SUN SPARC
ENTERPRISE
SERVERS

An Oracle White Paper
April 2010

Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 Server Architecture

Introduction

Serving the dynamic and growing data center IT services space is challenging for data center operations. Services need to be able to scale rapidly, often doubling capacity in a short period even as they remain highly available. Infrastructure must keep up with these enormous scalability demands, without generating additional administrative burden. Unfortunately, most data centers are already severely constrained by both real estate and power—and energy costs are rising. There is also a new appreciation for the role that the data center plays in reducing energy consumption and pollution. Virtualization has emerged as an extremely important tool as organizations seek to consolidate redundant infrastructure, simplify administration, and leverage underutilized systems. Security too has never been more important, with the increasing price of data loss and corruption. In addressing these challenges, organizations can ill afford proprietary infrastructure that imposes arbitrary limitations.

Employing Oracle’s UltraSPARC T2 and T2 Plus processors—the industry’s first massively threaded systems-on-a-chip (SoC)— Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers offer breakthrough performance and energy efficiency to drive data center infrastructure and address other demanding data center challenges. Third-generation CoolThreads chip multithreading (CMT) technology supports up to 128 threads in as little as one rack unit (1RU)—providing increased computational density while staying within variously constrained envelopes of power and cooling. Very high levels of integration help reduce latency, lower costs, and improve security and reliability. Optimized system design provides support for a wide range of IT services application types. Uniformity of management interfaces and adoption of standards help reduce administrative costs, while an innovative chassis design shared across Oracle’s volume servers provides density, efficiency, and economy for modern data centers. With both the processor and

Oracle Solaris available under open source licensing, organizations are free to innovate with a worldwide technical community.

The Evolution of Chip Multithreading

Oracle's UltraSPARC processors have led the industry for years—first, with the introduction of multithreaded, multicore chip design in the UltraSPARC T1 processor and now with the third-generation UltraSPARC T2 Plus processor. By any measure, these first-generation CMT processors were an unprecedented success. Delivering up to five times the throughput in a quarter of the space and power, systems using these processors have rapidly been welcomed and accepted. Now third-generation CMT technology is evolving rapidly to meet the constantly changing demands of a wide range of enterprise data center applications.

Business Challenges for Enterprise Applications

Organizations across many industries hope to address larger markets, reduce costs, and gain better insights into their customers. At the same time, an increasingly broad array of wired and wireless client devices are bringing network computing into the everyday lives of millions of people. This strong demand has a "pull-through" effect on the IT services that must be satisfied in the data center. These trends are redefining data center scalability and capacity requirements, even as they collide with fundamental real estate, power, and cooling constraints.

- **Driving data center virtualization and ecoefficiency**. Coincident with the need to scale services, many data centers are recognizing the advantages of deploying fewer standard platforms to run a mixture of commercial and technical workloads. This process involves consolidating underused and often sprawling server infrastructures with effective virtualization solutions that serve to enhance business agility, improve disaster recovery, and reduce operating costs. This focus can help reduce energy costs and break through data center capacity constraints by improving the amount of realized performance for each watt of power the data center consumes.

  Ecoefficiency provides tangible benefits, improving ecology by reducing the carbon footprint to meet legislative and corporate social responsibility goals, even as it improves the economy of the organization paying the electric bill. As systems are consolidated onto more dense and capable computing infrastructure, demand for data center real estate is also reduced. With careful planning, this approach can also improve service uptime and reliability by reducing hardware failures resulting from excess heat load. Servers with high levels of standard reliability, availability, and serviceability (RAS) are now considered a requirement.

- **Building out for Web-scale applications.** Web-scale applications engender a new pace and urgency to infrastructure deployment. Organizations must accelerate time to market and time to service, while delivering scalable high-quality and high-performance applications and services. Many need to be able to start small with the ability to scale very quickly, with new customers and innovative new Web services often implying a doubling of capacity in months rather than years.

At the same time, organizations must reduce their environmental impact by working within the power, cooling, and space available in their current data centers. Operational costs too are receiving new scrutiny, along with system administrative costs that can account for up to 40 percent of an IT budget. Simplicity and speed are paramount, giving organizations the ability to respond quickly to dynamic business conditions. Organizations are also striving to eliminate vendor lock-in as they look to preserve previous, current, and future investments. Open platforms built around open standards help provide maximum flexibility while reducing costs of both entry and exit.

- **Securing the enterprise at speed.** Organizations are increasingly interested in securing all communications with their customers and partners. Given the risks, end-to-end encryption is essential to inspire confidence in security and confidentiality. Encryption is also increasingly important for storage, helping to secure stored and archived data even as it provides a mechanism to detect tampering and data corruption.

  Unfortunately, the computational costs of increased encryption can increase the burden on already overtaxed computational resources. Security also needs to take place at line speed, without introducing bottlenecks that can impact the customer experience or slow transactions. Solutions must help to ensure security and privacy for clients and bring business compliance for the organization, all without impacting performance or increasing costs.

Rule-Changing Chip Multithreading Technology

Addressing these challenges has outstripped the capabilities of traditional processors and systems, and required a fundamentally new approach.

Moore’s Law and the Diminishing Returns of Traditional Processor Design

The oft-quoted tenant of Moore’s law states that the number of transistors that will fit in a square inch of integrated circuitry will approximately double every two years. For more than three decades the pace of Moore’s law has held, driving processor performance to new heights. Processor manufacturers have long exploited these gains in chip real estate to build increasingly complex processors, with instruction-level parallelism (ILP) as a goal. Today, these traditional processors employ very high frequencies along with a variety of sophisticated tactics to accelerate a single instruction pipeline, including

- Large caches
- Superscalar designs
- Out-of-order execution
- Very high clock rates

- Deep pipelines
- Speculative prefetches

Although these techniques have produced faster processors with impressive-sounding multiple-gigahertz frequencies, they have largely resulted in complex, hot, and power-hungry processors that are not well-suited to the types of workloads often found in modern data centers. In fact, many data center workloads are simply unable to take advantage of the hard-won ILP provided by these processors. Applications with high shared memory and high simultaneous user or transaction counts are typically more focused on processing a large number of simultaneous threads (thread-level parallelism, or TLP) rather than running a single thread as quickly as possible (ILP).

Making matters worse, the majority of ILP in existing applications has already been extracted, and further gains promise to be small. In addition, microprocessor frequency scaling itself has leveled off because of microprocessor power issues. With higher clock speeds, each successive processor generation has seemingly demanded more power than the last, and microprocessor frequency scaling has leveled off in the 2 GHz to 3 GHz range as a result. Deploying pipelined superscalar processors requires more power, limiting this approach by the fundamental ability to cool the processors.

Chip Multiprocessing with Multicore Processors

To address these issues, many in the microprocessor industry have used the transistor budget provided by Moore's law to group two or more conventional processor cores on a single physical die—creating multicore processors, or chip multiprocessors (CMPs). The individual processor cores introduced by many CMP designs have no greater performance than previous single-processor chips, and in fact, have been observed to run single-threaded applications more slowly than single-core processor versions. However, the aggregate chip performance increases since multiple programs (or multiple threads) can be accommodated in parallel (TLP).

Unfortunately, most currently available chip multiprocessors simply replicate cores from existing (single-threaded) processor designs. This approach typically yields only slight improvements in aggregate performance since it ignores key performance issues such as memory speed and hardware thread context switching. As a result, although these designs provide some additional throughput and scalability, they can consume considerable power and generate significant heat—without a commensurate increase in overall performance.

Chip Multithreading with CoolThreads Technology

Oracle engineers were early to recognize the disparity between processor speeds and memory access rates. While processor speeds continue to double every two years, memory speeds have typically doubled only every six years. As a result, memory latency now dominates much application performance, erasing even very impressive gains in clock rates. This growing disconnect is the result of memory suppliers focusing on density and cost as their design center, rather than speed.

Unfortunately, this relative gap between processor and memory speeds leaves ultrafast processors idle as much as 85 percent of the time, waiting for memory transactions to complete. Ironically, as traditional processor execution pipelines get faster and more complex, the effect of memory latency grows—fast, expensive processors spend more cycles doing nothing. Worse still, idle processors often continue to draw power and generate heat. It is easy to see that frequency (gigahertz) is truly a misleading indicator of real performance.

First introduced with the UltraSPARC T1 processor, CMT takes advantage of CMP advances, but adds a critical capability—the ability to scale with threads rather than frequency. Unlike traditional single-threaded processors and even most current multicore processors, hardware multithreaded processor cores allow rapid switching between active threads as other threads stall for memory. Figure 1 illustrates the difference between CMP, fine-grained hardware multithreading (FG-MT), and CMT. The key to this approach is that each core in a CMT processor is designed to switch between multiple threads on each clock cycle. As a result, the processor's execution pipeline remains active doing real useful work, even as memory operations for stalled threads continue in parallel.

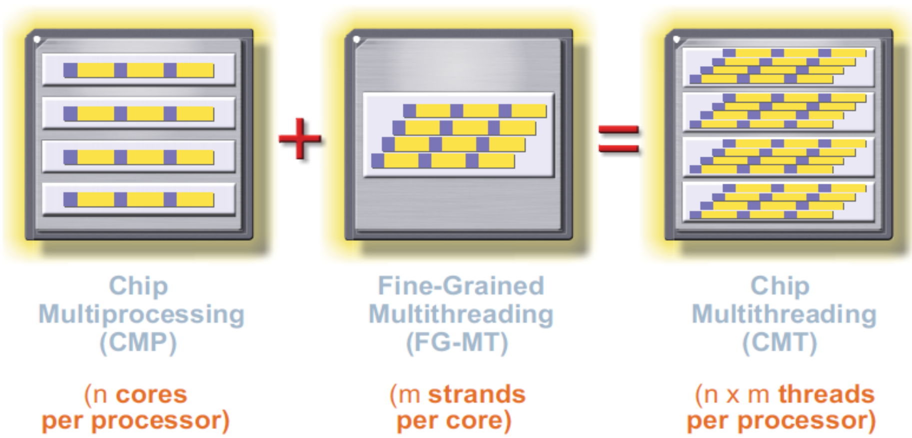

Figure 1. CMT combines CMP and fine-grained hardware multithreading.

CMT provides real value since it increases the ability of the execution pipeline to do actual work on any given clock cycle. Use of the processor pipeline is greatly enhanced because a number of execution threads now share its resources. The negative effects of memory latency are effectively masked, because the processor and memory subsystems remain active in parallel to the processor execution pipeline. Since these individual processor cores implement much-simpler pipelines that focus on scaling with threads rather than frequency (emphasizing TLP over ILP), they are also substantially cooler and require significantly less electrical energy to operate. This innovative approach results in CoolThreads processor technology—multiple physical instruction execution pipelines (one for each core), with multiple active thread contexts per core. In addition, UltraSPARC T2 and UltraSPARC T2 Plus processors feature two execution pipelines per core to further boost scalability.

The UltraSPARC T2 and T2 Plus Processors

Unlike complex single-threaded processors, CMT processors use the available transistor budget to implement multiple hardware multithreaded processor cores on a chip die. The UltraSPARC T2 and UltraSPARC T2 Plus processors take the CMT model to the next level, providing up to eight cores per processor, with each core supporting up to eight threads via two independent pipelines—effectively doubling the throughput of the UltraSPARC T1 processor without raising the clock frequency. In addition, these processors use the increased transistor budget resulting from the use of a 65 nm silicon technology to implement the industry's first massively threaded system–on-a-chip (SoC), with a single processor die hosting:

- Up to 64 threads per processor (up to eight cores supporting eight threads each)
- On-chip Level 1 and Level 2 caches
- Per-core floating-point capabilities
- Per-core cryptographic acceleration
- Two on-chip 10 Gigabit Ethernet (GbE) interfaces (UltraSPARC T2 processor only)
- On-chip PCI Express (PCIe) interface
- On-chip cache coherency logic and links (UltraSPARC T2 Plus processor only)

Through SoC design, the UltraSPARC T2 processor significantly enhances the general-purpose nature of the CPU—building in eight floating-point units (one per core). Enhanced floating-point capabilities open the UltraSPARC T2 to the world of compute-intensive applications as well as the traditionally CMT-friendly data center throughput applications. No-cost security and cryptographic acceleration is provided by the on-chip, per-core streaming accelerators. In addition, the ability to move data in and out of the UltraSPARC T2 processor is significantly aided by an integrated PCIe interface and dual 10 GbE interfaces on the UltraSPARC T2 processor. The UltraSPARC T2 Plus processor replaces the dual 10 GbE interfaces with cache coherency logic and links that facilitate a multisocket, glueless system designs.

Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/5240 Servers

Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers (Figure 2) are all designed to leverage the considerable resources of the UltraSPARC T2 and UltraSPARC T2 Plus processors in the form of cost-effective, general-purpose platforms. Oracle's Sun SPARC Enterprise T5120/T5220 servers deliver up to twice the throughput of their predecessors, while leading competitors in terms of performance,

performance per watt, and SWaP performance (as evaluated by the Space, Watts, and Performance metric detailed later in this section). Oracle's Sun SPARC Enterprise T5140/T5240 servers extend this scalability by adding dual sockets for UltraSPARC T2 Plus processors and considerably large memory support. All these systems also extend the benefits of CMT from multithreaded commercial workloads into technical workloads rich in floating-point operations.

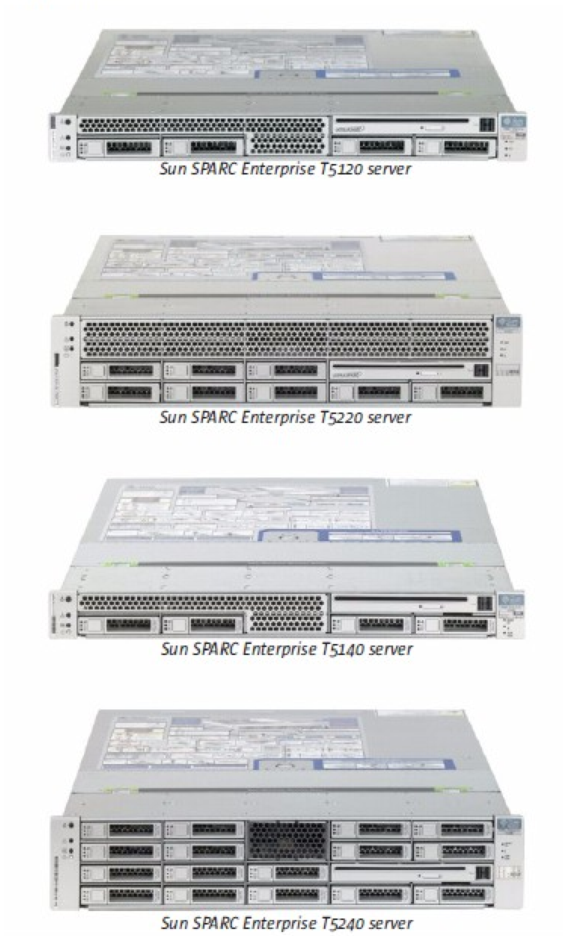

Figure 2. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers are all designed to leverage the considerable resources of the UltraSPARC T2 and UltraSPARC T2 Plus processors.

