Product Information

The NeXT™ Computer System
Product Background Information

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OVERVIEW

The NeXT™ Computer System encompasses the best of personal computers and workstations, adding important innovations necessary to meet the demands of higher education. It transcends a simple merging of capabilities to offer a new kind of computing and software development environment.

NeXT made the needs of higher education, gleaned from direct collaboration with leaders in higher education, integral to its product design process. To create the hardware and software tools for this market, NeXT chose to innovate in four key areas:

• **A mainframe on two chips:** High performance at an affordable price is a prerequisite for establishing the future generation of software. Fast processors provide only part of the solution. Equally important is an architecture that carefully manages the flow of information within the system for peak efficiency. NeXT answered with its ICP and OSP, two proprietary VLSI chips that endow the NeXT Computer System with mainframe-like capabilities.

• **NextStep®:** The UNIX® operating system is the standard for higher education and research. Unfortunately, the complexity of UNIX-based computers has put them outside the reach of almost everyone except scientists and engineers. In addition, traditional approaches to UNIX application development require an inordinate amount of time and expertise to develop graphical end-user applications. NeXT solved these problems through an object-oriented software environment called NextStep. On the one hand, NextStep makes the power of UNIX accessible to everyone; on the other hand, it greatly reduces the time, expertise, and code required to write graphical end-user applications.

• **Personal Optical Storage and the Digital Library:** Tapping a computer's ideal capabilities has traditionally been hampered by inadequate mass storage and limited searching and indexing capabilities. NeXT addressed this problem by using a new storage technology, called magneto-optics, to create a read/write/erasable 256 Megabyte Optical Disk. This removable disk is the standard mass storage device for the NeXT Computer System. Included with the disk is a Digital Library and powerful searching and indexing capabilities.

• **Sound and music:** Despite its overwhelming importance as a medium for communication, sound has remained an unexploited resource in computing. NeXT has made sound an integral part of its computer, through features ranging from a microphone jack and true CD-quality stereo output to a powerful processor called a DSP. To facilitate the development of applications that use sound, the NeXT system software includes a Sound Kit ™ and a Music Kit™. In addition, voice mail capabilities have been fully integrated into the system's electronic mail.

Each of these innovations is significant in itself; combined, they exceed the sum of their parts and result in a computer with unparalleled capabilities.

Hardware System Components

The NeXT Computer System begins with the Computer, a one-foot cube that houses the main CPU (central processing unit) board, plus room for three additional expansion boards of the same size; a universal power supply, which makes the system usable throughout the world; and up to two 5.25-inch full-height mass storage devices. Standard in the cube are eight megabytes (MB) of main memory, expandable to 16 MB on the main CPU board.

The computer is powered by Motorola's top-of-the-line microprocessor and memory management unit, the 68030, and the 68882 Floating-Point Unit for fast mathematical computation, both running at 25 megahertz (MHz). The system also includes a 10 MIPS (million instructions per second) Motorola 56001 Digital Signal Processor, which supports complex, computation-intensive processes including CD-quality music and sound synthesis. Also standard is high-performance Ethernet® networking.

The CPU board contains two proprietary VLSI (very large-scale integration) chips that endow the NeXT Computer System with mainframe-like qualities. One, called the Integrated Channel Processor (ICP), ensures high system throughput by carefully managing and optimizing the flow of data within the system, particularly between the main memory, the CPU and peripheral devices such as the network, sound output, monitor and disk drives.

The other VLSI chip, called the Optical Storage Processor (OSP), controls the system's read/write/erasable 256 Megabyte Optical Disk. The Optical Disk represents a new form of mass storage technology, combining laser technology and magnetic (Winchester disk) technology. Information on the Optical Disk can be edited and manipulated, not just read, and the entire disk can be removed and carried between computers for convenience and security.

The NeXT Computer System also features the MegaPixel Display, with a 17-inch, crisp, high-resolution screen. Images on the screen can appear as black, white and various shades of gray, through the use of two bits per pixel. This shading ability adds depth to the images that appear on the MegaPixel Display, which in turn adds depth to an observer's interpretation.

In addition to its visual capabilities, the MegaPixel Display houses impressive sound capabilities. The system can generate CD-quality stereo sound (i.e., 44.1 kHz, 16-bit two-channel digital audio). Users can listen to the sound through a built-in speaker, through stereo headphones via a built-in headphone jack or through a connected audio system via built-in line-out jacks. The Display also features a microphone jack for voice input. Because the MegaPixel Display derives its power from the cube, it requires no separate AC plugs or external power sources.

An optional but recommended component of the NeXT Computer System is the 400 dpi Laser Printer. It is the first full PostScript® laser printer affordable to individuals. As its name implies, the printer can produce extremely high-quality output of 400 dots per inch (dpi), as well as the "standard" desktop laser printer output of 300 dpi.

