ORACLE
Exadata

Oracle Exadata Database Machine X8M-8

The Oracle Exadata Database Machine is engineered to deliver dramatically better performance, cost effectiveness, and availability for Oracle databases. Exadata features a modern cloud-enabled architecture with scale-out high-performance database servers, scale-out intelligent storage servers with state-of-the-art PCI flash, leading-edge storage cache using persistent memory, and cloud scale RDMA over Converged Ethernet (RoCE) internal fabric that connects all servers and storage. Unique algorithms and protocols in Exadata implement database intelligence in storage, compute, and networking to deliver higher performance and capacity at lower costs than other platforms, for all types of modern database workloads including Online Transaction Processing (OLTP), Data Warehousing (DW), In-Memory Analytics, Internet of Things(IoT), as well as efficient consolidation of mixed workloads. Simple and fast to implement, the Exadata Database Machine powers and protects your most important databases. Exadata can be purchased and deployed on premises as the ideal foundation for a private database cloud, or it can be acquired using a subscription model and deployed in the Oracle Public Cloud or Cloud at Customer with all infrastructure management performed by Oracle.

Oracle Exadata Database Machine X8M-8

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The Exadata Database Machine X8M-8 is a high-end database machine that has the same extreme performance, storage, and Network Fabric as the X8M-2, but uses large-scale 8-socket SMP servers instead of the 2-socket servers in X8M-2. Each of the 8-socket servers in the X8M-8 has a total of 192 processor cores and 3 terabytes to 6 terabytes of DRAM. The Exadata Database Machine X8M-8 excels at high-end online transaction processing (OLTP), multi-rack Data Warehouses, and In-Memory Database workloads. It is ideally suited for applications that desire large scale-up servers with large memory capacity.

Key Features

- Up to 576 CPU cores and 18 TB memory per rack for database processing
- Up to 576 CPU cores per rack dedicated to SQL processing in storage
- Up to 21 TB of Persistent Memory Acceleration per rack
- 100 Gb/sec RoCE Network
- Complete redundancy for high availability
- From 2 to 3 Database Servers per rack
- From 3 to 14 Storage Servers per rack
- Up to 720 TB of flash capacity (raw) per rack
- Up to 2.3 PB of disk capacity (raw) per rack

ENGINEERED FOR FAST AND RELIABLE DEPLOYMENT

The Exadata Database Machine is the most cost-efficient and highest performance platform for running Oracle Databases. Exadata is easy to deploy even for the most mission-critical systems, as the database servers, storage servers and network are pre-configured, pre-tuned and pre-tested by Oracle experts. Extensive end-to-end testing and validation ensures all components including database software, operating system, firmware, drivers, etc., work seamlessly together and that there are no performance bottlenecks or single points of failure.

Because all Exadata Database Machines are identically configured, customers benefit from the experience of thousands of other customers' Exadata Database Machine deployments. Customer machines are also identical to the machines Oracle Support uses for problem identification and resolution, the machines Oracle Development uses for development and testing of the Oracle Database, and the machines that run Oracle's own public cloud services. **Exadata is the most thoroughly tested and tuned platform for running Oracle Database.**

Any application that uses the Oracle Database today can be seamlessly migrated to the Exadata Database Machine, with no changes to the application. Likewise, any Oracle Database can also be easily migrated off Exadata, eliminating "lock-in" concerns.

Key Benefits

- Pre-configured, pre-tested system optimized for all database applications
- Uncompressed I/O bandwidth of up to 560 GB/sec per full rack from SQL
- Ability to perform up to 9M 8K database read I/O operations, and 5.1M 8K flash write I/O operations per second in a single rack
- Easily add compute or storage servers to meet the needs of any size application
- Scale by connecting multiple Exadata Database Machine X8M-8 racks or Exadata X8M Storage Expansion Racks. Up to 18 racks can be connected by simply adding RoCE cables and internal switches. Larger configurations can be built with external RoCE switches

EXTREME SYSTEM SCALABILITY AND GROWTH WITH ELASTIC CONFIGURATIONS

The Exadata Database Machine uses a scale-out architecture for both database servers and storage servers. As workloads grow, database CPUs, storage, and networking can be added to an Exadata Database Machine to scale without bottlenecks. The **architecture expands from small to extremely large configurations to accommodate workloads of any size.**

A brand new high-bandwidth low-latency 100 Gb/sec **RDMA over Converged Ethernet (RoCE) Network Fabric** connects all the components inside an Exadata Database Machine. Specialized database networking protocols deliver much lower latency and higher bandwidth than is possible with generic communication protocols for **faster response time for OLTP operations and higher throughput for analytic workloads.** External connectivity to the Exadata Database Machine is via standard 10 Gb/sec or 25 Gb/sec Ethernet.

Within the Exadata family, Exadata X8M-8 is a high-end database machine that is particularly well suited to large OLTP databases that benefit from running on small numbers of large compute nodes, in-memory database workloads requiring very large memory capacity, large multi-rack configurations

that benefit from reduced numbers of database nodes, and databases with high I/O requirements that can benefit from very large buffer caches.

Exadata Database Machine is the most versatile database platform. The Exadata X8M-8 Database Machine uses powerful database servers, each with eight 24-core x86 processors and 3 TB of memory (expandable up to 6 TB). Exadata also uses scale-out, intelligent storage servers available in two configurations – High Capacity (HC) or Extreme Flash (EF). HC Storage Servers have four NVMe PCI Flash cards each with 6.4 TB (raw) Exadata Smart Flash Cache and twelve 14 TB 7,200 RPM disks. EF Storage Servers have an all-flash configuration with eight NVMe PCI Flash drives, each with 6.4 TB (raw) storage capacity. Exadata X8M HC and EF Storage now include persistent memory, further boosting capacity and performance. HC and EF Servers receive twelve 128 GB Intel® Optane™ DC Persistent Memory modules as a new tier between DRAM and flash. Exadata combines persistent memory with **innovative RDMA algorithms that bypass the network and I/O stack, eliminating expensive CPU interrupts and context switches, reducing latency by 10x**, from 200µs to less than 19µs.

The minimal configuration of an Exadata Database Machine consists of two database servers and three storage servers, which **can be expanded into elastic configurations adding more database a third database server and/or storage servers within the same rack**. Elastic configurations provide a flexible and efficient mechanism to meet any size business need.

In addition to expanding within a rack, **multiple Exadata X8M racks can be connected using the integrated RoCE network fabric** to form even larger configurations. For example, a system composed of four racks is simply four times as powerful as a single rack: it provides four times the I/O throughput, four times the storage capacity, and four times the processing power. It can be configured as a single system or logically partitioned for multiple databases. Scaling out is easy, as Oracle Real Application Clusters (RAC) can dynamically add more processing power, and Automatic Storage Management (ASM) can dynamically add more storage capacity.

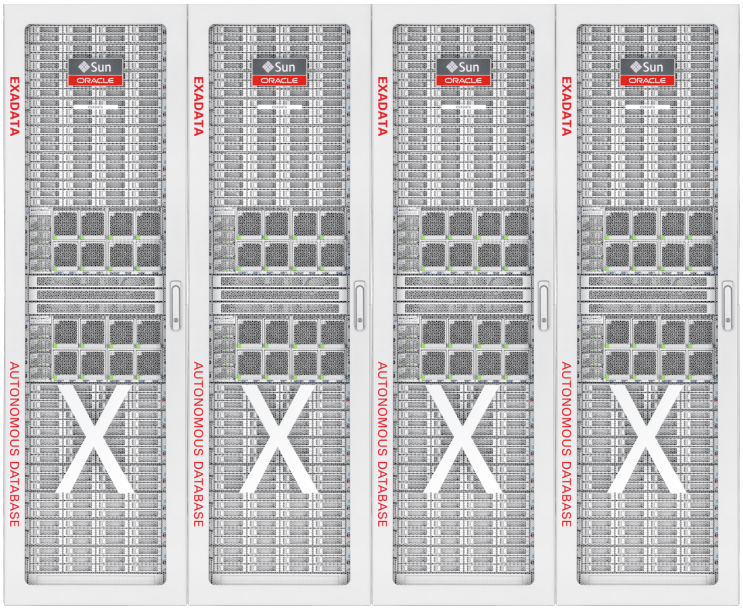

Figure 1. Elastic Scale-out to Multi-rack Exadata

Related Products

- Oracle Database Exadata Cloud Service
- Oracle Database Exadata Cloud at Customer
- Oracle Exadata Database Machine X8M-8
- Oracle Exadata Storage Expansion Rack X8M
- Oracle Exadata Storage Server X8M-2 Plus Network Fabric
- Oracle Exadata Database Server X8M-8 Plus Network Fabric
- Oracle Database 11g, 12c, 18c and 19c
- Real Application Clusters
- Partitioning
- Multitenant
- Database In-Memory
- Advanced Compression
- Advanced Security
- Active Data Guard
- GoldenGate
- Real Application Testing
- OLAP
- Advanced Analytics
- Business Intelligence
- Enterprise Manager
- Oracle Linux
- Oracle Virtual Machine

