



An Oracle White Paper

Oracle Server X5-2 System Architecture

Introduction	2
Product Overview	2
Best for Oracle Software	2
Oracle-Unique NVMe Design and Database Smart Flash Cache ..	3
Agility, Performance, and Reliability with Oracle Real Application Clusters	5
Efficient Computing and Virtualization	6
Challenges of Compute Density	6
Innovative Reliability, Availability, and Serviceability (RAS)	7
Hardware Designed for Advanced RAS	7
Fault Management and Diagnostics.....	7
Oracle's x86, Oracle Linux, and Oracle Software—Engineered To Work Together	10
System Design	10
Single-Pane-of-Glass Management.....	14
Conclusion	15

Introduction

Oracle Server X5-2, Oracle's latest two-socket server, is the newest addition to the family of Oracle's x86 servers that are purpose-built to be best for running Oracle software. The new Oracle Server X5-2 1U system is optimal for running Oracle Database in a clustered configuration with Oracle Real Application Clusters (Oracle RAC) and other clustered database solutions, as well as enterprise applications in virtualized environments.

Product Overview

Oracle Server X5-2 supports up to two Intel® Xeon® E5-2600 v3 processors. Each Intel Xeon processor provides up to 18 cores, with a core frequency of up to 2.6 GHz, and has up to 45 MB L3 cache along with 24 dual inline memory module (DIMM) slots, when fully populated with twenty-four 32 GB DDR4-2133 DIMMs, provides 768 GB of memory. Memory bandwidth increases to 2,133 MT/sec per channel compared to 1,600 MT/sec in the previous generation.

In addition, Oracle Server X5-2 has four PCIe Gen3 slots (2 x16, 2 x8 lanes), four 10GBase-T ports, six USB ports, and eight 2.5-inch drive bays providing 9.6 TB of hard disk drive (HDD) storage or 3.2 TB of solid state drive (SSD) storage. An optional DVD drive is supported to allow local access for operating system installation.

The SSD drives used in Oracle Server X5-2 are SAS-3 drives with a bandwidth of 12 Gb/sec providing double the performance of the previous generation. Oracle Server X5-2 can also be configured with up to four NVM Express (NVMe) drives from Oracle for a total of 6.4 TB of high-performance, high-endurance PCIe flash.

Best for Oracle Software

Oracle Server X5-2 systems are ideal x86 platforms for running Oracle software. Only Oracle provides customers with an optimized hardware and software stack that comes complete with choice of OS, virtualization software, and cloud management tools—all at no extra charge. Oracle's optimized hardware and software stack has enabled a 10x performance gain in its engineered systems and has delivered world-record benchmark results. Oracle's comprehensive, open standards-based x86 systems provide the best platform on which to run Oracle software with enhanced reliability for data center environments.

In today's connected world, vast amounts of unstructured data flow into an enterprise, creating an immediate business need to extract queryable structured data grams from this slew of information. Online transaction processing (OLTP) is a technology that historically has been used for traditional enterprise applications such as enterprise resource planning (ERP) and human capital management (HCM). Now OLTP finds itself in a unique position

to accelerate business intelligence and analytics. As such, this places greater demands on the database, I/O, and main memory requirements in data centers. Oracle Database is designed to take advantage of hardware features such as high-core-count central processing units (CPUs), non-uniform memory access (NUMA) memory architectures, and tiered storage of data that enhance system performance.

Benefits include increased transaction throughput and improved application response times, which reduce the overall cost per transaction.

Oracle Server X5-2, NVM Express and Oracle Database Smart Flash Cache

Oracle Database utilizes a feature called Database Smart Flash Cache. This feature is available on Oracle Linux and Oracle Solaris and allows customers to increase the effective size of the Oracle Database buffer cache without adding more main memory to the system. For transaction-based workloads, Oracle Database blocks are normally loaded into a dedicated shared memory area in main memory called the system global area (SGA). Database Smart Flash Cache allows the database buffer cache to be expanded beyond the SGA in main memory to a second level cache on flash memory. The new NVMe flash drives in Oracle Server X5-2 provide a high-bandwidth, low-latency implementation of Database Smart Flash Cache based on PCI Express (PCIe) that vastly improves OLTP transaction times.

