Sun ORACLE | SUN FIRE X86 SERVERS

An Oracle White Paper

June 2014

Oracle's x86 Systems, Oracle Linux, and Oracle Database: Engineered to Work Together

ORACLE

Introduction

Running Oracle software on Oracle's x86 systems provides performance, reliability, and supportability advantages not found on third-party x86 servers. The combination of Oracle Database, Oracle Linux, and Oracle's x86 systems represents an integrated stack that has been designed and tested to deliver maximum performance and reliability in enterprise IT environments.

Oracle's x86 systems and Oracle Linux are co-engineered with Oracle Database so that the combined hardware and software stack, benefiting from numerous optimizations, produces advantages that are greater than the sum of the individual advantages. This yields an increased return on Oracle software investments as well as a system-wide lowering of operating and management costs.

Secondly, users of an Oracle hardware and software stack realize better quality and higher reliability. Oracle Linux and Oracle's x86 systems are used by Oracle developers and quality assurance teams to write and test the database and applications code. With every daily software build by Oracle’s product development team, testing provides one more opportunity to examine edge cases and to improve the extensive quality review of Oracle software on Oracle hardware.

Using the combination of Oracle Database, Oracle Linux, and Oracle's standalone x86 servers, customers also realize the benefits from Oracle’s highly optimized engineered systems such as Oracle Exadata, which delivers a 10x improvement in large-scale database performance. These engineered systems start with Oracle's x86 standalone servers as core building blocks for compute and storage servers within the overall system architecture. Any resulting x86 hardware optimizations then flow back into Oracle’s standalone x86 servers. These optimizations include not just firmware modifications to enhance storage and networking, but even routine physical operation, such as a special cooling design that optimizes airflow when thermally sensitive, database flash cache is present.

Oracle's approach to x86 system hardware design is distinctive. Other Tier 1 vendors use an off-the-shelf, or a slightly modified off-the-shelf, x86 motherboard design. Only Oracle starts with the standard Intel® Xeon® line of processors and a clean sheet of paper. Oracle's focus is to design a system that runs both Oracle software best and provides capabilities demanded by enterprise usage. Even Oracle’s x86 server manufacturing tests are based on Oracle software.

But the focus on reliability and performance goes deeper. For example, Oracle's x86 systems typically do not include new-to-market disk drives until the suppliers have amassed sufficient field experience to demonstrate their projected mean time to failure (MTTF) metrics. This cautionary approach helps Oracle customers reduce avoidable system downtime and hence, risk.

One of Oracle’s best in-the-field sources for actual stress and reliability metrics is Oracle Cloud Solutions. This service, based primarily on Oracle's x86 standalone systems running the Oracle software stack, provides 1.2 trillion business transactions per day across 41+ petabytes of managed storage. Feedback provides design ideas on capabilities and availability that we incorporate into Oracle's standalone x86 servers, benefiting our customers.

Finally, users of the combined stack of Oracle Database, Oracle Linux, and Oracle's x86 servers enjoy reduced operating costs and management complexity through the use of a single integrated system management tool, Oracle Enterprise Manager. Oracle Enterprise Manager provides system administration capabilities for the entire Oracle software and hardware stack, applications to disk, and it provides system management for other Oracle products such as engineered systems and Oracle's SPARC systems. This unique approach enables better analytics, easier lifecycle management, and simpler support and diagnostics. And with just one point of contact for support, service issues can be reported quickly.

An Oracle-on-Oracle solution provides assurance that the Oracle software is deployed in a thoroughly tested and optimized environment, increasing reliability and performance, and thereby reducing business risk. This white

paper, written for IT managers and DBA's, describes some of the capabilities and advantages of Oracle's integrated hardware and software stack.

Value of Oracle's Integrated Stack

Running Oracle software on Oracle hardware enables the software to benefit from database optimization from Oracle Database and the Oracle Linux kernel all the way down to Oracle's x86 system firmware. This integrated stack results in the following advantages:

- **Value-add x86 systems design**—Oracle software and hardware engineers work together to ensure that Oracle's x86 systems are designed specifically for Oracle software. In addition to designing the specific enhancements described in this paper, Oracle engineers design only systems that are capable of running the fastest processors and other interfaces, making the systems ideal for enterprise deployments.
- **Faster deployment**—Oracle's proven stack means that fewer issues will get in the way of rolling out new IT services so software projects can get into production faster while leveraging the performance and reliability advantages of the integrated stack.
- **Unified support**—Only Oracle can provide a single point of contact for support across the entire hardware and software stack ranging from Oracle Applications and Oracle Database to Oracle Linux and Oracle's x86 systems. This eases problem resolution and gives customers the assurance that fixes and enhancements are provided with the entire stack in mind.
- **Freedom to focus on core business** —Reliability and better management in the systems infrastructure not only helps reduce IT operations costs but also enables IT organizations to focus resources on activities that can add value to the business enterprise.

