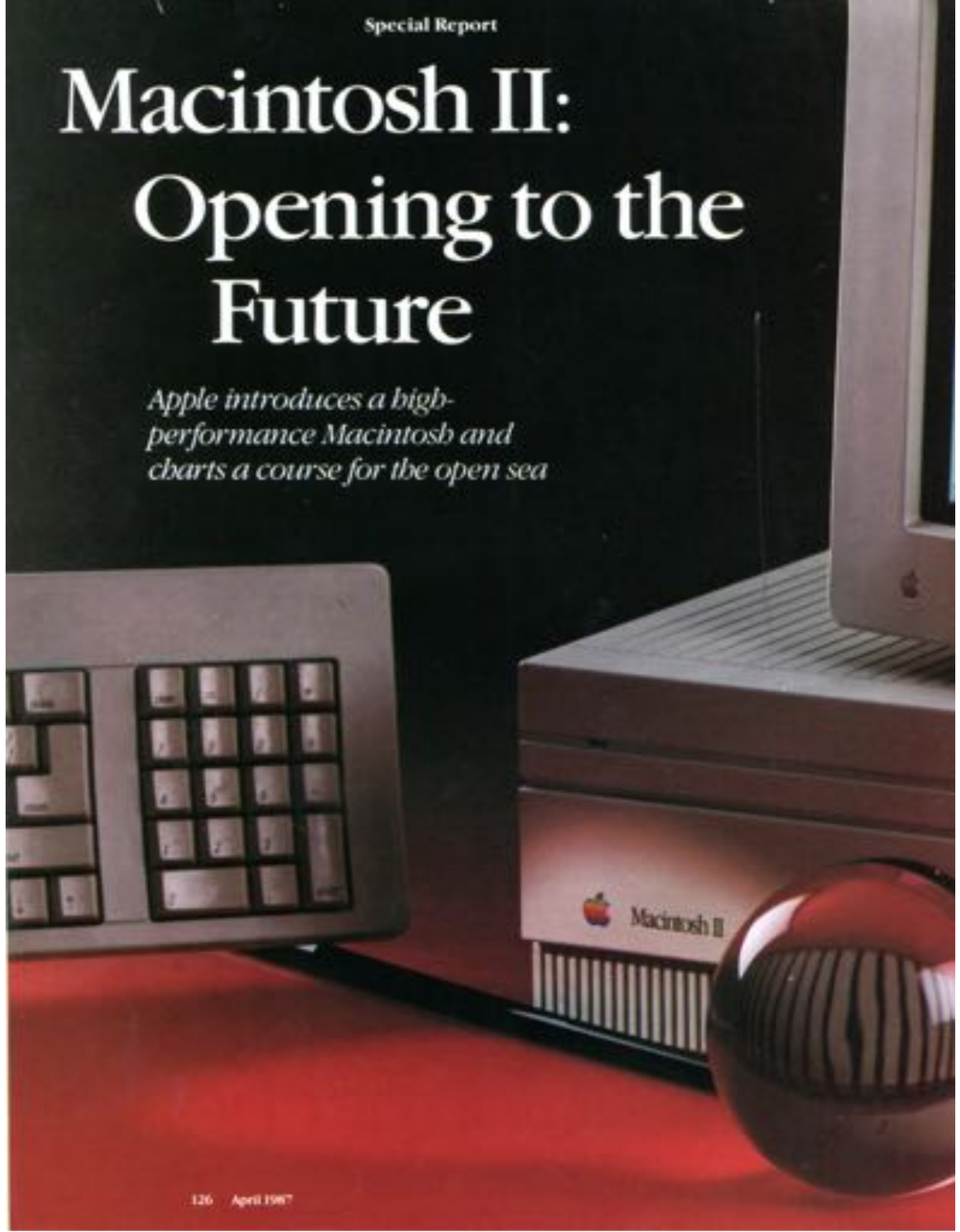
Special Report

Macintosh II: Opening to the Future

Apple introduces a high-performance Macintosh and charts a course for the open sea



by David Ushijima

Start small, then expand. Apple has taken a sound business practice and applied it to the Macintosh. For years, Mac owners have wondered if Apple would ever deliver a Macintosh with a large color screen, more powerful graphics and sound capabilities, and, most of all, slots that would give owners the freedom to expand their machines. Even without these amenities, the Macintosh has established

The Mac II Development Team—I
The Mac II's designers: (back row, from left to right) Michael Blanchard, Bruce Lee, Dave Wilson; (front row) Dave Turnbull, Jennifer Weinstein, Ralph Hastie, Mark Lentczner

The Mac II Development Team—II
The Mac II's designers: (back row, from left to right) Bill Mackenzie, Alan Oppenheimer, Ron Hochsprung; (front row) Brian Berkeley, Toby Farrand, Roy Ashcland, John Medica, Mike Dhuey

itself as the leader in affordable, graphics-oriented personal computers. Now Apple introduces the high-performance Macintosh II and opens up the possibilities of a colorful future—one in which a powerful CPU along with a raft of intelligent coprocessor-based cards and peripherals will define the next generation of personal graphics workstations.

