The Sun Ultra™ 5 and Ultra 10 Workstation Architecture

Technical White Paper

Printed in the United States of America.
901 San Antonio Road, Palo Alto, California 94303 U.S.A

Please
Recycle

Contents

Low-Cost Computing from Sun 1

With escalating processor clock rates, high-performance networking technologies, and accelerated graphics cards, computing performance is increasing at a phenomenal rate. While such advances allow access to the powerful applications that users demand, organizations remain concerned about the costs associated with these performance gains. Indeed, businesses are increasingly cost-conscious, and managers are constantly looking for technology to give them high performance solutions at significantly lower cost.

The personal computing (PC) industry has tempered these fears by moderating skyrocketing computing costs through advanced volume manufacturing techniques. Nevertheless, while the lower costs of PCs have satisfied shrinking hardware budgets, they have left users wanting in functionality. These trends indicate a conflict in expectations — users want lower cost systems, but are unwilling to accept the lower functionality that typically accompanies them.

With this in mind, in 1998 Sun set a new standard for low cost system, technology, and the performance that users require with the introduction of the Sun Ultra™5 and Ultra 10 workstations. By capturing the manufacturing techniques and capitalizing on the economies of scale that have propelled the PC industry, Sun gives its customers the cost benefits without sacrificing the quality, reliability, functionality, and performance that users have come to expect.

This white paper describes the Ultra 5 and Ultra 10 workstations, employing the high-performance UltraSPARC™-IIi processors coupled with Sun's flexible, low-cost, and high-performance graphics options.

Introducing the Ultra 5 and Ultra 10 Workstations

The most significant feature of Sun's Ultra 5 and Ultra 10 workstations is that they offer the high performance users demand, at relatively low cost. Utilizing PC manufacturing techniques and leveraging the economies of scale of volume system components, the Ultra 5 and Ultra 10 platforms provide outstanding functionality and price/performance ratios in both desktop and tower configurations. With several configuration options, users can choose the system that best matches their price/performance requirements (Table 1-1).

	Ultra 5 Workstation	Ultra 10 Workstation
Enclosure	• Desktop system • "Pizza box" enclosure • 43.6 x 11.2 x 43.0 (cm) 17.1 x 4.4 x 16.9 (in.)	• Mini-tower • Fits in open office or standard 19-inch rack • 17.6 x 40.2 x 43.5 (cm) 6.9 x 15.8 x 17.1 (in.)
Processors	• 400-MHz UltraSPARC-IIi • 2-MB ECache	• 440-MHz UltraSPARC-IIi • 2-MB ECache
Memory	• 4 DIMM slots • Up to 512-MB memory • ECC error correction	• 4 DIMM slots • Up to 1-GB memory • ECC error correction
Internal Storage	• 20-GB, 7200-rpm EIDE disk drive • 16.7 MB/second internal disk I/O • 1.44-MB floppy • 48x CD-ROM drive	• Up to two 20-GB, 7200-rpm EIDE disk drives • 16.7 MB/second internal disk I/O • 1.44-MB floppy • 48x CD-ROM drive
System I/O	• Three 33-MHz 32-bit PCI slots • Two independent PCI I/O buses	• Four 33-MHz 32-bit PCI slots • Two independent PCI I/O buses
Graphics	• Built-in PGX24™ 24-bit graphics • Optional PGX32™ graphics	• Built-in PGX24 24-bit graphics • Optional PGX32 (PCI) • Sun Creator3D, Sun Elite3D m3, or Sun Elite3D m6 graphics available (UPA)
Performance	• 16.5 SPECint95 • 21.3 SPECfp95	• 17.9 SPECint95 • 22.7 SPECfp95
Operating Environment	• Solaris™ 8 (pre-installed) • Solaris 7 (11/99) (pre-installed) • Solaris 2.6 (5/98) • Solaris 2.5.1 (11/97)	• Solaris 8 (pre-installed) • Solaris 7 (11/99) (pre-installed) • Solaris 2.6 (5/98) • Solaris 2.5.1 (11/97)

Table 1-1 The Ultra 5 and Ultra 10 systems provide a broad variety of features. Note that performance numbers are subject to change.

All Ultra 5 and Ultra 10 workstation systems are configured with high performance, 64-bit SPARC™Version 9 compliant UltraSPARC-IIi processors. Fully binary compatible with existing software, the UltraSPARC-IIi processor accelerates SPARC processor-based applications to very high levels of performance.

In addition to UltraSPARC-IIi processor, Ultra workstation systems employ the Ultra port architecture (UPA), a low-latency system interconnect pioneered in the Ultra 1 and 2 systems, and capable of very high levels of performance and scalability. Consistent with other aspects of the Ultra 5 and Ultra 10 workstation design, UPA clock rates have been boosted to 100 MHz, yielding 1.6 GB/second throughput. Combined with high-performance PCI technology, these systems provide increased bandwidth and access to a multitude of third-party products that today's users demand.

Meeting the Needs of Today's Businesses

Designed for cost-conscious workstation users who require high performance and expansion capacity, the Ultra 5 and Ultra 10 workstations meet the needs of users in a number of disciplines:

- Software development (CASE)
- Telecommunications
- Mechanical CAD (MCAD)
- Electronic design automation (EDA)
- GIS/mapping
- Digital content creation (DCC)

Able to deliver high performance at low cost, the Ultra 5 and Ultra 10 systems are ideal for cost-sensitive or volume applications where high processor and graphics performance is required, or the ability to easily increase memory and disk capacity is important. Their modular design allows incremental additions of both system performance and I/O options (Figure 1-1).

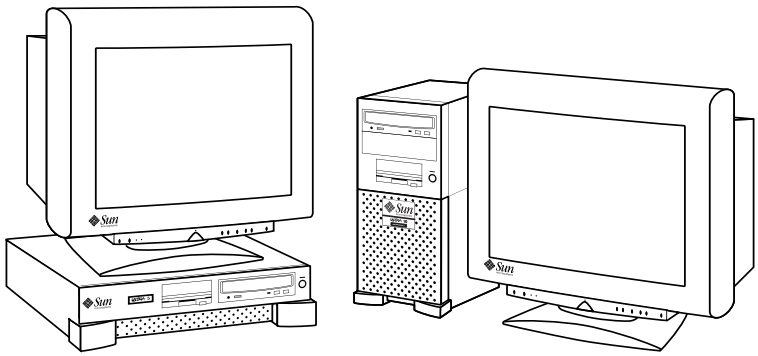

Figure 1-1 The Sun Ultra 5 and Ultra 10 workstation platforms

Scalable Workstations from Sun

Sun's Ultra 5 and Ultra 10 workstations run the Solaris™ Operating Environment, and enjoy full binary compatibility with other SPARC processor-based Sun systems. With carefully balanced performance, a full complement of advanced features, maximum upgradability, excellent expandability, and outstanding performance, the Ultra 5 and Ultra 10 platforms are a powerful combination of reliable Sun technology and low-cost manufacturing techniques that offer an exceptional desktop computing option.

Ultra 5 and Ultra 10 Workstation Architecture

2

The Ultra 5 and Ultra 10 systems were designed to provide good performance, scalability, and flexibility at very a low cost. The use of high-volume components and application-specific integrated circuits (ASICs) have resulted in a greatly reduced part count, high reliability, and low cost without compromising access to a full complement of expansion options through high performance, standardized interfaces.

The following pages describe the Ultra 5 and Ultra 10 workstation architectures in detail, including a discussion of the UltraSPARC-IIi processor, memory subsystem, UPA interconnect architecture, PCI bus, significant ASICs, and standard peripherals. Because the Ultra 10 workstation supports some very powerful graphics capabilities, a separate chapter describing the Sun™Elite3D m3, Sun Elite3D m6, and Sun Creator3D graphics immediately follows this one.

Motherboard

In the Ultra 5 and Ultra 10 workstations, a single LPX-sized motherboard is used in both the desktop and mini-tower systems. Features integrated into, or supported by the motherboard include:

- Modular processor card with 2-MB external cache
- Four 50-ns (60-ns compatible), 168-pin EDO JEDEC DRAM DIMM sockets with ECC error correction
- 10BASE-T/100BASE-T Fast Ethernet, self-sensing

- Two 16.7 MB/second DMA EIDE connectors for internal hard disks and CD-ROM
- Riser card connector to support three (two long, one short), 32-bit, 33-MHz, 5-volt PCI slots on the Ultra 5 workstation, and four full-size 32-bit, 33 MHz, 5-volt PCI slots on the Ultra 10 workstation. Optional PGX32 graphics boards use one of these slots.
- Two serial ports
  - Asynchronous/synchronous RS423A / RS232A, DB25 connector
  - Asynchronous RS423A, DB9 connector
- Centronics-compatible parallel-port interface, IEEE 1284 Bidirectional, DB25 connector
- Sun Type-6 keyboard and mouse support (compatible with Type-5 keyboard)
- CD quality, EBus-based audio
- PGX24 on-board graphics with 24-bit support up to 1152 x 900 resolution, 8-bit support up to 1280 x 1024 resolution, and DB15 connector
- Time-of-day NVRAM for clock and ID functions
- UPA64s connector for Sun Creator3D, Sun Elite3D m3, and Sun Elite3D m6 graphics boards

Figure 2-1 depicts the common systems design employed in Ultra 5 and Ultra 10 systems.

