ORACLE EXADATA DATABASE MACHINE X5-2

The Oracle Exadata Database Machine is engineered to be the highest performing, most cost effective and most available platform for running Oracle Database. Exadata is a modern architecture featuring scale-out industry-standard database servers, scale-out intelligent storage servers, state-of-the-art PCI flash storage servers and an extremely high speed InfiniBand internal fabric that connects all servers and storage. Unique software algorithms in Exadata implement database intelligence in storage, PCI based flash, and InfiniBand networking to deliver higher performance and capacity at lower costs than other platforms. Exadata runs all types of database workloads including Online Transaction Processing (OLTP), Data Warehousing (DW), In-Memory Analytics and consolidation of mixed workloads. Simple and fast to implement, the Exadata Database Machine powers and protects your most important databases and is the ideal foundation for a consolidated database cloud.

Engineered System For Fast and Reliable Deployment

The Exadata Database Machine is an easy to deploy system that includes all the hardware needed for running Oracle Database. The database servers, storage servers and network are pre-configured, pre-tuned and pre-tested by Oracle experts, eliminating weeks or months of effort 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.

Because all Exadata Database Machines are identically configured, customers benefit from the experience of thousands of other users that have deployed the Exadata Database Machine for their mission critical applications. Customer machines are also identical to the machines Oracle Support uses for problem identification and resolution, and the machines Oracle Engineering uses for development and testing of Oracle Database. Hence, **Exadata is the most thoroughly tested and tuned platform for running Oracle Database and is also the most supportable platform.**

ORACLE

KEY FEATURES

- Up to 684 CPU cores and 14.6.TB memory per rack for database processing
- Up to 288 CPU cores per rack dedicated to SQL processing in storage
- From 2 to 19 database servers per rack
- From 3 to 18 Oracle Exadata Storage Servers per rack
- Up to 230 TB of Flash Storage per rack
- 40 Gb/second (QDR) InfiniBand Network
- Uncompressed and mirrored usable capacity of up to 604 TB per rack
- Hybrid Columnar Compression often delivers 10X-15X compression ratios
- Complete redundancy for high availability
- Oracle Linux

KEY BENEFITS

- Uncompressed I/O bandwidth of up to 263 GB/second per rack from SQL
- Ability to perform up to 4,144,000 database 8K read I/O operations per second
- Easily upgrade to meet the needs of any size application
- Scale by connecting multiple Exadata Database Machine X5-2 racks or Exadata Storage Expansion Racks. Up to 18 racks can be connected by simply connecting via InfiniBand cables and using internal switches. Larger configurations can be built with external InfiniBand switches
- Pre-configured system optimized for all database applications

The Oracle Exadata Database Machine runs the standard Oracle Database. Therefore, **any application that uses the Oracle Database today can be seamlessly migrated to use the Exadata Database Machine with no changes to the application.**

Unlike competing hardware platforms such as IBM Mainframes, Teradata, or IBM Puredata System for Analytics (Netezza), the Exadata platform does not "lock in" customers. These competing platforms have extensive proprietary software interfaces that make it extremely complex and expensive to migrate applications to a different platform. Because Exadata is based on the industry standard Oracle database, applications can be easily and quickly migrated on or off the Exadata platform.

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 an Exadata Database Machine grows, database CPUs, storage, and networking can be added in a balanced fashion ensuring scalability without bottlenecks.

The scale-out architecture accommodates any size workload and allows seamless expansion from small to extremely large configurations while avoiding performance bottlenecks and single points of failure.

A high-bandwidth low-latency 40 Gb/second **InfiniBand network** connects all the components inside an Exadata Database Machine. Specialized database networking protocols run over the InfiniBand network and provide **much lower latency and higher bandwidth** communication than is possible using generic communication protocols. This enables both faster response time for OLTP operations, and higher throughput for Analytic workloads. External connectivity to the Exadata Database Machine is provided using standard 10 Gigabit Ethernet.

