# ORACLE EXADATA STORAGE EXPANSION RACK X6-2

Oracle Exadata and Oracle SuperCluster deliver extreme performance and scalability for all your database applications including Online Transaction Processing (OLTP), Data Warehousing (DW) and 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 or a SuperCluster. A natural extension of the Exadata Database Machine and the SuperCluster, the Exadata Storage Expansion Rack can be used to satisfy the Big Data requirements of the largest mission critical databases.

## Engineered System For Fast Deployment of All Your Databases

Exadata and SuperCluster are easy to deploy systems that include all the hardware needed for running the Oracle Database. The database servers, storage servers and network are pre-configured, pre-tuned, and pre-tested by Oracle experts, eliminating the weeks of effort that is typically required to deploy a high performance system. Extensive end-to-end testing ensures all components work seamlessly together and there are no performance bottlenecks or single points of failure that can affect the complete system. The Exadata Storage Expansion Rack takes this to the next level.

## Extreme Performance and Capacity

The Exadata Storage Expansion Rack enables you to grow the Exadata storage capacity and bandwidth of any Exadata Database Machine or SuperCluster. 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 or SuperCluster using the integrated InfiniBand fabric. Storage is configured and added to a database online with a few simple commands.

## Extreme System Scalability and Growth with Elastic Configurations

The Exadata Storage Expansion Rack offers you more flexibility than ever to grow. With the introduction of Elastic Configurations starting with X5, Exadata Storage Expansion Rack can be configured and purchased as small as a Quarter Rack with four storage servers and additional storage servers can be added one at a time or as many as

KEY FEATURES

- Grow the storage capacity of Oracle Exadata Database Machines and Oracle SuperCluster
- Includes from 4 to 19 Oracle Exadata Storage Servers
- Mirrored usable capacity of up to 690TB per rack before compression
- Up to 380 CPU cores dedicated to SQL processing in storage
- Up to 486.4TB of Smart Flash Cache
- Connected directly to Exadata X6-2 and X6-8 and SuperCluster via 40 Gbps InfiniBand
- Hybrid Columnar Compression often delivers 10X-15X compression ratios
- Complete redundancy for high availability

KEY BENEFITS

- Uncompressed I/O bandwidth of up to 475 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 InfiniBand switches

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 Rack, Oracle continues to use a building-block approach to connect the Exadata Storage Expansion Rack to the Exadata Database Machine and the SuperCluster using the integrated InfiniBand fabric to easily scale the system to any size. Exadata Storage Expansion Quarter or Elastic Racks can be coupled to Exadata Database Machine Full, Half and Quarter or Elastic Rack systems in almost any combination. Up to 18 Exadata Database Machine racks and Exadata Storage Expansion Racks can be easily connected via InfiniBand cables and internal switches. An 18 rack Exadata configuration each with 19 Storage Servers has a raw disk capacity of up to 32 Petabyte (32,832 TB) and 6,840 CPU cores dedicated to SQL processing. Larger configurations can be built with additional InfiniBand switches.

As new Exadata Storage Expansion Racks are connected to an Exadata Database Machine or a SuperCluster, 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, SuperCluster 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 and the SuperCluster 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 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 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 Rack Storage Server has two Xeon® x86 processors that are used for database offload. A Max Configuration Exadata Storage Expansion

RELATED PRODUCTS

- Exadata Database Machine X6-2
- Exadata Database Machine X6-8
- Oracle Exadata Storage Server X6-2
- Oracle SuperCluster
- Oracle Database 11g and 12c
- 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
- Consulting Services
- Oracle University courses

Rack with 19 Storage Servers has a total of 380 processor cores that can be used to offload the database servers. The CPUs in Exadata 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 very advanced 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. As the name implies, this technology utilizes 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 tremendous 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 by consuming CPU for decompression. Because the Exadata Database Machine is able to offload decompression overhead into large numbers of 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 they do without it. Hybrid Columnar Compression delivers the compression and analytic performance benefits of columnar storage while avoiding the dramatic slowdown that columnar-only data stores experience for drilldown operations that often involve single row access.

Two modes of Hybrid Columnar Compression are available. **Warehouse compression** mode is suitable for read intensive workloads such as Data Warehouses and provides large storage savings while providing 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.

