Developer Note

PowerBook Computer

Developer Note

Technical Publications

Apple Computer, Inc.
1 Infinite Loop
Cupertino, CA 95014
408-996-1010

Simultaneously published in the United States and Canada.

Contents

Chapter 4 Expansion Features 75

Chapter 5 System Software 93

Figures and Tables

About This Developer Note

This developer note is a technical description of the new PowerBook computer , with the emphasis on the features that are new or different from those of earlier PowerBook computers.

This developer note is intended to help hardware and software developers design products that are compatible with the Macintosh products described here. If you are not already familiar with Macintosh computers or if you would like additional technical information, you may wish to read the supplementary reference documents described in this preface.

Contents of This Note

The information in this note is arranged in five chapters and an appendix.

- Chapter 1, "Introduction," introduces the new PowerBook computer and describes its features.
- Chapter 2, "Architecture," describes the internal logic of the computer, including the main ICs that appear in the block diagram.
- Chapter 3, "Devices and Ports,"describes the standard I/O ports and the built-in I/O devices.
- Chapter 4, "Expansion Features," describes the expansion features of interest to developers. It includes development guides for expansion-bay devices, the RAM expansion modules, and the PC Card slot.
- Chapter 5, "System Software," describes the system software that comes with the computer, with emphasis on the new Open Firmware features.
- Appendix A is a list of the abbreviations used in this developer note.

Supplemental Reference Documents

For more information about the technologies mentioned in this developer note, you may wish to consult some of the following references.

3D Graphics

Developers of 3D graphics for games should know about OpenGL® for Macintosh®, a new version of SGI's application programming interface (API) and software library for 3D graphics.

Information is available on the World Wide Web at

http://www.apple.com/opengl

Developer support and documentation is available at

http://developer.apple.com/opengl/

If you are interested in taking advantage of the 3D graphics acceleration features available on the graphics card, you should have *3D Graphics Programming With QuickDraw 3D.* The current documentation for QuickDraw 3D is part of the QuickTime documentation and is available on the World Wide Web at

http://developer.apple.com/techpubs/quicktime/qtdevdocs/QD3D/qd3d_book.htm

RAM Expansion Modules

The new PowerBook computer uses PC100 compliant, 144-pin DRAM SO-DIMMs. The mechanical characteristics of the DIMM are given in the JEDEC specification for the 144-pin 8-byte DRAM SO-DIMM. The specification number is JEDEC MO-190-C; it is available from the Electronics Industry Association's web site, at

http://www.jedec.org/download/default.htm

The electrical characteristics of the DIMM are given in section 4.5.6 of the JEDEC Standard 21-C, release 7. The specification is available from the Electronics Industry Association's website at

http://www.jedec.org/download/pub21/

The RAM DIMMs are required to be PC100 compliant. The PC100 specification is available from Intel's website at

http://developer.intel.com/design/chipsets/memory/sdram.htm#S1

PowerPC G3 Microprocessor

For more information about the PowerPC 750™ microprocessor used in the PowerBook computer, you may wish to refer to the standard reference, *PowerPC 740/750 Microprocessor Implementation Definition Book IV.* Information about the PowerPC 750 and other G3 microprocessors is also available on the World Wide Web at

http://www.mot.com/SPS/PowerPC/index.html

http://www.chips.ibm.com/products/powerpc/

Mac OS 9

For a description of the version of the Mac OS that comes with the new models, you should refer to the technote for Mac OS 9. Other technotes contain information about the NewWorld software architecture and the API changes for Power Manager 2.0 referred to in Chapter 5, "System Software." The technotes are available on the Technote website at

http://developer.apple.com/technotes/

You should also have copies of the relevant books describing the system software for Macintosh computers available in technical bookstores and on the World Wide Web at

http://developer.apple.com/techpubs/mac/mac.html

ATA Devices

For information about the system software for ATA devices such as the IDE drive, see *ATA Device Software for Macintosh Computers.* That book is available on the reference library issue of the developer CD (June, 1999) and on the World Wide Web at

http://developer.apple.com/techpubs/hardware/DeviceManagers/ata/ata_ref/frameset.html

The implementation of the ATA interface on this computer is a subset of the ATA/ATAPI-4 specification (ANSI NCITS 317-1998 AT Attachment - 4 with Packet Interface Extension). That specification is maintained by the National Committee on Information Technology Standards (NCITS) Technical Committee T13; more information is available on their website at

http://www.t13.org/

USB Interface

For more information about USB on the Macintosh computer, you should refer to Apple Computer's *Mac OS USB DDK API Reference.* Information is also available on the World Wide Web, at:

http://developer.apple.com/techpubs/hardware/DeviceManagers/usb/usb.html

USB game controllers are supported by the InputSprocket component of the Apple Games Sprockets software architecture. InputSprocket software and information about the InputSprocket APIs can be found at

http://developer.apple.com/games/

For full specifications of the Universal Serial Bus, you should refer to the USB Implementation Forum on the World Wide Web, at:

http://www.usb.org/developers/index.html

FireWire Interface

For additional information about the FireWire IEEE 1394a interface and the Apple APIs for FireWire software, refer to the resources available on the Apple FireWire website at

http://www.apple.com/firewire/

The IEEE 1394a draft standard is available from the IEEE; you can order that document electronically from the IEEE Standards Department website at

http://standards.ieee.org/catalog/bus.html

You may also find useful information at the 1394 trade association's website at

http://www.1394ta.org/

ROM-in-RAM Architecture

The system software in all current Macintosh computers uses a ROM-in-RAM approach, also called the New World architecture, as described in Chapter 5, "System Software." For more information about this architecture, see Technote 1167, *NewWorld Architecture,* available on Apple's technote website at

http://developer.apple.com/technotes/tn/tn1167.html

Open Firmware

The ROM-in-RAM software architecture follows some of the standards defined by the Open Firmware IEEE 1274-1994 specification and the CHRP binding.

The primary Open Firmware reference is the *IEEE 1275-1994 Standard for Boot (Initialization, Configuration) Firmware: Core Requirements and Practices.* You can order that document electronically from the IEEE Standards Department website at

http://standards.ieee.org/catalog/bus.html

or you can order it by mail from

IEEE Standards Department
445 Hoes Lane, P. O. Box 1331
Piscataway, NJ 08855-1331
Telephone 800-678-4333 (US), 908-562-5432 (International)

The basis for the bootinfo file format and use is described in the document *PowerPC Microprocessor Common Hardware Reference Platform (CHRP) System Binding to: IEEE Std 1275-1994 Standard for Boot (Initialization, Configuration) Firmware.* A bootinfo file contains Open Firmware script, a description, information for individual operating systems, icons, along with other information.

An introduction to Open Firmware as used with PCI expansion cards on the Macintosh computer is given in *Designing PCI Cards and Drivers for Power Macintosh Computers.*

Three technotes provide additional information about Open Firmware on the Macintosh computer. They are

- *TN 1061: Open Firmware, Part I*, which introduces Forth programming, describes a typical device tree, and outlines a technique for debugging Open Firmware drivers. It is available on the Technote website at http://developer.apple.com/technotes/tn/tn1061.html
- *TN 1062: Open Firmware, Part II*, which describes the contents of an expansion ROM for Open Firmware and lists properties common to all device types. It is available on the Technote website at http://developer.apple.com/technotes/tn/tn1062.html
- *TN 1044: Open Firmware, Part III*, which describes a typical device tree. It is available on the Technote website at: http://developer.apple.com/technotes/tn/tn1044.html

Additional information about Open Firmware is provided at Apple's developer Q&A site

http://developer.apple.com/qa/hw/hw-1.html

CHAPTER 1

Introduction

The new PowerBook computer resembles the previous PowerBook G3 Series 1999 but has a new internal design that supports more powerful features. This chapter summarizes the features of the PowerBook computer and addresses issues affecting compatibility with older machines and software.

Features

Here is a list of the features of the PowerBook computer. Each feature is described in a later chapter, as indicated in the list.

- **Processor:** The computer has a PowerPC G3 microprocessor running at a clock speed of 400 or 500 MHz. For more information, see "G3 Microprocessor" (page 30).
- **Cache:** The computer has a backside L2 cache consisting of 1 MB of fast static RAM. The ratio of the microprocessor and backside cache clock speeds is 5:2. See "Backside Cache" (page 31).
- **RAM:** The computer has two standard SO-DIMM expansion slots for SDRAM modules. The computer comes with 64 or 128 MB of SDRAM installed. RAM is expandable up to 512 MB total, using currently available memory devices. See "RAM Expansion Slots" (page 85).
- **ROM:** NewWorld ROM-in-RAM implementation with 1 MB of boot ROM. For information about the ROM, see "Boot ROM" (page 32). For information about the ROM-in-RAM implementation, see "ROM in RAM" (page 94).
- **Hard disk storage:** The computer has a built-in hard disk drive with a capacity of 6, 12, or 18 GB. For more information and developer guidelines for alternative hard drives, see "Hard Disk Drive" (page 49).
- **Display:** The computer has a 14.1-inch TFT display with XGA resolution (1024 x 768 pixels). See "Flat Panel Display" (page 64).
- **External monitor:** All configurations support dual displays, with a standard VGA video connector for an external video monitor with resolution up to 1280 by 1024 pixels and an S-video connector for PAL and NTSC video monitors. See "External Monitors" (page 65).
- **Video RAM:** The ATI RAGE Mobility 128 graphics controller contains 8 MB of video SDRAM, which supports millions of colors on the internal display or an external monitor. See "Video Display Subsystem" (page 33).

- **Graphics acceleration:** The ATI RAGE Mobility 128 graphics controller provides 2D and 3D acceleration. For more information, see "Video Display Subsystem" (page 33).
- **Battery bays:** The computer has two battery bays, one on either side. The computer can operate with the AC power adapter or with one or two batteries installed. Each battery uses lithium ion cells and provides 50 Watt-hours at a nominal 10.8 V.
- **Expansion bay:** The battery bay on the right side of the computer is also an expansion bay for a DVD drive or other IDE devices. Storage devices in the expansion bay can be removed and replaced while the computer is operating. For more information, see "Expansion Bay" (page 76).
- **DVD-ROM drive:** The computer is shipped with a DVD-ROM drive installed in the expansion bay. The drive can also read DVD-RAM disks. For more information, see **"DVD-ROM Drive" (page 55)**.
- **CardBus slot:** The computer has a CardBus slot that accepts one Type I or Type II PC card or CardBus Card. For more information, see "CardBus Slot" (page 92).
- **USB ports:** The computer has two USB ports for an external keyboard, a mouse, and other USB devices, described in "USB Ports" (page 40).
- **FireWire ports:** The computer has two IEEE-1394a high-speed serial FireWire ports, which support transfer rates of 100, 200, and 400 Mbps. For more information, see "FireWire Ports" (page 43).
- **Modem:** The computer has a built-in modem with 56 Kbps data rate and V.90 support. For more information, see "Internal Modem" (page 46).
- **Ethernet:** The computer has a built in Ethernet port with an RJ-45 connector for 10Base-T and 100Base-TX operation. For more information, see "Ethernet Port" (page 45).
- **Infrared link:** The computer has an IrDA infrared link capable of transferring data at up to 4 Mbits per second. For more information, see "Infrared Communication Link" (page 49).
- **Wireless LAN:** An AirPort Card wireless LAN module is available as a configure-to-order option or as a user-installable upgrade. For more information, see "AirPort Card Wireless LAN Module" (page 47).

- **Sound:** The computer has a built-in microphone and stereo speakers as well as a line-level stereo input jack and a stereo headphone jack. See "Sound System" (page 70)
- **Keyboard:** The keyboard has an embedded numeric keypad and inverted-T arrow keys. Some of the function keys are used to control the display brightness and speaker volume; the other function keys are programmable by the user. See "Keyboard" (page 56).
- **Trackpad:** The integrated flat pad includes tap/double tap and drag features. For more information, see "Trackpad" (page 56).
- **Weight:** The computer weighs 2.8 kg (6.1pounds).
- **Size:** The computer is 322.6 mm (12.7 inches) wide, 264.2 mm (10.4 inches) deep, and 43.2 mm (1.7 inches) thick.

Appearance

The PowerBook computer has a steamlined enclosure that opens up like a clamshell. Figure 1-1 is a front view of the computer. Figure 1-2 is a back view showing the I/O ports.

Figure 1-1 Front view of the computer

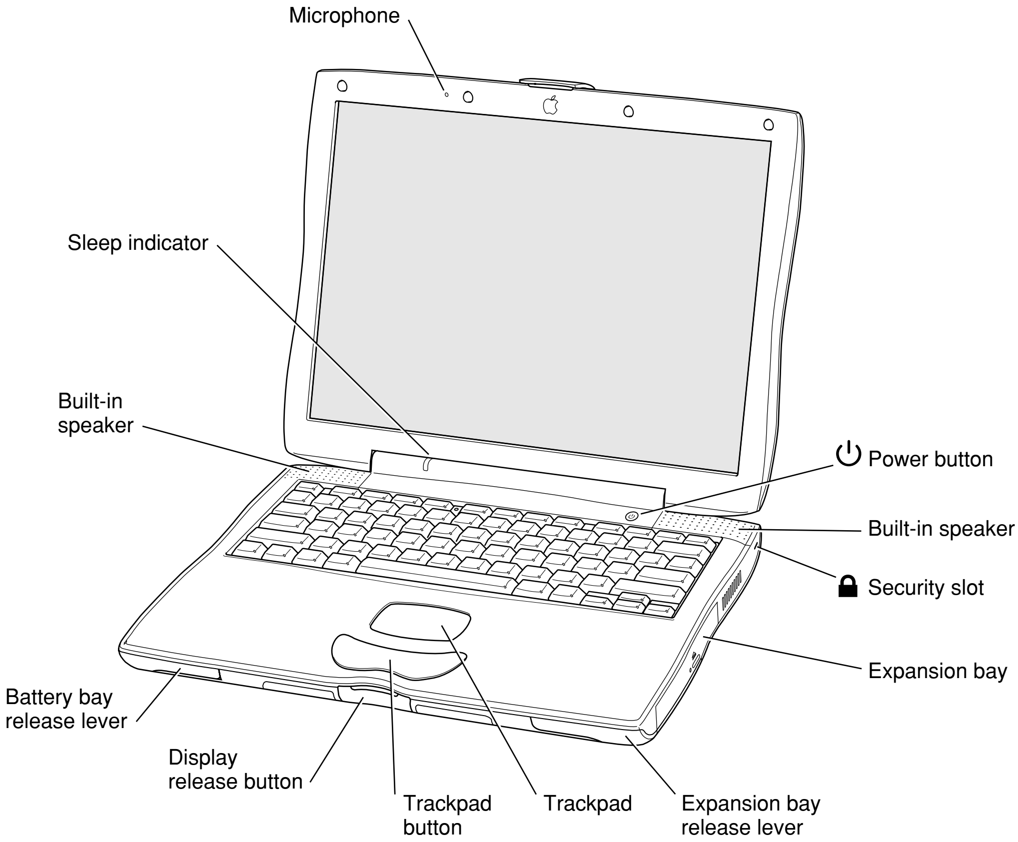
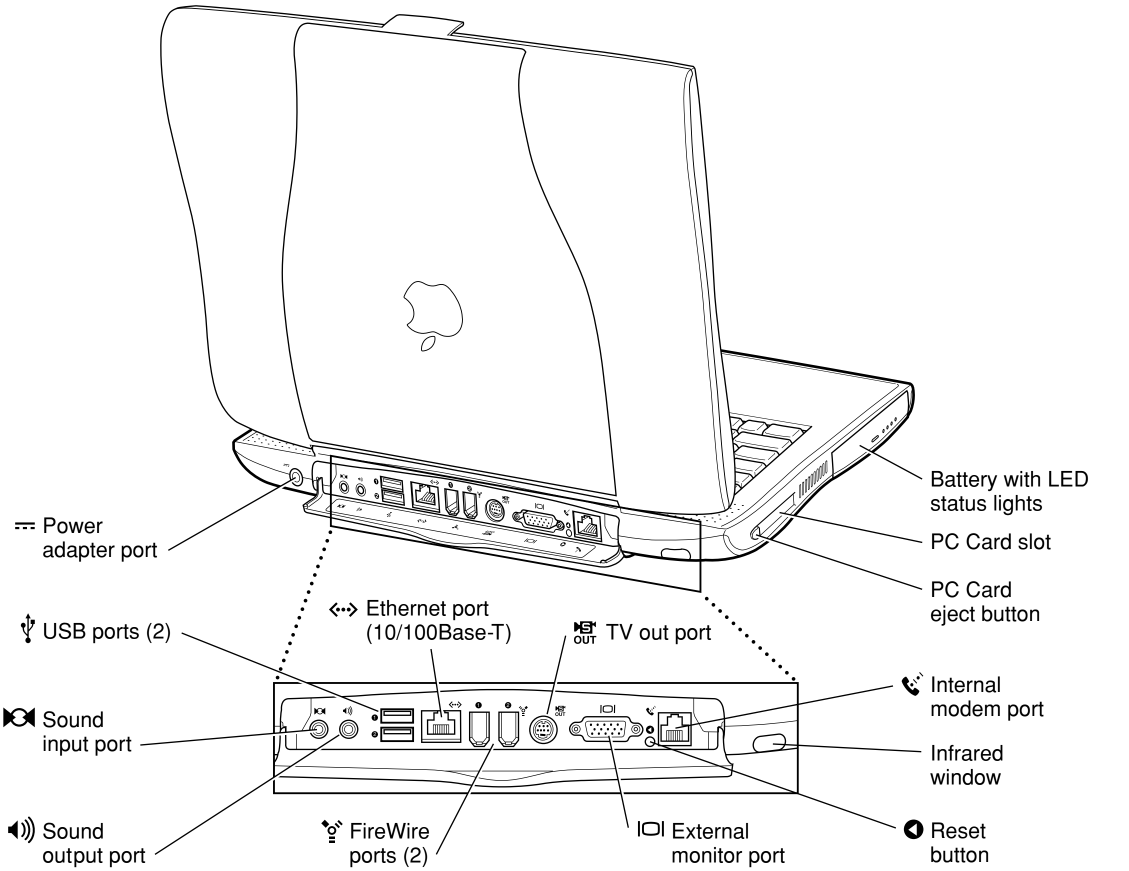