First Look

When you first see the Macintosh II, you'll wonder whether it's really a Macintosh. The machine breaks out of the Mac mold in favor of the more traditional approach—the familiar compact cabinet is gone, and in its place is a handsomely designed base unit and monitor whose sculpturing resembles that of the Apple IIGS. Unfortunately, the base unit leaves a LaserWriter-size footprint, making its presence sorely felt on your desktop.

Because the Mac II sacrifices a small footprint for more space inside the cabinet, it overcomes one of the limitations of its predecessors: internal disk storage. While earlier machines had no provision for a second floppy drive and only limited space for internal hard drives, you can configure the Mac II with either a second 3.5-inch 800K floppy disk drive or an internal 20-, 40-, or 80-megabyte hard disk from Apple. Of course, you can still add external SCSI drives, and with the existing drives from third-party companies, there will be plenty of disk drives to choose from.

Under the Hood

The Macintosh II, powered by a Motorola 68020 running at 16 megahertz, comes standard with the Motorola 68881 floating-point coprocessor. In addition, you get 1MB of RAM, an internal 800K floppy drive, and six expansion slots that conform to the NuBus standard (see "Looking at the NuBus"). To configure a minimal system, you must add a keyboard—you can now choose from two—and a color or monochrome video card and monitor. The video card plugs into the NuBus, so you can add various color or monochrome cards and displays from third-party manufacturers, as well as from Apple. Beyond that, you can add hard disk storage, more memory, and NuBus cards from third-party manufacturers (see "Filling The Slots" in this issue).

With previous Macintosh models, your choices were limited; with the Macintosh II, however, you can choose from an abundance of options. You can configure a minimal system with a monochrome display and floppy disk storage for under $4300; or for under $6000, you can build a color hard disk system that will rival the performance of color workstations costing twice as much.

Horsepower to Spare

Immediately after you press the power switch on the keyboard, you get a tantalizing preview of the goodies to come. The start-up sound I heard could have passed for a chord played by a steel drum quartet (Apple engineers had not decided on a final sound.) The new machine produces stereo sound with amazing clarity, and the machine I used sounded all the more impressive with the addition of two Bose speakers attached to the stereo sound port.

After a few seconds of wondering whether this was a Macintosh or an entirely different animal, I saw the familiar start-up screen followed by the desktop. With all that has changed on the Mac II, it's somehow comforting to know that it is still a Mac at heart. Even the desktop is basically unchanged from its previous incarnation.

Although you can run Apple's UNIX System V operating system (A/UX) or the familiar Mac operating system on the Mac II, you can't run them at the same time (see "An Open Forum" in this issue). Apple foresees a separate market for engineers, scientists, designers, universities, programmers and businesses that need a standard UNIX workstation, while the majority of users will opt for the familiar Mac operating system.

The new Mac I ran had a preliminary version of a revised Finder and System, although they differed little from the Mac Plus Finder and System. The Trash Can bulges when you throw something in it, and the hands of the watch spin while you are waiting—though Apple engineers said that the software shipped with the machine might not implement the spinning hands. The Mac II's Finder menus underwent only minor changes: the Shut Down command now turns the machine off and Restart command has the same effect as pressing the programmer's Reset switch on a Mac Plus. Also, Cleanup Selection and Cleanup Window commands have been added to the Special menu.

Looking at the NuBus

The NuBus, first developed at the Massachusetts Institute of Technology, was later used by Western Digital in the Nu Machine. Subsequently, Texas Instruments incorporated the NuBus into its Explorer artificial intelligence workstation. Representatives from Texas Instruments, MIT, AT&T, and Apple, among others, formed a committee to standardize the bus under the auspices of the Institute of Electrical and Electronic Engineers (IEEE). The NuBus used in the Mac II is actually slightly different from the specification developed by the IEEE Microprocessor Standards Committee.

Exploring the Bus

The NuBus was designed to transfer information, in the form of electrical signals, between elements of a computer system like the CPU, memory, and various controllers. NuBus signals travel synchronously at a rate of up to 10 megahertz. The bus consists of 96 signal lines, including 32 bits of address and data, utility, and control lines, as well as power and ground signals.

One of the strengths of the NuBus is that it defines simple rules, called the bus protocol, by which up to 16 boards, or devices, can coexist on the bus. Apple chose to include only 6 slots in the Mac II.

Unlike boards for the IBM PC expansion bus, the boards you plug into the NuBus slots do not require any address jumpers. In fact, each board includes a configuration ROM that contains information, such as an initialization program and device drivers. The system reads the contents of the configuration ROM and installs the board automatically when you turn on the machine.