Taken together, the hardware components of the NeXT Computer System create a powerful, efficient and aesthetic platform that allows users to extend far beyond their traditional desktop computer boundaries.

Software

Every NeXT Computer System includes an unprecedented amount of software as standard, from system software to a wide range of applications.

NeXT chose Mach as its operating system. Mach is compatible with UNIX 4.3BSD, which dominates computing in universities and research institutions. Originally developed by researchers at Carnegie Mellon University, Mach has been licensed and modified by NeXT for the NeXT Computer System.

Mach inherits the advantages of UNIX—its prevalence and familiarity, its multitasking capabilities, its versatility and its ability to run on a full range of computer platforms. In addition, Mach has been optimized for fast interprocess communication. This capability is important in a multitasking environment in which multiple applications share information and cooperate to get a task done.

Traditionally, the power of UNIX has come at the expense of ease of use. As a result, UNIX has been limited largely to scientists and engineers. Creating graphical end-user applications has presented an equally difficult problem, requiring developers to expend great effort and much time. This difficulty has limited UNIX software development to a small number of sophisticated developers. NeXT has addressed both the end users' and developers' problems through an application development environment and user interface called NextStep. NextStep is a window-based, object-oriented environment that significantly simplifies both software development and use of the computer. It consists of four components: the Window Server, the Workspace Manager™, the Application Kit™ and Interface Builder™.

NextStep provides a graphical, icon-based user interface so users can simply and intuitively launch applications and navigate through the computer's file system. Even applications and files on remote file servers can be accessed as easily as if they were stored locally. For software developers, NextStep offers the Application Kit, an extensible set of about 25 software classes that define interacting objects such as windows, scrollers and buttons. The Application Kit cuts developers' application construction time to a fraction of the traditional time required.

Another component of NextStep—Interface Builder—is a tool for rapid construction of a user interface for any type of application. Interface Builder takes previously programmed software objects, such as those in the Application Kit, and allows even users with minimal programming expertise to graphically create a user interface and connect these objects to develop applications.

NextStep uses the Display PostScript™ system, which includes a high- performance implementation of the PostScript language, the de facto imaging standard for printing, as its single imaging model for both screen and printer. The use of the Display PostScript system ensures true WYSIWYG (What You See Is What You Get) between the screen and the printer and simplifies the programming of graphical applications that support high-quality printing.

Another significant software breakthrough of the NeXT Computer System is the first Digital Library. Made possible by the 256 Megabyte Optical Disk, a Digital Library consists of reference and other works stored in the computer. These on-line works can contain entire books, images of photographic quality or musical pieces. To give users a head start, every NeXT Computer System contains a standard Digital Library that includes a full dictionary and thesaurus, a book of quotations and the complete works of Shakespeare.

Coupled with the Digital Library is the Digital Librarian™, a powerful searching and indexing tool developed by NeXT. It gives users almost instantaneous access to any textual information, in any form, anywhere on the disk. Bundled application software, also standard with every NeXT Computer System, includes a full-featured word processor, a graphical electronic mail application with integrated voice mail, the powerful NeXT SQL Database Server from Sybase, Allegro CL® Common Lisp and Mathematica™, a symbolic mathematics program.

A MAINFRAME ON TWO CHIPS

Background

In workstations and personal computers, speed and performance are usually measured in MIPS. But MIPS measure only specific, CPU-intensive tasks. The real key to higher performance is *system throughput*, which measures typical situations involving *all* the computer's components.

There are four keys to high performance: fast processors adapted to specific problems; a CPU freed from managing all input and output (I/O); a reduced need to go constantly to memory; and efficient use of data routes.

Both personal computer and workstation architectures contain inherent throughput bottlenecks. For its computer, NeXT needed to devise a new architecture to circumvent these bottlenecks. The company found its model in the mainframe, then modified the model to fit into a personal computer-sized package. In effect, it created a mainframe computer on two custom chips: the Integrated Channel Processor (ICP) and the Optical Storage Processor (OSP).

What NeXT Means by "A Mainframe on Two Chips"

High performance begins with fast processors. For its main processor, NeXT chose the 5 MIPS 25 MHz Motorola 68030 with built-in memory management. Recognizing that certain computing problems are better handled by special-purpose processors, NeXT included two of them: a 25 MHz Motorola 68882 Floating-Point Unit, for fast computation of floating-point operations, and a 10 MIPS Motorola 56001 Digital Signal Processor (DSP) for array and signal processing operations, including sound processing. Because these special-purpose processors perform specific types of activities extremely fast, they can work in the system to significantly boost overall performance. For example, in certain types of operations the DSP is 50 to 100 times as fast as the 68030.

