format='DD-MON-RR';
Session altered.

SQL> select sysdate from dual;
SYSDATE
---------
09-SEP-17

SQL> alter session set nls_date_format='MM-DD-YYYY';
Session altered.

SQL> select sysdate from dual;

SYSDATE
----------
09-09-2017

SQL> alter session set nls_date_format='DAY-MON-RR';

Session altered.
```

For additional details about Oracle session parameters:
https://docs.oracle.com/database/121/SQLRF/statements_2015.htm#i2143260

Migration to: PostgreSQL Session Parameters

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Overview

PostgreSQL provides session-modifiable parameters that are configured using the `SET SESSION` command. Configuration of parameters using `SET SESSION` will only be applicable in the current session. To view the list of parameters that can be set with `SET SESSION`, you can query `pg_settings`:

```
SELECT * FROM pg_settings where context = 'user';
```

Examples of commonly-used session parameters:

1. **client_encoding -** configures the connected client character set.
2. **force_parallel_mode -** forces use of parallel query for the session.
3. **lock_timeout -** sets the maximum allowed duration of time to wait for a database lock to release.
4. **search_path -** sets the schema search order for object names that are not schema-qualified.
5. **transaction_isolation -** sets the current Transaction Isolation Level for the session.

Example

Change the Date format of the connected session:

```
mydb=> set session DateStyle to POSTGRES, DMY;
SET
mydb=> select now();
                 now
-------------------------------------
 Sat 09 Sep 11:03:43.597202 2017 UTC
(1 row)


mydb=> set session DateStyle to ISO, MDY;
SET
mydb=> select now();
             now
-----------------------------
 2017-09-09 11:04:01.3859+00
(1 row)
```

Oracle vs. PostgreSQL Session parameter examples

Please note that the list below is partial and is meant to highlight various session-level configuration parameters in both Oracle and PostgreSQL. Not all parameters are directly comparable.

	Oracle	PostgreSQL
Configure time and date format	`ALTER SESSION SET nls_date_format = 'dd/mm/yyyy hh24:mi:ss';`	`SET SESSION datestyle to 'SQL, DMY';`
Configure the current default schema/database	`ALTER SESSION SET current schema='schema_name'`	`SET SESSION SEARCH_PATH TO schemaname;`
Generate traces for specific errors	`ALTER SESSION SET events '10053 trace name context forever';`	N/A

Run trace for a SQL statement	`ALTER SESSION SET sql_trace=TRUE;`
	
	`ALTER SYSTEM SET EVENTS 'sql_trace [sql:&&sql_id] bind=true, wait=true';`
		N/A

Modify query optimizer cost for index access	`ALTER SESSION SET optimizer_index_cost_adj = 50`	`SET SESSION random_page_cost TO 6;`
Modify query optimizer row access strategy	`ALTER SESSION SET optimizer_mode=all_rows;`	N/A
Memory allocated to sort operations	`ALTER SESSION SET sort_area_size=6321;`	`SET SESSION work_mem TO '6MB';`
Memory allocated to hash-joins	`ALTER SESSION SET hash_area_size=1048576000;`	`SET SESSION work_mem TO '6MB';`

For additional details:
https://www.postgresql.org/docs/9.6/static/sql-set.html

Migrating from: Oracle Alert.log and logs files

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Overview

The primary error log file for the Oracle database is known as the “Alert Log” with a file name that in the following format: “`alert<SID>.log`”. The Alert Log contains verbose information regarding the activity of the Oracle database including informational messages and errors. Each event includes a timestamp indicating when the event occurred.

When encountering database issues, the Oracle Alert Log is the first place to look for troubleshooting and to investigate errors, failures or for any other messages that might indicate a potential database problem.

Example

1. Partial contents of the Oracle database Alert Log File:

```
Sun Sep 03 13:27:23 2017
Starting ORACLE instance (normal)
************************ Large Pages Information *******************
Per process system memlock (soft) limit = 64 KB

Total Shared Global Region in Large Pages = 0 KB (0%)