Since only one device, called the bus master, can control the bus at any one time, the boards vie for control of the bus through a scheme called bus arbitration. Unlike other bus arbitration methods, the NuBus gives each device a fair chance to become the bus master. Even the Mac II's CPU vies for control of the bus just like any of the six NuBus devices. Because the Mac II's NuBus was designed to coordinate the operations of up to seven processors, including the 68020 on the motherboard, very powerful systems can be built by combining cards with processors dedicated to functions like communications, graphics, and array processing.

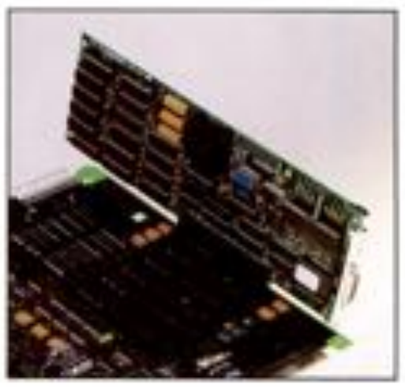
Slots, Super Slots, and the NuBus

Each NuBus card can access the full 4 gigabytes of memory, including the Mac II's program and system RAM. In addition, a NuBus master can control any of the Mac's peripherals: the SCSI port or the AppleTalk or modem port, for example.

The Mac's CPU communicates with the NuBus cards by reading and writing to and from memory locations that have been set aside specifically for the NuBus. When you are running Mac system software, the top 256MB of the 4-gigabyte address space bits, called slot space, are divided into 16 areas of 16MB each. In this mode, Mac software can only access 1MB of the six areas reserved for the Mac II's slots. When the Mac runs 32-bit-mode software, like UNIX, or when a NuBus card has control of the bus, a much larger area, called super slot space, is set aside for each of the six NuBus cards. Each super slot space contains 256MB.

NuBus Slots

By plugging cards into the six NuBus slots, you can expand the basic features of the Mac II. Because the cards are self-configuring, you don't need to set address switches or install special software.



The Mac Shows Its Colors

With the color machine powered up, the only major change you'll notice (and you'll have to look closely) is the small Apple icon displayed in color. Currently the Finder doesn't take full advantage of color. In December, Apple engineers were still finalizing guidelines for the use of color in menus and on the desktop. Until they reach a conclusion, the Finder you'll see on the Mac II will be black and white. However, because the Toolbox has been revamped for color, any application, including future versions of the Finder, can use color.

The Mac II's graphics display depends entirely on the video display card and monitor you choose. Using Apple's 4- or 8-bit color card, you can show off the Mac's screen graphics in either razor-sharp monochrome or color that is nearly photographic in quality (see "A Mac of a Different Color").

I saw several demonstrations of color images that had been digitized on a $15,000 color scanner and then processed on a VAX. Although the images were dithered, they were displayed with incredible clarity and accuracy.

And this is only the beginning. The Mac II's color drawing routines are capable of recording 32 bits per pixel (over 4 billion colors). Because the video card plugs into a NuBus slot, other manufacturers can produce their own cards, which could extend the Mac II's video capabilities to rival the best graphics displays and image processors available today.

Unlike the IBM PC, which can only run graphics applications written for the video card installed, the Mac II's color graphics applications need not know which video card is installed. This is what makes the new Mac so powerful: its color display system is totally independent of the application software.

A Competitive Performer

If you've ever wished for a Macintosh with more speed, you'll have fun keeping up with this one. After I opened a few windows and started two or three applications, the difference in performance was energizing. Windows snapped open and shut, menus responded instantly, and I could scroll through text and graphics documents much faster than I ever could on a Plus. The Macintosh II's 68020 CPU offers at least a fourfold increase in performance over the Mac Plus, and the 68881 coprocessor can implement applications that rely on numeric calculations up to 200 times as quickly. If you use three-dimensional

AppleTalk programs will take advantage of devices attached to the NuBus.

graphics or other calculation-intensive applications, you'll have cause to celebrate.

The new CPU's increase in performance results from its ability to read 32 bits at a time—twice as many as the 68000—and the fact that it runs at twice the speed of the previous generation of Macs. In addition, the 68020 contains a built-in instruction cache, thereby storing 256 of the most recently used bytes in fast memory; and an efficient coprocessor interface that off-loads numeric calculations to the 68881 coprocessor and address translations to the 68851 Memory Management Unit. The Mac II has the power and sophistication that until recently could only be found in a minicomputer or workstation.

