
17-inch PowerBook G4 Developer Note



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Contents

Introduction [Introduction to 17-inch PowerBook G4 Developer Note](#) 9

[Organization of This Document](#) 9

Chapter 1 [Overview of 17-inch PowerBook G4](#) 11

[New Features](#) 11
[All Features](#) 11
[Appearance](#) 13
[Peripheral Devices](#) 14
[System Software](#) 15
 [Open Firmware](#) 15
 [Computer Identification](#) 15
 [Power Management](#) 15

Chapter 2 [Architecture](#) 19

[Block Diagram and Buses](#) 19
 [Block Diagram](#) 19
 [Main IC and Buses](#) 20
[Microprocessor and Caches](#) 21
 [PowerPC G4 Microprocessor](#) 21
 [Level 2 Cache](#) 21
[Intrepid Controller Functions and Buses](#) 21
 [System RAM](#) 22
 [Boot ROM](#) 22
 [FireWire Controllers](#) 22
 [Ethernet Controller](#) 22
 [Video Display Subsystem](#) 23
 [DMA Support](#) 24
 [Interrupt Support](#) 24
 [USB Interface](#) 24
 [Ultra DMA ATA-100 Interface](#) 24
 [EIDE Interface](#) 24
 [Modem Support](#) 24
 [Sound Circuitry](#) 25
 [Power Controller](#) 25
[AirPort Extreme Interface](#) 25

PC Card/CardBus Controller IC 26
PCI USB 2.0 Controller 26

Chapter 3 **Devices and Ports 27**

USB 2.0 Ports 27
 USB Connectors 27
 USB Class Drivers 28
FireWire Ports 28
 FireWire 400 Connector 29
 FireWire 800 Connector 30
 FireWire Device Programming 31
 Target Disk Mode 31
Ethernet Port 32
Internal Modem 33
AirPort Extreme 34
 Data Security 34
 AirPort Extreme Hardware 35
 AirPort Extreme Software 35
Bluetooth Technology 35
Hard Disk Drive 36
 Hard Disk Dimensions 36
 Hard Disk Connector 37
SuperDrive 40
Trackpad 41
Keyboard 41
 Changing the Operation of the Keyboard 42
Flat-Panel Display 47
External Monitors 48
 Dual Display and Mirror Mode 48
 Analog Monitor Resolutions 48
 Digital Display Resolutions 49
 DVI-I Connector 50
External Video Port 51
Sound System 52
 Sound Inputs 52
 Sound Outputs 53
 Digitizing Sound 54

Chapter 4 **Expansion Features 55**

RAM Expansion Slots 55
 Accessing the RAM Slots 55
 Mechanical Design of DDR RAM SO-DIMMs 56
 Electrical Design of DDR RAM SO-DIMMs 56
 RAM SO-DIMM Electrical Limits 58

PC Card/CardBus Slot 59

Appendix A **Supplemental Reference Documents** 61

Apple Technical Notes 61
3D Graphics 61
PowerPC G4 Microprocessor 61
Velocity Engine 62
Mac OS X 62
I/O Kit 62
Open Firmware 62
RAM Expansion Modules 63
ATA Devices 63
USB Interface 64
FireWire Interface 64
Digital Visual Interface 64
Wireless Networks 65
Bluetooth 65

Appendix B **Abbreviations** 67

Abbreviations and Standard Units 67
Other Abbreviations 67

C O N T E N T S

Tables and Figures

Chapter 1 **Overview of 17-inch PowerBook G4** 11

- Figure 1-1 Front view of the computer 13
- Figure 1-2 Side views showing I/O ports 14

Chapter 2 **Architecture** 19

- Figure 2-1 Block diagram 20
- Table 2-1 Buses supported by the Intrepid IC with DDR RAM 22

Chapter 3 **Devices and Ports** 27

- Figure 3-1 USB Type A port 27
- Figure 3-2 6-pin FireWire connector 29
- Figure 3-3 9-pin FireWire 800 connector 30
- Figure 3-4 Maximum dimensions of the internal hard disk 37
- Figure 3-5 Hard disk connector and location 38
- Figure 3-6 Keyboard layout 42
- Figure 3-7 Alternate operations of function and control keys 43
- Figure 3-8 Embedded numeric keypad operation 44
- Figure 3-9 DVI-I connector 50
- Figure 3-10 S-video connector 51
- Table 3-1 Pin assignments on the USB port 28
- Table 3-2 Pin assignments on the 6-pin FireWire connector 29
- Table 3-3 Signals on the 9-pin FireWire 800 connector 30
- Table 3-4 Signals for 10Base-T and 100Base-T operation 32
- Table 3-5 Signals for 1000Base-T operation 33
- Table 3-6 Pin assignments on the ATA hard disk connector 38
- Table 3-7 Signals on the ATA hard disk connector 39
- Table 3-8 Media read and written by the SuperDrive 40
- Table 3-9 The function keys as control buttons 45
- Table 3-10 Embedded keypad keys 46
- Table 3-11 Control keys that change 46
- Table 3-12 Picture sizes on the flat-panel display 47
- Table 3-13 Picture sizes on an analog monitor 48
- Table 3-14 Picture sizes on a digital display 49
- Table 3-15 Main signals on the DVI-I connector 50
- Table 3-16 MicroCross signals on the DVI-I connector 50

Table 3-17 Pin assignments for the S-video output connector 51
Table 3-18 Picture sizes for S-video output 52

Chapter 4 **Expansion Features** 55

Figure 4-1 Removing RAM expansion slot cover 56
Table 4-1 Sizes of RAM expansion modules and devices 57
Table 4-2 Types of DRAM devices 58

Introduction to 17-inch PowerBook G4 Developer Note

This developer note is a technical description of the 17-inch PowerBook G4. The note provides information about the computer's internal design, input-output features, and expansion capabilities.

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 ["Appendix A"](#) (page 61).

Organization of This Document

The information in this note is arranged in four chapters and two appendices.

- [Chapter 1, "Overview of 17-inch PowerBook G4"](#), (page 11) introduces the 17-inch PowerBook G4 and describes its features.
- [Chapter 2, "Architecture"](#), (page 19) describes the internal logic of the computer, including the main ICs that appear in the block diagram.
- [Chapter 3, "Devices and Ports"](#), (page 27) describes the standard I/O ports and the built-in I/O devices.
- [Chapter 4, "Expansion Features"](#), (page 55) 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.
- ["Appendix A"](#) (page 61) contains links to supplemental reference documents.
- ["Appendix B"](#) (page 67) is a list of the abbreviations used in this developer note.

I N T R O D U C T I O N

Introduction to 17-inch PowerBook G4 Developer Note

Overview of 17-inch PowerBook G4

This chapter outlines the features of the 17-inch PowerBook G4, with emphasis on the changes from the previous model.

New Features

Here is a list of the features that are new to the 17-inch PowerBook G4. Each feature is described in a later chapter, as indicated.

- **Processor:** The computer has a PowerPC G4 microprocessor running at a clock speed of 1.5 GHz. For more information, see [“PowerPC G4 Microprocessor”](#) (page 21).
- **RAM:** The computer has two standard PC2700 (333 MHz) DDR SO-DIMM expansion slots for SDRAM modules. The computer comes with 512 MB of SDRAM installed in one slot. Available as build to order options are 1 GB and 2 GB RAM. See [“RAM Expansion Slots”](#) (page 55).
- **Hard disk storage:** The computer comes with a built-in 4200 rpm hard disk drive with a capacity of 80 GB. Available as a build to order option is an 80 GB 5400 rpm hard drive. For more information, see [“Hard Disk Drive”](#) (page 36).
- **Graphics IC and memory:** The ATI Mobility Radeon 9700 graphics controller operates on the AGP-4x bus along with 64 MB of DDR video SDRAM. An ATI Mobility Radeon 9700 with 128 MB memory is available as a build to order option. For more information, see [“Video Display Subsystem”](#) (page 23).
- **SuperDrive :** The computer has a built-in 4x SuperDrive. For more information, see [“SuperDrive”](#) (page 40).
- **Weight:** The computer weighs 6.9 pounds or less, depending on the configuration.

All Features

Here is a list of all features of the 17-inch PowerBook G4. Each feature is described in a later chapter, as indicated.

- **Processor:** The computer has a PowerPC G4 microprocessor running at a clock speed of 1.5 GHz. For more information, see [“PowerPC G4 Microprocessor”](#) (page 21).

- **System bus:** The speed of the system bus is 167 MHz.
- **L2 cache:** The L2 cache has a capacity of 512 KB; see [“Level 2 Cache”](#) (page 21).
- **RAM:** The computer has two standard PC2700 (333 MHz) DDR SO-DIMM expansion slots for SDRAM modules. The computer comes with 512 MB of SDRAM installed in one slot. Available as build to order options are 1 GB and 2 GB RAM. See [“RAM Expansion Slots”](#) (page 55).
- **ROM:** The computer has 1 MB of boot ROM used by Open Firmware at startup. For information about the ROM, see [“Boot ROM”](#) (page 22). For information about Open Firmware, see [“Open Firmware”](#) (page 62).
- **Hard disk storage:** The computer comes with a built-in 4200 rpm hard disk drive with a capacity of 80 GB. Available as a build to order option is an 80 GB 5400 rpm hard drive. For more information, see [“Hard Disk Drive”](#) (page 36).
- **Display:** The display is a 100 dpi, 17 inch wide-screen TFT with a resolution of 1440x900. See [“Flat-Panel Display”](#) (page 47).
- **External monitor:** The computer supports an external video monitor, using the DVI connector for a digital video display and an S-video connector for a PAL or NTSC video monitor. Included with the computer are a DVI-to-VGA adapter and an S-video-to-composite adapter; a DVI-to-ADC Apple Display Connector adapter is available separately. See [“External Monitors”](#) (page 48).
- **Graphics IC and memory:** The ATI Mobility Radeon 9700 graphics controller operates on the AGP-4x bus along with 64 MB of DDR video SDRAM. An ATI Mobility Radeon 9700 with 128 MB memory is available as a build to order option. For more information, see [“Video Display Subsystem”](#) (page 23).
- **Battery bay:** The computer has a single battery bay. The battery uses lithium ion cells and provides 58 watt-hours at 10.8 V (nominal) for up to 4.5 hours.
- **Power adapter:** The computer comes with a 65 W power adapter with safety ground. For more information, see [“Power Controller”](#) (page 25).
- **SuperDrive:** The computer has a built-in SuperDrive. For more information, see [“SuperDrive”](#) (page 40).
- **PC Card/CardBus slot:** The computer has a PC Card/CardBus slot that accepts one Type I or Type II PC Card or a CardBus Card. For more information, see [“PC Card/CardBus Slot”](#) (page 59).
- **USB 2.0 ports:** The computer has two USB 2.0 ports for an external keyboard, a mouse, and other USB devices, described in [“USB 2.0 Ports”](#) (page 27).
- **FireWire ports:** The computer has one IEEE-1394a 400 Mbps serial FireWire 400 port and one IEEE-1394b 800 Mbps serial FireWire 800 port. For more information, see [“FireWire Ports”](#) (page 28).
- **Target disk mode:** The 17-inch PowerBook G4 can act like a FireWire storage device connected to another computer. See [“Target Disk Mode”](#) (page 31).
- **Modem:** The computer has a built-in modem with 56 Kbps data rate and V.34, V.90, and V.92 support. For more information, see [“Internal Modem”](#) (page 33).
- **Ethernet:** The computer has a built in Ethernet port with an RJ-45 connector for 10Base-T, 100Base-T, and 1000Base-T operation. For more information, see [“Ethernet Port”](#) (page 32).
- **AirPort Extreme:** The fully-integrated, 54 Mbps AirPort Extreme provides a wireless LAN connection. For more information, see [“AirPort Extreme”](#) (page 34).