Oracle's x86 Optimizations for Oracle Software

Oracle's x86 systems are differentiated from commodity x86 servers by Oracle technologies that are designed into the hardware, firmware, and software layers. The systems start with industry-standard x86 processors and chipsets, but then layer Oracle-specific IP into the design and development, validation, and manufacturing of the systems. The result is a highly differentiated x86 server designed for running Oracle software. Figure 1 illustrates Oracle's optimizations. Oracle is proud of its joint working relationship with Intel, whereby the two companies not only collaborate on x86 system design, but also on Oracle OS and Oracle Database design. This produces an integrated x86 stack that fully utilizes x86 capabilities and allows Oracle to influence chip design for better Oracle software performance. Such cross-layer optimizations would be nearly impossible to replicate in a multivendor stack approach.

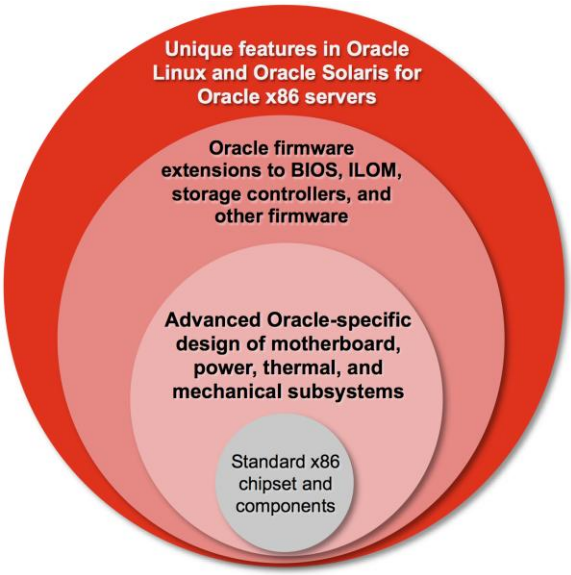

Figure 1. Optimizations span multiple levels of hardware, firmware, and software in Oracle's x86 systems.

Many of the functionality improvements are achieved through optimizations within multiple levels of the stack. It is this integration at the interface points between two adjacent layers of the solution stack that makes Oracle software run exceptionally wellon Oracle hardware.

Database-Hardened Storage Controller

The storage controller that manages internal storage devices within Oracle's x86 servers has been “database hardened” through the rigorous testing of Oracle Exadata workloads. Oracle’s database engineers, working with Oracle's system engineers, redesigned the storage controller firmware and driver stack to support extreme I/O throughput while ensuring the highest levels of reliability, availability, and diagnostic capability. Further, Oracle’s storage controller enhancements include improvements to cache recovery, path failover, and I/O handling, as well as reliability enhancements in the areas of device failure detection, SCSI recovery, and disk failure and recovery. This is possible only in an environment where engineers have complete access to the all-source code.

Network Card Optimization

Another example of how Oracle’s firmware optimizations enhance database performance is the value built into the network interface card and its firmware.

For example, in clustered configurations of x86 servers, the active node must consistently exchange system health information with its passive peer. The traditional approach for this

handshake capability is to have these messages originate at the OS level that consumes CPU cycles.

For Oracle's x86 systems deployed in a cluster configuration with Oracle Real Application Clusters (Oracle RAC), a performance optimization has been made to reduce system overhead of the network interfaces. The network interface card firmware has been modified to reduce the overhead and latency of messages that are exchanged between servers that form the cluster. Because this signal is so frequent, database performance is boosted by offloading the work to the network card.

