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An Oracle White Paper

Oracle Server X5-2L System Architecture

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Introduction

Oracle Server X5-2L, 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. This 2U server is optimized for customers requiring a robust and reliable platform for running single-node Oracle Database or as a storage server with Oracle Solaris and ZFS for customers requiring significant amounts of direct-attached storage.

Product Overview

Oracle Server X5-2L supports up to two Intel® Xeon® E5-2600 v3 processors, each providing up to 18 cores. Each core has up to 45 MB L3 cache along with 24 dual inline memory module (DIMM) slots that provide 768 GB of memory when populated with twenty-four 32 GB DDR4-2,133 DIMMs. Memory bandwidth increases by 33 percent to 2,133 MT/sec per channel compared to 1,600 MT/sec in the previous generation. In addition, it includes six PCIe Gen3 slots (2 x 16, 4 x 8 lanes), four 10GBase-T ports, six USB ports, and three disk cage options:

- 8 x 2.5-inch + optional DVD, with up to 9.6 TB of storage
- 12 x 3.5-inch + 2 x 2.5-inch (rear), with up to 50.4 TB of storage
- 24 x 2.5-inch + 2 x 2.5-inch (rear), with up to 31.2 TB of storage

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

Best for Oracle Software

The Oracle Server X5-2L 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 delivered world-record benchmark results. Oracle's comprehensive, open standards-based x86 systems provide the best platform to run Oracle software with enhanced reliability in data center environments.

In today's connected world vast amounts of unstructured data flows into the enterprise, creating an immediate business need to extract queriable structured data grams from this slew of information. Online transaction processing (OLTP), a technology that historically has been used for traditional enterprise applications such as enterprise resource planning (ERP) and human capital management (HCM) now 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 Database utilizes a feature called Database Smart Flash Cache. This feature is available on Oracle Linux and Oracle Solaris, and it 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.

Oracle Solaris and ZFS Acceleration with Flash

As companies look for ways to correct the imbalance between system processing needs and storage system throughput capabilities, it is essential to find an approach that maximizes IOPS. With hard disk drive performance affected by seek, rotation, and transfer times, the latency created when transferring data to and from drives results in I/O bottlenecks. Flash can be placed in a new storage tier to assist hard disk drives by holding frequently accessed data. By utilizing flash to handle CPU I/O, and hard disk drives to store massive data sets, a hybrid storage pool gives organizations significant performance gains without sacrificing capacity.

Oracle Solaris ZFS is an enterprise-class, general-purpose file system that provides virtually unlimited file system scalability and increased data integrity to large-scale solutions. By automatically allocating space from pooled storage when needed, Oracle Solaris ZFS simplifies storage management and gives organizations the flexibility to optimize data for performance. Oracle Solaris ZFS can utilize flash in many different ways to accelerate performance of applications that can benefit from a large amount of direct-attached storage. Some of the flash-specific optimizations in Oracle Solaris and ZFS are in the areas of adaptive replacement cache to accelerate reads and the ZFS intent log to accelerate writes.

Oracle Server X5-2L, with its 24-disk cage configuration, is the ideal choice for implementing a storage server solution using Oracle Solaris and ZFS. It offers a wide range of choices for the disk drive subsystem, ranging from HDDs, conventional SSDs, and NVMe SSDs, allowing users to configure tiered storage that is optimized for spindle density and flash-to-disk ratios. In addition, the compute power of Oracle Server X5-2L is used by Oracle Solaris ZFS to execute algorithms related to block allocations, compression, intelligent prefetch, monitoring RAID functionality, and the overall health of the storage subsystem.

Oracle Server X5-2L and NVM Express

Oracle Server X5-2L 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 X5-2L. Oracle Solaris and Oracle Linux are co engineered with Oracle Server X5-2L 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