Overview

With support for up to 128 threads, large memory, cryptographic acceleration, and integrated on-chip I/O technology, these servers represent a departure from traditional system design. Oracle's Sun SPARC Enterprise T5120/T5140 servers are ideal for providing high throughput within significant power, cooling, and space constraints. Oracle's Sun SPARC Enterprise T5120 server supports a single UltraSPARC T2 processor whereas Oracle's Sun SPARC Enterprise T5140 supports two UltraSPARC T2 Plus processors. Both systems feature a compact and power-efficient one rack unit (1RU) rack mount package. As compute nodes within massive, horizontally scaled environments, Oracle's Sun SPARC Enterprise T5120/T5140 servers can help provide a substantial building block for application tier, Web services, or even high-performance computing (HPC) infrastructure. Network infrastructure applications such as portal, directory, network identity, file service, and backup are all a good fit for these servers.

Oracle's Sun SPARC Enterprise T5220/T5240 servers provide both throughput as well as expandability, with extra I/O and internal disk options afforded by the 2RU rack mount form factor. Oracle's Sun SPARC Enterprise T5220 servers support a single UltraSPARC T2 processor whereas Oracle's Sun SPARC Enterprise T5240 servers support dual UltraSPARC T2 Plus processors. With greater I/O and internal disk, typical workloads include demanding midtier application server deployments or Web-tier and application-tier consolidation and virtualization projects requiring maximum uptime with future growth and integration into diverse environments. Oracle's Sun SPARC Enterprise T5220/T5240 servers are also ideal for online transaction processing (OLTP) database deployments.

Designed to complement each other, as well as the rest of Oracle’s server product line, Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers address the dynamic needs of the modern data center.

- **Efficient and predictable scalability.** With support for 64 threads and large memories, Oracle's Sun SPARC Enterprise T5120/T5220 servers are the first to use the 10 GbE, I/O, and cryptographic acceleration provided directly on the UltraSPARC T2 processor silicon itself. This approach provides leading levels of performance and scalability with extremely high levels of power, heat, and space efficiency.

  Oracle's Sun SPARC Enterprise T5140/T5240 servers extend this breakthrough compute and memory density, delivering up to 128 threads in as little as 1RU, while typically consuming less than 700 watts of power. These systems also deliver twice the I/O bandwidth of the Sun SPARC T5120/T5220 servers by providing a PCIe root complex associated with each socket.

- **Accelerated time to market.** Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers running Oracle Solaris provide full binary compatibility with earlier UltraSPARC systems, preserving investments and rapid time to market. The CoolTools for SPARC help accelerate application selection, profiling, testing, tuning, debugging, and the deployment of key applications on CMT systems.

- **Industry-leading tools for virtualization and consolidation.** Oracle’s chip multithreading (CMT) technology is ideal for consolidation, providing low-level multithreading support for virtualization at every layer of the technology stack. Oracle’s Virtual Machine for SPARC (OVMS) technology exploits the UltraSPARC T2 and UltraSPARC T2 Plus processor’s up to 64 threads per socket, offering multiple guest operating system instances. In addition, Oracle Solaris Containers provide virtualization within a single Oracle Solaris instance. The advanced

Oracle Solaris ZFS file system provides storage virtualization for storage and considerable scalability.

- **System and data center reliability.** Reliability is key to keeping applications available and costs down. With the greater levels of integration provided by an SoC design, Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers offer greatly reduced part counts, and provide commensurately higher levels of reliability, availability, and serviceability (RAS). Lower power consumption and higher performance per watt greatly reduce generated heat loads and the associated issues they cause. Technologies such as Solaris Predictive Self Healing are integrated with the hardware, and help keep systems available.
- **A tradition of leading ecoefficiency.** Oracle's Sun SPARC Enterprise T1000 and Oracle's Sun SPARC Enterprise T2000 servers were the industry's first ecoresponsible servers. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers continue this tradition by offering the best performance and performance per watt across a wide range of commercial and technical workloads. In addition, the UltraSPARC T2 processor was the first processor to incorporate unique power management features at both core and memory levels of the processor.
- **Zero-cost security.** Providing secure communications and data protection has never been more important, with attempted electronic intrusion and theft at an all-time high. With up to eight integrated cryptographic accelerators on each UltraSPARC T2 and UltraSPARC T2 Plus processor, there is simply no need to send plain text on the network or store plain text in storage systems. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers support many more crypto operations per second than competitive systems with dedicated crypto accelerator cards—all with minimal impact to system overhead.
- **Simplified management.** Each of Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 server provides an Integrated Lights Out Manager (ILOM) service processor, compatible with Oracle’s x64 servers. Integrated Lights Out Manager provides a command-line interface (CLI), a Web-based graphical user interface (GUI), and Intelligent Platform Management Interface (IPMI) functionality to aid with out-of-band monitoring and administration. Integrated Lights Out Manager also provides an Advanced Lights Out Management (ALOM) backward-compatibility mode for administrators familiar with Sun Fire and Oracle's Sun SPARC Enterprise T1000 and Oracle's Sun SPARC Enterprise T2000 servers.
- **The industry’s most open platform.** Oracle's Sun SPARC Enterprise servers are the industry’s most open platforms, providing the only mainstream processor and hypervisor offered under the GNU General Public License (GPL). These systems offer a choice of operating systems, including Oracle Solaris, Linux, and BSD variants. Oracle Solaris is free and open, offering full binary compatibility and enterprise-class features.

Innovative System Design

Beyond the capabilities of individual systems, Oracle understands that data centers have unique and pressing needs that require attention on the part of system designers. Density, performance, and scalability are all essential considerations, but systems must also be serviceable and fit in with modern data center strategies that consider power, cooling, and serviceability. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers share an innovative design philosophy that extends across Oracle's volume x64 and SPARC server platforms. Principles of this philosophy include

- **Maximum compute density.** Oracle's volume servers provide leading density in terms of CPU cores, memory, storage and I/O. This focus on density often lets Oracle's 1RU rack mount servers replace competitive 2RU servers, for a 50 percent space savings.
- **Continued investment protection.** Oracle designs for maximum investment protection. Even with breakthrough technology such as chip multithreaded processors, applications simply run without modification.
- **Leading storage capacity.** Oracle's volume servers provide leading density and flexible RAID options. Smaller disk drives and innovations in structure, airway, and carrier design allow more disk capacity in smaller spaces, while enhancing system airflow.
- **Common, shared management.** Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers are designed for ease of management and serviceability with service processors shared by other Oracle volume server platforms. Systems and components are designed for easy identification, and hot-swap components facilitate online replacement.
- **Common chassis design.** Shared chassis design leverages key system innovations across multiple architectures, provides for common components and subassemblies, and greatly simplifies administration for those deploying multiple processor architectures.

Table 1 compares Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers.

TABLE 1. ORACLE'S SUN SPARC ENTERPRISE T5120/T5220 AND ORACLE'S SUN SPARC ENTERPRISE T5140/T5240 SERVER FEATURES

FEATURE	ORACLE'S SUN SPARC ENTERPRISE T5120 SERVER	ORACLE'S SUN SPARC ENTERPRISE T5220 SERVER	ORACLE'S SUN SPARC ENTERPRISE T5140 SERVER	ORACLE'S SUN SPARC ENTERPRISE T5240 SERVER
CPUs	Four-core or eight-core 1.2 GHz or eight-core 1.4 GHz or 1.6 GHz UltraSPARC T2 processor	Four-core or eight-core 1.2 GHz or eight-core 1.4 GHz or 1.6 GHz UltraSPARC T2 processor	Dual four-, six-, or eight-core 1.2 GHz or eight-core 1.4 GHz UltraSPARC T2 Plus processors	Dual four-, six-, or eight-core 1.2 GHz or eight-core 1.4 GHz or 1.6 GHz UltraSPARC T2 Plus processors[1]
Threads	Up to 64	Up to 64	Up to 128	Up to 128
Memory capacity	Up to 128 GB (2 GB, 4 GB, or 8 GB FB-DIMMs)	Up to 128 GB (2 GB, 4 GB, or 8 GB FB-DIMMs)	Up to 128 GB (2 GB, 4 GB, or 8 GB FB-DIMMs)	Up to 128 GB (2 GB, 4 GB, or 8 GB FB-DIMMs)[2]
Maximum internal disk drives	Up to eight SFF 2.5-inch SAS 73 GB, 146 GB, or 300 GB disk drives, RAID 0/1[3]	Up to 16 SFF SAS 2.5-inch SAS 73 GB, 146 GB, or 300 GB disk drives, RAID 0/1	Up to eight SFF 2.5-inch SAS 73 GB, 146 GB, or 300 GB disk drives, RAID 0/1[4]	Up to 16 SFF 2.5-inch SAS 73 GB, 146 GB, or 300 GB disk drives, RAID 0/1[5]
Removable and pluggable I/O	• Slimline DVD-R • Four USB 2.0 ports	• Slimline DVD-R • Four USB 2.0 ports	• Slot loading DVD+/-RW • Four USB 2.0 ports	• Slot loading DVD+/-RW • Four USB 2.0 ports
PCI	One x8 PCIe slot and two x4 PCIe or XAUI combo slots[6]	• Two x8 PCIe • Two x4 PCIe • Two x4 PCIe or XAUI	• One x8 PCIe slot • Two x8 PCIe or XAUI combo slots[8]	• Four x8 PCIe slots • Two x8 PCIe or XAUI combo slots[9]

[1] High-line power input (200 V-240 V) is required for eight-disk backplane and 1.6 GHz processor support. High-line power input is also required for the 16-disk backplane and either 1.4 GHz or 1.6 GHz processors.

[2] 256 GB maximum memory configuration requires the optional memory mezzanine kit.

[3] Eight-disk backplane is not supported with 1.6 GHz CPU (Oracle's Sun SPARC Enterprise T5120 server) or with 1.4 GHz CPU or DC power supply (Oracle's Sun SPARC Enterprise T5140 server).

[4] Eight-disk backplane is not supported with 1.6 GHz CPU (Oracle's Sun SPARC Enterprise T5120 server) or with 1.4 GHz CPU or DC power supply (Oracle's Sun SPARC Enterprise T5140 server).

[5] Optional XAUI adapter cards required for access to dual 10 GbE ports on all systems. Each XAUI consumes a PCIe slot.

[6] Eight-disk backplane is not supported with 1.6 GHz CPU (Oracle's Sun SPARC Enterprise T5120 server) or with 1.4 GHz CPU or DC power supply (Oracle's Sun SPARC Enterprise T5140 server).

		combo slots[7]		
Ethernet	• Four onboard Gigabit Ethernet ports (10/100/1000) • Two 10 GbE ports via XAUI combo slots	• Four onboard Gigabit Ethernet ports (10/100/1000) • Two 10 GbE ports via XAUI combo slots	• Four onboard Gigabit Ethernet ports (10/100/1000) • Two 10 GbE ports via XAUI combo slots[10]	• Four onboard Gigabit Ethernet ports (10/100/1000) • Two 10 GbE ports via XAUI combo slots[11]
Power supplies	Two hot-swappable AC 720 W or DC 660 W power supply units (N+1 redundancy)	Two hot-swappable AC 750 W or 1100 W or DC 1200 W power supply units (N+1 redundancy)	Two hot-swappable AC 720 W or DC 660 W power supply units (N+1 redundancy)	Two hot-swappable AC 1100 W or DC 1200 W power supply units (N+1 redundancy)
Fans	Four hot-swappable fan trays, with two fans per tray, N+1 redundancy	Three hot-swappable fan trays, with two fans per tray, N+1 redundancy	Six hot-swappable fan trays, with two fans per tray, N+1 redundancy	Five hot-swappable fan trays, with two fans per tray, N+1 redundancy
Form factor	1RU	2RU	1RU	2RU
Operating systems	Oracle Solaris 10 8/07 and 10/08 , Ubuntu Linux certified	Oracle Solaris 10 8/07 and 10/08 OS, Ubuntu Linux certified	Oracle Solaris 10 8/07 and 10/08 or later	Oracle Solaris 10 8/07 and 10/08 or later

Leading Reliability, Availability, and Serviceability

The Oracle Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers provide excellent reliability, availability, and serviceability (RAS) characteristics. Highly reliable parts and a relatively low total component count minimize the opportunity for system errors. Dual PCIe root complexes and the ability to configure multiple processors on Oracle's Sun SPARC Enterprise T5140/T5240 servers add to resiliency. In addition, these servers include core and thread off-lining capabilities, integrated disk RAID

[7] Optional XAUI adapter cards required for access to dual 10 GbE ports on all systems. Each XAUI consumes a PCIe slot.

[9] Eight-disk backplane is not supported with 1.6 GHz CPU (Oracle's Sun SPARC Enterprise T5120 server) or with 1.4 GHz CPU or DC power supply (Oracle's Sun SPARC Enterprise T5140 server).

[8] Eight-disk backplane is not supported with 1.6 GHz CPU (Oracle's Sun SPARC Enterprise T5120 server) or with 1.4 GHz CPU or DC power supply (Oracle's Sun SPARC Enterprise T5140 server).

[10] Using an XAUI adapter card converts one RJ-45 Gigabit Ethernet port into a 10 GbE port. If two XAUI ports are used, only 2 GbE ports are available.

[11] Optional XAUI adapter cards required for access to dual 10 GbE ports on all systems. Each XAUI consumes a PCIe slot.

functions, and extensive ECC hardware protection—along with redundant hot-swap disks, power supplies, and fans. The following key design elements in the Oracle Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers are key to improving the dependability of IT services:

- Reduced parts count
- Processor thread and core off-lining and built-in RAID capabilities
- Redundancy and hot-swap components
- Parity protection and error correction capabilities
- System monitoring
- Integrated Lights Out Manager service processor
- Superior energy efficiency
- Robust virtualization technology
- Comprehensive fault management

Innovative Support for Solid State Drives

Modern servers are driving throughput levels that can rapidly outpace the capabilities of traditional storage solutions. While many servers can achieve processing capabilities in excess of one million I/O operations per second (IOPS), today's fastest hard disk drives (HDDs) are only capable of about 300 to 400 IOPS. To match throughput more closely to server performance, and to address the challenging demands of data-intensive applications, many data centers implement large pools of high-speed disk drives. In some cases, a large buffer of expensive DRAM is also deployed so that the application's working set can be stored in memory to reduce latency.

Flash technology provides a more-economical alternative that can dramatically enhance application I/O performance while also operating with significantly better energy efficiency than conventional HDDs. Recent advances in the quality of flash technology have made solid-state drives (SSDs) an effective and reliable solution for enterprise storage. Flash technology contains no moving parts, avoiding the seek times and rotational latencies inherent with traditional HDD technology.

Because SSDs offer low latency and are less expensive than DRAM storage, they balance cost and performance in a manner that can provide significant value for I/O-intensive workloads. SSDs offer a disk drive form factor (Figure 3), and are directly supported by the drive bays of Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers.

Figure 3. SSDs provide enterprise flash technology in a standard disk drive form factor.