Large Pages used by this instance: 0 (0 KB)
Large Pages unused system wide = 0 (0 KB)
Large Pages configured system wide = 0 (0 KB)
Large Page size = 2048 KB
```

Common events logged in the Alert Log include:

1. Database startup or shutdown.
2. Database redo log switch.
3. Database errors and warnings, starting with `ORA-` and followed by an Oracle error number.
4. Network and connection issues
5. Links for a detailed trace files regarding a specific database event

The Oracle Alert Log can be found inside the database Automatic Diagnostics Repository (ADR), a hierarchical file-based repository for diagnostic information:

`$ADR_BASE/diag/rdbms/{DB-name}/{SID}/trace`

In addition, several other Oracle server components have their own unique log files, such as the database listener, Automatic Storage Manager (ASM), etc.

For additional details:
https://docs.oracle.com/cd/B28359_01/server.111/b28310/diag005.htm#ADMIN11267
https://docs.oracle.com/database/121/SUTIL/GUID-E0FF3013-2EBF-4110-88BF-69E7DD2BBD7C.htm#SUTIL1474

Migration to: PostgreSQL Error Log via Amazon RDS Console

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PostgreSQL provides detailed logging and reporting of errors that occur during the database and connected sessions lifecycle. In an Amazon Aurora deployment, these informational and error messages are accessible using the Amazon RDS console.

PostgreSQL vs. Oracle error codes

Oracle error codes start with the “ORA-” prefix. PostgreSQL messages expressed by assigning five-character error codes divided by message class such as: successful completion, warning, no data and more.

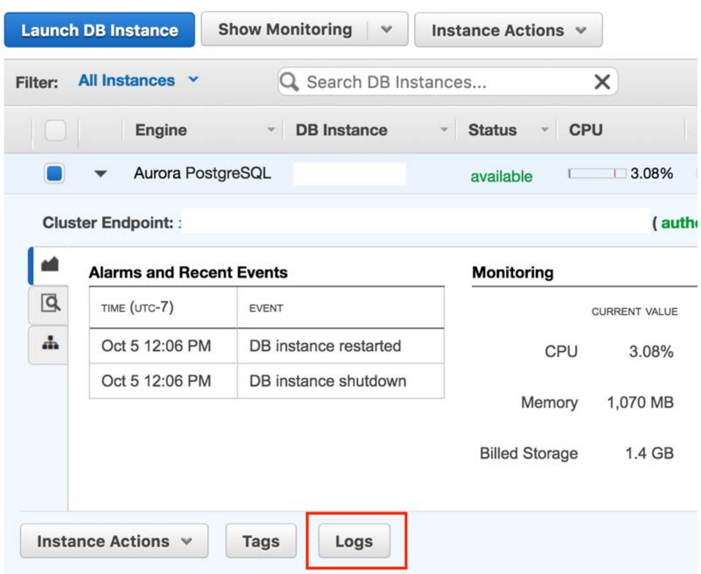
Oracle	PostgreSQL
ORA-00001: unique constraint (string.string) violated	**SQLSTATE[23505]: Unique violation: 7** ERROR: duplicate key value violates unique constraint "constraint_name"

For additional details about PostgreSQL Error Codes:
https://www.postgresql.org/docs/9.6/static/errcodes-appendix.html

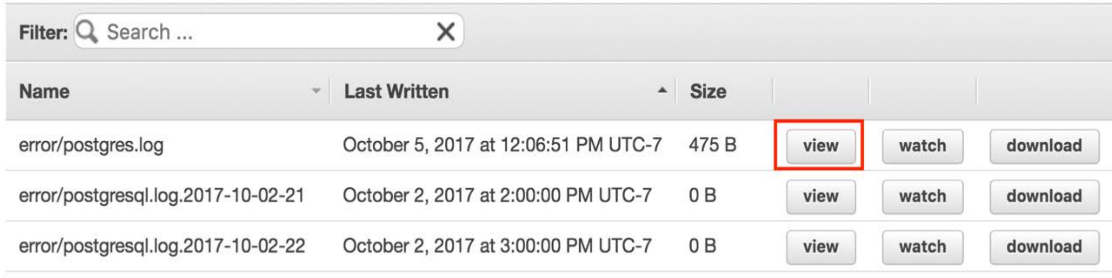
Example

Access the PostgreSQL error log using the Amazon RDS/Aurora Management Console:

- Navigate to: **Services > RDS > Instances > Select Instance**



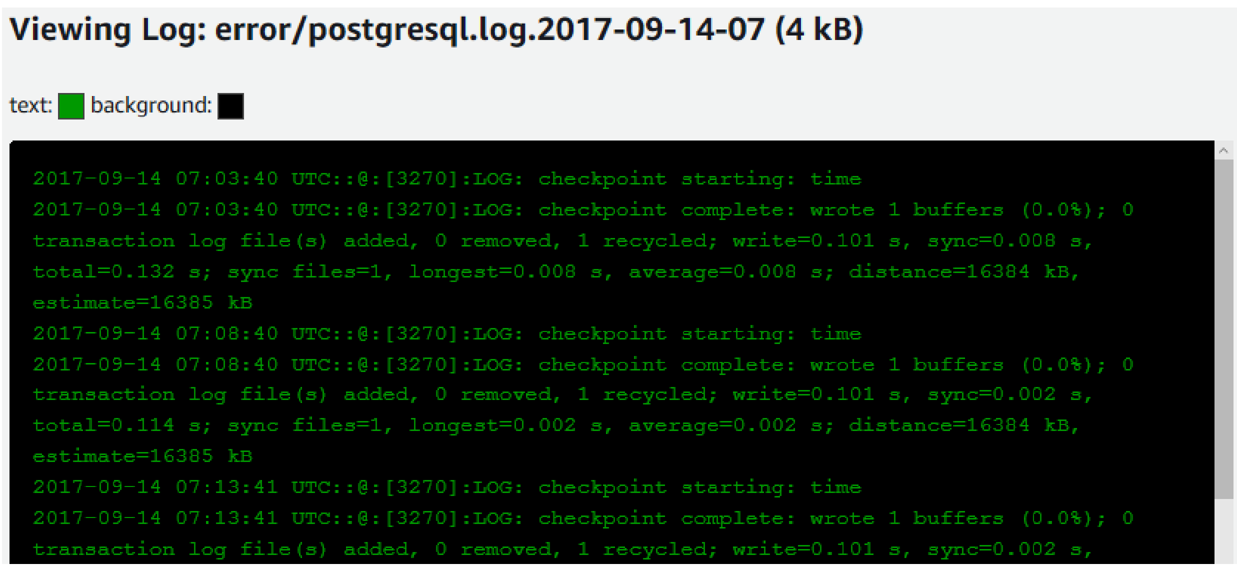
- Click **Logs**.
- Select a specific PostgreSQL log file and select **View** to review a static version of log file. Optionally, select **Watch** for a dynamic (updating) view of log file.



Notes

1. You can use the search box to search for a specific log file.
2. You can click on the download button to download the log file to your local machine.

Partial contents of a PostgreSQL database error log as viewed from the Amazon RDS Management Console:



PostgreSQL error log configuration

Several parameters control how and where PostgreSQL log and errors files will be placed:

Common Amazon Aurora configuration options

Oracle	PostgreSQL
`log_filename`	Sets the file name pattern for log files. *Modifiable via an Aurora **Database** Parameter Group*
`log_rotation_age`	(min) Automatic log file rotation will occur after N minutes. *Modifiable via an Aurora **Database** Parameter Group*
`log_rotation_size`	(kB) Automatic log file rotation will occur after N kilobytes. *Modifiable via an Aurora **Database** Parameter Group*