In designing its computer, however, NeXT saw that a computer's architecture could ultimately limit its performance, regardless of the speed of the processors. The architecture determines the interactions between various components, such as main memory, the CPU and peripherals, and has a major impact on the overall performance of the system. In almost all computer architectures, from microcomputers to mainframes, main memory plays a central role. Every piece of data that moves between the CPU and peripherals gets stored for some time in memory. As a result, memory and the path to memory often become a crippling bottleneck. It was this bottleneck that NeXT set out to break through.

In most personal computer architectures, the CPU and all peripherals attach directly to the main memory through a relatively simple memory "bus." This architecture fulfills the design goals of simplicity and low cost, but also provides a built-in performance bottleneck.

The bus has a limited bandwidth, or volume of data traffic it can support, between the main memory, CPU and peripherals. This bandwidth establishes the boundaries of system performance. Beyond the simplest support for video and sound, the CPU must transfer each and every byte of data for I/O. As a result, the CPU must frequently wait as I/O devices use the bus, which prevents it from performing computational tasks for the user. Its performance, regardless of its rated value, drops to 0 MIPS if it must wait for the bus before performing its next operation. In addition, this arrangement severely limits the number of possible I/O devices that the system can support.

The architecture of workstations evolved to overcome this throughput bottleneck, first by adding separate video memory for the display. Later, workstations also provided a small, dedicated, high-speed cache memory between the main memory and CPU. These features reduced the need for the CPU or monitor to access the main memory, which alleviated some of the traffic problem.

Workstation users, however, quickly give up their bandwidth gains when they add networking, disk expansion, array processors and I/O expansion options, all of which must compete for access to main memory and the memory bus. In addition, the CPU is forced to take time away from computation and devote it to managing the added number of peripheral devices.

The engineers at NeXT saw that both personal computer and workstation architectures were being pushed to their performance limits. They looked instead to an architecture that solves the I/O bottleneck problem better than any other: the mainframe.

Mainframe computers typically add separate processors to each channel into and out of the centralized main memory. In this way, each peripheral function has its own dedicated processor for managing the flow of data from the device into memory and back out. To handle the extra demands on the system, literally hundreds of chips are required. In all, this architecture ends up requiring several hundred chips that must be packaged, powered, cooled and made reliable. The price paid by mainframes for this high-performance architecture has meant large size, complexity, high price, and hot and noisy operation.

NeXT has shrunk the mainframe I/O processing scheme onto two custom VLSI chips located on the system's single board. This single board is packaged in a one-foot cube featuring compact size, simple design, an affordable price, and cool and quiet operation.

Integrated Channel Processor Boosts Performance
NeXT implemented the mainframe's solution to the data throughput bottleneck in its Integrated Channel Processor chip. The ICP boosts performance by doing three things:

1) It moves data and executes the lowest-level protocols for each I/O device, thus freeing the 68030 (main processor) for other tasks.
2) It uses its own on-chip memory to minimize the need to access the memory bus, thus reducing contention among the main processor and peripherals.
3) It ensures the most efficient possible use of the bus by moving data in optimally sized chunks.

The ICP provides 12 separate direct memory access (DMA) channels to manage all I/O for the system. Each channel allows an I/O device to move data directly between it and the main memory without interrupting the 68030. This frees the 68030 from the constant barrage of data from peripheral devices, allowing it to perform those operations more directly involved with a software application itself.

NeXT is not the first company to use DMA, but the NeXT Computer System is the first to bring such powerful, integrated I/O control to the desktop. Also, its 12 separate, buffered DMA channels far exceed any previous workstation-class computer.

Built into the ICP and each DMA channel is a memory buffer. Two of the computer's DMA channels, for example, are devoted to Ethernet networking. Packets from Ethernet are buffered in one of the ICP's two allotted channels, rather than going directly to the main memory. This process is efficient because it reduces the load on the memory, thus alleviating a major throughput bottleneck. When the ICP must transfer data to and from main memory, it does so in 128-bit chunks, using the system's burst mode. This method moves twice as much data in a given time compared to moving standard, 32-bit data chunks, and thus ensures optimal use of the bus.

The other DMA channels in the NeXT Computer System operate in the same efficient manner. They are devoted to such functions as the serial ports (two channels), monitor, printer, memory-to-memory copy and digital signal processing. Two channels connect directly to the OSP chip. One of these supports the 256 Megabyte Optical Disk and the other supports a SCSI (small computer system interface) controller.

Mainframe-Like Storage Capacities

Besides high system throughput, mainframe computers offer tremendous mass storage capabilities. In the NeXT Computer System, these storage capacities are made possible by the Optical Storage Processor and a SCSI controller chip.