Oracle Server X5-2 introduces a new flash technology called NVM Express that provides a high-bandwidth, low-latency PCI Express (PCIe) interface to large amounts of flash within the system. Oracle Database with Database Smart Flash Cache and Oracle Solaris ZFS are specifically engineered to take advantage of this low-latency, high-bandwidth interface to flash in Oracle Server X5-2. Oracle Solaris and Oracle Linux are co-engineered with Oracle Server X5-2 to function in enterprise-class workloads by enabling hot-pluggable capabilities. Traditional SSDs with a SAS/SATA interface are a popular method of adding flash to a server, and these take advantage of legacy storage controller and disk cage infrastructure. NVM Express is an entirely new end-to-end design that eliminates the performance bottlenecks of using conventional storage interfaces.

Figure 1 illustrates a block diagram of a traditional SAS-3 SSD connected to a server. The server PCIe root complex is connected to a PCIe/SAS controller that translates PCIe to SAS protocol to allow the server to read and write the SAS-3 SSD. As NVMe SSDs already use the PCIe protocol, there is no need for the PCIe/SAS controller translation as shown in Figure 2.

Oracle-Unique NVMe Design and Database Smart Flash Cache

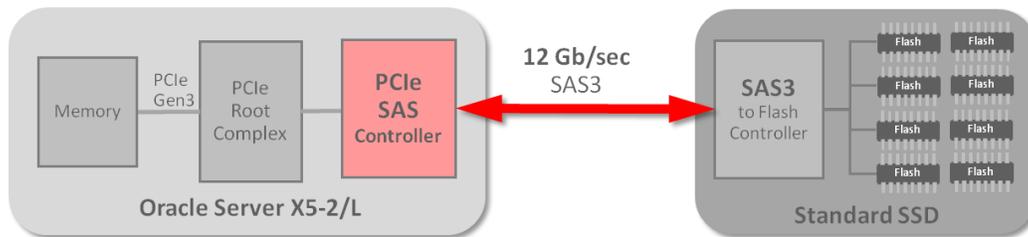


Figure 1. Traditional SAS-3 solid state drive architecture

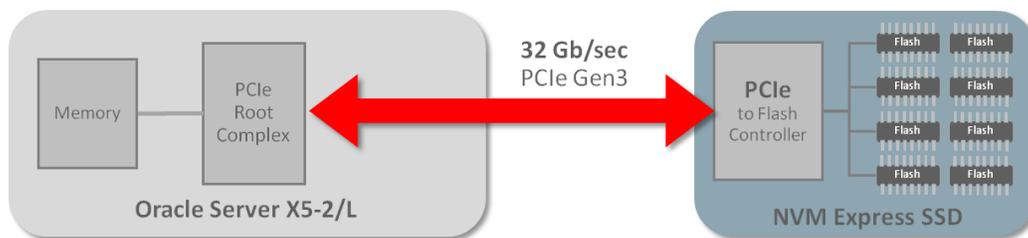


Figure 2. Oracle NVMe solid state drive architecture

Oracle's NVMe drives have a much lower latency and higher bandwidth than standard SAS-3 drives due to the fact that the drive connects directly to four lanes of the PCIe Gen3 with an aggregate bandwidth of 32 Gb/sec as opposed to 12 Gb/sec for a traditional SAS-3 SSD.

Oracle Server X5-2 can be configured with up to four NVMe small form factor (SFF) SSDs that support up to 6.4 TB of flash storage.

As flash technologies are temperature sensitive, most high-performance flash drives will throttle down their I/O speeds as temperatures rise in order to protect the flash from damage. Oracle's NVMe SSDs, on the other hand, include multiple temperature sensors that are monitored by Oracle Server X5-2's Oracle Integrated Lights Out Manager (Oracle ILOM) service processor (SP) to ensure the drive maintains optimum operating temperature. Oracle ILOM modulates the fan speed to ensure sufficient cooling for maximum system performance at all times. The benefits of this being that the system consistently operates at maximum performance across the full operating temperature range of the server independent of system configuration.

Agility, Performance, and Reliability with Oracle Real Application Clusters

Designed as an optimal server for running Oracle Database in a clustered configuration, Oracle Server X5-2 can be combined with Oracle Real Application Clusters (Oracle RAC) to achieve high availability, performance, and agility.

Oracle Real Application Clusters provides a unique technology for scaling applications. Traditionally, when database servers run out of capacity, they are replaced with new, larger, more expensive servers. However, for databases using Oracle RAC, there are alternatives for increasing the capacity.