`log_min_messages`	Sets the message levels that are logged (`DEBUG`, `ERROR`, `INFO`, etc.…). *Modifiable via an Aurora **Database** Parameter Group*

`log_min_error_statement`	Causes all statements generating error at or above this level to be logged (`DEBUG, ERROR, INFO,` etc.…). *Modifiable via an Aurora **Database** Parameter Group*
`log_min_duration_statement`	Sets the minimum execution time above which statements will be logged (ms). *Modifiable via an Aurora **Database** Parameter Group*

Note

Modifications to certain parameters, such as **`log_directory`**`(`which sets the destination directory for log files) **`or logging_collector`** (which start a subprocess to capture `stderr` output and/or `csvlogs` into log files) are disabled for Aurora PostgreSQL instance

Log severity levels supported by PostgreSQL:

Severity	Usage
DEBUG1…DEBUG5	Provides successively-more-detailed information for use by developers
INFO	Provides information implicitly requested by the user
NOTICE	Provides information that might be helpful to users
WARNING	Provides warnings of likely problems
ERROR	Reports an error that caused the current command to abort
LOG	Reports information of interest to administrators
FATAL	Reports an error that caused the current session to abort
PANIC	Reports an error that caused all database sessions to abort

For additional details about PostgreSQL Error Reporting and Logging:
https://www.postgresql.org/docs/9.6/static/runtime-config-logging.html

Migrating from: Oracle Table Statistics

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Overview

Table statistics are one of the important aspects that can affect SQL query performance. Table Statistics allow the query optimizer to make informed assumptions when deciding how to generate the execution plan for each query. Oracle provides the DBMS_STATS package to manage and control the table statistics which can be collected automatically or manually.

The following statistics are usually collected on database tables and indexes:

- Number of table rows.
- Number of table blocks.
- Number of distinct values or nulls.
- Data distribution histograms.

Automatic Optimizer Statistics Collection

By default, Oracle will collect table and index statistics by using automated maintenance tasks leveraging the database scheduler to automatically collect statistics at predefined maintenance windows. Using the data modification monitoring feature in Oracle, which is responsible for tracking the approximate number of INSERTs, UPDATEs, and DELETEs for that table, the automatic statistics collection mechanism knows which table statistics should be collected.

Manual Optimizer Statistics Collection

When the automatic statistics collection is not suitable for a particular use-case, the optimizer statistics collection can be performed manually, at several levels:

1. GATHER_INDEX_STATS	Index statistics
2. GATHER_TABLE_STATS	Table, column, and index statistics
3. GATHER_SCHEMA_STATS	Statistics for all objects in a schema
4. GATHER_DICTIONARY_STATS	Statistics for all dictionary objects
5. GATHER_DATABASE_STATS	Statistics for all objects in a database

Example

1. Collecting statistics at the table level (schema - HR, table - EMPLOYEES):