Space, Watts, and Performance: The SWaP Metric

Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers deliver leading performance across a range of multithreaded workloads and benchmarks. However, with energy and real estate costs and pressures, it is not enough to measure performance in isolation. Delivering the required level of throughput in a fixed space and power envelope is critical. Traditional system-to-system benchmarks are valuable as a way of comparing one system to another, but are limited when it comes to understanding the power and density attributes of the systems being compared. For this reason, Oracle has developed the SWaP metric, standing for space, watts, and performance.

Designed to provide a simple and transparent measure of overall server efficiency, SWaP is calculated using the following formula:

SWaP = Performance / (Space * Power Consumption) where,

- Performance is measured by industry-standard benchmarks
- Space refers to the height of the server in rack units
- Power is measured by watts used by the system, taken during actual benchmark runs or from vendors' site planning guides

UltraSPARC T2 and T2 Plus Processors

The UltraSPARC T2 and UltraSPARC T2 Plus processors are the industry's first systems-on-a-chip, supplying the most cores and threads of any general-purpose processors available, and integrating all key system functions.

The World's First Massively Threaded Systems-on-a-Chip

The UltraSPARC T2 and UltraSPARC T2 Plus processors eliminate the need for expensive custom hardware and software development by integrating computing, security, and I/O onto a single chip. Binary compatible with earlier UltraSPARC processors, no other processor delivers so much performance in so little space and with such small power requirements—letting organizations rapidly scale the delivery of new network services with maximum efficiency and predictability. The UltraSPARC T2 Plus and UltraSPARC T2 processors are shown in Figure 4, to the left of the previous-generation UltraSPARC T1 processor. Even with twice the computational throughput and significantly higher levels of integration, the UltraSPARC T2 and UltraSPARC T2 Plus processors are physically smaller than the UltraSPARC T1 processor.

Figure 4. The UltraSPARC T2 Plus, UltraSPARC T2, and UltraSPARC T1 processors with CoolThreads technology (left to right respectively) allow organizations to rapidly scale the delivery of new network services with maximum efficiency and predictability.

Table 2 provides a comparison between the UltraSPARC T2 and the UltraSPARC T1 processor.

TABLE 2. ULTRASPARC T1, ULTRASPARC T1T2, AND ULTRASPARC T1T2 PLUS PROCESSOR FEATURES

FEATURE	ULTRASPARC T1 PROCESSOR	ULTRASPARC T2 PROCESSOR	ULTRASPARC T2 PLUS PROCESSOR
Cores per processor	Up to 8	Up to 8	Up to 8
Threads per core	4	8	8
Threads per	32	64	64

processor			
Hypervisor	Yes	Yes	Yes
Sockets supported	1	1	2 or 4[A]
Memory	• Four memory controllers • Four DIMMs per controller	• Four memory controllers • Up to 16 FB-DIMMs	• Two memory controllers • Up to 16 or 32 FB-DIMMs
Caches	• 16 KB instruction cache • 8 KB data cache • 3 MB L2 cache (four banks, 12-way associative)	• 16 KB instruction cache • 8 KB data cache • 4 MB L2 cache (eight banks, 16-way associative)	• 16 KB instruction cache • 8 KB data cache • 4 MB L2 cache (eight banks, 16-way associative)
Technology	• Nine-layer Cu metal • CMOS process • 90 nm technology	65 nm technology	65 nm technology
Floating point	1 FPU per chip	• 1 FPU per core • 8 FPUs per chip	• 1 FPU per core • 8 FPUs per chip
Integer resources	Single execution unit per core	Two integer execution units per core	Two integer execution units per core
Cryptography	Accelerated modular arithmetic operations (RSA)	• Stream processing unit per core • Support for the 10 most popular ciphers	• Stream processing unit per core • Support for the 10 most popular ciphers
Additional on-chip resources		• Dual 10 GbE interfaces • PCIe interface (x8)	• PCIe interface (x8) • Coherency logic and links (4.8 Gb/second)

A. Two-socket implementations include Oracle's Sun SPARC Enterprise T5140/T5240 servers, whereas Oracle's Sun SPARC Enterprise T5440 server represents a four-socket implementation.

Taking Chip Multithreaded Design to the Next Level

When designing the next-generation of CMT processors, the in-house design team started with key goals in mind:

- Increasing computational capabilities to meet the growing demand from Web applications by providing twice the throughput of the UltraSPARC T1 processor
- Supporting larger and more-diverse workloads with greater floating-point performance

- Powering faster networking to serve new network-intensive content
- Providing end-to-end data center encryption
- Increasing service levels and reducing downtime
- Improving data center capacities while reducing costs

CMT architecture is ultimately very flexible, allowing different modular combinations of processors, cores, and integrated components. The considerations listed above drove an internal engineering effort that compared different approaches with regard to making improvements on the successful UltraSPARC T1 architecture. For example, simply increasing the number of cores would have gained additional throughput, but would have resulted in consuming extra die area, leaving no room for integrated components such as floating-point processors.

The final UltraSPARC T2 and UltraSPARC T2 Plus processor designs recognize that memory latency is truly the bottleneck to improving performance. By increasing the number of threads supported by each core, and by further increasing network bandwidth, these processors are able to provide approximately twice the throughput of the UltraSPARC T1 processor.

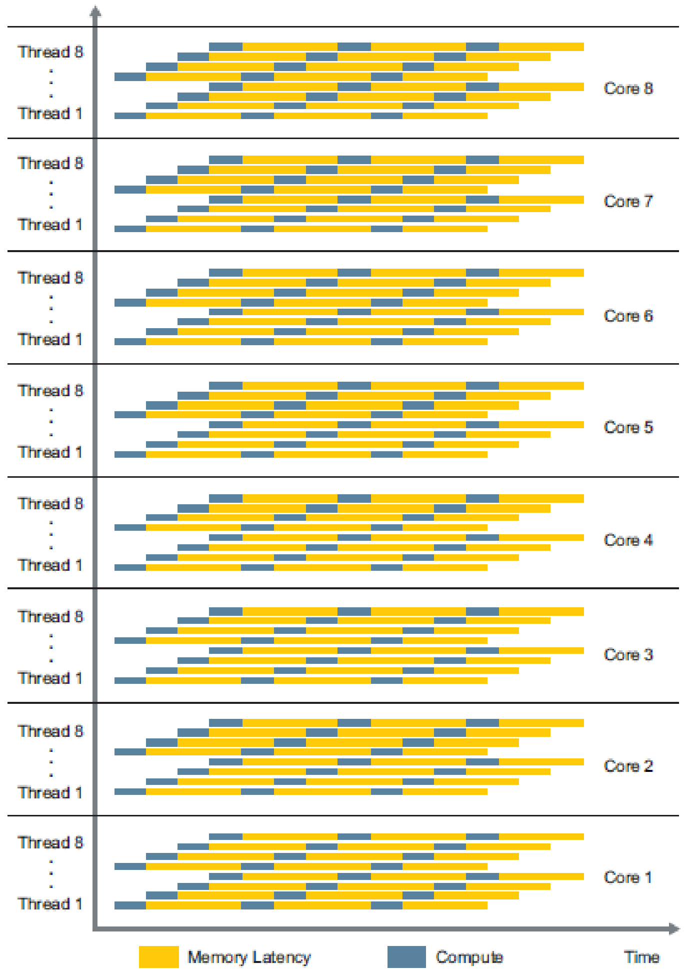

Figure 5. A single eight-core UltraSPARC T2 or UltraSPARC T2 Plus processor supports up to 64 threads, with up to 2 threads running in each core simultaneously.

Each UltraSPARC T2 and UltraSPARC T2 Plus processor provides up to eight cores, with each core able to switch between up to eight threads (64 threads per processor). In addition, each core provides two integer execution units, so that a single UltraSPARC core is capable of executing two threads at a time. Figure 5 provides a simplified high-level illustration of the thread model supported by an eight-core UltraSPARC T2 or UltraSPARC T2 Plus processor.

UltraSPARC T2 and UltraSPARC T2 Plus Processor Architecture

The UltraSPARC T2 processor and the UltraSPARC T2 Plus processor extend Oracle's CMT initiative with an elegant and robust architecture that delivers real performance to applications.

UltraSPARC T2 Processor Architecture

A high-level block diagram of the UltraSPARC T2 processor is shown in Figure 6.

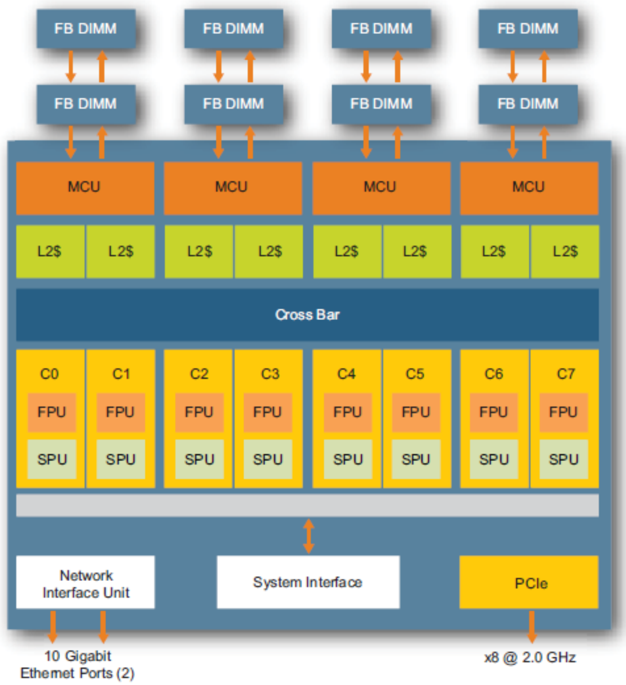

Figure 6. The UltraSPARC T2 processor combines up to eight cores, memory management, cryptographic support, 10 GbE, and PCIe on a single chip. Oracle's Sun SPARC Enterprise does not expose 10 GbE interfaces.)

Up to eight cores on each UltraSPARC T2 processor are interconnected with a full on-chip nonblocking 8 x 9 crossbar switch. The crossbar connects each core to the eight banks of Level 2 cache, and to the system interface unit for IO. The crossbar provides approximately 300 GB/sec of bandwidth and supports 8-byte writes from a core to a bank and 16-byte reads from a bank to a core. The system interface unit connects networking and I/O directly to memory through the individual cache banks. Using FB-DIMM memory supports dedicated northbound and southbound lanes to and from the caches to accelerate performance and reduce latency. This approach provides higher bandwidth than with DDR2 memory, with up to 42.4 GB/sec of read bandwidth and 21 GB/sec of write bandwidth.

Each core provides its own fully pipelined floating point and graphics unit (FPU), as well as a stream processing unit (SPU). The FPUs greatly enhance floating-point performance over that of the UltraSPARC T1 processor, while the SPUs provide wire speed cryptographic acceleration with more than 10 popular ciphers supported, including DES, 3DES, AES, RC4, SHA-1, SHA-256, MD5, RSA to 2048 key, ECC, and CRC32. Embedding hardware cryptographic acceleration for these ciphers allows end-to-end encryption with no penalty in either performance or cost.

UltraSPARC T2 Plus Processor Architecture

Figure 7 provides a block-level diagram of the UltraSPARC T2 Plus processor.

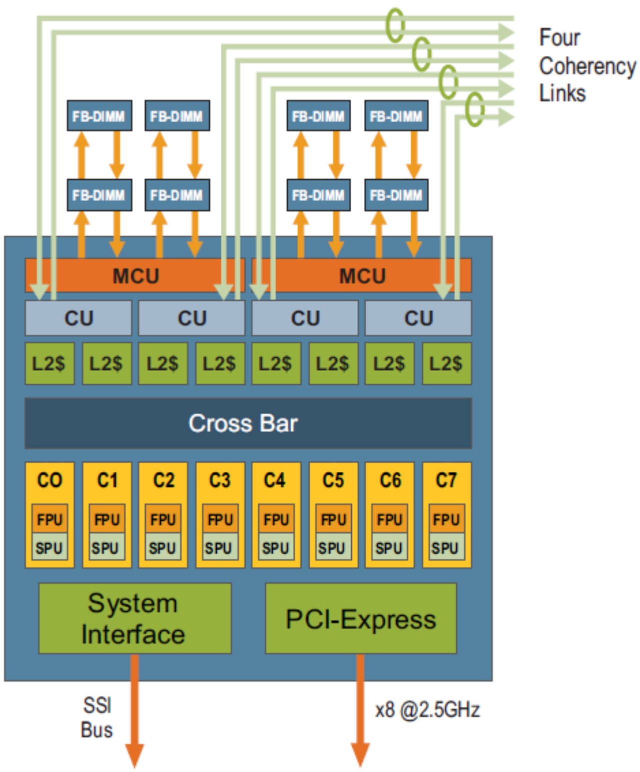

Figure 7. The UltraSPARC T2 Plus processor provides four coherence links to connect to up to four other processors.

The UltraSPARC T2 Plus architecture omits the dual on-chip 10 GbE interfaces that are provided on the UltraSPARC T2 processor, and uses the on-chip real estate to provide four coherency units (CUs). The processor also replaces two memory channels with four coherence channels (or coherence links)—one provided by each CU. These links run a cache coherence (snoopy) protocol over an FB-DIMM-like physical interface to provide up to 4.8 gigatransfers per port, providing 204 Gb/sec in each direction. The memory link speed of the UltraSPARC T2 Plus processor was also increased to 4.8 Gb/sec over the 4.0 Gb/sec of the UltraSPARC T2 processor.

The UltraSPARC T2 Plus processor can support both two- and four-socket implementations. A typical two-socket implementation is shown in Figure 8. Dual-socket UltraSPARC T2 Plus implementations interconnect the processors' four coherence links; no additional circuitry is required.

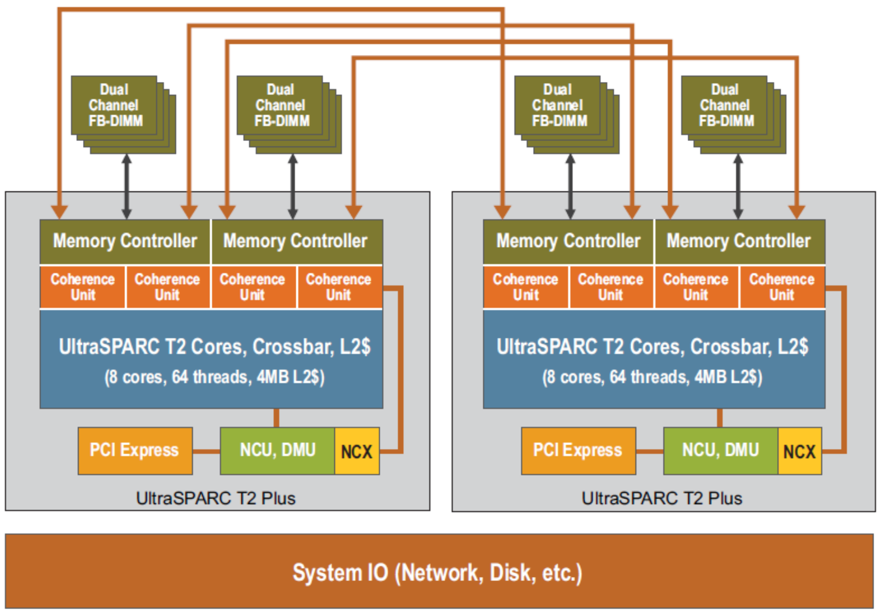

Figure 8. This is a typical dual-socket UltraSPARC T2 Plus configuration.