Elastic configurations provide an extremely flexible and efficient mechanism to expand computing power and/or storage capacity of any given Exadata system. The Exadata X5-2 Database Machine uses powerful compute servers each with two x86 18-core processors and 256GB of memory (expandable up to 768GB). The storage servers have 4 PCI Flash cards each with 1.6 TB (raw) Exadata Smart Flash Cache and 12x 8 TB 7,200 RPM HC disks for High Capacity configuration and 8 PCI Flash drives each with 1.6 TB (raw) storage capacity for Extreme Flash configuration. The starting configuration of an Exadata Database Machine consists of 2 database servers and 3 storage servers, which can be further elastically expanded by adding more database or storage severs as requirements grow.

Exadata Database Machine is the most versatile database platform. With Elastic Configurations, the system can be custom configured to meet any business use case.

In addition to upgrading within a rack, **multiple racks can be connected using the integrated InfiniBand fabric** to form even larger configurations. For example, a system composed of four Full Racks is simply four times as powerful as a single rack system — providing quadruple the I/O throughput, quadruple the storage capacity, and quadruple the processors. It can be configured as a large single system or logically partitioned for consolidation of multiple databases. Scaling out is easy with Exadata Database Machine. Oracle Real Application Clusters (RAC) can dynamically add more processing power, and Automatic Storage Management (ASM) can dynamically add more storage.

Fig 1: Elastic Scale-out to Multi-rack Exadata

When even larger storage capacity is required, the **Oracle Exadata Storage Expansion Rack** is available. The Exadata Storage Expansion Rack enables you to grow the Exadata storage capacity and bandwidth of any Exadata Database Machine. 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 connects to the Exadata Database Machine using the integrated InfiniBand fabric and is extremely simple to configure, as there are no LUNs or mount points. Storage is configured and added to a database online with a few simple commands. The starting configuration of the Oracle Exadata Storage Expansion Rack consists of four storage servers and can be further expanded by adding additional storage servers.

Exadata Database Machines protect your investment by allowing **newer generation servers and storage to be deployed seamlessly into existing Exadata Database Machines**. Similarly, new software releases are compatible with previous generation Exadata Database Machines. All currently supported Exadata platforms can be combined in a single configuration and can run the latest Exadata software.

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 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 Server has two x86 processors that are used for database offload. A full rack Exadata Database Machine can have a total of 288 processor cores in the storage servers 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 provides dramatic reductions in storage for large databases**. Hybrid Columnar Compression enables the highest levels of data compression 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. Typical storage savings is an industry leading 10x. On conventional systems, enabling high data compression has the drawback of reducing performance. Because the Exadata Database Machine is able to offload decompression overhead into large numbers of processors in Exadata storage, most analytics workloads run faster using Hybrid Columnar Compression than they do without it. Hybrid Columnar Compression delivers the compression and analytic performance benefits of column storage while avoiding the dramatic slowdown that pure columnar stores experience for drilldown operations (single row access).

Two modes of Hybrid Columnar Compression are available. **Query optimized 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 seldom accessed data that is 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

RELATED SERVICES

The following services are available from Oracle:
- Advanced Customer Services
- Oracle Premier Support for Systems
- Oracle Infrastructure as a Service On-Premise (IaaS)
- Oracle Platinum Services
- Oracle PlatinumPlus Services
- Consulting Services
- Oracle University courses

global indexes on the table), to ensure seamless tiering across different compression types as data ages and becomes less active.

Record breaking I/O Performance from Extreme Flash Storage Server

Exadata X5-2 introduces **Extreme Flash Storage Servers**. Each Extreme Flash storage server contains eight 1.6 TB state-of-the-art PCI Flash drives. PCI flash delivers ultra-high performance by placing flash memory directly on the high speed PCI bus rather than behind slow disk controllers and directors. Exadata flash uses the latest NVMe (Non-Volatile Memory Express) flash protocol to achieve extremely low I/O overhead.