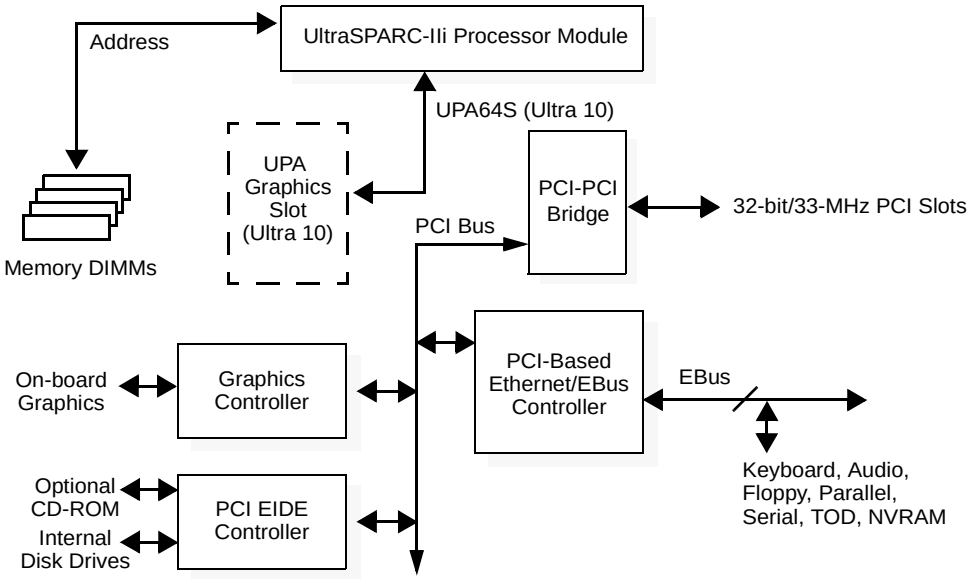

Figure 2-1 Ultra 5 and Ultra 10 platforms utilize a common system design

The UltraSPARC-IIi Microprocessor

The heart of the Ultra 5 and Ultra 10 platforms is the UltraSPARC-IIi microprocessor. The processor incorporates on-chip memory and I/O control to facilitate its easy and economical integration into a system:

- *UltraSPARC-IIi microprocessor*, a high-performance, highly-integrated superscalar processor implementing the SPARC-V9 64-bit RISC architecture and visual instruction set (VIS™ software)
- *PCI bus module (PBM)*, provides a direct interface with a 32-bit PCI version 2.1 compliant bus
- *I/O memory management unit (IOM)*, manages virtual to physical memory address mapping using translation lookaside buffers for improved performance
- *External cache unit (ECU)*, handles instruction and data cache misses efficiently and provides high transfer bandwidth

- *Memory and UPA64S control unit (MCU),* manages all transactions to DRAM and the UPA64S subsystem for high performance graphics

Key Features of the UltraSPARC-IIi Processor

The UltraSPARC-IIi processor is part of a second generation of UltraSPARC pipeline-based products. In addition to using a new process technology, the UltraSPARC-IIi CPU provides a higher clock frequency, multiple SRAM modes and system-to-processor clock ratios to accommodate varying economics for a range of products. At the same time, it provides software compatibility with all other UltraSPARC processor-based systems. UltraSPARC-IIi CPU offers the following key features:

- SPARC Version 9 architecture compliant
- Binary compatible with existing SPARC applications
- VIS software to support advanced multimedia capabilities
- Four-way superscalar design incorporating nine execution units — four integer execution units (IEUs), three floating-point execution units (FPUs), and two graphics execution units (GRUs)
- Software prefetch instruction and multiple outstanding requests support
- Selectable little- or big-endian byte ordering
- 64-bit address pointers with transparent 32-bit addressing compatibility
- 16-KB write-through, nonallocating-on-write-miss, direct mapped data cache
- 16-KB instruction cache featuring in-cache 2-bit branch prediction and single cycle branch following
- Integrated second-level cache controller supports a 2-MB cache. Sustained throughput of 1 load per cycle
- Block load / store instructions for increased bandwidth
- Includes JTAG boundary scan and special performance instrumentation to support product development and testing
- Employs 0.35 micron five-layer metal CMOS process
- On-chip power management

The UltraSPARC-IIi processor supports both 2D and 3D graphics as well as image processing, video compression and decompression, and video effects through the sophisticated VIS instruction set. VIS provides high levels of

multimedia performance, including real-time H.261 video compression/decompression and two streams of MPEG2 decompression at full broadcast quality with no additional hardware support.

UltraSPARC-IIi Processor Functional Units

In a single chip implementation, the UltraSPARC-IIi processor features a very high level of integration (Figure 2-2). Its highly integrated, SPARC-V9 compliant implementation consists of a prefetch and dispatch unit, an integer execution unit with two ALUs, a floating-point unit, an I/O memory management unit, a memory controller unit, a load and store unit with a separate address generation adder, an external cache unit, a graphics unit, a PCI bus module, and instruction and data caches.

Prefetch and Dispatch Unit

The UltraSPARC-IIi processor's prefetch and dispatch unit (PDU) helps ensure that all execution units remain busy by fetching instructions before they are needed in the pipeline. Instructions can be prefetched from all levels of the memory hierarchy, including the instruction cache, external cache, and main memory. The PDU was designed with several features to support the high performance requirements of UltraSPARC-IIi processor:

- A 12-entry prefetch buffer decouples instruction prefetching from instruction dispatch and prevents pipeline stalls
- A 16 KB two-way associative I-cache that is physically indexed and tagged
- Pre-decoded instructions in the I-cache
- A 9-stage instruction pipeline to help minimize latency
- Dynamic branch prediction to allow for greater prediction accuracy

I/O Memory Management Unit (IOM)

Superscalar performance can only be maintained if the integer execution unit (IEU) can be supplied with the appropriate instructions and data — a job performed by the memory hierarchy. The UltraSPARC-IIi I/O memory management unit (IOM) provides the functionality of a reference MMU and an IOMMU, handling all memory operations as well as arbitration between data stores and memory:

- The IOM implements virtual memory and translates virtual addresses of each running process to physical addresses in memory. It provides the translation of a 44-bit virtual address to a 41-bit physical address through the use of a translation lookaside buffer (TLB).
- The IOM also provides memory protection so that a process can be prohibited from reading or writing the address space of another, guaranteeing memory integrity between processes. Access protection is also supported to ensure that any given process does not gain unauthorized access to memory.
- The IOM performs the arbitration function between I/O, D-cache, I-cache, and TLB references to memory. In essence, the IOM implements the function of a “traffic cop,” controlling and prioritizing access to main memory, helping to minimize memory contention.

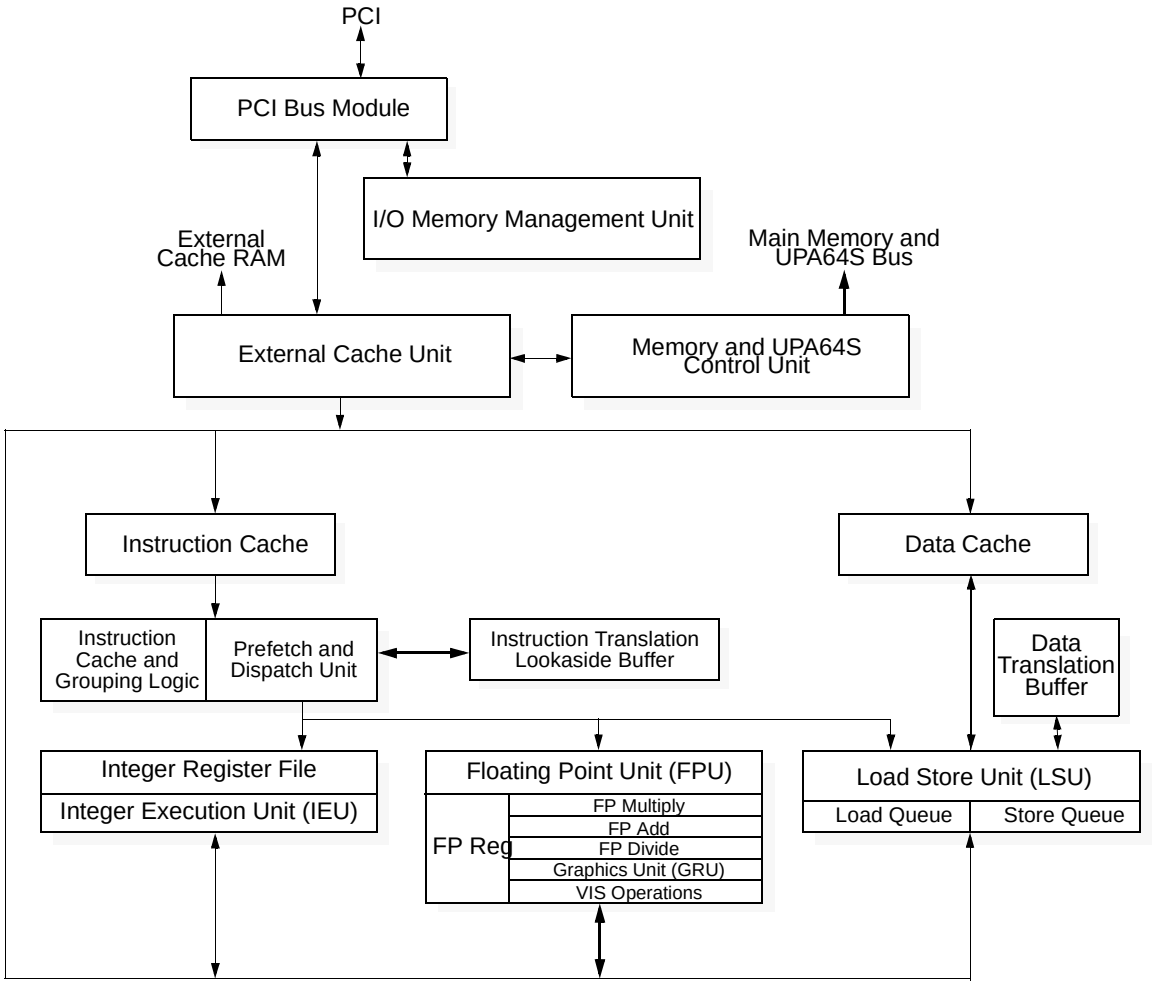

Figure 2-2 UltraSPARC-IIi functional block diagram

Integer Execution Unit (IEU)

The integer execution unit (IEU) is designed to maximize performance while maintaining full software compatibility, helping to minimize processor architectural changes to host software.

The UltraSPARC-IIi IEU incorporates several important features:

- Two ALUs for arithmetic, logical, and shift operations
- An early-finish-detect multicycle integer multiplier
- A multicycle integer divider
- Eight-window register file
- Result bypassing
- A completion unit which allows a nine-stage pipeline with minimal bypasses

Load/Store Unit (LSU)

The load / store unit (LSU) is responsible for generating the virtual address of all loads and stores, for accessing the data cache, for decoupling load misses from the pipeline through the load buffer, and for decoupling the stores through a store buffer. One load or one store can be issued per cycle. To further optimize data stores, a store compression capability allows two or more stores to be “compressed” together if they are in the same 8-byte block, so that a single data transfer occurs between the UltraSPARC processor and the second-level cache. This frees up the data bus allowing load misses and instruction misses to be processed more rapidly.

Floating-Point Unit (FPU)

The UltraSPARC-IIi processor floating-point unit (FPU) is a pipelined floating-point processor that conforms to SPARC-V9 architecture specifications. Its IEEE-compliant design consists of five separate functional units to support floating-point and multimedia operations. The separation of execution units enables UltraSPARC-IIi processor to issue and execute two floating-point instructions per cycle. Source and data results are stored in a 32-entry register file. Most floating-point instructions have a throughput of one cycle, a latency of three cycles, and are fully pipelined. The FPU is able to operate on both single-precision (32-bit), and double-precision (64-bit) numbers, normalized or denormalized, in hardware, and quad-precision (128-bit) operands in software.

Graphics Unit (GRU)

Sun's UltraSPARC processors are the industry's first general-purpose processors that deliver 64-bit compute power combined with the throughput needed for the advanced graphics and real-time video applications. Able to decompress and manipulate video information with broadcast video resolution in real time, UltraSPARC-IIi processor can eliminate the need for a dedicated video processor.

