Oracle Database In-Memory
Powering the Real-Time Enterprise

19ᶜ ORACLE®
Database

KEY FEATURES

- In-Memory Column Format accelerates Analytics by orders of magnitude
- Dual-format architecture combines the best of column and row formats
- Many In-Memory optimizations, including In-Memory storage indexes, In-Memory compression, SIMD vector processing
- In-Memory Expressions and In-Memory Join Groups further increase performance
- Automatic In-Memory controls the content of the In-Memory column store
- Scale-up on the world's largest SMPs with 1000s of CPU threads
- Scale-Out on RAC clusters with in-memory fault tolerance, and the ability to isolate analytics from OLTP on different servers
- Maximum Availability Architecture including support for In-Memory column store on Active Data Guard Standby
- 100% compatible with existing applications
- Support for External Tables allows analytics on data not managed by Oracle Database.

KEY BENEFITS

- Dramatically faster Data Warehouses, Analytics, Business Intelligence, Dashboards, Reports
- Fast ad-hoc analytics without the need to pre-create indexes
- Reduces space consumed by analytic indexes that are no longer required
- Faster mixed workload OLTP
- Concurrent analytics and OLTP

Oracle Database In-Memory – part of Oracle Database 18c Enterprise Edition – adds in-memory database functionality to existing databases, and transparently accelerates analytics by orders of magnitude while simultaneously speeding up mixed-workload OLTP. With Oracle Database In-Memory, users get immediate answers to business questions that previously took hours.

Oracle Database In-Memory delivers leading-edge in-memory performance without the need to restrict functionality, or accept compromises, complexity and risk. Deploying Oracle Database In-Memory with any existing Oracle Database compatible application is as easy as flipping a switch - no application changes are required. Oracle Database In-Memory is fully integrated with Oracle Database's renowned scale-up, scale-out, storage tiering, availability, and security technologies making it the most industrial-strength offering on the market.

The ability to easily perform real-time data analysis together with real-time transaction processing on all existing applications enables organizations to transform into Real-Time Enterprises that quickly make data-driven decisions, respond instantly to customer demands, and continuously optimize all key processes.

Dual-Format Architecture

Oracle Database In-Memory optimizes analytics and mixed workload OLTP, delivering outstanding performance for transactions while simultaneously supporting real-time analytics, business intelligence, and reports.

This breakthrough capability is enabled by the "dual-format" architecture of Oracle Database In-Memory. Up to now, databases have forced users to store data in either column or row format. Column format is highly efficient for analytics, but imposes very large overheads when used in OLTP environments. Similarly, row format enables extremely fast OLTP, but is less optimized for analytics. The only way to optimize for both OLTP and analytics has been to copy data from OLTP systems to analytic systems using complex ETL processes that add a great deal of expense and latency.

The dual-format architecture of Oracle Database In-Memory eliminates this tradeoff by representing tables simultaneously using traditional row format and a new in-memory

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- No database size limit
- Transparently blends memory, flash, and disk to achieve highest performance and lowest cost
- Industrial strength availability and security
- Robustness and maturity of Oracle Database
- Easy implementation and management

column format. The Oracle SQL Optimizer automatically routes analytic queries to the column format and OLTP queries to the row format, transparently delivering best-of-both-worlds performance. Oracle Database automatically maintains full transactional consistency between the row and the column formats, just as it maintains consistency between tables and indexes.
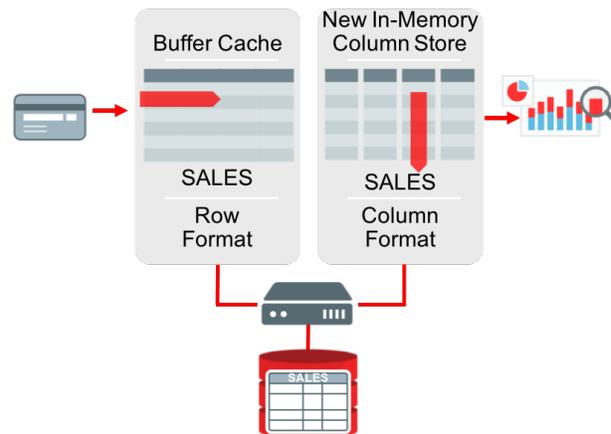

Figure 1. Oracle's unique dual-format architecture

Dual row and column formats are a unique feature of Oracle Database In-Memory.