Core Architecture and Pipelines

Both the UltraSPARC T2 and UltraSPARC T2 Plus processors share the same core design. Figure 9 provides a block-level diagram representing a single UltraSPARC core on the UltraSPARC T2 processor (up to eight cores are supported per processor).

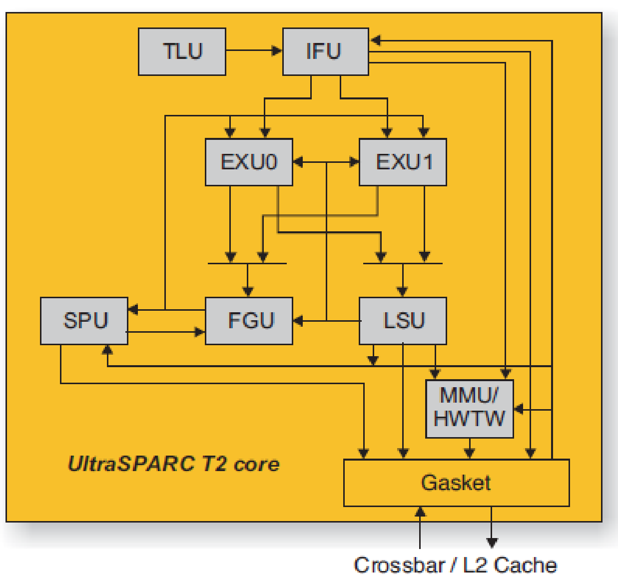

Figure 9.This is a block-level diagram of the UltraSPARC T2 and UltraSPARC T2 Plus core.

Components implemented in each core include

- **Trap logic unit.** The trap logic unit (TLU) updates the machine state as well as handling exceptions and interrupts.
- **Instruction fetch unit.** The instruction fetch unit (IFU) includes the 16 KB instruction cache (32-byte lines, 8-way set associative) and a 64-entry fully associative instruction translation lookup buffer (ITLB).
- **Integer execution unit.** Dual integer execution units (EXUs) are provided per core with four threads sharing each unit. Eight register windows are provided per thread, with 160 integer register file (IRF) entries per thread.
- **Floating point/graphics unit.** A floating point/graphics unit (FGU) is provided within each core and it is shared by all eight threads assigned to the core. Thirty-two floating-point register file entries are provided per thread.
- **Stream processing unit.** Each core contains a stream processing unit (SPU) that provides cryptographic coprocessing.
- **Memory management unit.** The memory management unit (MMU) provides a hardware table walk (HWTW) and supports 8 KB, 64 KB, 4 MB, and 256 MB pages.

An eight-stage integer pipeline and a 12-stage floating-point pipeline are provided by each UltraSPARC T2 and UltraSPARC T2 Plus processor core (Figure 10). A new "pick" pipeline stage has been added to choose two threads (out of the eight possible per core) to execute each cycle.

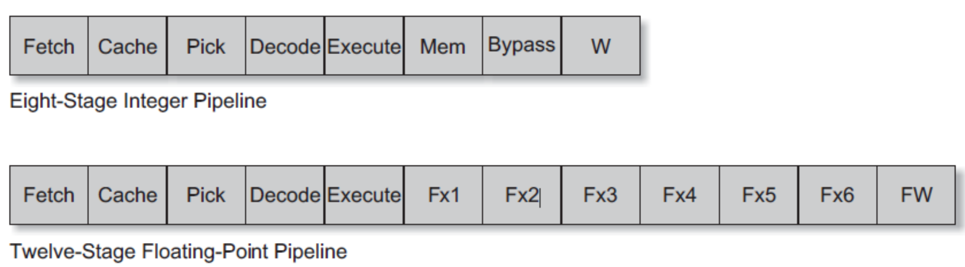

Figure 10. An 8-stage integer pipeline and a 12-stage floating-point pipeline are provided by each UltraSPARC T2 and UltraSPARC T2 Plus processor core.

To illustrate how the dual pipelines function, Figure 11 depicts the integer pipeline with the load store unit (LSU). The instruction cache is shared by all eight threads within the core. A least-recently-fetched algorithm is used to select the next thread to fetch. Each thread is written into a thread-specific instruction buffer (IB) and each of the eight threads is statically assigned to one of two thread groups within the core.

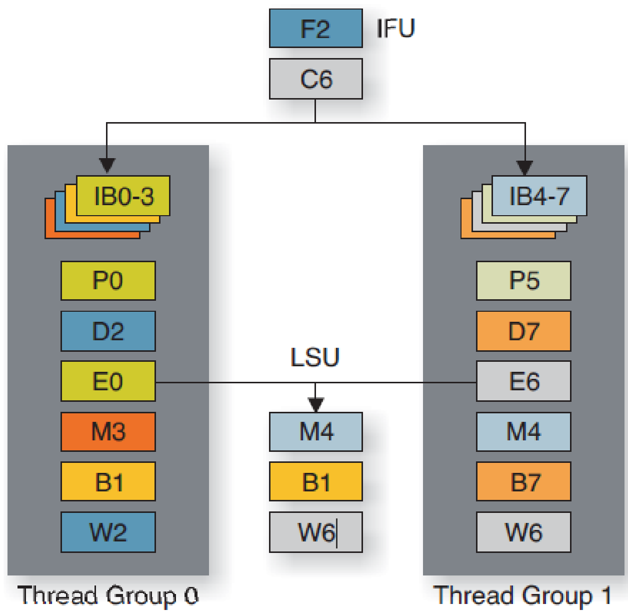

Figure 11. Threads are interleaved between pipeline stages with very few restrictions (integer pipeline shown, letters depict pipeline stages, numbers depict different scheduled threads).

The pick stage chooses one thread each cycle within each thread group. Picking within each thread group is independent of the other, and a least-recently-picked algorithm is used to select the next thread to execute. The decode state resolves resource conflicts that are not handled during the pick stage. As shown in the illustration, threads are interleaved between pipeline stages with very few restrictions. Any thread can be at the fetch or cache stage, before being split into either of the two thread groups. Load/store and floating-point units are shared between all eight threads. Only one thread from either thread group can be scheduled on such a shared unit.

Integrated Networking

By providing integrated on-chip networking, the UltraSPARC T2 processor is able to provide better networking performance. All network data is supplied directly from and to main memory. Placing networking so close to memory reduces latency, provides higher memory bandwidth, and eliminates inherent inefficiencies of I/O protocol translation.

The UltraSPARC T2 processor provides two 10 GbE ports with integrated serializer/deserializer (SerDes), offering line-rate packet classification at up to 30 million packets/second (based on layers 1-4 of the protocol stack). Multiple DMA engines (16 transmit and 16 receive DMA channels) match DMAs to individual threads, providing binding flexibility between ports and threads. Virtualization support includes provisions for eight partitions, and interrupts may be bound to different hardware threads.

Stream Processing Unit

The SPU on each UltraSPARC T2 core runs in parallel with the core at the same frequency. The cipher/hash unit provides support for popular RC4, DES/3DES, AES-128/192/256, MD5, SHA-1, and SHA-256 ciphers. The SPU is designed to achieve wire-speed encryption and decryption on both of the processor's 10 GbE ports.

Integral PCI Express Support

The UltraSPARC T2 and UltraSPARC T2 Plus processors provide an on-chip PCIe interface that operates at 4 GB/sec bidirectionally through a point-to-point dual-simplex chip interconnect. An integral IOMMU supports I/O virtualization and process device isolation by using the PCIe BUS/Device/Function (BDF) number. The total I/O bandwidth is 3 GB/Sec to 4 GB/sec, with maximum payload sizes of 128 to 512 bytes. An x8 SerDes interface is provided for integration with off-chip PCIe switches.

Power Management

Beyond the inherent efficiencies of CMT design, the UltraSPARC T2 and UltraSPARC T2 Plus processors are the first to incorporate unique power management features at both the core and memory levels of the processor. These features include reduced instruction rates, parking of idle threads and cores, and ability to turn off clocks in both cores and memory to reduce power consumption. Substantial innovation is present in the areas of

- Limiting speculation such as conditional branches not taken
- Extensive clock gating in the data path, control blocks, and arrays
- Power throttling that allows extra stall cycles to be injected into the decode stage

Server Architecture

Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers have been designed to provide breakthrough performance while maximizing reliability and minimizing power consumption and complexity. This section details the physical and architectural aspects of these systems.

System-Level Architecture

The system-on-a-chip (SoC) design of the UltraSPARC T2 and T2 Plus processors mean that sophisticated system-level functionality can be accomplished with a minimum of high-quality components. The sections that follow describe the architecture of the various systems.

Oracle's Sun SPARC Enterprise T5120/T5220 Servers

A unified motherboard design is common to both the Oracle Sun SPARC Enterprise T5120/T5220 servers (Figure 12).

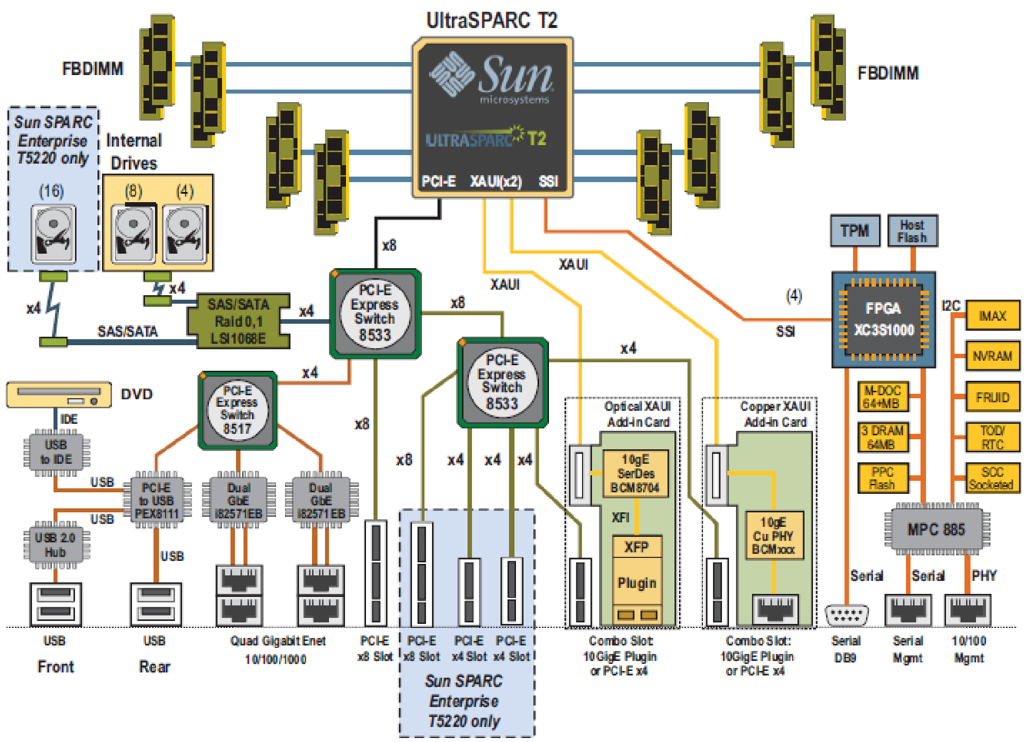

Figure 12. A unified motherboard design is common to both Oracle's Sun SPARC Enterprise T5120/T5220 servers.

The motherboard is a 20-layer printed circuit board (PCB) containing the UltraSPARC T2 processor, FB-DIMM sockets for main memory, Integrated Lights Out Manager service processor, disk controller, and I/O subsystems. I/O options include USB, DVD control, quad Gigabit Ethernet, and two levels of PLX PCIe branching out into sockets for a wide variety of third-party PCIe expansion options. Shaded regions indicate features that are only available on Oracle's Sun SPARC Enterprise T5220 server.

Oracle's Sun SPARC Enterprise T5140/T5240 Servers

Oracle's Sun SPARC Enterprise T5140/T5240 servers share a common motherboard design (Figure 13).

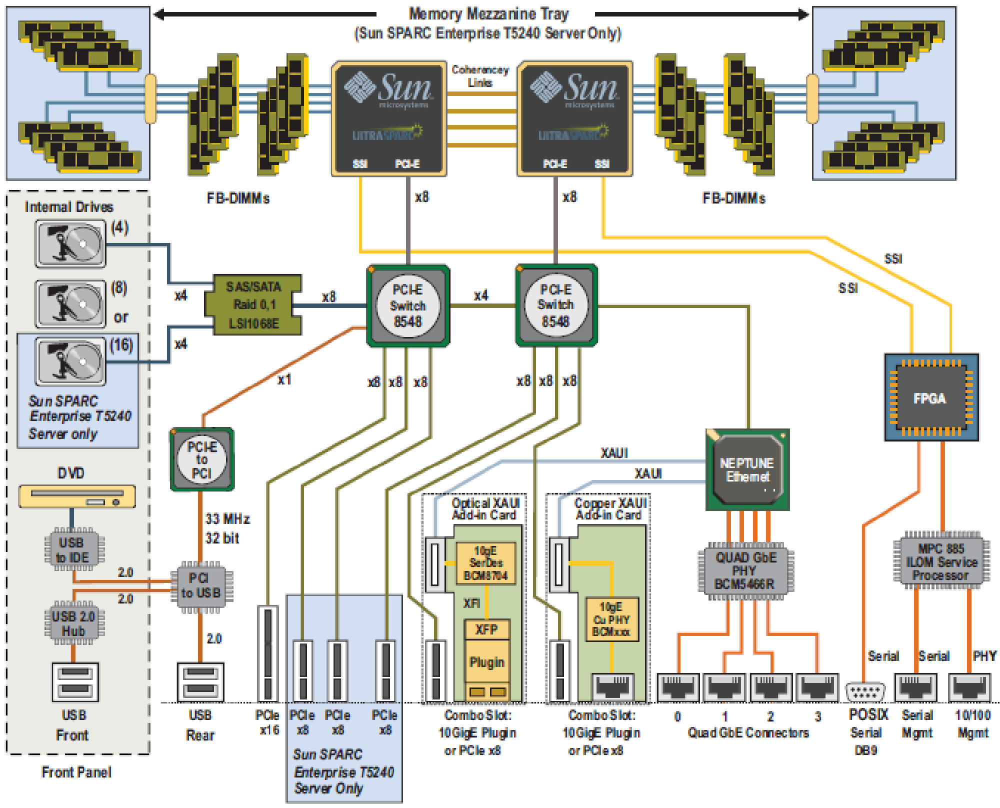

Figure 13. Oracle's Sun SPARC Enterprise T5140/T5240 servers share a common motherboard design.