The UltraSPARC-IIi processor provides a comprehensive set of graphics instructions that provide fast hardware support for 2D and 3D graphics, image manipulation and compression, and video and audio processing. 16-bit and 32-bit partitioned add, boolean, and compare are provided as are 8-bit and 16-bit partitioned multiplies. Single-cycle pixel distance, data alignment, packing, and merge operations are all supported in the GRU.

External Cache Control Unit (ECU)

It is the responsibility of the ECU to efficiently handle I-cache and D-cache misses. The ECU can handle one access every other cycle to the external cache. However, the combination of the load buffer and the ECU is fully pipelined. This low latency can effectively make the external cache a part of the pipeline. For programs with large data sets, this means data can be maintained in the external cache and instructions scheduled with load latencies based on the E-Cache latency. Floating-point applications can use this feature to effectively "hide" D-Cache misses. The size of the external cache can be 256 KB, 512 KB, 1 MB, or 2 MB, where the line size is always 64 bytes. The actual amount of cache supported is system dependent.

Memory Controller Unit (MCU)

UltraSPARC-IIi processors employ a memory controller unit (MCU). This I/O subsystem handles input and output between local resources, including the processor, main memory, control space, and all external system resources, such as the UPA64S subsystem (used for high performance graphics). Specifically, all transactions to the system, such as E-cache misses, interrupts, snoops, and writebacks are handled by the MCU.

All transactions to the DRAM and UPA64S subsystem are also handled by the MCU. The MCU communicates with the system at a frequency lower than UltraSPARC-IIi processor frequency (the ratio is typically 1/4). The MCU provides support for multiple outstanding load and writeback requests to the Ultra Port Architecture (UPA) bus.

PCI Bus Module (PBM)

Unlike its predecessors, the UltraSPARC-IIi processor incorporates a PCI bus controller. Compliant with version 2.1 of the PCI specification, the PBM enables the UltraSPARC-IIi processor to interface directly with the PCI bus. The PBM is optimized for 16-, 32-, and 64-byte transfers, and can support up to four PCI bus masters. While the PCI address space is not cacheable for CPU references, coherent DMA is supported. All reads and writes to memory from PCI are cache coherent, and interrupt handling is synchronized to the completion of all prior DMA writes.

Key features of the PBM include support for PCI features:

- Single 64-byte DMA read/write buffer, single 64-byte PIO read/write buffer
- 64-bit addressing (dual address cycle) for DMA bypass
- Fast back-to-back cycles as a DMA target

Cache Architecture

Virtually all high-performance microprocessors use caches to reduce bus traffic and increase system throughput. Cache stores contain copies of part of a memory image. The choice of whether to update or invalidate copies of modified blocks is called the *cache consistency protocol*. These consistency protocols ensure that copies of data remain consistent with the copies in main memory. Consistency can be supported by write-invalidate, write-through, and competitive caching algorithms.

A complete UltraSPARC-IIi processor subsystem consists of the UltraSPARC-IIi processor, synchronous SRAM components for the external cache tags and data, and a series of transceivers. The main role of the transceivers is to move data bidirectionally between the UltraSPARC-IIi processor and memory DIMMs.

Instruction Cache

The instruction cache is a 16-KB two-way set associative cache with 32-byte blocks. The cache is physically indexed and contains physical tags. The set is predicted as part of the next field so that only the index bits of an address are necessary to address the cache (13 bits which matches the minimum page size). The instruction cache returns up to 4 instructions from an 8 instruction-wide line.

Data Cache

The UltraSPARC-IIi processor data cache (D-cache) is a 16-KB direct mapped, software selectable write-through nonallocating cache that is used on Load or Store accesses from the CPU to cacheable pages of main memory. It is a virtually-indexed and virtually-tagged cache. The D-cache is organized as 512 lines with two 16-byte sub-blocks of data per line. Each line has a cache tag associated with it. On a data cache miss to a cacheable location, 16 bytes of data are written into the cache from main memory.

Visual Instruction Set (VIS™ Software)

The UltraSPARC family of microprocessors were the first in the industry to fully support advanced multimedia and networking. By introducing a comprehensive set of multimedia instructions, known as the visual instruction set (VIS™ software), UltraSPARC provides enhanced hardware support for 2D and 3D graphics, video and audio processing, and image manipulation.

- Image data manipulation

  The graphics unit in UltraSPARC-IIi processor relies on the integer registers for addressing image data and the floating point registers for manipulating image data. This division of duty between the integer and floating point registers enables UltraSPARC-IIi processor to make use of all available internal registers, helping to maximize throughput.

  The UltraSPARC-IIi processor also includes a variety of instructions that are essential for advanced image manipulation. For example, UltraSPARC-IIi processor supports a filtering operation for scaling, rotating, and smoothing images. The filtering operation processes four pixels at a time, giving UltraSPARC-IIi processor an order of magnitude performance advantage over other processors.

- Motion estimation

  Able to perform motion estimation in support of motion compensation, a technique used to code real-time video for compression, the UltraSPARC-IIi processor can greatly accelerate multimedia applications. Motion estimation takes advantage of the minimal changes in the position of images from one frame to the next. The processor performs hundreds of comparisons for a region of the image, searching for a motion value that minimizes the estimation error. The error is calculated by summing the differences for each pixel in the region between a reference frame and a newer frame.

  The UltraSPARC-IIi processor helps minimize this compute-intensive operation by operating on eight pixels at a time. The motion compensation process for eight pixels requires eight subtractions, eight absolute values, eight additions, a load of eight pixels, an align of eight pixels, and one final addition. The UltraSPARC-IIi processor performs this complex set of operations for eight pixels in just one clock compared to the minimum of 48 instructions and numerous clocks typically required by other processors. Because motion estimation is the dominant operation for compression, the UltraSPARC-IIi processor's high throughput for this operation allows it to support compression for desktop video conferencing without the aid of external circuitry.

- High performance

  Unique block load/store commands in UltraSPARC-IIi processor allow the processor to execute 64-byte loads and stores directly into main memory. The block load/store commands avoid "cache pollution" by eliminating data allocation to external cache. With the resulting high copy bandwidth, UltraSPARC-IIi processor can move images directly from main memory to the screen fast enough to eliminate image flicker.

Although VIS was created to accelerate the manipulation of graphics data, it handles other types of partitioned data just as well. Other uses of VIS include the processing of audio data and in encryption/decryption applications.

Memory Subsystem

External Cache Memory

The Ultra 5 and Ultra 10 workstation systems feature a 2-MB external secondary cache (ECache) with 64-byte line size. The datapath to the Ecache is 64 bits wide and is parity protected.

Main Memory

The Ultra 5 and Ultra 10 systems have a memory system which uses four EDO 3.3V DIMMs with a 60 nanosecond or faster access time. The systems support 128-MB and 256-MB modules for increased memory capacity. Maximum memory capacity is 1-GB on all Ultra 5 and Ultra 10 systems.

To increase memory system performance without requiring expensive components, the Ultra 5 and Ultra 10 systems employ a high speed, two-way interleaved architecture. DIMMs must be added to the system in pairs. Each pair must use the same sized DIMMs. Because of the two-way interleave, adding DRAM in sets of four identical sized DIMMs results in the best memory system performance.

PCI Connectivity

In addition to its commitment to expand the capacity and performance of all of its systems, Sun is continually looking for ways to increase their openness and standards compliance. Sun has chosen to support PCI on the Ultra 5 and Ultra 10 systems for a variety of reasons:

- PCI is an open, architecture-independent bus

  Because PCI is open and shipping in volume, it has been quickly adopted by both consumers and producers of computer hardware.

- PCI is fast

  The PCI bus architecture is designed to provide high performance, with its I/O performance a key differentiator from other bus architectures. Running at 33 MHz on the Ultra 5 and Ultra 10, PCI offers configurations that meet a variety of developer and user needs.

- PCI is standardized

  PCI is a standard bus architecture that has been adopted by the volume personal computer industry. Because of its wide acceptance, PCI-compliant adapter cards are available from more sources than ever before.

PCI provides a high performance bus that is optimized for high speed data transfers. System-board resident, the PCI bus operates at high speeds and is used as an interconnect between highly integrated components and subsystems, such as peripherals and add-on boards. The processor and main memory are connected to the PCI bus through a PCI host bridge that communicates with the CPU at 66 MHz on Ultra 5 and Ultra 10 systems.

The PCI bus is based on the industry standard PCI specification version 2.1. Unlike most standards, the PCI specification is very broad. It covers everything from multiple form factors and voltages to connector types. Sun has chosen to implement the most common options available on the Ultra 5 and Ultra 10 workstations:

- 33-MHz bus
- 32-bit cards
- 5-volt cards
- 7-inch (short) cards
- 12-inch (long) cards
- PCI Specification 2.1 compliance

To help ensure sustained high performance, Ultra 5 workstation systems support three slots (four slots in Ultra 10 systems) that utilize a 32-bit PCI bus known as Bus “A”. Bus “A” is a 32-bit, 33-MHz, 5-volt bus. Bus “B” is a 32-bit, 33-MHz PCI bus that supports on-board devices, a special peripheral chip, the PCI-based graphics controller, and the EIDE controller chip.

Sun offers support for a variety of PCI-based adaptor cards, including graphics, networking, video, SCSI, and high speed serial and parallel interfaces. In addition, Sun is working with a host of third-party partners to develop PCI hardware and software that is certified for operation on Ultra 5 and Ultra 10 systems running the Solaris Operating Environment.

Built-in PGX24 Graphics

To provide standard high performance graphics and enable users to take advantage of commercially available, low cost components, the Ultra 5 and Ultra 10 systems utilize an on-board PGX24 graphics. A highly integrated graphics controller, PGX24 graphics utilizes an ATI chip includes 2D and video accelerators, palette DAC, and a dual-clock synthesizer to provide low-cost, 8-bit or 24-bit color graphics that is accessible via a standard VGA connector (DB15) from the back panel on both systems.

A low-cost, high-volume graphics controller, PGX24 graphics provides a host of standard features on the Ultra 5 and Ultra 10 systems:

- Low-cost, built-in (on-board) 8-bit or 24-bit color
- Wide range of resolutions, up to 1152 x 900 (24-bit) and 1280 x 1024 (8-bit)
- 2D and windowing acceleration
- OpenWindows™environment and CDE support
- OpenGL® and X Windows API support
- Hardware acceleration, including rectangle fill, line draw, polygon fill, planning/scrolling, bit masking, monochrome expansion, scissoring, and full ROP support
- Packed pixel support for true color
- Large command and display FIFOs (48 and 24 double-words respectively)
- High performance FIFO management to memory controller
- 8 x 8 x 8 SRC brush support
- Quick setup with alias registers

In addition to the built-in PGX24, Sun Ultra 5 and Ultra 10 workstations support a variety of other graphics options, including the PGX32, Sun Creator3D, Sun Elite3D m3, and Sun Elite3D m6 graphics processors. These products are described in more detail in *Chapter 3: High-Performance Graphics.*

Networking and I/O

All Ultra 5 and Ultra 10 systems provide standard 100-Mbps Fast Ethernet which can autosense and switch to 10-Mbps operation automatically, if needed. They also incorporate a 16.7 MB/second EIDE disk interface using a standard 40-pin connector. The Ultra 5 workstation can accommodate up to two internal IDE devices; the Ultra 10 workstation can accommodate three.