The new column format is a pure in-memory format. Tables are stored on disk using Oracle's existing row-based or hybrid columnar formats. Since there is no persistent columnar storage format, there are no additional storage costs or storage synchronization issues. Changes to the purely in-memory column format are very fast because they don't need expensive persistent logging.

High performance transactions in combination with column formats is a unique feature of Oracle Database In-Memory. Most databases don't allow efficient OLTP when using column formats.

Having both a column and a row-based in-memory representation does not double memory requirements. Oracle uses its highly optimized buffer cache management algorithms to keep only actively accessed row data in memory. Oracle's in-memory columnar format uses sophisticated compression to expand memory capacity and improve query performance. Compression ratios vary from 2X – 20X, depending on the option chosen and redundancy in the data.

Comprehensive In-Memory Optimizations

Oracle Database In-Memory implements state-of-the-art algorithms for in-memory scans, in-memory joins, and in-memory aggregation. For example:

- Analytic queries typically reference only a small number of the columns in a table. Oracle Database In-Memory minimizes work and maximizes performance by accessing only those columns needed by a query, and by processing these columns directly without having to decompress them first.
- Tables are logically split into sections, and minimum and maximum values of every column are maintained for every section of a table. This allows queries to quickly skip table sections that only contain data outside of the range of data needed by the query.
- Some columns have many repeated values. Oracle Database In-Memory compresses these repeated values to save memory, and optimizes processing by executing query predicates just once for each unique column value.

"Now we can run time-sensitive analytical queries directly against our OLTP database. This is something we wouldn't have dreamt of earlier."

Arup Nanda
Enterprise Architect
Starwood Hotels and Resorts

- Modern microprocessors support SIMD (<u>S</u>ingle <u>I</u>nstruction for <u>M</u>ultiple <u>D</u>ata values) vector processing instructions to accelerate graphics and scientific computing. Oracle Database In-Memory can use these SIMD vector instructions to process multiple column values in a single CPU clock cycle.
- In-Memory table joins take advantage of the new columnar compressed format by converting join conditions into filters applied during very fast data scans or by executing the join on the compressed values within the join columns.
- *In-Memory Join Groups*, if declared, can further speed up in-memory hash joins by eliminating the overhead of decompressing and hashing column values. This further reduces CPU cycles and improves join performance.
- *In-Memory Expressions* enable frequently evaluated expressions to be materialized into the In-Memory column store. Analytic workloads typically spend a considerable amount of time on expression evaluation for each row returned by a query.
- In-Memory aggregation algorithms leverage the column format to speed up analytic queries and reports that aggregate large amounts of data.
- *In-Memory Dynamic Scans* accelerate In-Memory table scans by dynamically parallelizing the reading of IMCUs. This is controlled automatically by Resource Manager when additional CPU is available.
- *In-Memory External Tables* enables the population of External Tables without materializing them in Oracle Database. This enables analytic queries to take advantage of Database In-memory to access external data seamlessly and take advantage of the rich analytic functions available in Oracle Database.

Together, these optimizations enable Oracle Database In-Memory to run queries at the astounding rate of billions of rows per second for each CPU core. Analytics that previously took hours or days to run now completes in seconds, enabling real-time business decisions.

Mixed Workload OLTP

Mixed workload databases run reports and ad hoc queries in addition to OLTP transactions. It is common to create dozens of indexes on important tables purely to speed up reports. The Oracle Database In-Memory column format eliminates the need for most of these analytic indexes by delivering performance similar to having an index on every column, but with much less transaction overhead. Removing analytic indexes speeds up OLTP operations since these analytic indexes no longer need to be maintained by every transaction.

