

# Oracle Exadata

# Storage Expansion

# X8M-2

The Oracle Exadata Database Machine is engineered 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. The Oracle Exadata Storage Expansion Rack is engineered to be the simplest, fastest and most robust way to add additional storage capacity to an Exadata Database Machine. A natural extension of the Exadata Database Machine the Exadata Storage Expansion Rack can be used to satisfy the Big Data requirements of the largest mission critical databases.

## 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. The Exadata Storage Expansion Rack takes this to the next level.

## EXTREME PERFORMANCE AND CAPACITY

The Exadata Storage Expansion X8M rack enables you to grow the Exadata storage capacity and bandwidth of any Exadata Database Machine X8M. It is designed for database deployments that require very large amounts of data including: historical or archive data, backups, documents, images, XML, LOBs, etc. The expansion rack is extremely simple to configure as there are no LUNs or mount points to set up. It connects to the Exadata Database Machine X8M using the integrated RoCE Network fabric. Storage is configured and added to a database online with a few simple commands.

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Oracle Exadata Storage  
Expansion X8M-2

## EXTREME SYSTEM SCALABILITY AND GROWTH WITH ELASTIC CONFIGURATIONS

The Exadata Storage Expansion X8M offers you more flexibility than ever to grow. Exadata Storage Expansion X8M can be configured and purchased as small as a Quarter Rack with four storage servers, additional storage servers can be added one at a time or as many as needed up to a maximum of 19. With the flexibility of adding between 4 and 19 storage servers, there is a configuration that fits any application. In addition to upgrading from a small to large Exadata Storage Expansion X8M, Oracle continues to use a building-block approach to connect the Exadata Storage Expansion X8M to the Exadata Database Machine X8M using the integrated RoCE Network fabric to easily scale the system to any size. Exadata Storage Expansion X8M can be coupled to Exadata Database Machine X8M Elastic Rack systems in almost any combination. Up to 18 Exadata Database Machine X8M racks and Exadata Storage Expansion X8M racks can be easily connected via RoCE cables and internal switches. An Exadata X8M-2 traditional full rack configuration, along with 17 Exadata Storage Expansion X8M racks, each with 19 High Capacity Storage Servers, has a raw disk capacity of 56 Petabytes (56,616 TB) and 10,784 CPU cores dedicated to SQL processing. Larger configurations can be built with additional RoCE switches.

As new Exadata Storage Expansion X8M racks are connected to an Exadata Database Machine X8M, the storage capacity and performance of the system grows. The system can be run in single system image mode or logically partitioned for consolidation of multiple databases. Scaling out is easy with Exadata Database Machine X8M and Exadata Storage Expansion Racks. Automatic Storage Management (ASM) dynamically and automatically balances the data across Exadata Storage Servers, online, evenly spreading the I/O load across the racks, fully utilizing all the hardware and easily integrating the expansion rack into the configuration. The I/O Resource Manager can also be used to apportion I/O bandwidth to different databases and users of the system to deliver on business service level targets.

## EXTREME PERFORMANCE BY OFFLOADING DATA INTENSIVE PROCESSING

As data volumes grow exponentially, 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 many CPUs can consume data at many tens to hundreds of gigabytes a second. This is far faster than conventional architectures that use storage arrays can deliver data through their storage heads and the storage network.

The scale-out architecture of the Exadata Database Machine X8M not only provides high performance and scalability, it also includes a unique technology that offloads data intensive SQL operations into the Oracle Exadata Storage Servers. By pushing SQL processing to the Exadata Storage Servers, data filtering and processing occurs immediately and in parallel across all storage servers as data is read from disk, flash and persistent memory. 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 names. The result is that the data transferred to the database servers is reduced by orders of magnitude. This greatly accelerates query execution, eliminates bottlenecks, and significantly reduces the CPU usage of the database servers.