Related Services

The following services are available from Oracle:

- Advanced Customer Services
- Oracle Premier Support for Systems
- Oracle Platinum Services
- Oracle Consulting Services
- Oracle University courses

When large storage capacity is required, the **Oracle Exadata X8M Storage Expansion Rack** is available. The Exadata Storage Expansion Rack enables customers to grow the storage capacity and corresponding bandwidth of any Exadata Database Machine. It is designed for database deployments with very large amounts of data, including historical or archive data, backups, documents, images, XML, JSON, and LOBs. The storage expansion rack connects to the Exadata Database Machine using the integrated RoCE network fabric and is configured with a few simple commands, as there are no LUNs or mount points. The starting configuration of the Oracle Exadata Storage Expansion Rack consists of four storage servers and can be expanded with additional storage servers.

"I would recommend Exadata as a platform for performance, reliability and ease of support. Those three things mean very much to me in my daily life."

Richard Ewald
Senior Technical Architect
Sprint

NEW WITH EXADATA X8M: GROUNDBREAKING RDMA BASED NETWORK FABRIC

The Exadata X8M release provides the next generation in ultra-fast cloud scale networking fabric, RDMA over Converged Ethernet (RoCE). RDMA (Remote Direct Memory Access) allows one computer to directly access data from another without Operating System or CPU involvement, for high bandwidth and low latency. The network card directly reads/writes memory with no extra copying or buffering and very low latency. RDMA is an integral part of the Exadata high-performance architecture, and has been tuned and enhanced over the past decade, underpinning several Exadata-only technologies such as Exafusion Direct-to-Wire Protocol and Smart Fusion Block Transfer. As the RoCE API infrastructure is identical to InfiniBand's, **all existing Exadata performance features are available on RoCE.**

The Exadata X8M release implements 100 Gb/sec RoCE network fabric, making the world's fastest database machine even faster. Real world database workloads running on Exadata X8M-2, deployed with the new **shared persistent memory accelerator**, have smashed the previous benchmark of 6.7M Read IOPS, set by Exadata X8, with over 16 Million Read OLTP Read IOPS (8K IOs).

"Oracle Exadata enabled seamless and rapid migration of our cloud-based, integrated business applications, required no major modifications, and helped us reduce costs. With Oracle, we dramatically improved our batch processing speed by 241x and overall system performance by 3x, enabling us to improve operating efficiency for our daily, critical tasks and to enhance customer service."

Kyoji Kato
Executive Officer and GM
Daiwa House

NEW WITH EXADATA X8M: SHARED PERSISTENT MEMORY ACCELERATION

New with Exadata X8M, storage servers include persistent memory (PMEM) data and commit accelerators in front of flash cache, enabling orders of magnitude lower latency accessing remotely stored data. Persistent memory is a new silicon technology, adding a distinct storage tier of performance, capacity, and price between DRAM and Flash. As the persistent memory is physically present on the memory bus of the storage server, reads perform at memory speed, much faster than flash. Writes are persistent, surviving power cycles, unlike DRAM. By utilizing RDMA to access persistent memory remotely, **Exadata Smart PMEM Cache** is able to bypass the network, I/O software, interrupts and context switches, achieving more than 10x lower latency than previous Exadata generations, down to less than 19 microseconds. Smart Exadata System Software also ensures data is mirrored across storage servers, which provides additional fault-tolerance. Exadata's unique end-to-end integration between Oracle Database and Exadata Storage automatically identifies the hottest data blocks to store, while ensuring database, persistent memory, and flash cache do not hold the same block multiple times, increasing the efficiency across the storage tiers. Adding persistent memory to the storage tier means the aggregate performance of this new cache tier can be dynamically used by any database on any server. This is a significant advantage over general-purpose storage architectures, which preclude sharing across servers.

Another smart new Exadata System Software feature boosts log write performance. Log write latency is critical for OLTP performance, a faster log write means faster commit times. Inversely, any slowdown of log writes can cause the database to stall. Unique to Exadata X8M, **Exadata Smart PMEM Log** automatically enables the database to issue a one-way RDMA log write to persistent memory. RDMA and persistent memory technologies allow the log write to occur without acknowledgement, and smart software places the write across multiple servers for resilience. This leads to an 8x performance increase in log writes.

Security and management of this new tier are also automated. Persistent memory is configured automatically at installation time, with no user interaction required. Hardware monitoring is configured out of the box. Persistent memory is only accessible to databases using database access controls, ensuring end to end security of data. Deploying persistent memory in Exadata X8M is so simple, it's transparent.

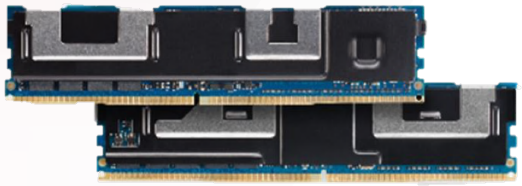

Figure 2. Intel® Optane™ DC Persistent Memory modules

EXTREME FLASH STORAGE SERVER: RECORD-BREAKING I/O PERFORMANCE

Exadata **Extreme Flash (EF) Storage Server**, first introduced with Exadata X5, is the foundation of a database-optimized all-flash Exadata Database Machine. Each EF Storage Server contains eight 6.4 TB Flash Accelerator F640v2 NVMe PCI Flash drives, offering 51.2 TB raw flash capacity per EF Storage Server. This state-of-the-art flash memory improves speed and power efficiency, and provides an expected endurance of 8 years or more for typical database workloads. In addition, Exadata delivers ultra-high performance by placing these flash devices directly on the high speed PCI bus rather than behind slow disk controllers and directors. Exadata X8M adds the shared persistent memory acceleration tier, twelve 128 GB Intel® Optane™ DC Persistent Memory modules in front of flash to boost performance even more.

"Oracle Exadata Database Machine is helping to transform our business. Our SAP environment, one of the world's largest, can now support twice as much throughput with improved stability."

Milt Simonds
Director, Enterprise Platform Delivery
AmerisourceBergen Corporation

Exadata X8M uses a combination of scale-out storage, RDMA over Converged Ethernet networking, database offload, persistent memory accelerator and PCI Flash to deliver extremely high performance from memory and flash. A single rack configuration of Exadata Database Machine X8M-8, with 3 database servers and 14 Extreme Flash storage servers, using the new persistent memory accelerator, can achieve up to **9 Million random 8K database read and 5.1 Million random 8K flash write I/O operations per second (IOPS)**.

These are real-world end-to-end performance figures measured running SQL workloads with standard 8K database I/O sizes inside a single rack Exadata system, unlike storage vendor performance figures based on small I/O sizes and low-level I/O tools and are therefore many times higher than can be achieved from realistic SQL workloads. Exadata's performance on real database workloads is orders of magnitude faster than traditional storage array architectures, and is also much faster than current all-flash storage arrays, whose architecture bottlenecks flash throughput.

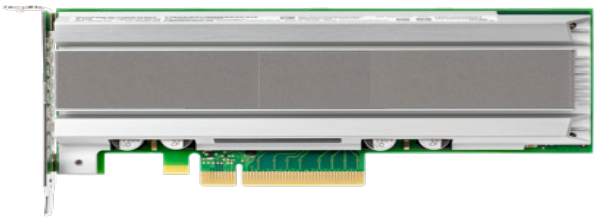

Figure 3. Flash Accelerator PCIe Card

HIGH CAPACITY STORAGE SERVER: TIERED DISK FLASH AND PERSISTENT MEMORY DELIVER COST OF DISK WITH SHARED MEMORY PERFORMANCE

The second Exadata storage option is the **High Capacity (HC) Storage Server**. This server includes twelve 14 TB SAS disk drives with 168 TB total raw disk capacity. It also has four Flash Accelerator F640v2 NVMe PCIe cards with a total raw capacity of 25.6 TB of flash memory. Exadata X8M adds the shared persistent memory acceleration tier, twelve 128 GB Intel® Optane™ DC Persistent Memory modules in front of flash to boost performance even more. Deployed using smart software, **Exadata Smart PMEM Cache**, only the hottest database blocks are automatically cached in this new tier. Accessible over RDMA direct from the database delivers the highest I/O rates at an extremely low latency.