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 12c 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 which benefits from a pure columnar access, 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.

## 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. Exadata X6 enhances previous generation EF Storage Servers**,** by doubling the flash capacity. Each EF Storage Server contains eight 3.2 TB state-of-the-art Flash Accelerator F320 PCI flash drives, offering 25.6TB raw flash capacity per EF Storage Server. An Exadata Storage Expansion Rack with 19 Extreme Flash storage servers includes 152 PCI flash drives providing 486.4 TB of flash memory. For the first time in the database industry, Exadata introduces flash drives based on 3D V-NAND technology. 3D V-NAND is a unique innovation in Flash semiconductor technology that leads to improved speed, power efficiency and endurance compared to previous generations of Flash. In addition, Exadata delivers ultra-high performance by placing the flash drives directly on the high speed PCI bus rather than behind slow disk controllers and directors. Finally, Exadata flash uses the latest NVMe (Non-Volatile Memory Express) flash protocol to achieve extremely low I/O overhead.

Fig. 1: Flash Accelerator F320 PCIe Card

Flash performance is often limited and bottlenecked by traditional storage architecture. In contrast, Exadata uses a combination of scale-out storage, InfiniBand networking, database offload, and PCI flash to deliver extremely high performance rates from flash. A traditional Max Configuration Exadata Storage Expansion Rack X6-2, with 19 Extreme Flash storage servers, can achieve up to **475 GB per second of analytic scan bandwidth from SQL**, and up to 9.4 Million random 8K read I/O operations per second (IOPS) and 8.55 Million random 8K write I/O operations per second (IOPS) when running database workloads.

This performance is orders of magnitude faster than traditional storage array architectures, and is also much faster than current all-flash storage arrays. It is important to note that these are real-world end-to-end performance figures measured running SQL workloads with realistic I/O sizes inside a single rack Exadata system. They are not component-level measurements based on low-level I/O tools.

## High Capacity Storage Server: Tiered Disk and Flash Deliver Cost of Disk with Performance of Flash

The second Exadata storage option for Exadata Storage Expansion Rack is the Exadata X6-2 **High Capacity (HC) Storage Server**. This server includes twelve 8 TB SAS disk drives with 96 TB total raw disk capacity. It also has four Flash Accelerator F320 NVMe PCIe cards with a total raw capacity of 12.8 TB of flash memory. These flash cards are also based on innovative 3D V-NAND technology. Exadata flash in a High Capacity 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 since caching provides flash level performance for much more data than fits directly into flash.

Exadata Smart Flash Cache automatically caches frequently accessed data while keeping infrequently accessed data on disk. This provides the performance of flash with the capacity and low cost of disk. The Exadata Smart Flash Cache understands database workloads and knows when to avoid caching data that the database will rarely access or is too big to fit in the cache. For example, Exadata doesn't cache I/Os caused by backups, table scans, or temporary results that will be quickly deleted. In addition to automatic caching, administrators can optionally provide SQL directives to ensure that specific tables, indexes, or partitions are always retained in the flash cache. Tables can be retained in flash cache without the need to move the table to different tablespaces, files or LUNs as is often required with traditional storage.

Exadata's Smart Flash Cache is designed to deliver flash-level I/O rates and response times for data that is many times larger than the physical flash capacity in the machine by moving active data into flash, while leaving cold data on disk. It is common for hit rates in the Exadata Smart Flash Cache to be over 90%, or even 98% in real-world database workloads even though flash capacity is more than 7 times smaller than disk capacity. Such high flash cache hit rates mean that Exadata Smart Flash Cache provides an **effective flash capacity** that is many times larger than the physical flash cache. For example, a full rack Exadata Storage Expansion Rack X6-2 with 19 High Capacity Storage Servers often has an effective flash capacity of 690 TB.

Flash performance is often limited and bottlenecked by traditional storage architectures. In contrast, Exadata uses a combination of scale-out storage, InfiniBand networking, database offload, and PCI flash to deliver extremely high performance rates from flash. A single Exadata Storage Expansion X6-2 with 19 HC Storage Servers achieves up to 407 GB per second of analytical scan bandwidth from SQL, and up to 9.03 Million random 8K read I/O operations per second (IOPS) and 7.79 Million random 8K write I/O operations per second (IOPS) when running database workloads. This performance is orders of magnitude faster than traditional database architectures. It is important to note that these are real-world end-to-end performance figures measured running SQL workloads with realistic IO sizes inside a single rack Exadata system. They are not component level measurements based on low level IO tools.