In addition, these systems support a standard complement of I/O devices through connectors on the back panel (Figure 2-3):

- Audio ports
- Serial-ports (DB9 and DB25)
- Centronics-compatible parallel port
- Keyboard/mouse

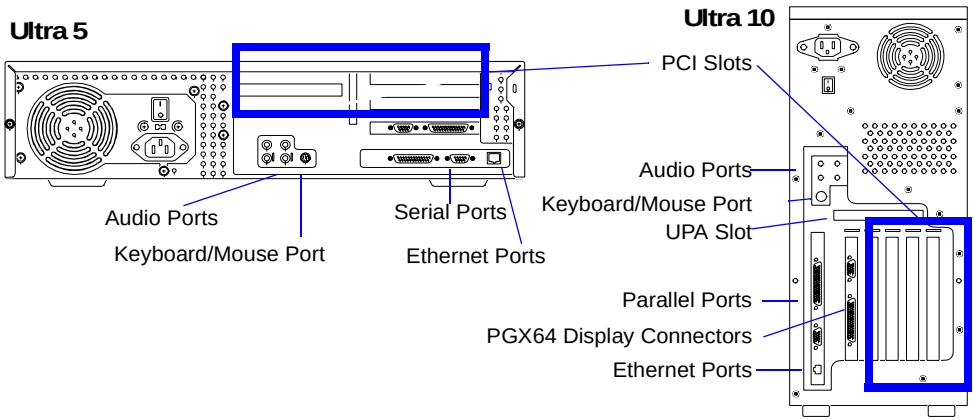

Figure 2-3 In the tradition of Sun workstations, the Ultra 5 and Ultra 10 systems feature broad connectivity options

Monitors

All Ultra 5 and Ultra 10 systems support the family of Sun monitors:

- 17-inch format
- 21-inch format
- 24-inch (HDTV) format
- 18-inch flat-panel display

In addition to its standard 21-inch color display, Sun is now supports a HDTV format, 24-inch monitor. This monitor support resolutions up to 1920 x 1200 with a 16:10 aspect ratio. This monitor is ideal for advanced multimedia and video service development. As Table 2-1 shows, Sun's 24-inch display can support a variety of dpi and resolution settings.

	Resolution			
	1280 x 800	**1440 x 900**	**1600 x 1000**	**1920 x 1200**
Refresh Rate	76 Hz	76 Hz	66/76 Hz	70 Hz
Double Buffered Operation	Yes	No	No	No
Dots Per Inch (dpi)	69	77	86	103

Table 2-1 Sun's 24-inch HDTV monitor supports a wide variety of DPI and resolution settings

It is important to note that not all graphics cards support the 1920 x 1200 resolution. For the Ultra 10 workstation, only the Sun Creator3D graphics board supports HDTV. The Sun Elite3D graphics boards do not support that resolution as discussed later in this document.

Ethernet/Fast Ethernet

To support higher performance network connectivity, all Ultra 5 and Ultra 10 systems support 10/100-Mbps Fast Ethernet. Fast Ethernet technology from Sun is backwards compatible with 10-Mbps Ethernet, with the speed being autosensed by the interface. The Ethernet interface on Ultra 5 and Ultra 10 systems supports access to Category 5 twisted pair through an RJ45 connector.

Fast Ethernet is a direct extension of the 10BASE-T Ethernet standard, but is capable of supporting a wider range of applications requirements with its greater throughput. Particularly compelling is its compatibility with the installed base of wiring currently employed for 10BASE-T, making it the most cost-effective migration path for most users. Like its predecessor, the standards for Fast Ethernet are well defined and accepted throughout the industry, and a large number of compatible products are available from a variety of vendors.

Audio

On-board audio capabilities enable Ultra 5 and Ultra 10 systems to provide high-quality audio utilizing an internally-mounted speaker as well as through external audio connectors.

The audio subsystem employed in Ultra 5 and Ultra 10 systems supports a variety of standard sampling rates, including:

- 16-bit, 48-KHz digital audio tape (DAT)
- 16-bit, 44.1-KHz CD
- 16-bit, 16-KHz medium-quality audio for applications like speech processing
- 8-bit, 8-KHz standard telephony

The backpanel provides a variety of audio connectors enabling Ultra 5 and Ultra 10 systems to be connected to standard audio equipment such as amplifiers and tape recorders. A small mono external microphone is provided, making audio input and output more convenient.

Parallel Port

The usefulness of parallel ports on desktop machines has grown due to the increased availability of peripherals that use them, especially low-cost, high-quality printers. And with data rates up to 2 MB/second, the bidirectional parallel port can be used for other applications such as data acquisition, scanning, and high speed communications.

The parallel port can operated using programmed I/O or DMA. Its interface direction, timing, and protocol is programmable to meet the wide variety of Centronics interfaces that exist on peripheral devices.

Access to the parallel port is through a DB25 connector located on the backpanel.

Serial Ports

RS-232C and RS-423 serial ports provide a convenient way to connect Ultra 5 and Ultra 10 systems to devices such as modems and terminals. All systems include two serial ports, one with a DB25 connector (synchronous and asynchronous), the other with a DB9 connector (asynchronous), with standard pinouts on each. Synchronous transfers can occur up to 960-Kbps, while asynchronous transfers can occur at up to 460 Kbps, significantly faster than earlier Sun workstation systems.

EIDE

The Ultra 5 and Ultra 10 systems support the enhanced integrated drive electronics (EIDE) peripheral interface via direct memory access (DMA). This enables the EIDE interface, running at 16.7 MB/second or faster. The Ultra 5 and the Ultra 10 can support up to three internal EIDE devices.

Keyboard and Mouse

Standard with each Ultra system is a Sun Type-6 keyboard, which has a layout compatible with the common IBM AT 101-key keyboard. For UNIX users, a keyboard with a UNIX layout is also available. This keyboard includes keys for controlling audio and for turning the system on and off.

The mouse connects to an 8-pin DIN connector located on the keyboard. The keyboard connects to the back panel of the Ultra 5 and Ultra 10 systems. All Ultra workstation systems are equipped with an opto-mechanical mouse.

I/O Subsystem Implementation

On-board PCI Device Control

The on-board PCI device control ASIC has two functions on Ultra 5 and Ultra 10 systems. It supplies 10/100 Mbit/second Ethernet media access control (MAC). It also implements the EBus2 interface, an asynchronous 8-bit bus that supports flash PROM/EPROM, NVRAM, serial ports, audio, floppy interface, parallel port with ECP/EPP support, and keyboard and mouse interfaces.

Enclosure and Power

The enclosure designs employed in Ultra 5 and Ultra 10 workstations are designed to accommodate uncompromised expansion (Figure 2-4). The Ultra 5 utilizes a “pizza-box” design, while the Ultra 10 employs a “mini-tower” enclosure that can be placed upright at the deskside or on the desktop next to the monitor, or on its side in a rackmount configuration.

In addition to affording room for PCI expansion cards and Sun Creator3D, Sun Elite3D m3, or Sun Elite3D m6 UPA graphics, both systems accommodate additional peripheral expansion options:

- Ultra 5 workstations

  Ultra 5 systems include one front access half-height 5.25-inch bay for the standard CD-ROM drive, and front access PCMCIA slots (2 Type II or 1 Type III) via an optional adapter. An additional 5.25-inch hard drive can be added with a special bracket kit.

- Ultra 10 workstations

  All Ultra 10 systems include one dedicated front access 5.25-inch bay for the standard CD-ROM drive, an additional 5.25-inch bay for a second internal hard disk drive, front access PCMCIA slots (2 Type II or 1 Type III) via an optional adapter.

All Ultra 5 and Ultra 10 systems support external disk options and tape library systems for high reliability storage and backup needs via PCI-based host bus SCSI adapters.

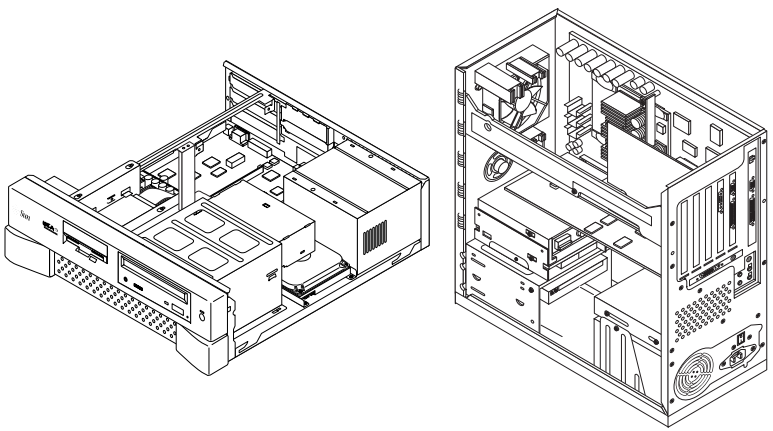

Figure 2-4 The Ultra 5 and Ultra 10 systems feature flexible expansion options

Power Management

Ultra 5 workstations come equipped with a 200W switched power supply, while Ultra 10 systems include a 250W switched power supply. The power supplies provide all the power needed for internal expansion options. Sun has also recognized the need for environmentally-sensitive construction and operation of its systems. The Ultra 5 and Ultra 10 platforms are Energy Star compliant, with the ability to automatically shut down after a predefined period of time. The checkpoint-and-resume capability of Solaris Operating Environment enables users to quickly resume work in progress after startup. Power management software also monitors the frequency of shutdown requests, and determines if the thermal shock of repeated power cycles would contribute to decreasing hardware reliability. If so, the shutdown request is deferred.

Specifications

All Ultra 5 and Ultra 10 workstations meet all relevant domestic and international agency safety, ergonomics, EMI, and environmental requirements.

High-Performance Graphics 3

Sun understands that graphics is rapidly shifting away from being a specialized requirement of technical users and is becoming an essential part of nearly every computing discipline. Sun believes that as this trend continues, the standards for graphics functionality and performance will continue to rise. The Ultra 10 workstation anticipates this trend by supporting high performance graphics options that rival the best products available on the market today.

The Ultra workstations support two kinds of graphics: PCI-based and UPA-based graphics. The Ultra 5 does not have a UPA slot; however, the Ultra 10 workstation does. The following graphics are supported in these systems.