Flash in the HC Storage Server can be used directly as flash disks, but is almost always configured as a flash cache (**Exadata Smart Flash Cache**) in front of disk storage behind the PMEM Cache to deliver the best performance. Exadata Smart Flash Cache is used in-sync with PMEM Cache to automatically cache frequently accessed data while keeping infrequently accessed data on disk, delivering the high I/O rates and fast response times of flash with the large capacity and low cost of disk. Exadata uniquely understands database workloads and **knows when to avoid caching data that will negatively affect overall performance**. For example, if large write I/Os caused by backups or large table scans are likely to disrupt higher priority OLTP or scan operations, those large I/Os will bypass the flash cache and go straight to disk. Otherwise, Exadata System Software will utilize additional spare flash capacity and I/O bandwidth to optimize performance by caching these I/Os. In addition to automatic caching, administrators can optionally provide SQL directives to ensure that specific tables, indexes, or partitions are preferentially retained in the flash cache.

It is common for hit rates in the Exadata Smart Flash Cache to be over 95%, or even 99% in real-world database workloads, yielding an effective flash capacity many times larger than the physical flash. For example, a traditional full rack, with 8 database servers and 14 High Capacity Storage Servers often has an effective flash capacity close to the usable disk capacity of 700 TB.

The Exadata Smart Flash Cache also caches database block writes using Exadata Write Back Flash Cache technology. Write caching eliminates disk bottlenecks in large scale OLTP and batch workloads. The flash write capacity of a single full rack Exadata Database Machine X8M-8 with 3 database servers and 11 High Capacity Storage Servers exceeds **5.1 Million 8K flash write I/O operations per second (IOPS)**. The Exadata write cache is transparent, persistent, and fully redundant, with performance comparable to dozens of enterprise disk arrays with thousands of disk drives.

The automatic data tiering between RAM, persistent memory, flash and disk in Exadata provides tremendous advantages over other flash-based solutions. Many storage vendors have developed flash-only arrays to achieve higher performance than traditional arrays. These flash-only arrays deliver better performance but cannot match the cost advantages of Exadata's smart tiering of data between disk and flash, as the overall size of data that can benefit from flash is limited to the size of expensive flash. And these flash arrays are unable to benefit from Exadata's unique database-aware storage optimization technologies. Generic data deduplication provided by some flash arrays is effective for Virtual Desktop Infrastructure environments, but not for databases.

Exadata not only delivers much more capacity than generic all-flash arrays, it also delivers better performance. Flash-only storage arrays cannot match the throughput of Exadata's integrated and optimized architecture with full 100 Gb/sec RDMA over converged ethernet based scale-out network, fast PCI Flash, offload of data intensive operations to storage, and algorithms throughout that are specifically optimized for databases.

"We chose Oracle Exadata because it offered a complete solution ... we've created daily financial reports 4x faster and liquidity risk reports 7x faster to consistently meet our service-level agreement, improved credit risk management, and reduced our data center footprint."

Vaibhav Samant
Senior Vice President, IT
HDFC Bank Ltd.

EXTENDED CAPACITY STORAGE SERVER: MUCH LOWER COST EXADATA STORAGE FOR LOW USE DATA

A third Exadata storage option was introduced with Exadata X8 - the **Extended (XT) Storage Server**. Each Exadata XT Storage Server includes twelve 14 TB SAS disk drives with 168 TB total raw disk capacity. To achieve a lower cost, flash is not included, and storage software is optional in this storage server. For the X8M generation, the XT Extended Storage server benefits from the addition of 100Gb/s network.

This storage option extends the operational and management benefits of Exadata to rarely accessed data that must be kept online. Exadata's Extended (XT) Storage Server is:

- Efficient – The XT server offers the same high capacity as the HC Storage server, including Hybrid Columnar Compression
- Simple – The XT server adds capacity to Exadata while remaining transparent to applications, transparent to SQL, and retains the same operational model
- Secure – The XT server enables customers to extend to low-use data the same Exadata security model and encryption used for online data
- Fast and Scalable – Unlike other low-use data storage solutions, the XT server is integrated to the Exadata fabric, for fast access and easy scale-out
- Compatible – The XT server is just another flavor of Exadata Storage server – you can just add XT servers to any Exadata rack

With Exadata Extended (XT) Storage Server, enterprises can meet their long-term data retention compliance requirements with the same trusted and continually validated Exadata solution, avoiding the operational risks and costs of managing information lifecycle across multiple platforms.

"The heart and soul of our stack right now is Oracle Exadata Database Machine. With Oracle Exadata, we've been able to reduce queries from days to minutes, and those that used to take minutes to seconds."

Chris Wones
Enterprise Architect
Dunnhumby

ACCELERATING DATABASE PROCESSING WITH SMART SYSTEM SOFTWARE

As data volumes continue their fast growth, conventional storage arrays struggle to quickly transfer data from disk and flash to database servers at a rate that keeps the CPUs busy. Modern servers with dozens of CPU cores can consume data at many tens to hundreds of gigabytes a second. This is far faster than conventional storage arrays can deliver data through their storage controllers and the storage network.

Exadata System Software enables Exadata's unparalleled performance without any of the bottlenecks of traditional storage, by implementing a unique highly efficient database-optimized storage infrastructure on the Exadata Storage Server. Each Exadata Storage Server has two 16-core x86 processors that are used to offload database processing, and a rack of Exadata Database Machine can have a total of up to 576 processor cores in the storage servers able to offload the database servers. The CPUs in the storage servers do not replace database CPUs. Instead they accelerate database intensive workloads similar to how graphics cards accelerate image intensive workloads.

One of the many unique features of Exadata System software is **Smart Scan** technology, which **offloads data intensive SQL operations from the database servers directly into the storage servers**. By pushing SQL processing to the storage servers, data filtering and processing occur immediately and in parallel across all storage servers, as data is read from disk and flash. **Only the rows and columns that are directly relevant to a query are sent to the database servers**.

For example, if a query is executed to identify the customers who placed sales orders over $1000 in the month of March, an Exadata system will offload the scanning of the table to the Exadata storage, filter out all sales orders that are less than $1000, filter out sales orders not in March, and extract just the relevant customer information. This reduces the data transferred to the database servers by orders

"[With Exadata] We can more quickly process 65 billion daily transactions for data charging, while providing real-time information for customer inquiries, increasing customer satisfaction, and reducing costs."

Jin Hyung Lee
ICT Team Manager, Networking Engineering
SK Telecom

of magnitude. Smart Scan greatly accelerates query execution, eliminates bottlenecks, and significantly reduces the CPU usage of the database servers.

Storage Index is another powerful **unique** capability of Oracle Exadata System software that helps avoid unnecessary I/O operations and improves overall performance. The storage index, maintained in-memory at the storage server, tracks summary information for table columns contained in a storage region on that storage server. When a query specifies a WHERE clause, Exadata System software examines the storage index using a Bloom filter to determine if rows with the specified column value might exist in a region of disk on the storage server. If the column value doesn't exist in the Bloom filter, then scan I/O in that region for that query is skipped. Storage Indexes make many SQL operations run dramatically faster because large numbers of I/O operations are automatically replaced by a few in-memory lookups.

"Exadata is the heart of the booking engine, and we cannot operate as a business, we cannot sell tickets without it."

James Callaghan
Chief Technologist
Westjet

Besides the intrinsic capabilities of Exadata System software, the combination of Oracle Database software, Exadata System software and Exadata infrastructure enables several additional unique capabilities that offer unparalleled performance levels for **OLTP** workloads. For example, **Exafusion Direct-to-Wire Protocol** uniquely allows database processes to read and send Oracle Real Applications Cluster (Oracle RAC) messages directly over the ultra-fast RoCE network using **Remote Direct Memory Access** (RDMA), bypassing the OS kernel and networking software overhead. This improves the response time and scalability of Oracle RAC OLTP configurations on Oracle Exadata Database Machine, especially for workloads with high-contention updates.

In some OLTP workloads, more than half of remote reads are for Undo Blocks to satisfy read consistency. Exadata uniquely leverages ultra-fast **RDMA to read UNDO blocks** from other database instances, further improving OLTP performance.