Just for the sake of comparison, I ran a few standard benchmarks. Even though the machine I ran had a preliminary version of the system software, the results can give you an idea of the kind of performance to expect. I ran the Whetstone, a test that measures a machine's floating-point performance; the Dhrystone, an overall test consisting of a balanced mix of a CPU's instructions; and the sieve of Erastosthenes, a simple test using integer math, arrays, and branches. The results are shown in Figure 1. An alternative comparison would pit the Mac running UNIX against other machines running the same operating system, but that will have to wait until Apple releases its version of UNIX.

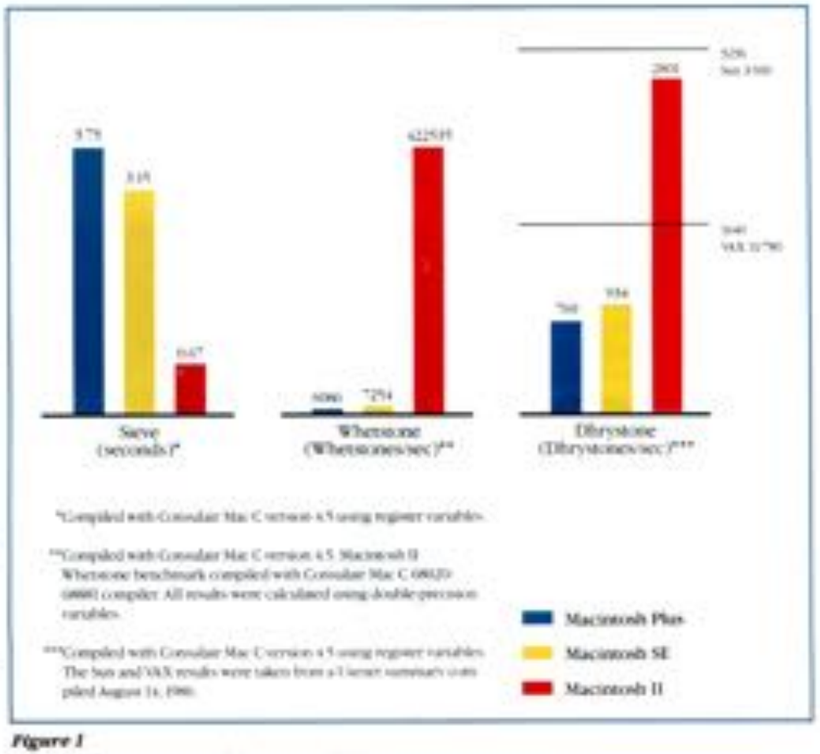


Figure 1
Benchmark comparison of the Macintosh Plus, the Macintosh SE, and the Macintosh II

example, can simulate 125 colors, and 8 bits can simulate 256 colors. In short, the Mac II can display more color with less memory than a similarly equipped IBM PC, which at 4 bits of memory has only 16 colors to display. You have to press your nose close to the screen to see that colors are dithered and not displayed in continuous tones, as with color television.

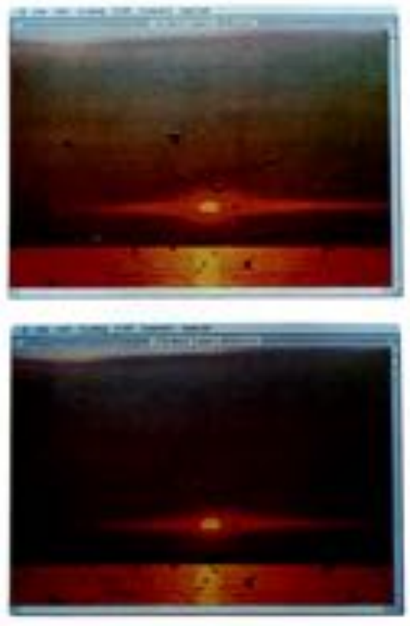
Pix Map is a bit-map extension that describes how pixels are stored. When Pix Map commands are used, other routines, such as Copy Bits, may be applied to multiple bit planes with a single command. Again, the result is more graphics capability from less memory.

It's Smart, but Is It Fast?

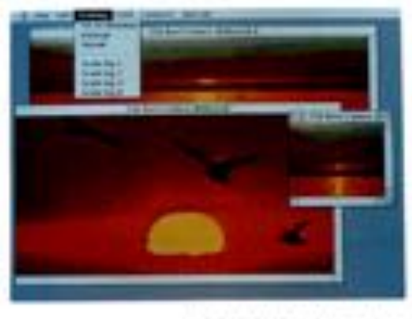
As with previous Macintoshes, the computer's microprocessor processes all graphics functions. The video card supports screen display memory, color, bus arbitration/communications, and alternate video operation modes. This approach diverges from that taken by many "high-performance" graphics cards, such as those supplied for IBM PC-family computers, which have their own graphics microprocessors (see "The Graphic Mac," *Macworld*, November 1986).