Applications that traditionally ran on large symmetric multiprocessing (SMP) servers have migrated to run on pools of small x86 servers in a cluster. Using this strategy, current hardware investment can be maintained and new servers can be added to the pool without downtime. As Oracle Server X5-2 packs up to 36 CPU cores and 768 GB of memory into a compact 1U form factor, it provides a high-performance, resilient, and scalable building block for the cluster. Adding additional servers to the pool allows the load on the system to be balanced across all servers hence improving the overall performance.

Oracle Server X5-2 two-socket servers are an ideal choice for Oracle RAC as they provide the granularity IT managers require for small building blocks in their data centers with a high level of performance and best-in-class reliability—making them a no-compromise solution for this application.

When using the Database Smart Flash Cache feature of Oracle Database 12c in combination with the NVMe SSDs, Oracle Server X5-2 accelerates access to shared storage by keeping recently accessed data in direct attached flash drives. This reduces the frequency of data access from slower network attached storage (NAS) or storage attached networks (SAN).

The firmware for the SAS controller, NVMe drives, and network interface cards (NICs) is optimized to ensure maximum performance and reliability. This is particularly important for networking in an Oracle RAC environment in which different servers share common data. The firmware is optimized to minimize the processing overhead of keep-alive messages between nodes in a cluster further improving system performance.

The reliability of Oracle Server X5-2 is key in an Oracle RAC configuration. For example, if one node of a two-node Oracle RAC configuration goes down, there is a loss of redundancy in the cluster that impacts overall performance. Oracle Server X5-2 provides the highest level of reliability in the market and is an excellent choice for two-node Oracle RAC configurations. Oracle Integrated Lights Out Manager (Oracle ILOM) and advanced diagnostics tools work in conjunction with hardware features to identify component-level issues and offline faulty subsystems, therefore improving reliability and uptime. Oracle's

software stack enables total application-to-disk visibility, ensuring maximum system uptime and lowest total cost of ownership.

Efficient Computing and Virtualization

With organizations facing growing IT expenses, it is essential to be able to do more with less. Server virtualization is the foundation of private cloud infrastructures and serves as the consolidation mechanism for heterogeneous workloads. Oracle Server X5-2 is the ideal platform for virtualization, providing the ability to get the most out of each server by simultaneously maximizing memory capacity, I/O, and compute density.

The best virtualization platforms allow for high virtual machine (VM) density while providing fast live migration, reliability, and performance. While one important metric for estimating VM density is core density, there are actually many other factors—such as memory capacity, memory bandwidth, and I/O bandwidth—that are equally important in determining how many VMs can be consolidated onto one server. Enterprise-class VM environments rely heavily on I/O bandwidth and low-latency networks to be able to migrate VMs for load balancing as well as failover scenarios. The I/O slots can be configured with high-bandwidth low-latency fabrics such as InfiniBand. Combined with Oracle Virtual Networking, enterprises get the benefit of high server consolidation ratios as a large number of VMs can be reliably deployed and managed. The cable aggregation advantages of Oracle Virtual Networking, combined with a full suite of tools like Oracle Fabric Manager and Oracle Enterprise Manager 12c, allow customers to benefit from simplifications of managing virtualized infrastructures.

By allowing more VMs per server, organizations can reduce operating expenses by having fewer physical servers in their inventories. This means less patching, less maintenance, less cabling, and easier overall systems management. Oracle Server X5-2 strikes an ideal balance for virtualized environments: its high VM consolidation factor provides simplified infrastructure while at the same time providing a cost-effective means for scaling out.

With up to 106 Gb/sec of raw I/O bandwidth, combined with the high core and memory density, Oracle Server X5-2 is also an ideal server for consolidating enterprise virtual machines when used with Oracle VM. With an optimal balance among core density, memory footprint, and I/O bandwidth, Oracle Server X5-2 can be easily deployed into existing data centers as the building block of a private cloud or infrastructure-as-a-service (IaaS) implementation. When combined with Oracle Fabric Interconnect and Oracle SDN, Oracle Server X5-2 packs in the most VMs per rack in the industry while enabling fast live migration and cable consolidation. This consolidation can result in 70 percent less I/O complexity and 50 percent cost reduction.

Challenges of Compute Density

Today's IT architects are constantly faced with the challenges of increasing compute density at the expense of serviceability, expandability, and reliability. Oracle Server X5-2 is designed with a holistic approach of engineering hardware and firmware together. This

integrated design allows Oracle Server X5-2 to provide a substantial performance improvement over the previous generation while remaining within the same power profile. Specifically, the server design maximizes efficiency, providing the best combination of compute power and density that allows these servers to fit into existing and Greenfield data centers.