	Type	# Supported on Ultra 5	# Supported on Ultra 10
PGX24	Built-in	1	1
PGX32	PCI	3	4
Sun Creator3D	UPA	—	1
Sun Elite3D m3	UPA	—	1
Sun Elite3D m6	UPA	—	1

Table 3-1 Graphics supported on the Ultra 5 and 10 workstations

Graphics Performance

The table below indicates the performance that customers can expect from each frame buffer that is supported by the Ultra 5 and 10 systems.

Benchmark	PGX24	PGX32	Sun Creator3D	Sun Elite3D m3	Sun Elite3D m6
Xmark93	11.5	12.1	29.6	30.8	30.8
2D vectors / sec.	897 K	897 K	5.0 M	5.0 M	5.0 M
3D vectors / sec.	521 K	521 K	3.7 M	4.9 M	8.8 M
3D triangles / sec.	—	—	1.5 M	3.0 M	5.9 M
3D quads / sec.	—	—	698 K	1.2 M	1.3 M
ProCDRS-02	—	—	8.6	13.7	19.0
DX-05	—	—	12.0	27.8	30.7
PLBwire93	18.3	—	250	303	435
PLBsurf93	—	—	403	519	673

Table 3-2 Graphics performance benchmarks on the Ultra 5 and 10 workstations *(Performance data as of December 2000. Configuration for timing includes Solaris 8 Operating Environment and Sun OpenGl for Solaris API version 1.2.1.)*

PCI-based Graphics

The PGX™series of graphics is Sun's standard, low-cost graphics family used for basic windowing operations.

PGX32 Graphics

Optionally available on all Sun Ultra workstations is the PGX32 graphics board, a PCI-based accelerator utilizing a 3Dlabs Permedia 2 graphics processor chip, and capable of simultaneous 8- and 24-bit rendering without contention for colormap entries (i.e., minimal colormap flashing). PGX32 graphics includes 2D and video acceleration, palette DAC, and a dual-clock synthesizer to provide low-cost, 8-bit or 24-bit color graphics that is accessible via a standard VGA connector (HD-15) or 13W3 video adaptor.

In addition to providing a flexible, low-cost 24-bit, accelerated 2D frame buffer, PGX32 graphics provides:

- 8-MB high-speed SGRAM supporting a wide range of resolutions, up to 1280 x 1024 true color (8+24-bit) and 1600 x 1280 in pseudo-color (8-bit)
- 8-bit only 1600 x 1000 resolution to support Sun's 24-inch wide-format display
- Full backward compatibility with PGX24 and PGX frame buffers
- 2D windowing acceleration
- OpenWindows and CDE support
- Accelerated OpenGL and X Windows support
- An 8-bit overlay plane allows 8-bit windows to be superimposed on 24-bit visuals without damaging underlying visual for seamless window integration and manipulation
- Hardware acceleration, including rectangle fill, line draw, polygon fill, planning/scrolling, bit masking, monochrome expansion, scissoring, and full ROP support
- Packed pixel support for true color

The PCI 33-MHz card format used on the PGX32 frame buffers provides excellent performance and also allows for multiple displays in a system. with up to four PGX32 frame buffers in one system, an important capability for users who need to monitor multiple tasks simultaneously. Up to three displays are supported on the Ultra 5 workstation and up to four displays are supported in the Ultra 10 workstation.

UPA-based Graphics

Imaging, multimedia, and video applications all place large demands on system architectures. Furthermore, the design goal to make 24-bit graphics a standard feature on high performance Ultra systems places additional stress on interconnect performance — three times the pixel data must travel through the system when dealing with 24-bit data rather than 8-bit data. To help ensure excellent performance, a high-performance path is needed for image data to move between the CPU, memory, and frame buffer.

3D graphics applications can also be slowed if the flow of graphics commands fails to keep the pipeline of the graphics device full. Because the first portion of the 3D graphics pipeline uses the UltraSPARC processor's floating point units,

the need for a high-bandwidth path between the CPU and the frame buffer was further underscored. The UPA interconnect, with its 64-bit data path to the graphics subsystem, can move data at the required high speeds between the CPU, memory, and graphics systems, providing greater throughput than previous systems in commonly encountered, real-world situations.

Sun Creator3D Graphics

Available as an option on the Ultra 10 workstation, Sun Creator3D graphics delivers outstanding window system, 3D, geometry, and imaging acceleration.

Sun Creator3D graphics is a 15-MB double-buffered version of Sun's Creator graphics card, and provides good acceleration of 3D applications or fast animation in 2D and 3D:

- Full performance, low0cost, 24-bit true color is standard
- Transparent acceleration for X11, XGL™, XIL™, and OpenGL graphics libraries
- Common frame buffer and register architecture
- 8-bit X11 visuals supported include pseudocolor (default), linear / nonlinear greyscale, direct color
- 24-bit X11 visuals supported include direct color, linear / nonlinear truecolor
- 8-bit pseudocolor overlays
- High resolution (1920 x 1200 and 1280 x 900 in single buffer mode)
- Stereo ready
- On-board YCC to RGB color space conversion for fast video decompression
- Full 3D solids, dynamic shading, rotation, and Z-buffering acceleration
- Full double-buffered 24-bit true color, 8-bit overlay, 28-bit Z-buffer, 4-bit stencil

Sun Creator3D Graphics Theory of Operation

Because the decision had been made to develop the graphics subsystem as part of the overall system architecture, it was possible for engineers to place components in the system where it would be most beneficial to graphics performance. Such placement minimizes overhead and ensures best possible utilization of bus bandwidths and investments in ASIC technology, resulting in

a very highly-integrated, economical, modular architecture that is tightly coupled the CPU, memory interconnect, frame buffer, and graphics accelerator (Figure 3-1).

In Ultra 10 systems with Sun Creator3D boards, graphics processing is spread out across the system to take advantage of appropriate resources: the UltraSPARC-IIi processor provides fast, scalable image and video processing; the Sun Creator3D graphics module accelerates the window system and 2D graphics; and both work together to accelerate pipelined 3D graphics instructions.

With large amounts of image and graphics data moving between processor, memory, and the Sun Creator3D graphics system, the UPA interconnect is essential to achieving high graphics performance. Its use of independent address buses, deep pipelining, and burst transfers make this possible.

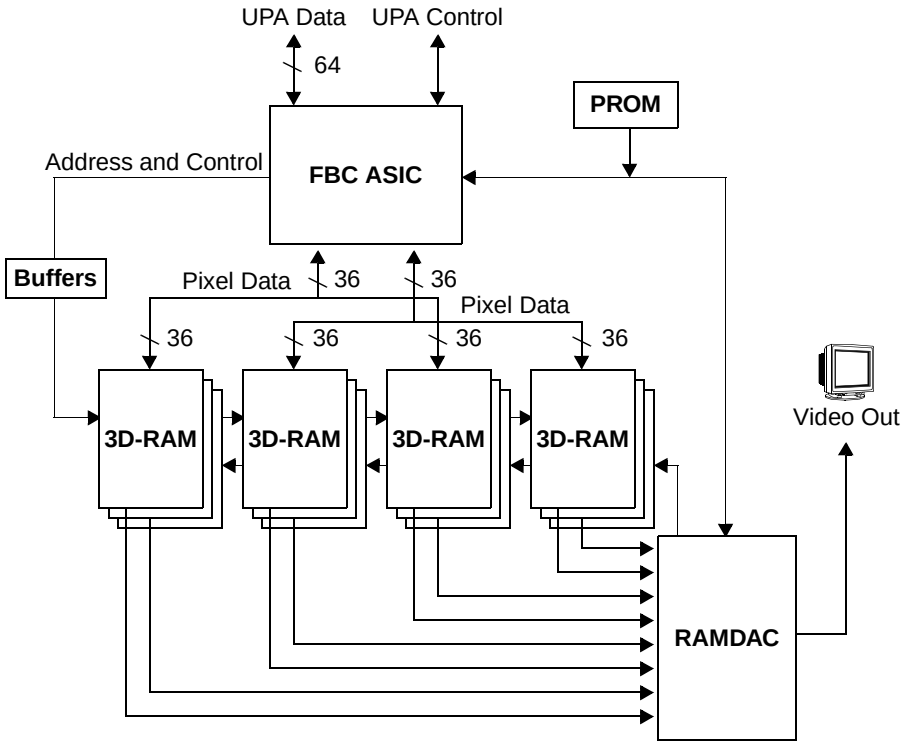

Figure 3-1 Ultra 10 workstations equipped with Sun Creator3D graphics cards use a very highly-integrated, modular architecture that tightly couples the CPU, the system memory interconnect, the frame buffer, and graphics accelerator technology

Key Graphics Technologies in Sun Creator3D Graphics Systems

The Sun Creator3D graphics card is a powerful, highly integrated module designed for a wide range of high-end graphics applications. Acting both as a frame buffer and accelerator, Sun Creator3D graphics contains three key components:

- Frame buffer controller ASIC

  Sun Creator3D graphics equipped Ultra 10 systems support a frame buffer controller ASIC (FBC2) that provides the rear half of the 3D graphics rendering pipeline, providing acceleration for windowing functions and

complex graphics applications. It also performs pixel processing to accelerate high-end 3D functionality such as transparency and antialiasing. An extremely powerful processor, the FBC2 is capable of 2.1 billion operations per second (BOPs), and provides rendering acceleration for dot, line, text, triangles, and fill patterns. Other capabilities include acceleration of common windowing functions, including fill, scroll, text, 2D and 3D vectors, and polygons (the UltraSPARC-IIi handles pixel imaging and copy functions).

- 3D-RAM

  The Sun Creator3D graphics frame buffer is implemented with an innovative technology co-developed by Sun and Mitsubishi Electronics. 3D-RAM provides SRAM rendering speeds for 3D graphics at DRAM density and cost. (Overall, 3D-RAM is five to ten times faster than VRAMs for this application.) Each 3D-RAM contains an on-chip ALU for anti-aliasing and alpha blending operations, and is four times faster for Z-buffering, by eliminating the read-modify-write cycle. 15 MB of 3D-RAM are provided on Sun Creator3D graphics.

- High performance RAMDAC

  A specially designed circuit converts digital pixels into analog signals and sends them to the display. Developed in partnership with Brooktree, the Bt497 RAMDAC incorporates a large degree of integration, supporting the simultaneous display of both 8-bit and 24-bit images, a 64 x 64 hardware cursor, and programmable video timing for multiple resolution support.

Sun Elite3D m3 and Sun Elite3D m6 Graphics

Sun Elite3D graphics-equipped Ultra 10 workstation systems are designed to help accelerate applications that manipulate large numbers of complex 3D solids and for use in MCAD, geotechnical, animation, or related fields. Sun Elite3D graphics dramatically improves performance in double-buffering, triangle and quad rendering, and lighting and shading without sacrificing fast 8- and 24-bit window system, imaging, or video performance.