Figure 1-2 Back view showing I/O ports



Peripheral Devices

In addition to the devices that are included with the computer, several peripheral devices are available separately:

- The AirPort Card wireless module is available separately as a user-installable option.

- The AirPort Base Station is available separately for use with one or more AirPort-enabled computers.
- The PowerBook Intelligent Lithium Ion Battery is available separately as an additional or replacement battery.
- The PowerBook 45W AC Adapter, which comes with the computer, is also available separately. The adapter can recharge the internal battery in four hours while the computer is running or in two hours while the computer is shut down or in sleep mode.

Compatibility Issues

While the PowerBook computer has many new features, there should be no compatibility problems with applications and peripherals that operate correctly with earlier PowerBook G3 Series models, with the exceptions described in this section.

SCSI Port Not Present

The PowerBook computer does not have a SCSI port. Any software designed to communicate directly with a SCSI device will not run properly. It is possible that USB converters will be able to support some of those devices. Software that communicates with the SCSI manager will be supported; see “SCSI Legacy” (page 104).

Earlier PowerBook G3 Computers

The new PowerBook computer is not the same as the PowerBook G3 Series 1999 or earlier PowerBook computers. An article in Apple’s Tech Info Library (TIL) discusses ways to tell these computers apart. You can read the article on the World Wide Web at:

http://til.info.apple.com/techinfo.nsf/artnum/n24604

Expansion Bay Modules

The expansion bay in the PowerBook computer is the similar to the one in the PowerBook G3 Series 1999 computers (sometimes called the bronze PowerBook). For more information, see "Mechanical Design of Expansion Bay Modules" (page 76).

RAM Expansion Modules

For RAM expansion, the PowerBook computer uses PC100-compliant SO-DIMMs that contain SDRAM devices. For information, see "RAM Expansion Slots" (page 85).

IMPORTANT

Unlike earlier PowerBook models, the new PowerBook computer requires PC100-compliant RAM expansion modules. SO-DIMMs that are not PC100-compliant will not work. ▲

AppleVision Display

The AppleVision display uses an ADB connection for computer calibration of the display. The PowerBook computer has no ADB port, and the USB-to-ADB adapter does not work in this capacity, so the user cannot use system software to calibrate the display. The user can still adjust the display manually.

System Software

The PowerBook computer has newly designed system software that provides Open Firmware booting and Mac OS ROM in RAM. The system software is described in Chapter 5.

The system software that comes with the PowerBook computer is Mac OS 9 with the addition of the extensions and control panels required for product-specific features. For a description of the general Mac OS 9 release, developers should refer to the Technote for Mac OS 9. The technote is available on the Technote web site at

http://developer.apple.com/technotes/

Machine Identification

With the ROM-in-RAM system software, it is no longer possible to use the box flag to identify the computer model. For guidelines about machine identification, see “Computer Identification” (page 99).

CHAPTER 2

Architecture

This chapter describes the architecture of the PowerBook computer. It includes information about the major components on the main logic board: the microprocessor, the other main ICs, and the buses that connect them to each other and to the I/O interfaces.

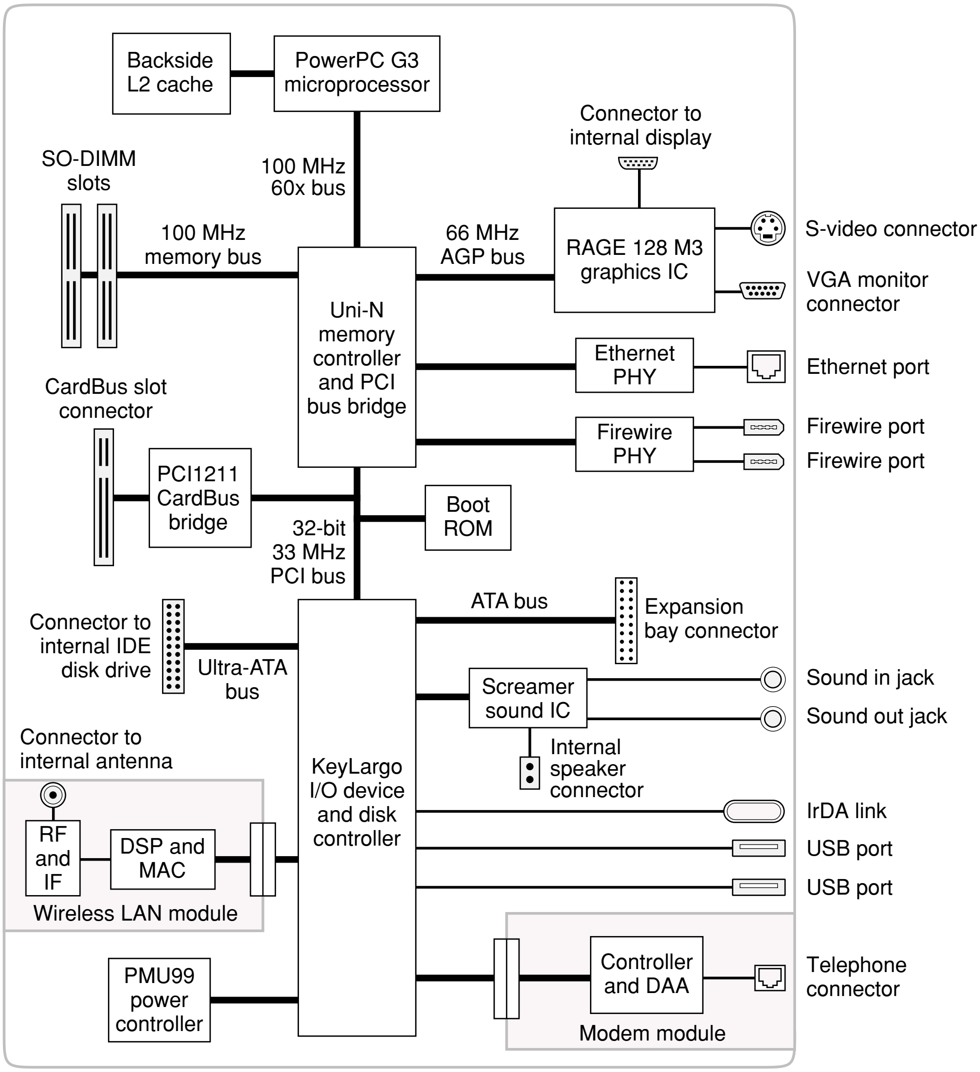
Block Diagram and Buses

This section is an overview of the major ICs and buses on the computer's main logic board.

Block Diagram

Figure 2-1 is a simplified block diagram of the main logic board. The diagram shows the main ICs and the buses that connect them together.

Figure 2-1 Block diagram



Main ICs and Buses

The architecture of the PowerBook computer is designed around the PowerPC G3 microprocessor and two new custom ICs: the Uni-N memory controller and bus bridge, and the KeyLargo I/O device controller. Those three ICs occupy the center of the block diagram.

The PowerPC G3 microprocessor is connected to the Uni-N memory controller and bus bridge IC by a 60x bus with 64 data lines and a bus clock speed of 100 MHz. The Uni-N IC has other buses that connect with the KeyLargo IC, the main system RAM, and the graphics IC. The buses implemented by the Uni-N IC are summarized in Table 2-1, which is in the section “Memory Controller and Bus Bridge”.

The Uni-N IC is connected to the KeyLargo I/O controller IC by a 32-bit PCI bus with a bus clock speed of 33 MHz. That bus also connects to the Boot ROM. The KeyLargo IC has other buses that connect with the hard disk drive and the CD-ROM or DVD-ROM drive, the power controller IC, the sound IC, the internal modem module, and the optional wireless LAN module.

Each of the components listed here is described in one of the following sections.

Microprocessor and Cache

The microprocessor communicates with the rest of the system by way of a 100-MHz, 64-bit 60x bus to the Uni-N IC. The microprocessor has a separate backside bus to its second-level cache.

G3 Microprocessor

The processor in the PowerBook computer is a PowerPC G3 microprocessor. The PowerPC G3 microprocessor has several features that contribute to superior performance, including:

- large on-chip (L1) caches, 32 KB each for instruction cache and data cache
- a built-in cache controller and cache tag RAM for the second level (L2) cache
- a separate backside bus for the L2 cache, providing faster clock speed and overlapped bus transactions
- a microprocessor core optimized for Mac OS applications

The PowerPC G3 microprocessor in the PowerBook computer runs at a clock speed of 400 or 500 MHz.

Backside Cache

The data storage for the backside L2 cache consists of 1 MB of fast static RAM on the processor module. The controller and tag storage for the backside cache are built into the microprocessor. The cache controller includes bus management and control hardware that allows the cache to run at a sub-multiple of the processor's clock speed, rather than at the clock speed of the main system bus. The ratio of the clock speeds of the microprocessor and the backside cache is 5:2.

Memory Controller and Bus Bridge

The Uni-N memory controller and bus bridge IC provides cost and performance benefits by combining several functions into a single IC. It contains the memory controller, the PCI bus bridge, the Ethernet and FireWire interfaces, and the AGP port.

In addition to the four buses listed in Table 2-1, the Uni-N IC also has separate interfaces to the physical layer (PHY) ICs for Ethernet and FireWire and an I^2C interface that is used for configuring the memory subsystem.

Table 2-1 Buses supported by the Uni-N IC

Name of bus	Destinations	Width of data path	Bus clock speed
60x bus	Microprocessor	64 bits	100 MHz
Memory bus	System RAM	64 bits	100 MHz
PCI bus	KeyLargo IC and Boot ROM	32 bits	33 MHz
AGP port	Graphics IC	32 bits	66 MHz

The microprocessor and the I/O controller IC are described in their own sections. The following sections describe the other subsystems that are connected to the Uni-N IC.

System RAM

The memory subsystem in the PowerBook computer supports two slots for 144-pin SO-DIMMs (small-outline dual inline memory modules). The data bus to the RAM and DIMM is 64 bits wide, and the memory interface is synchronized to the 60x bus interface at 100 MHz. See “RAM Expansion Slots” (page 85).

Boot ROM

The boot ROM is connected to the Uni-N IC by way of the PCI bus plus three additional control signals: chip select, write enable, and output enable. The boot ROM is a 1 M by 8 bit device.

FireWire Controller

The Uni-N IC includes an IEEE 1394a FireWire controller with a maximum data rate of 400 Mbits (50MB) per second. The Uni-N IC provides DMA (direct memory access) support for the FireWire interface.

The controller IC implements the FireWire link layer. A physical layer IC, called a PHY, implements the electrical signalling protocol of the FireWire interface. The PHY supports two FireWire ports by way of external connectors in the I/O bay.

The computer is capable of accepting external power through the FireWire connector to operate the PHY when the computer is turned off. While the PHY is operating, it acts as a repeater from one port to another so that the FireWire bus remains connected. For more information, see “FireWire Connectors” (page 43).

Ethernet Controller

The Uni-N IC includes an ethernet media access controller (MAC) that implements the Link layer. As a separate channel connected directly to the Uni-N IC, it can operate at its full capacity without degrading the performance of other peripheral devices. The Uni-N IC provides DB-DMA support for the Ethernet interface.

The controller is connected to a PHY interface IC that is capable of operating in either 10-BaseT or 100-BaseTX mode. The actual speed of the link is automatically negotiated by the PHY and the bridge or router to which it is connected. For more information, see "Ethernet Port" (page 45).

Video Display Subsystem

The graphics controller IC is an ATI RAGE Mobility 128. Along with 8 MB of on-chip SDRAM, the graphics IC contains 2D and 3D acceleration engines, front-end and back-end scalers, a CRT controller, and an AGP 2X bus interface with bus master capability.

The features of the RAGE Mobility 128 include

- 8 MB of embedded video SDRAM
- 2D and 3D graphics acceleration
- video acceleration
- support for MPEG decoding
- support for dual-display mode
- composite video output for a TV monitor

The interface between the graphics IC and the rest of the system is an AGP 2X (accelerated graphics port, double speed) bus on the Uni-N IC. To give the graphics IC fast access to system memory, the AGP bus has separate address and data lines and supports deeply pipelined read and write operations. The AGP bus has 32 data lines and a clock speed of 66 MHz.

The graphics IC uses a graphics address remapping table (GART) to translate AGP logical addresses into physical addresses. The graphics driver software can allocate memory in both the on-chip SDRAM and the main memory.

The graphics IC supports the built-in flat-panel display and an external monitor. The external monitor can either mirror the built-in display or show additional desktop space (dual-display mode). For information about the displays and supported resolutions, see "Flat Panel Display" (page 64) and "External Monitors" (page 65).

I/O Controller

The I/O controller IC in the PowerBook computer is a custom IC called KeyLargo. It provides the interface and control signals for the following devices:

- the internal hard drive
- a storage device (such as the DVD-ROM drive) in the expansion bay
- the USB ports
- the built-in modem
- the sound codec IC
- the power manager IC
- the infrared link
- the optional wireless LAN module

DMA Support

The KeyLargo IC provides DB-DMA (descriptor-based direct memory access) support for the following I/O channels:

- Ultra DMA ATA interface to the the internal hard drive
- modem slot interface to the built-in modem
- DAV channel to the sound IC

The DB-DMA system provides a scatter-gather process based on memory resident data structures that describe the data transfers. The DMA engine is enhanced to allow bursting of data files for improved performance.

Interrupt Support

The KeyLargo IC has an interrupt controller (MPIC) that handles interrupts generated within the IC as well as external interrupts, such as those from the Ethernet and FireWire controllers.