Key features of the Oracle Sun SPARC Enterprise T5140/T5240 motherboards include

- Dual sockets for UltraSPARC T2 Plus processors, connected by four coherence links
- A memory mezzanine tray to supply additional memory to Oracle's Sun SPARC Enterprise T5240 server (up to 256 GB system maximum with 8 GB low-voltage FB-DIMMs)
- Integration of Oracle's Neptune chip to provide 10 Gigabit Ethernet functionality as well as standard quad Gigabit Ethernet ports (10/100/1000-BaseT)

The motherboard interconnects for all of these systems have been greatly simplified over previous-generation systems. Twelve-volt power is distributed to the motherboard through a pair of metal bus bars, connected to a power distribution board (PDB). A single flex circuit connector routes all critical power control and DVD drive signaling over to the PDB. One or two mini-SAS cables connect the motherboard to the disk drive backplane, providing data access to the system hard drives.

Memory Subsystem

In Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers, the UltraSPARC T2 or UltraSPARC T2 Plus processor provides on-chip memory controllers that communicate directly to FB-DIMM memory through high-speed serial links. Four dual-channel FBDIMM memory controller units (MCUs) are provided on the UltraSPARC T2 processor while the UltraSPARC T2 Plus processor provides two MCUs. Each MCU can transfer data at an aggregate rate of 4.0 Gb/sec (UltraSPARC T2) or 4.8 Gb/sec (UltraSPARC T2 Plus). Sixteen motherboard memory socket locations on Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers provide sufficient board space for two rows of 667 MHz FB-DIMMs per channel. Oracle's Sun SPARC Enterprise T5240 servers support an optional memory mezzanine tray that can be added to support an additional 16 FB-DIMM slots. The memory mezzanine tray (Figure 14) allows Oracle's Sun SPARC Enterprise T5240 server to support up to 256 GB of RAM using 8 GB FB-DIMMs.

Figure 14. An optional memory mezzanine tray doubles the memory capacity of Oracle's Sun SPARC Enterprise T5240 servers to up to 256 GB.

I/O Subsystem

Each UltraSPARC T2 and UltraSPARC T2 Plus processor incorporates a single, eight-lane (x8) PCIe port capable of operating at 4 GB/sec bidirectionally. In each server, this port natively interfaces to the I/O devices through a series of PLX technology PCIe expander chips, connecting either to PCIe card slots, or to bridge devices that interface with PCIe, such as those listed below.

- **Disk controller.** Disk control is managed by an LSI Logic SAS1068E SAS controller chip that interfaces to a four-lane (x4) PCIe port. RAID levels 0 and 1 are provided as standard.
- **Modular disk backplanes.** Depending on the system, a 4- , 8-, or 16-disk backplane is attached to the LSI disk controller by one or more x4 SAS links. The 16-disk backplane provides a 28-port LSI Logic SAS Expander to support the additional disk drives.

- **Solid state drives.** Solid state drives (SSDs) can be substituted for disk drives in all Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers. Servers in a 1RU chassis such as Oracle's Sun SPARC Enterprise T5120/T5140 servers can support up to four SSDs. Servers in a 2RU chassis such as Oracle's Sun SPARC Enterprise T5220/T5240 servers can support up to eight SSDs. Remaining slots can be occupied with conventional SAS hard disk drives.
- **Gigabit Ethernet.** On Oracle's Sun SPARC Enterprise T5120/T5220 servers, two x4 PCIe ports connect to two Intel Ophir dual Gigabit Ethernet chips, providing four 10/100/1000 Mb/sec Ethernet interfaces on the rear of each chassis. On Oracle's Sun SPARC Enterprise T5140/T5240 servers, Oracle's Neptune Ethernet chip provides two 10/100/1000-BaseT ports and two 10/100/1000/10000-BaseT interfaces, exposed as four RJ-45 connectors on the rear panel.
- **Dual 10 Gigabit Ethernet.** Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers all provide dual 10 Gb X (ten) Attachment Unit Interface (XAUI) connections, expressed through shared XAUI/PCIe slots. On Oracle's Sun SPARC Enterprise T5120/T5220 servers, these ports are provided by the dual 10 GbE ports integrated into the UltraSPARC T2 processor. On Oracle's Sun SPARC Enterprise T5140/T5240 servers, the 10 GbE interfaces are provided by Oracle's Neptune Ethernet chip. When the 10 GbE ports are connected, two of the Gigabit Ethernet ports become unavailable for use.
- **USB and DVD.** On all servers, a single-lane PCIe port connects to a PCI bridge device. A second bridge chip converts the 32-bit 33 MHz PCI bus into multiple USB 2.0 ports. The system's USB interconnect is driven from those ports. On Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers, the DVD is driven from a further bridge chip that interfaces one of the USB ports to IDE format.

Chassis Design Innovations

Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers share basic chassis design elements. This approach not only provides a consistent look and feel across the product line, but it simplifies administration through consistent component placement and shared components. Beyond mere consistency, this approach reflects a data center design focus that places key technology where it can make a difference for the data center.

- **Enhanced system and component serviceability.** Finding and identifying servers and components in a modern data center can be challenging. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers are optimized for lights-out data center configurations with easy-to-identify servers and modules. Color-coded operator panels provide easy-to-understand diagnostics and systems are designed for deployment in hot-isle/cold-isle multiracked deployments with both front and rear diagnostic LEDs to pinpoint faulty components. Fault Remind features identify failed components.

Consistent connector layouts for power, networking, and management make moving between Oracle’s systems straightforward. All hot-plug components are tool-less and easily available for serviceability. For instance, an integral hinged lid provides access to dual fan modules so that fans can be serviced without exposing sensitive components or causing unnecessary downtime.

- **Robust chassis, component, and subassembly design.** Oracle’s volume servers share chassis that are carefully designed to provide reliability and cool operation. Even features such as the hexagonal chassis ventilation holes are designed to provide the best compromise for high strength, maximum airflow, and maximum electronic attenuation. Next-generation hard disk drive carriers leverage the hexagonal ventilation of the chassis and provide a 7 percent smaller front plate for greater storage density while increasing airflow to the system.

  A removable disk cage in each system plugs directly in front of the fan tray assemblies, allowing airflow to be directed both above and below the disk drives, and then above and below the memory DIMMs and mezzanine boards to efficiently cool the system. Dual cooling fan modules are isolated from the chassis to avoid transfer of rotational vibration to other system components. Also, integration of the fan power board into the fan tray assembly protects users from electrical shock during fan removal/insertion.

  In spite of their computational, I/O, and storage density, Oracle’s servers are able to maintain adequate cooling using conventional technologies. In fact, although the fan trays can hold a large number of fans, only the number of fans actually needed to cool the various systems are configured. Minimized DC-DC power conversions also contribute to overall system efficiency. By providing 12-volt power to the motherboard, power conversion stages are eliminated. This approach reduces generated heat, and introduces further efficiencies to the system.

- **Minimized cabling for maximized airflow.** To minimize cabling and increase reliability, a variety of smaller boards and riser cards are employed, appropriate to each chassis. These infrastructure boards serve various functions in Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers.

  - Power distribution boards distribute system power from the dual power supplies to the motherboard and to the disk backplane (via a connector board).
  - Connector boards eliminate the need for many discrete cables, providing a direct card plug-in interconnect to distribute control and most data signals to the disk backplane, fan boards, and the PDB.
  - Fan boards provide connections for power and control for both the primary and secondary fans in the front of the chassis. No cables are required because every dual fan module plugs directly into one of these PCBs, which, in turn, plugs into the connector board.
  - PCIe riser cards plug directly into the motherboard, allowing PCIe cards to be installed.

- In Oracle's Sun SPARC Enterprise T5140/T5240 servers, two XAUI riser cards provide slots that access to the on-chip 10 GbE interfaces on the UltraSPARC T2 Processor or the Neptune Ethernet chip. Alternately, these slots can provide access to PCIe interfaces. Each slot can either accept an optical/copper XAUI card, or an industry-standard low-profile PCIe card with up to an x8 form factor edge connector. Cards are installed in a horizontal orientation.
- The disk backplane mounts to the disk cages in the chassis, delivering disk data through one or two four-channel, discrete mini-SAS cables from the motherboard. A 4- or 8-disk backplane is offered for Oracle's Sun SPARC Enterprise T5120/T5140 servers, whereas Oracle's Sun SPARC Enterprise T5220/T5240 servers support either an 8- or 16-disk backplane.
- Also provided via the disk backplane are two USB connections to the front of the system.

Oracle's Sun SPARC Enterprise T5120 Server Overview

The compact Oracle Sun SPARC Enterprise T5120 server provides significant computational power in a space-efficient, low-power 1RU rack mount package. With high levels of price/performance, a low acquisition cost, and tightly integrated high-performance 10 Gigabit Ethernet, this server is ideally suited to the delivery of horizontally scaled transaction and Web services that require extreme network performance, and can function as a very capable HPC compute node. The server is designed to address the challenges of modern data centers with greatly reduced power consumption and a small physical footprint. Depending on the model selected, Oracle's Sun SPARC Enterprise T5120 server features a single four-core, six-core, or eight-core UltraSPARC T2 processor.

Enclosure

The 1RU Oracle Sun SPARC Enterprise T5120 server enclosure is designed for use in a standard 19-inch rack (Table 3).

TABLE 3. DIMENSIONS AND WEIGHT OF ORACLE'S SUN SPARC ENTERPRISE T5120 SERVER

DIMENSION	U.S.	INTERNATIONAL
Height	1.746 inches (1RU)	44 millimeters
Width	16.75 inches	425 millimeters

Depth	28.125 inches	714 millimeters
Weight (approximate, without PCI cards or rack mounts)	40 pounds	18 kilograms

The Oracle Sun SPARC Enterprise T5120 server includes the following major components:

- An UltraSPARC T2 processor with four or eight cores at 1.2 GHz, or eight cores at 1.4 GHz or 1.6 GHz
- Up to 128 GB of memory in 16 Fully Buffered Dual Inline Memory Module (FB-DIMM) slots (2 GB, 4 GB, and 8 GB FB-DIMMs supported)
- Four onboard 10/100/1000 Mb/sec Ethernet ports
- Dedicated low-profile PCIe slot (x8)
- Two combination XAUI or low-profile PCIe x4 slots
- Four USB 2.0 ports (two forward, two rear facing)
- Four or eight available disk drive slots support SAS disk drives or up to four SSDs (Note: Eight-disk backplane is not supported with 1.6 GHz CPUs)
- ILOM system controller
- Two (N+1) hot-swappable, high-efficiency 720 watt AC or 660 watt DC power supplies

Four fan assemblies (each with two fans) populated of a possible eight, under environmental monitoring and control, N+1 redundancy. Fans are accessed through a dedicated top panel door.

Front and Rear Perspectives

Figure 15 illustrates the front and rear panels of Oracle's Sun SPARC Enterprise T5120 server, showing both the four-disk and eight-disk backplanes.

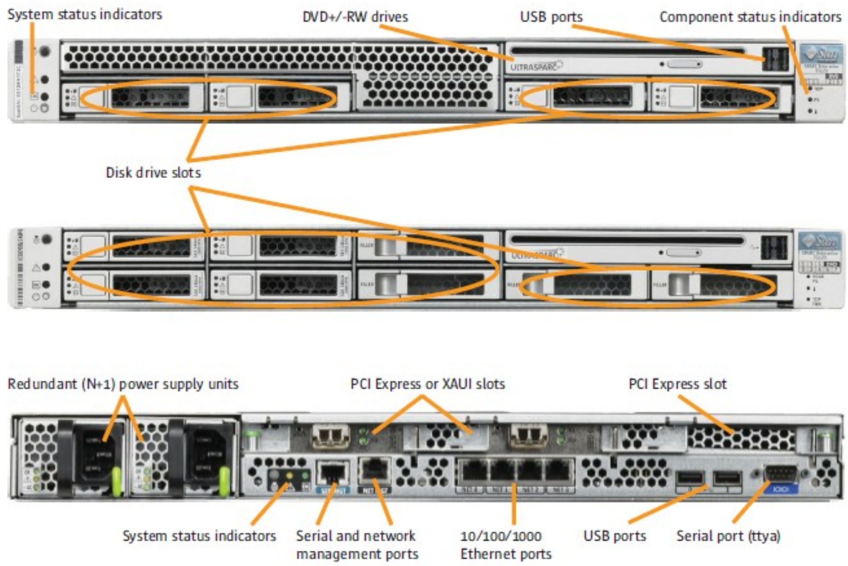

Figure 15. This illustrates the front and rear panels of Oracle's Sun SPARC Enterprise T5120 server.

External features of Oracle's Sun SPARC Enterprise T5120 server include

- Front and rear system and component status indicator lights that provide locator (white), service required (amber), and activity status (green) for the system
- Up to four or eight hot-plug SAS disk drives or SSDs insertable through the front panel
- One slimline, slot-accessible DVD+/-RW accessible through the front panel
- Four USB 2.0 ports, two on the front panel, and two on the rear
- Two hot-plug/hot-swap (N+1) power supplies with integral fans insertable from the rear
- Rear power-supply indicator lights that convey the status of each power supply
- A single power plug on each hot-plug/hot-swap power supply
- Four 10/100/1000Base-T autosensing Ethernet ports
- A DB-9 TTYA serial port for serial devices (not connected to the ILOM system controller serial port)
- A total of three PCIe card slots, two of which can alternately support XAUI cards connected to the UltraSPARC T2 10 GbE interfaces
- Two management ports for use with the ILOM system controller; RJ-45 serial management port provides default connection to the ILOM controller

Oracle's Sun SPARC Enterprise T5220 Server Overview

The expandable Oracle's Sun SPARC Enterprise T5220 server is optimized to deliver transaction and Web services, including Java 2 Platform, Enterprise Edition (J2EE platform) technology application services; enterprise application services (such as enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM)); and distributed databases. With considerable expansion capabilities and integrated virtualization technologies, Oracle's Sun SPARC Enterprise T5220 server is also an ideal platform for consolidated Tier 1 and Tier 2 workloads.

Enclosure

The Oracle Sun SPARC Enterprise T5220 server features a compact, yet expandable 2RU rack mount chassis (Table 4), giving organizations the flexibility to scale their processing and I/O needs without wasting precious space.

TABLE 4. DIMENSIONS AND WEIGHT OF ORACLE'S SUN SPARC ENTERPRISE T5220 SERVER

SERVER/DIMENSION	U.S.	INTERNATIONAL
Height	3.49 inches (2 RU)	88 millimeters
Width	16.75 inches	425 millimeters
Depth	28.125 inches	714 millimeters
Weight (without PCI cards or rack mounts)	55 pounds	25 kilograms

Oracle's Sun SPARC Enterprise T5220 server includes the following major components:

- An UltraSPARC T2 processor with four or eight cores at 1.2 GHz or eight cores at 1.4 GHz or 1.6 GHz
- Up to 128 GB of memory in 16 FB-DIMM slots (2 GB, 4 GB, and 8 GB FB-DIMMs)
- Four onboard 10/100/1000 Mb/sec Ethernet ports
- Four dedicated low-profile PCIe slots
- Two combination XAUI or low-profile PCIe x4 slots
- Four USB 2.0 ports (two forward, two rear facing)

- Eight or 16 available disk drives slots that support SAS commodity disk drives or SSDs
- ILOM system controller
- Two (N+1) hot-plug/hot-swap high-efficiency 750 watt or 11 watt AC power supplies or 1200 watt DC power supplies
- Three fan assemblies (each with two fans) populated of a possible six, under environmental monitoring and control, N+1 redundancy

Front and Rear Perspectives

Figure 16 illustrates the front and back panels of Oracle's Sun SPARC Enterprise T5220 server, including views of both the 8- and 16-disk backplanes.