Apple defends the decision to burden the microprocessor with all graphics functions, pointing out that the Mac Plus already performs well in areas like drawing speed, even when compared with an IBM PC AT and an IBM-supplied graphics card.

It remains to be seen, however, whether graphics applications, such as mechanical design or animation, will be able to wring sufficient speed from the processor, given all the tasks it must handle. Should secondary processors be supplied for graphics, the high capacity of the NuBus will prove advantageous. Moreover, developers will not be able to rush in with a surfeit of graphics accelerators, as they did in the IBM market, because of the need to adhere to Macintosh resources, and because much of color QuickDraw has been incorporated into 128K of a 256K proprietary ROM. Certainly for graphic arts, some image processing, and paint applications, the existing graphics card is far ahead of any products supplied by IBM for its market. — *Jerry Borrell*



Sunset in Color
Apple's video card enables the Mac II to display images in 16 or 256 colors. The original image from which these screens were computed was digitized using 24 bits of color information per pixel. The top photo was created by replacing each pixel in the original image with the nearest matching pixel chosen from one of 16 colors. The bottom image was created in a similar fashion, using 256 colors.



Dithering for Effect
Although a Mac II equipped with Apple's video card can display up to 256 colors, a technique called dithering, in which neighboring pixels alternate between two available colors, creates the illusion of many more.

GRAPHICS BY MIKE FOSS AND LEON RAPHAN

used in earlier machines still controls the built-in floppy drives. But the revised IWM will be able to read 1.6MB floppies when 1.6MB drives become available.

Peripheral Expansion and Networking

In adding new features to the Mac II, Apple hasn't broken with the Mac's peripheral past. The Mac II still offers the same modem and printer ports for connecting existing serial devices. The only change to the two ports is the addition of a new signal on a previously unused pin. The signal can be used on either port to receive a modem's carrier-detect input, or on the modem port as an external clock signal from a synchronous modem.

The Mac II's AppleTalk implementation has not changed beyond the addition of several new AppleTalk protocols in ROM. According to Apple engineers, the Mac II is compatible with existing AppleTalk hardware and software.

Since the AppleTalk protocol is not tied to the Mac's serial port—the serial port, or physical layer, is independent of the message-passing and connection-oriented protocols of higher layers—AppleTalk programs will be able to take advantage of other AppleTalk devices attached to the NuBus.

By plugging a network card into the NuBus, you will be able to replace AppleTalk's physical layer with a higher-performance layer like Ethernet. Doing so will allow AppleTalk software to take advantage of Ethernet's 10-megabit-per-second transfer rate. AppleTalk normally transfers only 230.4 kilobits per second. The implications will be important, particularly for college and university environments or office-networked machines where, because of the number of networked machines and the heavy communications traffic, users demand a higher throughput than the Mac's built-in printer port can provide. Also, equipped with a communications board, the Mac II can act as a bridge between a local AppleTalk network and a larger, area-wide network like Ethernet or IBM's Token Ring network.

Dueling Keyboards

The Mac II now offers a choice of two keyboards, both of which connect to the Mac via the Apple Desktop Bus (ADB) introduced with the Apple IIGS. You can choose from the standard 81-key unit, which resembles the Apple IIGS keyboard, or an expanded 105-key unit, which includes 15 function keys, a 10-key numeric keypad, and a T-shaped cursor pad.

The ADB, a low-speed serial communications bus, lets you connect up to 16 devices to the Mac II. Currently only the Mac II's keyboard and mouse attach to the ADB, but you can just as easily attach other devices: graphics tablets, trackballs, and speech input devices, for example. Any devices that attach to the Mac II's ADB should work with the Apple IIGS.

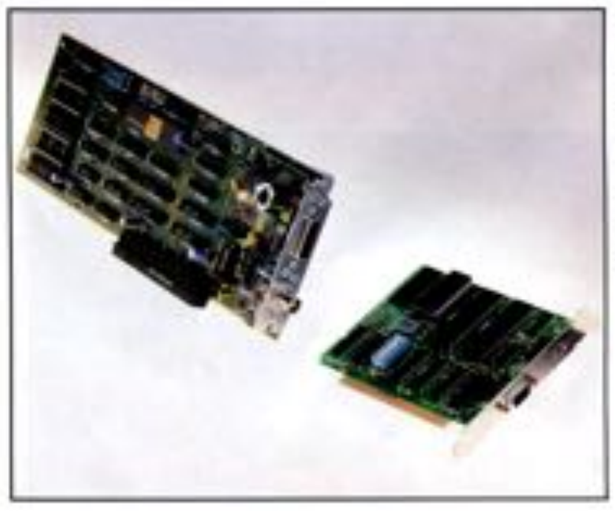
Images that had been digitized on a color scanner were displayed with incredible clarity.