USB Interface

The KeyLargo IC implements two independent USB controllers (root hubs), each of which is connected to one of the ports on the back panel of the computer. The use of two independent controllers allows both USB ports to support high data rate devices at the same time with no degradation of their performance. If a user connects a high-speed (12 Mbps) device to one port and another high-speed device to the other, both devices can operate at their full data rates.

The two external USB connectors support USB devices with data transfer rates of 1.5 Mbps or 12 Mbps. For more information about the connectors, see "USB Connectors" (page 40).

USB devices connected to the PowerBook computer are required to support USB-suspend mode as defined in the USB specification. Information about the operation of USB-suspend mode on Macintosh computers is included in the *Mac OS USB DDK API Reference*. That document is part of Apple's USB DDK and is available on the World Wide Web, at:

http://developer.apple.com/techpubs/hardware/DeviceManagers/usb/usb.html

The USB ports on the PowerBook computer comply with the Universal Serial Bus Specification 1.1 Final Draft Revision. The USB controllers comply with the Open Host Controller Interface (OHCI) specification.

Ultra DMA Interface

The KeyLargo IC provides an Ultra DMA IDE (integrated drive electronics) channel that is connected to the internal hard disk drive. The KeyLargo IC provides DB-DMA (descriptor-based direct memory access) support for the Ultra DMA interface.

The Ultra DMA IDE interface, also called Ultra-DMA/66 and ATA-4, is an improved version of the EIDE interface.

The internal hard disk drive is connected as device 0 (master) in an ATA Device 0/1 configuration.

EIDE Interface

The KeyLargo IC provides an EIDE interface (ATA bus) that supports the storage device in the expansion bay—usually the DVD-DOM drive—and the wireless LAN module. The DVD-ROM drive is an ATAPI drive and is connected as device 0 (master).

Modem Support

The KeyLargo IC has a Macintosh serial port that is the interface to the modem connector. The KeyLargo IC provides DB-DMA support for the modem interface. The modem provides analog call progress signals to the Screamer sound IC.

The internal hardware modem is a separate module that contains the modem ICs (controller and datapump) and the interface to the telephone line (DAA). For more information about the modem, see “Internal Modem” (page 46).

Sound IC Support

The KeyLargo IC has a traditional DAV port that connects to the Screamer sound IC. The KeyLargo IC provides DB-DMA support for the DAV port.

The Screamer sound IC is an audio codec with added input and output controls. It is a 16-bit device with two analog stereo input channels and two analog stereo output channels. Either stereo pair of input channels can be selected for digitization by the internal A-to-D converter.

For a description of the features of the sound system, see “Sound System” (page 70).

Power Controller

The power management controller in the PowerBook computer is a custom IC called the PMU99. It supports several power-saving modes of operation, including idle, doze, and sleep. For more information, see “Power Saving Modes” (page 100).

Infrared Link Interface

The controller for the infrared link is part of the KeyLargo IC. The IR transceiver is connected to a serial port on the KeyLargo IC. For information about the operation of the infrared link, see "Infrared Communication Link" (page 49).

AirPort Card Interface

The interface between the AirPort Card wireless LAN module and the KeyLargo IC is a subset of the PCMCIA interface.

The AirPort Card contains a media access controller (MAC), a digital signal processor (DSP), and a radio-frequency (RF) section. The card has a connector for the cable to the antennas, which are built into the computer's enclosure .

The design of the AirPort Card is based on the IEEE 802.11 standard. The card transmits and receives data at up to 11 Mbps and is compatible with older systems that operate at 1 or 2 Mbps. For information about its operation, see "AirPort Card Wireless LAN Module" (page 47).

CardBus Controller IC

The interface to the PC Card slot is connected to the PCI bus. The CardBus controller IC is a PCI1211 device made by Texas Instruments. It supports both 16-bit PC Cards and 32-bit CardBus Cards.

CHAPTER 3

Devices and Ports

This chapter describes both the built-in I/O devices and the ports for connecting external I/O devices. Each of the following sections describes an I/O port or device.

USB Ports

The PowerBook computer has two Universal Serial Bus (USB) ports that can be used to connect additional I/O devices such as a USB mouse, printers, scanners, and low-speed storage devices.

For more information about USB on the Macintosh computer, refer to Apple Computer's *Mac OS USB DDK ATI Reference*. Information is also available on the World Wide Web, at:

http://developer.apple.com/dev/usb/

For full specifications of the Universal Serial Bus, refer to the USB Implementation Forum on the World Wide Web, at:

http://www.usb.org/developers/index.html

USB Connectors

The USB ports use USB Type A connectors, which have four pins each. Two of the pins are used for power and two for data. Figure 3-1 is an illustration of a Type A port and matching connector. Table 3-1 shows the pin assignments.

Figure 3-1 USB Type A port

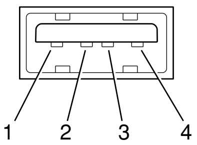


Table 3-1 Pin assignments on the USB port

Pin	Signal name	Description
1	VCC	+5 VDC
2	D–	Data –
3	D+	Data +
4	GND	Ground

The computer provides 5-volt power at 500 mA for each of the two ports.

The USB ports support both low-speed and high-speed data transfers, at up to 1.5 Mbits per second and 12 Mbits per second, respectively. High-speed operations requires the use of shielded cables.

The PowerBook computer comes with version 1.3 of the Macintosh USB system software, which supports all four data transfer types defined in the USB specification.

USB devices can provide a remote wakeup function for the computer. The USB root hub in the computer is set to support remote wakeup whenever a device is attached to or disconnected from the bus.

Booting from a USB Device

The PowerBook computer can boot from a USB storage device that follows the USB Mass Storage Class specification.

Class drivers are software components that are able to communicate with many USB devices of a particular kind. If the appropriate class driver is present, any number of compliant devices can be plugged in and start working immediately without the need to install additional software. The Mac OS for the PowerBook computer includes USB Mass Storage Support 2.0, a class driver that supports devices that meet the USB Mass Storage Class specification.

USB Compatibility Issues

The USB ports take the place of the ADB and serial I/O ports found on earlier Macintosh computers, but they do not function the same way. The following sections describe the differences.

ADB Compatibility

Apple provides an ADB/USB shim to support processes that control ADB devices by making calls to the ADB Manager and the Cursor Device Manager. The ADB/USB shim makes it possible for processes that support an ADB keyboard to work with the USB keyboard equivalent.

For example, the ADB/USB shim allows applications to set the caps lock and num lock LEDs on the Apple USB keyboard. The ADB/USB shim also allows the Cursor Device Manager to support a USB mouse.

Keyboards other than the Apple USB keyboard can be used with the PowerBook computer, but they will be treated as having an ADB device ID of 2.

IMPORTANT

The ADB/USB shim does not support USB devices other than the Apple USB keyboard and mouse. ▲

Note

The ADB/USB shim is built into the Mac OS ROM image on the PowerBook computer, as it is on all Power Macintosh systems that have USB ports. ◆

Serial Port Compatibility

The system software includes a serial shim, called SerialShimLib, that enables processes that use the Communications Toolbox CRM to find and use a USB modem device. For more information about the shim, and a sample modem driver that shows how to use it, please refer to the Mac OS USB DDK, available from the Apple Developer Development Kits page on the World Wide Web, at

http://developer.apple.com/sdk/

Apple also provides a USB Communication Class driver, so modem vendors whose devices comply with the USB Communication Class specification do not need to write their own vendor-specific USB class drivers. See "USB Drivers" (page 102).

Not for Networking

USB is a serial communications channel, but it does not replace LocalTalk functionality on Macintosh computers; you cannot connect two Macintosh computers together using the USB. The best method for networking PowerBook computers is through the built-in Ethernet port.

FireWire Ports

The PowerBook computer has two external FireWire IEEE 1394 ports. The FireWire ports

- support serial I/O at 100, 200, and 400 Mbps (megabits per second)
- provide up to 6 watts of power when the computer system is on
- accept external power input from the bus
- support booting the system from a mass storage device
- support target disk mode

The FireWire hardware and software provided with the PowerBook computer are capable of all asynchronous and isochronous transfers defined by IEEE standard 1394.

FireWire Connectors

Each FireWire connector has six contacts, as shown in Figure 3-2. The connector pin assignments are shown in Table 3-2.

Figure 3-2 FireWire connector

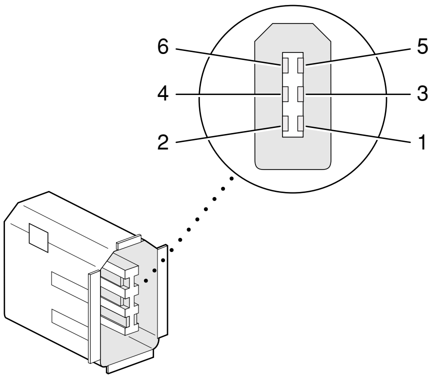


Table 3-2 Pin assignments on the FireWire connector

Pin	Signal name	Description
1	Power	Unregulated DC; 10–12 V no load
2	Ground	Ground return for power and inner cable shield
3	TPB-	Twisted-pair B, differential signals
4	TPB+	Twisted-pair B, differential signals
5	TPA-	Twisted-pair A, differential signals
6	TPA+	Twisted-pair A, differential signals
Shell	—	Outer cable shield

When the computer is on, the power pin provides a maximum voltage of 12 V (no load) and up to 6 W power (at each connector). Maximum current is 0.5 A and is controlled by an auto-resetting fuse.

The power pin also accepts external power at 8 to 33 V, in conformity with the P1394a draft standard, to keep the FireWire bus connected when the computer is turned off or in Sleep mode.

Pin 2 of the 6-pin FireWire connector is ground for both power and the inner cable shield. If a 4-pin connector is used on the other end of the FireWire cable, its shell should be connected to the wire from pin 2.

The signal pairs are crossed in the cable itself so that pins 5 and 6 at one end of the cable connect with pins 3 and 4 at the other end. When transmitting, pins 3 and 4 carry data and pins 5 and 6 carry clock; when receiving, the reverse is true.

FireWire Device Programming

Developers of FireWire peripherals are required to provide device drivers. A driver for DV (digital video) is included in QuickTime 4.0.

The PowerBook computer can boot from a FireWire storage device that implements SBP-2 (Serial Bus Protocol) with the RBC (reduced block commands) command set. Detailed information is available only under non-disclosure agreement; contact Developer Technical Support at dts@apple.com.

When connected to another computer by a FireWire bus, the PowerBook computer can operate as a mass storage device. See “Target Disk Mode” (page 98).

For additional information about the FireWire interface and the Apple APIs for FireWire device control, refer to the resources available on the Apple FireWire web site at

http://developer.apple.com/hardware/FireWire/

or send electronic mail to

firewire@apple.com

Ethernet Port

The PowerBook computer has a built-in 10/100 Mbps Ethernet port. The user can connect it to either a 10Base-T or a 100Base-TX hub; the port will automatically sense which type of hub is connected.

The connector for the Ethernet port is a short, shielded RJ-45 connector on the back of the computer. Table 3-3 shows the signals and pins on the connector.

Table 3-3 Signals on the Ethernet connector

Pin	Signal name	Signal definition
1	TXP	Transmit (positive lead)
2	TXN	Transmit (negative lead)
3	RXP	Receive (positive lead)
4	–	Not used
5	–	Not used
6	RXN	Receive (negative lead)
7	–	Not used
8	–	Not used

The Ethernet interface in the PowerBook computer conforms to the ISO/IEC 802.3 specification, where applicable, and complies with IEEE specifications 802.3i (10Base-T) and 802.3u-1995 (100Base-T).

Internal Modem

The PowerBook computer comes with a built-in modem. The connector for the modem is an RJ-11 connector on the back of the computer.

The modem has the following features:

- modem bit rates up to 56 Kbps (supports K56flex and V.90 modem standards)
- Group 3 fax modem bit rates up to 14.4 Kbps

The modem appears to the system as a serial port that responds to the typical AT commands. The modem provides a sound output for monitoring the progress of the modem connection.

AirPort Card Wireless LAN Module

The PowerBook computer supports the AirPort Card, an internal wireless LAN module. The AirPort Card is available as a configure-to-order option or as a user-installable upgrade through The Apple Store.

The AirPort Card can be used for local printer sharing, file exchange, internet access, and e-mail access.

The AirPort Card transmits and receives data at up to 11 Mbps. It is also interoperable with some older wireless LANs, as specified in "Hardware Components" (page 47).

Wireless connection to the internet or a wired LAN requires a base station as the connection to the internet or a bridge between the wireless signals and a wired LAN. Software included with the AirPort Card enables a Macintosh computer that has an AirPort Card installed to act as a base station. The user also has the option of purchasing an AirPort Base Station that can be connected to the wired LAN or to a 56 Kbps hardware modem.

Data Security

Three features of the AirPort Card help to maintain the security of data transmissions:

- The system uses direct-sequence spread-spectrum (DSSS) technology that uses a multi-bit spreading code that effectively scrambles the data for any receiver that lacks the corresponding code.
- The system can use a table of authentic network client ID values to verify each client's identity before granting access to the network.
- When communicating with a base station, the system encrypts the data using Wired Equivalent Privacy (WEP) with a 40-bit security key.

Hardware Components

The AirPort Card is a wireless LAN module based on the IEEE 802.11 standard and using direct-sequence spread-spectrum (DSSS) technology. It is interoperable with PC-compatible wireless LANs that conform to the 802.11 standard and use DSSS.

The AirPort Card contains a media access controller (MAC), a digital signal processor (DSP), and a radio-frequency (RF) section. The antennas are built into the computer's case.

The MAC provides the data communication protocols and the controls for the physical layer.

The DSP provides the core physical layer functionality and controls the RF section. The DSP communicates with the MAC for data exchange, physical layer control, and parameter settings.

The RF section provides modulation and transmission of outgoing signals and reception and demodulation of incoming signals. Its power output when transmitting is nominally 31 mW.

When transmitting data, the DSP converts the outgoing data stream into a DSSS signal and sends it to the RF section. When receiving data, the DSP accepts incoming DSSS data from the RF section and converts it to a normal data stream.

Two antennas are connected to the AirPort Card. One antenna is always used for transmitting. Either of the two antennas may be used for receiving. Using a diversity technique, the DSP selects the antenna that gives the best reception.

Software Components

Software that is provided with the AirPort Card includes

- AirPort Setup Assistant, a standalone assistant that takes users through the steps necessary to set up the AirPort Card, set up an AirPort Base Station, or set up a software base station.
- AirPort Application, an application that allows users to switch between wireless networks and to create and join peer-to-peer networks.
- AirPort Control Strip Module, which provides a signal strength indication and most of the functions of the AirPort Application.
- AirPort Admin, a utility for the advanced user. With it the user can edit the administrative and advanced settings for a hardware or software base station. It can also be used to determine the location for the base station that gives the best reception.

Infrared Communication Link

The PowerBook computer has a directed infrared (IR) communication link connected internally to a serial port on the KeyLargo IC. When the computer is placed within range of another device with an IR interface, it can send and receive serial data. The other device may be another IR-equipped PowerBook, a desktop computer with an IR communications link, or some other device that complies with the Infrared Data Association (IrDA) standard.

Operating range is 1 meter, and the devices must be positioned with their IR ports pointed toward each other within about 15 degrees.

The IR link in the PowerBook computer supports IrDA at up to 4.0 Mbps. The IrDA modulation method complies with the IrDA physical layer standard, which can be found at ftp://www.irda.org.

Hard Disk Drive

The PowerBook computer has an internal hard disk drive with a storage capacity of 6, 12, or 18 GB. The drive uses the extended IDE (integrated drive electronics) interface, which is also referred to as the ATA interface.