Smart Flash Cache Optimizations

Using flash devices as a cache in the storage tier can deliver huge improvements in database performance. In the case of Oracle Database, it can deliver up to a 15x improvement in database I/O service times. However, achieving optimal performance with the flash cache requires the selection of appropriate flash technology that is best suited for the write-intensive workloads of Oracle Database—and, both the database and the operating system be flash aware. In addition to designing its flash storage cards specifically for database and enterprise application workloads, Oracle has optimized Oracle's x86 systems, Oracle Database, and Oracle Linux to take full advantage of the flash cache.

Both Oracle Database and Oracle Linux are cache aware so that they automatically utilize Oracle’s Sun Flash storage devices as a low-latency data store and know when the timing is right to synchronize this flash storage with hard disk storage. Support for flash cache in Oracle Database allows customers to increase the effective size of the Oracle Database buffer cache without adding more main memory to the system. The flash storage then acts as a second-level cache that is especially beneficial during read transaction of database applications.

Oracle’s Sun Flash PCIe cards utilize a write-optimized high-endurance flash product that offers the performance and reliability required for Oracle Database. The storage is delivered in a PCIe card form factor and is integrated with special firmware in Oracle's x86 systems to enhance flash performance.

One of the challenges with flash storage is that its performance and endurance is highly temperature sensitive. For this reason, most flash cards are designed to throttle back their performance when the temperature in the environment of the card exceeds a certain threshold, in order to preserve the life of the flash devices. This reliability feature trades off slower performance to greatly reduce the potential for device wear or failure.

Oracle's x86 systems offer a unique approach to optimizing flash storage performance through a firmware feature in x86 servers that detects the temperature of each flash storage card and adjusts the airflow over the card by speeding up the appropriate fan whenever the zone containing the flash storage card is getting too warm. These airflow

adjustments keep the flash cards cool so they do not have to throttle back their speed and can perform at near top speed at all times. The result is faster overall performance for I/O-intensive database workloads.

Oracle's Sun Server X4-2L systems can support up to four 800 MB flash storage cards—for a total of 3.2 TB of usable internal flash—and can deliver nearly a half million IOPS per server when this flash storage is used. Databases that are deployed using a combination of inexpensive hard disk drives in combination with Oracle's Database Smart Flash Cache achieve performance levels that are comparable with implementations of a database that is stored completely in flash, but at much less cost.

It's also important to note that Oracle's Sun Flash storage can accelerate storage performance even for external storage systems, such as when Oracle's x86 is connected to a storage area network (SAN).

Oracle Linux Optimizations for Oracle Database

Over 15 years ago, Oracle Database became the first commercial database ported to generic Linux, and subsequent development efforts with Oracle Linux are made to optimize performance and reliability for Oracle Database and other Oracle software. As mentioned earlier, Oracle Linux also has been optimized by virtue of being instantiated in Oracle's engineered systems. Oracle Linux engineers also work closely with Intel to take advantage of new Intel CPU features.

Oracle Linux Achieves 80 Percent Annual Growth

According to Gartner (March 2013), Oracle Linux placed in the top three in the Linux server operating system market and grew more than 80 percent year over year in 2012. This growth rate outpaced the overall Linux server operating system market growth[1].

Not all Linux distributions pick up the same fixes and enhancements, and timing of release of patches can be critical to database stability. Database technology is a primary focus for Oracle, so any generic Linux kernel changes that have an impact on database technology are given top priority, unlike other third party Linux distributions that have a broader/general purpose focus.

[1] Source: Gartner, Market Share, All Software Markets, Worldwide, 2012 – March 29, 2013.

Examples of Oracle's investments in Oracle Linux to deliver enterprise-grade performance and reliability when running Oracle software include:

- Performance enhancements for large memory configurations and high-core count processors
- Optimization of 10 GbE performance in the network stack
- I/O subsystem and block layer enhancements
- Better support for flash cards

The default shipment for Oracle Linux includes Oracle's Unbreakable Enterprise Kernel, which contains the enhancements described above. The entire Oracle Linux distribution is engineered to support the integrated Oracle software stack. For example, there is a component called Oracle Enterprise Manager Agent Preinstall RPM, which installs specific versions of various software packages and tunes the Oracle Linux operating environment for Oracle Database. Oracle Enterprise Manager Agent Preinstall RPM automatically tunes system parameters such as shared memory size, semaphores, and network buffer settings so that Oracle Database will run well on the specific platform being used.

All of Oracle's x86 systems have the option of coming preinstalled with Oracle Linux.