The Extreme Flash Storage Server replaces the previous High Performance disk configuration of the Exadata Storage Server and is backward compatible with all supported Exadata systems.

Fig 2: Flash Accelerator F160 PCIe Card

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 full rack Exadata Database Machine X5-2, with 8 database servers and 14 Extreme Flash storage servers can achieve up to **263 GB per second of data scan bandwidth**, and up to **4.144 Million random 8K read and write I/O operations per second** (IOPS), and **0.25 ms Flash latency at 2 Million 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.

Tiered Disk and Flash Delivers Cost of Disk with Performance of Flash

The second Exadata storage option is the Exadata X5-2 **High Capacity Storage Server**. This server includes twelve 8 TB SAS disk drives (96 TB total) and four Flash Accelerator F160 NVMe PCIe cards with a total raw capacity of 6.4TB of flash memory. 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 since caching provides flash level performance for much more data than fits directly into flash.

The Exadata Smart Flash Cache automatically caches frequently accessed data while keeping infrequently accessed data on disk drives. 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. A single full rack Exadata Database Machine X5-2, with 8 database servers and 14 High Capacity storage servers can achieve up to **140 GB per second of data scan bandwidth**, and up to **4.144 Million random 8K read I/O operations per second** (IOPS), and **0.25 ms Flash latency at 1 Million IOPS** when running database workloads.

Exadata's Smart Flash Cache is designed to deliver flash-level IO 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 Database Machine X5-2 with 8 database servers and 14 High Capacity Storage Servers often has an effective flash capacity equal to the full disk capacity of 1344TB.

The Exadata Smart Flash cache also caches database block writes. Write caching eliminates disk bottlenecks in large scale OLTP and batch workloads. The flash write capacity of a single full rack Exadata Database Machine X5-2 with 8 database servers and 14 High Capacity Storage Servers exceeds **2.69 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 Smart Flash Cache also 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.

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 X5 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... 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. Third party flash arrays will also not benefit from Exadata Hybrid Columnar Compression. 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 flash-only 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.

Fault Tolerant and Fastest Database In-Memory Machine

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.

Elastic configurations enable users to configure systems with very large system memory. An X5-2 system can have up to 14.6 TB system memory and 19 database servers in one single rack. In addition, the 40Gb per second InfiniBand network provides extremely high throughput and very low latencies for in-memory queries that are distributed across nodes.

Exadata implements Oracle Database In-Memory's Fault Tolerant capability, a feature that is unique to Oracle Engineered Systems. 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 dramatically slower. This means generic configurations will fail to meet business

SLAs. However, when deployed on Exadata, the Fault-Tolerant feature of Oracle Database In-Memory can eliminate this slowdown by duplicating any subset of the in-memory data across nodes. If a node fails, queries can transparently use the duplicate copy of data on a surviving node and processing can continue without interruption.

Enhanced Consolidation using Exadata Virtual Machines

Consolidated environments running on Exadata can use Oracle Virtual Machine (OVM) to deliver a high degree of isolation between workloads. This is a very desirable feature for hosted, shared, service provider, and test/dev environments. Using OVM, multiple software clusters can be deployed on the same Exadata Database Machine, which enables consolidation of applications that have specific clusterware version needs.

Exadata Database Machine is the world's fastest virtualized database platform. Exadata virtual machines use high speed InfiniBand networking with Single Root IO Virtualization (SR-IOV) to ensure that performance within a virtual machine is similar to Exadata's famous raw hardware performance. Exadata Smart Scans greatly decrease virtualization overhead compared to other platforms by dramatically reducing message traffic to virtual machines. Exadata virtual machines can dynamically expand or shrink CPUs and memory based on the workload requirement of the applications running in that virtual machine.