The OSP implements the interface between the 256 Megabyte Optical Disk and the DMA channel assigned to the disk drive. It replaces dozens of chips, and without its development NeXT could not have made the Optical Disk the Computer's standard mass storage device. The OSP includes sophisticated error correction code (ECC) circuitry. ECC hardware ensures the integrity of users' data on the disk, and can correct errors on the fly when reading from the disk.

The chip contains two separate buffers: One stores incoming data from the disk, and the other sends outgoing data via the DMA channel to the computer. Both buffers work simultaneously. As the OSP reads one block of data off the disk, it is also correcting and sending the previous block.

The built-in SCSI controller chip implements the interface to high-speed SCSI devices such as Winchester disk drives, scanners and tape drives. The chip supports SCSI devices at transfer rates up to 4.8 MB per second. Standard options in the NeXT Computer System include 330 MB and 660 MB high-performance SCSI Winchester disks. These inexpensive options for high-performance storage can also be combined with the Optical Disk's capabilities to turn a NeXT Computer System into a network file server.

NEXTSTEP: A GRAPHICAL USER INTERFACE AND DEVELOPMENT ENVIRONMENT

Background

All the computing power in the world means nothing if people cannot reach it. Powerful computers have been too hard to use, and accessible computers have made software development too difficult.

Computer users have had to choose between visual, intuitive user interfaces and power features such as multitasking and built-in networking. The academic community has embraced computer systems based on the UNIX operating system for its versatility and multitasking, making UNIX the standard for higher education and research. Unfortunately, the complexity of UNIX-based computers has put them outside the reach of almost everyone except scientists and engineers.

The traditional approaches to UNIX application development also required software developers to spend an inordinate amount of time developing graphical end-user applications.

NeXT chose Mach, a UNIX-compatible operating system, then created a user interface and object-oriented application development environment called NextStep that addressed the problems of both end users and developers.

NextStep: A User Interface and Development Environment

NeXT has developed the first visual, graphic-based application development and user environment that harnesses the powerful capabilities of multitasking computers for all users and software developers. Through its four components—the Window Server, the Workspace Manager, the Application Kit and Interface Builder—NextStep provides tools that simplify and enhance the work of users and software developers alike.

For the end user, NextStep masks the complexities of the operating system behind a window-based, graphical user interface called the workspace. At the same time, NextStep provides developers with an environment in which they can create innovative and important applications in a fraction of the customary time. And NextStep even provides tools for non-programmers to create their own simple applications or design their own user interfaces.

The User Interface

The workspace is what appears on the screen when the user starts working on the computer. It is controlled by the Workspace Manager, which provides the user with the ability to locate and manage files, display the contents of directories, and launch applications and utilities, all without any knowledge of UNIX. The user can locate files via a directory browser and can display a directory's contents as icons or as a simple listing of names. The workspace features "docking," or the ability to secure up to 12 icons for applications at the righthand side of the MegaPixel Display, for rapid access. Also, at any time, an application's windows and menus can be collapsed into a single icon to place them aside temporarily. The application continues to run, but it no longer takes up space on the screen.

The Workspace Manager is optimized to take advantage of the NeXT Computer System's large-screen MegaPixel Display, as well as the multitasking capabilities of Mach. It lets users move quickly and intuitively from one task to another and navigate easily through the file system. People experienced in UNIX commands can open a shell window if they choose to interact directly with Mach.

The underlying Window Server manages the overlapping windows that appear on the screen and dispatches mouse and keyboard "events" to the application programs. It is based on a client/server architecture, in which the Window Server provides services (i.e., manages the mouse, keyboard and windows) for multiple clients (applications) simultaneously. In such a multitasking environment, all the applications can use the Window Server without interfering with each other.

The Window Server is responsible for all the images that are "drawn" on the screen. It has a built-in PostScript interpreter, developed by Adobe Systems Incorporated in conjunction with NeXT, through which an application draws to the screen just as it does to the printer. As a result, the NeXT Computer System finally delivers on the industry promise of true WYSIWYG.

To display something on the screen, application programs send the Window Server a message in the PostScript language, directing the desired action. Similarly, when the user hits a key on the keyboard or moves the mouse, the Window Server intercepts these events and notifies the appropriate application.

The Development Environment

At the core of NextStep's software development capabilities is the Application Kit. The Application Kit is a set of about 25 software classes, denoting interactive objects such as windows, buttons and scrollers, that allows developers to rapidly construct even complex applications. It combines rich functionality with an easily comprehensible system that is also extensible, so that developers can modify existing objects' capabilities.

Developers build applications by literally picking and choosing objects from the Application Kit, modifying them as necessary, and then connecting them to form their specific application. Using Objective-C®, an object-oriented version of the widely used, high-level C programming language, developers change only those aspects of an object required to meet their specific needs. This contrasts with traditional approaches in which the developer must learn and use literally hundreds of subroutine calls to formulate even a simple application.