Sun Elite3D m3 and Sun Elite3D m6 graphics systems provide 88 bit planes, including full 24-bit double-buffer planes as required for smooth animation. A 28-bit Z-buffer is included to provide hardware assistance for hidden surface removal and dynamic rendering of 3D objects. Both the Sun Elite3D m3 and m6

graphics devices are fully upward compatible with the Sun Creator3D systems and do not compromise window system, 2D graphics, imaging, or video performance.

Sun Elite3D graphics features include:

- Simultaneous 8-bit and 24-bit visual support
- Multiple hardware colormaps
- Adjustable gamma correction
- 8-bit SOV-compliant pseudocolor overlay
- Transparent acceleration for X11 and XIL graphics libraries
- Transparent acceleration for 3D APIs (XGL, OpenGL, and Java 3D™ APIs)
- 3D solids, dynamic shading, rotation, and Z-buffered acceleration
- Full double-buffered 24-bit true color, 8-bit overlay, 28-bit Z-buffer (floating point), 4-bit stencil (with full support for OpenGL stencil functions)
- High resolution (1280 x 1024 @ 76 Hz noninterlaced)
- Stereo-ready (single pass, 960 x 680 @112 Hz noninterlaced)
- DDC2B monitor serial communication with EDID support

The Sun Elite3D m3 and Elite3D m6 graphics, provide a very high level of performance with either three (m3) or six (m6) independent, high performance floating point processors, enabling Sun Elite3D graphics systems to offer 3D performance two to four times faster than a Sun Creator3D system. Table 3-3 depicts the performance characteristics of the Sun Elite3D m3 graphics system.

Sun Elite3D graphics also provides support for a range of important 2D and 3D functions described in Table 3-4.

2D Operations	3D Operations	Other Features
• Bresenham lines	• Accelerated dots, lines, triangles, and quads	• Viewport clipping
• Polygons	• Hardware antialiasing of dots and lines	• Window ID clipping
• Font support	• Hardware support of large antialiased dots up to 10 pixels in diameter	• Hardware line patterning for all lines
• Rectangle fill	• Gouraud shaded triangles	• 32 x 32 area pattern

2D Operations	3D Operations	Other Features
• Fast block clear	• Specular lighting	• Flexible blending operations
	• Hardware per-pixel depth-cue	• Full set of Boolean operations
	• Hardware transparency (both alpha-blended and screen-door)	• Stateless frame buffer available in both 8 and 24 bits
	• Alpha interpolation per pixel	• Full plane mask
	• Texture map support	
	• Compressed 3D geometry decompression	

Table 3-3 Functionality supported by the Sun Elite3D graphics

Sun Elite3D Graphics Theory of Operation

The Sun Elite3D m3 and Sun Elite3D m6 graphics modules are comprised of a number of specialized ASICs for interface and control (*AFB-Command*), floating point operations (*AFB-Float*), and pixel drawing (*AFB-Draw*). Like Sun Creator3D, Sun Elite3D graphics modules use twelve 3D-RAM chips to provide a 1280 x 1024 double-buffered 24-bit frame buffer with a 28-bit depth buffer. Sun Elite3D graphics and Sun Creator3D graphics also share the same Bt498+ RAMDAC (Figure 3-2). To avoid difficulties implementing switched bidirectional buses at 120-MHz, the Sun Elite3D graphics design uses unidirectional point-to-point buses for all three of its internal high speed buses. One of the busses (*FD-Bus*) runs at 800 MB/second.

The *AFB-Command* ASIC buffers and converts incoming 3D geometric data to independent primitives (triangles, lines, dots) which are then distributed to the three floating-point chips for further processing. In addition to the regular data input functions, AFB-Command has a decompression unit capable of converting highly compressed 3D geometric data back into the standard formats required by the rest of the graphics pipeline. (Software APIs such as the Java 3D API provide geometry compression.) The AFB-Command chip also permits the efficient reading and writing of pixels to and from the frame buffer memory.

The *AFB-Float* components are designed to transform, light, clip, and set up primitives which are passed to it from the AFB-Command chip. Three floating point units are used on the Sun Elite3D m3 board, while six are employed on the Sun Elite3D m6 board. This module enhances performance by providing algorithm-specific circuits dedicated to just one (or a few) stage(s) of the graphics pipeline.

AFB-Draw takes in screen-space (fully transformed and lit) primitives and renders them into the frame buffer, drawing dots, lines and triangles as efficiently as possible. It also performs optional antialiasing on dots and lines. AFB-Draw contains edge walking and span interpolation circuitry to render individual pixels.

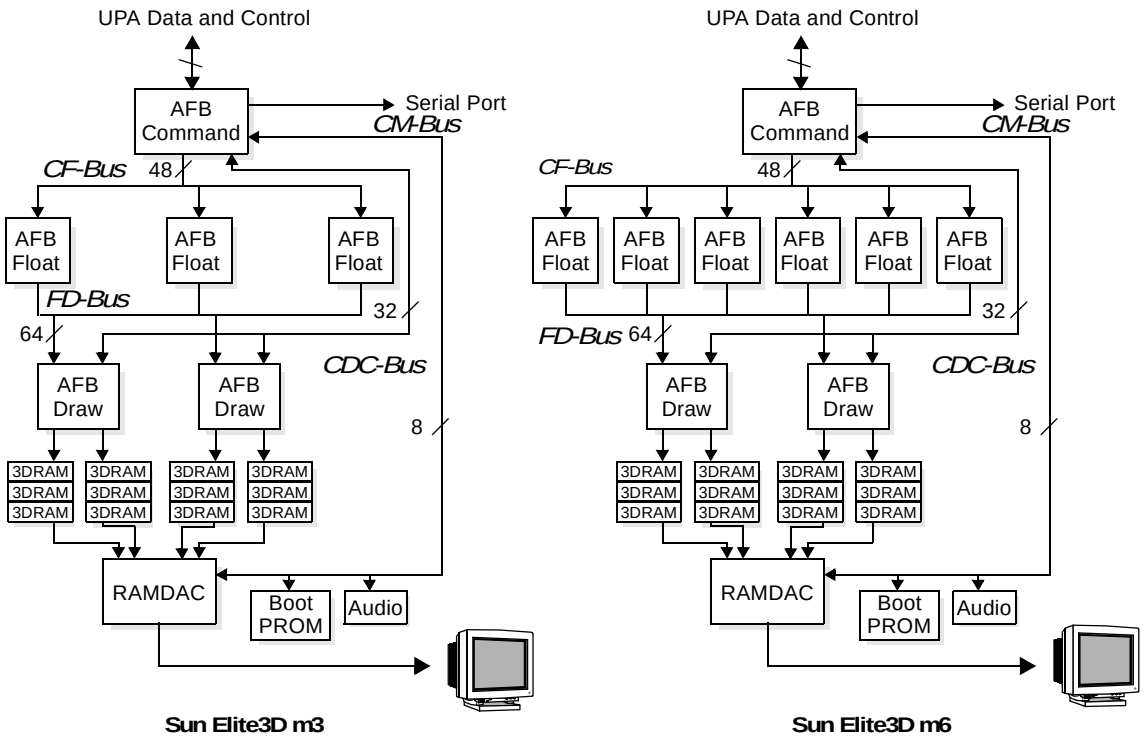

Figure 3-2 The Sun Elite3D m3 and m6 graphics accelerators

Other functionality includes:

- Single-pixel dots, antialiased dots, and large antialiased dots
- X11 Bresenham lines
- X11 Bresenham edge 2D polygons
- DDA lines and antialiased DDA lines
- DDA Gouraud interpolated triangles
- DDA triangles with texture mapping
- Screen aligned rectangular patterned fills and vertical scrolls
- Fonts (stencil)

Support is also included on a per pixel basis for:

- Alpha channel blend / transparency
- Screen door transparency
- Depth cueing
- Write-masks
- WIDs (Window IDs)

Key to the performance of Sun Elite3D graphics is the rate at which AFB-Draw can render 24-bit depth-cued pixels into the 3D-RAM based frame buffer — nearly 400 million pixels per second. To achieve these high rates, the 3D-RAM is four-way interleaved, with two AFB-Draw ASICs to control each of the two interleaves.

AFB-Draw also handles all pixel operations such as blending, depth-cuing, boolean operations, bit masks, fonts, window-ID clipping, viewport clipping, and so forth. There is logic in the chip to allow “direct port” accesses to slip in between “accelerator port” access as needed. AFB-Draw also supports frame buffer read operations over the UPA interconnect.

Software 4

Solaris Operating Environment Software

All Ultra 5 and 10 workstations come ready to use with the Solaris 7 Operating Environment and 64-bit Solaris 8 Operating Environment (release 10/00 or later) pre-installed. The Solaris 8 Operating Environment provides the enhanced level of functionality expected of a Sun workstation, including a proven, scalable 64-bit kernel, standards-based networking, and Java technology support. These technologies provide the foundation for building and deploying enterprise-class systems for multi-vendor, multi-client workgroup environments, as well as highly available data center environments. The strengths of the Solaris Operating Environment lie in its enterprise-class reliability, scalability, and performance.

The 64-bit Solaris 8 Operating Environment provides enhancements in overall performance, scalability, reliability, availability, security, and ease-of-use while maintaining backward compatibility for all existing 32-bit Solaris Operating Environment applications and commands. The Solaris 8 Operating Environment continues the tradition of providing exceptional functionality and performance by delivering the following major enhancements:

- *Mainframe-class reliability, availability, and serviceability* for systems of all sizes
- *Higher performance*, the complete 64-bit computing environment provides greater capacity, precision, and performance
- *Enhanced scalability* with a 64-bit kernel that enables access to more system resources and the ability to consolidate applications onto a single server

- *Greater ease of use*, including Web-based installation, text and voice notes, and a graphical process manager
- *Comprehensive global support*, including support for the Euro currency symbol, complex text formats for Arabic, Thai, and Hebrew languages, and support for the development of multilingual applications
- *Software investment protection* with complete binary compatibility that allows today's 32-bit Solaris Operating Environment applications to continue to run on the Solaris 8 Operating Environment without modification or recompilation.
- *Extended security features* through authentication, data integrity, data privacy, and single sign-on capabilities so that tampering, snooping, and eavesdropping do not compromise data or associated transactions
- *32-bit and 64-bit development environment*, helping developers to generate a single set of source code that runs on both operating modes

Designed to deliver the power, flexibility, availability, and compatibility to support enterprise-wide computing, the Solaris 8 Operating Environment combines four key computing elements — operating system, networking, window system, and user environment — into a stable, high-quality foundation that helps enable the development, delivery, and management of a wide range of computing solutions.