The implementation of the ATA interface on this computer is a subset of the ATA/ATAPI-4 specification (ANSI NCITS 317-1998 AT Attachment - 4 with Packet Interface Extension). That specification is maintained by the National Committee on Information Technology Standards (NCITS) Technical Committee T13; more information is available on their website at

http://www.t13.org/

The software that supports the internal hard disk is the same as that in previous PowerBook models with internal IDE drives and includes DMA support. For the latest information about that software, see *Technote #1098, ATA Device Software Guide Additions and Corrections,* available on the world wide web at

http://developer.apple.com/technotes/tn/tn1098.html

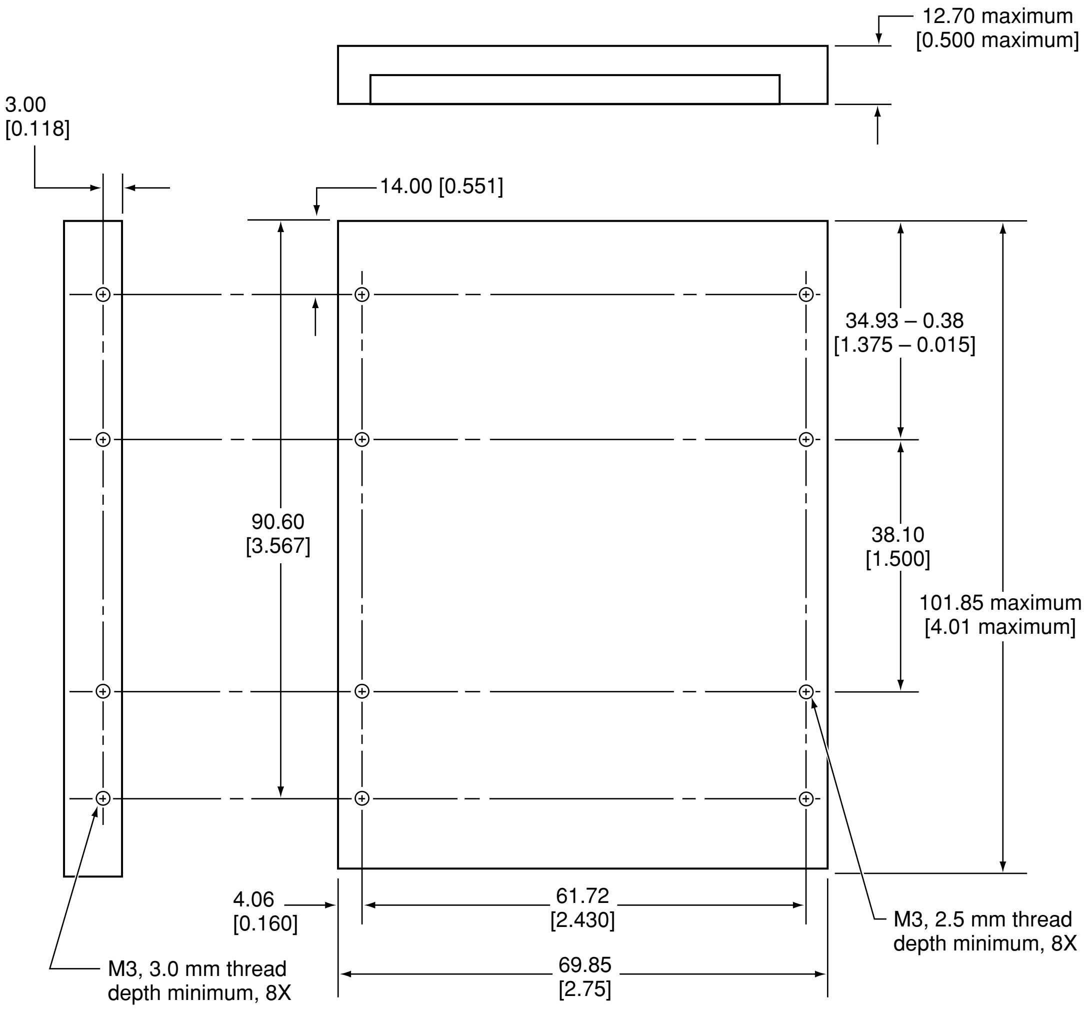
The web page for Technote #1098 includes a link to a downloadable copy of *ATA Device Software Guide*.

Hard Disk Dimensions

Figure 3-3 shows the maximum dimensions of the hard disk and the location of the mounting holes. The hard disk is the same physical size as the ones in the 1999 PowerBook G3 Series computers: only 12.7 mm (0.5 inches) high.

The minimum clearance between any conductive components on the drive and the bottom of the mounting envelope is 0.5 mm.

Figure 3-3 Maximum dimensions of the internal hard disk

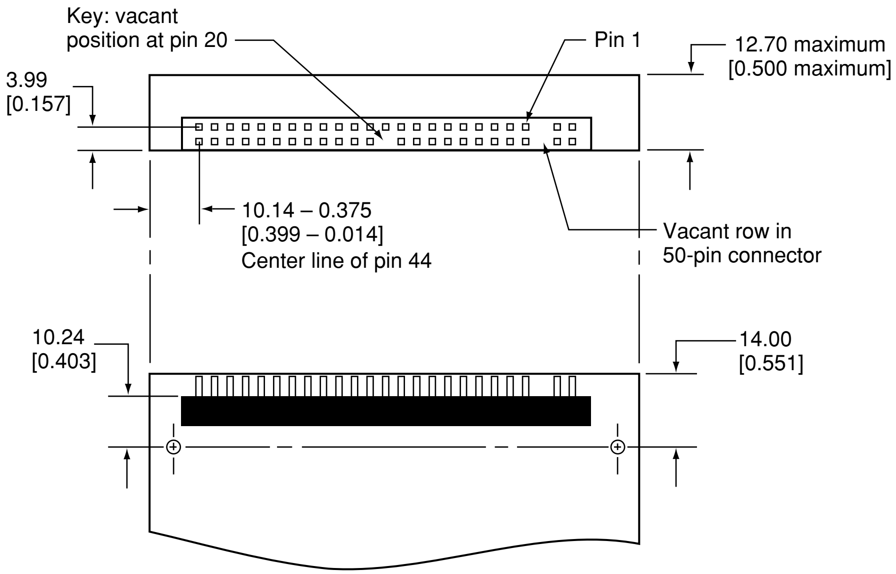


Note: Dimensions are in millimeters [inches].

Hard Disk Connector

The internal hard disk has a 48-pin connector that carries both the ATA signals and the power for the drive. The connector has the dimensions of a 50-pin connector, but with one row of pins removed, as shown in Figure 3-4. The remaining pins are in two groups: pins 1–44, which carry the signals and power, and pins 46–48, which are reserved. Pin 20 has been removed, and pin 1 is located nearest the gap, rather than at the end of the connector.

Figure 3-4 Hard disk connector and location



Signal Assignments

Table 3-4 shows the signal assignments on the 44-pin portion of the hard disk connector. A slash (/) at the beginning of a signal name indicates an active-low signal.

Table 3-4 Pin assignments on the ATA hard disk connector

Pin number	Signal name	Pin number	Signal name
1	/RESET	2	GROUND
3	DD7	4	DD8
5	DD6	6	DD9
7	DD5	8	DD10
9	DD4	10	DD11
11	DD3	12	DD12
13	DD2	14	DD13
15	DD1	16	DD14
17	DD0	18	DD15
19	GROUND	20	KEY
21	DMARQ	22	GROUND
23	/DIOW	24	GROUND
25	/DIOR	26	GROUND
27	IORDY	28	CSEL
29	/DMACK	30	GROUND
31	INTRQ	32	/IOCS16
33	DA1	34	/PDIAG
35	DA0	36	DA2
37	/CS0	38	/CS1
39	/DASP	40	GROUND
41	+5V LOGIC	42	+5V MOTOR
43	GROUND	44	Reserved

NOTE CSEL, /DASP, /IOCS16, and /PDIAG are not used; see Table 3-5

ATA Signal Descriptions

Table 3-5 describes the signals on the ATA hard disk connector.

Table 3-5 Signals on the ATA hard disk connector

Signal name	Signal description
DA(0–2)	Device address; used by the computer to select one of the registers in the ATA drive. For more information, see the descriptions of the CS0 and CS1 signals.
DD(0–15)	Data bus; buffered from IOD(16–31) of the computer's I/O bus. DD(0–15) are used to transfer 16-bit data to and from the drive buffer. DD(8–15) are used to transfer data to and from the internal registers of the drive, with DD(0–7) driven high when writing.
/CS0	Register select signal. It is asserted low to select the main task file registers. The task file registers indicate the command, the sector address, and the sector count.
/CS1	Register select signal. It is asserted low to select the additional control and status registers on the ATA drive.
CSEL	Cable select; not available on this computer (n.c.).
/DASP	Device active or slave present; not available on this computer (n.c.).
IORDY	I/O ready; when driven low by the drive, signals the CPU to insert wait states into the I/O read or write cycles.
/IOCS16	I/O channel select; not available on this computer (n.c.).
/DIOR	I/O data read strobe.
/DIOW	I/O data write strobe.
/DMACK	Used by the host to initiate a DMA transfer in response to DMARQ.
DMARQ	Asserted by the device when it is ready to transfer data to or from the host.

Table 3-5 Signals on the ATA hard disk connector (continued)

Signal name	Signal description
INTRQ	Interrupt request. This active high signal is used to inform the computer that a data transfer is requested or that a command has terminated.
/PDIAG	Asserted by device 1 to indicate to device 0 that it has completed the power-on diagnostics; not available on this computer (n.c.).
/RESET	Hardware reset to the drive; an active low signal.
Key	This pin is the key for the connector.

The built-in ATA devices and ATA devices in the expansion bay are separately connected to the I/O bus through bidirectional bus buffers.

DVD-ROM Drive

The PowerBook computer comes with a 6x-speed DVD-ROM drive in the expansion bay. The drive is fully compatible with existing CD-ROM media; it supports CD-ROM at 24X speed maximum and DVD at 6X constant linear velocity (CLV). The DVD-ROM drive supports the following disc formats:

- DVD-ROM (one- or two-layer, one- or two-sided)
- DVD-RAM (read only)
- CD-ROM (Modes 1 and 2) and CD-ROM XA (Mode 2, Forms 1 and 2)
- CD-Audio, Photo CD, CD-RW (read only), CD-R (read only), and CD-Extra
- CD-I (Mode 2, Forms 1 and 2), CD-I Ready, and CD-I Bridge
- Video CD

Digital audio signals from the DVD-ROM can be played through the sound outputs under the control of the Sound Manager.

The DVD-ROM drive is an ATAPI drive and is connected as device 1 (slave) in an ATA Device 0/1 configuration.

Trackpad

The pointing device in the PowerBook computer is a trackpad. The trackpad is a solid-state device that emulates a mouse by sensing the motions of the user's finger over its surface and translating those motions into ADB commands.

The user makes selections either by pressing a button below the trackpad or by tapping and double tapping on the pad itself. The trackpad responds to one or two taps on the pad itself as one or two clicks of the button. The user can tap and drag on the trackpad in much the same manner as clicking and dragging with the mouse. The tap and double tap functions are optional; the user activates or deactivates them by means of the Trackpad control panel.

Keyboard

The keyboard is a compact, low-profile design with a row of function keys and inverted-T cursor motion keys.

Removing the Keyboard

The keyboard is removable to allow access to the internal components and expansion connectors inside the computer. The keyboard is held in place by a locking screw and two latches.

The keyboard locking screw is a slotted screw that is part of the Num Lock LED, which is located between the F4 and F5 function keys. The computer is shipped with the locking screw in the unlocked position. If the locking screw is in the locked position, turning the screw 180° unlocks the keyboard.

The two latches are between the ESC key and the F1 key and between the F8 and F9 keys. The user can release the latches by pulling them toward the front of the computer.

Changing the Operation of the Keyboard

Several of the keys on the keyboard have more than one mode of operation.

- Function keys F1–F6 can also control the display brightness, speaker volume, and the Num Lock function.
- The other function keys can be set by the user to open applications, documents, or AppleScripts.
- Certain control keys can be used as page-control keys.
- The keys on the right side of the keyboard can be used as a numeric keypad.

The next sections describe these groups of keys and the way their alternate modes of operation are selected by using the Fn key, the Num Lock key, and the Function Keys checkbox in the Keyboard control panel.

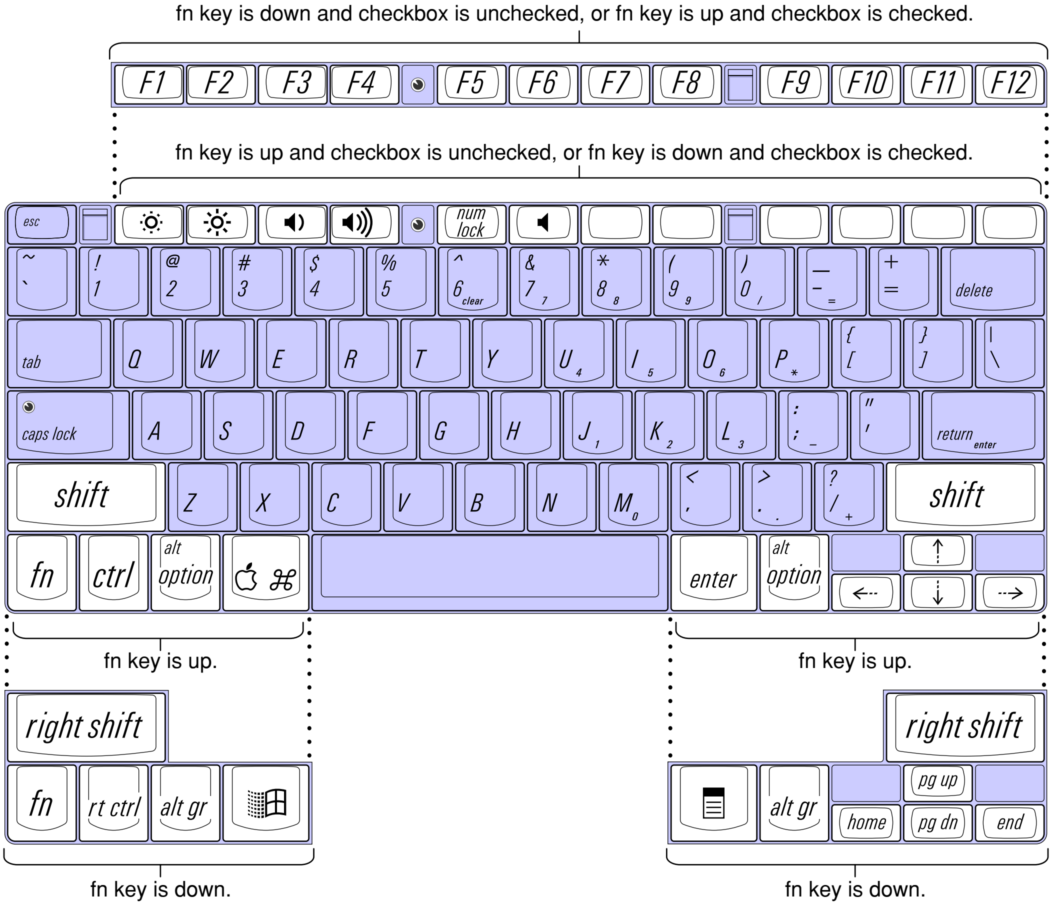
Keyboard Illustrations

Figure 3-5 shows the actual appearance of the keyboard. Figure 3-6 shows the alternate modes of operation of the function and control keys. Figure 3-7 shows the embedded numeric keypad.