```
SQL> BEGIN
      DBMS_STATS.GATHER_TABLE_STATS('HR','EMPLOYEES');
     END;
/

PL/SQL procedure successfully completed.
```

2. Collecting statistics at a specific column-level (schema - HR, table - EMPLOYEES, column - DEPARTMENT_ID):

```
SQL> BEGIN
      DBMS_STATS.GATHER_TABLE_STATS('HR','EMPLOYEES',
                  METHOD_OPT=>'FOR COLUMNS department_id');
     END;
/

PL/SQL procedure successfully completed.
```

For additional information on Oracle Collecting Table Statistics:
http://docs.oracle.com/cd/E25054_01/server.1111/e16638/stats.htm#i41448
https://docs.oracle.com/database/121/TGSQL/tgsql_stats.htm#TGSQL390

Migration to: PostgreSQL Table Statistics

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Overview

Use the ANALYZE command to collect statistics about a database, a table or a specific table column. The PostgreSQL ANALYZE command collects table statistics which support generation of efficient query execution plans by the query planner.

1. **Histograms** - ANALYZE will collect statistics on table columns values and create a histogram of the approximate data distribution in each column.
2. **Pages and rows -** ANALYZE will collect statistics on the number of database pages and rows from which each table is comprised.
3. **Data sampling** - for large tables, the ANALYZE command will take random samples of values rather than examining each and every single row. This allows the ANALYZE command to scan very large tables in a relatively small amount of time.
3. **Statistic collection granularity** - executing the ANALYZE command without any parameter will instruct PostgreSQL to examine every table in the *current schema*. Supplying the table name or column name to the ANALYZE, will instruct the database to examine a specific table or table column.

   Automatic Statistics Collection

   By default, PostgreSQL is configured with an "autovacuum daemon" which automates the execution of statistics collection via the ANALYZE commands (in addition to automation of the VACUUM command). The "autovacuum daemon" scans for tables which show signs of large modifications in data to collect the current statistics. Autovacuum is controlled by several parameters.

   For additional details:
   https://www.postgresql.org/docs/9.6/static/runtime-config-autovacuum.html

Manual Statistics Collection

PostgreSQL allows collecting statistics on-demand using the ANALYZE command at a database level, table-level or table column-level.

1. ANALYZE on indexes is not currently supported.
2. ANALYZE requires only a read-lock on the target table, so it can run in parallel with other activity on the table.
3. For large tables, ANALYZE takes a random sample of the table contents. Configured via the show `default_statistics_target` parameter. The default value is 100 entries. Raising the limit might allow more accurate planner estimates to be made at the price of consuming more space in the `pg_statistic` table.

Examples

1. Gather statistics for the entire database:

```
psql=> ANALYZE;
```

2. Gather statistics for a specific table. The VERBOSE keyword displays progress.