The **Smart Fusion Block Transfer** capability **uniquely** improves performance of a RAC OLTP configuration further by eliminating the impact of redo log write latency, especially when hot blocks need to be transferred between sending and receiving nodes. The block is transferred as soon as the I/O to the redo log is issued at the sending node, without waiting for it to complete. Oracle internal tests show that Smart Block Transfer increases throughput (about 40% higher) and decreases response times (about 33% less) for communication-intensive workloads.

"Exadata delivers an amazing 20x compression for our Data Warehouse."

Jonathan Walsh
Head of BI & DW
Morrisons, Plc.

To further accelerate OLTP workloads, new with Exadata X8M High Capacity and Extreme Fast Storage Servers, a Persistent Memory Commit Accelerator is added, enabling the database to perform log writes via RDMA direct to the persistent memory buffer of multiple storage servers in parallel. Deployed as **Exadata Smart PMEM Log,** it avoids interaction with the Operating System and the overhead of transferring data via the standard I/O path. This one-way transaction increases performance of log writes by up to 8 times.

In addition, Exadata **uniquely** uses Machine Learning to implement **Automatic Indexing with Oracle Database 19c**. Automatic Indexing continually analyzes executing SQL and creates new indexes to accelerate performance. Automatic Indexing **continuously learns and tunes** the database as the underlying data model or usage patterns change.

Exadata also **uniquely** implements **Real Time Statistics** gathering as DML operations insert, update or delete data. Real Time Statistics allows the SQL optimizer to adapt plans dynamically as the distribution of data changes.

OPTIMIZING STORAGE USE AND I/O THROUGH COMPRESSION

The Exadata Storage Server provides a unique compression capability called **Hybrid Columnar Compression (HCC) that enables dramatic reductions in storage for large databases**. Hybrid Columnar Compression technology is an innovative method of organizing data within a database table

that uses a combination of both row and columnar methods for storing data. This hybrid approach achieves the compression benefits of columnar storage, while avoiding the performance shortfalls of a pure columnar format.

With Hybrid Columnar Compression, Exadata enables the highest levels of data compression possible with Oracle databases, and provides substantial cost-savings and performance improvements due to reduced I/O, especially for analytic workloads. Storage savings is data-dependent and often ranges from 5x to 20x. Average storage savings is an industry-leading 10x. On conventional systems, enabling high data compression has the drawback of reducing performance as it adds the load of decompression to the CPU. Because the Exadata Database Machine is able to offload decompression to processors in Exadata storage, and in addition there is reduced I/O need because of the high compression achieved, most analytic workloads run faster using Hybrid Columnar Compression than without it.

"I don't get the calls in the middle of the night anymore that we have a system down. Exadata is taken as always being available."

James Callaghan
Chief Technologist
Westjet

Two modes of Hybrid Columnar Compression are available. **Warehouse compression** mode is suitable for read-intensive workloads and provides large storage savings and enhanced analytic performance. **Archive compression** mode provides the highest degree of compression and is targeted at data that is seldom accessed but still must be kept online. In addition, this data can now be seamlessly stored on the XT storage server for further cost reduction.

On OLTP systems, Hybrid Columnar Compression can be used to compress older, less active data while newer, more active and update-intensive data can be compressed using Advanced Row Compression. Oracle Database Release 18c and above provides the ability to change the type of compression used by individual table partitions online (even if there are global indexes on the table), to ensure seamless tiering across different compression types as data ages and becomes less active.

For data analytics, Exadata Smart flash Cache implements a unique algorithm to accelerate reporting and analytical queries, called **Exadata Columnar flash Cache**. Columnar flash Caching implements a dual format architecture in Exadata flash by automatically transforming frequently scanned Hybrid Columnar Compressed data into a pure columnar format as it is loaded into the flash cache. Smart scans on pure columnar data in flash run faster because they read only the selected columns, reducing flash I/Os and storage server CPU consumption. This accelerates reporting and analytic queries while maintaining excellent performance for OLTP-style single row lookups.

"Our critical electronic payments service has been live on Exadata since early 2011 with 100% uptime. The service reliably processes the transfer of billions of Euros per week and achieves subsecond response times for online enquiries."

Martin McGeough
Database Technical Architect
Vocalink

FAULT TOLERANT AND FASTEST DATABASE IN-MEMORY MACHINE FOR ANALYTICS AND MIXED WORKLOADS

Exadata is the ideal platform for running Oracle Database In-Memory. Oracle Database In-Memory on Exadata does not require all data to reside in memory. Data can be stored across multiple tiers of storage, with the hottest data in memory providing extremely high query performance, active data on flash providing very high I/O throughput, and less active or older data on disk at a very low cost. **A single query can access data from all three tiers: memory, flash, and disk, completely transparently**. This allows Exadata to run faster, support higher capacities and deliver lower costs than competing products.

In addition, Exadata uniquely implements **In-Memory columnar formats in Flash Cache**. This feature extends the Exadata Columnar Flash Cache by automatically transforming data into In-Memory columnar formats as it is loaded into flash cache. Smart Scans also process multiple column values with a single instruction by leveraging ultra-fast Single Instruction Multiple Data (SIMD) Vector instructions. Smart Scan results are passed back to the database server in Oracle Database In-Memory formats, further reducing the load on database server CPUs. The effect is to seamlessly extend the In-Memory columnar store size from DRAM capacity in the database server to flash capacity in storage servers. An Exadata X8M-8 Full Rack HC has 360 TB of Flash Cache, capable of

servicing some of the largest in-memory workloads. Databases not using Oracle Database In-Memory still benefit from Exadata Columnar Flash Cache without the vector processing optimizations.

Exadata uniquely implements **Fault Tolerant memory duplication for Oracle Database In-Memory**. On a generic cluster configuration, when a server node fails, the in-memory data on that node is lost, and it takes many minutes to repopulate the in-memory data on a surviving node. During this time, analytic queries will run orders of magnitude slower. This means generic platforms will fail to meet business SLAs. However, on Exadata, Fault-Tolerant memory duplication can eliminate this slowdown by duplicating any subset of the in-memory data across the clustered database servers. If a database server fails, queries will transparently access the duplicate copy on a surviving database server and continue without interruption.

Exadata uniquely integrates with **Active Data Guard** to allow customers to run In-Memory analytics on a standby database, further improving the return on investment of the standby system, and enhancing availability and overall performance.

"By consolidating 350 database servers and storage systems onto Oracle Exadata, we gained a high-performance, reliable, and scalable mobile billing platform, enabling us to calculate billings data 10x faster, and halve maintenance costs."

Tomoki Shimamura
Senior Manager Billing Systems Group
NTT DoCoMo, Inc.

ENTERPRISE-CLASS SECURITY WITH EXTREME PERFORMANCE

Exadata Database Machine is the world's most secure database machine. Building on the high security capabilities in the Oracle Database such as Transparent Data Encryption (TDE), Exadata **uniquely moves decryption processing from database server software into the Exadata Storage Server hardware**. Exadata storage leverages hardware decryption and compression together to provide the highest performance secure databases. **Encryption occurs after the data is compressed so that the cost of decryption is decreased by the degree of compression**. By leveraging both technologies, Exadata is able to query fully encrypted and compressed databases with minimal overhead at a rate of hundreds of gigabytes of (original) user data per second. In addition, TDE provides a complete key management solution to keep all data encrypted and secure.

Exadata is designed and delivered as an integrated whole, instead of a collection of components. In traditional database deployments, the customer takes on all the system integration tasks, including the task of ensuring the security of each individual software and hardware component, and ensuring that security is maintained across the full product stack. **Oracle delivers full stack security in the Exadata Database Machine**. Exadata virtual machines provide an added layer of isolation at the operating system level. Additionally, on both physical and virtual deployments, Exadata systems use minimal Oracle Linux distributions to ensure that just the RPMs required to run the Oracle Database are installed and enabled. With this approach, system security is much stronger than default Linux installations and many security vulnerabilities are avoided. In addition, Exadata leverages the ksplice capability of Oracle Linux to apply security updates while the OS stays online.

"By integrating 20 legacy database servers for our investment trust sales system into four Oracle Exadata Database Machines, we can provide information to customers 136x faster, enhance our competitive advantage, and support transaction growth for the next 10 years at lower costs."

Tomoshiro Takemoto
Senior Managing Director
Cloud Computing Service Division
Nomura Research Institute Ltd.

Exadata security begins at power-up time with Secure Boot, which ensures that the system UEFI firmware only allows the execution of cryptographically signed boot loaders that the system recognizes as trustworthy. With each reboot of the server, every executed component is verified. This prevents malware from hiding embedded code in the boot chain.