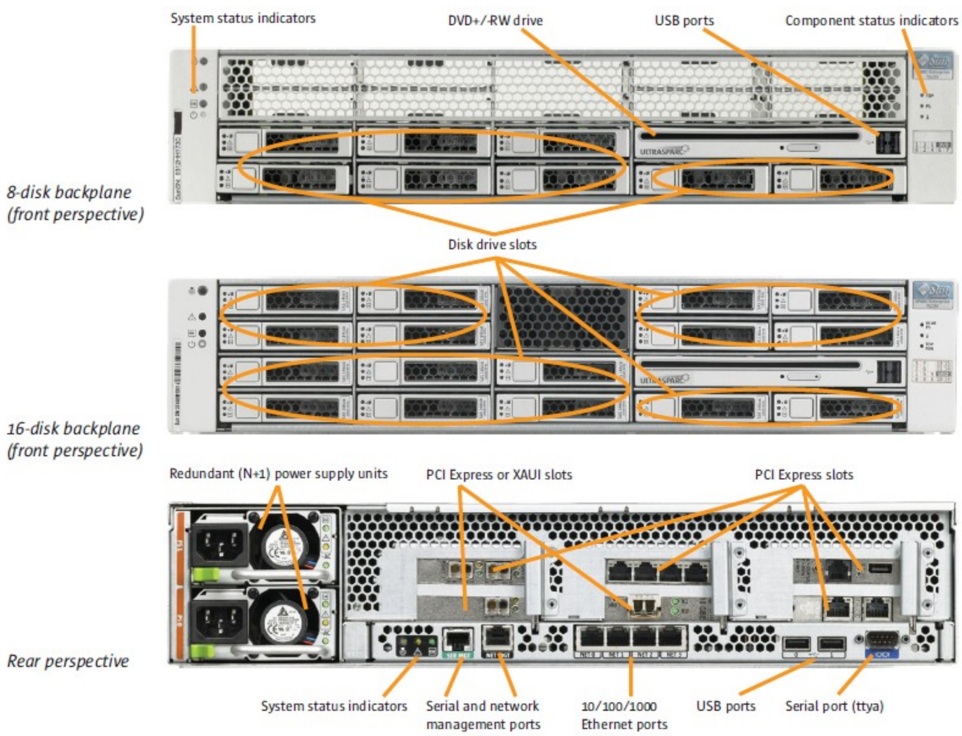

Figure 16. This illustrates the front and back panels of Oracle's Sun SPARC Enterprise T5220 server.

External features of Oracle's Sun SPARC Enterprise T5220 server include

- Front and rear system and component status indicator lights that provide locator (white), service required (amber), and activity status (green) for the system
- Up to 8 or 16 hot-plug SAS disk drives or SSDs insertable through the front panel of the system
- One slimline DVD +/-RW drive accessible through the front panel

- Four USB 2.0 ports, two on the front panel, and two on the rear
- Two hot-plug/hot-swap N+1 power supplies with integral plugs and fans insertable from the rear (rear power supply indicator lights convey the status of each power supply)
- Four 10/100/1000Base-T autosensing Ethernet ports
- A DB-9 TTYA serial port for serial devices (not connected to the ILOM system controller serial port)
- A total of six PCIe card slots, two of which can support XAUI cards connected to the UltraSPARC T2 10 GbE interfaces
- Two management ports for use with the ILOM system controller; RJ-45 serial management port provides default connection to the ILOM controller (network management port supports an optional RJ-45 10/100Base-T connection to the ILOM system controller)

Oracle's Sun SPARC Enterprise T5140 Server Overview

With support for up to two UltraSPARC T2 Plus processors, and up to 128 threads, the compact Oracle Sun SPARC Enterprise T5140 server provides breakthrough computational power in a space-efficient, low-power 1RU rack mount package. With high levels of price/performance and a low acquisition cost, this server is ideally suited to the delivery of horizontally scaled transaction and Web services, and presents many opportunities as a consolidation and virtualization server. The server is designed to address the challenges of modern data centers with greatly reduced power consumption and a small physical footprint. Depending on the model selected, the Sun
SPARC Enterprise T5140 server features dual four-core, six-core, or eight-core UltraSPARC T2 Plus processors.

Enclosure

The 1RU Oracle Sun SPARC Enterprise T5140 server enclosure is designed for use in a standard 19-inch rack (Table 5).

TABLE 5. DIMENSIONS AND WEIGHT OFORACLE'S SUN SPARC ENTERPRISE T5140 SERVER

DIMENSION	U.S.	INTERNATIONAL
Height	1.746 inches (1RU)	44 millimeters
Width	16.75 inches	425 millimeters
Depth	28.125 inches	714 millimeters
Weight (without PCI cards or rack mounts)	40 pounds	18 kilograms

The Oracle Sun SPARC Enterprise T5140 server includes the following major components:

- Two UltraSPARC T2 Plus processors with four, six, or eight cores at 1.2 GHz or eight cores at 1.4 GHz
- Up to 128 GB of memory in 16 FB-DIMM slots (2 GB, 4 GB, and 8 GB FB-DIMMs are supported)
- Four onboard 10/100/1000 Mb/sec Ethernet ports
- Dedicated low-profile PCIe slot (x8 with x16 connector)
- Two combination XAUI or low-profile PCIe x8 slots
- Four USB 2.0 ports (two forward, two rear facing)
- Four or eight available disk drives slots that support SAS commodity disk drives or SSDs (Note: Eight-disk backplane is not supported with either 1.4 GHz CPUs or the DC power supply)
- ILOM system controller
- Two (N+1) hot-swappable, high-efficiency 720 watt AC or 660 watt DC power supply units
- Six fan assemblies (each with two fans), under environmental monitoring and control, N+1 redundancy (fans accessible through a dedicated top panel door)

Front and Rear Perspectives

Figure 17 illustrates the front and rear panels of Oracle's Sun SPARC Enterprise T5140 server, including both views of the four-disk and eight-disk backplanes.

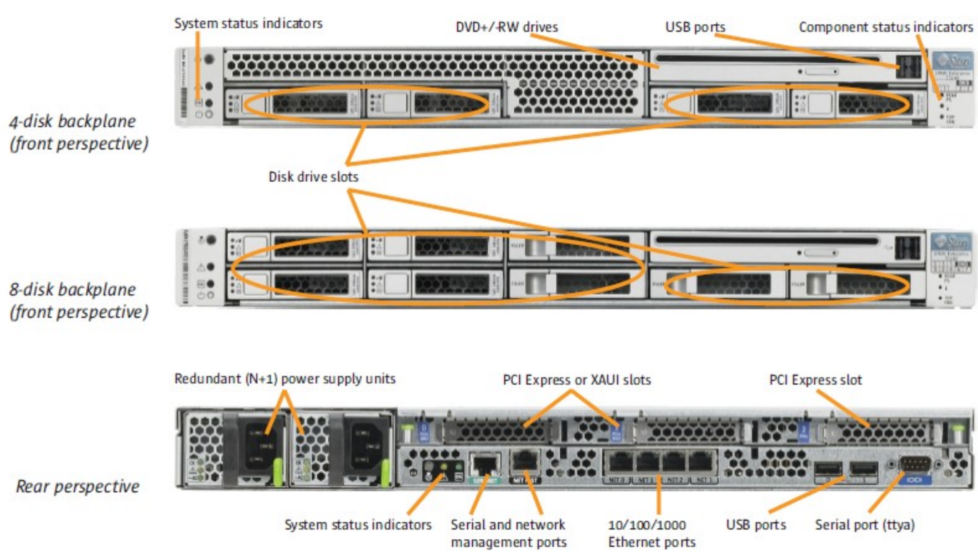

Figure 17. This illustrates the front and rear panels of Oracle's Sun SPARC Enterprise T5140 server.

External features of Oracle's Sun SPARC Enterprise T5140 server include

- Front and rear system and component status indicator lights that provide locator (white), service required (amber), and activity status (green) for the system
- Hot-plug SAS disk drives or SSDs that are insertable through the front panel of the system
- One slimline, slot-accessible DVD +/-RW accessible through the front panel
- Four USB 2.0 ports two on the front panel, and two on the rear
- Two hot-plug/hot-swap (N+1) power supplies with integral fans insertable from the rear
- Rear power-supply indicator lights that convey the status of each power supply
- A single power plug on each hot-plug/hot-swap power supply
- Four 10/100/1000Base-T autosensing Ethernet ports
- A DB-9 TTYA serial port for serial devices (not connected to the ILOM system controller serial port)
- A total of three PCIe card slots, two of which can alternately support XAUI cards connected to the Neptune Ethernet chip XAUI interfaces
- Two management ports for use with the ILOM system controller; RJ-45 serial management port provides default connection to the ILOM controller

Oracle's Sun SPARC Enterprise T5240 Server Overview

The expandable Oracle Sun SPARC Enterprise T5240 server is optimized to deliver highly scalable transaction and Web services, including J2EE platform technology application services, enterprise application services (ERP, CRM, and SCM), and distributed databases. With support for two UltraSPARC T2 Plus processors, considerable expansion capabilities, and integrated virtualization technologies, Oracle's Sun SPARC Enterprise T5240 server is also an ideal platform for consolidated Tier 1 and Tier 2 workloads.

Enclosure

Oracle's Sun SPARC Enterprise T5240 server features a compact, yet expandable 2RU rack mount chassis (Table 6), giving organizations the flexibility to scale their processing and I/O needs without wasting precious space.

TABLE 6. DIMENSIONS AND WEIGHT OFORACLE'S SUN SPARC ENTERPRISE T5240 SERVER

SERVER/DIMENSION	U.S.	INTERNATIONAL
Height	3.49 inches (2RU)	88 millimeters
Width	16.75 inches	425 millimeters
Depth	28.125 inches	714 millimeters
Weight (without PCI cards or rack mounts)	55 pounds	25 kilograms

Oracle's Sun SPARC Enterprise T5240 server includes the following major components:

- Two UltraSPARC T2 Plus processors with six, or eight cores at 1.2 GHz, or eight cores at 1.4 GHz1 or 1.6 GHz
- Up to 256 GB of memory in 16 or 32 FB-DIMM slots (2 GB, 4 GB, and 8 GB FB-DIMMs supported) with optional memory mezzanine tray
- Four onboard 10/100/1000 Mb/sec Ethernet ports
- Four dedicated low-profile x8 PCIe slots (all x8 electrically with one x16 physical connector)
- Two combination XAUI or low-profile PCIe x8 slots
- Four USB 2.0 ports (two forward, two rear facing)
- Up to 8 or 16 available disk drive slots supporting commodity SAS disk drives or SSDs
- ILOM system controller
- Two (N+1) hot-plug/hot-swap high-efficiency 1100 watt AC power supplies, or 1200 watt DC power supplies
- Five fan assemblies (each with two fans) under environmental monitoring and control, N+1 redundancy

Front and Rear Perspectives

Figure 18 illustrates the front and back panels of Oracle's Sun SPARC Enterprise T5240 server.

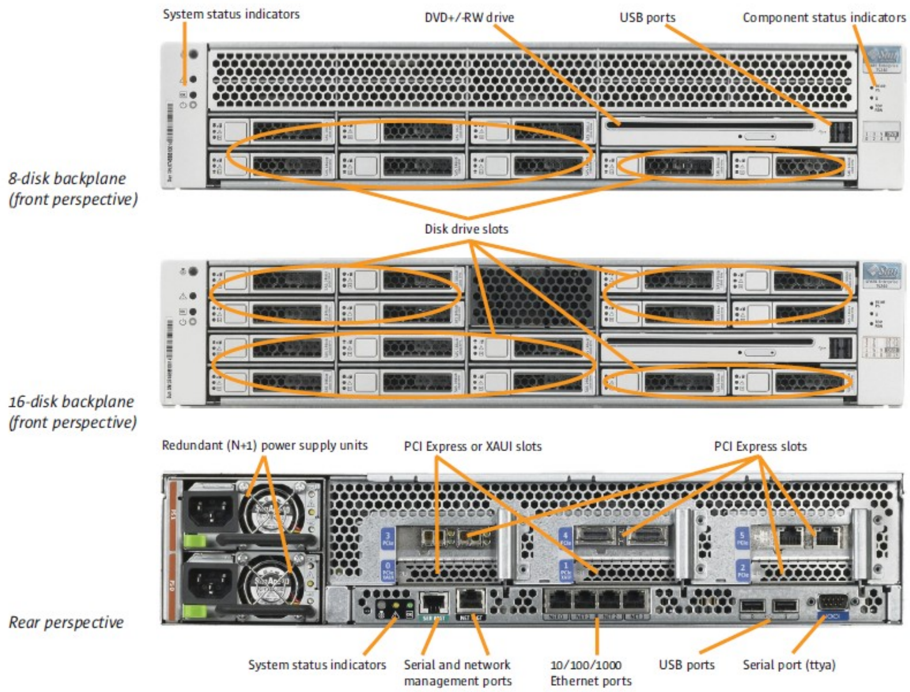

Figure 18. This illustrates the front and back panels of Oracle's Sun SPARC Enterprise T5240 server.

External features of Oracle's Sun SPARC Enterprise T5240 server include

- Front and rear system and component status indicator lights that provide locator (white), service required (amber), and activity status (green) for the system
- Hot-plug SAS disk drives or SSDs insertable through the front panel of the system
- One slimline DVD+/-RW drive accessible through the front panel
- Four USB 2.0 ports, two on the front panel, and two on the rear
- Two hot-plug/hot-swap N+1 power supplies with integral plugs and fans insertable from the rear (rear power supply indicator lights convey the status of each power supply)
- Four 10/100/1000Base-T autosensing Ethernet ports
- A DB-9 TTYA serial port for serial devices (not connected through the ILOM system controller serial port)
- A total of six PCIe card slots, two of which can support XAUI cards connected to the Neptune Ethernet chip XAUI interfaces

- Two management ports for use with the ILOM system controller; RJ-45 serial management port provides default connection to the ILOM controller (network management port supports an optional RJ-45 10/100Base-T connection to the ILOM system controller)

PCI Express Expansion Unit

With the strength of UltraSPARC T2 and T2 Plus processors, Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers are ideally suited for mission-critical applications and databases that often require fast access to considerable near-line storage. These systems also have considerable I/O capacity and bandwidth available for external expansion. To scale I/O expansion beyond the constraints of the individual system chassis, Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers support the attachment of an optional Sun External I/O Expansion Unit to provide additional I/O connectivity.