Rather than optimizing only for compute and memory density, like many commodity two-socket servers, Oracle Server X5-2 allows for the extreme I/O bandwidth and expandability required for enterprise virtualization workloads. This enables customers to consolidate I/O-intensive VMs, such as Oracle Database and applications, without compromising on performance.

Innovative Reliability, Availability, and Serviceability (RAS)

Oracle Server X5-2 is designed completely in house from the ground up and is engineered to be easily serviceable whilst maximizing reliability. Oracle engineers pay particular attention to the chassis design, which has special features added to improve performance whilst also improving reliability and serviceability. Oracle engineers have designed a rigorous testing process for all components of the server such as memory DIMMs, hard disk drives, power supplies, etc. These quality assurance tests are supplementary to those conducted by the supplier. All components of the system have to pass these tests prior to release of the products to market.

Hardware Designed for Advanced RAS

Oracle Server X5-2 is designed for maximum uptime with enterprise-grade availability features. All disks are hot swappable and support RAID 0, 1, 5, 6, 10, 50, and 60. The RAID controller has a 1GB write back cache design and uses an energy storage module to save data in flash upon server power failure. This energy storage module resides in a location in the server that guarantees data protection of the write-back cache for all operating conditions of the server. The power supplies and fans are also redundant and hot swappable, ensuring that a failure to any single component does not affect the running system. With two power supplies, the server offers N+N power redundancy.

The chassis and motherboard are designed to eliminate as many cables as possible; for example, the power supplies mate directly to connectors on the motherboard, eliminating a power distribution cable and a single point of failure. The fans also mount directly to the motherboard, eliminating cables, hence improving reliability. All disks are front accessible and hot swappable including the NVMe SFF drives.

Fault Management and Diagnostics

Reliability, availability, and serviceability (RAS) are extremely important to customers who demand maximum system availability when running business-critical applications. If a fault occurs in a server, revenue can be lost and extensive time and effort, can be spent

debugging the problem and waiting on replacement parts and service personnel to replace faulty components.

With higher levels of integration of various subsystems in the server, it is becoming more complex to diagnose faults down to the component level. A key element of serviceability that is taken into consideration in Oracle Server X5-2 is automatic fault diagnosis with accurate identification of faulty components.

Oracle Server X5-2 includes built-in fault management and diagnostic tools that increase system availability and enable faster service response times that increase server uptime. Oracle Server X5-2 includes Oracle Integrated Lights Out Manager (Oracle ILOM), which performs advanced health monitoring of the server operating environment (power and cooling), CPUs, and memory subsystems. This advanced diagnosis engine is resident in the embedded service processor firmware and constantly monitors the state of these subsystems without interfering with the functionality of the host. Automatic notifications are generated in the event of problems. Building on the fault management infrastructure, Oracle ILOM has the ability to raise automatic service requests (ASRs). This feature enables service requests to be generated automatically and important fields pre-populated for use by Oracle service personnel. The elimination of human intervention in the service request generation process improves accuracy of problem notification to Oracle.

On a typical server, the host operating system and the service processor have mutually exclusive (although sometimes partially overlapping) subsystems that they manage. The host operating system has ownership of the CPU, memory, and I/O subsystems while the service processor presides over the fans, power supplies, DIMMs, and other miscellaneous chassis components. For these reasons, data center managers are often forced to monitor the health of the host operating system and the service processor as if they were separate entities.

Oracle Server X5-2 overcomes the above limitations by enabling a bidirectional communication path between Oracle ILOM and Oracle Solaris or Oracle Linux that facilitates exchange of critical health information between the host and the service processor. Having a dedicated interconnect between the host OS and Oracle ILOM allows a holistic and single view of all problems in a system. Data center managers and administrators can depend on this operating system and hardware integration for complete system diagnosis, eliminating the need to connect to multiple management entities.

Oracle Solaris and Oracle Linux include a set of diagnosis engines that process raw error events from the hardware and provide an automated and intelligent method for problem diagnosis and fault isolation. These engines are part of the Fault Management Architecture feature of Oracle Solaris and Oracle Linux and include a set of agents that respond to fault events, such as off-lining a faulty CPU thread or retiring a memory page on a DIMM. These advanced, self-healing features help reduce unplanned downtime by isolating a problem at runtime and keeping applications running.