Operating System

Based on UNIX® System V Version 4 (SVR4), the Solaris 8 Operating Environment provides a rich applications development environment, and fully supports multithreaded applications as well as symmetric multiprocessing (SMP) on multiprocessor machines. The Solaris Operating Environment enables maximum portability across platforms by conforming to several important standards including SPARC ABI, CDE-compliant Motif, X11R6, POSIX 1003.1b and 1003.2, NIS, WebNFS™software, HTTP, XML, IIOP, UNIX 95 and UNIXþ98 branding, X/Open (XPG4 base functionality), Energy Star, Kodak Color Management System, and ISO 9660.

Networking

Sun's open systems computing environment (ONC+™environment) provides transparent access to information and services distributed throughout the environment. The Solaris Operating Environment also defines a standard

interface to ONC+ for alternative networking technologies (DCE and NetWare) helping to smooth integration with enterprise computing environments. Networking products such as LDAP, DHCP, NIS+, NFS, and RPC/XDR are supported for remote execution and data exchange. Transport layer independence provides support for a variety of network transport protocols such as TCP/IP (Figure 4-1).

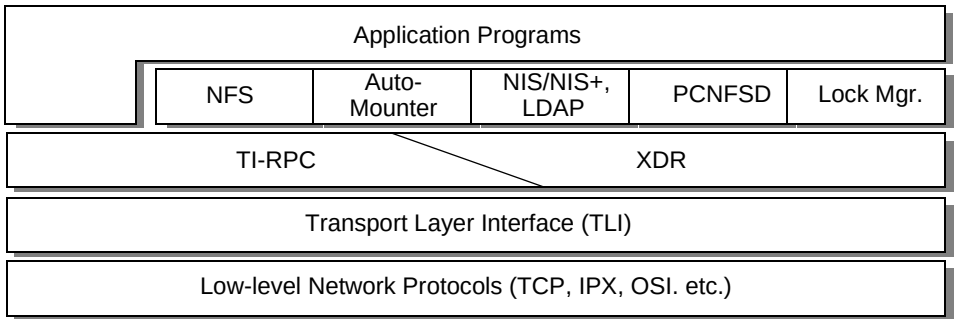

Figure 4-1 The Solaris Operating Environment supports a family of advanced networking protocols and services

Windowing Systems

The Solaris Operating Environment X11-based window server, user interface, and ToolTalk™ messaging services are engineered to exploit the Solaris Operating Environment distributed client-server computing model. To ensure a consistent look and feel across all major UNIX platforms, Sun includes the Common Desktop Environment (CDE) with every copy of the Solaris Operating Environment. Users and developers have the choice of continuing to use the Motif-based industry-standard CDE, or the GNOME environment. The CDE environment includes graphics, imaging, audio and video services, and Display PostScript to facilitate the development and delivery of multimedia applications for communication and collaboration across the enterprise.

CDE has been extended to include a variety of tools to simplify the management of applications and the desktop environment — a front panel to launch applications with a single click; a workspace manager to create multiple virtual desktops, including support for multiple monitors; a style manager to personalize the use of colors, backdrops, mouse and keyboard behavior, and startup characteristics. Other tools include text and icon editors, an image viewer, process and system management controls, workgroup calendaring, file

and print manager, web-browser, performance meter, and MIME-compatible electronic mail. Solaris Operating Environment CDE features drag-and-drop and cut-and-paste across OpenWindows and Motif applications.

The Solaris 8 Operating Environment software supports numerous graphics and windowing APIs such as Xlib, Display Postscript™, Java 2D™, Java 3D, and OpenGL to assist in the development of applications (Figure 4-2). In addition, the Solaris Operating Environment includes Xlib, Java 3D, and OpenGL 64-bit ready, high performance graphic APIs.

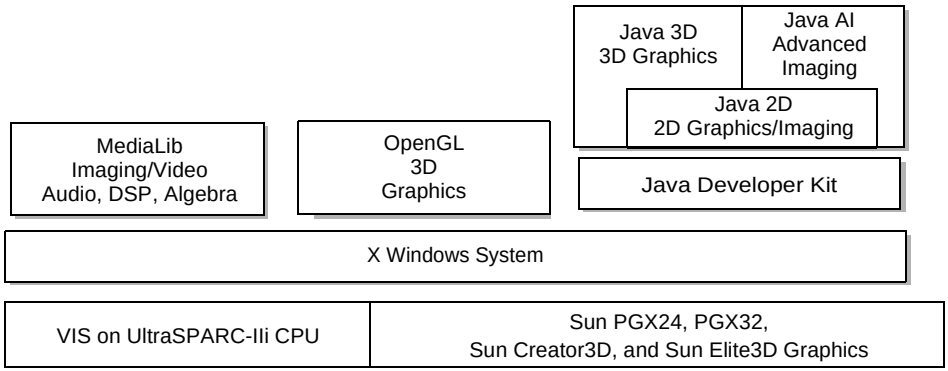

Figure 4-2 Solaris Operating Environment foundation graphics libraries and layered interfaces from Sun

Installation

The 64-bit Solaris 8 Operating Environment comes pre-installed and ready to use on all Ultra 5 and 10 workstations. For re-installations or operating system upgrades Sun offers additional choices including Solaris JumpStart™and Solaris Web Start with either remote or local CD installation.

Installation of the Solaris Operating Environment can be fully automated using the Solaris JumpStart software technology. When the system is first powered on, Solaris JumpStart software locates the install information over the network or from a local CD drive. The software installation is driven by profiles customized by the system administrator, or from a default installation profile, called the SmartStart™profile. The SmartStart profile intelligently determines the best installation based on heuristics such as the amount of installed memory and available disk capacity.

Solaris Web Start software eliminates the UNIX system administration chores normally associated with software deployment through a flexible software management console that can be run from any desktop in an organization's network. An easy to use tool for software deployment and management, Solaris Web Start software is a Java technology-based utility that simplifies and accelerates the installation of the operating system and associated software. A browser interface provides a familiar way to deploy and manage software resources in the workgroup and even across the Web. Customization and configuration options provide the flexibility needed for even the most unusual configurations, and by leveraging Sun's Solaris JumpStart technology, Solaris Web Start software provides the advanced replicated installation and remote software deployment features demanded by enterprise administrators:

- One-button and custom deployment options simplify installation and configuration.
- Java technology-based management console looks like a set of web pages.
- Support for a variety of media, including CD-ROMs and the Web, enhances distribution options.
- Extensive context-sensitive and on-line documentation delivers help and support when needed.
- File system tools streamline the software installation process.
- Replicated installation "profiles" ease the enterprise administration burden.
- Remote option directs deployment from any desktop to any host.
- A Software Developers Kit (SDK) extends the benefits of Solaris Web Start to all developers of Solaris applications.

Ultra 5 and Ultra 10 Workstation Operating Environment Support

The Ultra 5 and Ultra 10 systems described in this paper ship standard with the Solaris 7 (11/99) version of the Solaris Operating Environment, and the Solaris 8 Operating Environment. All Ultra 5 and Ultra 10 systems are also supported by other Solaris Operating Environment software releases, including Solaris 2.5.1 Operating Environment and later.

Support for Graphics Accelerators

Ultra 5 and 10 systems support all of Sun's Solaris 8 Operating Environment graphics APIs, including the OpenGL, Java 3D, and Java Advanced Imaging libraries, Display PostScript, and the OpenWindows (X11-compliant) window system. Industry-standard X-extension libraries, such as Xlib and PEXlib, are also available and are accelerated via the Sun foundation graphics libraries.

As both imaging and geometry devices, the graphics products available for Ultra systems accelerate many of the APIs mentioned above. The following sections briefly describe the foundation graphics interfaces and the functions accelerated by the on-board Sun PGX24, PGX32, and Sun Creator3D, and Sun Elite3D graphics subsystems.

OpenGL API

The OpenGL graphics application programming interface is an industry-standard, vendor-neutral software interface which operates independently of operating and window system platforms. Based upon its proprietary predecessor, GL, OpenGL is an applications programming interface that provides 2D and 3D graphics functions, including modeling, transformations, color, lighting, and smooth shading, as well as advanced features such as texture mapping, NURBS, fog, alpha blending, and motion blur. The OpenGL API works in both immediate and non-editable display-list graphics modes.

The OpenGL library is targeted at developers creating interactive 3D applications for the enterprise, the intranet, and the Internet. These developers are generally affiliated with technical markets or in research facilities. Potential users include those in computer-aided design and manufacturing, global information systems, simulation, industrial design and modeling, entertainment, biochemistry, and petroleum exploration.

Sun™OpenGL® 1.2.1 for Solaris™software provides a complete solution for developing and deploying interactive 3D applications across Sun workstations. It enables mainstream, industry-leading 3D graphics and visualization applications to be deployed on Ultra 5 and 10 systems at a compelling price/performance ratio.

The widespread multivendor availability of OpenGL libraries ensures source code portability of 3D graphics clients. Sun OpenGL 1.2.1 for Solaris is a compliant implementation of OpenGL 1.2 from the OpenGL Architecture

Review Board and is, therefore, source code compatible with other compliant OpenGL applications. Most existing OpenGL applications will only need to be recompiled in order to run under Sun OpenGL 1.2.1 for Solaris.

Additional Sun-specific extensions are provided in Sun OpenGL 1.2.1 for Solaris, including:

- *Global Alpha Extension*. Allows applications to specify an alpha component that can be applied globally to all primitives (useful for cases in which many vertices share the same alpha value, because the application does not have to send an alpha component for each vertex)
- *Vertex Extension*. Allows applications to specify all vertex data (color, normal, coordinates, an so on) in a single function call (saves function calls overhead)
- *Triangle List Primitive*. Allows multiple triangle strips or fans to be specified within a single `glBegin-glEnd` pair (for improved performance)

Fully integrated with the Solaris 8 Operating Environment, OpenGL 1.2.1 allows developers to take advantage of it's advanced features, including multithreading and full support for 64-bit computing. OpenGL 1.2.1 also includes new imaging extensions to allow developers access to both graphics and imaging functionality within the same application and other enhancements to support increased performance and functionality. Solaris OpenGL can run with Common Desktop Environments (CDE) or OpenWindows environments. A defined common extension to the X Window System allows OpenGL client to run across distributed heterogeneous networks.

More information about OpenGL 1.2.1 can be found at: *http://www.sun.com/software/graphics/OpenGl/*.

Java 3D Application Programming Interface

The Java 3D API is used for writing stand-alone three-dimensional graphics applications or Web-based 3D applets. The Java 3D API gives developers high level constructs for creating and manipulating 3D geometry and tools for constructing the structures used in rendering that geometry. With Java 3D constructs, application developers can describe very large virtual worlds, which, in turn, are efficiently rendered by Java 3D API implementations.

The Java 3D API specification is the result of a joint collaboration between Silicon Graphics, Inc., Intel Corporation, Apple Computer, Inc., and Sun Microsystems, Inc. All had advanced, retained mode APIs under active internal development, and were looking at developing a single, compatible, cross-platform API based on Java technology.