Ongoing Collaboration with Intel

Oracle engineers know what is needed to accelerate database performance and collaborate with Intel engineers to provide direction on product roadmaps at both Oracle and Intel. On the one hand, Oracle provides input to Intel to help define future requirements for next-generation Intel chipsets. On the other hand, Oracle product teams are made aware of future Intel product directions and the specific capabilities of chips that are soon to be released. This enables Oracle software products and tools to be designed around the most leading-edge Intel technologies. As a result, Oracle is generally among the first to market with solutions that take advantage of new Intel chip capabilities.

The engineering-level partnership between Oracle and Intel has resulted in advanced processor capabilities that directly affect database performance:

- Encryption capabilities in new Intel CPUs provide a 3x performance increase when using encryption with Oracle Database. Encrypting the database now results in less than 1 percent overhead, enabling many more organizations to take advantage of encryption to improve security without performance penalties.
- Oracle Database 12*c* is able to execute checksum calculations 40 percent faster due to Intel checksum capabilities that are now part of the processor. Oracle uses checksums regularly to validate the integrity of data on disk, so improving performance in this area greatly impacts overall database throughput and integrity.

- Oracle Database hash calculations and distribution algorithms improve performance by utilizing new Intel instructions.
- NUMA optimizations in new Intel chipsets enable 50 percent faster database locking for Oracle Database.
- The Intel variable thread model enables Oracle Linux to more fully utilize the CPU and thus drive faster performance and better scalability for Oracle Database.

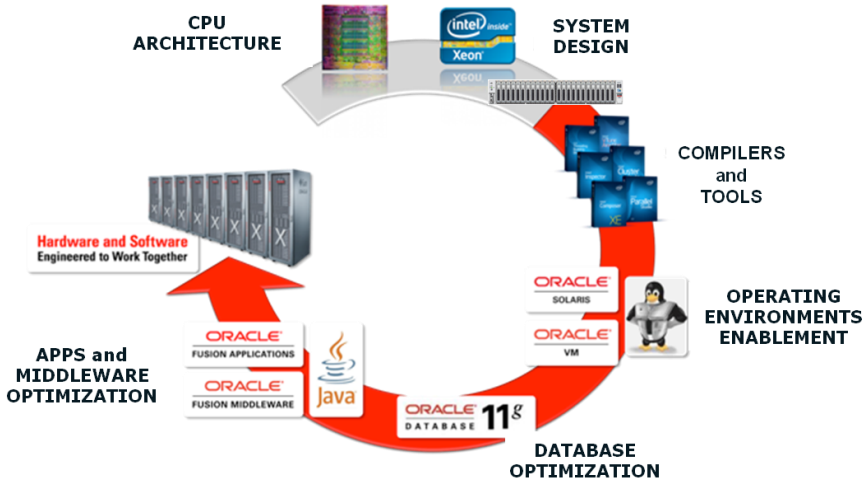

Figure 2. The Oracle and Intel relationship.

Oracle's x86 Performance Leadership

Oracle is driven to provide the best enterprise performance for its software. Because of Oracle's advanced designs and use of highest performing CPU and components, Oracle's systems have naturally achieved the highest performance metrics using benchmarks, including many world records.

As of March 2014, Oracle continued to hold the top Linux result for TPC-C with Oracle's Sun Server X2-8 system running Oracle Linux with Unbreakable Enterprise Kernel

Release 2. The Sun Server X2-8 system demonstrated the world's fastest x86 online transaction processing (OLTP) database performance on the TPC-C benchmark with a score of 5,055,888 tpmC,[2] making it the first x86 system to achieve more than 5 million tpmC. In addition to being the top Linux result, this world-record result beat the next best x86 system score by almost 70 percent[3] (Figure 2).

The TPC-C benchmark provides a comparative performance metric for OLTP applications and the SPECjEnterprise2010 benchmark provides a real-world workload for measuring application server performance.

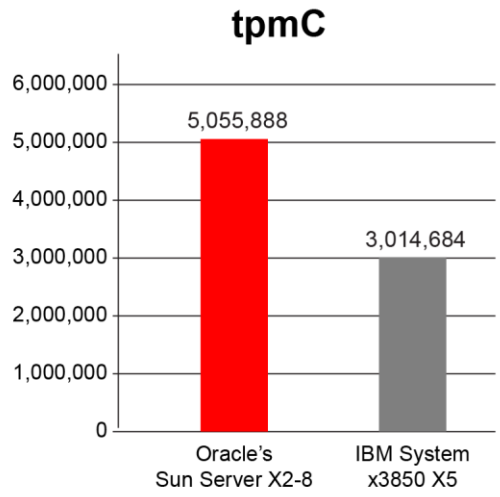

Figure 3. Oracle's Sun Server X2-8 beat the next closest x86 system result by 68 percent.