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 Storage Expansion with 19 HC Storage Servers exceeds 7.7 Million 8K write I/Os per second. The Exadata write cache is transparent, persistent, and fully redundant. The I/O performance of the Exadata Smart Flash Cache is comparable to dozens of enterprise

disk arrays with thousands of disk drives.

To further accelerate OLTP workloads, the Exadata Smart Flash Cache also implements a special algorithm to reduce the latency of log write I/Os called Exadata Smart Flash Logging. The time to commit user transactions or perform critical updates is very sensitive to the latency of log writes. Smart Flash Logging takes advantage of the flash memory in Exadata storage combined with the high speed RAM memory in the Exadata disk controllers to greatly reduce the latency of log writes and avoid the latency spikes that frequently occur in other flash solutions. The Exadata Smart Flash Logging algorithms are unique to Exadata.

Exadata uses only enterprise grade flash that is designed by the flash manufacturer to have high endurance. Exadata is designed for mission critical workloads and therefore does not use consumer grade flash that can potentially experience performance degradations or fail unexpectedly after a few years of usage. The enterprise grade flash chips used in Exadata X6 have an expected endurance of 8 years or more for typical database workloads.

The automatic data tiering between RAM, flash and disk implemented in Exadata provides tremendous advantages over other flash-based solutions. When third-party flash cards or flash disks are used directly in database servers, the data placed in flash is only available on that server since local flash cannot be shared between servers. This precludes the use of RAC and limits the database deployment to the size of a single server handicapping performance, scalability, availability, and consolidation of databases. Any component failure, like a flash card, in a single server can lead to a loss of database access. Local flash lacks the intelligent flash caching and Hybrid Columnar Compression provided in Exadata and is much more complex to administer.

Real world experience has shown that server local flash cards and flash disks can become crippled without completely failing leading to database hangs, poor performance, or even corruptions. Flash products have been seen to intermittently hang, exhibit periodic poor performance, or lose data during power cycles, and these failures often do not trigger errors or alerts that would cause the flash product to be taken offline. Worse, these issues can cause hangs inside the Operating System causing full node hangs or crashes. Exadata software automatically detects and bypasses poorly performing or crippled flash. When an unusual condition is detected, Exadata will automatically route I/O operations to alternate storage servers.

Many storage vendors have recognized that the architecture of their traditional storage arrays inherently bottleneck the performance of flash and therefore have developed new flash-only arrays. These flash-only arrays deliver higher performance than traditional arrays but give up the cost advantages of smart tiering of data between disk and flash. Therefore the overall size of data that benefits from flash is limited to the size of expensive flash. Exadata smart flash caching often provides flash level performance for data that is many times larger than physical flash since it automatically keeps active data that is experiencing heavy IO activity in flash while leaving cold data that sees infrequent IO activity on low-cost disk. Database and Flash Cache Compression further extend the capacity of Exadata flash. Third party flash arrays will also not benefit from Exadata Hybrid Columnar Compression. In addition, data deduplication provided by some flash arrays is very effective for VDI environments but is ineffective 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 InfiniBand based scale-out, fast PCI flash, offload of data intensive operations to storage, and algorithms that are specifically optimized for databases.

## Extreme Backup & Recovery Performance

On example of the Big Data strengths of the Exadata Storage Expansion Rack is when used as a destination for Exadata Database Machine or SuperCluster backups. A full database backup can be created at up to 27 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 Rack. It is by far the fastest and simplest way to backup and recover your Oracle Exadata Database Machine or SuperCluster.

## Mission Critical High Availability

The Exadata Storage Expansion Rack is engineered to provide the highest levels of availability. **All types of failures are protected against** simple failures such as disk, server, or network, as well as complex site failures and human errors. Each Exadata Database Machine has **completely redundant hardware,** including redundant InfiniBand 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 configured 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[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 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 leverages InfiniBand integration to very quickly determine that the suspect server is not reachable through any network path and can immediately initiate eviction of the failed server from the cluster. This entire operation can be completed in less than 2 seconds, leading to virtual elimination of application brownout conditions.