Figure 3-5 Keyboard layout

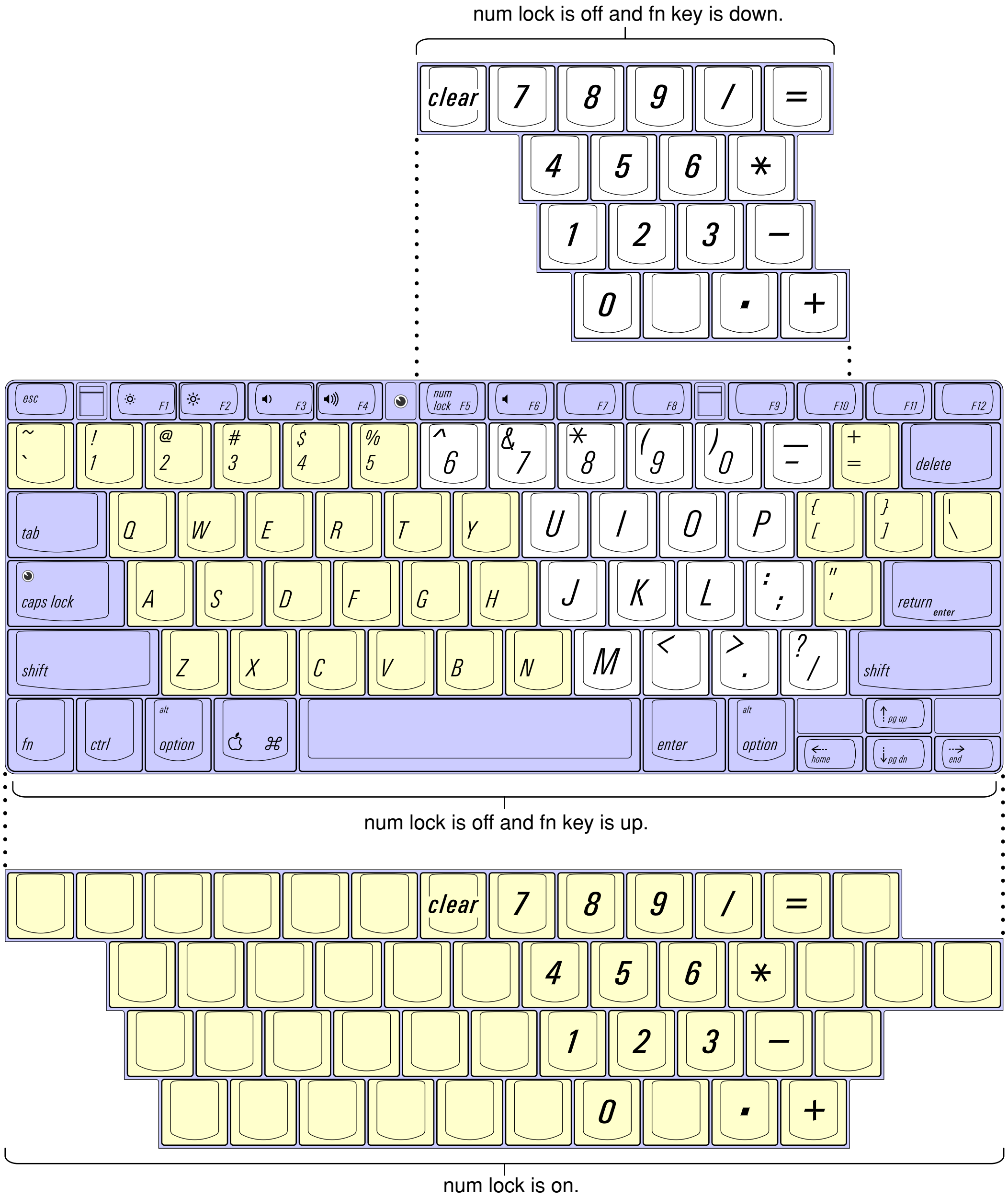
Figure 3-6 and Figure 3-7 include duplicate versions of some keys in order to show their alternate modes of operation. In some cases, the alternate key captions shown in the figures do not appear on the keyboard. For the actual appearance of the keyboard, refer to Figure 3-5.

Figure 3-6 Alternate operations of function and control keys



Note: Characters on highlighted keys are enlarged for clarity.

Figure 3-7 Embedded numeric keypad operation



Using the Fn Key

Pressing the Fn key affects three sets of keys: the function keys F1–F12, the embedded numeric keypad, and certain modifier keys.

- It toggles the function keys between their control-button operation and their F1–F12 functions, as shown in Table 3-6 and Figure 3-6. The user selects the default modes of operation of those keys as described in the section "The Function-Keys Checkbox".
- It selects the embedded numeric keypad on the right portion of the alphanumeric keys, as shown in Table 3-8 and Figure 3-7.
- It changes certain control keys, including the cursor control keys, to page control keys, as shown in Table 3-9 and Figure 3-7.

Using the Num Lock Key

Pressing the Num Lock key affects two sets of keys: the embedded keypad and the rest of the alphanumeric keys.

- It selects the embedded numeric keypad, as shown in Table 3-8 and Figure 3-7.
- It makes the rest of the alphanumeric keys functionless (NOPs), as shown in Figure 3-7.

The Function-Keys Checkbox

The Fn key lets the user switch the mode of operation of the function keys at any time. The user selects the default mode of the function keys by means of the Function-keys checkbox in the Keyboard Control Panel.

The Function-keys checkbox lets the user choose whether the function key operations are primary or secondary. "Function keys primary" means the function keys are normally in their F1–F12 mode of operation and pressing the Fn key selects their control-button mode. "Function keys secondary" means the function keys are normally in their control-button mode and pressing the Fn key selects their function-key mode.

In other words, pressing the Fn key reverses the mode of operation of the function keys from the default mode set by the checkbox. Table 3-6 summarizes the checkbox settings and the operation of the Fn key. The operations of the individual function keys are shown in Table 3-6 and Figure 3-6.

Table 3-6 Setting the default behavior of the function keys

Make Function Keys Primary checkbox	Operations of function keys	
	Fn key up	Fn key down
Checked	F1–F12 functions	Control buttons
Not checked	Control buttons	F1–F12 functions

Table 3-7 The function keys as control buttons

Key name	Control button
F1	Decrease display brightness
F2	Increase display brightness
F3	Decrease speaker volume
F4	Increase speaker volume
F5	Num Lock
F6	Mute the speaker
F7	User definable
F8	User definable
F9	User definable
F10	User definable
F11	User definable
F12	User definable

Operations of the Function Keys

Function keys F1 through F6 are used as control buttons for the display and sound; function keys F7 through F12 are open for the user to define. The operations of the function keys are controlled by the Function keys checkbox and the Fn key. Table 3-7 is a list of the function keys and their operations as control buttons. The Keyboard Control Panel allows the user to assign operations to function keys F7 through F12. Operations that can be assigned include

- opening an application
- opening a document
- evoking an AppleScript
- logging on to a FileServer by way of an alias

The Embedded Keypad

A certain group of alphanumeric keys can also function as an embedded keypad. The user selects this mode by using the Fn key or the Num Lock key. Figure 3-7 shows the keys making up the embedded keypad and Table 3-8 lists them.

Table 3-8 Embedded keypad keys

Key name	Keypad function
6	Clear
7	7
8	8
9	9
0	/ (divide)
-	= (equals)
U	4
I	5
O	6

Table 3-8 Embedded keypad keys (continued)

Key name	Keypad function
P	* (multiply)
J	1
K	2
L	3
;	– (subtract)
M	0
,	NOP
.	. (decimal)
/	+ (add)

When the embedded keypad is made active by the Num Lock key, the other alphanumeric keys have no operation (NOP), as shown in Figure 3-7. The affected keys include certain special character keys: plus and equal sign, right and left brackets, vertical bar and backslash, and straight apostrophe.

Other Control Keys

The cursor control keys can also be used as page control keys. Other control keys can take on the functions of certain keys on a PC keyboard, for use with PC emulation software. The Fn key controls the modes of operation of this group of keys. Table 3-9 is a list of these keys and their alternate functions. These control keys are also show in Figure 3-7.

Table 3-9 Control keys that change

Key name	Alternate function
Shift	Right shift key
Control	Right control key
Option	Alt gr (right Alt key)
Command	Windows® key
Enter	Menu key (for contextual menus)
Left arrow	Home
Up arrow	Page up
Down arrow	Page down
Right arrow	End

Flat Panel Display

The PowerBook computer has a built-in color flat panel display that is 14.1 inches across, measured diagonally. The display contains 1024 by 768 pixels and can work with up to millions of colors. The display is backlit by a cold cathode fluorescent lamp (CCFL). The display uses TFT (thin-film transistor) technology for high contrast and fast response.

The display also supports 640 by 480 and 800 by 600 resolutions. The graphics controller IC includes a scaling function that expands displays with those smaller resolutions to fill the screen. Scaling up of smaller displays also reduces the pixel resolution of the display, as shown in Table 3-10.

The scaling function is available only when the internal flat panel is the only active display. When the internal display and an external monitor are both operating and mirror mode is selected, both displays show full-sized images only when the display resolution for the external monitor is set to the standard resolution: 1024 by 768. Both displays can operate with other resolution settings, but in mirror mode, one of them will have a display that is smaller than the full screen and has a black border around it. With the resolution for the external monitor set to 640 by 480 or 800 by 600, the image on the internal display is smaller than the screen. For resolution settings larger than 1024 by 768, the image on the external monitor is smaller than the screen.

When the flat panel display and an external video monitor are operating at the same time, less video memory is available for each, so the maximum pixel depth at the largest image sizes is less. These modes and restrictions are summarized in Table 3-10.

Table 3-10 Flat-panel resolutions and pixel depths

Image size	Pixel resolution	Pixel depth, no external monitor	Pixel depth, with external monitor
640 by 480	58 dpi	24 bpp	24 bpp
800 by 600	71 dpi	24 bpp	24 bpp
1024 by 768	91 dpi	24 bpp	16 bpp

External Monitors

The computer has a built-in connector for an external VGA, SVGA, or XGA monitor or projection device. An adapter, included with the computer, allows the user to attach a standard Apple video cable. The computer also has an S-video connector that supplies a video signal for an NTSC or PAL video monitor or VCR.

An external monitor or projection device connected to the computer can increase the amount of visible desktop space. This way of using an external monitor is called dual display to distinguish it from mirror mode, which shows the same information on both the external display and the built-in display.

Monitors and Picture Sizes

With the included adapter, the PowerBook computer can be used with any Apple monitor, including the AV monitors, the 17-inch and 20-inch multiple scan monitors, and Apple Studio Displays (except those that have only a DVI connector). The computer also supports VGA, SVGA, and XGA monitors. Table 3-11 lists the picture sizes and frame rates supported.

Table 3-11 Picture sizes supported

Picture size (pixels)	Frame rate	Pixel depth, flat panel inactive	Pixel depth, flat panel active
512 by 384	60 Hz	24 bpp	24 bpp
640 by 480	60 Hz	24 bpp	24 bpp
640 by 480	67 Hz	24 bpp	24 bpp
640 by 480	72 Hz	24 bpp	24 bpp
640 by 480	75 Hz	24 bpp	24 bpp
640 by 480	85 Hz	24 bpp	24 bpp
640 by 870	75 Hz	24 bpp	24 bpp
800 by 600	56 Hz	24 bpp	24 bpp
800 by 600	60 Hz	24 bpp	24 bpp
800 by 600	72 Hz	24 bpp	24 bpp
800 by 600	75 Hz	24 bpp	24 bpp
800 by 600	85 Hz	24 bpp	24 bpp
832 by 624	75 Hz	24 bpp	24 bpp
1024 by 768	60 Hz	24 bpp	24 bpp
1024 by 768	70 Hz	24 bpp	24 bpp
1024 by 768	72 Hz	24 bpp	24 bpp
1024 by 768	75 Hz	24 bpp	24 bpp
1024 by 768	85 Hz	24 bpp	24 bpp
1152 by 870	75 Hz	24 bpp	24 bpp

Table 3-11 Picture sizes supported (continued)

Picture size (pixels)	Frame rate	Pixel depth, flat panel inactive	Pixel depth, flat panel active
1280 by 960	75 Hz	24 bpp	16 bpp
1280 by 1024	60 Hz	24 bpp	16 bpp
1280 by 1024	75 Hz	24 bpp	16 bpp

The computer includes 8 MB of video memory, which is enough to provide pixel depths up to 24 bits per pixel on all supported monitors when the flat panel display is inactive (display closed). When an external video monitor and the flat panel display are operating at the same time, half the video memory is available for each. In that case, the maximum pixel depth available on the external monitor at the 1280-by-960 and 1280-by-1024 picture sizes is only 16 bpp.

Monitor Connector

The connector is a standard DB-9/15 connector for use with a VGA, SVGA, or XGA monitor. Figure 3-8 shows the pin configurations and Table 3-12 lists the signal pin assignments.

Figure 3-8 Signal pins on the monitor connector

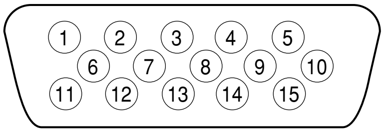


Table 3-12 Signals on the monitor connector

Pin	Signal name	Description
1	RED	Red video signal
2	GREEN	Green video signal
3	BLUE	Blue video signal
4	MONID(0)	Monitor ID signal 0
5	GND	DDC return
6, 7, 8	AGND_VID	Analog video ground
9	+5V_IO	5 V power
10	GND	HSYNC and VSYNC ground
11	VGA_ID	VGA ID signal
12	MONID(2)	Monitor ID signal 2
13	HSYNC	Horizontal synchronization signal
14	VSYNC	Vertical synchronization signal
15	MONID(1)	Monitor ID signal 1

Monitor Adapter

The computer comes with a monitor adapter that allows the user to connect a standard Apple monitor cable to the computer. The Apple part number for the adapter is 590-1118.

External Video Connector

The PowerBook computer has an S-video connector for composite video output to a PAL or NTSC video monitor or VCR. The video output connector is a 7-pin S-video connector. Figure 3-9 shows the arrangement of the pins and Table 3-13 shows the pin assignments on the S-video connector.

Figure 3-9 S-video connector

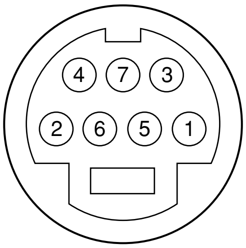


Table 3-13 Pin assignments for the S-video output connector

Pin number	S-video output connector
1	Analog GND
2	Analog GND
3	Video Y (luminance)
4	Video C (chroma)
5	Composite video
6	Unused
7	Unused

An adapter is available that can be plugged into the S-video connector and accepts an RCA plug from a composite video monitor.

The PowerBook computer provides composite video output at picture sizes and frame rates compatible with the NTSC and PAL standards; the picture sizes are listed in Table 3-14. Those picture resolutions produce underscanned displays on standard monitors.

Table 3-14 Picture sizes for composite video output

Picture size	Pixel depth
512 by 384	24 bpp
640 by 480	24 bpp
720 by 480 (NTSC only)	24 bpp
720 by 576 (PAL only)	24 bpp
800 by 600	24 bpp
832 by 624	24 bpp
1024 by 768	24 bpp

Sound System

The sound system for the PowerBook computer supports 44.1 kHz 16-bit stereo sound output and input, available simultaneously.

The sound circuitry and system software can create sounds digitally and either play the sounds through the built-in speakers or send the sound signals out through the sound output jack or one of the USB port. The PowerBook computer also records sound data from several sources: the built-in microphone, an analog stereo sound source connected to the line-level sound input jack, or single-channel digital sound from the modem card or from a CardBus card. For each sound input source, sound playthrough can be enabled or disabled. In addition, sound data from digital sources such as CD can be sent to the sound system for conversion to analog output for the speakers and the sound output jack.

The frequency response of the sound circuits, not including the microphone and speakers, is –3 dB at 20 Hz and 20 kHz. Total harmonic distortion and noise is less than 0.05 percent with a 1-V rms sine wave input. The signal-to-noise ratio (SNR) is 85 dB, with no audible discrete tones.

Sound Inputs

The sound system accepts inputs from six possible sources:

- built-in microphone
- external stereo sound input jack
- sound signals from the communication (modem) slot
- 1-bit sound from the CardBus socket
- digital sound accompanying zoomed video from the CardBus socket

The microphone preamp and the sound input jack have dedicated analog input channels on the Screamer IC; the other inputs send digital data to the IC. The analog inputs are switched on and off by the hardware; they can be selected one at a time for play-through or recording. The digital inputs can be selected or mixed by the Screamer IC.