- **Bluetooth support:** Fully-integrated Bluetooth support enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices. For more information, see [“Bluetooth Technology”](#) (page 35).
- **Sound:** The computer has a built-in microphone, stereo speakers, a stereo headphone out, and an audio line in. See [“Sound System”](#) (page 52).
- **Illuminated keyboard:** The computer has a backlit keyboard for optimal usability in all lighting conditions. 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. See [“Keyboard”](#) (page 41).
- **Ambient light sensor:** The computer has an ambient light sensor which monitors light levels and activates the illuminated backlit keyboard and adjusts the display brightness.
- **Trackpad:** The integrated trackpad includes tap/double-tap and drag features and palm-rejection capabilities. For more information, see [“Trackpad”](#) (page 41).
- **Weight:** The computer weighs 6.9 pounds or less, depending on the configuration.
- **Size:** The computer is 15.4 inches (39.2 cm) wide, 10.2 inches (25.9 cm) deep, and 1.0 inches (2.6 cm) thick.

Appearance

[Figure 1-1](#) (page 13) is a front view of the 17-inch PowerBook G4. [Figure 1-2](#) (page 14) provides side views showing the I/O ports.

Figure 1-1 Front view of the computer

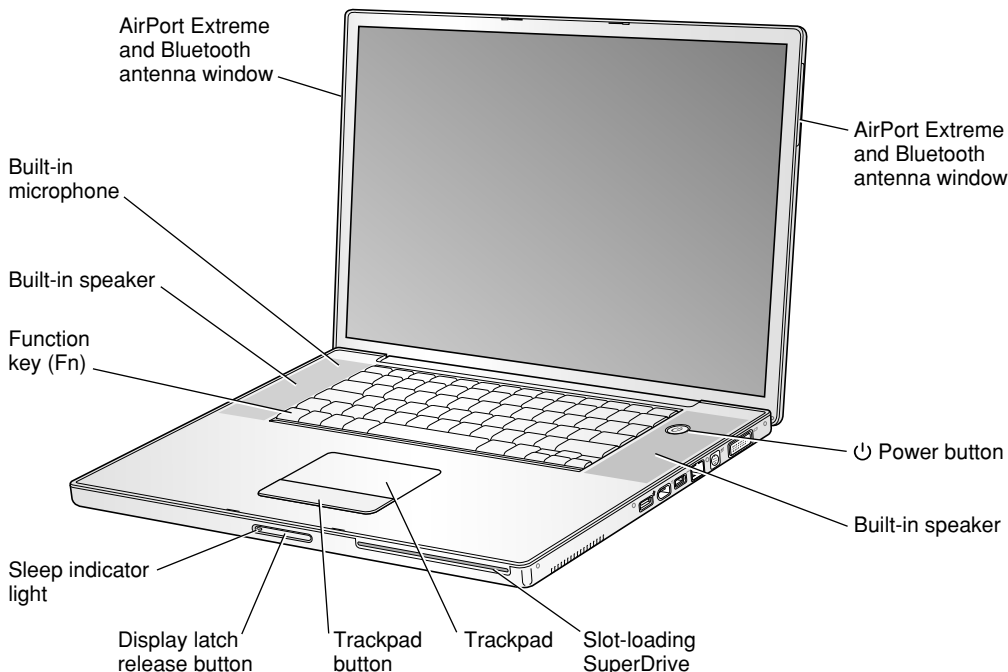
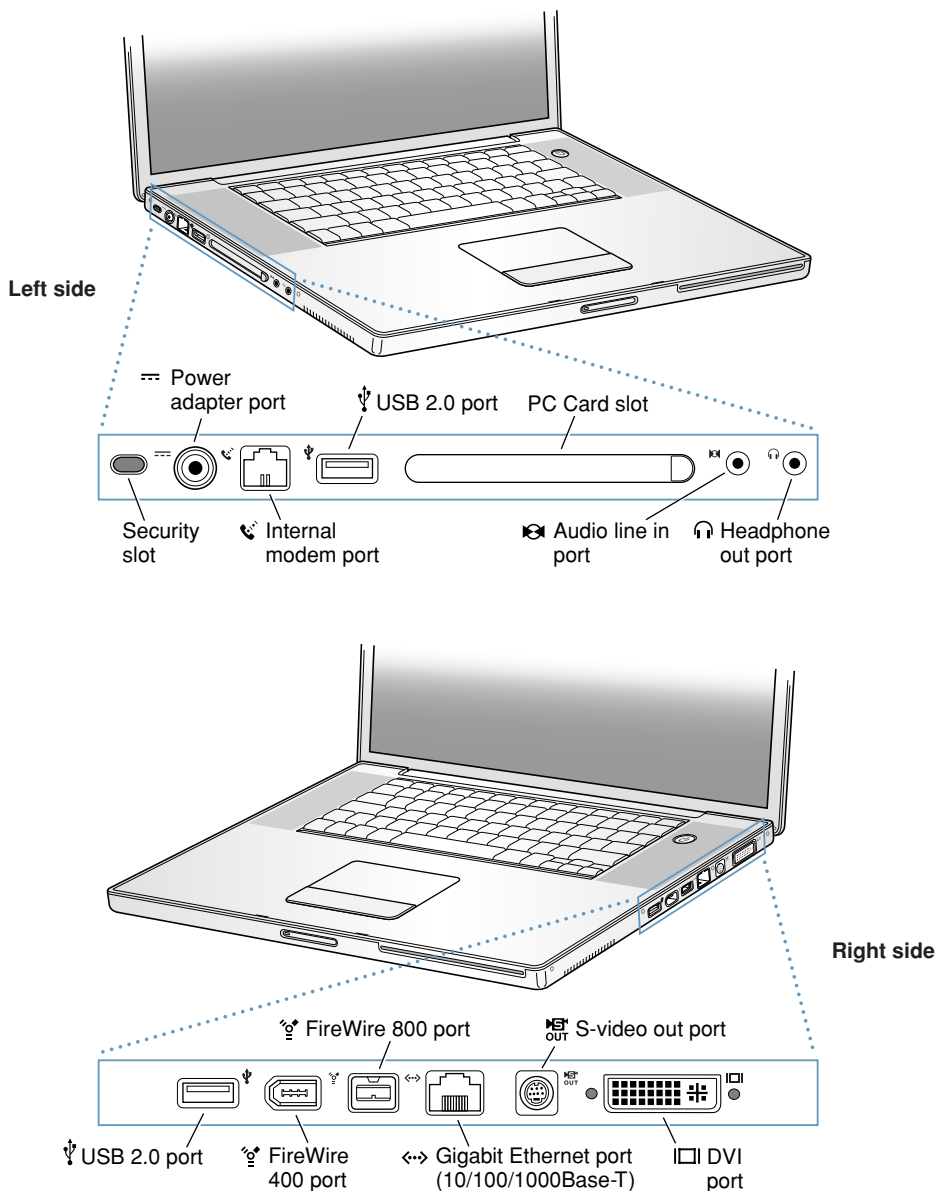


Figure 1-2 Side views showing I/O ports



Peripheral Devices

Included with the computer are a 65 W Apple Portable Power Adapter, an S-video-to-composite cable, a DVI-to-VGA cable, and a modem cable. In addition to these devices, the following peripheral devices are available separately:

- The PowerBook G4 Rechargeable Battery is available as an additional or replacement battery.
- The 65 W Apple Portable Power Adapter, which comes with the computer, is also available separately. The adapter can fully recharge a completely depleted battery in three hours or less while the computer is shut down or in sleep mode.

- The Apple DVI to ADC Adapter, which enables the 17-inch PowerBook G4 to support Apple's ADC displays.
- The Apple Keyboard, a full-featured, wired USB keyboard, is available separately.
- The Apple Mouse, an optical, wired USB mouse, is available separately.
- The Apple Wireless Mouse with built-in Bluetooth is available separately.
- The Apple Wireless Keyboard with built-in Bluetooth is available separately.
- The AirPort Extreme Base Station.

System Software

The 17-inch PowerBook G4 comes with Mac OS X version 10.3.3. For the latest information, see the references listed in [“Mac OS X”](#) (page 62).

Here are a few items of interest about the system software on the 17-inch PowerBook G4.

Open Firmware

System software on all current Macintosh models uses a design based on Open Firmware. With this approach, the ROM on the main logic board contains only the Open Firmware code needed to initialize the hardware and load an operating system. The rest of the system code is loaded into RAM from disk or from the network. For more information, see the references listed in [“Open Firmware”](#) (page 62).

Computer Identification

Rather than reading the box flag or the model string and then making assumptions about the computer's features, applications that need to find out the features of the computer should use IORegistry calls to test for the features they require. IORegistry calls are part of the I/O Kit API. For more information, see the references listed at [“I/O Kit”](#) (page 62).