Both the keyboard and the mouse attach to the ADB connectors at the rear of the machine. Alternatively, the mouse can plug into the keyboard. Each device that connects to the ADB has its own microprocessor so that it can send and receive messages to and from the Mac II's CPU.

Music to Compute By

Although the Mac II can't match the 16-voice harmony of the Apple IIGS, it plays a fairly mean tune with its four built-in voices. The Mac II's sound capabilities are based on a custom sound chip designed by Apple's engineers. The Apple Sound Chip (ASC) contains two 1K sound buffers that allow sounds to be played independently of the Mac II's CPU. The ASC feeds two Sony sound chips that handle the filtering and amplification. If you listen through headphones or attach a stereo amplifier or external speakers, you get an unusually clean stereo sound.

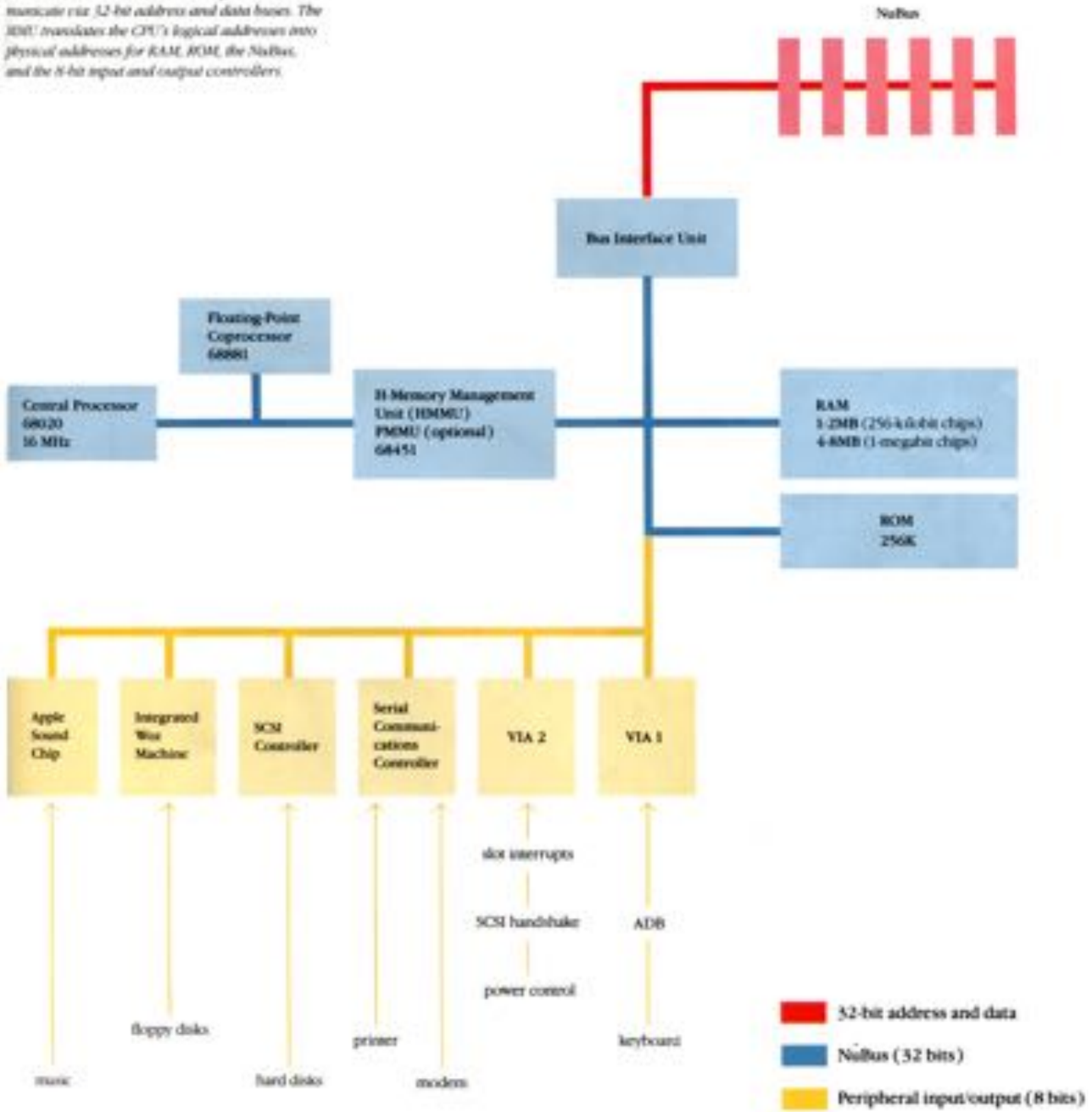
The key to controlling the Mac II's sound is a Toolbox routine called Sound Manager. Just as QuickDraw contains drawing commands that insulate the application program from the graphics hardware, so the Sound Manager insulates sound applications from the sound hardware. Programs that use the Sound Manager will be able to take advantage of NuBus sound cards with no modifications. In fact, musicians and audiophiles will undoubtedly add advanced-function sound boards to give the Mac II professional-quality sound capabilities.