Scale-Out and Scale-Up

Oracle Database has been optimized and tuned for decades to scale-out on clusters of servers and scale-up on SMP servers. Oracle can parallelize a single SQL statement across thousands of processor cores, or run many concurrent users simultaneously with full isolation and consistency.

Oracle Database In-Memory builds on these technologies to scale-out to very high memory and CPU capacities by using all of the memory and processors in a cluster of servers. Unlike traditional in-memory databases, Oracle Database In-Memory has fully transparent and highly efficient scale-out capabilities for both analytics and OLTP.

"Oracle Database In-memory is a game changer for OLTP, DW, and mixed workloads. It dramatically improves the performance of all types of analytical queries."

Liviu Horn
AVP Database Management
McKesson Health Solution

Most other databases incur large overhead when data in column format is updated as part of mixed OLTP workloads.

"Full support for RAC scale-out means Oracle Database In-Memory can be used on our largest Data Warehouse, enabling more near real-time analytics."

Sudhi Vijayakumar
Senior Oracle DBA
Yahoo Inc

Most other in-memory databases cannot maintain duplicate in-memory copies and therefore will stall processing for many minutes or hours while data is reloaded from storage onto another node

Most other in-memory databases have limited and very immature high availability and security features.

"Oracle Database In-Memory option will permit us to remove roughly half the indexes from large mixed-workload databases, simultaneously speeding up both complex analytical queries and OLTP transactions."

Andrew Zitelli
Principal Software Engineer with Honors
Thales-Raytheon Systems

Many other in-memory databases have limited scale-up capabilities and no scale-out or very immature scale-out implementations.

Scale-out for real-world OLTP workloads with column formats is a unique feature of Oracle Database In-Memory.

In addition to being able to scale-out, Oracle Database In-Memory can also scale-up to very high memory and CPU capacities on large SMP servers with terabytes of memory.

In-Memory Fault-Tolerance

When a server node fails, the in-memory data on that node is lost. Queries can continue to run on surviving nodes, but it takes time to repopulate the in-memory data from storage, and during this time analytic queries will run much slower.

The fault-tolerance feature of Oracle Database In-Memory eliminates this slowdown on Oracle Engineered Systems by optionally duplicating data across the nodes of a cluster. Just as storage subsystems stripe and mirror data across disks to achieve high performance and high availability, Oracle Database In-Memory distributes and duplicates in-memory data across the nodes of a cluster. If a node fails, queries can transparently use the duplicate copy of data on surviving nodes.

Database In-Memory on Active Data Guard

With Oracle Database, it is possible to create, populate, and maintain an In-Memory column store on a standby database in an Active Data Guard configuration. This allows full use of the CPU and memory resources on the standby for analytic workloads and allows for flexible placement of the In-Memory column store across the primary and its affiliated standby databases.
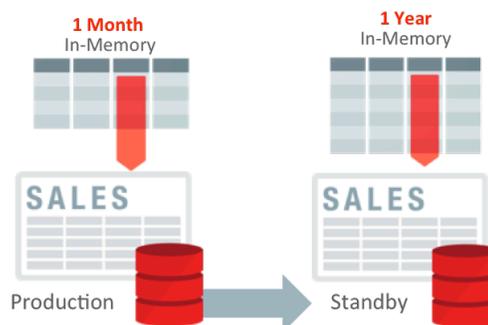

Figure 2. In-Memory column store fully usable on Standby with Active Data Guard

Automatic In-Memory

In Oracle Database 18c, Automatic In-Memory is available to automatically manage the contents of the IM column store. If the sum of the space of the segments that have been enabled for in-memory exceeds the available memory in the IM column store then Automatic In-Memory will kick in and manage the IM column store space using heat map statistics. Using access tracking, column statistics, and other relevant statistics segments can be automatically evicted from the IM column store to make room for the population of more active segments.