In addition, the disk and flash technologies used in Exadata X8M enable Stored Data Encryption. In Stored Data Encryption, disk and flash storage devices encrypt all user data as it enters the devices. Exadata's Secure Erase feature leverages this capability when an Exadata is re-purposed or decommissioned to instantly erase all user data present on storage devices by changing the encryption keys used to encrypt the user data. With Secure Erase, because the previous encryption key is deleted, there is no need to worry about latent data left on storage devices due to over-provisioning or sector sparing.

Exadata security has been probed and evaluated by hundreds of leading banks, telecoms, and government organizations worldwide. The security findings of all these evaluations have been

incorporated into the Exadata standard configuration. Therefore Exadata benefits from scrutiny both by Oracle Security experts and by hundreds of industry security experts around the world.

MISSION CRITICAL HIGH AVAILABILITY

The Exadata Database Machine is engineered to provide the highest levels of availability. **All types of failures are protected against** from simple failures such as disk, server, or network, to complex site failures and human errors. Each Exadata Database Machine has **completely redundant hardware**, including redundant networking, redundant Power Distribution Units (PDU), redundant power supplies, and redundant database and storage servers. Oracle RAC protects against database server failure. Oracle ASM provides data mirroring to protect against disk or storage server failures. Oracle RMAN provides extremely fast and efficient backups to disk or tape. Oracle's Flashback technology allows backing out user errors at the database, table or even row level. Using Oracle Data Guard, a second Exadata Database Machine can be deployed in a Maximum Availability Architecture (MAA) configuration to transparently maintain a real-time copy of the database at a remote site and provide full protection against primary database failures and site disasters.

"With Oracle Platinum Services, we achieved a 40% increase in operational efficiency - virtually eliminating the need for dedicated resources to perform updates, monitor systems, and resolve incidents."

Roland Schiller
Architect
Swiss Re

Exadata in an MAA configuration is recognized by the analyst firm IDC as a system that **delivers at least 5-nines availability** and is categorized in the IDC AL4 fault-tolerant market segment, along with HP Integrity NonStop and IBM z Systems[1].

The Exadata principle of deep hardware and software integration is also evident in the many ways Exadata uniquely assures high availability across several different failure conditions. One such unique capability is **Instant Detection of Compute and Storage Server Failures**. On non-Exadata platforms, detecting a server failure requires waiting for a long timeout, leading to extended application brownouts. Exadata X8M implements a unique RDMA-based **sub-second node death detection**, leading to virtual elimination of application brownout conditions.

"We've seen system performance increase 4x and the total cost of storage ownership fall by 30%, even as our data volumes have surged."

Holger Haun
Managing Director
IDS GmbH – Analysis and Reporting Service

Disk and flash devices occasionally exhibit very long latency I/O operations due to internal recovery of failed sectors, internal firmware reboots, or wear leveling. These long I/O operations can cause stalls in mission critical OLTP databases. With Exadata's **unique I/O Latency Capping**, Oracle Exadata System software automatically redirects read I/O operations to an ASM-mirrored copy of the data when the latency of a read I/O is much longer than expected. Similarly, it automatically redirects high latency write I/O operations to a healthy flash device, eliminating write outliers. Exadata System Software uses Machine Learning techniques to predict components susceptible to failure and takes proactive action to gracefully take such components out of service. If disks do fail, ASM performs a rebalance operation for the data that was resident on the disk. Exadata allows hot swapping of disks, fans, power supplies, and PCIe Flash cards to avoid downtime. Exadata System software takes rebalance one step further by preserving the flash cache population and storage indexes when moving data between storage servers to maintain consistent application performance. On rare occasions when there are outliers within the networking subsystem, Exadata redirects the I/O issued by the database server to another storage server.

Exadata automates monitoring of CPU, memory, Input/Output, file system, and network. This automation combines machine learning techniques with the deep lessons learned from thousands of mission critical real-world deployments. For example, Exadata can detect that anomalous use of system resources is affecting database performance, identify the process responsible, and issue an alert, without any pre-existing set-up.

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[1] Worldwide Fault-Tolerant Servers Market Shares, 2014: *Vendors Are Hearing the Customer – More Bold Moves Needed to Grow the Segment*, IDC, Peter Rutten, Lloyd Cohen, October 2015

Because of its industry leading availability, the Exadata Database Machine has been deployed by leading companies for their most critical applications including interbank fund transfers, online securities trading, real-time call tracking, and web-based retailing. Exadata's Mission Critical availability capabilities are not restricted to OLTP workloads; they also apply to warehousing and analytics.

IDEAL PLATFORM FOR DATABASE AS A SERVICE

"On an annual basis Exadata provides at least half a million dollars in savings in operating costs."

James Callaghan
Chief Technologist
Westjet

The Exadata Database Machine can host many databases, enabling massive database consolidation or a sophisticated Database as a Service private cloud. Multi-database environments inherently have diverse, complex, and unpredictable workloads mixing OLTP, analytics, and batch operations with sequential and random-access patterns. Exadata's ability to **run any type or mix of database workloads with industry leading scalability and performance** makes it an ideal consolidation platform – whether for multi-database workloads, or for pluggable databases with Oracle Multitenant in Oracle Database 12c, 18c, and Oracle Database 19c.

Multi-database environments create an inherent risk that one database will consume too many resources and therefore impact the quality of service of other databases. The Exadata Database Machine **uniquely** provides **end-to-end prioritization** from the application to database CPUs, network, and storage. Priorities and resource limits can be specified at the physical database, pluggable database, connection, application, user, or even job level to ensure that each of the consolidated databases or SQL operations receives the necessary resources and achieves the target response times.

Exadata **uniquely** implements **database and I/O resource management**. Fine-grained priorities specified for operations at the database level are automatically communicated to Exadata Storage Servers and applied to each I/O operation to ensure that prioritization of database operations applies to both CPU operations and I/O operations. The same resource management principles can also be applied when multiple databases are deployed on one Exadata rack, as is typical in a consolidated private cloud.

New in the X8M generation, Exadata utilizes RDMA over Converged Ethernet protocols to ensure network intensive workloads such as reporting, batch, and backups don't stall latency sensitive interactive workloads. Latency sensitive network operations, such as RAC Cache Fusion communication, and log file writes, travel across high priority network channels within the converged ethernet fabric. Non-latency sensitive traffic travels on other channels, with their own network switch buffers.

Because of Exadata's unique Consolidation and Database as a Service capabilities, Exadata is the **only** platform that can support up to 4000 Pluggable Databases within a single Oracle Multitenant Container Database.

FAST DEPLOYMENT OF DEVELOPMENT AND TEST DATABASES WITH EXADATA SNAPSHOTS AND CONTAINERS

Space-efficient database snapshots can be quickly created for test and development purposes directly on Exadata. Exadata database snapshots are integrated with Oracle Multitenant to provide an extremely simple interface for creating new pluggable database (PDB) snapshots.

Snapshots start with a shared read-only copy of the production database (or PDB) that has been cleansed of sensitive information. A hierarchy of read-write snapshots can be created from this shared copy. As changes are made, each snapshot writes the changed blocks to a sparse disk group. Since multiple users can create independent snapshots from the same base database copy, multiple test

and development environments can share space while maintaining independent databases for each task.

All Exadata specific features such as Smart Scan, resource management and Smart flash Cache work seamlessly on database instances created via Exadata snapshots, hence providing an exact test and development environment while using a fraction of valuable storage resources. Backups of snapshots on Exadata are also space efficient as only the changed information is backed up.

In addition, Exadata supports Docker containers, enabling customers to easily and rapidly provision databases for testing and development to foster agile development. Customer can also use Docker containers to host lightweight applications and agents.

COMPREHENSIVE SYSTEM MANAGEMENT

Oracle Enterprise Manager uses a holistic approach to manage the Exadata Database Machine and provides comprehensive capabilities from monitoring and reporting to active lifecycle management. It enables:

- Unified Monitoring: Oracle Enterprise Manager 13c uniquely supports a single pane of glass view of all the hardware and software components such as database servers, storage servers, network switches, and monitors the operations running on them and their resource utilization. DBAs can drill down from database monitoring screens to the Exadata storage layer to quickly determine root causes of any performance bottlenecks.
- Lights-out monitoring within Enterprise Manager is optimized for Exadata with predefined metrics and thresholds so that administrators receive timely notifications when issues arise, and manage those exceptions. In addition, hardware incidents are automatically detected and service requests logged to reduce problem resolution time.
- The Exachk tool, which is integrated with Enterprise Manager's powerful compliance framework, provides functionality for system administrators to automate the assessment of Engineered Systems for known configuration problems and best practices. Administrators can leverage the Consistency Check functionality to check for deviations in configuration across the racks or among the database servers of a rack.
- Exadata's built in Management Server (MS) processes constantly monitor the health of hardware and software components, and send alerts to both administrators and Oracle support when faulty components are detected.