Running Oracle Linux or Oracle Solaris on Oracle Server X5-2 ensures maximum system availability by providing early warnings of potential failures, fault visibility and dynamic off-lining of faulty hardware. All of these functions are available at no additional cost.

	Oracle x86 with Oracle Solaris or Oracle Linux	Non-Oracle x86 with third-party OS
Diagnosis of correctable and uncorrectable CPU and memory errors on Intel Xeon processor-based servers	✓	✓
Single view of all hardware problems on the server	✓	✗
Identification of faulty components using the same name that is printed on the chassis or motherboard	✓	✗
Fault indicator (LED) turned on for component and server that has a problem	✓	✗
Automatically generated service request for host diagnosed problems	✓	✗
Validated and quality tested for each new hardware model	✓	✗

Table 1: Benefits of Oracle Solaris and Oracle Linux on Oracle Server X5-2

Oracle's x86, Oracle Linux, and Oracle Software—Engineered To Work Together

Oracle invests heavily in engineering and quality assurance for its Oracle Linux operating system. While many customers choose Oracle Linux to support their mission-critical applications, Oracle Linux is also the principle development platform for Oracle's own database, middleware, and application software. More than 175,000 Oracle Linux installations are deployed on both physical and virtual servers.

Oracle Linux receives more than 128,000 hours of database and application testing each day, which makes Oracle software more reliable. Even before formal evaluation occurs, Oracle Linux is the base platform on which developers prove functionality, quality, and software viability. In addition, Oracle Linux includes Oracle's Unbreakable Enterprise Kernel, a feature that is specifically optimized for the best performance of Oracle software. Oracle engineers extensively test the Unbreakable Enterprise Kernel across Oracle's database, middleware, and application tiers on Oracle's x86 servers and engineered systems to ensure optimum functionality. This extensive testing ensures that the combination of Oracle Server X5-2 with Oracle Linux provides an extremely reliable, robust, and high-performance server for database and enterprise applications.

To streamline the installation of Oracle Linux or Oracle Solaris, Oracle provides the Oracle System Assistant, an embedded wizard-style tool that assists with each step of deploying the server. In addition to installing the operating system, Oracle System Assistant updates firmware, drivers, and configures RAID and Oracle ILOM—all of which improves the efficiency of server deployment.

System Design

Oracle Server X5-2 is designed to be a compact and energy-efficient 1U enterprise-class server powered by two Intel® Xeon® processor E5-2600 v3 product family CPUs. With up to 18 cores per socket, this server supports the highest performing processor and delivers extreme compute density in a compact 1U enclosure. This system has a maximum memory capacity of 768 GB with all 24 DIMM slots populated and has a maximum memory bandwidth of 2,133 MT/sec. When combined with 106 GB/sec of bidirectional I/O bandwidth, Oracle Server X5-2 provides the optimal balance of cores, memory, and I/O throughput, making it the highest performing server in its class for enterprise applications.

Oracle optimizes the design of the memory channels in the server and is able to beat Intel's plan of record that improves performance of enterprise applications. The higher bandwidth at higher memory capacities allows for better performance for Oracle RAC. The table below illustrates these optimizations.

	1 DIMM Per Channel		2 DIMMs Per Channel		3 DIMMs Per Channel	
	1.2 V		1.2 V		1.2 V	
	Intel	Oracle	Intel	Oracle	Intel	Oracle
8 and 16 GB RDIMM (MT/sec)	2,133	2,133	1,866	2,133	1,600	1,600
32 GB LRDIMM (MT/sec)	2,133	2,133	2,133	2,133	1,600	1,866

Table 2: Memory Channel Speeds on Oracle Server X5-2 (MT/sec)

Oracle Server X5-2 offers four PCIe Gen 3 expansion slots (two 16-lane and two 8-lane) and also includes four embedded 10GBase-T ports that free up PCIe slots for additional network and storage connectivity. There are six USB ports on this server, with two at the front of the chassis, two at the rear, and two internal. Each Oracle Server X5-2 includes a SAS-3 (12 Gb/sec) RAID controller in one of the 8-lane PCIe slots and includes eight small-form-factor drive bays. The server can be configured with up to 9.6 TB of hard disk drive capacity or up to 3.2 TB of conventional solid state drive flash capacity.