Each Exadata Storage Expansion X8M rack Storage Server has two Xeon® x86 processors that are used for database offload. A single Exadata Storage Expansion X8M with 19 Storage Servers has a total of 608 processor cores that can be used to offload the database servers. The CPUs in Exadata

### Key Features

- Grow the storage capacity of Oracle Exadata Database Machines X8M
- Includes from 4 to 19 Oracle Exadata Storage Servers
- Mirrored usable capacity of up to 1,294TB per rack before compression
- Up to 608 CPU cores dedicated to SQL processing in storage
- Up to 28.5 TB of Persistent Memory Acceleration per rack
- 100 Gb/sec RoCE Network
- Complete redundancy for high availability

### Key Benefits

- Pre-configured, pre-tested system optimized for all database applications
- Uncompressed I/O bandwidth of up to 760 GB/second per rack from SQL
- Engineered scale-out storage architecture pre-configured to easily expand system capacity and performance, online
- Simple upgrade to meet the needs of any size application
- Over 12 Petabytes of user data can be stored in a rack using the included Hybrid Columnar Compression
- Scale the configuration by connecting up to 18 Exadata Database Machines and Exadata Storage Expansion Racks without external switches. Larger configurations can be built with additional RoCE switches

Storage Servers do not replace database CPUs. Instead they accelerate data intensive workloads similar to how graphics cards accelerate image intensive workloads.

## 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.

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.

## 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.**

### Related Products

- Oracle Exadata Database Machine X8M-2
- Oracle Exadata Database Machine X8M-8
- Oracle Exadata Storage Server X8M-2 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

### 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

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).

### 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.

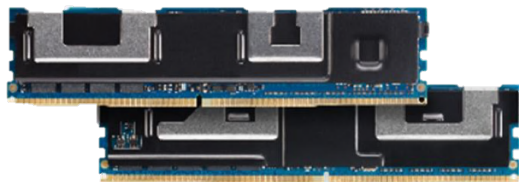


Figure 1. Intel® Optane™ DC Persistent Memory modules

### 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.

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-2, with 11 database servers and 11 Extreme Flash storage servers, using the new persistent memory accelerator, can achieve up to **16 Million random 8K database read and 5.17 Million random 8K flash write I/O operations per second (IOPS)**, which is an industry record for database workloads.

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.

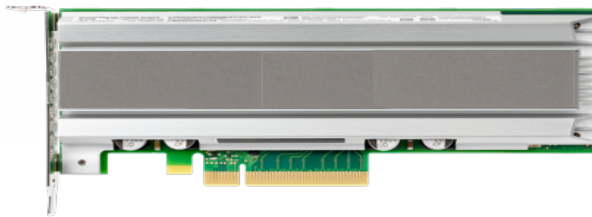


Figure 2. Flash Accelerator PCIe Card

## 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.

## **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.

## EXTREME BACKUP & RECOVER PERFORMANCE

One example of the Big Data strengths of the Exadata Storage Expansion rack is when used as a destination for Exadata Database Machine backups. A full database backup can be created at up to 48 TB/hour when backing up uncompressed data that is being written to mirrored disk in an Exadata Storage Expansion rack. It is capable of backing up hundreds of terabytes per hour when doing incremental database backups and petabytes per hour with incremental backups of Hybrid Columnar Compressed data. A disk backup on an Exadata Storage Expansion rack is usable directly without loss of performance and without having to do a restore. This is a unique backup capability only available when backing up to an Exadata Storage Expansion. It is by far the fastest and simplest way to backup and recover your Oracle Exadata Database Machine.

## 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 and Storage Expansion 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.

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<sup>1</sup>.

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.

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

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<sup>1</sup> 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

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.

Because of its industry leading availability, the Exadata Database Machine and Exadata Storage Expansion 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.

## 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.

## 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 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 Storage Expansion X8M-2 Key Capacity and Performance Metrics