Virtual machines on Exadata are considered Trusted Partitions and therefore software can be licensed at the virtual machine level instead of the physical processor level. Without Trusted Partitions, database options and other Oracle software must be licensed at a server or cluster level even though all databases running on that server or cluster may not require a particular option.

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, **Exadata 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 near zero overhead at hundreds of gigabytes of user data per second.

The Exadata system is designed and delivered as an integrated whole, and not a collection of components. In traditional database deployments, the customer takes on all the integration tasks for the system – 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.

Exadata security has been probed and evaluated by hundreds of leading banks, telecoms, and governments worldwide. The security findings of all these evaluations have been incorporated into the Exadata standard configuration, making it a highly secure database system.

Mission Critical High Availability

The Exadata Database Machine is engineered to provide the highest levels of availability. **All types of failures are protected against** including 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. 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 to transparently maintain a real-time copy of the database at a remote site to provide full protection against primary database failures and site disasters.

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. Mission Critical availability is not restricted to OLTP workloads; it also applies to warehousing and analytics workloads.

Comprehensive System Management

Oracle Enterprise Manager 12c uses a holistic approach to manage the Exadata Database Machine and provides comprehensive lifecycle management from monitoring to management and ongoing maintenance for the entire system. It provides **a unified view of all the hardware and software components** such as database servers, Exadata storage, and InfiniBand switches and allows monitoring the operations running on them and their resource utilization. DBAs can drill down from database monitoring screens to the storage layer of the Exadata Database Machine to quickly determine the root cause of application level performance bottlenecks. Lights-out monitoring within Enterprise Manager is optimized for the Exadata Database Machine with predefined metrics and thresholds so that administrators receive timely notifications when issues arise. In addition, hardware incidents are automatically detected and service requests logged to reduce problem resolution time. Administrators can use Consolidation Planner in Oracle Enterprise Manager to determine optimal consolidation strategies for different Exadata Database Machine configurations and the **Cloud Management Pack** to manage Database as a Service deployment.

Ideal Platform for Database as a Service

The Exadata Database Machine can host many databases, enabling Database Consolidation or a sophisticated Database as a Service (DBaaS) 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 platform for multi-database workloads.

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 provides unique **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 implements unique **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.

Exadata also implements unique **database network resource management** to ensure that network intensive workloads such as reporting, batch, and backups don't stall response time sensitive interactive workloads. Latency sensitive network operations such as RAC Cache Fusion communication and Log File Writes are automatically moved to the head of the message queue in server and storage network cards as well as InfiniBand network switches, bypassing any non-latency sensitive messages. Latency critical messages even jump ahead of non-latency critical messages that have already been partially sent across the network, ensuring low response times even in the presence of large network DMA (Direct Memory Access) operations.

Fast Deployment of Development and Test Databases with Exadata Snapshots

Space efficient Database Snapshots can be quickly created for test and development purposes directly on Exadata. Exadata database snapshots are integrated with the Multitenant Database Option to provide an extremely simple interface for creating new PDB snapshots.

Snapshots start with a shared read-only copy of the production database (or PDB) that has been cleansed of any sensitive information. 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, 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.

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 Service** 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, fault monitoring, Oracle 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 single 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 10X compared to a traditional system.

Exadata provides a huge RAM, flash and disk footprint for large data sets. Raw storage on an Exadata full rack exceeds 1.3 Petabyteand Hybrid Columnar Compression often expands storage and memory capacity 10X. By intelligently moving active data across storage 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.

Capacity-on-Demand Software Licensing

An X5-2 database server has a substantial amount of compute capacity with two x86 18-core processors (36 cores in total).

The Capacity-on-Demand feature allows up to 60% of the cores per server to be turned off during the hardware installation, leaving at least 14 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, and security at low cost, 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 Database.