The Sun External I/O Expansion Unit is a 4RU rack-mountable device, which accommodates up to two 12 additional PCIe slots—connected to, and managed by, Oracle's Sun SPARC Enterprise server. By using cassettes, the external I/O chassis supports the active replacement of hot-plug cards. A link I/O card mounted in the host provides connectivity to each of two "I/O boats" the Sun External I/O Expansion Unit and facilitates host management control via sideband signals. The link I/O card is available as a low-height copper card, and includes a single eight-lane PCIe bus with 4 GB/sec bandwidth. The architecture of the Sun External I/O Expansion Unit provides high-throughput I/O performance, supporting maximum data rates for many types of PCIe cards and bursty traffic from additional PCIe cards. Front and rear perspectives of the Sun External I/O Expansion Unit are shown in Figure 19.

Figure 19. This shows the front and rear perspectives of the Sun External I/O Expansion Unit with one I/O boat installed.

Each Sun External I/O Expansion Unit contains either one or two I/O boats, with each boat providing six external x8 PCIe slots. Individual I/O boats connect to Oracle's Sun SPARC Enterprise T5120/T5220 or Oracle's Sun SPARC Enterprise T5140/T5240 server via a link card that is installed in one of the system's PCIe slots. As a result, a fully configured Sun External I/O Expansion Unit requires two PCIe slots in the server chassis and provides an addition 10 PCIe slots. The Sun External I/O Expansion Unit includes several key technologies, including

- Link card side-band communication technology along with I/O manager capabilities built into the system software that allow seamless remote management and integration with the host server
- Redundancy and hot-plug capabilities for power supply units, fans, I/O boats, and I/O cards
- Thermal monitoring and remote diagnostic capabilities

Figure 20 provides a block-level diagram of the Sun External I/O Expansion Unit.

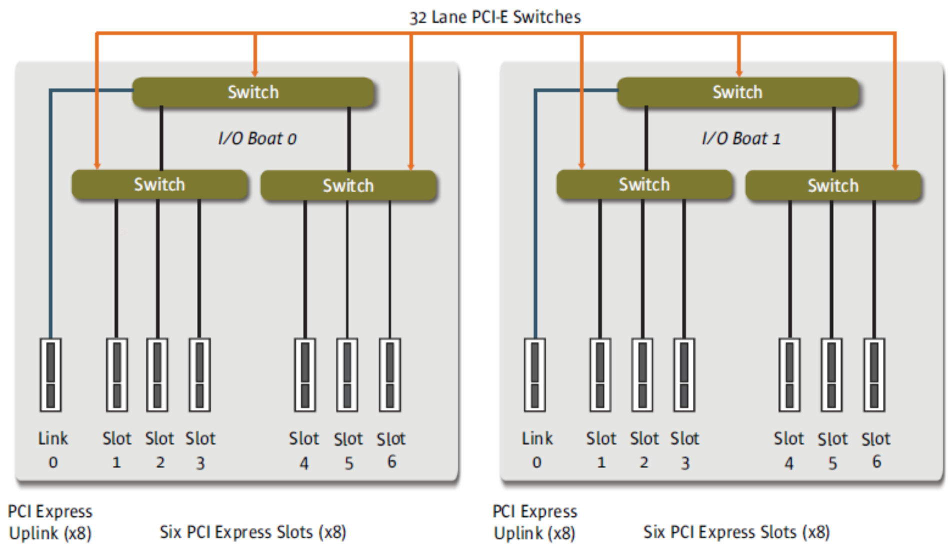

Figure 20. This is a block-level diagram of the Sun External I/O Expansion Unit architecture.

The Sun External I/O Expansion Unit consists of an advanced network of switches, bridges, and controllers to allow I/O data communication along with system control information via the PCIe link card connection to the host server. The x8 PCIe connection from the host is forwarded over the link card cable to a switch in each I/O boat. Two additional switches then connect to the six x8 PCIe slots in the I/O boat. The switches support the side-band management function of the link card, by providing the following functionality:

- Gathering and communicating I2C diagnostic and environmental information to the host server's ILOM service processor
- Executing system instructions to modify fan speeds or selectively power down components within the unit
- Performing locate/warning information via the front-panel LEDs
- Providing support for the online maintenance and replacement of power supply units, I/O boats, or I/O cards during system operation, and also supporting addition and deletion of active I/O cards

Enterprise-Class Management and Software

Although new technology often requires time for tools and applications to arrive, delivering agile and highly available services that take advantage of available resources requires stable development tools, operating systems, middleware, and management software. Fortunately, in spite of the breakthrough UltraSPARC T2 and UltraSPARC T2 Plus processor technology, Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise

T5120/T5240 servers provide full binary compatibility with earlier SPARC systems and are delivered ready to run with preloaded tools and the solid foundation of Oracle Solaris. Moreover, these systems are provided with a wealth of sophisticated tools that let organizations develop and tune applications as they consolidate and manage workloads while effectively using the resources of UltraSPARC T2 and UltraSPARC T2 Plus processors.

System Management Technology

As the number of systems grow in any organization, managing increasingly complex infrastructure throughout its lifecycle becomes difficult. Effective system management requires both integrated hardware that can sense and modify the behavior of key system elements, as well as advanced tools that can automate key administrative tasks.

Integrated Lights Out Manager

Provided across many of Oracle's x64 servers, the Integrated Lights Out Manager service processor acts as a system controller, facilitating remote management and administration of Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers. The service processor is fully featured and is similar in implementation to that used in Oracle's other modular and rack mount x64 servers. As a result, these servers integrate easily with existing management infrastructure. Critical to effective system management, the Integrated Lights Out Manager service processor

- Implements an IPMI 2.0-compliant services processor, providing IPMI management functions to the server's firmware, OS and applications, and to IPMI-based management tools accessing the service processor via the ILOM Ethernet management interface, providing visibility to the environmental sensors (both on the server module, and elsewhere in the chassis)
- Manages inventory and environmental controls for the server, including CPUs, DIMMs, and power supplies, and provides HTTPS/CLI/SNMP access to this data
- Supplies remote textual console interfaces
- Provides a means to download upgrades to all system firmware

The Integrated Lights Out Manager service processor also allows the administrator to remotely manage the server, independent of the operating system running on the platform and without interfering with any system activity. Integrated Lights Out Manager can also send e-mail alerts of hardware failures and warnings, as well as other events related to each server. The Integrated Lights Out Manager circuitry runs independently from the server, using the server's standby power. As a result, ILOM firmware and software continue to function when the server operating system goes offline, or when the server is powered off. Integrated Lights Out Manager monitors the following Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 server conditions:

- CPU temperature conditions
- Hard drive presence
- Enclosure thermal conditions
- Fan speed and status
- Power supply status
- Voltage conditions
- Oracle Solaris watchdog, boot time-outs, and automatic server restart events

Oracle Enterprise Manager Ops Center

Beyond local and remote management capabilities, data center infrastructure needs to be agile and flexible, allowing not only fast deployment but streamlined redeployment of resources as required. Oracle Enterprise Manager Ops Center technology provides an IT infrastructure management platform for integrating and automating management of thousands of heterogeneous systems. To improve lifecycle and change management, Oracle Enterprise Manager Ops Center supports the management of applications and the servers on which they run, including Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5240/T5240 servers. Oracle Enterprise Manager Ops Center takes a step-by-step approach to unraveling the challenges of getting systems operational quickly:

- **Discover.** As systems are added to the management network, administrators can use Oracle Enterprise Manager Ops Center to discover bare metal systems based on a given subnet address or IP range.
- **Group.** Given the number of systems to manage and the constant repurposing of systems, it is critical for IT organizations to find ways to group resources together. Oracle Enterprise Manager Ops Center lets users logically group systems together and perform actions across a group of systems as easily as performing actions on a single system. Systems can be grouped by function (for example, Web servers versus clusters servers), administrative responsibility, or other categorization based on organizational needs.
- **Provision.** Oracle Enterprise Manager Ops Center remotely installs operating systems onto selected systems. Administrators can use this functionality to provision operating systems onto bare-metal systems or reprovision existing systems. As the infrastructure lifecycle continues, Oracle Enterprise Manager Ops Center can update firmware and provision software packages and patches to selected systems.
- **Monitor.** When systems are up and running, administrators can use Oracle Enterprise Manager Ops Center to monitor system health, helping to ensure that everything is running at the optimal levels. The software provides detailed hardware monitoring for attributes such as fans, temperature, disk, and voltage usage, including bare-metal systems. Oracle Enterprise

Manager Ops Center also monitors OS attributes such as swap space, CPU, memory, and file systems. Administrators can define specific threshold levels and set preferred notification methods, including e-mail, pager, or Simple Network Management Protocol (SNMP) traps, for each monitored component as business needs demand.

- **Manage.** Businesses require that infrastructure lifecycle management extend beyond just deploying and monitoring systems. Oracle Enterprise Manager Ops Center includes Lights Out Management capabilities, such as powering systems on and off, and remote serial console access to help IT organizations manage their IT infrastructure from remote locations. Leveraging a role-based access control (RBAC) feature, organizations can grant permissions to specific users to perform specific management tasks.
- **Hybrid user interface.** Oracle Enterprise Manager Ops Center offers users a hybrid user interface (UI), accessible from the Web, that integrates both the GUI and CLI into one console. With this hybrid UI, operations performed in the GUI are simultaneously reflected in the CLI, and vice versa.

Scalability and Support for CoolThreads Technology

Oracle Solaris 10 is specifically designed to deliver the considerable resources of UltraSPARC T2 and UltraSPARC T2 Plus processor-based systems. In fact, Oracle Solaris 10 provides key functionality for virtualization, optimal use high availability, unparalleled security, and extreme performance for both vertically and horizontally scaled environments. Oracle Solaris 10 runs on a broad range of SPARC and x86/x64-based systems, and compatibility with existing applications is guaranteed. One of the most attractive features of systems based on UltraSPARC T2 and UltraSPARC T2 Plus processors is that they appear as a familiar SMP system to the Solaris OS and the applications it supports. In addition, Oracle Solaris 10 has incorporated many features to improve application performance on CMT architectures:

- **CMT awareness.** Oracle Solaris 10 is aware of the UltraSPARC T2 and UltraSPARC T2 Plus processor hierarchy so that the scheduler can effectively balance the load across all the available pipelines. Even though it exposes each of these processors as 64 logical processors, Oracle Solaris understands the correlation between cores and the threads they support, and provides a fast and efficient thread implementation.
- **Fine-granularity manageability.** For the UltraSPARC T2 and UltraSPARC T2 Plus processors, Oracle Solaris 10 has the ability to enable or disable individual cores and threads (logical processors). In addition, standard Oracle Solaris features such as processor sets provide the ability to define a group of logical processors and schedule processes or threads on them.
- **Binding interfaces.** Oracle Solaris allows considerable flexibility in that processes and individual threads can be bound to either a processor or a processor set, if required or desired.

- **Support for virtualized networking and I/O, and accelerated cryptography.** Oracle Solaris contains technology to support and virtualize components and subsystems on the UltraSPARC T2 processor, including support for the on-chip 10 GbE ports and PCIe interface. As a part of a high-performance network architecture, CMT-aware device drivers are provided so that applications running within virtualization frameworks can effectively share

  I/O and network devices. Accelerated cryptography is supported through the cryptographic framework in Oracle Solaris.

- **Nonuniform memory access optimization in Oracle Solaris.** With memory managed by each UltraSPARC T2 Plus processor on Oracle's Sun SPARC Enterprise T5140/T5240 servers, the implementation represents a nonuniform memory access (NUMA) architecture. In NUMA architectures, the speed needed for a processor to access its own memory is slightly different than that required to access memory managed by another processor. Oracle Solaris provides technology that can specifically help applications improve performance on NUMA architectures.
  - Memory Placement Optimization—Oracle Solaris 10 uses Memory Placement Optimization (MPO) to improve the placement of memory across the physical memory of a server, resulting in increased performance. Through MPO, Oracle Solaris 10 works to help ensure that memory is as close as possible to the processors that access it, while still maintaining enough balance within the system. As a result, many database and HPC applications are able to run considerably faster with MPO.
  - Hierarchical Lgroup Support—Hierarchical Lgroup Support (HLS) improves the MPO feature in Oracle Solaris. HLS helps the Solaris OS optimize performance for systems with more-complex memory latency hierarchies. HLS lets the Solaris OS distinguish between the degrees of memory remoteness, allocating resources with the lowest-possible latency for applications. If local resources are not available by default for a given application, HLS helps the Solaris OS allocate the nearest remote resources.
- **Oracle Solaris ZFS.** Oracle Solaris ZFS offers a dramatic advance in data management, automating and consolidating complicated storage administration concepts and providing unlimited scalability with the world's first 128-bit file system. Oracle Solaris ZFS is based on a transactional object model that removes most of the traditional constraints on I/O issue order, resulting in dramatic performance gains. Oracle Solaris ZFS also provides data integrity, protecting all data with 64-bit checksums that detect and correct silent data corruption.
- **A secure and robust enterprise-class environment.** Best of all, Oracle Solaris doesn't require arbitrary sacrifices. Existing SPARC applications continue to run unchanged on UltraSPARC T2 and UltraSPARC T2 Plus platforms, protecting investments. Certified multilevel security protects Oracle Solaris environments from intrusion. The fault management architecture in Oracle Solaris means that elements such as Oracle Solaris predictive self-healing can communicate directly with the hardware to help reduce both planned and unplanned

downtime. Effective tools such as Oracle Solaris DTrace help organizations tune their applications to get the most of the system's resources.

End-to-End Virtualization Technology

Virtualization technology is increasingly popular as organizations strive to consolidate disparate workloads onto fewer, more-powerful systems, while increasing use. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers are specifically designed for virtualization, providing very fine-grained division of multiple resources —from processing to virtualized networking and I/O. Most important, Oracle's virtualization technology is provided as a part of the system, not an expensive add-on.

A Multithreaded Hypervisor

Like the UltraSPARC T1 processor, the UltraSPARC T2 and UltraSPARC T2 Plus processors offer a multithreaded hypervisor—a small firmware layer that provides a stable virtual machine architecture that is tightly integrated with the processor. Multithreading is crucial, because the hypervisor interacts directly with the underlying chip-multithreaded processor. This architecture is able to context switch between multiple threads in a single core, a task that would require additional software and considerable overhead in competing architecture.

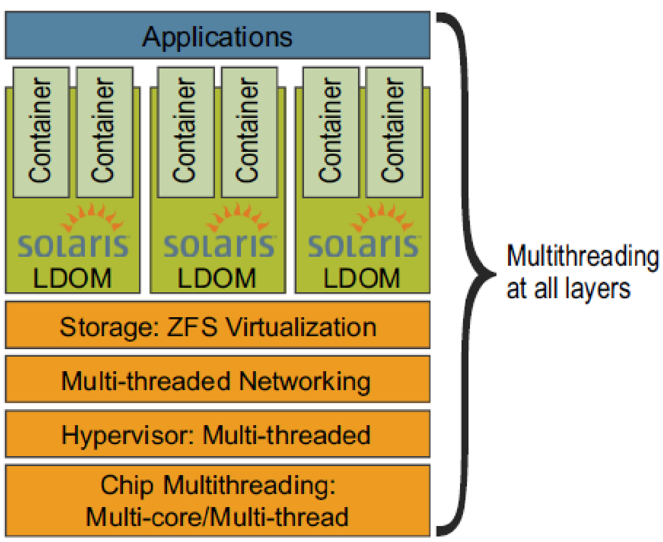

Figure 21. Oracle provides parallelization and virtualization at every level of the technology stack.