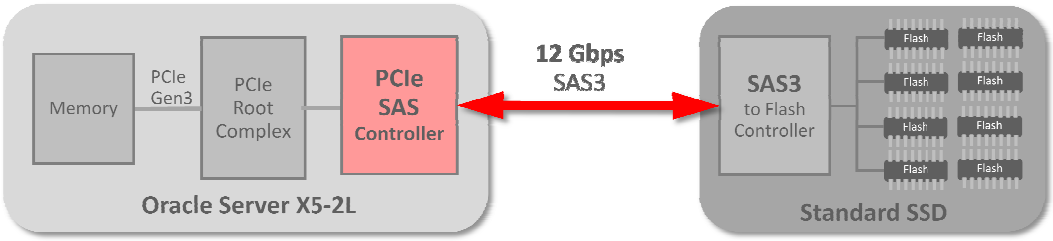

Figure 1. Traditional SAS-3 solid state drive architecture

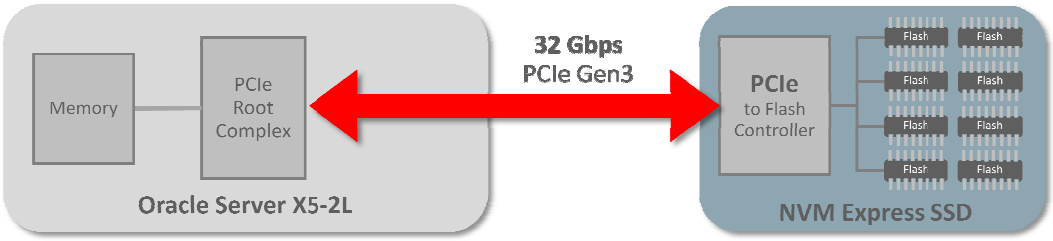

Figure 2. Oracle NVMe solid state drive architecture

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 X5-2L with the 8 x 2.5-inch disk cage and the 24 x 2.5-inch disk cage can be configured with up to four NVMe small-form-factor (SFF) SSDs that provide 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 X5-2L'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.

Extreme Flexibility and Reliability

Oracle Server X5-2L chassis is designed with flexibility in mind. It offers three disk cage options: an 8 x 2.5-inch disk cage configuration; a 12 x 3.5-inch disk cage (plus 2x 2.5-inch SFF in rear) configuration, and a 24 x 2.5-inch disk cage (plus 2x 2.5 inch SFF in rear) configuration. These options provide ultimate flexibility in disk choice to accommodate maximum redundancy and speed optimizations.

Oracle Server X5-2L with 8 x 2.5-inch disk cage configuration provides extreme I/O density with 6 PCIe 3.0 slots (two 16-lane and four 8-lane slots) offering 128 GB/sec of I/O bandwidth in a 2U form factor. The increased free airflow in the 2U chassis with larger fans (compared to a 1U server) combined with Oracle Advanced System Cooling features of Oracle Server X5-2L improves power efficiency of the cooling subsystem. The incremental power savings and maximum system uptime make this server ideally suited for environments in which power and cooling delivery to the rack is constrained.

Oracle Server X5-2L with 12 x 3.5-inch disk cage configuration has a maximum capacity of 50.4 TB of direct-attached storage, providing the flexibility to be used as a storage server. The compute power of Oracle Server X5-2L can be used to extend storage density for applications that require a combination of compute power and storage capacity at the same time, such as video compression and transcoding.

As Oracle Server X5-2L provides a 24-disk configuration, the reliability of the system can be enhanced by configuring some of the disks for redundancy to ensure a backup of critical data is maintained in direct-attached storage. For example, a database can be mirrored on redundant disks using RAID to ensure that no data is lost in the event of a faulty disk.

Oracle Server X5-2L incorporates Oracle ILOM and diagnostics tools to monitor the health of the system, evaluate potential faults, determine the root cause of actual faults

and offline faulty components whilst keeping the system up and running. Service requests to replace faulty components are automatically sent to the field service engineers, further improving system uptime. The 24-drive option allows a mix of magnetic, solid state, and NVMe drives to meet divergent system requirements of spindle density and traditional SSD based storage, as well as the high-bandwidth tiered flash needs of enterprise applications. (NVMe SSDs are only available in the 2.5-inch disk cage configurations.) Further, Oracle's engineering systems team uses Oracle's x86 servers as building blocks for Oracle Exadata, Oracle Exalogic, and Oracle Exalytics engineering systems—Oracle's flagship hardware products. The co engineering by Oracle's hardware and software teams in developing the engineering systems ensure that maximum performance and reliability are incorporated into the Oracle Server X5-2L design. As a result, both hardware and software work together in harmony.

Combining Oracle ILOM capabilities (runtime fault diagnosis and self-recovery)with the extensive reliability testing and built in redundancy makes Oracle Server X5-2L the most reliable two-socket server in the market for running Oracle Database in single-node configurations in remote or branch offices.