In order to achieve accelerated performance, Oracle Server X5-2 introduces hot-swappable, high-bandwidth flash using Oracle's unique NVMe design that supports up to four small-form-factor NVMe drives for a total capacity of 6.4 TB. These NVMe SSDs occupy designated slots of the eight-disk drive bay of Oracle Server X5-2. The server supports a mix of NVMe SSDs, traditional SSDs, and HDDs in the same chassis.

In the rear of the chassis is a dedicated management port that provides access to the Oracle ILOM service processor as well as support for a number of I/O option cards that enable Ethernet, Fibre Channel, and InfiniBand. Figure 3 illustrates the system block diagram and Table 3 provides the full feature set of Oracle Server X5-2.

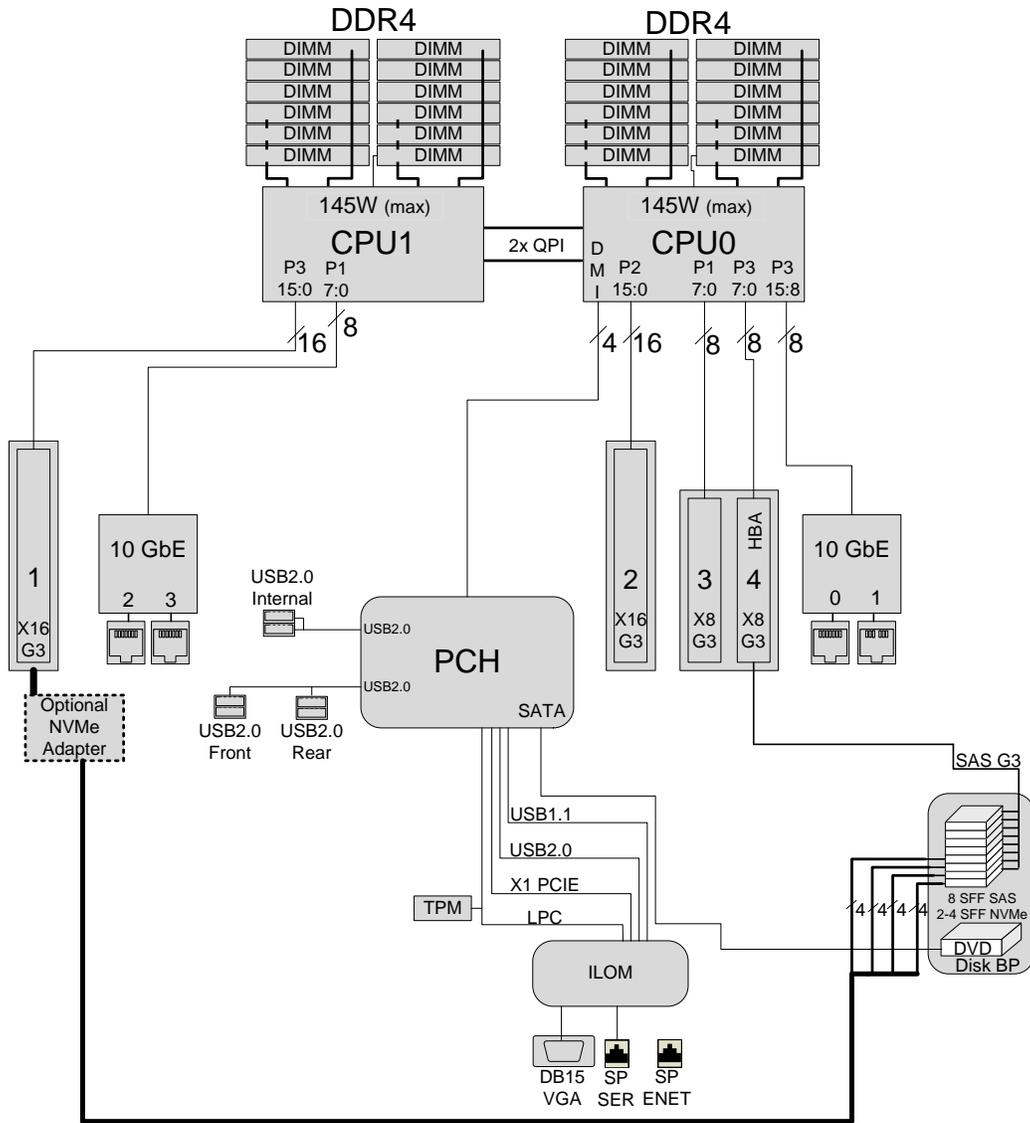


Figure 3. Oracle Server X5-2 server block diagram

	
Name	Oracle Server X5-2
Processor/ CPUs	1 or 2 processors from Intel® Xeon® processor E5-2600 v3 product family
Memory	<ul style="list-style-type: none"> • 8 GB and 16 GB registered or 32 GB load-reduced DDR4-2133 DIMMs • 24 DDR4 DIMM slots (12 DIMM slots per CPU socket) • Supports up to 768 GB of memory capacity
Internal disk	<ul style="list-style-type: none"> • Eight 2.5-in. front-accessible disk bays supporting a combination of SAS-2 or SAS-3 HDDs, SAS-3 SSDs, and NVMe SSDs (up to 4) • Optional DVD R/W drive
External disk and tape	oracle.com/storage
Graphics	VGA 2D graphics controller embedded, with 8 MB memory supporting 1,920x1,200 x 16bits
Expansion bus and ports	<ul style="list-style-type: none"> • 4 low profile PCIe Gen 3 slots • Four 100/1000/10000Base-T Ethernet ports • 1 dedicated 10/100/1000Base-T Ethernet management port • 1 asynchronous RJ45 serial port
Power	Dual redundant, hot-swappable power supply: 100 V AC to 240 V AC
Operating temperature	41°F to 95°F (5°C to 35°C)
Nonoperating temperature	-40°F to 158°F (-40°C to 70°C)
Rack units	1U
Height	42.6 mm (1.7 in.)
Width	436.8 mm (17.2 in.)
Depth	737.0 mm (29.0 in.)
Weight (max.)	40 lb. (18.1 kg)
Operating system	<ul style="list-style-type: none"> • Oracle Solaris • Oracle Linux • Oracle VM • Red Hat Enterprise Linux • SUSE Linux Enterprise Server • VMware • Microsoft Windows Server

Table 3: Oracle Server X5-2 Server Feature Set

Single-Pane-of-Glass Management

Oracle Enterprise Manager 12c is a suite of systems management tools that provides a single-pane-of-glass management solution for the entire Oracle stack. This enables organizations to manage their Oracle Server X5-2 servers from the hardware layer all the way up to the database and applications running on them.