Asset management software that reports the kind of computer it is running on can obtain the value of the model property from the IOService plane of the IORegistry. For the 17-inch PowerBook G4, the value of the model property is `PowerBook5,5`.

Power Management

Apple's power management techniques for the 17-inch PowerBook G4 are described in the following paragraphs.

Power Saving States

The power management protocols on the 17-inch PowerBook G4 support two power-saving states: idle and sleep.

- **Idle:** The system is idling with the main processor in a low-power state. All clocks are running; the system can return to running code within a few nanoseconds. Cache coherency is maintained in this state. The CPU automatically transitions between run and idle independent of the operating frequency. The operating frequency is based on the processor power management setting. For additional information, see “[Processor Power Management](#)” (page 16).
- **Sleep:** Most internal components are powered off and the state is saved; the DRAM state preserved for quick recovery. The processor is powered off with its 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 state after a few hundred milliseconds of inactivity. If the computer is attached to a network, it is able to respond to service requests and other events directed to the computer while it is in idle state.

While it is connected to an AC power supply, the computer can also respond to network activity when it is in sleep state. The user can enable this feature by selecting Wake-on-LAN in the Energy Saver preference pane.

When operating on the battery in sleep state, the computer consumes less than 1 watt of power, meeting the Energy Star power-saving standard. When operating on the power adapter in sleep state, the combined computer and adapter consume 3 to 4 watts of power.

Important: Peripherals such as PCMCIA cards and USB devices that do not conform to the computer’s power management protocols prevent the computer from switching to sleep state and so deny the user the benefits of this energy-saving state.

Processor Power Management

To lower power consumption and heat generation, the 17-inch PowerBook G4 incorporates an automatic power management technique called dynamic frequency switching (DFS). DFS is designed to run at high processor speed and voltage when the demand on the processor is high, and to run at low processor speed and voltage when the demand on the processor is low. When DFS is enabled, the processor dynamically adjusts its speed based on the current needs of the system. The processor speed will switch between 1.5 GHz and 750 MHz.

Switching between different processor speeds and voltages is achieved by a transition that should operate seamlessly to the user. For applications that are particularly demanding on the processor, it is recommended that the processor performance be set to highest.

The 17-inch PowerBook G4 allows the user to control DFS mode. The options for specifying either high, reduced, or automatic processor speeds are located at System Preferences>Energy Saver>Show Details>Options>Processor Performance; then select Highest, Automatic, or Reduced. DFS is enabled with the automatic setting.

If the 17-inch PowerBook G4 detects a system temperature that is high, due to high ambient temperatures or other factors, it will automatically force the system to reduced speed mode regardless of the selected setting.

Note: The 17-inch PowerBook G4 meets all applicable safety standards, including UL 60950 and IEC 60950.

Note: The memory bus speed is not shifted, as it was in previous models.

C H A P T E R 1

Overview of 17-inch PowerBook G4

Architecture

This chapter describes the architecture of the 17-inch PowerBook G4. 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.

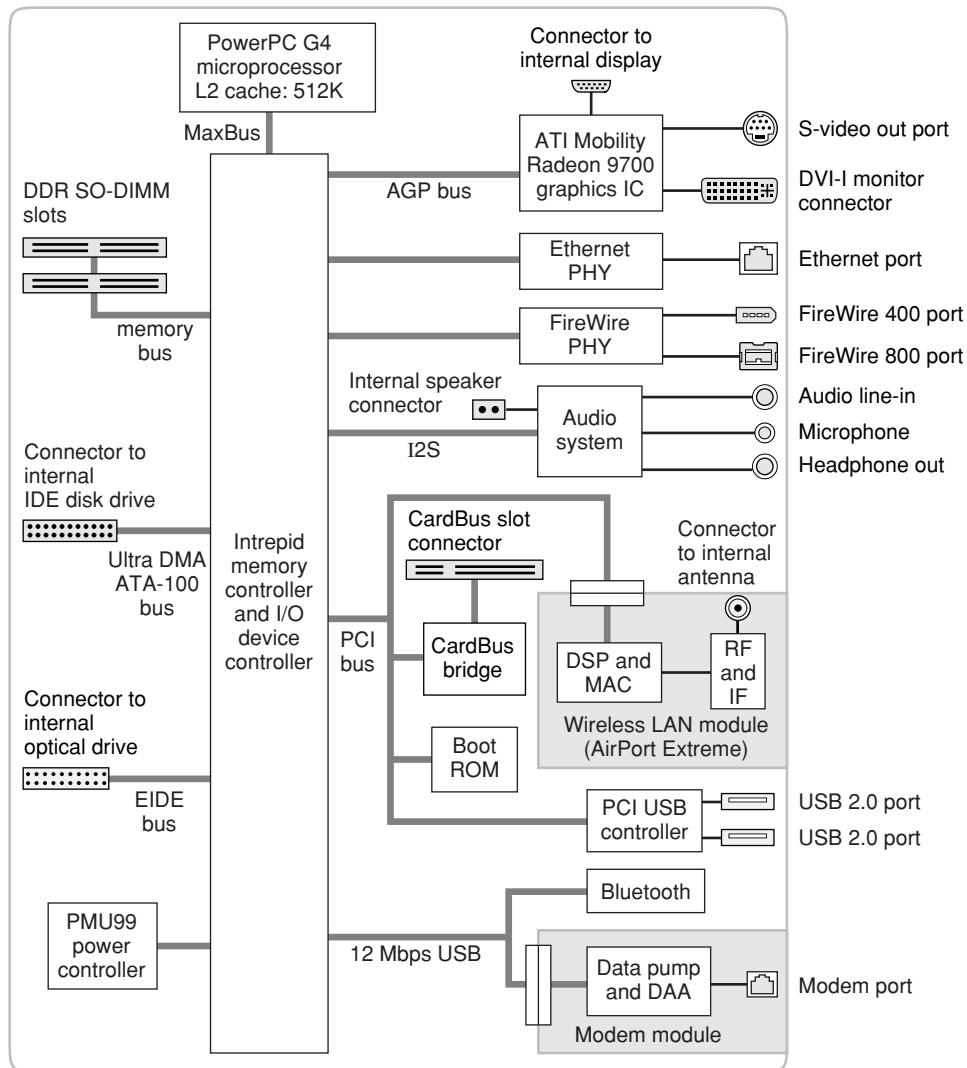
Block Diagram and Buses

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

Block Diagram

[Figure 2-1](#) (page 20) is a simplified block diagram of the main logic board. The diagram shows the input and output connectors, the main ICs, and the buses that connect them together.

Figure 2-1 Block diagram



Main IC and Buses

The architecture of the 17-inch PowerBook G4 is designed around the PowerPC G4 microprocessor and the Intrepid IC, which contains the memory controller and I/O device controller.

The PowerPC G4 microprocessor is connected to the Intrepid IC by a MaxBus bus. The bus clock speed is 167 MHz. Other buses that connect with the Intrepid IC are summarized in [Table 2-1](#) (page 22), which is in the section “[Intrepid Controller Functions and Buses](#)” (page 21).

The Intrepid I/O controller has a 32-bit PCI bus with a bus clock speed of 33 MHz. That bus also connects to the Boot ROM, the CardBus controller, the USB 2.0 controller, and the wireless LAN module. The Intrepid IC has other buses that connect with the hard disk drive and the optical drive, the power controller IC, the sound IC, and the internal modem module.

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

Microprocessor and Caches

The microprocessor communicates with the rest of the system by way of a 64-bit MaxBus bus to the Intrepid IC. The microprocessor has a separate bus to its internal second-level cache.

PowerPC G4 Microprocessor

The PowerPC G4 microprocessor used in the 17-inch PowerBook G4 has many powerful features, including an efficient pipelined system bus called MaxBus.

Features of the PowerPC G4 include

- 32-bit PowerPC implementation
- superscalar PowerPC core
- Velocity Engine (AltiVec technology): 128-bit-wide vector execution unit
- dual 32 KB instruction and data caches
- an on-chip level 2 (L2) cache consisting of 512 KB with a clock speed ratio of 1:1
- high bandwidth MaxBus (also compatible with 60x bus)
- fully symmetric multiprocessing capability

The PowerPC G4 microprocessor in the 17-inch PowerBook G4 runs at a clock speed of 1.5 GHz.

Level 2 Cache

The data storage for the L2 cache consists of 512 KB of fast static RAM that is built into the microprocessor chip along with the cache controller and tag storage. The built-in L2 cache runs at the same clock speed as the microprocessor.

Intrepid Controller Functions and Buses

The Intrepid IC provides the functions of a memory controller and an I/O device controller in the 17-inch PowerBook G4.

Note: In the device tree, the I/O controller is named “mac-io”.

In addition to the buses listed in [Table 2-1](#) (page 22), the Intrepid IC also has separate interfaces to the physical layer (PHY) ICs for Ethernet and FireWire, and an IIC (inter-IC control bus) interface that is used for configuring the memory subsystem.

Table 2-1 Buses supported by the Intrepid IC with DDR RAM

Bus	Destinations	Width of data path	Bus clock speed
MaxBus	Microprocessor	64 bits	167 MHz
Memory	System RAM	64 bits	333 MHz
PCI	AirPort Extreme, PC Card/CardBus, Boot ROM, USB 2.0 controller	32 bits	33 MHz
AGP4X	Graphics IC	32 bits	133 MHz
Ultra DMA ATA-100	Hard drive	16 bits	100 MBps
EIDE	SuperDrive	16 bits	16.7 MBps

The following sections describe the subsystems that are connected to the Intrepid IC.

System RAM

The memory subsystem in the 17-inch PowerBook G4 supports two slots for 333 MHz DDR (PC2700) 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 MaxBus bus interface at 167 MHz. See [“RAM Expansion Slots”](#) (page 55).

Boot ROM

The boot ROM is connected to the Intrepid IC by way of the high byte 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 Controllers

The Intrepid IC FireWire controller supports IEEE 1394a for a maximum data rate of 400 Mbps (50 MBps) and IEEE 1394b for a maximum data rate of 800 Mbps (100 MBps). The Intrepid IC provides DMA (direct memory access) support for the FireWire interface.