[2] TPC-C top 10 performance results as of March 13, 2014. Oracle's result of 5,055,888 tpmC was submitted on March 27, 2012 for Sun Server X2-8 with eight Intel Xeon E7-8870 CPUs and 4 TB of memory. The system was running Oracle Linux with Unbreakable Enterprise Kernel Release 2 and Oracle Database 11*g* Release 2 Enterprise Edition with Oracle Partitioning. Details can be viewed at http://tpc.org/tpcc/results/tpcc_result_detail.asp?id=112032701.

[3] As of March 13, 2014, the IBM System x3850 X5 had the next closest x86 system result with a score of 3,014,684 tpmC submitted on July 11, 2011. The Oracle result of 5,055,888 tpmC is 68 percent higher. Details of the IBM System x3850 X5 result are available at http://www.tpc.org/tpcc/results/tpcc_result_detail.asp?id=111071101.

Oracle's Sun Server X4-2 system set a world record result for two-socket x86 servers on the SPECjEnterprise2010 benchmark as of September 2013. The benchmark result of 11,259.88 SPECjEnterprise2010 EjOPS[4] was delivered using Sun Server X4-2 for the application tier and Sun Server X4-2L for the database tier. Both of these servers utilize Intel Xeon E5-2697 v2 processors, and the benchmark tests used Oracle WebLogic Server 12*c*, Java HotSpot 64-Bit Server 1.7.0_40, and Oracle Database 12*c* running on Oracle Linux.

As shown in Figure 3, Sun Server X4-2 demonstrated 16 percent better performance compared to the two-socket IBM System X3650 M4 server result of 9,696.43 SPECjEnterprise2010 EjOPS.[5]

SPECjEnterprise2010 heavily exercises all parts of the underlying infrastructure that make up the Java Platform, Enterprise Edition, environment. This includes the system hardware, the Java Virtual Machine (JVM) software, the database software, JDBC drivers, and the system network.

[4] SPEC and the benchmark name SPECjEnterprise are registered trademarks of the Standard Performance Evaluation Corporation. Sun Server X4-2,11,259.88 SPECjEnterprise2010 EjOPS. Results from www.spec.org as of 9/22/2013.

[5] SPEC and the benchmark name SPECjEnterprise are registered trademarks of the Standard Performance Evaluation Corporation. Sun Server X4-2,11,259.88 SPECjEnterprise2010 EjOPS; IBM System X3650 M4, 9,696.43 SPECjEnterprise2010 EjOPS. Results from www.spec.org as of 9/22/2013.

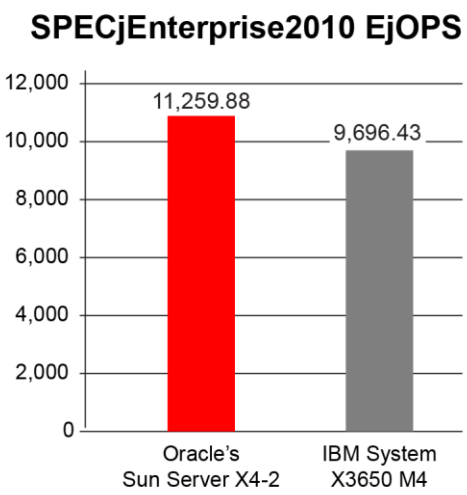

Figure 4. Oracle's Sun Server X4-2 delivered a world-record result with 16 percent better performance compared to the two-socket IBM System X3650 M4 server.

Enhanced Management Visibility and Control

Running a top-performing database is one issue, and managing its deployment and its upgrades is another. Oracle's system management approach addresses system configuration and provisioning as well as ongoing administration and monitoring of enterprise IT assets and services. As shown in Figure 4, there are Oracle tools for system setup and management as well enterprise management capabilities in Oracle Enterprise Manager 12*c*.