Each object in the Application Kit implements a particular functionality. For example, a window object implements the basic functionality shared by all windows, and a text object implements all the capabilities associated with handling text. The objects embody much of what characterizes the NeXT user interface, and their use in applications ensures a consistent interface. They interact with each other via Objective-C messages sent between them. When an object receives a message it carries out a certain action (e.g., a window closes).

The other important component of NextStep's application development environment is Interface Builder, a tool for rapid construction of a graphical user interface for any type of application. It overcomes a historical stumbling block in application development: the inordinate amount of time and software code needed to construct a graphical user interface. Writing software code for the user interface often greatly overshadows the effort to program the algorithms at the heart of an application.

Interface Builder works graphically, requiring minimal programming expertise, to drastically cut overall application development time. In addition, Interface Builder reaches beyond the professional developer, to make application development accessible to users such as university professors, students and researchers.

With Interface Builder, users choose from palettes of generic objects (buttons, windows and so on) that are graphical representations of underlying objects such as those in the Application Kit. They use the mouse to size the objects and locate them anywhere on the screen, and the keyboard to type in labels and titles. Then users assign an "action message" to an object and a target object for the message. For example, when a given button is clicked, the message "save" is sent to a previously programmed target object, which in turn responds by carrying out the procedures necessary to save the appropriate material.

Interface Builder works on objects that have already been programmed. Given a set of these functional objects, non-programmers can connect them to create a customized front end to the underlying application program. A university physics professor, for example, could combine objects from the Application Kit with specialized objects created by a third-party developer or a graduate student to tailor a thermodynamics application in one way for the research lab and in another way for an upper division physics class. Over time, it is expected that users will construct many such domain-specific objects.

The components of NextStep take full advantage of Mach and deliver these advantages to a wider range of users and software developers. Through NextStep, the NeXT Computer System proves that it is possible to combine power and ease of use without making sacrifices to either.

PERSONAL OPTICAL STORAGE AND THE DIGITAL LIBRARY: A COMPUTER WORLD ON A DISK

Background

Visionaries and educators looked at personal computers and saw the potential for opening the world's knowledge to an individual. But their lofty dreams always hit the same roadblock: inadequate mass storage capacities and poor searching and indexing capabilities.

NeXT needed a mass storage device with enormous capacity, yet which also had full read/write/erase capability, was reliable and affordable, and could be removed and easily carried. NeXT has delivered such a device in the 256 Megabyte Optical Disk.

To take full advantage of the storage technology, NeXT also needed a powerful software tool that would grant rapid and simple access to all information in the computer, including documents created by users and electronic mail messages.

The NeXT 256 Megabyte Optical Disk

The NeXT Computer System introduces the world's first removable, read/write/erasable Optical Disk, built-in and standard. Its 256 megabytes (MB) of storage capacity is equivalent to 300 to 400 complete books. It expands the horizons of research, learning and teaching.

The 256 Megabyte Optical Disk, based on a storage technology known as magneto-optics, combines the best features of both CD ROM (laser) and Winchester disk (magnetic) technologies. Like CD ROM, the Optical Disk is removable, reliable and able to store libraries of information efficiently. Like Winchester hard drives, it is fast and has full read/write/erase capabilities.

The disk has three layers: an aluminum surface, a substrate made of an amorphous rare-earth transition-metal alloy and a clear plastic covering. The substrate layer has two important properties: It is translucent, so that light goes through to the aluminum layer and is reflected back, and it has a crystalline structure whose orientation can be changed by an applied magnetic field under certain conditions.

An optical head containing a laser diode, optics and a detector is used to read to, or write from, the disk. Unlike a Winchester drive, in which the magnetic head literally flies over the surface of the disk at a few thousandths of an inch, the optical head is fixed on a track above the disk. As a result, optical drives are inherently more reliable than Winchester drives because the disk can never be damaged as a result of the head "crashing" onto the surface of the disk.

When writing to the disk, a magnetic field is applied and the laser is used to heat up a very small portion of the substrate to its Curie point, the temperature at which it is susceptible to change by the applied magnetic field. When the substrate cools, the crystals remain in that alignment until the next time they are heated beyond their Curie point. In this manner, a '1' or a '0' can be encoded on the disk.

To read from the disk, the same laser is focused, but without the presence of a magnetic field, on the aluminum reflective surface beneath the substrate. The detector in the optical head measures the amount of light reflected back, which in turn depends on the orientation of the crystals. It converts this value into an analog signal which is interpreted as a '1' or a '0'.