```
psql=> ANALYZE VERBOSE EMPLOYEES;
```

3. Gather statistics for a specific column:

```
psql=> ANALYZE EMPLOYEES (HIRE_DATE);
```

4. Specify the `default_statistics_target` parameter for an individual table column and reset it back to default:

```
psql=> ALTER TABLE EMPLOYEES ALTER COLUMN SALARY SET STATISTICS 150;

psql=> ALTER TABLE EMPLOYEES ALTER COLUMN SALARY SET STATISTICS -1;
```

Larger values will increase the time needed to complete an ANALYZE, but, will improve the quality of the collected planner's statistics which can potentially lead to better execution plans.

5. View the current (session / global) `default_statistics_target`, modify it to 150 and analyze the EMPLOYEES table:

```
psql=> SHOW default_statistics_target ;
psql=> SET default_statistics_target to 150;
psql=> ANALYZE EMPLOYEES ;
```

6. View the last time statistics were collected for a table:

```
select relname, last_analyze from pg_stat_all_tables;
```

Comparing Oracle and PostgreSQL Statistics Collection

Feature	Oracle	PostgreSQL
Analyze a specific database table	`BEGIN dbms_stats.gather_table_stats(ownname =>'hr', tabname => 'employees' , … ); END;`	`ANALYZE EMPLOYEES;`
Analyze a database table while only sampling certain rows	Configure via percentage of table rows to sample: `BEGIN dbms_stats.gather_tabke_stats( ownname=>'HR', … ` **`ESTIMATE_PERCENT=>100`**`); END;`	Configure via number of entries for the table: **`SET default_statistics_target to 150;`** `ANALYZE EMPLOYEES ;`
Collect statistics for a schema	`BEGIN EXECUTE DBMS_STATS.GATHER_SCHEMA_STATS(ownname => 'HR'); END`	`ANALYZE;`
View last time statistics were collected	`select owner,table_name,last_analyzed;`	`select relname, last_analyze from pg_stat_all_tables;`

For additional information on PostgreSQL Collecting Table Statistics:
https://www.postgresql.org/docs/9.6/static/sql-analyze.html
https://www.postgresql.org/docs/9.6/static/routine-vacuuming.html#AUTOVACUUM

Migrating from: Viewing Oracle Execution Plans

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Overview

Execution plans represent the choices made by the query optimizer of which actions to perform in order to access data in the database. Execution Plans are generated by the database optimizer for SELECT, INSERT, UPDATE and DELETES statements.

Users and DBAs can request the database to present the execution plan for any specific query or DML operation providing an extensive view on the optimizer's method of accessing data. Execution Plans are especially useful for performance tuning of queries, including deciding if new indexes should be created. Execution plans can be affected by data volumes, data statistics and instance parameters (global or session parameters).

Execution plans are displayed as a structured tree that presents the following information:

1. Tables access by the SQL statement and the referenced order for each table.
2. Access method for each table in the statement (full table scan vs. index access).
3. Algorithms used for joins operations between tables (hash vs. nested loop joins).
4. Operations that are performed on retrieved data as filtering, sorting and aggregations.
5. Information about rows begin processed (cardinality) and the cost for each operation.
6. Table partitions begin accessed.
7. Information about parallel executions.

Examples

1. Review the potential execution plan for a query using the EXPLAIN PLAN statement:

```
SQL> SET AUTOT TRACE EXP
SQL> SELECT EMPLOYEE_ID, LAST_NAME, FIRST_NAME FROM EMPLOYEES
     WHERE LAST_NAME='King' AND FIRST_NAME='Steven';


Execution Plan
----------------------------------------------------------
Plan hash value: 2077747057