Oracle Enterprise Manager 12*c* and Oracle Hardware Management Pack offer unique integrations with other Oracle hardware and software components to make it easier to manage enterprise servers running Oracle Database and Oracle Applications.

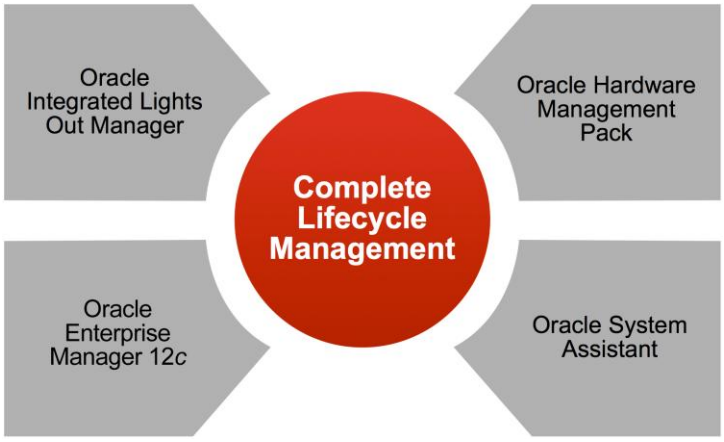

Figure 5. Oracle management tools address the full spectrum of management needs across the IT services lifecycle.

Oracle Enterprise Manager 12*c*

The Oracle Enterprise Manager framework provides a complete management environment for IT infrastructures and cloud services while offering deep visibility and control for Oracle hardware and software components. This visibility throughout the stack includes both physical servers and virtual machines, and enables faster, simpler, and better diagnosis of problems. Administrators can quickly and easily identify which layer of the stack is involved and can drill down for more details.

All layers of the stack can be monitored and controlled within Oracle Enterprise Manager 12*c* and all of the tools for managing Oracle Database and Oracle Applications are integrated, providing a complete picture of the application infrastructure. Oracle Enterprise Manager Ops Center and other Oracle Enterprise Manager modules provide the ability to drill down for a detailed view within a specific system component. Oracle Enterprise Manager Ops Center is included with support for Oracle's x86 systems, so management visibility and control for the server hardware and operating system layers is provided at no extra charge. Additional Oracle Enterprise Manager layered components can be licensed to enable detailed monitoring and control of the database, including support of database-as-a-service deployments.

There are three key aspects of Oracle Enterprise Manager 12*c*:

- **Complete cloud IaaS solution**—Oracle Enterprise Manager 12*c* contains capabilities for managing all phases of building, managing, and consuming an enterprise cloud. Using Oracle Enterprise Manager 12*c*, administrators can build and manage a rich catalog of cloud services—whether it is infrastructure as a service (IaaS), database as a service (DaaS), or platform as a service (PaaS)—all from a single management console. Capabilities include user-friendly self-service provisioning as well as metering and chargeback.
- **Integrated cloud stack management**—Oracle Enterprise Manager 12*c* enables integrated management of the entire cloud stack from application to disk. It helps eliminate much of the integration pain and cost that would otherwise be required to integrate the cloud environment with multiple point management solutions.
- **Business-driven clouds**—Oracle Enterprise Manager 12*c* enables creation of application-aware and business-driven clouds that have deep insight into applications, business services, and transactions.

Oracle Hardware Management Pack

Oracle Hardware Management Pack is a set of command-line tools and agents that provide improved hardware management and advanced storage diagnosis when running Oracle Linux on Oracle's x86 systems. Some parts of the server are not visible from the service processor and must be managed from within the operating system rather than

through Oracle Integrated Lights Out Manager (Oracle ILOM). When Oracle Hardware Management Pack is installed on top of Oracle Linux, administrators have access to command-line tools and agents for fault diagnosis and management of storage controllers as well as tools for configuring BIOS and RAID and managing updates for Oracle ILOM and firmware.

Oracle Hardware Management Pack is integrated with Oracle ILOM, which means that administrators can view Oracle Hardware Management Pack-related information from within the Oracle ILOM user interface. For example, the Oracle ILOM interface can provide visibility into the status and inventory of the storage subsystems, giving administrators a complete, unified view of server status information.