Disk and flash devices occasionally exhibit very long latency IO operations due to

[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

internal recovery of failed sectors, internal firmware reboots, or wear leveling. These long IO operations can cause stalls in mission critical OLTP databases. With Exadata **I/O Latency Capping**, Oracle Exadata Storage Server 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. If disks do fail, ASM performs a rebalance operation for the data that was resident on the disk. Exadata Storage Server software takes rebalance one step further by preserving the flash cache population when moving data between storage servers to maintain consistent application performance.

Because of its industry leading availability, the Exadata Database Machine and Exadata Storage Expansion Rack 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 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 1.8 Petabytes while raw flash storage can be up to 486.4 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, 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, and 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 and 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 Public Cloud.

## EXADATA STORAGE EXPANSION RACK X6-2 KEY CAPACITY AND PERFORMANCE METRICS

| Metric | Quarter Rack HC[1] | Quarter Rack EF[1] | Single Server HC | Single Server EF | Max Configuration HC | Max Configuration EF |
|---|---|---|---|---|---|---|
| Number of Storage Servers | 4 | 4 | 1 | 1 | 19 | 19 |
| **Flash Metrics** | | | | | | |
| Maximum SQL Flash Bandwidth [2] | 86 GB/sec | 100 GB/sec | 21 GB/sec | 25 GB/sec | 407 GB/sec | 475 GB/sec |
| Maximum SQL Flash Read IOPS [3] | 1,900,000 | 1,980,000 | 475,000 | 495,000 | 9,025,000 | 9,405,000 |
| Maximum SQL Flash Write IOPS [4] | 1,640,000 | 1,800,000 | 410,000 | 450,000 | 7,790,000 | 8,550,000 |
| PCI Flash Capacity (raw) [5] | 51.2 TB | 102.4 TB | 12.8 TB | 25.6 TB | 243.2 TB | 486.4 TB |
| **Disk Metrics** | | | | | | |
| Maximum SQL Disk Bandwidth [2] | 7.2GB/sec | N/A | 1.8 GB/sec | N/A | 34 GB/sec | N/A |
| Maximum SQL Disk IOPS [3] | 10,000 | N/A | 2,600 | N/A | 49,000 | N/A |
| Disk Data Capacity (raw) [5] | 384 TB | N/A | 96 TB | N/A | 1,824 TB | N/A |
| **Combined Metrics** | | | | | | |
| Data Capacity (usable) – Normal Redundancy [6] | 145.2 TB | 37.2 TB | 36.3 TB | 9.3 TB | 689.8 TB | 176.5 TB |
| Data Capacity (usable) – High Redundancy [6] | 113.9 TB | 29.1 TB | 28.5 TB | 7.3 TB | 541.1 TB | 138.4 TB |
| Maximum Data Load Rate [7] | 7 TB/hr | 8 TB/hr | 1.7 TB/hr | 2.0 TB/hr | 32 TB/hr | 38 TB/hr |

Actual system performance varies by application.

[1] EF = Extreme Flash; HC = High Capacity

[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.

[6] 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, DBFS disk group, and OS images and binaries.

[7] 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 RACK X6-2 HARDWARE

**Quarter Rack**

4 x Exadata Storage Servers X6-2:

- *80 CPU cores for SQL processing*
- *48 x 8 TB High Capacity Drive and 16 x 3.2 TB NVMe PCI Flash Cards for HC Quarter Rack, or 32 x 3.2 TB NVMe PCI Flash Drives for EF Quarter Rack*
- *3 x 36 port QDR (40 Gb/sec) InfiniBand Switches*

Additional Hardware Components:

- *42U Rack*
- *Ethernet switch for administrative connectivity to servers in the Database Machine*
- *2 x Redundant Power Distributions Units (PDUs)*

Included Spare Parts Kit Contains:

- *1 x 3.2 TB NVMe PCI Flash Card and 1 x 8 TB High Capacity disk, or*
- *1 x 3.2 TB NVMe PCI Flash drive*