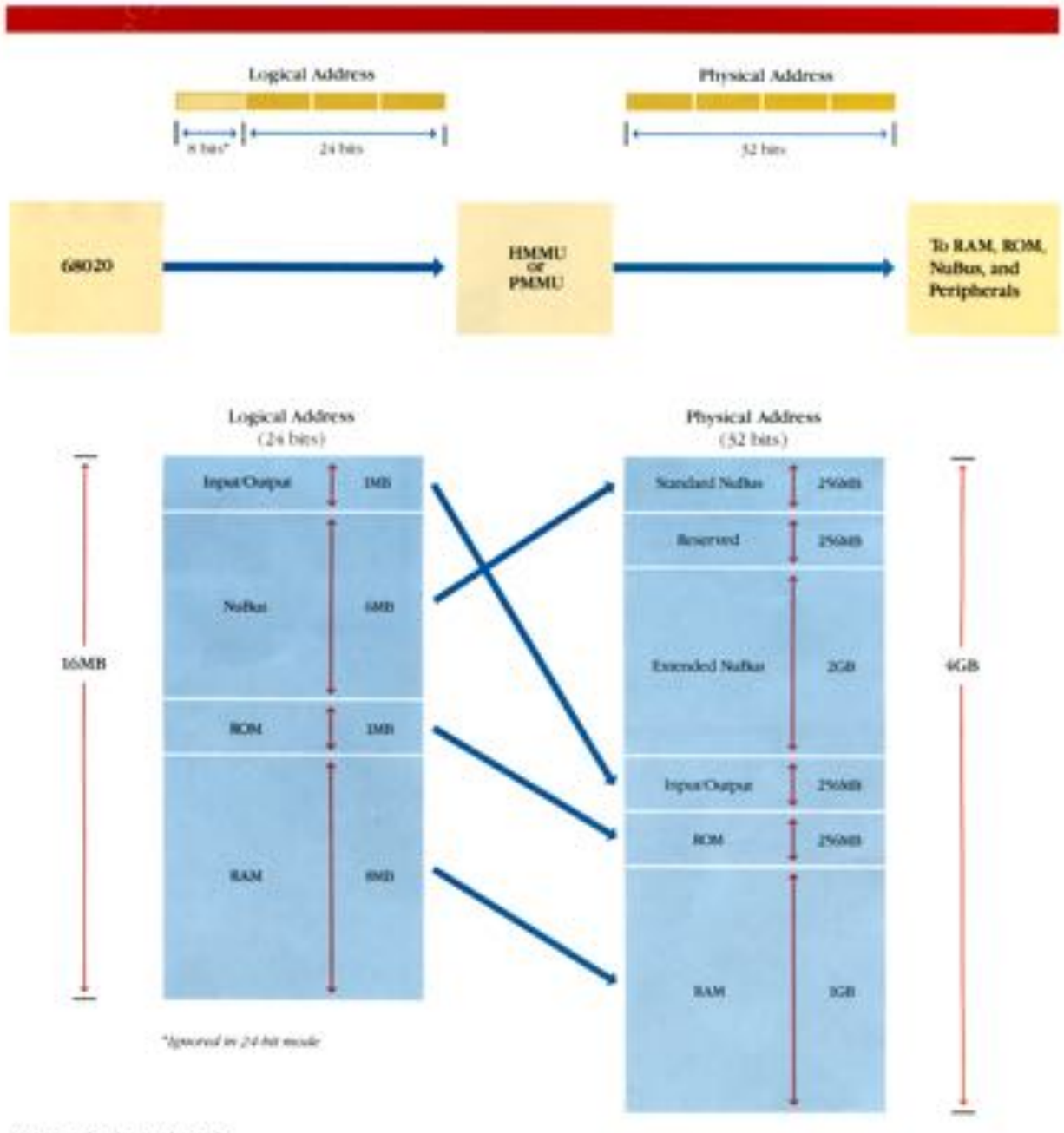


Network Options
For the first time, Mac users will be able to plug in an Ethernet card (left) to send AppleTalk messages over Ethernet. IBM PC users can connect to AppleTalk via Ethernet or the AppleTalk PC card (right).

Looking inside the Mac II

The 68020 CPU and the 68881 coprocessor communicate via 32-bit address and data buses. The HMU translates the CPU's logical addresses into physical addresses for RAM, ROM, the NuBus, and the 8-bit input and output controllers.





*Ignored in 24-bit mode

Mapping the New to the Old

The HMMU or PMMU maps the 24-bit logical addresses into 32-bit physical addresses when the Mac system software is running. This allows existing Mac software to use the 4-gigabyte address space of the Mac II.

you run the machine in 32-bit address mode, it still runs most of the existing Mac software.