In addition to the signal sources connected to the sound system, the computer also accepts digital sound data from a device in the expansion bay (such as the DVD drive) or from devices connected to the USB or FireWire ports. Sound data from those sources can be sent to the sound system to be converted to analog form for output to the speakers and the output jack.

Built-in Microphone

The sound signal from the built-in microphone goes through a dedicated preamplifier that raises its nominal 30-mV level to a nominal 150 mV (peak-to-peak) signal to the Screamer IC. That signal level assures good quality digitizing without driving the analog input into clipping.

External Sound Input

The external sound input jack is located on the back of the computer. The sound input jack accepts line-level stereo signals or an Apple PlainTalk microphone. When a connector is plugged into the external sound input jack, the computer turns off the sound input from the built-in microphone. The input jack has the following electrical characteristics:

- input impedance: 6.8k ohms
- maximum level: 2.0 V rms

Note
The sound input jack accepts the maximum sound output of an audio CD without clipping. When working with sound sources that have significantly lower levels, you may wish to increase the signal gain of the sound input circuit. You can do that using the Sound Manager as described in *Inside Macintosh: Sound.* ◆

Modem Activity Sound Signals

Modem activity sound signals from the communications slot are sent to the Screamer IC as 8-bit digital data.

CardBus Sound Input

The CardBus socket has a pin (SPKR_OUT) that carries a one-bit digital sound signal output from the PC Card and input to the computer's sound system. The one-bit digital signal from the sound output pin is routed to the Screamer IC, which in turn sends it to the built-in speaker and the external sound output jack.

Zoomed Video Sound

Sound that accompanies zoomed video signals from the CardBus slot is routed as digital data by way of the I^2S bus to the Screamer IC. When an external clock is used, the sound data are 8 bits wide; with the internal clock to the DAC, the data are 16 bits wide.

Sound Outputs

The sound system sends sound output signals to the built-in speakers and the external sound output jack.

External Sound Output

The sound output jack is located on the back of the computer at the left corner. The sound output jack provides enough current to drive a pair of low-impedance headphones. The sound output jack has the following electrical characteristics:

- output impedance: 33 ohms
- minimum recommended load impedance: 65 ohms
- maximum level: 1.17 V rms (3.3 V P-P)
- maximum current: 18 ma rms (25 mA peak)

Internal Speakers

The computer has two 28mm speakers located between the keyboard and the display. The computer turns off the sound signals to the speakers when an external device is connected to the sound output jack and during power cycling.

Digitizing Sound

The sound circuitry digitizes and records sound as 44.1 kHz 16-bit samples. If a sound sampled at a lower rate on another computer is played as output, the Sound Manager transparently upsamples the sound to 44.1 kHz prior to outputting the audio to the Screamer sound IC.

When recording sound from a microphone, applications that are may be affected by feedback should disable sound playthrough by calling the Sound Manager APIs.

C H A P T E R 4

Expansion Features

This chapter consists of three sections, each of which describes one of the expansion features of the PowerBook computer:

- "Expansion Bay"
- "RAM Expansion Slots"
- "CardBus Slot"

Expansion Bay

The battery bay on the right side of the computer also operates as an expansion bay. The expansion bay accepts an expansion module containing either a power device or a storage device. Storage devices available as expansion-bay modules include hard disk drives, Zip and SuperDisk cartridge drives, and a DVD-ROM drive.

Insertion of a module into the expansion bay is performed by sliding the module into the bay, where the module is automatically latched into place. For removal of a module, an eject lever is located in the front edge of each palmrest of the computer. Pulling out on the eject lever releases the latch for the module in the bay and then slides the module a little way out of the bay.

Note
For an illustration showing the locations of the expansion bay and the release lever, see Figure 1-1. ◆

An expansion module can be inserted or removed while the computer is operating, in sleep mode, or shut down. See "User Installation of an Expansion Bay Module" (page 83) for details.

Mechanical Design of Expansion Bay Modules

An expansion module for a 5.25-inch disk has a wing extending toward the back of the computer. An expansion module that does not use 5.25-inch media need not have the wing extension; it can be the size of a battery, which fits into the same slot. The expansion bay has a hinged door that covers the extension part of the opening when a small module is installed.

Figure 4-1 and Figure 4-2 show front and back views of the expansion bay module for a device that uses 5.25-inch media. Figure 4-3 and Figure 4-4 are corresponding views of a smaller expansion bay module. The modules are the same size and shape as the expansion modules for the PowerBook G3 Series 1999 computers.

Figure 4-1 Front view of an expansion bay module for 5.25-inch media

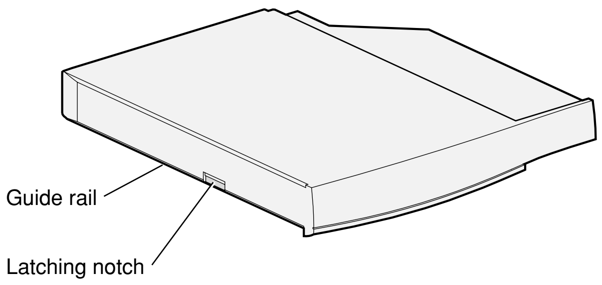


Figure 4-2 Back view of an expansion bay module for 5.25-inch media

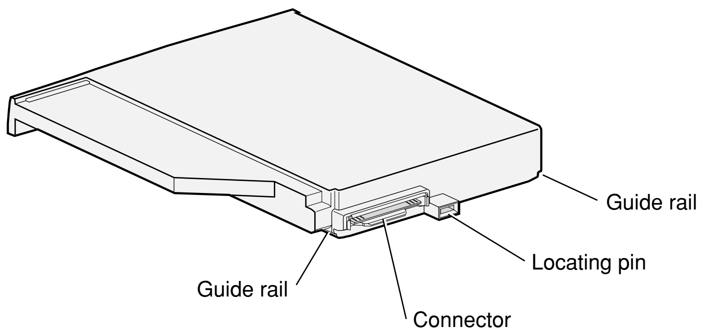


Figure 4-3 Front view of a small expansion bay module

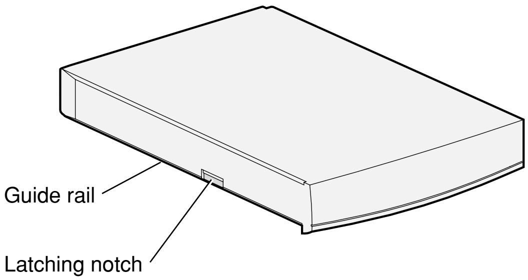
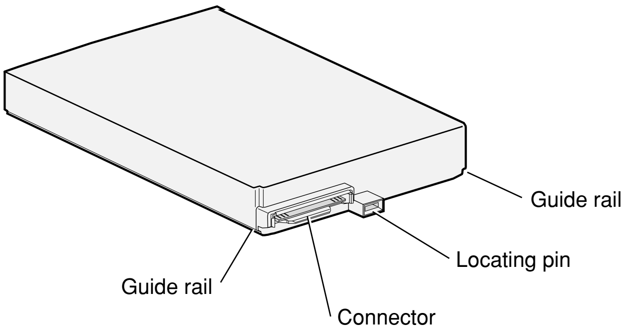


Figure 4-4 Back view of a small expansion bay module



Each expansion module has a notch on the side for the latching mechanism. The notch is on the left side of the module, which faces the front of the computer when the module is installed.

To obtain manufacturing specifications for the expansion bay module, contact Apple Developer Support.

Expansion Bay Connectors

The expansion bay has two connectors: a six-contact connector for batteries and a 60-pin connector for data devices. This section describes only the 60-pin connector.

The connector used on the expansion modules is Foxconn part number QL00303-A601. For information about obtaining this connector, contact Apple Developer Support.

IMPORTANT
The expansion bay's data connector is designed so that when a module is inserted into the expansion bay, the first connection is the ground by way of the connector shell, then the power pins make contact, and last of all the signal pins. ▲

Signals on the Expansion Bay Connector

Table 4-1 shows the signal assignments on the expansion bay connector. Signal names that begin with a slash (/) are active low.

Note
The table shows the signals in the same arrangement as the pins on the connector; that is, with pin 1 next to pin 31 and pin 30 next to pin 60. ◆

Table 4-1 Signals on the expansion bay connector

Pin	Direction	Signal name	Pin	Direction	Signal name
1		Reserved	31	I/O	IDE_D(12)
2		Reserved	32		GND
3		Reserved	33	I/O	IDE_D(14)
4		GND	34	I/O	IDE_D(10)
5		/IOCHRDY	35		+5V
6		+5V	36	I/O	IDE_D(9)
7		DIOW	37		GND
8		GND	38	I/O	IDE_D(8)
9	I/O	IDE_D(0)	39	I/O	IDE_D(11)
10		IDE_INTRQ	40		+5V
11	O	IDE_ADDR(1)	41	I/O	IDE_D(13)

Table 4-1 Signals on the expansion bay connector (continued)

Pin	Direction	Signal name	Pin	Direction	Signal name
12		GND	42		GND
13	O	IDE_ADDR(0)	43	I/O	IDE_D(2)
14	O	/CS1FX	44	I/O	IDE_D(1)
15		+5V	45		/CS3FX
16	I/O	IDE_D(3)	46		GND
17	I/O	IDE_D(4)	47		IDE_ADDR(2)
18		GND	48	O	/DMACK
19	I/O	IDE_D(5)	49		GND
20	I/O	IDE_D(6)	50		/DIOR
21		+5V	51		DMARQ
22	I/O	IDE_D(7)	52		+5V
23		/IDE_RST	53	I/O	IDE_D(15)
24		GND	54		GND
25		Reserved	55		Reserved
26		+5V	56		+5V
27		Reserved	57		DEVID(0)
28		GND	58		DEVID(1)
29	I/O	MB_USB_DP	59		DEVID(2)
30	I/O	MB_USB_DM	60		/DEVIN

Expansion Bay Signal Definitions

The signals on the expansion bay connector are of two types: expansion bay control signals and ATA signals. Table 4-2 describes the control signals and Table 4-3 (page 81) describes the ATA signals.

Table 4-2 Control signals on the expansion bay connector

Signal name	Signal description
/DEVID(0-2)	These signals identify the type of device in the expansion-bay module. A value of 011b identifies an IDE device; a value of 111b indicates no device is present.
/DEVIN	This signal should be low whenever a device is installed in the expansion bay; it is used by the KeyLargo IC to determine when a device has been inserted or removed. The expansion bay module should connect this pin to ground.
/IDE_RST	Reset signal.

Table 4-3 ATA signals on the expansion bay connector

Signal name	Signal description
/CS1FX	Register select signal. It is asserted low to select the main task file registers. The task file registers indicate the command, the sector address, and the sector count.
/CS3FX	Register select signal. It is asserted low to select the additional control and status registers on the IDE drive.
/DIOR	I/O data read strobe.
/DIOW	I/O data write strobe.
DMARQ	DMA request signal.
/DMACK	DMA acknowledge signal.
IDE_ADDR(0–2)	IDE device address; used by the computer to select one of the registers in the drive. For more information, see the descriptions of the /CS1FX and /CS3FX signals.
IDE_D(0–15)	IDE data bus, buffered from IOD(16–31) of the controller IC. IDE_D(0–15) are used to transfer 16-bit data to and from the drive buffer. IDE_D(0–7) are used to transfer data to and from the drive's internal registers, with IDE_D(8-15) driven high when writing.

Table 4-3 ATA signals on the expansion bay connector (continued)

Signal name	Signal description
IOCHRDY	I/O channel ready; when driven low by the IDE drive, signals the CPU to insert wait states into the I/O read or write cycles.
IDE_INTRQ	IDE interrupt request. This active high signal is used to inform the computer that a data transfer is requested or that a command has terminated.
/IDE_RST	Hardware reset to the IDE drive.

Note
Signal names that begin with a slash (/) are active low. ◆

Unused IDE Signals on the Expansion Bay Connector

Several signals defined in the standard interface for the IDE drive are not used by the expansion bay. Those signals are listed in Table 4-4 along with any action required for the device to operate in the expansion bay.

Table 4-4 Unused IDE signals on the expansion bay connector

Signal name	Comment
CSEL	This signal must be tied to ground to configure the device as the master in the default mode.
PDIAG	No action required; the device is never operated in master-slave mode.
DAS	No action required.

Power on the Expansion Bay Connector

Table 4-5 describes the power lines on the expansion bay connector. The +5V line is controlled by the /MB_PWR signal from the KeyLargo IC.

Table 4-5 Power lines on the expansion bay connector

Signal name	Signal description
GND	Ground.
+5V	5 V power.

The power lines are equipped with current-limiting devices to protect the computer from damaged modules or short circuits. The current limit is between 1.8 and 2.0 A.

IMPORTANT
For thermal reasons, the continuous power dissipation in the expansion bay must not exceed a total of 5 W. ▲

User Installation of an Expansion Bay Module

The user can insert a module into the expansion bay while the computer is operating. This section describes the sequence of control events in the computer and gives guidelines for designing an expansion bay module so that such insertion does not cause damage to the module or the computer.

IMPORTANT
The user must not remove a module from the expansion bay while the computer is communicating with the module or, for a module with a disk drive, while the disk is spinning. ▲

Sequence of Control Signals

Specific signals to the KeyLargo IC allow the computer to detect the insertion of a module into the expansion bay and take appropriate action. The sequence of events is diagrammed in Figure 4-5.

When a module is inserted, the computer performs the following sequence of events:

1. When a module is inserted, the /DEV_IN signal goes low, causing the KeyLargo IC to generate an interrupt.
2. System software responds to the interrupt and reads the DEV_ID pins to determine the type of module inserted.
3. System software sets the /MB_PWR_EN signal low, which turns on the power to the expansion bay.
4. System software sets the enable signal and internally notifies the appropriate driver of the presence of a newly inserted module.
5. System software sets the /MB_RESET signal high to bring the expansion bay module out of reset.

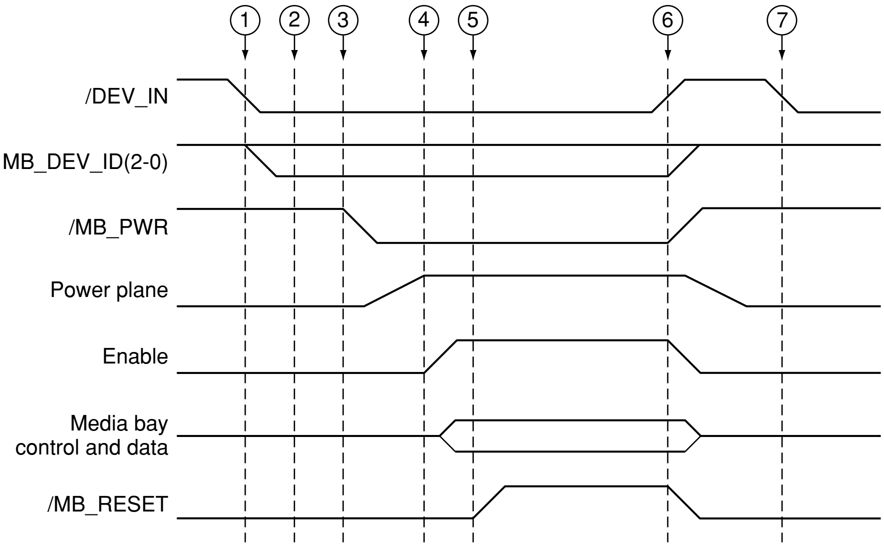
Essentially the reverse sequence occurs when a module is removed from the expansion bay:

6. When the module is removed, the /DEV_IN signal goes high. The KeyLargo IC responds by setting /MB_PWR high, the enable signal low, and /MB_RESET low, and generating an interrupt. System software responds to the interrupt and notifies the appropriate driver that the module has been removed.

When a module is resinserted into the expansion bay, the triggering event is the same:

7. When a module is reinserted, the /DEV_IN signal goes low. The KeyLargo IC responds by generating an interrupt, but keeps external signals deactivated, because the new device may be different from the one inserted previously.