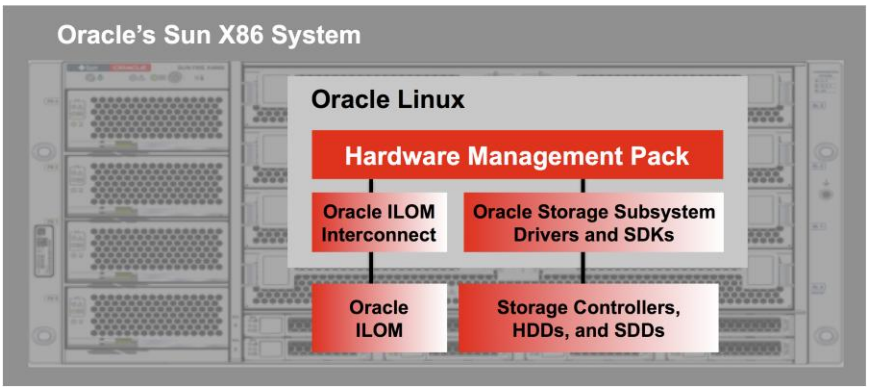

Figure 6. Oracle Hardware Management Pack is integrated with Oracle ILOM to provide a unified view of server status information.

Oracle's x86 Systems Portfolio

Oracle designs and manufactures a range of x86 systems based on the most recent and most powerful x86 processors, all targeted for highly reliable, enterprise deployments running Oracle software. Oracle's x86 systems are available in 1U and 2U configurations with two-socket designs, as well as 3U and 5U configurations with four- and eight-socket designs, respectively (Figure 6). Oracle is committed to continuing this specific form factor design through future generations of Intel CPUs.

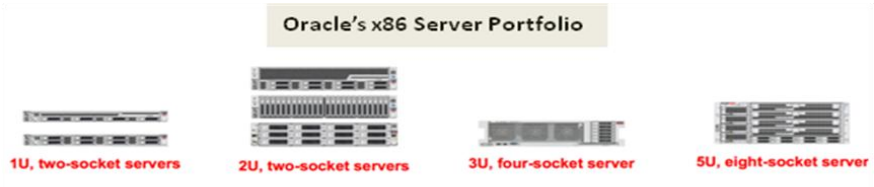

Figure 7. Oracle's x86 portfolio.

Each system design offers memory and storage options, and most systems offer an option for flash cache to accelerate performance for database applications. When purchased with Oracle support, the systems include—at no additional cost—an operating system, virtualization capabilities, infrastructure-as-a service software, and a management framework for managing the OS, virtualization, and IaaS layers. Database system management, including database-as-a-service enablement, can be licensed for an additional fee.

Conclusion

Oracle's integrated approach offers many unique advantages for running Oracle software on Oracle hardware:

- Only when organizations run on Oracle hardware can all the features and the full value of Oracle software be realized.
- Only Oracle provides database optimizations within its Linux operating system.
- Only Oracle designs its entire x86 server line and provides end-to-end manufacturing quality.
- Only Oracle focuses solely on enterprise-oriented x86 server configurations that stress throughput.
- Only Oracle enhances its firmware to increase the reliability, integrity, and speed of its software when running on Oracle hardware.
- Only Oracle can provide a single view of the entire deployment within a single management tool.

Table 1 provides links to additional resources.

TABLE 1. WEB RESOURCES FOR FURTHER INFORMATION

PRODUCT WEB PAGES	
Oracle's x86 systems	http://www.oracle.com/us/products/servers-storage/servers/x86/
Oracle Linux	http://www.oracle.com/linux/
Oracle Database 12*c* Enterprise Edition	http://www.oracle.com/us/products/database/enterprise-edition/
Oracle Enterprise Manager 12*c*	http://www.oracle.com/technetwork/oem/grid-control/overview/
Oracle Single System Management family of tools	http://www.oracle.com/goto/servermgmt/
Oracle Applications	http://www.oracle.com/applications/
WHITE PAPERS AND TECHNICAL ARTICLES OR GUIDES	
Plug into the Cloud with Oracle Database 12*c* (white paper)	http://www.oracle.com/database/
Oracle Database Smart Flash Cache (white paper)	http://www.oracle.com/technetwork/articles/systems-hardware-architecture/oracle-db-smart-flash-cache-175588.pdf
Advanced Uses of Oracle Enterprise Manager 12*c* (white paper)	http://www.oracle.com/us/products/enterprise-manager/wp-advanced-uses-em12c-1982907.pdf

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Hardware and Software, Engineered to Work Together