-------------------------------------------------------------------------------------------
| Id  | Operation                    | Name        | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------------------
|   0 | SELECT STATEMENT             |             |     1 |    16 |     2   (0)| 00:00:01 |
|   1 |  TABLE ACCESS BY INDEX ROWID| EMPLOYEES   |     1 |    16 |     2   (0)| 00:00:01 |
|*  2 |   INDEX RANGE SCAN           | EMP_NAME_IX |     1 |       |     1   (0)| 00:00:01 |
-------------------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   2 - access("LAST_NAME"='King' AND "FIRST_NAME"='Steven')
```

* SET AUTOT TRACE EXP instructs SQL*PLUS to show the execution plan without actually running the query itself.

The EMPLOYEES tables contains indexes for both the LAST_NAME and the FIRST_NAME columns, we can see that in step 2 of the execution plan above, the optimizer is performing an INDEX RANGE SCAN in order to retrieve the filtered employee name.

2. View a different execution plan, this time showing a FULL TABLE SCAN:

```
SQL> SET AUTOT TRACE EXP
SQL> SELECT EMPLOYEE_ID, LAST_NAME, FIRST_NAME FROM EMPLOYEES
     WHERE SALARY > 10000;

Execution Plan
----------------------------------------------------------
Plan hash value: 1445457117

-------------------------------------------------------------------------------
| Id  | Operation         | Name      | Rows  | Bytes | Cost (%CPU)| Time     |
-------------------------------------------------------------------------------
|   0 | SELECT STATEMENT  |           |    72 |  1368 |     3   (0)| 00:00:01 |
|*  1 |  TABLE ACCESS FULL| EMPLOYEES |    72 |  1368 |     3   (0)| 00:00:01 |
-------------------------------------------------------------------------------

Predicate Information (identified by operation id):
---------------------------------------------------

   1 - filter("SALARY">10000)
```

For additional details:
http://docs.oracle.com/cd/E25178_01/server.1111/e16638/ex_plan.htm
https://docs.oracle.com/database/121/TGSQL/tgsql_genplan.htm#TGSQL271

Migration to: Viewing PostgreSQL Execution Plans

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Overview

The PostgreSQL equivalent to EXPLAIN PLAN in the Oracle database is the EXPLAIN keyword which is used to display the execution plan for a supplied SQL statement. In similar manner to Oracle, the query planner in PostgreSQL will generate the estimated execution plan for actions such as: SELECT, INSERT, UPDATE and DELETE and will build a structured tree of plan nodes representing the different actions taken (the sign "->" represent a root line in the PostgreSQL execution plan). In addition, the EXPLAIN statement will provide statistical information regarding each action such as: cost, rows, time and loops.

When using the EXPLAIN command as part of a SQL statement, the statement will not execute and the execution plan would be an estimation. However, by using the EXPLAIN ANALYZE command, the statement will actually be executed in addition to displaying the execution plan itself.

PostgreSQL EXPLAIN Synopsis:

```
EXPLAIN [ ( option [, ...] ) ] statement
EXPLAIN [ ANALYZE ] [ VERBOSE ] statement

where option can be one of:

    ANALYZE [ boolean ]
    VERBOSE [ boolean ]
    COSTS [ boolean ]
    BUFFERS [ boolean ]
    TIMING [ boolean ]
    FORMAT { TEXT | XML | JSON | YAML }
```

Examples

1. Displaying the execution plan of a SQL statement using the EXPLAIN command:

```
psql=> EXPLAIN
       SELECT EMPLOYEE_ID, LAST_NAME, FIRST_NAME FROM EMPLOYEES
       WHERE LAST_NAME='King' AND FIRST_NAME='Steven';

------------------------------------------------------------------------------------------
 Index Scan using idx_emp_name on employees  (cost=0.14..8.16 rows=1 width=18)
   Index Cond: (((last_name)::text = 'King'::text) AND ((first_name)::text =
'Steven'::text))
(2 rows)
```

2. Running the same statement with the ANALYZE keyword:

```
psql=> EXPLAIN ANALYZE
       SELECT EMPLOYEE_ID, LAST_NAME, FIRST_NAME FROM EMPLOYEES
       WHERE LAST_NAME='King' AND FIRST_NAME='Steven';