EXADATA DATABASE MACHINE X5-2 STANDARD RACK CONFIGURATIONS

Full Rack	Half Rack	Quarter Rack	Eighth Rack
8 x Database Servers, each with:	4 x Database Servers, each with:	2 x Database Servers, each with:	2 x Database Servers, each with:

- *2 x Eighteen-Core Xeon® E5-2699 v3 Processors (2.3 GHz)*
- *256GB Memory (expandable to 768GB)*
- *Disk Controller HBA with 1 GB Supercap-backed Write Cache*
- *4 x 600 GB 10,000 RPM Disks*
- *2 x QDR (40Gb/s) InfiniBand Ports*

- *4 x 1/10 Gb Ethernet Ports (copper)*
- *2 x 10 Gb Ethernet Ports (optical)*
- *1 x ILOM Ethernet Port*
- *2 x Redundant Hot-Swappable Power Supplies*

Full Rack	Half Rack	Quarter Rack	Eighth Rack
288 CPU cores and up to 6TB memory for database processing (36 CPU cores and up to 768 GB memory per Database Server)	144 CPU cores and up to 3TB memory for database processing (36 CPU cores and up to 768 GB memory per Database Server)	72 CPU cores and up to 1.5TB memory for database processing (36 CPU cores and up to 768 GB memory per Database Server)	36 CPU cores and up to 1.5 TB memory for database processing (18 CPU cores per Database Server are enabled with up to 768 GB memory per Database Server)
14 x Exadata Storage Servers X5-2, each with:	7 x Exadata Storage Servers X5-2, each with:	3 x Exadata Storage Servers X5-2, each with:	3 x Exadata Storage Servers X5-2,each with:

- *2 x Eight-core processor for SQL processing and*
- *4 PCI Flash cards each with 1.6 TB (raw) Exadata Smart Flash Cache and 12x 8 TB 7,200 RPM High Capacity disks*
  OR
- *8 PCI Flash drives each with 1.6 TB (raw) storage*

Full Rack	Half Rack	Quarter Rack	Eighth Rack
224 CPU cores for SQL processing	112 CPU cores for SQL processing	48 CPU cores for SQL processing	48 CPU cores for SQL processing (24 cores enabled)
56 PCI flash cards with 89.6 TB (raw) Exadata Smart Flash Cache, 168 x 8 TB 7,200 RPM High Capacity disks	28 PCI flash cards with 44.8 TB (raw) Exadata Smart Flash Cache, 84 x 8 TB 7,200 RPM High Capacity disks	12 PCI flash cards with 19.2 TB (raw) Exadata Smart Flash Cache, 36 x 8 TB 7,200 RPM High Capacity disks	6 PCI flash cards with 9.6 TB (raw) Exadata Smart Flash Cache, 18 x 8 TB 7,200 RPM High Capacity disks (6 more flash cards and 18 more disk drives reserved for use on upgrade to quarter rack)
OR	OR	OR	OR
112 x 1.6 TB NVMe PCI Flash Drives	56 x 1.6 TB NVMe PCI Flash Drives	24 x 1.6 TB NVMe PCI Flash Drives	12 x 1.6 TB NVMe PCI Flash Drives
			(12 more reserved for use on upgrade to quarter rack)

2 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 1.6 TB NVMe PCI Flash card and 1 x 8 TB High Capacity disk, or*
- *1 x 1.6 TB NVMe PCI flash drive*