Innovative Reliability, Availability, and Serviceability (RAS)

Oracle Server X5-2L is designed completely in house from the ground up and is engineered to be easily serviceable whilst maximizing reliability. In particular, the chassis design has special features that improve performance whilst also improving reliability and serviceability. Oracle engineers 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 X5-2L 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 uptime when running business-critical applications. If a fault occurs in a server, revenue can be lost. Further, extensive time and effort can be spent debugging the problem and waiting on 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 X5-2L is automatic fault diagnosis with accurate identification of faulty components.

Oracle Server X5-2L includes built-in fault management and diagnostic tools that increase system availability and enable the faster service response times that increase server uptime. Oracle Server X5-2L 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 with 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 are separate entities.

Oracle Server X5-2L overcomes the above limitations by enabling a bidirectional communication path between Oracle ILOM and Oracle Solaris or Oracle Linux. This path 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 overall 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 X5-2L 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 X5-2L

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

Oracle invests heavily in engineering and quality assurance for its 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, utilizing more than 175,000 Oracle Linux installations 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, which 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 X5-2L 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 X5-2L is 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 the most flexible storage options in a 2U enclosure. When compared with the previous-generation server, this system increases memory capacity by 50 percent, to 768 GB, and increases memory bandwidth by 33 percent. With more than 50 percent increase in processing power and 13 percent increase in I/O bandwidth versus the previous generation, Oracle Server X5-2L provides optimal core, memory, and storage density combined with matched I/O throughput.

Oracle has optimized the design of the memory channels in the server and has been 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 Database. The table below illustrates these optimizations.

Memory Size	1 DIMM Per Channel		2 DIMMs Per Channel		3 DIMMs Per Channel	
	1.2V		1.2V		1.2V	
	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 X5-2L (MT/sec)

In order to achieve accelerated performance, Oracle Server X5-2L 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 8disk and 24 disk drive bays of Oracle Server X5-2L. The server supports a mix of NVMe SSDs, traditional SSDs, and HDDs in the same chassis.

Built for the demands of enterprise workloads, this server offers six PCIe 3.0 expansion slots (two 16-lane and four 8-lane slots) for maximum I/O card and port density. The four embedded 10GBase-T ports free PCIe slots for additional network and storage connectivity. Each Oracle Server X5-2L includes a SAS-3 (12 Gb/sec) RAID controller in one of the 8-lane PCIe slots. With 138 GB/sec of bidirectional I/O bandwidth, Oracle Server X5-2L can handle the most demanding enterprise workloads.

The 3-disk cage options offer a choice between maximizing storage capacity or storage performance. With the 8-disk and 24-disk configurations, Oracle Server X5-2L allows for three types of 2.5-inch small-form-factor drives: 10 K RPM hard drives, conventional solid state drives (SSDs), and NVMe flash drives (up to four). The small-form-factor hard drives provide more spindles in the chassis and higher I/O operations per second (IOPS) than large-form-factor disks. In addition, the SSD and NVMe options allow for tiered storage, ideal for accelerating enterprise applications. With the 12-disk configuration, the server maximizes storage capacity using 3.5-inch large-form-factor disks.

In the rear of the chassis is a dedicated management port for 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 X5-2L.