The key to the Mac II's compatibility with its predecessors is, of course, the Toolbox—routines stored in ROM. The Mac II now contains 256K of ROM space, twice as much as the Mac Plus has.

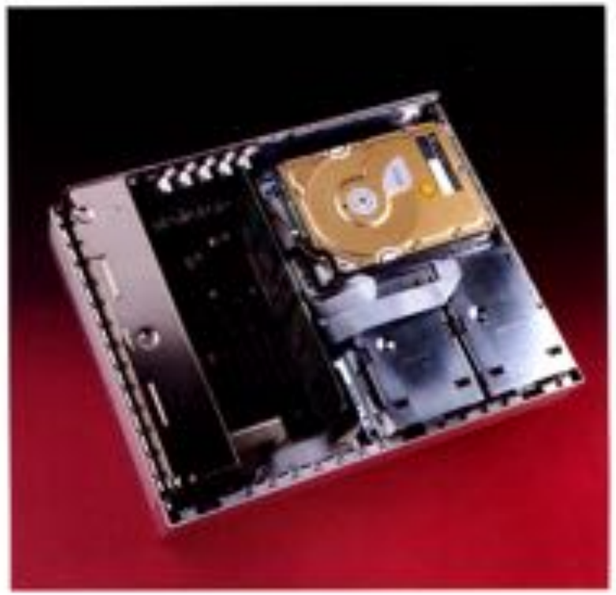
The Mac II's Toolbox contains all the routines the previous 128K ROM contained plus provisions for coloring Mac applications and managing devices that reside in the NuBus slots. In addition to a color QuickDraw, the ROM contains new versions of

- Control Manager, which lets programs use colored dialog boxes and other controls;
- Window Manager, which allows applications to display color windows;
- Menu Manager, which can add color to menus; and
- Text Edit, which lets applications incorporate colored fonts.

To manage the NuBus cards properly, the ROM now contains a new Start Manager and a Slot Manager; even the Device Manager has undergone changes. When you first turn the machine on, the Start Manager tests the Mac II's hardware, then looks for the start-up device. You select the start-up device, a NuBus card or disk drive, from the Control Panel. The Slot Manager uses the Device Manager to read in the resources stored on the NuBus card's configuration ROM. This may be a driver or start-up code. Additionally, the Device Manager can route information to a NuBus card.

The Standard Apple Numerics Environment (SANE), also in the ROM, has been completely rewritten for the 68881 coprocessor and is ten times faster than previous versions. Math operations that previously relied upon SANE routines now are routed to the math coprocessor. Programs compiled with tools like Apple's MPW assembler and Pascal, Consulair's (68020) C compiler, or Absoft's (68020) Fortran run even faster, since they access the 68881 directly. (See "New Ways to a Faster Mac," *Macworld*, August 1986).

The Mac II's ROM also contains code for the AppleTalk, Session, and Echo protocols, as well as the recently defined AppleTalk Filing Protocol. The routines for the ADB also reside in the ROM. Whatever space is left is filled with foreign-language fonts and other resources, depending on the localized version of the machine shipped.



Under the Hood

Lifting the top off the Mac II reveals its internal disk drives (shown here with the optional second floppy drive and hard disk installed). You install the NuBus cards in the slots to the left of the disk drives. The power supply is located on the far left.

Developers can take the machine in a thousand different directions.

One to Grow On

Continuity has been the hallmark of the most successful computers. Mainframes like IBM's System 370, as well as personal computers like the IBM PC and the Apple II, owe their longevity to their ties with a series of machines that offered users a range of performance options without abandoning the growing base of existing software.

The Macintosh II now gives the Macintosh user room to grow. Mac Plus and Mac SE owners looking for a higher performance alternative will no doubt turn to the Mac II. And they can do so without sacrificing their existing software.

The Macintosh II will appeal to users needing more power than previous models can offer. Graphic designers will benefit from the Mac II's color and improved displays. Scientists, engineers, and business users will revel in the Mac II's processing power and expansive memory.

The one feature the Mac II doesn't offer is the ability to run more than one application simultaneously while using the current Macintosh system software. By adding intelligent NuBus cards, however, you may be able to download files from another computer or print a document in the background. And although UNIX provides a multiuser and multitasking environment of its own, currently you can't run Mac applications under UNIX.

Perhaps the most significant addition to the Mac II is the NuBus. Because Apple finally opened up the machine, developers can take it in a thousand directions, something that Apple alone could not do. The NuBus's simple yet powerful approach to coprocessing will pave the way for much more powerful and complex add-on products. The beauty of it all is that any added complexity will be hidden behind the familiar Macintosh interface. □

For details about new Apple products, see your local Apple dealer.