The controller in the Intrepid IC implements the FireWire link layer. A physical layer IC, called a PHY, implements the electrical signaling protocol of the FireWire interface and provides the electrical signals to the port. For more information, see [“FireWire 400 Connector”](#) (page 29) and [“FireWire 800 Connector”](#) (page 30).

Ethernet Controller

The Intrepid IC includes an Ethernet media access controller (MAC) that implements the link layer. The Intrepid IC provides DB-DMA support for the Ethernet interface.

The Ethernet controller in the Intrepid IC is connected to a PHY interface IC that provides the electrical signals to the port. The PHY is capable of operating in either 10Base-T, 100Base-T, or 1000Base-T mode: The actual speed of the link is automatically negotiated by the PHY and the hub or switch to which it is connected. For more information, see [“Ethernet Port”](#) (page 32).

The PHY supports Auto-MDIX, which allows the use of straight-through cables in crossover situations (and conversely). For more information, see [“Ethernet Port”](#) (page 32).

Video Display Subsystem

The video display subsystem contains the graphics controller IC along with 64 MB of DDR SDRAM memory. The graphics IC, an ATI Mobility Radeon 9700, contains 2D and 3D acceleration engines, front-end and back-end scalars, a CRT controller, and an AGP4x bus interface with bus master capability.

The features of the ATI Mobility Radeon 9700 include

- graphics processor clock speed of 392 MHz
- memory clock speed of 202 MHz
- support for 64 MB of DDR video memory with 128-bit interface (with a build to order option of 128 MB memory)
- 2D and 3D graphics acceleration
- transform acceleration
- lighting acceleration
- video acceleration
- support for MPEG decoding
- support for video mirror mode
- support for dual-display mode
- S-video output for a TV monitor

The interface between the graphics IC and the rest of the system is an AGP4x (accelerated graphics port, quadruple speed) bus on the Intrepid IC. The AGP bus has 32 data lines, a clock speed of 133 MHz, and supports deeply pipelined read and write operations.

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 graphics SDRAM and the main memory.

The graphics IC supports the internal 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 47) and [“External Monitors”](#) (page 48).

DMA Support

The Intrepid 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
- IIS 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 Intrepid 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 Intrepid IC has three independent USB 1.1 Open Host Controller Interface (OHCI) controllers. One is used for the modem module and the Bluetooth interface and the other two are not used.

The external USB interface is via the PCI USB controller; see [“PCI USB 2.0 Controller”](#) (page 26).

Ultra DMA ATA-100 Interface

The Intrepid IC provides an Ultra DMA ATA-100 channel that is connected to the internal hard disk drive. The Intrepid IC provides DB-DMA (descriptor-based direct memory access) support for the ATA-100 interface.

The internal hard disk drive is connected as device 0 (master) in an ATA Device 0/1 configuration. For more information, see [“Hard Disk Drive”](#) (page 36).

EIDE Interface

The Intrepid IC provides a multiword DMA EIDE bus that supports the SuperDrive. The SuperDrive is an ATAPI drive and is device-selected as master in an ATA device configuration.

Modem Support

The internal modem is connected to an internal USB 1.1 port. The Intrepid IC provides DB-DMA support for the modem interface. The modem provides digital call progress signals to the sound circuitry.

The internal modem is a separate module that contains the data pump IC and the interface to the telephone line (DAA). For more information about the modem, see [“Internal Modem”](#) (page 33).

Sound Circuitry

The sound circuitry is connected to the Intrepid IC by a standard IIS (inter-IC sound) bus. The Intrepid IC provides DB-DMA (descriptor-based direct memory access) support for the IIS port.

Note: In the device tree, the sound circuitry is named “sound”.

The audio circuitry includes a signal processing IC that handles the equalization and volume control functions, a codec IC that performs A-to-D and D-to-A conversion, and a power amplifier that drives the headphone jack.

All audio is handled digitally inside the computer. The audio circuitry performs digital-to-analog conversion for the audio signals to the internal speakers and the headphone jack.

For a description of the features of the sound system, see [“Sound System”](#) (page 52).

Power Controller

The power management controller in the 17-inch PowerBook G4 is a custom IC called the PMU99. It supports several power-saving modes of operation, including idle, doze, and sleep.

Note: In the device tree, the power controller is named “via-pmu”.

A device’s ID voltage limits determines how the PMU identifies the power adapter. The 17-inch PowerBook G4 is designed to use the 65-Watt Apple Portable Power Adapter which ships with it. Although you can use a 45-Watt Apple portable power adapter with a 17-inch PowerBook G4, it may not provide sufficient power during some activities and power may be drawn temporarily from the battery. Should the battery become discharged, you may need to plug in the 65-Watt Apple Portable Power Adapter that came with the computer in order to start it up.

The 17-inch PowerBook G4 has a variable speed fan control circuit and a thermal circuit that will force the unit into reduce-processor mode at 68 degrees Celsius and into sleep mode if the processor temperature exceeds 79 degrees Celsius.

The 17-inch PowerBook G4 can operate from a 15 volt power outlet on an airline, but for safety reasons, the computer will not allow battery charging. In order for the computer to detect the connection to airline power, the airline power cable should have a sense resistor of 24.3 K ohms +/-1% connected between the power plug’s shell and ground.

AirPort Extreme Interface

AirPort Extreme contains a media access controller (MAC), a digital signal processor (DSP), and a radio-frequency (RF) section.

Two antennas are built into the computer's case. A diversity module is controlled by the AirPort Extreme to allow selection of either antenna. To improve reception, the AirPort Extreme measures the signal integrity from each antenna from the initial header time of each received data packet and selects the antenna with the strongest signal to receive the balance of the packet.

AirPort Extreme is compliant with the IEEE 802.11g standard. The card transmits and receives data at up to 54 Mbps and is compatible with 802.11b-standard 11 Mbps systems and older 802.11b-standard systems. For information about its operation, see ["AirPort Extreme"](#) (page 34).

PC Card/CardBus Controller IC

The interface to the PC Card slot is connected to the PCI bus. The CardBus controller IC is a PCI1510A device made by Texas Instruments. It supports both 16-bit PC Cards and 32-bit CardBus Cards.

PCI USB 2.0 Controller

The 17-inch PowerBook G4 CPU uses a PCI USB controller with one Enhanced Host Controller Interface (EHCI) function and two Open Host Controller Interface (OHCI) functions. The controller supports two external USB 2.0 ports.

The two external USB ports comply with the Universal Serial Bus Specification 2.0. The USB register set complies with the EHCI and OHCI specifications. For more information, see ["USB 2.0 Ports"](#) (page 27).

The two external USB 2.0 connectors support USB devices with data transfer rates of up to 480 Mbps. For more information about the connectors, see ["USB Connectors"](#) (page 27).

USB 2.0 devices connected to the 17-inch PowerBook G4 are required to support USB-suspend mode as defined in the USB specification. For additional reference information, see ["USB Interface"](#) (page 64).

The USB ports on the 17-inch PowerBook G4 comply with the Universal Serial Bus Specification 2.0. The USB controllers comply with the EHCI specification; the companion controllers comply with the OHCI specification. The internal USB 1.1 interface complies with the OHCI specification, see ["USB Interface"](#) (page 24).

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 2.0 Ports

The 17-inch PowerBook G4 has two external USB 2.0 ports that can be used to connect additional I/O devices such as a USB mouse, printers, scanners, and storage devices.

The USB ports on the 17-inch PowerBook G4 comply with the Universal Serial Bus Specification 2.0. For more information about USB on Macintosh computers, consult the references at “[USB Interface](#)” (page 64).

Note: Some self-powered USB devices inadvertently violate electrical specifications for self-powered USB devices. For details and ways to avoid this design issue, refer to <http://developer.apple.com/qa/hw/hw82.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](#) (page 27) 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

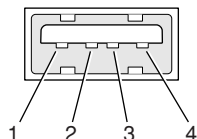


Table 3-1 Pin assignments on the USB port

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 external USB 2.0 ports support low-speed (1.5 Mbps), full-speed (12 Mbps), and high-speed (480 Mbps) data transfers. High-speed operation requires the use of shielded cables.

The 17-inch PowerBook G4 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 the bus.

USB Class Drivers

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.

FireWire Ports

The 17-inch PowerBook G4 has one FireWire 400 (IEEE 1394a) port and one FireWire 800 (IEEE 1394b) port. Both FireWire ports

- support booting the system from a mass storage device
- support target disk mode

The two FireWire ports share a single power supply that can provide up to 14 watts total. Both ports are on the same FireWire bus and can connect to up to 62 other FireWire devices.

The FireWire hardware and software provided with the 17-inch PowerBook G4 are capable of all asynchronous and isochronous transfers defined by IEEE standard 1394a and 1394b.

For additional information about the FireWire interface and the Apple API for FireWire device control, refer to the resources listed at [“FireWire Interface”](#) (page 64).

FireWire 400 Connector

The 6-pin FireWire 400 technology

- supports serial I/O at 100, 200, and 400 Mbps
- provides up to 7 watts of power when the computer system is on or when the power adapter is connected and in sleep mode

The FireWire 400 connector has six contacts, as shown in [Figure 3-2](#) (page 29). The connector pin assignments are shown in [Table 3-2](#) (page 29).

Figure 3-2 6-pin FireWire connector

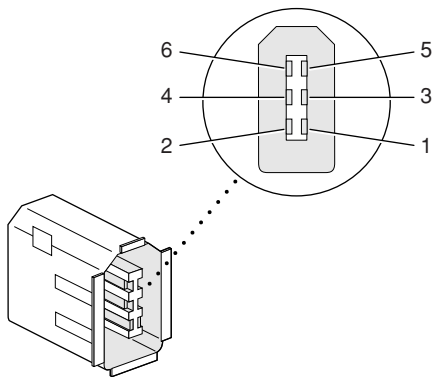


Table 3-2 Pin assignments on the 6-pin FireWire connector

Pin	Signal name	Description
1	Power	Unregulated DC; 12.8 V
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 or the power adapter is connected, the power pin provides a maximum voltage of 12.8 V (no load) and 7 W power per port. Maximum output current for both ports combined is 1.5 A and is controlled by a self-resetting fuse.