--------------------------------------------------------------------------------
 Seq Scan on employees  (cost=0.00..3.60 rows=1 width=18) (actual
                         time=0.012..0.024 rows=1 loops=1)
   Filter: (((last_name)::text = 'King'::text) AND ((first_name)::text =
              'Steven'::text))
   Rows Removed by Filter: 106
 Planning time: 0.073 ms
 Execution time: 0.037 ms
(5 rows)
```

By adding the ANALYZE keyword and executing the statement, we get additional information in addition to the execution plan.

3. Viewing a PostgreSQL execution plan showing a `FULL TABLE SCAN`:

```
psql=> EXPLAIN ANALYZE
       SELECT EMPLOYEE_ID, LAST_NAME, FIRST_NAME FROM EMPLOYEES
       WHERE SALARY > 10000;

------------------------------------------------------------------------------------------
 Seq Scan on employees  (cost=0.00..3.34 rows=15 width=18) (actual time=0.012..0.036 rows=15
loops=1)
   Filter: (salary > '10000'::numeric)
   Rows Removed by Filter: 92
 Planning time: 0.069 ms
 Execution time: 0.052 ms
(5 rows)
```

PostgreSQL can perform several scan types for processing and retrieving data from tables including: sequential scans, index scans, and bitmap index scans. The sequential scan (“`Seq Scan`”) is PostgreSQL equivalent for Oracle “`Table access full`” (full table scan).

For additional information on PostgreSQL Execution Plans:
https://www.postgresql.org/docs/9.6/static/sql-explain.html

Migrating from: Oracle SecureFile LOBs

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Overview

LOBs – or Large Objects is a mechanism for storing binary data inside the Oracle database. Oracle 11g introduced a new data type for storing Large Objects (LOBs) binary files directly inside the database using more efficient storage. This feature is known as Secure File Lobs and implemented using the `SECUREFILE` keyword as part of the `CREATE TABLE` statement

Primary benefits of using `SECUREFILE` lobs include:

- **Compression**
  With Oracle advanced compression utilized to analyze the SecureFiles LOB data to save disk space.

- **De-Duplication**
  Automatically detect duplicate LOB data within a LOB column or partition and by removing duplicates of repeating binary data, reduce storage space.

- **Encryption**
  Combined with Transparent Data Encryption (TDE).

Examples

1. Create a table using a SecureFiles LOB column:

```
SQL> CREATE TABLE sf_tab (
     COL1        NUMBER,
     COL2_CLOB   CLOB)
     LOB(COL2_CLOB) STORE AS SECUREFILE;
```

2. Provide additional options for LOB compression during table creation:

```
SQL> CREATE TABLE sf_tab (
     COL1        NUMBER,
     COL2_CLOB   CLOB)
     LOB(COL2_CLOB) STORE AS SECUREFILE COMPRESS_LOB(COMPRESS HIGH);
```

For additional details:
https://docs.oracle.com/cd/E11882_01/appdev.112/e18294/adlob_smart.htm#ADLOB45944
https://docs.oracle.com/database/121/ADLOB/adlob_smart.htm#ADLOB4444

Migration to: PostgreSQL LOBs

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Overview

PostgreSQL does not support the advanced storage, security, and encryption options of Oracle SecureFile LOBs. Regular Large Objects datatypes (LOBs) are supported by PostgreSQL and provides stream-style access.

Although not designed specifically from LOB columns, for compression PostgreSQL utilizes an internal TOAST mechanism (The Oversized-Attribute Storage Technique).

For more details about PostgreSQL please use the following link:
https://www.postgresql.org/docs/9.4/static/storage-toast.html

Supported large objected Data Types by PostgreSQL are:

- **BYTEA**
  - Stores a LOB within the table limited to 1GB.
  - The storage is octal and supports non printable characters.
  - The input / output format is HEX.
  - Can be used to store a URL references to an AWS S3 objects used by the database. For example: storing the URL for pictures stored on AWS S3 on a database table.

- **TEXT**
  - Data type for storing strings with unlimited length.
  - When not specifying the (n) integer for specifying the varchar data type, the TEXT datatype behaves as the text data type.

For data encryption purposes (not only for LOB columns), consider using AWS KMS:
https://aws.amazon.com/kms/

For additional information on PostgreSQL LOB Support:
https://www.postgresql.org/docs/current/static/largeobjects.html