Figure 4-5 Timing of control signals during module insertion and removal



Guidelines for Developers

Each expansion bay module must be designed to prevent damage to itself and to the computer when the user inserts or removes an expansion bay module with the computer running.

The expansion bay connector is designed so that when the module is inserted the ground and power pins make contact before the signal lines.

Even though you can design an expansion bay module that minimizes the possibility of damage when it is inserted hot—that is, while the computer is running—your instructions to the user should include warnings about the possibility of data corruption.

RAM Expansion Slots

The computer has two RAM expansion slots that accommodate standard SO (small outline) DIMMs using SDRAM devices. The slot on the underside of the processor card is normally occupied by a factory-installed SO-DIMM. The other slot is available for a user-installed SO-DIMM.

RAM expansion SO-DIMMs for the PowerBook computer must be PC100 compliant and must use SDRAM devices. If the user installs an SO-DIMM that uses EDO devices, the boot process will fail when the user attempts to restart the computer and the computer will not operate.

An SO-DIMM using currently-available parts can contain either 32, 64, 128, 256, or 512 MB of memory. The computer can support up to 1 GB total RAM using the highest-density devices available, but SO-DIMMs made with such devices may draw too much current in sleep mode to allow battery sleep swapping. See "RAM SO-DIMM Electrical Limits" (page 91).

Getting Access to the Slots

The RAM expansion slots are on the processor module. The user can get access to the slots by removing the keyboard and the heat shield, as shown in Figure 4-6.

Removing the Keyboard

The keyboard is held in place by a locking screw and two latches.

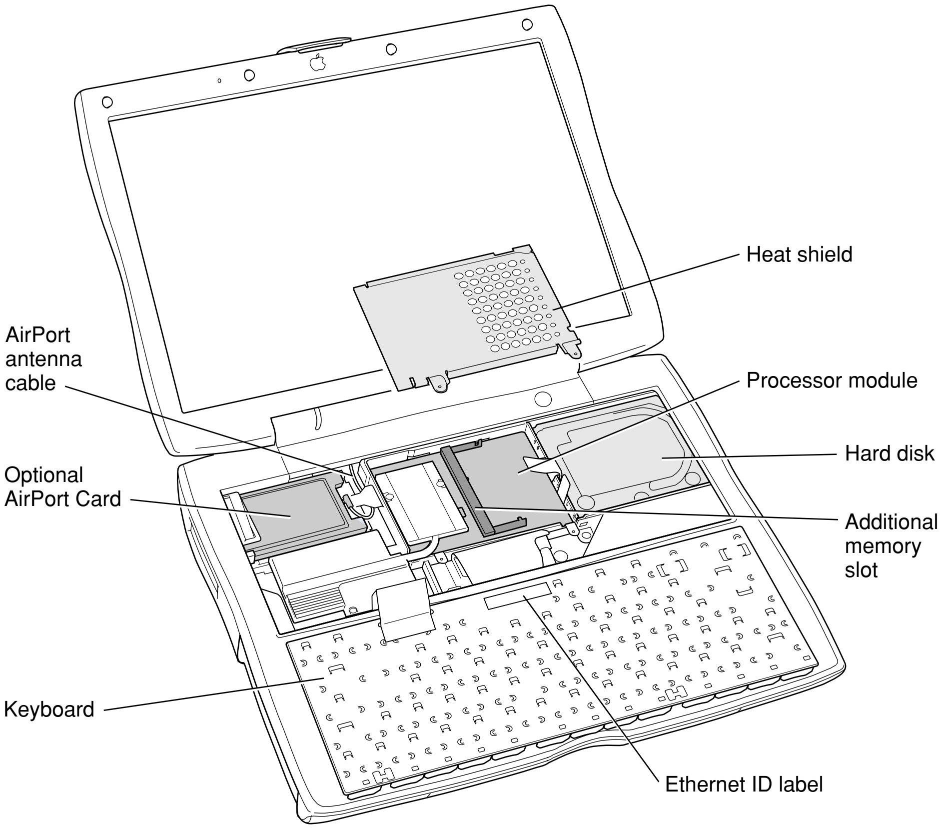
The keyboard locking screw is a slotted screw that is part of the Num Lock LED, which is located between the F4 and F5 function keys. Turning the screw 180° switches between the locked and unlocked positions. The computer is shipped with the locking screw in the unlocked position.

The two latches are between the ESC key and the F1 key and between the F8 and F9 keys. You release the latches by pulling them toward the front of the computer.

Removing the Heat Shield

A metal heat shield covers the processor module. The heat shield is held in place by two screws. After removing the screws, you can lift the heat shield out of the way.

Figure 4-6 Interior view showing RAM expansion slot



Mechanical Design of RAM SO-DIMMs

The RAM expansion modules used in the PowerBook computer are standard 144-pin 8-byte DRAM SO-DIMMs, as defined in the JEDEC specifications.

The mechanical characteristics of the RAM expansion SO-DIMM are given in the JEDEC specification for the 144-pin 8-byte DRAM SO-DIMM. The specification number is JEDEC MO-190-C; it is available from the Electronics Industry Association's web site, at

http://www.jedec.org/download/default.htm

The specification defines SO-DIMMs with nominal heights of 1.0, 1.25, 1.5, or 2.0 inches. The PowerBook computer can accommodate SO-DIMMS with heights up to 2.0 inches.

IMPORTANT

The JEDEC specifications for the heights of the SO-DIMMs gives a plus-or-minus 0.15 mm tolerance. In the PowerBook computer, the specified heights for the SO-DIMMs are maximum heights. ▲

The JEDEC specification defines the maximum depth or thickness of an SO-DIMM as 3.8 mm. That specification is also a maximum: Modules that exceed the specified thickness can cause reliability problems.

Electrical Design of RAM SO-DIMMs

The RAM SO-DIMMs are required to be PC100 compliant. The PC100 SDRAM specification, revision 1.63, is available from Intel's website at

http://developer.intel.com/design/chipsets/memory/sdram.htm#S1

The electrical characteristics of the RAM SO-DIMM are given in section 4.5.6 of the JEDEC Standard 21-C, release 7. The specification is available from the Electronics Industry Association's web site, at

http://www.jedec.org/download/default.htm

The JEDEC and PC100 specifications define several attributes of the DIMM, including storage capacity and configuration, connector pin assignments, and electrical loading. The specifications support SO-DIMMs with either one or two banks of memory.

The JEDEC specification for the SO-DIMM defines a Serial Presence Detect (SPD) feature that contains the attributes of the module. SO-DIMMs for use in the PowerBook computers are required to have the SPD feature. Information about the required values to be stored in the presence detect EEPROM is in section 4.1.2.5 and Figure 4.5.6–C (144 Pin SDRAM SO–DIMM, PD INFORMATION) of the JEDEC standard 21-C specification, release 7.

Capacitance of the data lines must be kept to a minimum. Individual DRAM devices should have a pin capacitance of not more than 5 pF on each data pin.

SDRAM Devices

The SDRAM devices used in the RAM expansion modules must be self-refresh type devices for operation from a 3.3-V power supply. The speed of the SDRAM devices must be 125 MHz or greater (8 ns access time).

The devices are programmed to operate with a CAS latency of 3. At that CAS latency, the access time from the clock transition must be 6 ns or less. The burst length must be at least 4 and the minimum clock delay for back-to-back random column access cycles must be a latency of 1 clock cycle.

When the computer is in sleep mode, the RAM modules are in self-refresh mode and the maximum power-supply current available for each bank of SDRAM is 8 mA (see the section "RAM SO-DIMM Electrical Limits"). Developers should specify SDRAM devices with low power specifications so as to stay within that limit.

Configuration of RAM SO-DIMMs

Table 4-6 shows information about the different sizes of SDRAM devices used in the memory modules. The first two columns show the memory size and configuration of the SO-DIMMs. The next two columns show the number and configuration of the SDRAM devices making up the memory modules.

Table 4-6 Sizes of RAM expansion modules and devices

SO-DIMM		SDRAM Devices		
Size	**Configuration**	**Number**	**Configuration**	**Banks**
16 MB	2 M x 64	2	2 M x 32	1
32 MB	4 M x 64	4	4 M x 16	1
32 MB	4 M x 64	4	2 M x 32	2
64 MB	8 M x 64	8	8 M x 8	1
64 MB	8 M x 64	8	4 M x 16	2
64 MB	8 M x 64	4	8 M x 16	1
128 MB	16 M x 64	8	16 M x 8	1
128 MB	16 M x 64	8	8 M x 16	2

Table 4-6 Sizes of RAM expansion modules and devices (continued)

SO-DIMM		SDRAM Devices		
Size	**Configuration**	**Number**	**Configuration**	**Banks**
256 MB	16 M x 64	16	16 M x 8	2
256 MB	16 M x 64	16	8 M x 16	4
256 MB	32 M x 64	8	32 M x 8	1
256 MB	32 M x 64	8	16 M x 16	2
512 MB	32 M x 64	16	32 M x 8	2
512 MB	32 M x 64	16	16 M x 16	4

Note
The PowerBook computer does not support memory interleaving, so installing two SO-DIMMs of the same size does not result in any performance gain. ◆

Address Multiplexing

Signals A[0] – A[12] and BA[0] – BA[1] on each RAM SO-DIMM make up a 15-bit multiplexed address bus that can support several different types of SDRAM devices. Table 4-7 lists the types of devices that can be used in the PowerBook computer by size, configuration, and sizes of row, column, and bank addresses.

IMPORTANT
The PowerBook computer supports only the types of SDRAM devices specified in Table 4-7. Other types of devices should not be used with this computer. ▲

Table 4-7 Types of DRAM devices

Device size	Device configuration	Row address bits	Column address bits
64 Mbits	2 M x 8 x 4	12	9
64 Mbits	1 M x 16 x 4	12	8
64 Mbits	512 K x 32 x 4	11	8
128 Mbits	4 M x 8 x 4	12	10
128 Mbits	2 M x 16 x 4	12	9
128 Mbits	1 M x 32 x 4	12	8
256 Mbits	8 M x 8 x 4	13	10
256 Mbits	4 M x 16 x 4	13	9

RAM SO-DIMM Electrical Limits

Each RAM SO-DIMM must not exceed the following maximum current limits on the +3 V supply:

Active	1.2 A (8 devices at 150 mA each)
Active	8 mA per bank

IMPORTANT
The restriction on sleep current is required not only to maximize the battery life but to meet the limitations of the backup battery during sleep swapping of the main battery. Developers of RAM expansion modules that exceed the limit on sleep current must include a warning to the user that battery sleep swapping may not work with those modules installed. ▲

The maximum current specified for active operation generally rules out the use of 4-bit-wide SDRAM devices in a RAM expansion module. Such a module would have 16 such devices, and the 1.2 A maximum current would allow only about 75 mA per device. To stay within the current limits, RAM expansion modules should use only 8-bit or 16-bit SDRAM devices.

CardBus Slot

The CardBus slot accepts one Type I or Type II card. The slot supports both 16-bit PC Cards and 32-bit CardBus Cards. The card can be removed and replaced while the computer is operating. The slot supports Zoomed Video on the card connector.

Note
The CardBus slot does not provide 12-V power. ◆

For information about the latest version of the PC Card Manager, developers should refer to the PC Card Manager v3.0 SDK. The SDK is available on the March 1997 Reference Library edition of the Developer CD and on the Apple Developer World web page at:

ftp://ftp.apple.com/developer/Development_Kits/PC_Card_SDKs.sit.hqx

CHAPTER 5

System Software

This chapter summarizes the ROM-in-RAM design of the software and describes the changes that have been made to support the new PowerBook computer.

The version of the Mac OS that comes with the PowerBook computer is Mac OS 9.

ROM in RAM

The system software in the new PowerBook computer uses the ROM-in-RAM approach also used in the PowerBook G3 Series 1999 computer and other current Macintosh computers. With the ROM-in-RAM approach, also called the NewWorld software architecture, a small ROM contains the code needed to initialize the hardware and load an operating system. The rest of the system code that formerly resided in the Mac OS ROM is loaded into RAM from disk or from the network.

The small ROM that is needed for the computer’s start-up activities, called the boot ROM, is 1 MB in size. It includes the hardware-specific code and tables needed to start up the computer, to run Open Firmware, to provide common hardware access services, and to load the Mac OS ROM image.

High-level software resides in an image called the Mac OS ROM that is read into RAM during startup. Once the Mac OS begins operation, the Mac OS ROM image in RAM behaves in the same way that the corresponding code in ROM formerly did. Most of the changes are completely transparent to the Mac OS.

For more information about the ROM-in-RAM approach, see Technote 1167, *NewWorld Architecture,* available on the Technote website at

http://developer.apple.com/technotes/tn/tn1167.html

Aspects of the New Approach

Some aspects of the ROM-in-RAM approach are apparent in the operation of the system.

RAM Footprint

The PowerBook computer has its Mac OS ROM image stored in RAM. The area of RAM that contains the Mac OS ROM image is excluded from the available memory space and is marked as read-only. This removes approximately 3 megabytes of RAM from availability for other uses. In effect, a system with 64 megabytes of RAM appears to have only 61 megabytes available.

Startup Disk Control Panel

Setting the startup device from the Startup Disk control panel makes the changes to the boot process that are needed for the ROM-in-RAM approach. The Startup Disk control panel sets the Open Firmware's boot-device configuration variable by modifying the Open Firmware NV-RAM partition that contains the Open Firmware's configuration variables.

IMPORTANT

The previous API for controlling the startup device selection, using `_GetDefaultStartup` and `_SetDefaultStartup`, is not effective on computers that use the ROM-in-RAM approach. ▲

Memory Mapping

With the ROM-in-RAM approach, memory is not mapped one-to-one as it has been for previous PCI-based Macs. This could be a compatibility issue with some software. Software that assumes the logical and physical addresses are the same will fail, even when virtual memory is not on. Well-behaved software—that is, software that always calls the `LogicalToPhysical` or `PrepareMemoryForIO` functions when it needs a physical memory address—will continue to work.

For more information see Technical Q&A DV 33, *PrepareMemoryForIO for the New World*, available on Apple's technote website at

http://developer.apple.com/qa/dv/dv33.html

Boot Process

The boot process for the PowerBook computer is similar to that for other Macintosh computers that use the ROM-in-RAM approach. The PowerPC processor executes its reset vector as defined by the Hardware Initialization code. This code runs diagnostics tests, and when enough hardware initialization has been performed to run Open Firmware, the boot beep sound is played and Open Firmware begins executing. The Open Firmware module probes the system's I/O buses to determine the device configuration and builds a device tree describing the hardware it finds.

The boot device, selected by the user with the Startup Disk control panel, is stored in Open Firmware's NV-RAM. Open Firmware attempts to locate that boot device, which can be a hard disk, a CD, a USB or FireWire storage device, or a network connection. If the selected boot device is not found, Open Firmware searches for a suitable boot device according to a predetermined search order.

Once the boot device has been found, the Mac OS ROM image is loaded into memory, decompressed, and write-protected so that it behaves just like actual ROM.

Some of the Mac OS ROM boot code is written in 68K code. In order to run the 68K ROM, the PowerPC Nanokernel is loaded, and the emulator task is started. The emulator begins executing code in the 68K ROM. This code uses the device tree provided by Open Firmware to install device drivers, Macintosh OS Services (referred to as Toolbox Managers), and finally the ROM loads the rest of the operating system from the startup device.

Hardware Initialization Code

The hardware initialization code contains calls to a series of Power-On Self Test (POST) routines. The principle features are a ROM checksum test, memory testing, detection of the manufacturing test pin, and test manager support. These diagnostics run in native Power PC code.

The hardware initialization code on the new PowerBook computer is different from that on earlier PowerBook models because of the new ICs (Uni-N and KeyLargo). Additional diagnostics are run out of the ROM in emulation.