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 800 Connector

The FireWire 800 port on the 17-inch PowerBook G4 is based on IEEE 1394b and enables a 800 Mbps transfer rate. FireWire 800 uses a 9-pin connector and is backwards compatible with original 1394 FireWire devices with 6-pin or 4-pin connectors. With the appropriate cable, the new 9-pin port works seamlessly with legacy FireWire devices. Cables are available to go from both 6-pin and 4-pin connectors to a 9-pin, and 9-pin to 9-pin.

Note: FireWire adapter cables are not included with the computer.

The 9-pin FireWire 800 connector is shown in [Figure 3-3](#) (page 30). Its connector signals and pin assignments are shown in [Table 3-3](#) (page 30).

Figure 3-3 9-pin FireWire 800 connector

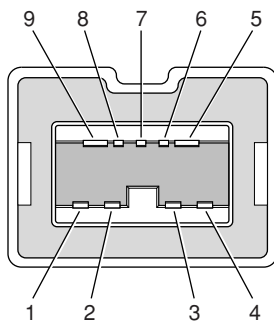


Table 3-3 Signals on the 9-pin FireWire 800 connector

Pin	Signal name	Description
1	TPB-	Twisted-pair B Minus
2	TPB+	Twisted-pair B Plus
3	TPA-	Twisted-pair A Minus
4	TPA+	Twisted-pair A Plus
5	TPA (R)	Twisted-pair A Ground Reference
6	VG	Power Ground
7	SC	Status Contact (no connection; reserved)
8	VP	Power Voltage (approximately 12.8 V DC)
9	TPB (R)	Twisted-pair B Ground Reference

VP (pin 8) provides up to 7 W power, shared with the other FireWire connectors. The voltage on the power pin is approximately 12.8 V.

The 9-pin FireWire 800 port is capable of operating at 100, 200, 400, and 800 Mbps, depending on the device to which it is connected. The FireWire 800 port is bilingual in that it supports both IEEE 1394a and 1394b. Using a cable with a 9-pin connector at one end and a 4-pin or 6-pin connector at the other, the 9-pin port is capable of directly connecting to all existing FireWire devices. Using a cable with 9-pin connectors at both ends, the 9-pin port is capable of operating at 800 Mbps.

The IEEE 1394b standard defines long-haul media using Cat 5 UTP and several kinds of optical fiber. The 17-inch PowerBook G4 is interoperable with such cables but cannot be directly connected to them. To use long-haul cables, connect the computer to a 1394b hub that has the desired kind of long-haul connectors. If the hub has a bilingual port, that port can be connected to any of the computer's FireWire ports. If the hub has a beta-only port, it can be connected only to the computer's 9-pin port.

FireWire Device Programming

Mac OS X includes general support for the FireWire bus and specific support for various kinds of FireWire devices and protocols. Developers can use the built-in support or provide additional applications and drivers for use with their products.

The general FireWire services will configure the FireWire bus, scan the bus for new devices, and allow multiple drivers and devices to share a single FireWire interface cooperatively. The general services also publish information about the bus and the devices in the IO Registry, so that IO Kit can match protocols and drivers to each connected FireWire device.

The specific device and protocol support in Mac OS X as provided with the 17-inch PowerBook G4 includes the following:

- General services for Serial Bus Protocol 2 (SBP-2) and support for most mass storage devices using SBP-2, such as hard disk drives, optical drives, flash card readers, Target Disk Mode (see “[Target Disk Mode](#)” (page 31)), and the iPod. Mac OS X can boot from most of these devices.
- General services for the Audio Video Control (AV/C) protocol and support for most digital video (DV) cameras and decks using this protocol, including video capture through standard QuickTime APIs.
- A QuickTime device driver for IIDC/DCAM type cameras such as the iSight.
- A network device driver supporting IP (Internet Protocol) over FireWire according to IEEE RFC 2734.
- Additional services for user-space and kernel access to all FireWire resources.

For information on writing FireWire drivers or applications, download the latest FireWire SDK from <http://developer.apple.com/sdk/>.

For additional references, refer to “[FireWire Interface](#)” (page 64).

Target Disk Mode

One option at boot time is to put the computer into a mode of operation called target disk mode.

When the 17-inch PowerBook G4 is in target disk mode and connected to another Macintosh computer by a FireWire cable, the 17-inch PowerBook G4 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 17-inch PowerBook G4 can operate in target disk mode as long as the other computer has a FireWire 1394a or 1394b port and is running either Mac OS X (any version) or Mac OS 9 with FireWire software version 2.3.3 or later.

To put the computer into target disk mode, hold 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, press the power button.

Note: The 17-inch PowerBook G4 is designed to use the 65 W Apple Portable Power Adapter which ships with it. A 45 W Apple portable power adapter works with the 17-inch PowerBook G4, but may provide insufficient power during some activities and power may be drawn temporarily from the battery. Therefore a 45 W power adapter is not recommended.

Ethernet Port

The 17-inch PowerBook G4 has a built-in Ethernet port that supports 10Base-T, 100Base-T, and 1000Base-T transfer rates. In operation, the actual speed of the link is auto-negotiated between the computer's PHY device and the network hub or switch to which it is connected.

The connector for the Ethernet port is an RJ-45 connector on the right side of the computer. [Table 3-4](#) (page 32) shows the signals and pin assignments for 10Base-T and 100Base-T operation. [Table 3-5](#) (page 33) shows the signals and pin assignments for 1000Base-T operation.

Table 3-4 Signals for 10Base-T and 100Base-T operation

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

Pin	Signal name	Signal definition
8	–	Not used

Table 3-5 Signals for 1000Base-T operation

Pin	Signal name	Signal definition
1	TRD+(0)	Transmit and receive data 0 (positive lead)
2	TRD–(0)	Transmit and receive data 0 (negative lead)
3	TRD+(1)	Transmit and receive data 1 (positive lead)
4	TRD+(2)	Transmit and receive data 2 (positive lead)
5	TRD–(2)	Transmit and receive data 2 (negative lead)
6	TRD–(1)	Transmit and receive data 1 (negative lead)
7	TRD+(3)	Transmit and receive data 3 (positive lead)
8	TRD–(3)	Transmit and receive data 3 (negative lead)

To interconnect two computers for 1000Base-T operation, you must use 4-pair cable (Category 5 or 6).

The Ethernet port on the 17-inch PowerBook G4 supports Auto-MDIX. It switches between MDI (Medium Dependent Interface) and MDI-X operation automatically, so it can be connected to another device by either a straight-through cable or a cross-over cable.

The Ethernet interface in the 17-inch PowerBook G4 conforms to the ISO/IEC 802.3 specification, where applicable, and complies with IEEE specifications 802.3i (10Base-T), 802.3u-1995 (100Base-T), and 802.3ab (1000Base-T).

Internal Modem

The 17-inch PowerBook G4 comes with a built-in modem. The connector for the modem is an RJ-11 connector on the left side of the computer.

The modem has the following features:

- modem bit rates up to 56 Kbps (supports V.34, V.90, and V.92 modem standards)
- fax modem bit rates up to 14.4 Kbps

The modem is connected to an internal USB port and is a vendor-specific USB device. The modem driver controls the modem hardware and presents a virtual serial port to the operating system and applications. Applications that bypass the operating system's modem driver and communicate directly with the SCC will not work properly.

Note: 56 Kbps technology refers to download speeds only and requires compatible modems at server sites. Other conditions may limit modem speed. FCC limitations allow a maximum of 53 Kbps during download transmissions.

AirPort Extreme

The 17-inch PowerBook G4 supports AirPort Extreme, a fully-integrated, internal wireless LAN module that is fully compliant with the IEEE 802.11g standard. By communicating wirelessly with a base station, AirPort Extreme can be used for internet access, email access, and file exchange. A base station provides the connection to the Internet or the bridge between the wireless signals and a wired LAN or both. The AirPort Extreme Base Station has connectors for a wired LAN, a DSL or cable modem, or a standard telephone line using the optional 56K modem that is built-in on some models.

AirPort Extreme transmits and receives data at speeds up to 54 Mbps, comparable to wired networking speeds. AirPort Extreme is also compatible with other devices that follow the IEEE 802.11b standard, including PC's. For more information about compatibility, see the reference at "[Wireless Networks](#)" (page 65).

Note: As is the case with the existing IEEE 802.11b standard, actual data throughput speeds will be lower than the indicated maximum connection speeds. Inherent in wireless LAN systems, bandwidth overhead is required for wireless routing, scrambling, security error correction, and other processes.

Data Security

AirPort Extreme has several features designed to maintain the security of the user's data.

- In 802.11b mode, 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 an Access Control List of authentic network client ID values (wireless and MAC addresses) to verify each client's identity before granting access to the network.
- When communicating with a base station, AirPort Extreme uses 64-bit and 128-bit WEP encryption to encode data while it is in transit. Additional security features may be available via firmware upgrades as 802.11 enhancements are ratified by IEEE.
- The AirPort Extreme Base Station can be configured to use NAT (Network Address Translation), protecting data from Internet hackers.
- The AirPort Extreme Base Station can authenticate users by their unique Ethernet IDs, preventing unauthorized computers from logging into your network. Network administrators can take advantage of RADIUS compatibility, used for authenticating users over a remote server. Smaller networks can offer the same security using a local look-up table located within the base station.

As an additional data security measure, VPN can be used in conjunction with the AirPort Extreme data security.

AirPort Extreme Hardware

AirPort Extreme is a fully-integrated, wireless LAN module based on the IEEE 802.11g standard using both OFDM (orthogonal frequency-division multiplexing) and DSSS technologies. Using DSSS, AirPort Extreme is interoperable with PC-compatible wireless LANs that conform to the 802.11b standard at speeds of 11 Mbps, 5.5 Mbps, 2 Mbps, and 1 Mbps. Using OFDM, AirPort Extreme is compatible with all 802.11g standard speeds.

Two antennas are built into the computer, on either side of the flat-panel display. One antenna is always used for transmitting. Either of the two antennas may be used for receiving. Using a diversity technique, AirPort Extreme may select the antenna that gives the best reception. The secondary antenna is used for Bluetooth.