EXADATA DATABASE MACHINE X5-2 KEY CAPACITY AND PERFORMANCE METRICS

Metric	Full Rack		Half Rack		Quarter Rack		Eighth Rack	
	HC[1]	EF[1]	HC	EF	HC	EF	HC	EF
Flash Metrics								
Maximum SQL Flash Bandwidth [2]	140 GB/s	263 GB/s	70 GB/s	131 GB/s	30 GB/s	56 GB/s	15 GB/s	28 GB/s
Maximum SQL Flash Read IOPS[3]	4,144,000	4,144,000	2,072,000	2,072,000	1,036,000	1,036,000	518,000	518,000
Maximum SQL Flash Write IOPS [4]	2,688,000	4,144,000	1,344,000	2,072,000	576,000	1,036,000	288,000	518,000
Data Capacity (raw) [5]	89.6 TB	179.2 TB	44.8 TB	89.6 TB	19.2 TB	38.4 TB	9.6 TB	19.2 TB
Effective Flash Cache Capacity [6]	Up to 1344 TB		Up to 672 TB		Up to 288 TB		Up to 144 TB	
Disk Metrics								
Maximum SQL Disk Bandwidth [2]	25 GB/s		12.5 GB/s		5.4 GB/s		2.7 GB/s	
Maximum SQL Disk IOPS [3]	36,000		18,000		7,800		3,900	
Data Capacity (raw) [5]	1344 TB	179 TB	672 TB	90 TB	288 TB	38 TB	144 TB	19 TB
Combined Metrics								
Data Capacity (usable) [7]	508 TB	66 TB	254 TB	33 TB	109 TB	14 TB	54 TB	7 TB
Maximum Data Load Rate [8]	21 TB/hour	21 TB/hour	10.5 TB/hour	10.5 TB/hour	5.0 TB/hour	5.3 TB/hour	2.5 TB/hour	3.0 TB/hour

Actual system performance varies by application.

[1]HC = High Capacity EF = Extreme Flash

[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 that 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] Effective Flash Capacity is larger than the physical flash capacity and takes into account the high flash hit ratios due to Exadata's intelligent flash caching algorithms, and the size of the underlying disk storage. It is the size of the data files that can often be stored in Exadata and be accessed at the speed of flash memory.

[7] 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 for a database after taking into account ASM redundancy and preserving adequate space to recover from a drive failure. Space needed for the DBFS disk group as well as space needed to host the OS and image binaries have been removed.

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

EXADATA DATABASE MACHINE X5-2 ELASTIC EXPANSION

Multi-Rack Connection	Expand Computing Capacity	Expand Storage Capacity	Eighth Rack to Quarter Rack Upgrade
Connect any combination of up to 18 Exadata Database Machine racks or Exadata Storage Expansion Racks via the InfiniBand fabric. Larger configurations can be built with external InfiniBand switches. Connected racks can be any combination of V2 X2, X3, X4 or X5 generation hardware.	Upgradability: Expand existing computing capacity by adding additional database servers Additional Hardware Components Included With The Upgrade: • *X5-2 Database Server* • *InfiniBand and Ethernet cables and adapters to connect all the components*	Upgradability: Expand existing storage capacity by adding additional storage servers Additional Hardware Components Included With The Upgrade: • *Exadata Storage Servers X5-2 with 8 x 1.6TB NVMe PCI Flash drives* • *or 12 x 8TB 7,200 RPM High Capacity disks* • *InfiniBand and Ethernet cables and adapters to connect all the components*	Upgradability: Field upgrade from Eighth Rack to Quarter Rack. Expand just compute or just storage or both. Additional Hardware Components Present In The Eighth Rack Are Enabled With The Upgrade: • *Eighteen additional cores of the Xeon® E5-2699 v3 Processors (2.3 GHz), in each Database Server, are enabled, and/or* • *Six disks and two Flash Cache cards, in each Exadata High Capacity Storage Server, or four NVMe PCI Flash drives in each Exadata Extreme Flash Storage Server are enabled*

Upgrade Support Services

Hardware installation and software configuration

OPTIONAL CUSTOMER SUPPLIED ETHERNET SWITCH INSTALLATION IN EXADATA DATABASE MACHINE X5-2

Each Exadata Database Machine X5-2 rack has 2U available at the top of the rack that can be used by customers to optionally install their own client network Ethernet switches in the Exadata rack instead of in a separate rack. Some space, power, and cooling restrictions apply.