Unlike CD ROM or WORM (Write-Once Read-Many) technology, in which the surface of the disk is permanently deformed to indicate a '1' or a '0', information on the NeXT Optical Disk can be erased or modified any number of times. In addition, because the laser is focused beneath the surface of the media, the Optical Disk resists dust and even fingerprints, although it comes in a protective cartridge.

The drive has the same form factor as a 5.25-inch full-height Winchester, and is a standard feature of the NeXT cube. Slots for the disks are located in the front of the cube. The drive features auto-insert and auto-eject to prevent disks from being accidentally removed.

The Digital Library

The NeXT 256 Megabyte Optical Disk makes possible the Digital Library, a term that embraces the visionaries' and educators' ideals. With a Digital Library, users can store on-line versions of complete reference or literary works, plus musical pieces and scores, illustrations and voice recordings. A powerful search and indexing tool, called the Digital Librarian, enables users to "thumb" through memos, mail messages, books and papers, for almost instantaneous access to any textual information, anywhere on the disk.

The NeXT Computer System's search facility lowers the practical barriers that often hinder information searches, both in the real world (libraries closed, books checked out) and on computers (expensive, need to learn search techniques). It is similar to the search and retrieval capabilities of a sophisticated data base with one vital difference: It operates on *all* the text information on the disk, not just data entered specifically into a data base. It allows users to browse rigorously for very specific information or meander from one idea to another, all with immediate results and little effort. And when it locates a reference, it displays the document in its original font and format, rather than in a generic, homogenized form.

A Digital Library could cover areas as diverse as: works of 19th-century English poets; all known DNA sequences, updated monthly, for doing molecular biology research in a simulated recombinant DNA wetlab; the score and music for a Mozart string quartet; speeches given by U.S. presidents; or the location of archaeological digs that have yielded artifacts and skeletal remains of prehistoric humans, plus illustrations and descriptions of the remains.

The NeXT Computer System comes standard with a Digital Library: on-line, complete versions of the *Webster's Ninth New Collegiate Dictionary®* (complete with full definitions, pronunciation, etymology and illustrations), *Webster's Collegiate® Thesaurus, The Oxford® Dictionary of Quotations* and the Oxford University Press® Edition of *William Shakespeare: The Complete Works*, as well as NeXT's complete technical and user documentation and other pertinent technical references.

In all, the Optical Disk represents a major change in the way information is distributed in a desktop computer. With the NeXT Optical Disk, users truly can have their computing world at their fingertips. It is likely that most users will fit all their applications, programs, commonly used reference books, notes, research papers and other material on a single disk. NeXT also expects that third parties will enhance the capabilities of the standard Optical Disk by creating additional Digital Libraries aimed at particular disciplines and areas of interest.

Because the disk is removable, users can carry their computing world with them, either to work at another computer or to ensure the security of their data. The disk cartridge itself measures 6 inches long by 5.25 inches wide, compact enough to carry in a coat pocket.

At less than 25 cents per megabyte, the Optical Disk is the lowest-cost random-access read/write storage media available today. In fact, it is even less expensive than paper. This low cost makes the accumulation of Digital Libraries practical.

While the NeXT Computer System comes standard with the 256 Megabyte Optical Disk, the system's storage can be expanded with a 660 MB or 330 MB high-performance Winchester drive.

SOUND AND MUSIC: OPENING NEW WORLDS OF SIMULATION, COMMUNICATION AND LEARNING

Background

Sound is an integral part of communication and learning. Some people, in fact, learn best when they *hear* something. And everyone can comprehend better when their emotional and personal responses are evoked by sound and visual pathways combined.

Nevertheless, sound has been virtually ignored by all but a few very specialized computers. The technology to produce high-quality sound has existed for years, but was never made part of basic computer design.

NeXT decided that encouraging the development of sound, voice and music applications for all users required making sound capabilities a high priority in the essential design of its computer. As evidence of this priority, the NeXT Digital Signal Processor (DSP) chip holds a prominent place in the NeXT Computer System's fundamental architecture.

Sound on the NeXT Computer System

NeXT built a number of features into its computer to encourage developers to create applications that use sound as a primary communication pathway. Every NeXT Computer System is capable of producing CD-quality stereo output (specifically 44.1 kHz, 16-bit two-channel digital audio) by virtue of circuitry contained in the MegaPixel Display. In fact, the NeXT Computer System uses the same chips that form the basis of most CD players today. A built-in speaker, a stereo headphone jack and line-out jacks for connecting to an audio system are standard features of the Display. The MegaPixel Display also has a microphone jack for voice-quality sound input. Finally, two channels of the ICP are devoted to sound, so that sound I/O does not overload the system and diminish performance.

While these capabilities are impressive, perhaps the key innovation by NeXT was to give a special-purpose processor, the 10 MIPS Motorola 56001 Digital Signal Processor chip, equal weight in the architecture along with the two main processing chips (the Motorola 68030 central processor and the Motorola 68882 Floating-Point Unit).