METRIC	QUARTER RACK HC <sup>1</sup>	QUARTER RACK EF <sup>1</sup>	SINGLE SERVER HC	SINGLE SERVER EF	SINGLE SERVER XT <sup>1</sup>	MAX CONFIG HC	MAX CONFIG EF
Number of Storage Servers	4	4	1	1	1	19	19
<b>Flash Metrics</b>							
Maximum SQL flash bandwidth <sup>2</sup>	100 GB/sec	160 GB/sec	25 GB/sec	40 GB/sec	N/A	475 GB/sec	760 GB/sec
Maximum SQL flash read IOPS <sup>3</sup>	6,000,000	6,000,000	1,500,000	1,500,000	N/A	28,500,000	28,500,000
Maximum SQL flash write IOPS <sup>4</sup>	1,880,000	1,880,000	470,000	470,000	N/A	8,930,000	8,930,000
PCI Flash capacity (raw) <sup>5</sup>	102.4 TB	204.8 TB	25.6 TB	51.2 TB	N/A	486.4 TB	972.8 TB
<b>Disk Metrics</b>							
Maximum SQL disk bandwidth <sup>2</sup>	7.2 GB/s	N/A	1.8 GB/s	N/A	N/A	34 GB/s	N/A
Maximum SQL disk IOPS <sup>3</sup>	10,000	N/A	2,600	N/A	N/A	49,000	N/A
Data capacity (raw) <sup>5</sup>	672 TB	205 TB	168 TB	51 TB	168 TB	3192 TB	973 TB
<b>Combined Metrics</b>							
Data Capacity (usable) – Normal Redundancy <sup>6</sup>	254 TB	75 TB	64 TB	18.8 TB	64 TB	1294 TB	382 TB
Data Capacity (usable) – High Redundancy <sup>6</sup>	199.6 TB	59.0 TB	49.9 TB	14.7 TB	49.9 TB	948.0 TB	280.2 TB
Maximum data load rate <sup>7</sup>	10 TB/hour	10 TB/hour	2.5 TB/hour	2.5 TB/hour	2.5 TB/hour	48 TB/hour	48 TB/hour

Actual system performance varies by application.

<sup>1</sup> EF = Extreme Flash; HC = High Capacity; XT = Extended. Actual system performance varies by application.

<sup>2</sup> Bandwidth is peak physical scan bandwidth achieved running SQL, assuming no database compression. Effective user data bandwidth is higher when database compression is used.

<sup>3</sup> 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.

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

<sup>5</sup> 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 bytes.

<sup>6</sup> Actual space available for a database after mirroring (ASM normal redundancy) while also providing adequate space (one disk on Quarter and Half Racks and two disks on a Full Rack) to reestablish the mirroring protection after a disk failure in the normal redundancy case.

<sup>7</sup> Load rates are typically limited by database server CPU, not IO. Rates vary based on load method, indexes, data types, compression, and partitioning.

## Exadata Storage Expansion X8M-2 Hardware

QUARTER RACK
<p>4 x Exadata Storage Server X8M-2:</p> <ul style="list-style-type: none"> <li>• 128 CPU cores for SQL processing</li> <li>• 48 x 128 GB Persistent Memory</li> <li>• 48 x 14 TB High Capacity Drive and 16 x 6.4 TB NVMe PCI Flash Cards for HC Quarter Rack, or, 32 x 6.4 TB NVMe PCI Flash Drives for EF Quarter Rack</li> <li>• 3 x 36-port 100 Gb/s RoCE switches</li> </ul>
<p>Additional Hardware Components:</p> <ul style="list-style-type: none"> <li>• 42U Rack</li> <li>• Ethernet switch for administrative connectivity.</li> <li>• 2x Redundant Power Distribution Units (PDUs)</li> </ul>
<p>Included Spare Parts Kit Contains:</p> <ul style="list-style-type: none"> <li>• 1 x 6.4 TB NVMe PCI Flash Card and 1 x 14 TB High Capacity disk, or</li> <li>• 1 x 6.4 TB NVMe PCI Flash drive, or</li> </ul>

## Exadata Storage Expansion X8M-2 Connectivity and Upgrades

CONNECTION TO EXADATA DATABASE MACHINE	UPGRADABILITY
<p>Connect any combination of up to 18 Exadata Database Machine X8M racks or Exadata Storage Expansion X8M Racks via the RoCE Network Fabric.</p> <p>Larger Configurations can be built with external RoCE switches. Connected racks can be X8M generation hardware.</p>	<p>After the initial quarter rack, additional HC, EF, XT or combination of HC, EF and XT storage servers can be added one at a time or as many as needed up to a maximum configuration (19 storage servers).</p> <p>Hardware Components included with the upgrade:</p> <ul style="list-style-type: none"> <li>• RoCE and Ethernet cables and adapters to connect all the components</li> <li>• 12 x 14 TB High Capacity Drives and 4 x 6.4 TB NVMe PCI Flash Cards, and 12 x 128 GB Persistent Memory Modules for each additional HC storage server, or</li> <li>• 8 x 6.4 TB NVMe PCI Flash Drives and 12 x 128 GB Persistent Memory Modules for each additional EF storage server, or</li> <li>• 12 x 14 TB High Capacity Drives for each additional XT storage server</li> </ul>
<p>Upgrade Support Services:</p> <ul style="list-style-type: none"> <li>• Hardware Installation and Software Configuration</li> </ul>	