HIGHEST LEVEL OF SERVICE

Oracle offers a complete set of support services for the Exadata family of products including: 24x7 hardware service, system monitoring, software installation and configuration among other standard and custom offerings.

Of particular value is **Oracle Platinum Services** that is available exclusively for Oracle's Engineered Systems. Platinum Services provides fault monitoring, faster response times, and expedited escalation to development. With Platinum Services, Oracle support engineers perform software maintenance and patching remotely. Platinum Services provides a higher level of support than has ever been available before for all software and hardware within an Engineered System including the Oracle Database. Platinum Services is provided at no extra charge to Exadata customers.

IT AGILITY

Exadata is a complete system for running databases including storage, servers, and internal networks. Management of a traditional database system is typically spread across the management teams of each of the components such as the database team, the storage team, and the system administration

team. In contrast, an **Exadata system is typically managed by a unified Database Machine Administration (DMA) team**. Database Machine Administrators have full control of all resources in the Exadata Database Machine including storage resources. New database deployments and configuration changes can be implemented by the Database Machine Administrators without coordination across different component management teams that are often overloaded and have differing priorities. Database Machine Administrators can focus on application and business specific enhancements rather than coordinating across component teams, or tuning and triaging of low level configuration issues.

DRAMATICALLY LOWER COSTS

Because of the extreme performance, high storage capacity, and unique compression capabilities delivered by the Exadata Database Machine, workloads that would require very large traditional hardware systems can be run on much smaller Exadata systems. The hardware needed for an application deployed on an Exadata system is often reduced 2-4X compared to a traditional system.

Exadata provides a huge RAM, flash, and disk footprint for large data sets. Raw disk storage on an Exadata full rack can exceed 3 Petabytes while raw flash storage can be up to 920 TB. In addition, Hybrid Columnar Compression often expands storage and memory capacity 10X. By intelligently moving active data across disk, flash, and memory tiers, Exadata simultaneously delivers the highest performance and the lowest cost.

Exadata has the **unique** ability to consolidate many databases supporting multiple workloads in a single cloud platform. High-end OLTP, analytics, batch, reporting, and backups can all run simultaneously within and across databases with extreme performance. **The extreme performance and capacity of Exadata enables very large numbers of databases and workloads to be consolidated on Exadata**. Consolidating databases on Exadata reduces system hardware cost, software cost, and greatly reduces ongoing operations cost.

The uniformity of Exadata Database Machine configurations results in large cost savings. **Exadata standardizes not just technologies, but also integration, testing, security, hardening, tuning, and support**. Customers deploy Exadata systems much faster and with a lot less labor than traditional systems. Low level tuning, integration, and maintenance is reduced or eliminated. Because all Exadata users run a configuration that is identical to thousands of other users, and is identical to Oracle's internal configurations, it is far less likely that issues will be encountered, and issue resolution is quicker and simpler reducing both operations cost and downtime cost.

CAPACITY-ON-DEMAND SOFTWARE LICENSING

An X8M-8 database server has a substantial amount of compute capacity with eight 24-core x86 processors (192 cores in total). The Capacity-on-Demand feature allows a number of cores per database server to be turned off during the hardware installation, leaving at least 56 cores enabled. As your workload grows and more cores are needed, Capacity-on-Demand can be used to re-enable cores and license software 2 cores at a time. This pay-as-you-grow approach to software licensing is another way in which Exadata helps to align costs with business growth.

EXADATA BUSINESS BENEFITS

Beyond the operational benefits of extreme performance, availability, security, and deployment flexibilities across on-premises and Cloud, Exadata also directly benefits the business.

Exadata accelerates time to market for new business applications since the time needed for system configuration, tuning, and testing is largely eliminated. Deployment times are reduced from months to days, and the risk of unexpected system level issues after go-live is greatly reduced. When a new

application is deployed, it is common for unanticipated application usage patterns to create performance issues. Exadata's huge I/O, network, and compute throughput can absorb spikes created by unanticipated workloads without slowing response times of mission critical workloads. Overall Exadata speeds application deployment and reduces risk, allowing businesses to innovate faster.

Exadata's extreme performance, large memory, and flash capacity enhance employee productivity and customer satisfaction by greatly improving user response times. **Users spend more time doing useful work, and less time waiting** for the system to respond.

Exadata's extreme performance does not just improve business efficiency, it also **enables business users to make smarter decisions, discover growth opportunities, and reduce costs**. Users can analyze data in real-time, explore different possibilities, and perform rapid iteration to find better solutions. Exadata enables:

- Real-time business data analysis
- Faster financial closes
- Better planning and budgeting
- More effective and faster projections

CONCLUSION

Exadata delivers a fully integrated database platform with the latest hardware technologies and **unique** software to deliver extreme performance, availability, and security. This coupled with cost savings, ease of management, and enhanced supportability result in greater business agility and efficiency. Given what can be achieved with Exadata, it is no surprise it is the new global standard for running Oracle Databases – whether on-premises, or in the Oracle Cloud.

Exadata Server Hardware[1,2]

SERVER TYPE	CPU	MEMORY	DISK	FLASH	NETWORK
Database Server	8x 24-core Intel Xeon 8268 processors (2.9GHz)	3 TB (default) to 6 TB (max)	None	2 x 6.4 TB PCIe NVMe Flash Cards	8x 10/25 Gb Ethernet ports (client) 8x 1/10 Gb copper Ethernet ports, (1 used for host ADMIN) 8x 100 Gb QSFP28 RoCE Fabric ports 1x ILOM Ethernet port
Storage Server HC	2x 16-core Intel Xeon 5218 processors (2.3GHz)	192 GB 1.5 TB Persistent Memory	12x 14 TB 7,200 RPM disks	4x 6.4 TB NVMe PCIe3.0 Flash cards	2x 100 Gb QSFP28 RoCE Fabric ports 1x 1/10 Gb copper Ethernet port (mgmt) 1x ILOM Ethernet port
Storage Server EF		192 GB 1.5 TB Persistent Memory	None	8x 6.4 TB NVMe PCIe3.0 Flash cards	
Storage Server XT	1x 16-core Intel Xeon 5218 processors (2.3GHz)	96 GB	12x 14 TB 7,200 RPM disks	None	

[1] All servers include redundant hot swappable fans and power supplies

[2] Table includes individually purchasable servers only. HC = High Capacity, EF = Extreme Flash, XT = Extended.

Exadata Rack Configurations[1,2]

RACK SIZE	DATABASE SERVERS AND CORES	STORAGE SERVERS AND CORES	HIGH CAPACITY STORAGE SERVER CAPACITY (RAW)		EXTREME FLASH STORAGE SERVER CAPACITY (RAW)
Half Rack[3]	2x servers, 384 cores	3x servers, 96 cores for SQL offload	504 TB disk, 76.8 TB Flash, 4.5 TB Persistent Memory		153.5 TB Flash, 4.5 TB Persistent Memory
Full Rack[4]	2x servers, 384 cores	14x servers, 448 cores for SQL offload	2,352 TB disk, 358.4 TB Flash, 21 TB Persistent Memory		716.8 TB Flash, 21 TB Persistent Memory
+Database Servers	1 additional servers[5], 576 cores max per rack	n/a	n/a	or	n/a
+Storage Servers	n/a	Up to 14x servers[5], 448 cores max per rack	2,352 TB disk, 354.8 TB Flash, 27.6 TB Persistent Memory maximum per rack		921.6 TB Flash, 27.6 TB Persistent Memory maximum per rack

[1] Each rack is 42 RU (Rack Units) in height, has 2x redundant Power Distribution Units (PDUs), 2x 36-port 100 Gb/s RoCE switches and 1x 48-port Management Ethernet switch for administration. Included Spare Parts Kit Contains:

- 1 x 6.4 TB NVMe PCI Flash card and 1 x 14 TB High Capacity disk, or
- 1 x 6.4 TB NVMe PCI Flash card

[2] Elastic configurations allow adding a database or storage servers to a half rack to achieve the exact ratio of compute to storage that the application needs. A full rack elastic configuration cannot exceed 16 servers and 42 RU (Rack Units). Database Servers = 5 RU, Storage Servers = 2 RU

[3] Maximum number of database servers allowed in an elastic configuration is 3. Maximum number of storage servers allowed in an elastic configuration is 14.