Digital signal processors are specialized processors whose architectures and instruction sets handle the computing tasks required to analyze digital representations of real-world (analog) data. Digital signal processing has always been considered a function useful to a narrow range of technical applications, such as complicated numerical or spectrum analysis, radar, high-speed communications, and sonar and medical imaging. The idea of a dedicated chip such as the DSP as standard on a general-purpose desktop computer is revolutionary. In practice, the DSP is also ideal for the kind of processing required to synthesize sound and music.

DSP and Sound

Sound can include human voices, music, "nature" sounds or non-musical sounds that accentuate or identify certain patterns being studied, such as changes in gaseous pressure in a closed container or the variations in depth of an underwater valley.

The NeXT DSP chip handles tasks required to manipulate waveforms, including sound and music. These tasks typically involve performing the same operation on a large array of numbers.

Programming a DSP remains a fairly arcane endeavor, so NeXT provides two object-oriented kits to aid developers: the Sound Kit™ and Music Kit™. These kits, along with a bundled suite of array processing routines, allow a developer to tap much of the power of the DSP without programming it directly. The Sound Kit and Music Kit were developed by some of the leading authorities in the field of computer music.

Sound is only one of many applications for the DSP. Others include serving as the basis for a FAX or communications modem; image processing, in which an image must be manipulated and analyzed, as with weather trends or medical imaging; and real-time analysis of laboratory results from various equipment.

Simulations and Other Applications

Educators expect that realistic simulations—involving both visual and auditory components—will be among the computer's greatest contributions to the learning process. Sound is a critical component to implementing realistic simulations, and the DSP's capabilities are crucial to real-time sound.

One immediate application for the NeXT Computer System's sound capabilities is the voice-mail capability of the mail application bundled with the system. Based on UNIX mail, NeXT mail presents a graphical front end and enables users to record and play voice messages as part of their mail messages. The NeXT voice mail has the same quality of voice transmission as a telephone call, except that it goes from one computer to another. The sound is stored and transmitted in a compressed ASCII format that is compatible with standard mail protocols, so it may be sent over networks around the world.

People can make voice annotations part of a document sent via electronic mail. As recipients read the document on the screen, they can hear explanations of pertinent portions, as recorded playback of the sender's own voice. Similarly, researchers such as engineers or social scientists can attach sound as well as graphical representation to their data, thus providing greater insight into hidden trends.

The 256 Megabyte Optical Disk is integral to the sound capabilities of the NeXT Computer System. For example, history, political science or philosophy students studying civil rights could call up the actual speeches given by Martin Luther King, Jr., in his own voice, from a Digital Library. Because sound files are often very large, the mass storage capabilities of the NeXT system are fundamental to these applications.

Disciplines that already depend largely on sound, such as music and language instruction, are obvious beneficiaries of the NeXT Computer System's sound and DSP capabilities.

In the future, computer sound and DSP applications are expected to gain in importance. As research into voice recognition software continues, the ability to recognize and synthesize realistic, individual voice patterns will be increasingly valued as a new interface between people and machines. Also, increased use of real-time simulations will open up new experiences and learning opportunities for people separated by time, distance, money or practical considerations from experiencing an event in person.

PERSONAL POSTSCRIPT® LASER PRINTING

Background

The combination of lower cost laser printer "engines" and PostScript software revolutionized computer printing in the mid-1980s. The quality of 300 dpi output coupled with the power of the PostScript imaging model raised the standard for business and academic documents. But the cost of PostScript printers has generally relegated them to use as shared resources, justifiable only for university departments or company workgroups.

NeXT wanted to make a high-resolution, PostScript laser printer that an individual could afford.

The 400 dpi Laser Printer

With its eight page per minute 400 dpi Laser Printer, NeXT has made a PostScript laser printer that is affordable at the individual level. NeXT Computer System users can avoid the waiting that usually characterizes shared laser printers.

Unlike other laser printers in its price range ($2,000 for higher education), the NeXT 400 dpi Laser Printer includes the power and quality of Adobe's PostScript page description language. PostScript software confers device independence, so that documents can be printed on a variety of printers and typesetting equipment without modification. The NeXT printer adds features previously found only in printers costing up to four times as much.

For example, it is the first printer in its class (i.e., under $10,000) that can produce extremely high-quality output of 400 dots per inch (dpi). This capability provides nearly double the resolution (from 90,000 to 160,000 dots per square inch) of a 300 dpi laser printer. Having more dots in the same space smoothes curved lines and text characters and improves the appearance of gray scales in printed graphics. The printer also has a 300 dpi mode for faster printing.