## Exadata Storage Expansion X8M-2 Support Services

### Components:

- *Hardware Warranty: 1 year with a 4 hour 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 and Solaris 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)*

## Exadata Storage Expansion X8M-2 Environmental Specifications

METRIC	QUARTER RACK	MAXIMUM CONFIGURATION	SINGLE SERVER
Height	78.74" (2000 mm)		3.42 in. (86.9 mm)
Width	23.66" (601 mm)		17.52 in. (445.0 mm)
Depth	47.13" (1197 mm)		29.88 in. (759.0 mm)
Acoustic Noise (Operating)	9.2 B	9.6 B	8.2 B
<b>Environmentals with High Capacity Disks</b>			
Weight	915.7 lb (415.4 kg)	2061.2 lb (934.9 kg)	67.5 lb (30.6 kg)
Maximum Power Usage	4.3 kW (4.4 kVA)	15.8 kW (16.2 kVA)	0.6 kW (0.6 kVA)
Typical Power Usage <sup>1</sup>	3.0 kW (3.1 kVA)	11.1 kW (11.3 kVA)	0.4 kW (0.4 kVA)
Cooling at Maximum Usage	14,580 BTU/hour	54,041 BTU/hour	1,947 BTU/hour
	15,382 kJ/hour	57,014 kJ/hour	2,054 kJ/hour
Cooling at Typical Usage	10,206 BTU/hour	37,829 BTU/hour	1,363 BTU/hour
	10,767 kJ/hour	39,910 kJ/hour	1,438 kJ/hour
Airflow at Maximum Usage <sup>2</sup>	675 CFM	2502 CFM	90 CFM
Airflow at Typical Usage <sup>2</sup>	472 CFM	1751 CFM	63 CFM
<b>Environmentals with Extreme Flash Drives</b>			
Weight	851.3 lb (386.1 kg)	1755.3 lb (796.2 kg)	60.6 lb (27.5 kg)
Maximum Power Usage	4.4 kW (4.5 kVA)	16.4 kW (16.7 kVA)	0.8 kW (0.8 kVA)

METRIC	QUARTER RACK	MAXIMUM CONFIGURATION	SINGLE SERVER
Typical Power Usage <sup>1</sup>	3.1 kW (3.1 kVA)	11.5 kW (11.7 kVA)	0.6 kW (0.6 kVA)
Cooling at Maximum Usage	14,976 BTU/hour	55,922 BTU/hour	2,730 BTU/hour
	15,800 kJ/hour	58,997 kJ/hour	2,880 kJ/hour
Cooling at Typical Usage	10,483 BTU/hour	39,145 BTU/hour	1,911 BTU/hour
	11,060 kJ/hour	41,298 kJ/hour	2,106 kJ/hour
Airflow at Maximum Usage <sup>2</sup>	602 CFM	2188 CFM	126 CFM
Airflow at Typical Usage <sup>2</sup>	422 CFM	1531 CFM	88 CFM

Operating temperature/humidity: 5 °C to 32 °C (41 °F to 89.6 °F), 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 Storage Expansion X8M-2 Regulations and Certifications

Regulations <sup>1,2,3</sup>	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 <sup>2,3</sup>	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 <sup>3</sup>	2014/35/EU Low Voltage Directive, 2014/30/EU EMC Directive, 2011/65/EU RoHS Directive, 2012/19/EU	

<sup>1</sup> 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.

<sup>2</sup> Other country regulations/certifications may apply.

<sup>3</sup> In some cases, as applicable, regulatory and certification compliance were obtained for the shelf-level systems only.

## 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*
- *Trusted Partitions for Oracle Virtual Machine*
- *Automated VLAN Creation*
- *Oracle Exadata Deployment Assistant*
- *Separate Management Switch and Connectivity*

- *Exacl 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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## Integrated Cloud Applications & Platform Services

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