Corresponding layers of virtualization technology are built on top of the hypervisor, as shown in Figure 21. The strength of Oracle's approach is that all the layers of the architecture are fully multithreaded, from the processor up through applications that use the fully threaded Java application model. Far from new technology, Oracle Solaris has provided multithreading support since 1992. This experience has helped to inform technology decisions at other levels, ultimately resulting in a system that parallelizes and virtualizes at every level. In addition to the processor and hypervisor, Oracle provides fully multithreaded networking and the fully multithreaded Oracle Solaris ZFS file system. Oracle VM Server for SPARC (previously called Sun Logical Domains), Oracle Solaris Containers, and multithreaded applications are able to receive exactly the resources they need.

Oracle VM Server for SPARC

Supported in all Sun servers from Oracle using CMT technology, Oracle VM Server for SPARC provides full virtual machines that run an independent operating system instance, and contain virtualized CPU, memory, storage, console, and cryptographic devices. Within the Oracle VM Server for SPARC architecture, operating systems such as Oracle Solaris 10 are written to the hypervisor, which provides a stable, idealized, and virtualizable representation of the underlying server hardware to the operating system in each domain. Each domain is completely isolated, and the maximum number of virtual machines created on a single platform relies upon the capabilities of the hypervisor, rather than the number of physical hardware devices installed in the system. For example, Oracle's Sun SPARC Enterprise T5220 server with a single UltraSPARC T2 processor supports up to 64 domains,[12] and each individual domain can run a unique OS instance.

By taking advantage of domains, organizations gain the flexibility to deploy multiple operating systems simultaneously on a single platform. In addition, administrators can leverage virtual device capabilities to transport an entire software stack hosted on a domain from one physical machine to another. Domains can also host Oracle Solaris Containers to capture the isolation, flexibility, and manageability features of both technologies. Deeply integrating Oracle VM Server for SPARC with both the UltraSPARC T2 and UltraSPARC T2 Plus processors and Oracle Solaris 10 increases flexibility, isolates workload processing, and improves the potential for maximum server utilization.

The Oracle VM Server for SPARC architecture includes underlying server hardware; hypervisor firmware; virtualized devices; and guest, control, and service domains. The hypervisor firmware provides an interface between each hosted operating system and the server hardware. An operating system instance controlled and supported by the hypervisor is called a guest domain. Communication to the hypervisor, hardware platform, and other domains for creation and control of guest domains is handled by the control domain. Guest domains are granted virtual device access via a service domain, which controls both the system and hypervisor, and also assigns I/O.

To support virtualized networking, Oracle VM Server for SPARC implements a virtual Layer 2 switch, to which guest domains can be connected. East guest domain can be connected to multiple vswitches and multiple guest domains can also be connected to the same vswitch. Vswitches can either be associated with a real physical network port, or they may exist without an

[12] Though possible, this practice is not a generally recommended.

associated port, in which case the vswitch provides only communications between domains within the same server. This approach also gives guest domains a direct communication channel to the network (Figure 22). Each guest domain believes it owns the entire NIC and the bandwidth it provides, yet in practice only a portion of the total bandwidth is allotted to the domain. As a result, every NIC can be configured as demand dictates, with each domain receiving bandwidth on an as-needed basis. Dedicated bandwidth can be made available by tying a vswitch device to a dedicated physical Ethernet port.

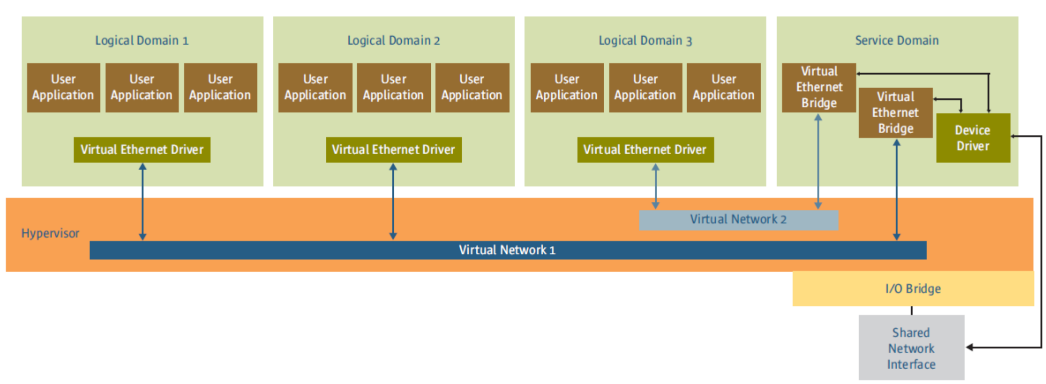

Figure 22. Data moves directly between an LDOM and a virtualized device.

Oracle Solaris Containers

Oracle Solaris 10 provides a unique partitioning technology called Oracle Solaris Containers that can be used to create an isolated and secure environment for running applications. A Container is a virtualized operating system environment created within a single instance of Oracle Solaris. Containers can be used to isolate applications and processes from the rest of the system. This isolation helps enhance security and reliability since processes in one zone are prevented from interfering with processes running in another zone.

Resource management tools provided with the Oracle Solaris help allocate resources such as CPUs to specific applications. CPUs in a multiprocessor system (or threads in the UltraSPARC T2 and UltraSPARC T2 Plus processors) can be logically partitioned into processor sets and bound to a resource pool, which in turn can be assigned to a Container. Resource pools provide the capability to separate workloads so that consumption of CPU resources do not overlap, and also provide a persistent configuration mechanism for processor sets and scheduling class assignment. In addition, the dynamic features of resource pools enable administrators to adjust system resources in response to changing workload demands.

Fault Management and Predictive Self-Healing

Oracle Solaris 10 introduced a new architecture for building and deploying systems and services capable of fault management and predictive self-healing. The predictive self-healing feature in oracle Solaris 10 is an innovative capability that automatically diagnoses, isolates, and recovers from many hardware and application faults. As a result, business-critical applications and essential system services can continue uninterrupted in the event of software failures, major hardware component failures, and even software misconfiguration problems.

- **Oracle Solaris fault manager.** The fault manager feature in Oracle Solaris collects data relating to hardware and software errors. This facility automatically and silently detects and diagnoses the underlying problem, with an extensible set of agents that automatically respond by taking the faulty component offline. Easy-to-understand diagnostic messages link to articles in Oracle's knowledge base to clearly guide administrators through corrective tasks that require human intervention. The open design of the fault manager feature also permits administrators and field personnel to observe the activities of the diagnostic system. With fault manager, the overall time from a fault condition to automated diagnosis to any necessary human intervention is greatly reduced, increasing application uptime.
- **Oracle Solaris service manager.** The service manager feature in Oracle Solaris creates a standardized control mechanism for application services by turning them into first-class objects that administrators can observe and manage in a uniform way. These services can then be automatically restarted if they are accidentally terminated by an administrator, if they are aborted as the result of a software programming error, or if they are interrupted by an underlying hardware problem. In addition, service manager reduces system boot time by as much as 75 percent by starting services in parallel according to their dependencies. An "undo" feature helps safeguard against human errors by permitting easy change rollback. The service manager feature is also simple to deploy; developers can convert most existing applications to take full advantage of service manager capabilities by simply adding a simple XML file to each application.

Predictive self-healing and fault management provide the following specific capabilities on Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers:

- CPU offlining takes a core or threads offline that has been deemed faulty. Offlined CPUs are stored in the resource cache and stay offline on reboot unless the processor has been replaced, in which case the CPU is cleared from the resource cache.
- Memory page retirement retires pages of memory that have been marked as faulty. Pages are stored in the resource cache and stay retired on reboot unless the offending DIMM has been replaced, in which case affected pages are cleared from the resource cache.
- I/O retirement logs errors and faults.
- fmlog logs faults detected by the system.

Cool Tools: Performance and Rapid Time to Market

No matter how compelling new hardware or OS platforms may be, organizations must be ensured that the costs and risks of adoption are in line with the rewards. In particular, organizations want to be able to continue to leverage the considerable advantages of popular commercial and open source software. Developers don't want to have to switch compilers and basic development tools. Administrators can scarcely afford a more-complex support matrix or more time spent getting applications to run effectively in a new environment. Oracle's Cool Tools Program is designed specifically to take the cost and risk out of moving Web tier environments.

Application Selection

Application selection helps identify those applications that stand to benefit from CoolThreads technology. The CoolThreads Selection Tool (coolst) helps determine application suitability for both the UltraSPARC T1 and UltraSPARC T2 architectures, accelerating the understanding of application execution and helping to take the risk out of investment decisions. The tool measures the number of lightweight processes (threads) to determine potential parallelism. Oracle also provides a growing range of precompiled and optimized common open source applications such as Apache, MySQL, and Perl in a Cool Stack collection.

Development

Developers need to be able to build, test, and evaluate applications, producing the most effective code while advancing their productivity with their chosen tools.

- **GCC for SPARC systems (GCC4SS).** Specifically tuned and optimized for SPARC systems, GCC4SS complements the popular GCC compiler suite, delivering up to three times the performance of compiled applications with even greater levels of reliability. At the same time, GCC4SS is 100 percent compatible with GCC, supporting all ABIs, language extensions, and flags.
- **Oracle Solaris Studio 12.** Oracle Solaris Studio 12 provides developers with the latest record-setting, high-performance, optimizing C, C++, and FORTRAN compiler compilers for Oracle Solaris on SPARC and x86/x64 platforms. Command-line tools and a NetBeans-based integrated development environment (IDE) are provided for application performance analysis and debugging of mixed source language applications. In addition to providing multiplatform support, Oracle Solaris Studio 12 compilers are compatible with GCC, Visual C++, C99, OpenMP, and FORTRAN 2003.
- **Binary Improvement Tool and Simple Performance Optimization Tool.** Used for code coverage analysis, the Binary Improvement Tool (BIT) provides instruction and call count data at runtime, helping to significantly improve developer productivity and application performance. The BIT does not require source code, and works with both executables and

libraries. The Simple Performance Optimization Tool (SPOT) also helps deliver improved developer productivity by automating the gathering and reporting of code data.

- **Sun Memory Error Discovery Tool (Discover).** Memory access errors can be one of the hardest types of errors to detect, because symptoms of the error typically appear arbitrarily far from the point where the error occurred. The Sun Memory Error Discovery Tool (Discover) is designed to detect and report common memory access errors. Reported errors include accessing uninitialized memory, writing past the end of an array, or accessing memory after it has been freed.

Tuning and Debugging

Administrators and developers alike need to monitor, analyze, and tune applications under real-world conditions. The following tools aid with tuning and debugging:

- **Corestat.** Corestat provides an online monitoring tool for core use of the UltraSPARC T2 processor, providing a more-accurate measure of processor and system use than tools that only measure the use of individual threads. Implemented as a Perl script and updated for UltraSPARC T2 processor awareness, Corestat aggregates instructions executed by all the threads on a single core, revealing the cycles per instruction of key workloads and indicating where more tuning is needed.
- **Automatic Tuning and Trouble-Shooting System (ATS).** In the interest of automating application tuning, ATS automatically reoptimizes and recompiles binaries with no need for source code. ATS identifies the inadequate optimization and then automatically rebuilds the application with the correct options for optimization. ATS is a plug-in for GCC4SS and Oracle Solaris Studio 12.

Deployment

Cool Tools deployment elements provide applications that are already optimized for CoolThreads technology, and save critical time in configuring systems for performance and consolidation. Deployment elements include

- **Cool Tuner.** Cool Tuner provides an onsite "virtual" tuning expert, delivering system performance improvements by automatically applying current best practices including both patching and tuning. Depending on administrator experience, Cool Tuner can save hours to weeks of effort tuning servers based on CoolThreads technology.
- **Cool Stack.** Cool Stack represents a collection of the most commonly used free and open source applications, preoptimized for servers based on CoolThreads technology running Oracle Solaris. Including such popular applications as Apache, Perl, PHP, Squid, Tomcat, and MySQL database software, these applications have been recompiled with Oracle Solaris Studio 12 compilers to deliver a 30 to 200 percent performance improvement over standard binaries

compiled with GCC. Cool Stack applications also bring performance benefits to any SPARC system.

- **Consolidation Tool for Oracle's Sun Fire Servers.** Powerful Oracle Solaris Containers offer myriad consolidation possibilities and the Consolidation Tool for Sun Fire Servers speeds their deployment. With a wizard-based GUI, this tool simplifies and automates the installation of consolidated applications, enabling even novice administrators to create a fully virtualized and consolidated environment using Containers. The result is fast and high-quality consolidated deployments.

Conclusion

Delivering on the demands of IT services applications and virtualized, ecoefficient data centers requires a comprehensive approach that includes innovative processors, system platforms, and operating systems, along with leading application, middleware, and management technology. With its strong technology positions and R&D investments in all of these areas, Oracle is in a unique position to deliver on this vision. Far from futuristic, Oracle has effective solutions today that can help organizations cope with the need for performance and capacity while effectively managing space, power and heat. Building on the successful UltraSPARC T1 processor, the UltraSPARC T2 and UltraSPARC T2 Plus processors deliver approximately twice the throughput and efficiency, and serves as the industry's first massively threaded system-on-a-chip. With 64 threads per processor, on-chip memory management, two 10 GbE interfaces, PCIe, and on-chip cryptographic acceleration, the UltraSPARC T2 processor fundamentally redefines the capabilities of a modern processor. By incorporating cache coherency for multiprocessor support, UltraSPARC T2 Plus processors allow these capabilities to be multiplied incrementally. Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers leverage these strengths to provide powerful and highly scalable server platforms while delivering new levels of performance and performance per watt in a compact rack mount chassis. The result is data center infrastructure that can truly scale to meet new challenges with a very small footprint.

Oracle's Oracle's Sun SPARC Enterprise T5120/T5220 and Oracle's Sun SPARC Enterprise T5140/T5240 servers provide the computational, networking, and I/O resources needed by the most demanding databases, IT services, enterprise applications and Web services while facilitating highly effective consolidation efforts. With end-to-end support for multithreading and virtualization, these systems can consolidate workloads and effectively use system resources even as they preserve investments in SPARC and Oracle Solaris technology and provide tools for open source software environments. With innovations such as Oracle VM Server for SPARC, Oracle Solaris Containers, and Java technology, organizations can adopt these radical new systems for their most important projects—acting responsibly toward the environment and the bottom line.

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

Oracle's Sun SPARC Enterprise T5120/T5220
and
Oracle's Sun SPARC Enterprise T5140/T5240
Server Architecture
April 2010

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