EXADATA DATABASE MACHINE X5-2 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 Infrastructure as a Service On-Premise (IaaS)*
- *Oracle Platinum Services*
- *Oracle PlatinumPlus 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 X5-2 EXPANSION SERVERS KEY CAPACITY AND PERFORMANCE METRICS

Metric	X5-2 Database Server Plus InfiniBand Infrastructure	X5-2 High Capacity Storage Server Plus InfiniBand Infrastructure	X5-2 Extreme Flash Storage Server Plus InfiniBand Infrastructure
Maximum SQL Flash Bandwidth [2]	NA	10 GB/s	19 GB/s
Maximum SQL Read IOPS [3]	518,000	400,000	400,000
Maximum SQL Write IOPS [4]	518,000	192,000	377,000
Flash Data Capacity (raw) [5]	NA	6.4 TB	12.8 TB
Disk Data Capacity (raw) [5]	NA	96 TB	NA

Elastic Configuration Performance is computed by taking the minimum of the sum of database server's performance and sum of storage server's performance. For example a configuration consisting of 3 database servers (3x518,000 = 1554K Read IOPs) and 4 HC storage servers (4 x 400,000 = 1600K Read IOPs) will have a read performance of 1554K IOPs.

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 IO requests running SQL. Note that the IO size greatly affects Flash IOPS. Others quote IOPS based on smaller IOs that 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 DATABASE MACHINE X5-2 COMPONENT ENVIRONMENTAL SPECIFICATIONS

Metric	X5-2 Database Server Plus InfiniBand Infrastructure	X5-2 High Capacity Storage Server Plus InfiniBand Infrastructure	X5-2 Extreme Flash Storage Server Plus InfiniBand Infrastructure
Height	1.7 in. (42.6 mm)	3.5 in. (87.6 mm)	
Width	17.5 in. (445.0 mm)	17.5 in. (445.0 mm)	
Depth	29.0 in. (737.0 mm)	29.0 in. (737.0 mm)	
Acoustic noise (operating)	7.8 B	7.8 B	7.8 B
Weight	45.0 lbs (20.4 kgs)	73.0 lbs (33.1 kgs)	62.0 lbs (28.1 kgs)
Maximum power usage	0.7 kW (0.7 kVA)	0.6 kW (0.6 kVA)	0.6 kW (0.6 kVA)
Typical power usage [1]	0.5 kW (0.5 kVA)	0.4 kW (0.4 kVA)	0.4 kW (0.4 kVA)
Cooling at maximum usage	2,481 BTU/hour (2,617 kJ/hour)	2,000 BTU/hour (2,109 kJ/hour)	2,037 BTU/hour (2,149 kJ/hour)
Cooling at typical usage	1,736 BTU/hour (1,832 kJ/hour)	1,400 BTU/hour (1,477 kJ/hour)	1,426 BTU/hour (1,504 kJ/hour)
Airflow at maximum usage [2]	115 CFM	93 CFM	94 CFM
Airflow at typical usage [2]	80 CFM	65 CFM	66 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 X5-2 ENVIRONMENTAL SPECIFICATIONS

Metric	Full Rack	Half Rack	Quarter Rack	Eighth Rack
Height Width Depth	• 78.66" - 1998 mm • 23.62" – 600 mm • 47.24" – 1200 mm			
Acoustic noise (operating)	8.6 B	8.5 B	8.3 B	8.3 B