Functions of the hardware initialization code include

- initialization of the Uni-N bridge and memory controller IC

- memory sizing using I^2C presence detect on the memory module
- memory timing setup with support for fast SDRAM devices
- L2 cache detection and sizing
- initialization of the KeyLargo I/O controller IC
- generating diagnostic sounds, including the boot chord that is emitted when hardware initialization has been successfully completed

The firmware in the boot ROM sets up and sizes memory, then stores the information in the device tree where it is available to the operating system. The firmware obtains information about the memory by way of the serial presence detect mechanism of the SO-DIMM that is used for memory expansion. The JEDEC standard for the SO-DIMM mandates that all SO-DIMMs include a ROM with information about the memory. The Uni-N IC reads that information from the ROM by way of the I^2C bus.

Open Firmware

Open Firmware is a boot environment developed using the Forth programming language. The purpose of Open Firmware is to provide a machine-independent mechanism for loading operating systems from a variety of boot devices. Open Firmware probes the PCI bus looking for devices and possible Open Firmware drivers for those devices. These drivers can either be built into the Open Firmware module or located in the external device, thus providing plug-and-play capabilities for new boot devices. Open Firmware is capable of using these drivers to load an operating system from the device.

Functions of the Open Firmware code include

- configuration of the Uni-N and KeyLargo ICs
- construction of the device tree
- probing of the devices and inclusion of some device drivers
- selection of the boot device
- optional user selection of FireWire Disk Mode; see “Target Disk Mode” (page 98)

On the new PowerBook computer, the Open Firmware code has been extended so that the device tree describes the new hardware features of the computer. The Open Firmware code also includes FCode drivers for the new hardware channels: UltraDMA66, FireWire, and USB.

The default operating system, the Mac OS ROM image, is loaded from the current startup device. The user may interrupt Open Firmware's boot device selection by holding down the Option key while booting. This invokes the OS Picker, an Open Firmware application that lets the user select an alternate operating system or boot device.

Alternatively, the user can interrupt Open Firmware by holding down the Command, Option, O, and F keys. Open Firmware responds by providing a command-line interface using the keyboard and built-in display. Using this interface, users can change the stored parameters used by Open Firmware.

Target Disk Mode

One option at boot time is to put the computer into a mode of operation called Target Disk mode. This mode is similar to SCSI Disk mode on a PowerBook computer equipped with a SCSI port, except it uses a FireWire connection instead of a special SCSI cable.

When the PowerBook computer is in Target Disk mode and connected to another Macintosh computer by a FireWire cable, the PowerBook computer operates like a FireWire mass storage device with the SBP-2 (Serial Bus Protocol) standard. Target Disk mode has two primary uses:

- high-speed data transfer between computers
- diagnosis and repair of a corrupted internal hard drive

The PowerBook computer can operate in Target Disk Mode as long as the other computer has FireWire 2.3 or newer.

To put the computer into Target Disk mode, the user holds down the T key while the computer is starting up. When Open Firmware detects the T key during the boot process, it transfers control to special Open Firmware code.

To take the computer out of Target Disk mode, the user presses the power button.

For more information about Target Disk mode, see the section "Target Mode" in Technote 1189, *The Monster Disk Driver Technote*. The technote is available on the Technote website at

http://developer.apple.com/technotes/

System Software Support

The following sections describe the parts of the Mac OS ROM Image that support specific features of the PowerBook computer.

Computer Identification

All ROMs based on NewWorld share the same box flag. The intent is for applications to use properties in the Open Firmware tree rather than checking BoxFlag to find out the features of the machine. As with other computers that use ROM-in-RAM, a call to `gestaltMachineType` returns the value 406 ($196).

IMPORTANT

Programs such as control panels and installers that use the box flag to verify that this is a valid CPU on which to execute must be changed to verify the existence of the hardware they require. You should look for the features you need, rather than reading the box flag or the model string and then making assumptions about the computer's features. ▲

Asset management software that reports the kind of machine it is run on can obtain the value of the property at `Devices:device-tree:compatible` in the name registry. The model string is the first program-useable string in the array of C strings in the `compatible` field. For the PowerBook computer, the value of the model property is `PowerBook3,1`.

The string obtained from the `compatible` property cannot be displayed to the computer user. A better method, if it is available, is to use the result from calling `Gestalt ('mnam', &result)` where `result` is a string pointer. This call returns a Pascal style string that can be displayed to the user.

Applications should not use either of these results to infer the presence of certain features; instead, applications should use Gestalt calls to test for the features they require.

Power Saving Modes

The PowerBook computer meets the following energy saving standards:

- Energy Saver
- Energy Star (US)
- Blue Angel (Germany)

To meet those standards, the default configuration of the computer must draw less than 7 watts in Sleep mode and less than 5 watts in off mode, while plugged into the AC adapter and with the battery removed.

The Power Manager has been redesigned to reduce power consumption in Sleep mode. The new version, Power Manager 2.0, is a native Mac OS manager designed to implement common power management policy across all Macintosh models by means of the new Power Plugin component. For information about API changes in Power Manager 2.0, refer to Technote 1190, *Power Manager 2.0.* The technote is available on the Technote website at

http://developer.apple.com/technotes/

With the new power management architecture, the following operating modes are defined:

- **Run Single:** The processor is running at maximum processing capacity.
- **Idle:** The system is idling with the main processor stopped in sleep mode. All clocks are running; the system can return to running code within a few nanoseconds. Cache coherency is maintained in this level of idle.
- **Sleep:** The system is completely shut down, with only the DRAM state preserved for quick recovery. All processors are powered off with their state preserved in DRAM. All clocks in the system are suspended except for the 32.768 Khz timebase crystal on the PMU99 IC.

The computer automatically enters Idle mode after several seconds of inactivity. If the computer is attached to a network and an AC power supply, it is able to respond to service requests and other events directed to the computer while it is in Idle mode. The user can enable this by selecting Wake-on-LAN in the Energy Saver control panel.

The computer cannot respond to network activity when it is in Sleep mode. To prevent the computer from going into Sleep mode, the user must set the Sleep setting in the Energy Saver control panel to “Never.”

Although the current public Power Manager interfaces will be maintained for application compatibility, this is a major revision that may affect developers. Information about the API changes for Power Manager 2.0 is available in a technote, which can be obtained from the website at

http://developer.apple.com/technotes/index.html

Suspend and Resume

Suspend and Resume provides a way for the computer to shut off or lose power and then, once power returns, restore the system to the state before the power loss. The Suspend feature saves the computer's RAM contents on the hard disk before turning off the power. The difference between the Suspend state and normal power off is the presence of the saved RAM contents, along with some other hardware information, on the hard disk.

Note
The Suspend and Resume feature requires that Virtual Memory be turned on. ◆

IMPORTANT
Drivers are required to save whatever is necessary to restore state after a loss of power. ▲

The Energy Saver control panel has a checkbox that lets the user specify whether or not to save memory before the system goes into Sleep mode. The default is yes.

When the user presses the power key, the computer starts up and automatically reloads the RAM contents from the hard disk. The computer goes through a process similar to a normal boot, but it does not display the startup screen or the extension icons; instead, it displays a progress bar. After it restores the prior state, the computer resumes execution of whatever application was executing at the time the power was lost.

Sleep and wake queues are executed for Suspend and Resume.

ATA Manager 4.0

Mac OS 9 includes ATA Manager 4.0, which has a modular design similar to that of SCSI Manager 4.3. This modularity provides the flexibility to have multiple ATA controllers working at the same time—for example, those for the

UltraDMA66 and EIDE interfaces. ATA Manager 4.0 supports both controllers together by including ATA Interface Modules (AIMs) for both.

With the new modular design, the ATA Manager and the ATA plug-ins divide the responsibilities. The ATA Manager is resposible for

- registering ATA plug-ins
- routing each request to the appropriate plug-in
- calling completion routines for asynchronous calls

ATA plug-ins are responsible for

- handling each request
- error handling
- returning errors

USB Drivers

A Universal Serial Bus Services Library layer provides hardware abstraction. Below it is the UIM (USB Interface Module) that communicates with the USB hardware in the KeyLargo IC. Above it are the class drivers that are loaded dynamically when new devices are plugged onto the bus.

USB class drivers are software components that are able to communicate with similar USB devices of a particular kind. If the appropriate class driver is present, any number of compliant devices can be plugged in and start working immediately without the need to install additional software.

USB Mass Storage Support 1.3 includes the following class drivers:

- Audio Class driver: Supports USB audio devices such as speakers and microphones.
- Mass Storage Class driver: Supports booting from a USB storage device that follows the USB Mass Storage Class specification. Mass Storage Class drivers do not support CD, CD-R, or other read-only media types.
- Communication Class driver: Supports USB communication devices that support the Abstract Control Model subclass.
- Printer Class driver: Supports USB printers. The LaserWriter 8 driver can communicate through this driver to any Postscript-based printer.

- HID driver: Provides support in InputSprockets for all HID-class devices (such as joysticks and game controllers) and for most force-feedback devices.
- Keyboard and Mouse driver: Supports all USB keyboards and mouse devices that support boot protocol (HID Class, Subclass 1).
- HUB Class driver: Supports all USB compliant hubs.

Version 1.3 of the Macintosh USB system software supports all four data transfer types defined in the USB specification.

Other New Drivers

The system software includes new drivers for the FireWire ports, the Ethernet port, and the wireless LAN module.

The new FireWire Interface Module (FWIM) supports 1394 OHCI (open host controller interface). The FireWire driver also includes services for mass storage devices with the SBP-2 (Serial Bus Protocol) standard.

The new Ethernet driver supports 100Base-T operation and Wake on LAN. The Ethernet driver uses the Open Transport Data Link Provider Interface (DLPI).

The driver for the wireless LAN module is not part of the Mac OS ROM image but resides in the Extensions folder.

Legacy Drivers

The absence of serial ports, ADB ports, a SCSI port, and a floppy drive, and the addition of the USB and FireWire ports, may affect the behavior and appearance of various system components. Modifications for such changes are in Mac OS 9 itself.

Some managers and drivers remain in the system to support existing applications that depend on those older devices. New applications are expected to use the new I/O channels such as USB and FireWire.

Floppy Disk Legacy

The PowerBook computer has no built-in floppy disk drive, so the existing `.Sony` driver has been disabled using the same techniques as in the iMac software. MFM Floppy disks can be supported by a USB-based LS-120 disk drive developed by a third party.

ADB Legacy

The PowerBook computer has no ADB ports. The ADB Manager is still present, to retain compatibility with programs that require it.

The system software has an ADB shim layer to allow USB keyboards and mice to appear as legacy ADB devices.

SCSI Legacy

Although there is no SCSI connector on the PowerBook computer, the high-level SCSI interfaces remain in the system. That allows for possible support for SCSI devices using a USB-to-SCSI adapter. Such an adapter would take the USB commands coming from the USB port and convert them into SCSI commands to send to the drive. A SCSI driver would also need to be written that would take the SCSI commands coming from the system and embed them in USB commands that would be sent to the device through the adapter.

Other New Features

The system software for the iBook supports several other new features.

Sound Software Components

The I^2S-based sound system in the new PowerBook computer is the first such implementation on a PowerBook computer. To support this new hardware, a Sound HAL (hardware abstraction layer) has been written. In addition to the HAL, a port handler has been written to describe the hardware capabilities.

Note
The Sound Manager API has not been changed. ◆

Keyboard and Key Caps

Several of the keys on the keyboard have more than one mode of operation. The function keys can also control the display and speakers; the keys on the right side of the keyboard can also be used as a numeric keypad; and certain control keys can also be used as page-control keys. The Keyboard Control Panel has been changed to support these features, as described in the section "Keyboard" (page 56).

External keyboards connected using USB will work. The image displayed by Key Caps toggles when input from an external keyboard is detected.

Onscreen Display

The Pismo computer uses on-screen display meters for its sound and display control buttons. There are separate on-screen display meters for display brightness, sound volume, and mute.

Wireless LAN Module

A software driver for the AirPort Card wireless LAN module is included in the Extensions folder. For more information, please see "AirPort Card Wireless LAN Module" (page 47).

Software DVD Decoding

The DVD-ROM drive in the PowerBook computer does not include hardware for decoding MPEG movies on DVD. Instead, the decoding is performed in software running on the main processor.

Abbreviations

Standard units of measure used in this note include:

A	amperes	MB	megabytes
dB	decibels	Mbps	megabits per second
GB	gigabytes	Mbits	megabits
Hz	hertz	MHz	megahertz
KB	kilobytes	mm	millimeters
kg	kilograms	ns	nanoseconds
kHz	kilohertz	V	volts
mA	milliamperes	VDC	volts direct current
mAh	milliampere-hours		

Other abbreviations used in this note include:

$n	hexadecimal value n
10Base-T	an Ethernet standard for data transmission at 10 Mbits per second
100Base-TX	an Ethernet standard for data transmission at 100 Mbits per second
68K	the 68000 family of microprocessors
ADB	Apple Desktop Bus
AIM	ATA Interface Module
ANSI	American National Standards Institute
API	application programming interface
ASIC	application-specific integrated circuit
ATA	AT attachment
BIOS	basic input/output system
CAS	column address strobe, a memory control signal
CD	compact disc

CD-ROM	compact disc read-only memory
CHRP	Common Hardware Reference Platform
CPU	central processing unit
CRM	Communications Resource Manager
CRT	cathode ray tube, a video display device
DAA	data access adapter (a telephone line interface)
DAC	digital-to-analog converter
DIMM	Dual Inline Memory Module
DB-DMA	descriptor-based direct memory access
DMA	direct memory access
DVI	Digital Visual Interface
EDO	extended data out
EEPROM	electrically eraseable programmable ROM
EIDE	enhanced integrated device electronics
G3	Generation 3, the third generation of PowerPC microprocessors, including the PPC 740 and PPC 750
GND	ground
HFS	hierarchical file system
HID	human interface device, a class of USB devices
IC	integrated circuit
IDE	integrated device electronics
IEC	International Electrotechnical Commission
I/O	input and output
IR	infrared
IrDA	Infrared Data Association
ISO	International Organization for Standardization
JEDEC	Joint Electron Device Engineering Council
JIS	Japanese Industrial Standards
L1	level 1 or first level, a type of CPU cache
L2	level 2 or second level, a type of CPU cache
LED	light emitting diode

Mac OS	Macintosh Operating System
MESH	the name of an Apple custom IC
modem	modulator-demodulator, a data communications interface for use with analog telephone lines
NMI	nonmaskable interrupt
NOP	no operation
NV-RAM	nonvolatile random-access memory
OHCI	Open Host Controller Interface
OS	operating system
PCI	Peripheral Component Interconnect, an industry-standard expansion bus
PLL	phase-locked loop
POST	power-on self test
RAM	random-access memory
RAID	random array of inexpensive disks
RCA	Radio Corporation of America
rms	root mean square
ROM	read-only memory
RTAS	run-time abstraction services
SBP	Serial Bus Protocol
SCC	Serial Communications Controller
SCSI	Small Computer System Interface
SDRAM	synchronous dynamic RAM
SGRAM	synchronous graphics RAM; used for display buffers
SMB	System Management Bus (for Smart Battery)
SNR	signal to noise ratio
SO-DIMM	small outline dual inline memory module
SPD	Serial Presence Detect, a feature of the SO DIMM

USB	Universal Serial Bus, an industry-standard expansion bus
VCC	positive supply voltage (voltage for collectors)
VIA	versatile interface adapter

Index

A

B

C

D

J

K

L

M

N

O

P

R

S

T

U

V

W

X

Z

This Apple manual was written, edited, and composed on a desktop publishing system using Apple Macintosh computers and FrameMaker software. Line art was created using Adobe™ Illustrator and Adobe Photoshop.

Text type is Palatino® and display type is Helvetica®. Bullets are ITC Zapf Dingbats®. Some elements, such as program listings, are set in Adobe Letter Gothic.

Developer Press Art List

Pismo Developer Note

Writer	*Allen Watson*	Art Director	*Dave Arrigoni*
Prod. Editor	*Lorraine Findlay*	Illustrator	*Dave Arrigoni*
# of Figures	*18*	Draft stage	*To Production*