Database In-Memory Formats on Exadata Flash Cache

Database In-Memory supports the In-Memory columnar format in Exadata Flash Cache. This provides Exadata customers with the ability to extend the In-Memory Column store to the Exadata Flash Cache which has Terabytes of capacity.
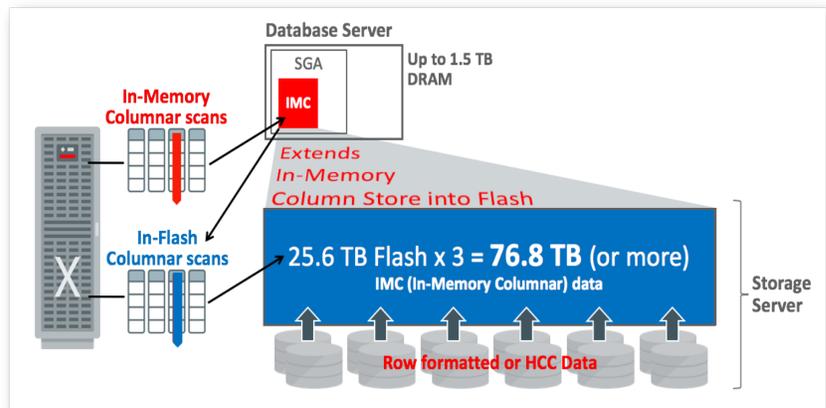

Figure 3. In-Memory column store extended into Exadata Flash Cache

The ability to support the In-Memory columnar format in both DRAM and Flash significantly extends the ability of customers to run analytic queries on much larger data footprints than ever before.

Lower Costs

The ultra fast performance delivered by Oracle Database In-Memory not only improves response times, it also lowers costs and improves productivity. For example: hardware and software for both servers and storage can potentially be reduced; employees are more productive because they no longer need to wait for slow reports; and database administrators spend less time tuning.

Real-Time Enterprise

Traditionally simple transactions execute in real-time, but answering business questions that require detailed data analysis can take hours. Oracle Database In-Memory takes advantage of massively scalable hardware with new in-memory data structures and algorithms to immediately answer any question. Oracle Database In-Memory processes data at a rate of *billions* of rows per second rather than millions. Moreover, analytics can run directly in OLTP databases, further reducing delays and improving accuracy by avoiding having to transform and copy data to a different systems.

The ability to easily combine real-time data analysis with real-time transaction processing on all existing applications enables organizations to become *Real-Time Enterprises* that:

- Make data-driven decisions based on immediate and accurate answers

"Utilizing Oracle Database In-Memory against our JD Edwards ERP suite for real time summarization has the potential to radically change the way we deliver reporting, analysis and insights to our business leaders."

Michael Macrie
Chief Information Officer
Land O'Lakes

No other in-memory database can match the functionality of the Oracle Database, and most impose restrictions on SQL syntax or database functionality when column formats are used. These restrictions make it impossible to run most existing applications without extensive modifications or limitations.

- Respond instantly to customer demands for information, choices, personalization, and engagement
- Continuously optimize all key processes including sales, marketing, manufacturing, staffing, costing, etc. using detailed, up-to-date data

Using Oracle Database In-Memory, organizations can become Real-Time Enterprises that out-innovate competitors, delight customers, and improve the bottom line.

Oracle In-Memory Applications

Oracle has embraced the benefits of Oracle Database In-Memory throughout its products. Each of Oracle's Applications - including Oracle Fusion Applications, Oracle JD Edwards EnterpriseOne, Oracle PeopleSoft, Oracle Siebel, Oracle E-Business Suite, and Oracle Hyperion—is developing new In-Memory modules that leverage Oracle Engineered Systems and Oracle Database In-Memory to transform critical but slow business processes into real-time processes. For example:

- Cost and Profitability Analysis that took 57 hours now runs in minutes
- Financial Position Analysis that took over 4 hours now runs in seconds
- Sales Order Analysis that took days now runs in less than a second
- Consumption Driven Planning that took 13 hours now runs in minutes

Users and application developers can use Oracle Database In-Memory to make similar improvements in their own applications.