[4] Full rack configurations added as examples of elastic configurations previously available as static size.

Other Elastic Expansion Options

Multi-Rack Connection	Connect any combination of up to 18 Exadata Database Machine racks or Exadata Storage Expansion Racks via the RoCE Network Fabric. Larger configurations can be built with external RoCE switches. Connected racks must contain Exadata RoCE hardware.

Exadata Capacity and Performance Metrics: Individual Servers

SERVER TYPE	MAXIMUM SQL FLASH BANDWIDTH[2]	MAXIMUM SQL READ IOPS[1,3]	MAXIMUM SQL WRITE IOPS[4]	PERSISTENT MEMORY CAPACITY (RAW) [5]	PCI FLASH CAPACITY (RAW)[5]	DISK DATA CAPACITY (RAW) [5]
Database Server	n/a	5,000,000	3,000,000	n/a	n/a	n/a
Storage Server HC[1]	25 GB/s	1,500,000	470,000	1.5 TB	25.6 TB	168 TB
Storage Server EF[1]	40 GB/s	1,500,000	470,000	1.5 TB	51.2 TB	n/a
Storage Server XT[1]	n/a	n/a	n/a	n/a	n/a	168 TB

[1] HC = High Capacity, EF = Extreme Flash, XT = Extended. PMEM = Persistent Memory. Actual system performance varies by application.

[2] Bandwidth is peak physical scan bandwidth achieved running SQL, assuming no database compression. Effective user data bandwidth is higher when database compression is used.

[3] Based on 8K I/O requests running SQL. Note that the I/O size greatly affects Flash IOPS. Other products quote IOPS based on smaller I/Os that are not relevant for databases.

[4] Based on 8K I/O requests running SQL. Flash write I/Os measured at the storage servers after ASM mirroring, which usually issues multiple storage I/Os to maintain redundancy.

[5] Raw capacity is measured in standard disk drive terminology with 1 GB = 1 billion bytes.

Exadata Typical Rack Configurations: Flash Capacity and Performance Metrics (HC & EF)

FLASH METRICS		MAXIMUM SQL FLASH BANDWIDTH[2]	MAXIMUM SQL PMEM READ IOPS[1,3]	MAXIMUM SQL FLASH WRITE IOPS[4]	PCI FLASH CAPACITY (RAW)[5]
Full Rack	**HC[1]**	350 GB/s	10,000,000	6,000,000	358.4TB
	EF[1]	560 GB/s	10,000,000	6,000,000	716.8 TB
Half Rack	**HC**	75 GB/s	4,500,000	1,410,000	76.8 TB
	EF	120 GB/s	4,500,000	1,410,000	153.6 TB

[1] EF = Extreme Flash; HC = High Capacity; PMEM = Persistent Memory

[2] Bandwidth is peak physical scan bandwidth achieved running SQL, assuming no database compression. Effective user data bandwidth is higher when database compression is used.

[3] Based on 8K IO requests running SQL. Note that the IO size greatly affects Flash IOPS. Others quote IOPS based on smaller IOs and are not relevant for databases.

[4] Based on 8K IO requests running SQL. Flash write I/Os measured at the storage servers after ASM mirroring, which usually issues multiple storage IOs to maintain redundancy.

[5] Raw capacity is measured in standard disk drive terminology with 1 GB = 1 billion bytes. Usable capacity is measured using normal powers of 2 space terminology with 1 TB = 1024 * 1024 * 1024 * 1024 bytes.

Exadata Typical Rack Configurations: Disk Capacity and Performance Metrics (HC)

DISK METRICS	MAXIMUM SQL DISK BANDWIDTH[1]	MAXIMUM SQL DISK IOPS[2]	DATA CAPACITY (RAW)[3]
Full Rack	25 GB/s	36,000	2,352 TB
Half Rack	5.4 GB/s	7,800	504 TB

[1] Bandwidth is peak physical scan bandwidth achieved running SQL, assuming no database compression. Effective user data bandwidth is higher when database compression is used.

[2] Based on 8K IO requests running SQL. Note that the IO size greatly affects Flash IOPS. Others quote IOPS based on smaller IOs and are not relevant for databases.

[3] Raw capacity is measured in standard disk drive terminology with 1 GB = 1 billion bytes. Usable capacity is measured using normal powers of 2 space terminology with 1 TB = 1024 * 1024 * 1024 * 1024 bytes.

Exadata Typical Rack Configurations: Combined Metrics (HC & EF)

COMBINED METRICS		DATA CAPACITY (USABLE) NORMAL REDUNDANCY[1]	DATA CAPACITY (USABLE) HIGH REDUNDANCY[1]	MAXIMUM DATA LOAD RATE[2]
Full Rack	**HC**	953 TB	699 TB	35 TB/hour
	EF	282 TB	206 TB	35 TB/hour
Half Rack	**HC**	191 TB	150 TB	7.5 TB/hour
	EF	56 TB	44 TB	7.5 TB/hour

[1] Usable capacity is measured using normal powers of 2 space terminology with 1 TB = 1024 * 1024 * 1024 * 1024 bytes. It is the actual space available to create a database after taking into account space needed for ASM redundancy, recovering from a drive failure. Normal redundancy calculations reflect the use of Grid Infrastructure version 12.2.0.1 or later.

[2] Load rates are typically limited by database server CPU, not I/O. Rates vary based on load method, indexes, data types, compression, and partitioning.

Exadata Database Machine Component Environmental Specifications

METRIC	EXADATA DATABASE SERVER X8M 8 PLUS NETWORK FABRIC	EXADATA STORAGE SERVER X8M 2 HIGH CAPACITY (HC) PLUS NETWORK FABRIC	EXADATA STORAGE SERVER X8M 2 EXTREME FLASH (EF) PLUS NETWORK FABRIC	EXADATA STORAGE SERVER X8M 2 EXTENDED (XT) PLUS NETWORK FABRIC	EXADATA EIGHTH RACK STORAGE SERVER X8M 2 HIGH CAPACITY (HC) PLUS NETWORK FABRIC
Height	8.63 in. (219.25 mm)	3.42 in. (86.9 mm)			
Width	17.5 in. (445 mm)	17.52 in. (445.0 mm)			
Depth	32.8 in. (833 mm)	29.88 in. (759.0 mm)			
Acoustic noise (operating)	8.7 B	8.2 B	8.2 B	8.2 B	8.2 B
Weight	198.8 lb (90.2 kg)	76.7 lb (34.8 kg)	60.6 lb (27.5 kg)	66.7 lb (30.2 kg)	67.5 lb (30.6 kg)
Maximum power usage	3.5 kW (3.6 kVA)	0.8 kW (0.8 kVA)	0.8 kW (0.8 kVA)	0.5 kW (0.5 kVA)	0.6 kW (0.6 kVA)
Typical power usage[1]	2.5 kW (2.5 kVA)	0.5 kW (0.6 kVA)	0.6 kW (0.6 kVA)	0.3 kW (0.3 kVA)	0.4 kW (0.4 kVA)
Cooling at maximum usage	11,953 BTU/hour	2,631 BTU/hour	2,730 BTU/hour	1,570 BTU/hour	1,947 BTU/hour
	12,610 kJ/hour	2,775 kJ/hour	2,880 kJ/hour	1,656 kJ/hour	2,054 kJ/hour
Cooling at typical usage	8,367 BTU/hour	1,842 BTU/hour	1,911 BTU/hour	1,099 BTU/hour	1,363 BTU/hour
	8,827 kJ/hour	1,943 kJ/hour	2,016 kJ/hour	1,159 kJ/hour	1,438 kJ/hour
Airflow at maximum usage[2]	553 CFM	122 CFM	126 CFM	73 CFM	90 CFM
Airflow at typical usage[2]	387 CFM	85 CFM	88 CFM	51 CFM	63 CFM

Operating temperature/humidity: 5 ºC to 32 ºC (41 ºF to 89.6 ºF), 10% to 90% relative humidity, non-condensing

Altitude Operating: Up to 3,048 m, max. ambient temperature is de-rated by 1° C per 300 m above 900 m

[1] Typical power usage varies by application load

[2] Airflow must be front-to-back.