## EXADATA STORAGE EXPANSION RACK X6-2 CONNECTIVITY AND UPGRADES

| Connection to Exadata Database Machine | Upgradability |
|---|---|
| Connect any combination of up to 18 Exadata Database Machine racks or Exadata Storage Expansion Racks via the InfiniBand fabric.<br>Larger Configurations can be built with external InfiniBand switches.<br>Connected racks can be any combination of v2, X2, X3,X4, X5 or X6 generation hardware. | After the initial quarter rack, additional HC, EF or combination of HC and EF storage servers can be added one at a time or as many as needed up to a maximum configuration (19 storage servers).<br>Hardware Components included with the upgrade:<br>• *InfiniBand and Ethernet cables and adapters to connect all the components*<br>• *12 x 8 TB High Capacity Drive and 4 x 3.2 TB NVMe PCI Flash Cards for each additional HC storage server*<br>• *Or 8 x 3.2 TB NVMe PCI Flash Drives for each additional EF storage server* |

Upgrade Support Services:

Hardware Installation and Software configuration

## EXADATA STORAGE EXPANSION RACK X6-2 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 RACK X6-2 ENVIRONMENTAL SPECIFICATIONS

| Metric | Quarter Rack | Single Server | Maximum Configuration |
|---|---|---|---|
| Number of Storage Servers | 4 | 1 | 19 |
| Height<br>Width<br>Depth | | • *78.66" - 1998 mm*<br>• *23.62" – 600 mm*<br>• *47.24" – 1200 mm* | |
| Acoustic noise (operating) | 8.4 B | 7.8 B | 8.5 B |
| **Environmentals With High Capacity Disks** | | | |
| Weight | 847.5 lbs (384.4 kg) | 73.0 lbs (33.1 kg) | 1937.5 lbs (878.8 kg) |
| Maximum power usage<br>Typical power usage [1] | 3.6 kW ( 3.7 kVA)<br>2.5 kW ( 2.6 kVA) | 0.6 kW ( 0.6 kVA)<br>0.4 kW ( 0.4 kVA) | 12.4 kW ( 12.7 kVA)<br>8.7 kW ( 8.9 kVA) |
| Cooling at maximum usage<br>Cooling at typical usage | 12,239 BTU/hour<br>12,913 kJ/hour<br>8,568 BTU/hour<br>9,039 kJ/hour | 2,006 BTU/hour<br>2,117 kJ/hour<br>1,404 BTU/hour<br>1,482 kJ/hour | 42,334 BTU/hour<br>44,663 kJ/hour<br>29,634 BTU/hour<br>31,264 kJ/hour |
| Airflow at maximum usage [2]<br>Airflow at typical usage [2] | 567 CFM<br>397 CFM | 93 CFM<br>65 CFM | 1960 CFM<br>1372 CFM |
| **Environmentals With Extreme Flash Drives** | | | |
| Weight | 803.5 lbs (364.5 kg) | 62.0 lbs (28.1 kg) | 1728.5 lbs (784.0 kg) |
| Maximum power usage<br>Typical power usage [1] | 3.4 kW ( 3.5 kVA)<br>2.4 kW ( 2.4 kVA) | 0.5 kW ( 0.6 kVA)<br>0.4 kW ( 0.4 kVA) | 11.6 kW ( 11.9 kVA)<br>8.1 kW ( 8.3 kVA) |
| Cooling at maximum usage<br>Cooling at typical usage | 11,680 BTU/hour<br>12,322 kJ/hour<br>8,176 BTU/hour<br>8,626 kJ/hour | 1,866 BTU/hour<br>1,969 kJ/hour<br>1,307 BTU/hour<br>1,378 kJ/hour | 39,676 BTU/hour<br>41,859 kJ/hour<br>27,773 BTU/hour<br>29,301 kJ/hour |
| Airflow at maximum usage [2]<br>Airflow at typical usage [2] | 541 CFM<br>379 CFM | 86 CFM<br>60 CFM | 1837 CFM<br>1286 CFM |

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

Regulations [3]

- *Safety: UL/CSA 60950-1, EN 60950-1, IEC 60950-1 CB Scheme with all country differences*
- *RFI/EMI: EN55022, EN61000-3-11, EN61000-3-12*
- *Immunity: EN 55024*
- *Emissions and Immunity: EN300 386*

Certifications [3]

- *North America (NRTL), European Union (EU), International CB Scheme, BSMI (Taiwan), C-Tick (Australia), CCC (PRC), MSIP (Korea), CU EAC (Customs Union), VCCI (Japan)*

European Union Directives [3]

- *2006/95/EC Low Voltage Directive, 2004/108/EC EMC Directive, 2011/65/EU RoHS Directive, 2012/19/EU WEEE Directive*

[1] Typical power usage varies by application load.