The Java 3D API draws its ideas from the considerable expertise of the participating companies, from existing graphics APIs, and from new technologies. Java 3D API's low-level graphics constructs synthesize the best ideas found in low-level APIs such as Direct3D, OpenGL, XGL, and QuickDraw3D. Similarly, Java 3D API's higher-level constructs leverage the best ideas found in several modern scene graph-based systems. Java 3D API also introduces some concepts not commonly considered part of the graphics environment, such as 3D spatial sound to provide a more immersive experience for the user.

Java 3D API provides a host of capabilities that yield a high degree of interactivity while preserving true platform independence, including:

- High-performance
- Rich set of 3D features
- High-level, object-oriented paradigm
- Wide variety of file formats, including vendor-specific CAD formats, interchange formats, VRML 1.0, and VRML 2.0
- New 3D view model, enabling images to be rendered on a wide variety of display devices
- High-performance vector math library for advanced object classes
- Rendering models and modes
- Sound and MIDI support
- Geometry compression, enabling geometry to be represented in an order of magnitude less space than most traditional 3D representations, with very little loss in object quality

Java Advanced Imaging API

Image processing techniques are used for manipulating and displaying images. Examples of image-processing techniques range from simple operations such as contrast enhancement, cropping, and scaling to more complex operations such as advanced geometric warping and frequency domain processing.

These techniques are used in a variety of applications including:

- Astronomy
- Medical imaging
- Geospatial data processing
- Defense and intelligence
- Photography
- E-Commerce and retail

The Java Advanced Imaging API broadens the reach of the Java platform to allow sophisticated, high performance image processing functionality to be incorporated into Java applets and applications. Going beyond the functionality of traditional imaging APIs, the Java Advanced Imaging API provides a high-performance, platform-independent and extensible image processing framework.

For more information see *http://java.sun.com/products/java-media/jai/*.

Software Development Support

Sun provides a range of powerful software development tools to help developers author successful applications.

Forte™ Developer Products

Successful application development requires that programmers have high performance compilers and tools. The Forte™ Developer suite of products (formerly known as Sun WorkShop™ software) includes highly optimizing, automatically parallelizing compilers; libraries of highly optimized routines; and tools to help analyze and tune code for additional runtime performance. Forte Developer software features include:

- Integrated programming environment
- Motif user interface, providing a standard look and feel
- Tight, editor-centric tool integration
- Hyperlinks, enabling easy tool navigation
- Multiprocessing, multithreaded development tools
- Distributed and parallel make utilities
- Incremental linker, for faster builds

- Fix and Continue, enabling defects to be found and fixed quickly
- AppGuru, enabling very fast application development for C++
- New version of Rogue Wave Tools.h++ 7.0 class library
- Motif and Windows GUI Builder, for cross-platform development
- Quick and easy GUI development
- Forte C++ 6 software, enabling quick and easy GUI development
- GUI capture and testing, providing reverse engineering capabilities
- Three dimensional data visualizer, speeding debugging of complex arrays
- WorkSets and PickLists, facilitating quick access to work sessions
- Forte TeamWare software, for source code and configuration management
- Extensive on-line manuals and help system

Versions of Forte are available that support the Fortran, C, C++, and Java programming languages). Of particular interest to developers is the ability of Forte to perform several advanced optimizations that can speed applications performance:

- *Instruction scheduling*, to arrange the order in which instructions are executed and make optimal use of available machine resources.
- *Profile feedback*, to obtain frequency information about a program. The program is executed and the frequency information is applied to optimizations such as code motion and inlining.
- *Loop parallelization*, to rearrange loop code so that multiple processors may be work in parallel to complete the loop.
- *Cache blocking*, to rearrange loop code to make maximum use of the processor cache.
- *Loop inversion*, to reverse the order of nested loops to gain the advantages of improved loop parallelization or better cache blocking.

To take advantage of innovative UltraSPARC-IIi processor features, Sun Forte Developer software's compilers support both traditional and hybrid versions of the SPARC Version 9 architecture. Full 64-bit computing is available with SPARC V9 support. A hybrid version, called V8+, precludes the use of all V9 64-bit addressing instructions, ensuring 32-bit compatibility with existing versions of the Solaris Operating Environment and with other existing applications, while still allowing access to most of the UltraSPARC-IIi processor's advanced capabilities, including the VIS software.

Java Applications Development

A discussion of software development would not be complete without mentioning Java technology. The Java programing language delivers true platform-independent software development for a large number of applications. Software developers have instantly recognized the potential of Java applications, with thousands of firms currently developing, or planning to develop Java technology-based products. Sun Microsystems, the original developer of the Java programming language, offers software developers a unique opportunity with a comprehensive product line designed to streamline development.

The object-oriented Java platform delivers the benefits of reusable code, reduced cost of ownership, and broad integration, with the complex, heavyweight object housekeeping process required by other object-oriented development models. Sun's family of Java APIs and development products, Forte for software, the Java 2 Software Development Kit, and Java Studio™ software, help empower developers to create an entire new class of applications that truly enable network-based computing. The Ultra 5 and 10 workstations are ideal platforms for these tools, permitting the development of both client and server components of Java technology solutions. Products can then be easily deployed to more powerful Sun Java Web servers or Sun Ray™ appliances.

The Java 2 Software Development Kit comes with the Solaris 8 Operating Environment. The Java 2 SDK provides both essential development tools required for creating Java applications and a high-performance, scalable runtime environment that reliably delivers the faster execution of Java applications. Designed to deliver superior performance and scalability across the enterprise, applications developers recognize that the runtime system in Java 2 for Solaris sets a new standard for Java technology performance and reliability.

Open Firmware

Ultra workstations support the use of a standardized PROM-resident monitor program that is written in a special threaded-interpretive language. Called Open Firmware, this monitor is conformant to the IEEE 1275-1994 standard, also known as Standard for Boot (Initialization Configuration) Firmware. Open Firmware can be brought up during the power-on process if a problem is encountered, or by executing a system *shutdown* followed by a level-0 *init(1M)*.

Once the Open Firmware monitor has control, a variety of diagnostics are available for key subsystems and peripherals:

- Video graphics
- Ethernet interface and AUI
- Internal and external disk drives
- Tape, diskette, and CD-ROM drives
- Serial ports
- Keyboard
- Memory

The Open Firmware monitor also provides tools to allow the continuous monitoring of the network and selective probing of devices on the SCSI bus.

Boot-time behavior and some diagnostics in Ultra 5 and Ultra 10 systems are controlled through 1 MB of flash PROM. The use of flash PROMs permits the reprogramming of specific code blocks to implement updates and enhancements without requiring physical access to the PROMs. Reprogramming may be done from a CD-ROM located in the system or remotely by a system administrator over a local area network.

Diagnostics

The Ultra 5 and Ultra 10 platforms have been designed for easy diagnosis and problem repair. Supporting this are several PROM-resident and UNIX platform-based diagnostic programs that can be applied by end users and service personnel.

Power-On Self-Test (POST)

Under user control, a power-on self-test (POST) can be automatically executed to test the system board, NVRAM, on-board I/O devices, and memory system each time power is applied to the system. While not intended to be a comprehensive diagnostic, POST can quickly establish that no severe problems exist with the system, and communicates that through a set of light-emitting diodes (LEDs) on the keyboard. POST tests may be monitored via a serial-port connection to another desktop system or dumb terminal.

SunVTS™ Software

The SunVTS™ system exerciser is a graphically oriented UNIX application that permits the continuous exercising of system resources and internal and external peripheral equipment. Used to determine if the system is functioning properly, the SunVTS utility incorporates a multifunctional stress test of the system through operating system level calls, and allows the addition of new tests as they become available.

References

Sun Microsystems Computer Company posts product information in the form of data sheets, specifications, and white papers on its Internet World Wide Web Product Information Home pages at the following URLs:

- *http://www.sun.com* / desktop / products / Ultra5
- *http://www.sun.com* / desktop / products / Ultra10
- Ultra 5 and 10 Workstation Documentation = *http://www.sun.com/products-n-solutions/hardware/docs/Workstation_Products/Workstations/UltraSPARC_Workstations/Sun_Ultra_510/index.html*
- Software White Papers = *http://www.sun.com/software/whitepapers.html*.

Look for the these and other Sun technology white papers:

- *The UltraSPARC-IIi Processor Architecture*, White Paper.
- *Creator Graphics Technology*, White Paper.
- *Sun Elite3D Graphics*, White Paper.
- *SunFastEthernet*, White Paper.

Sun Microsystems Incorporated
901 San Antonio Road
Palo Alto, CA 94303 USA
650 960-1300
FAX 650 969-9131
http://www.sun.com

Sales Offices

Argentina: +54-1-317-5600
Australia: +61-2-9844-5000
Austria: +43-1-60563-0
Belgium: +32-2-716-7911
Brazil: +55-11-5181-8988
Canada: +905-477-6745
Chile: +56-2-638-6364
Colombia: +571-622-1717
Commonwealth of Independent States:
+7-502-935-8411
Czech/Slovak Republics:
+42-2-205-102-33
Denmark: +45-44-89-49-89
Estonia: +372-6-308-900
Finland: +358-9-525-561
France: +33-01-30-67-50-00
Germany: +49-89-46008-0
Greece: +30-1-680-6676
Hong Kong: +852-2802-4188
Hungary: +36-1-202-4415
Iceland: +354-563-3010
India: +91-80-559-9595
Ireland: +353-1-8055-666
Israel: +972-9-956-9250
Italy: +39-39-60551
Japan: +81-3-5717-5000
Korea: +822-3469-0114
Latin America/Caribbean:
+1-650-688-9464
Latvia: +371-755-11-33
Lithuania: +370-729-8468
Luxembourg: +352-491-1331
Malaysia: +603-264-9988
Mexico: +52-5-258-6100
Netherlands: +31-33-450-1234
New Zealand: +64-4-499-2344
Norway: +47-2218-5800
People's Republic of China:
Beijing: +86-10-6849-2828
Chengdu: +86-28-678-0121
Guangzhou: +86-20-8777-9913
Shanghai: +86-21-6247-4068
Poland: +48-22-658-4535
Portugal: +351-1-412-7710
Russia: +7-502-935-8411
Singapore: +65-438-1888
South Africa: +2711-805-4305
Spain: +34-1-596-9900
Sweden: +46-8-623-90-00
Switzerland: +41-1-825-7111
Taiwan: +886-2-514-0567
Thailand: +662-636-1555
Turkey: +90-212-236 3300
United Arab Emirates:
+971-4-366-333
United Kingdom: +44-1-276-20444
United States: +1-800-821-4643
Venezuela: +58-2-286-1044
Worldwide Headquarters:
+1-650-960-1300