100% Compatible

Oracle Database In-Memory is designed to be completely and seamlessly compatible with existing applications. No changes are required to use it with any application or tool that runs against Oracle Database. Analytic queries are automatically routed to the column store by the SQL optimizer, and transactional semantics are guaranteed by the database.

Easy to Implement and Manage

In addition to being compatible at the application level, Oracle Database In-Memory is easy to implement and manage. Enabling Oracle Database In-Memory is as easy as setting the size of the in-memory column store and identifying tables or partitions to bring into memory.

Summary: Highest Performance, Maturity, and Compatibility

Oracle Database In-Memory transparently accelerates analytic queries by orders of magnitude enabling real-time decisions. It dramatically accelerates Data Warehouses, Data Marts, and Mixed Workload OLTP environments. Oracle Database In-Memory implements a unique dual-format architecture that delivers fast analytics together with high-performance OLTP.

Oracle Database In-Memory is easily deployed under any existing application that is compatible with Oracle Database. No application changes are required. Oracle Database In-Memory uses Oracle's mature scale-up, scale-out, and storage-tiering technologies to cost effectively run any size workload. Oracle's industry leading

availability and security features all work transparently with Oracle Database In-Memory, making it the most robust offering on the market.

Extreme performance for both analytics and transactions enables organizations to continuously optimize processes and make rapid data-driven decisions thereby transforming into Real-Time Enterprises that are extremely agile and efficient.

ORACLE DATABASE IN-MEMORY

POWERING THE REAL-TIME ENTERPRISE

Speed Up Analytics by Orders of Magnitude	Oracle Database In-Memory transparently extends industry-leading Oracle Database with columnar in-memory technology. Users get immediate answers to business questions that previously took hours because highly optimized in-memory column formats and SIMD vector processing enable analytics to run at a rate of billions of rows per second per CPU core.
Unique Architecture Runs Analytics in Real-Time while Accelerating Mixed Workload OLTP	Column format is optimal for analytics while row format is optimal for OLTP. Oracle Database In-Memory uses both formats simultaneously to allow real-time analytics on both Data Warehouses and OLTP databases. Indexes previously required for analytics can be dropped, accelerating mixed-workload OLTP.
Compatible with All Existing Applications	Deploying Oracle Database In-Memory with any existing Oracle Database-compatible application is as easy as flipping a switch, no application changes are required. All of Oracle's extensive features, data types, and APIs continue to work transparently.
Industry-Leading Scale-Up	Oracle's highly mature scale-up technologies enable application transparent In-Memory scale-up on SMP computers with up to tens of terabytes of memory and thousands of CPU threads. Data is analyzed at the enormous rate of hundreds of billions of rows per second with outstanding efficiency and no feature limitations.
Industry-Leading Scale-Out	Oracle's highly mature scale-out technologies enable application transparent In-Memory scale-out across large clusters of computers with 100s of terabytes of memory and thousands of CPU threads. Data is analyzed at the enormous rate of trillions of rows per second with no feature limitations.
Industry-Leading High Availability and Security	Oracle's renowned Availability and Security technologies all work transparently with Oracle Database In-Memory ensuring extreme safety for mission critical applications. On Oracle Engineered Systems, In-Memory fault tolerance duplicates in-memory data across nodes enabling queries to instantly use an in-memory copy of data if a node fails.
Cost Effective for Even the Largest Database	Oracle Database In Memory does not mandate that all data must fit in memory. Frequently accessed data can be kept In-Memory while less active data is kept on much lower cost flash and disk.
Powering the Real-Time Enterprise	The ability to easily perform real-time data analysis together with real-time transaction processing on all existing applications enables organizations to transform into Real-Time Enterprises that quickly make data-driven decisions, respond instantly to customer demands, and continuously optimize all key processes.

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