Exadata Database Machine Environmental Specifications

METRIC	FULL RACK	HALF RACK
Height	78.74” (2000 mm)	
Width	23.66” (601 mm)	
Depth	47.13” (1197 mm)	
Acoustic noise (operating)	9.6 B	9.3 B
Environmentals With High Capacity Disks		
Weight	2049.5 lb (929.6 kg)	1243.8 lb (564.2 kg)
Maximum power usage	18.7 kW (19.0 kVA)	10.2 kW (10.4 kVA)
Typical power usage [1]	13.1 kW (13.3 kVA)	7.1 kW (7.3 kVA)
Cooling at maximum usage	63,643 BTU/hour	34,705 BTU/hour
	67,144 kJ/hour	36,614 kJ/hour
Cooling at typical usage	44,550 BTU/hour	24,293 BTU/hour
	47,001 kJ/hour	25,630 kJ/hour
Airflow at maximum usage [2]	2946 CFM	1607 CFM
Airflow at typical usage [2]	2063 CFM	1125 CFM
Environmentals With Extreme Flash Drives		
Weight	1824.1 lb (827.4 kg)	1195.5 lb (542.3 kg)
Maximum power usage	19.1 kW (19.4 kVA)	10.3 kW (10.5 kVA)
Typical power usage [1]	13.3 kW (13.6 kVA)	7.2 kW (7.3 kVA)
Cooling at maximum usage	65,029 BTU/hour	35,002 BTU/hour
	68,605 kJ/hour	36,927 kJ/hour
Cooling at typical usage	45,520 BTU/hour	24,501 BTU/hour
	48,024 kJ/hour	25,849 kJ/hour
Airflow at maximum usage [2]	3011 CFM	1620 CFM
Airflow at typical usage [2]	2107 CFM	1134 CFM

Operating temperature/humidity: 5 ºC to 32 ºC (41 ºF to 89.6 ºF), 10% to 90% relative humidity, non-condensing

Altitude Operating: Up to 3,048 m, max. ambient temperature is de-rated by 1° C per 300 m above 900 m

[1] Typical power usage varies by application load.

[2] Airflow must be front-to-back.

Exadata Database Machine X8M-8 Regulations and Certifications

Regulations [1,2,3]	**Product Safety:**	UL/CSA 60950-1, EN 60950-1, IEC 60950-1 CB
	EMC	
	Emissions:	FCC CFR 47 Part 15, ICES-003, EN55032,
	Immunity:	EN55024
Certifications [2,3]	North America (NRTL), European Union (EU), International CB Scheme, HSE Exemption (India), BSMI (Taiwan), CCC (PRC), EAC (EAEU including Russia), RCM (Australia), VCCI (Japan), Mexico, KC (Korea)	
European Union Directives [3]	2014/35/EU Low Voltage Directive, 2014/30/EU EMC Directive, 2011/65/EU RoHS Directive, 2012/19/EU	

[1] All standards and certifications referenced are to the latest official version at the time the data sheet was written. For additional detail, please contact your sales representative.

[2] Other country regulations/certifications may apply.

[3] In some cases, as applicable, regulatory and certification compliance were obtained for the shelf-level systems only.

Exadata Database Machine Support Services

- *Hardware Warranty: 1 year with a 4 hr web/phone response during normal business hours (Mon-Fri 8AM-5PM), with 2 business day on-site response/Parts Exchange*
- *Oracle Premier Support for Systems includes Oracle Linux support and 24x7 with 2 hour on-site hardware service response (subject to proximity to service center)*
- *Oracle Premier Support for Operating Systems*
- *Oracle Customer Data and Device Retention*
- *System Installation Services*
- *Software Configuration Services*
- *Oracle Platinum Services*
- *Business Critical Service for Systems*
- *Oracle Exadata Start-Up Pack*
- *System Upgrade Support Services including hardware installation and software configuration*
- *Oracle Auto Service Request (ASR)*

Key Features and Functionality

Exadata and Database Software Features - Analytics

- *Unique Automatic Parallelization and Offload of Data Scans to storage*
- *Unique Filtering of Rows in Storage based on 'where' clause*
- *Unique Filtering of Rows in Storage based on columns selected*
- *Unique Storage Offload of JSON and XML Analytic Queries*
- *Unique Filtering of rows in Storage based on Join with other Table*
- *Unique Hybrid Columnar Compression*
- *Unique Storage Index Data Skipping*
- *Unique I/O Resource Management by User, Query, Service, DB, etc.*
- *Unique Automatic Transformation to Columnar Format in Flash Cache*
- *Unique Smart Flash Caching for Table Scans*
- *Unique Storage Offload of Index Fast Full Scans*
- *Unique Storage Offloads of Scans on Encrypted Data, with FIPS compliance*
- *Unique Storage offload for LOBs and CLOBs*
- *Unique Storage offload for min/max operations*
- *Unique Data Mining Offload to Storage*
- *Unique Reverse Offload to DB servers if Storage CPUs are Busy*
- *Unique Automatic Data Columnarization in Flash Cache*
- *Unique Automatic Conversion of Data to In-Memory Formats when Loading into Flash Cache*

Exadata and Database Software Features - OLTP

- *Unique Database Aware PCI Flash*
- *Unique Exadata Smart Flash Caching*
- *Unique Exadata Smart Flash Logging*
- *Unique Smart Write-back Flash Cache*
- *Unique I/O Prioritization by DB, User, or workload to ensure QOS*
- *Unique Exafusion Direct-to-Wire Protocol*
- *Unique Database Intelligent Network Resource Management*
- *Unique Exachk full-stack validation*
- *Unique Full-stack security scanning*
- *Unique Database scoped security*
- *Unique Cell-to-Cell Rebalance preserving Flash Cache and Storage Index*
- *Unique Full-Stack Secure Erase*
- *Unique Instant Data File Creation*
- *Unique Smart Fusion Block Transfer*
- *Unique Control of Flash Cache Size per Database*
- *Unique In-Memory OLTP Acceleration*
- *Unique Undo-Block Remote RDMA Read*
- *Unique Support for More Than 252 Pluggable Databases with Multitenant Option*

Exadata and Database Software Features - High Availability

- *Unique Instant Detection of Node or Cell Failure*
- *Unique In-Memory Fault Tolerance*
- *Unique Sub-second Failover of I/O on stuck disk or Flash*
- *Unique Offload backups to storage servers*
- *Unique Exadata Data Validation (extended H.A.R.D.)*
- *Unique Prioritize Recovery of Critical Database Files*
- *Unique Automatic Repair of Corrupt Disk Data By Reading Other Storage Servers*
- *Unique Avoidance of Read I/Os on Predictive failed disks*
- *Unique Confinement and power cycle of temporarily poor performing drives*
- *Unique Shutdown Prevention If Mirror Storage Server is Down*
- *Unique Detection and Disabling of Unreliable Network Links*
- *Unique Preservation of Storage Index on Rebalance*

Manageability Features

- *Oracle Embedded Integrated Lights Out Manager (ILOM)*
- *Oracle Enterprise Manager Exadata Plug-in*
- *Unique Active AWR includes storage stats for end to end monitoring*
- *IPv6 Support for Ethernet Connections*
- *Capacity on Demand*
- *Cell software transparent restart*
- *Flash and disk life cycle management alert*
- *Automatic Disk Scrub and Repair*
- *Automated VLAN Creation*
- *Oracle Exadata Deployment Assistant*
- *Separate Management Switch and Connectivity*
- *Exacli command line management from remote servers*
- *Cellcli command line management of Storage Servers*
- *DCLI distributed command line automation tool*

Oracle Database Software (available separately):

- ***For database servers:*** *Oracle Database 11g Release 2 Enterprise Edition, Oracle Database 12c Enterprise Edition Release 1 and 2, Oracle Database 18c Enterprise Edition Release 1, and Oracle Database 19c. Oracle Database Options such as Oracle Real Application Clusters, Oracle Partitioning, Oracle Multitenant, Oracle Active Data Guard. See the release specific documentation for feature support.*
- ***For storage servers:*** *Oracle Exadata System Software. Licenses are transferable from one system to another, or to a new system*

Oracle Software (included):

- **For database servers:** Oracle Linux 7 Update 7 with the Unbreakable Enterprise Kernel 5. Zero-loss Zero-copy Datagram Protocol (ZDP) RoCEv2 protocol used to communicate between the Exadata Storage Servers and the Oracle Database which is based on the Reliable Datagram Sockets (RDS) OpenFabrics Enterprise Distribution (OFED)

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