AirPort Extreme Software

The 17-inch PowerBook G4 includes software for setting up and using AirPort Extreme:

- AirPort Extreme Setup Assistant, an easy-to-use program that guides users through the steps necessary to set up AirPort Extreme or set up an AirPort Extreme Base Station.
- Users can switch between wireless networks and can create and join peer-to-peer networks. These functions are accessed via the AirPort Extreme status menu.
- AirPort Extreme Admin Utility, a utility for advanced users and system administrators. With it the user can edit the administrative and advanced settings needed for some advanced configurations.

Bluetooth Technology

Bluetooth is a fully integrated, open specification that enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices. Bluetooth support is built into Mac OS X and compliant with Bluetooth specification v1.1. It operates on a globally available 2.4 GHz frequency band (ISM band) for worldwide compatibility and has a maximum throughput of 1Mbps.

The Bluetooth technology supports the following profiles:

- synchronization —enables synchronization of devices over Bluetooth
- serial —provides a wireless serial connection to other Bluetooth devices
- dial-up networking (DUN) — enables a mobile phone to act as a modem
- object push —enables the transfer of files between Bluetooth devices
- human interface device (HID) — enables the use of Bluetooth input devices (keyboards and mice)
- hardcopy cable replacement profiler (HCRP) — defines functionality that enables a Bluetooth link to replace a printer cable, allowing standard Bluetooth drivers to be adapted to use Bluetooth links.

Note: Currently, Apple's Bluetooth Update Version 1.5 supports only printing.

Bluetooth and AirPort Extreme share the antennas in the 17-inch PowerBook G4's display housing.

Internal, fully-integrated Bluetooth is standard on the 17-inch PowerBook G4.

For more information on Bluetooth technology, refer to [“Bluetooth”](#) (page 65).

Hard Disk Drive

The 17-inch PowerBook G4 has a 4200 rpm internal hard disk drive with a storage capacity of 80 GB; available as a build to order option is an 80 GB 5400 rpm hard drive. The drive has fluid dynamic bearings for quieter operation. The drive uses the Ultra ATA-100 (IDE, integrated drive electronics) interface and is ATA-6 compatible. Data Transfer Mode for the drive is ATA-100.

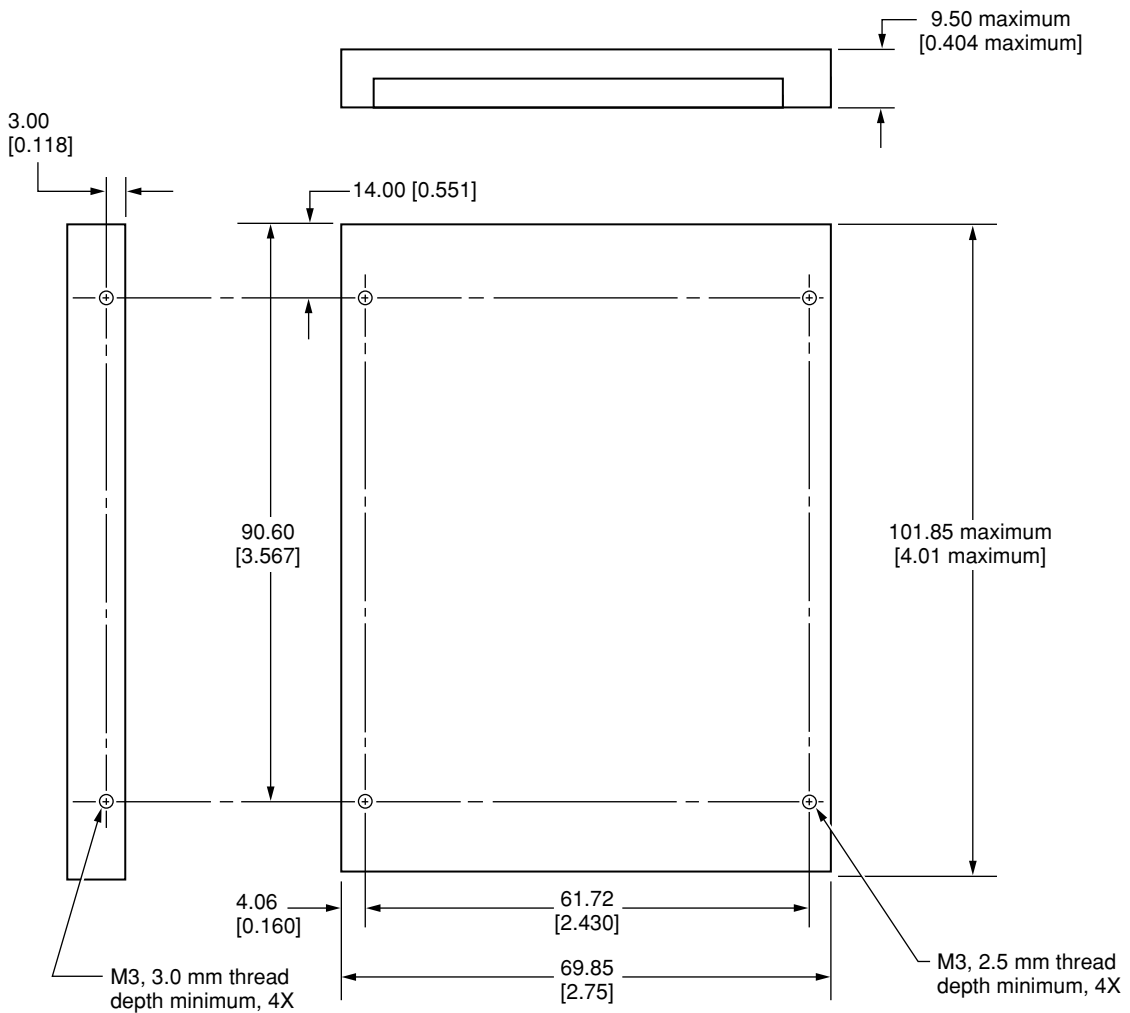
The software that supports the internal hard disk is the same as that in previous models with internal IDE drives and includes DMA support.

To obtain the reference documents listed here, see the reference links at [“ATA Devices”](#) (page 63).

Hard Disk Dimensions

[Figure 3-4](#) (page 37) shows the maximum dimensions of the hard disk and the location of the mounting holes. The minimum clearance between any conductive components on the drive and the bottom of the mounting envelope is 0.5 mm.

Figure 3-4 Maximum dimensions of the internal hard disk

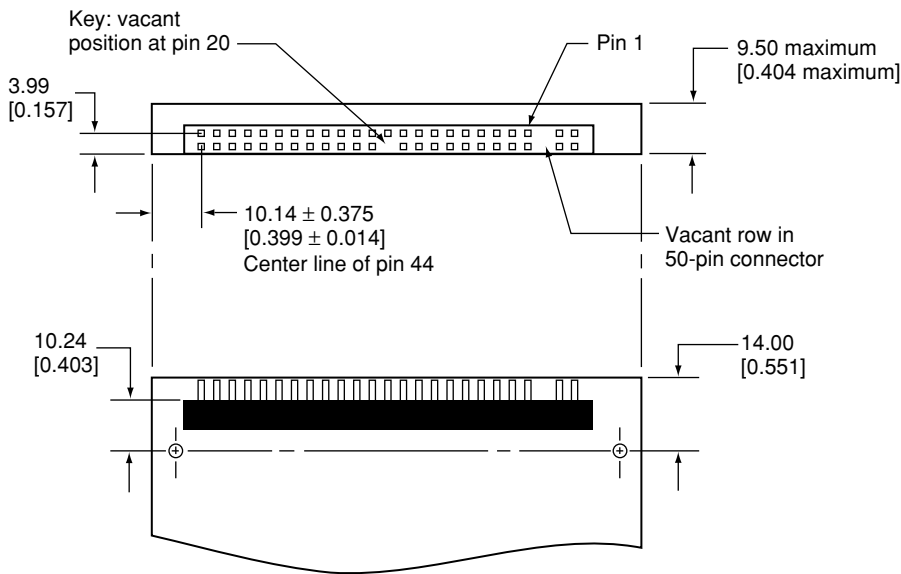


Note: Dimensions are in millimeters [inches].

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 3-5](#) (page 38). The remaining pins are in two groups: pins 1–44, which carry the signals and power, and pins 45–48, 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 3-5 Hard disk connector and location



Note: Dimensions are in millimeters [inches].

Signal Assignments

Table 3-6 (page 38) 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 3-6 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

Pin number	Signal name	Pin number	Signal name
23	/DIOW, /STOP	24	GROUND
25	/DIOR, /HDMARDY, HSTROBE	26	GROUND
27	IORDY, /DDMARDY, DSTROBE	28	CSEL
29	/DMACK	30	GROUND
31	INTRQ	32	obsolete
33	DA1	34	/PDIAG, /CBLID
35	DA0	36	DA2
37	/CS0	38	/CS1
39	/DASP	40	GROUND
41	+5V LOGIC	42	+5V MOTOR
43	GROUND	44	Reserved

/IOCS16 is not used; see [Table 3-7](#) (page 39).

ATA Signal Descriptions

[Table 3-7](#) (page 39) describes the signals on the ATA hard disk connector.

Table 3-7 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.
/CBLID	The host checks this signal after power on or hardware reset to detect whether an 80-conductor cable is present.
/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.).

Signal name	Signal description
/DDMARDY	Drive ready to receive Ultra DMA data.
/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.
DSTROBE	Strobe for Ultra DMA data transfers to host.
/HDMARDY	Ultra DMA data ready.
HSTROBE	Strobe for Ultra DMA data transfers from host.
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.
DMARQ	Asserted by the device when it is ready to transfer data to or from the host.
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.
/STOP	Stop request; an active low signal.
Key	This pin is the key for the connector.

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

SuperDrive

The 17-inch PowerBook G4 has a slot-loading SuperDrive. The SuperDrive can read and write DVD media and CD media as shown in Table 3-8. The SuperDrive drive also provides DVD-Video playback.