Oracle Enterprise Manager Ops Center 12c, part of the Oracle Enterprise Manager family, is an enterprise management tool that allows IT staff to manage all aspects of their servers. In addition to providing detailed hardware monitoring and reporting for hardware problems, Oracle Enterprise Manager Ops Center can provision a bare metal system with an operating system and also configure virtualization.

Oracle Enterprise Manager Cloud Control a feature of Oracle Enterprise Manager 12c, can be used to implement private cloud on Oracle Server X5-2. Oracle Enterprise Manager Cloud Control provides a complete cloud lifecycle management solution enabling users to quickly set up, manage, and support enterprise clouds and traditional Oracle IT environments from applications to disk.

Conclusion

As business success often depends closely on enterprise applications, IT departments strive to provide an optimal software and hardware infrastructure—one that delivers responsive performance, scalable capacity, and “always-on” availability. Oracle Server X5-2 is designed to simplify field installation, reduce cabling, minimize power consumption, maximize system uptime, and improve compute density, making it an ideal choice for system deployment.

Oracle Server X5-2 is also the best two-socket server for running Oracle Database in a clustered configuration and for high-density virtualization environments that require an optimal balance among core density, memory footprint and I/O bandwidth.

The key new features incorporated in Oracle Server X5-2, such as the high-bandwidth, low-latency NVMe flash drives, SAS-3 SSDs and DDR4 memory; significantly improve the performance over the previous generation. Combining these features with built-in, proactive fault detection and advanced diagnostics ensures Oracle Server X5-2 provides extreme reliability for enterprise workloads.

Oracle's x86 systems serve as a key building block for Oracle's engineered systems, such as Oracle Exadata, which have achieved a 10x performance gain through integration and optimization. These optimizations have been incorporated into the design of Oracle Server X5-2 further improving its performance and reliability—making it an ideal choice for enterprises that value the quality, system availability, and server efficiency that result in reduced total cost of ownership.

More information about Oracle Server X5-2 can be found at:
<http://my.oracle.com/site/pd/sss/servers/x86/cnt2235456.html> or, an Oracle representative can be reached at +1.800.ORACLE1.



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Hardware and Software, Engineered to Work Together