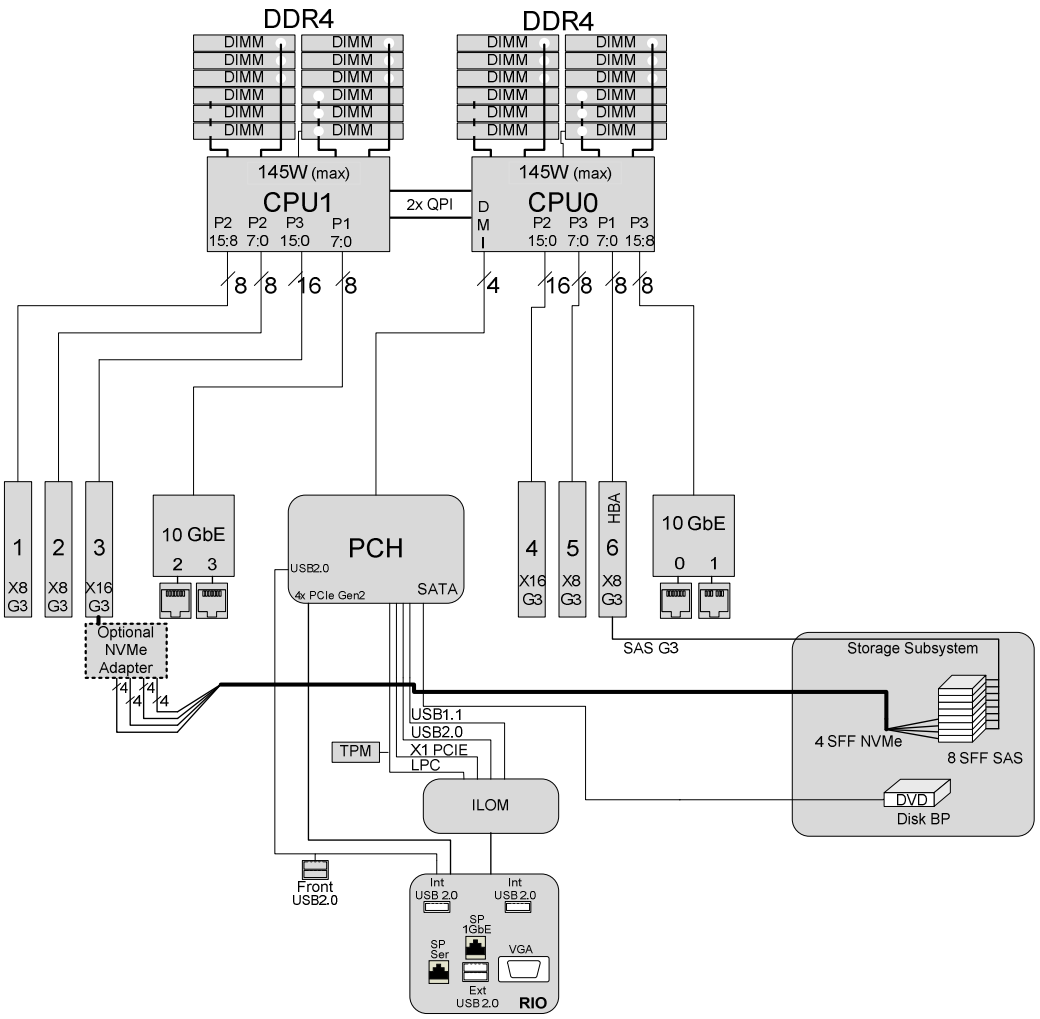

Figure 3. Oracle Server X5-2L, the 8-disk server block diagram

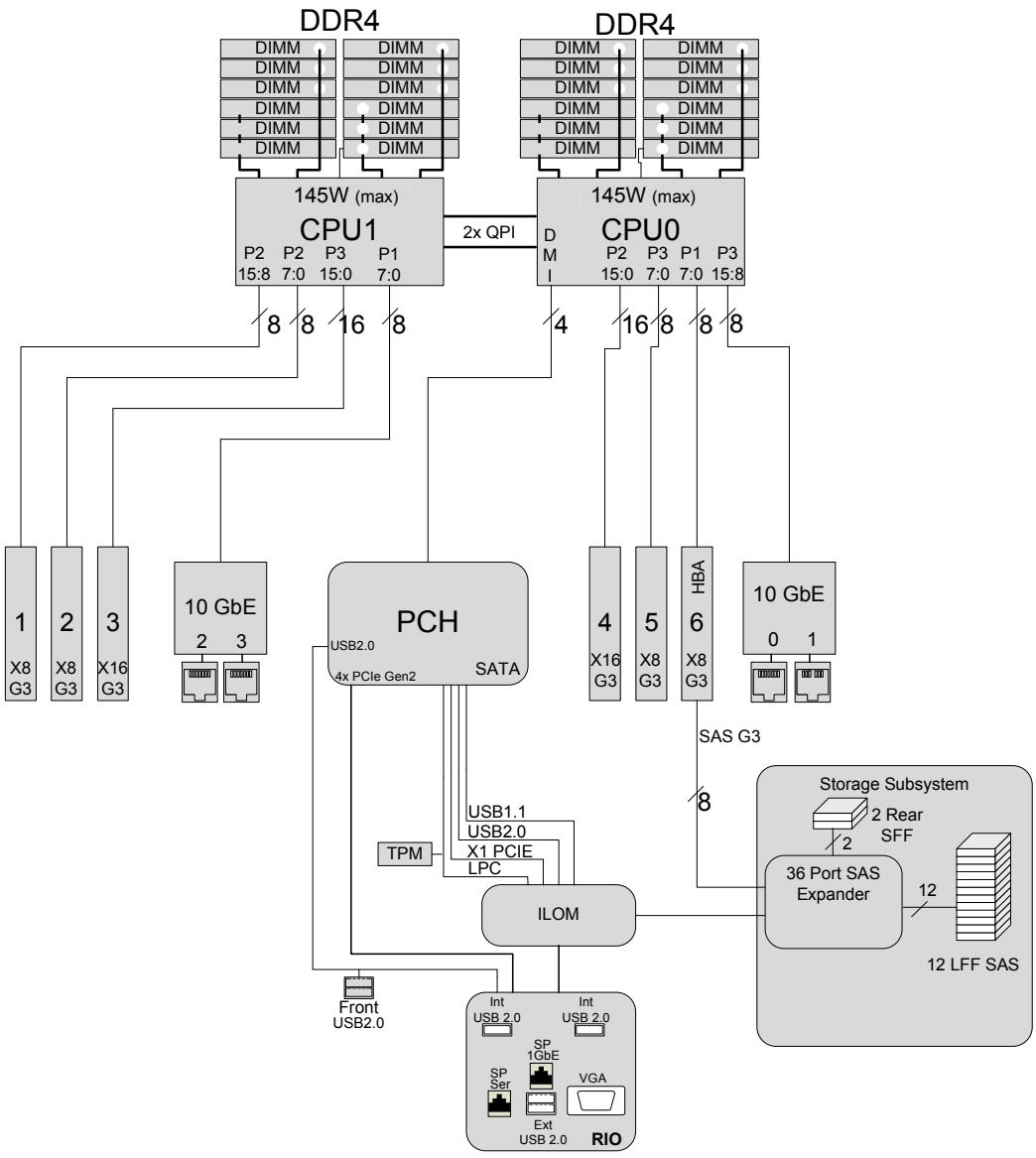

Figure 4. Oracle Server X5-2L, the 12-disk server block diagram

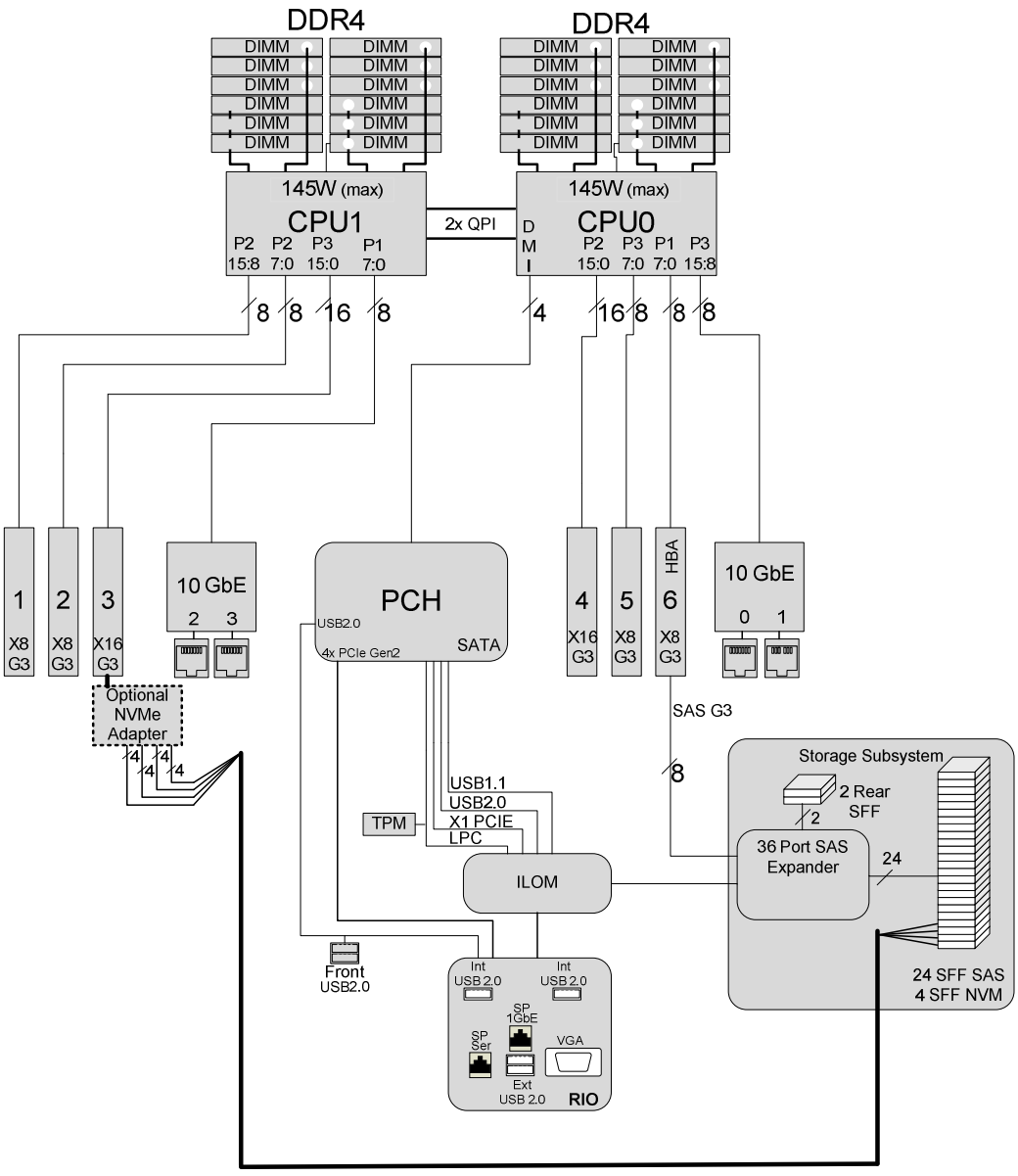

Figure 5. Oracle Server X5-2L, the 24-disk server block diagram

	
Name	Oracle Server X5-2L
Processor/ CPUs	One or two processors from Intel® Xeon® processor E5-2600 v3 product family
Memory	8 GB and 16 GB registered, or 32 GB load-reduced DDR4-2,133 DIMMs supported Twenty-four DDR4 DIMM slots (12 DIMM slots per CPU socket) supporting up to 768 GB of memory capacity
Internal disk	Three disk cage options with front-accessible disk bays: Eight 2.5-inch front-accessible disk bays supporting a combination of SAS-2 HDDs, SAS-3 SSDs, and NVMe SSDs (up to 4), as well as an optional DVD+/- RW drive Twelve 3.5-inch disk bays for SAS-2 HDDs and 2 rear-accessible 2.5-inch disk bays for SAS-2 HDDs or SAS-3 SSDs Twenty-four 2.5-inch disk bays supporting a combination of SAS-2 HDDs, SAS-3 SSDs, and NVMe SSDs (up to 4), as well as 2 rear-accessible 2.5-inch disk bays for SAS-2 HDDs or SAS-3 SSDs