Environmentals With High Capacity Disks

Metric	Full Rack	Half Rack	Quarter Rack	Eighth Rack
Weight	1928.5 lbs (874.8 kg)	1236.5 lbs (560.9 kg)	840.5 lbs (381.2 kg)	840.5 lbs (381.2 kg)
Maximum power usage	15.3 kW (15.6 kVA)	8.2 kW (8.4 kVA)	4.1 kW (4.2 kVA)	3.4 kW (3.4 kVA)
Typical power usage [1]	10.7 kW (10.9 kVA)	5.8 kW (5.9 kVA)	2.9 kW (2.9 kVA)	2.4 kW (2.4 kVA)
Cooling at maximum usage	52,052 BTU/hour 54,915 kJ/hour	28,133 BTU/hour 29,680 kJ/hour	14,082 BTU/hour 14,856 kJ/hour	11,530 BTU/hour 12,164 kJ/hour
Cooling at typical usage	36,437 BTU/hour 38,441 kJ/hour	19,693 BTU/hour 20,776 kJ/hour	9,857 BTU/hour 10,399 kJ/hour	8,071 BTU/hour 8,515 kJ/hour
Airflow at maximum usage [2]	2410 CFM	1302 CFM	652 CFM	534 CFM
Airflow at typical usage [2]	1687 CFM	912 CFM	456 CFM	374 CFM

Environmentals With Extreme Flash Drive

Metric	Full Rack	Half Rack	Quarter Rack	Eighth Rack
Weight	1774.5 lbs (804.9 kg)	1159.5 lbs (525.9 kg)	807.5 lbs (366.3 kg)	807.5 lbs (366.3 kg)
Maximum power usage	15.4 kW (15.7 kVA)	8.3 kW (8.5 kVA)	4.2 kW (4.2 kVA)	3.4 kW (3.5 kVA)
Typical power usage [1]	10.8 kW (11.0 kVA)	5.8 kW (5.9 kVA)	2.9 kW (3.0 kVA)	2.4 kW (2.4 kVA)
Cooling at maximum usage	52,578 BTU/hour 55,469 kJ/hour	28,396 BTU/hour 29,958 kJ/hour	14,195 BTU/hour 14,975 kJ/hour	11,674 BTU/hour 12,317 kJ/hour
Cooling at typical usage	36,804 BTU/hour 38,829 kJ/hour	19,877 BTU/hour 20,970 kJ/hour	9,936 BTU/hour 10,483 kJ/hour	8,172 BTU/hour 8,622 kJ/hour
Airflow at maximum usage [2]	2434 CFM	1315 CFM	657 CFM	540 CFM
Airflow at typical usage [2]	1704 CFM	920 CFM	460 CFM	378 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 X5-2 REGULATIONS AND CERTIFICATIONS

Regulations [1]

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 [1]

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 [1]

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

[1]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

Oracle Database Software (sold separately)

For database servers	Oracle Database 11g Release 2 Enterprise Edition and Oracle Database 12c Enterprise Edition
	Oracle Real Application Clusters, Oracle Partitioning, Oracle Multitenant and other Oracle Database options are available
	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 6 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)

Exadata Storage Software Features (Partial List)

• *Smart Scan Technology*	• *IO and Network Resource Management*
• *Smart Flash Cache*	• *Storage Index*
• *Smart Flash Logging*	• *Hybrid Columnar Compression*
• *Columnar Flash Cache*	• *Smart Scans of Data Mining model scoring*
• *Exadata Snapshots*	• *Exadata Virtual Machines*
• *Exafusion Direct to Wire OLTP Protocol*	• *I/O Analysis in AWR reports*

High-Availability Features

• *Redundant power supplies for all servers*	• *Backup is performed using Oracle Recovery Manager*
• *Redundant InfiniBand switches*	• *Point in time restores are performed using Oracle Flashback Technologies*
• *Redundant Power Distribution Units*	• *Oracle Data Guard for protection against disasters*
• *Oracle Automatic Storage Management: All database files mirrored; disk failures do not interrupt query processing*	• *Near instant server death detection*
• *Oracle Real Application Clusters: database server failures are tolerated*	• *I/O latency capping*
• *Oracle Exadata Storage Server Software: storage server failures are tolerated*	• *In-Memory Fault Tolerance*

Manageability Features

- *Oracle Embedded Integrated Lights Out Manager (ILOM)*
- *Oracle Enterprise Manager 12c*

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Hardware and Software, Engineered to Work Together

Oracle is committed to developing practices and products that help protect the environment