From the outset, the 400 dpi Laser Printer was designed to function as an integrated component of the NeXT Computer System. As a result, NeXT endowed the printer with extremely sophisticated features, while keeping the price extremely low.

Other PostScript-compatible printers contain a powerful CPU and two or more megabytes of memory in the printer, in addition to the computer's CPU and memory.

The NeXT 400 dpi Laser Printer avoided this duplication, imaging instead directly in the computer's memory. Images to be printed are created in the computer and sent to the printer via a high-speed, custom laser printer port.

Users control the printer from the computer. NeXT removed all lights, buttons, power switches, status messages (e.g., amount of toner left in the cartridge, location of paper jams) and other control features from the printer itself.

Convenience Features

NeXT designed a number of convenience features into the 400 dpi Laser Printer. One advantage of the printer's efficient design is that it consumes approximately 30 percent less power than printers relying on their own CPUs.

Unlike standard laser printers requiring separate trays for different paper sizes, the NeXT printer features a single Universal Paper Tray. This tray adjusts for automatic or manual feeding of paper sizes ranging from A4 size and envelopes to standard letterhead. In addition, the printer has a straight paper path, which allows even envelopes or thick paper to pass through without curling or jamming. And the printer's compact size corresponds more closely to personal dot matrix printers than to current desktop laser printers.

The NeXT 400 dpi Laser Printer automatically shifts to a standby mode if no data is sent to the computer for approximately two minutes. The printer remains on during this phase, but the temperature of its internal heating element (necessary to affix toner to the paper) drops from 180°F to 160°F. This temperature drop during periods of inactivity causes the printer to consume less power overall, helping its internal components last longer and remain more reliable.

Other convenience features include the use of industry-standard toner cartridges and a universal power supply. With this power supply, users need only flip a switch in the printer, and add the proper power cord and plug, to use the printer throughout the world.

SOFTWARE AS PART OF THE SYSTEM

Background

Traditionally, computers have treated hardware and software (apart from operating system software) as related but separate entities. In the NeXT Computer System, hardware and software unite to form a single entity that embodies a new kind of working, researching, learning and application development environment.

As part of its computer system, NeXT includes a great deal of software in the basic system cost.

Software on the NeXT Computer System

The NeXT Computer System, by virtue of its 256 Megabyte Optical Disk and overall architecture, includes a wide array of innovative and useful software as standard.

System Software:

- Mach OS—a multitasking operating system compatible with UNIX 4.3BSD; includes TCP/IP and the standard UNIX utilities as well as Mach extensions
- Sun Microsystem's Network File System™
- System administration tools

Application Development Tools:

- Objective-C® 4.0 preprocessor (The Stepstone Corporation)
- GNU ANSI C compiler (Free Software Foundation)
- GNU C debugger—a source-level debugger with extensions for Objective-C; developed by the Free Software Foundation and NeXT
- Standard Berkeley UNIX 4.3BSD utilities
- Terminal emulator
- Window-based text editor
- GNU Emacs (Free Software Foundation)
- DSP Tools—assembler, debugger and array processing routines

NextStep:

- Window Server, including Display PostScript™ interpreter and fonts
- Application Kit™
- Interface Builder™
- Workspace Manager™

Additional Kits:

- Sound Kit™
- Music Kit™

Applications:

- Digital Librarian™—high-performance software tool for indexing and searching through very large text databases in seconds
- Electronic mail—compatible with standard UNIX mail; features a graphical user interface and the ability to record and play voice mail
- Jot™—a personal text data base manager for storing and retrieving ideas, notes, reminders, pieces of electronic mail, documents, papers and other textual information
- WriteNow™—a full-featured word processing package redesigned specially for the NeXT Computer System
- Mathematica™ (Wolfram Research Inc.)—a numeric, symbolic and graphical system for mathematical computations; with built-in programming capabilities for creating "live notebooks" that mix text, graphics and equations
- NeXT™ SQL Database Server (from Sybase, Inc.)—a powerful transaction-oriented data base server
- Allegro CL® Common Lisp (Franz, Inc.)—a high-productivity, extended Common Lisp programming environment

Digital Library

- *Webster's Ninth New Collegiate Dictionary®*—with full-text indexing, exact and prefix match, spelling checker, a wide range of fonts and hundreds of detailed pictures that take advantage of the resolution of the MegaPixel Display and the imaging strengths of the Display PostScript System
- *Webster's Collegiate® Thesaurus*—one click on the thesaurus icon gives a list of synonyms for any word in the dictionary
- *The Oxford® Dictionary of Quotations*—an indispensable reference book for scholars that makes the full range of quotations more accessible
- Oxford University Press® Edition of *William Shakespeare: The Complete Works*—every play and sonnet by the world's greatest dramatist
- All NeXT technical and user manuals as well as other relevant technical documentation