External disk and tape	oracle.com/storage
Graphics	VGA 2D graphics controller embedded, with 8 MB memory supporting 1,920 x 1,200 x 16 bits
Expansion bus and ports	Six 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)
Non operating temperature	-40°F to 158°F (-40°C to 70°C)
Rack units	2U
Height	87.6 mm (3.5 in.)
Width	444.5 mm (17.5 in.)
Depth	737.0 mm (29.0 in.)
Weight (max.)	8-disk configuration – 24.5 kg (54 lb.), 12-disk configuration – 29.9 kg (66 lb.) 24-disk configuration – 29.0 kg (64 lb.)
Operating system	Oracle Solaris, Oracle Linux, Oracle VM, Red Hat Enterprise Linux, SUSE Linux Enterprise Server, VMware, Microsoft Windows Server

Table 3: Oracle Server X5-2L Server Feature Set

Single-Pane-of-Glass Management

Oracle Enterprise Manager 12*c* 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 X5-2L servers from the hardware layer all the way up to the database and applications running on them.

Oracle Enterprise Manager Ops Center 12*c*, part of the Oracle Enterprise Manager family, is an enterprise management tool that allows IT staff members 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 X5-2L. 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 X5-2L is designed to simplify field installation, reduce cabling, minimize power consumption, maximize system uptime, and improve storage density, making it an ideal choice for system deployment.

Oracle Server X5-2L is the ideal 2U platform for single-node databases and enterprise storage solutions. Supporting the standard and enterprise editions of Oracle Database, this server delivers best-in-class database reliability in single-node configurations. Optimized for compute, memory, I/O, and storage density simultaneously, Oracle Server X5-2L delivers extreme storage capacity at lower cost when combined with Oracle Solaris and ZFS file system compression.

The key new features incorporated in Oracle Server X5-2L, 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 X5-2L 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 X5-2L, 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 X5-2L can be found at http://www.oracle.com/goto/x5-2l or an Oracle representative can be reached at +1.800.ORACLE1.

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