Table 3-8 Media read and written by the SuperDrive

Media type	Reading speed (maximum)	Writing speed
DVD-R	6x (CAV max)	4x (ZCLV)
DVD-RW	6x (CAV max)	2x (CLV)
DVD-ROM	8x (CAV max, single layer) 6x (CAV max, dual layer)	–
CD-R	24x (CAV max)	16x (ZCLV)

Media type	Reading speed (maximum)	Writing speed
CD-RW	24x (CAV max)	8x (CLV)
CD or CD-ROM	24x (CAV max)	–

The Apple SuperDrive is an ATAPI drive and writes to DVD-R 4.7 gigabyte General Use media. These discs are playable in most standard DVD players and computer DVD-ROM drives.

Digital audio signals from the SuperDrive can be played through the sound outputs under the control of the System Preferences.

Important: The SuperDrive supports only 12 cm disc media. It does not support 8 cm discs or noncircular media.

Trackpad

The pointing device in the 17-inch PowerBook G4 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 the trackpad 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 and can be activated or deactivated by means of the mouse pane in System Preferences.

The trackpad on the 17-inch PowerBook G4 has palm-rejection capabilities that help prevent unintended trackpad input while typing is being performed. When the "Ignore accidental trackpad input" checkbox is selected on the keyboard and mouse pane of Systems Preferences, the system software attempts to filter out unintended contact with the trackpad. The trackpad will not respond when a mouse is present and the "Ignore accidental trackpad input" checkbox is selected on the mouse pane of Systems Preferences.

Note: If the trackpad is not responding to intended input, check to see if the "Ignore accidental trackpad input" checkbox is selected.

Keyboard

The keyboard is a full-size, 19 mm pitch, low-profile design with a row of function keys and cursor motion keys in an inverted-T arrangement. A dedicated media eject key is located to the right of the F12 function key.

The 17-inch PowerBook G4 has a backlit keyboard and ambient light sensors that control the brightness of the display and the keyboard backlighting. In low light, the computer automatically illuminates the backlit keyboard and lowers the display brightness. As light levels increase, the display brightness is re-adjusted automatically and the keyboard backlighting is turned off. There are two light sensors, one under each speaker grill.

Access to internal components and expansion connectors is no longer via the keyboard, so the keyboard is not latched for removal. Access to the memory cards is via the RAM expansion slot and is explained in “RAM Expansion Slots” (page 55).

Changing the Operation of the Keyboard

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

- Function keys F1–F10 can also control features such as the display brightness, the speaker volume, the dual display feature, the Num Lock function, and the illuminated keyboard brightness. Refer to [Table 3-9](#) (page 45) for the entire list. A media eject key is located to the right of the F12 function key.
- 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, and the Num Lock key.

Keyboard Illustrations

[Figure 3-6](#) (page 42) shows the actual appearance of the keyboard. [Figure 3-7](#) (page 43) shows the alternate modes of operation of the function and control keys. [Figure 3-8](#) (page 44) shows the embedded numeric keypad.

Figure 3-6 Keyboard layout



[Figure 3-7](#) (page 43) and [Figure 3-8](#) (page 44) 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 3-6](#) (page 42).

Figure 3-7 Alternate operations of function and control keys

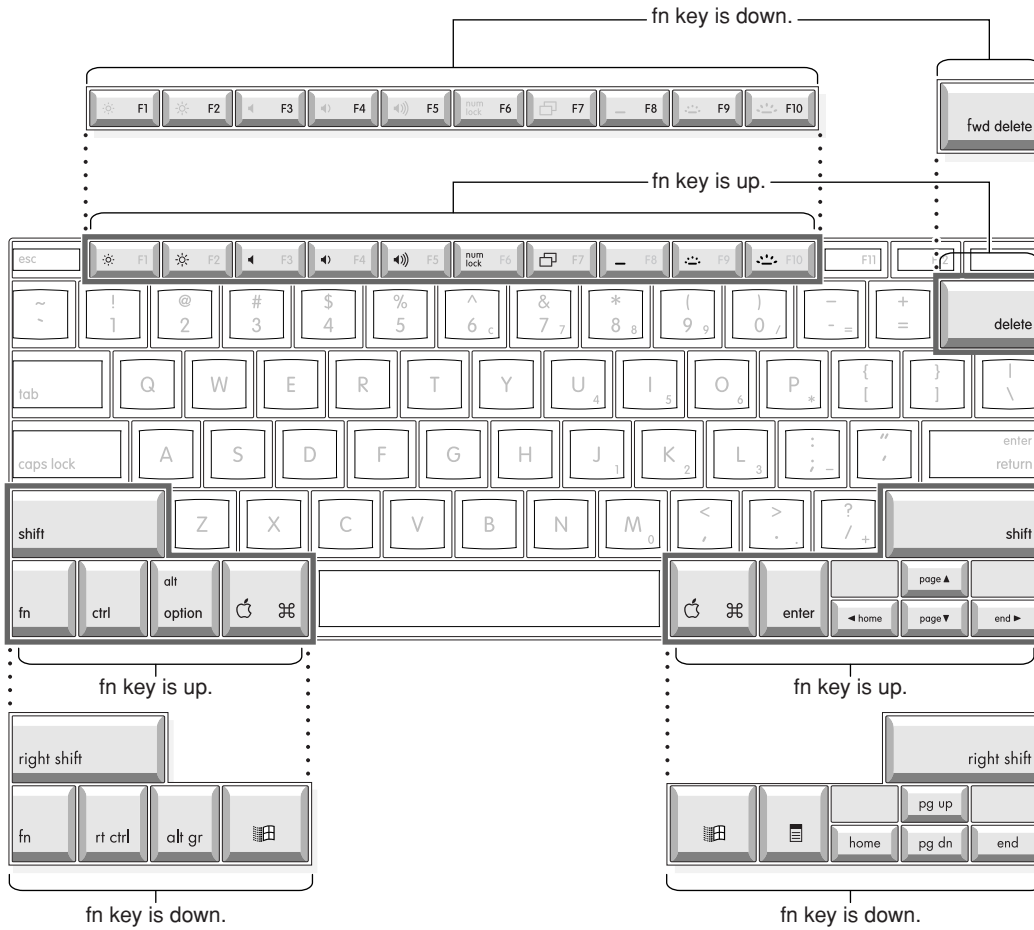
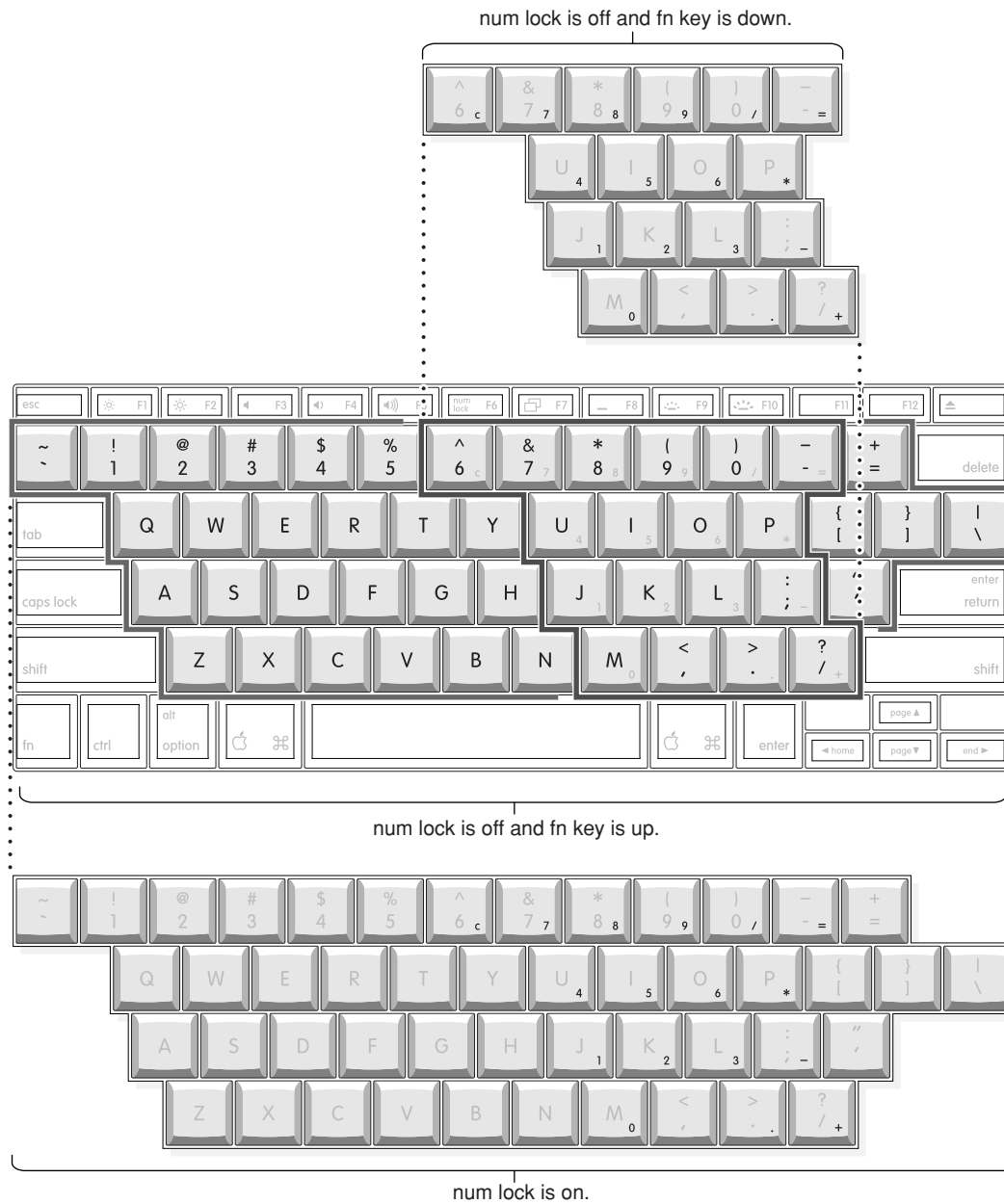


Figure 3-8 Embedded numeric keypad operation

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–F10 functions, as shown in [Table 3-9](#) (page 45) and [Figure 3-7](#) (page 43).
- It selects the embedded numeric keypad on the right portion of the alphanumeric keys, as shown in [Table 3-10](#) (page 46) and [Figure 3-8](#) (page 44).

- It changes certain control keys, including the cursor control keys, to page control keys, as shown in [Table 3-11](#) (page 46) and [Figure 3-8](#) (page 44).