[2] Airflow must be front-to-back

[3] All standards and certifications referenced are to the latest official version at the time the data sheet was written. Other country regulations/certifications may apply. In some cases, as applicable, regulatory and certification compliance were obtained at the component level.

## KEY FEATURES & FUNCTIONALITY

**Exadata and Database Software Features - Analytics**

- *Automatically Parallelize and Offload Data Scans to storage*
- *Filter Rows in Storage based on 'where' clause*
- *Filter Rows in Storage based on columns selected*
- *JSON and XML Offload*
- *Filter rows in Storage based on Join with other Table*
- *Hybrid Columnar Compression*
- *Storage Index data skipping*
- *I/O Resource Management by User, Query, Service, DB, etc.*
- *Automatic Transformation to Columnar Format in Flash Cache*
- *Smart Flash Caching for Table Scans*
- *Offload Index Fast Full Scans*
- *Offloads Scans on Encrypted Data, with FIPS compliance*
- *Storage offload for LOBs and CLOBs*
- *Storage offload for min/max operations*
- *Data Mining Offload*
- *All Ports Active InfiniBand Messaging*
- *Reverse Offload to DB servers if Storage CPUs are Busy*
- *Automatic Data Compression in Flash Cache*
- *Offload JSON and XML analytic queries*

**Exadata and Database Software Features - OLTP**

- *Database Aware PCI Flash*
- *Exadata Smart Flash Caching*
- *Exadata Smart Flash Logging*
- *Write-back Flash Cache*
- *I/O Prioritization by DB, User, or workload to ensure QOS*
- *Exafusion Direct-to-Wire Protocol*
- *Network Resource Management*
- *Exachk full-stack validation*
- *Full-stack security scanning*
- *NVMe flash interface for lowest latency IO*
- *Database scoped security*
- *Cell-to-Cell Rebalance preserving Flash Cache*
- *Secure disk and flash erase*
- *Oracle VM with SRIOV*
- *InfiniBand Partitioning*
- *Instant data file creation*
- *Active Bonding of InfiniBand*
- *Smart Fusion Block Transfer*
- *Automatic VLAN creation*
- *Set Minimum or Maximum Flash Cache Size per Database*

**Exadata and Database Software Features - High Availability**

- *Instant Detection of Node or Cell Failure*
- *In-Memory Fault Tolerance*
- *Sub-second Failover of I/O on stuck disk or flash*
- *Offload backups to storage servers*
- *Exadata Data Validation (H.A.R.D.)*
- *Prioritize rebalance of critical files*
- *Automatic Hard Disk scrub and repair*
- *Power cycle failed drives to Eliminate false drive failures*
- *Avoid reading Predictive failed disks*
- *Cell software transparent restart*
- *Flash and disk life cycle management alert*
- *Confinement of temporarily poor performing drives*
- *Prevent shutdown if mirror server is down*
- *Detection and disabling of unreliable network links*
- *Preserve Storage Index on Rebalance*
- *Automatic disk scrub and repair*

Manageability Features

- *Oracle Embedded Integrated Lights Out Manager (ILOM)*
- *Oracle Enterprise Manager Exadata Plug-in*
- *Active AWR includes storage stats for end to end monitoring*
- *IPv6 Support for Ethernet Connections*
- *Capacity on Demand*
- *Trusted Partitions for Oracle Virtual Machine*
- *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 and Oracle Database 12c Enterprise Edition. 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 Storage Server Software. Licenses are transferable from one system to another, or to a new system

**Oracle Software (included):**

**For database servers**: Oracle Linux 6 Update 7 with the Unbreakable Enterprise Kernel 2. Zero-loss Zero-copy Datagram Protocol (ZDP) InfiniBand 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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