Note: In Mac OS X, a third-party utility is needed to implement user-programmable function key assignments.

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 3-10](#) (page 46) and [Figure 3-8](#) (page 44).
- It makes the rest of the alphanumeric keys functionless (NOPs), as shown in [Figure 3-8](#) (page 44).

The Function Keys

[Table 3-9](#) (page 45) defines the default operation of the function keys. The "Use the F1-F12 keys for custom actions" checkbox in the Keyboard and Mouse pane in System Preferences allows you to toggle the default operation of these keys to custom actions. When this checkbox is enabled, the function keys operate as F1 through F12 keys that can be customized within individual software applications. Holding down the fn key while the checkbox is enabled, will go back to perform the default action that is listed in [Table 3-9](#) (page 45).

Table 3-9 The function keys as control buttons

Key name	Control button
F1	Decrease display brightness
F2	Increase display brightness
F3	Mute the speaker
F4	Decrease speaker volume
F5	Increase speaker volume
F6	Num Lock
F7	Switch between dual display and mirroring modes
F8*	Keyboard illumination control
F9*	Decrease keyboard illumination
F10*	Increase keyboard illumination
* Available when the ambient light is low enough to enable the backlight illumination feature.	

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 3-8](#) (page 44) shows the keys making up the embedded keypad and [Table 3-10](#) (page 46) lists them.

Table 3-10 Embedded keypad keys

Key name	Keypad function		Key name	Keypad function
6	Clear		P	* (multiply)
7	7		J	1
8	8		K	2
9	9		L	3
0	/ (divide)		;	– (subtract)
-	= (equals)		M	0
U	4		,	NOP
I	5		.	. (decimal)
O	6		/	+ (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 3-8](#) (page 44). 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 3-11](#) (page 46) is a list of these keys and their alternate functions. These control keys are also shown in [Figure 3-8](#) (page 44).

Table 3-11 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)

Key name	Alternate function
Left arrow	Home
Up arrow	Page up
Down arrow	Page down
Right arrow	End

Flat-Panel Display

The 17-inch PowerBook G4 has a built-in, wide-screen, 100 dpi, color flat-panel display with a resolution of 1440 by 900 pixels and measures 17 inches diagonally.

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.

In addition to its native resolution (1440 by 900) the display also supports several non-native resolutions, as shown in Table 3-12. The graphics controller IC includes a scaling function that expands displays with those smaller resolutions to fill the screen.

The display's native resolution, 1440 by 900, has an aspect ratio of 16:10. When selecting a picture resolution with an aspect ratio of 4:3, the user can choose to have it displayed with square pixels and black margins on the sides, or with stretched pixels that fill the display from side to side. These options are shown in [Table 3-12](#) (page 47).

Table 3-12 Picture sizes on the flat-panel display

Picture size	Display area used	Black margins	Shape of pixels
800 by 600	1200 by 900	yes	square
800 by 600	1440 by 900	no	stretched
1024 by 640	1440 by 900	no	square
1024 by 768	1200 by 900	yes	square
1024 by 768	1440 by 900	no	stretched
1152 by 720	1440 by 900	no	square
1440 by 900	1440 by 900	no	square (native)

External Monitors

The computer has a Digital Visual Interface (DVI) port for connecting to flat panel displays, a VGA monitor, or projection devices. The DVI connector supports DVI-equipped displays and projectors. A DVI-to-VGA adapter is included for use with analog monitors. With a DVI-to-ADC adapter, available separately, the 17-inch PowerBook G4 can be used with any Apple flat panel display.

The computer also has an S-video-to-composite cable that supplies a video signal for an NTSC or PAL video monitor or VCR. See “[External Video Port](#)” (page 51).

Note: When a dongle is used to attach a display, connect the dongle to the display *before* plugging the dongle into the computer.

Dual Display and Mirror Mode

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. Use the F7 key to switch between the dual display mode and the mirror mode.

When mirror mode is selected, the scaling function is available on the internal display, and on the internal display and an external monitor when both are operating. However, the monitors could have black borders during mirroring, depending on the supported timings between the two displays and on the monitor’s selection algorithm. Both displays show full-sized images only when the display resolution for the external monitor is set to the internal display’s native resolution: 1440 by 900. Both displays can operate with other resolution settings, but in mirror mode, one of them has 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 its screen. For resolution settings larger than 1440 by 900, the image on the external monitor is smaller than its screen.

Analog Monitor Resolutions

The 17-inch PowerBook G4 comes with an adapter for use with an analog video monitor. [Table 3-13](#) (page 48) lists the standard picture sizes and frame rates supported.

Table 3-13 Picture sizes on an analog monitor

Picture size (pixels)	Frame rate
800 by 600	85 Hz
1024 by 768	85 Hz
1280 by 960	85 Hz
1280 by 1024	85 Hz

Picture size (pixels)	Frame rate
1600 by 1024	85 Hz
1600 by 1200	85 Hz
1920 by 1080	85 Hz
1920 by 1200	85 Hz
1920 by 1440	85 Hz
2048 by 1536	75 Hz

Note: [Table 3-13](#) (page 48) lists the most common resolutions; additional resolutions are possible.

When the flat-panel display and an external video monitor are operating at the same time, each is allocated 32 MB of video memory in 64 MB VRAM systems or 64 MB of video memory in 128 MB VRAM systems. This allocation is enough to support the full 24-bit pixel depth at resolutions up to 2048 by 1536 pixels.

Digital Display Resolutions

[Table 3-14](#) (page 49) shows the resolutions supported on flat-panel (digital) displays. The 64 MB of video RAM (and the 128 MB VRAM build-to-order option) on the accelerated graphics card supports pixel depths up to 24 bits per pixel at all resolutions.

Table 3-14 Picture sizes on a digital display

640 by 480
800 by 500
800 by 600
1024 by 640
1024 by 768
1280 by 800
1280 by 1024
1600 by 1200
1920 by 1200

DVI-I Connector

The external monitor connector is a DVI-I connector. It carries both digital and analog video signals. [Figure 3-9](#) (page 50) shows the contact configuration; [Table 3-15](#) (page 50) and [Table 3-16](#) (page 50) list the signals and pin assignments.

Figure 3-9 DVI-I connector

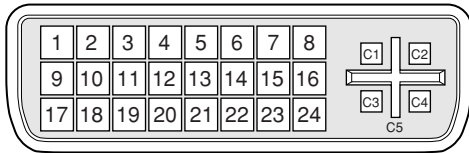


Table 3-15 Main signals on the DVI-I connector

Pin	Signal name	Pin	Signal name
1	TMDS Data2-	13	TMDS Data3+
2	TMDS Data2+	14	+5V Power
3	TMDS Data2/4 Shield	15	Ground for +5V Power
4	TMDS Data4-	16	Hot Plug Detect
5	TMDS Data4+	17	TMDS Data0-
6	DDC Clock	18	TMDS Data0+
7	DDC Data	19	TMDS Data0/5 Shield
8	Analog Vertical Sync	20	TMDS Data5-
9	TMDS Data1-	21	TMDS Data5+
10	TMDS Data1+	22	TMDS Clock Shield
11	TMDS Data1/3 Shield	23	TMDS Clock+
12	TMDS Data3-	24	TMDS Clock-

Table 3-16 MicroCross signals on the DVI-I connector

Pin	Signal name
C1	Analog Red Video
C2	Analog Green Video
C3	Analog Blue Video
C4	Analog Horizontal Sync

Pin	Signal name
C5	Analog Common Ground Return

The graphics data sent to the digital monitor use transition minimized differential signaling (TMDS). TMDS uses an encoding algorithm to convert bytes of graphics data into characters that are transition-minimized to reduce EMI with copper cables, and DC-balanced for transmission over fiber optic cables. The TMDS algorithm also provides robust clock recovery for greater skew tolerance with longer cables or low-cost short cables. For additional information about TMDS, see the references shown in “[Digital Visual Interface](#)” (page 64).

External Video Port

The 17-inch PowerBook G4 has a video port that provides S-video output to a PAL or NTSC video monitor or VCR. The video output connector is a 7-pin S-video connector. [Figure 3-10](#) (page 51) shows the arrangement of the pins and [Table 3-17](#) (page 51) shows the pin assignments on the S-video connector.

Figure 3-10 S-video connector

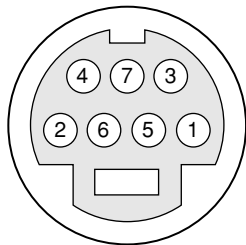


Table 3-17 Pin assignments for the S-video output connector

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 S-video-to-composite adapter is included and accepts an RCA plug for connecting to a composite video device.

The 17-inch PowerBook G4 provides video output at picture sizes and frame rates compatible with the NTSC and PAL standards; the picture sizes are listed in [Table 3-18](#) (page 52). Those picture sizes produce underscanned displays on standard monitors.

Table 3-18 Picture sizes for S-video output

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

Sound System

The sound system for the 17-inch PowerBook G4 supports stereo sound output and input, available simultaneously. The sound circuitry handles audio data as 16-bit samples at a 44.1 kHz sample rate.

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 headphone out port or one of the USB ports.

The 17-inch PowerBook G4 can record sound data from the built-in microphone, an audio CD, the audio line in , or a USB audio device. For each sound input source, sound play-through can be enabled or disabled. Sound data from digital sources is converted to analog form for output to the speakers and the headphone out port.

Sound Inputs

The sound system accepts inputs from the following sources:

- the built-in microphone
- the audio line in port
- a CD or DVD in the SuperDrive via IIS
- a digital audio device connected to a USB or FireWire port via IIS

The audio line in port and microphone preamp share a dedicated analog input channel in the audio circuitry; the other inputs send digital data. The analog input can be set for play-through or recording. The digital inputs can be selected or mixed by the audio sound circuitry.

The computer also accepts digital sound data from the SuperDrive 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 headphone out.

Built-in Microphone

The built-in microphone is located at the bottom of the left speaker grill.

The sound signal from the built-in microphone goes through a dedicated preamplifier that raises its nominal 30 mV level to a nominal 700 mV RMS signal to the sound circuitry. That signal level assures good quality digitizing without driving the analog input into clipping.

Audio Line In

The audio line in is a 3.5 mm mini jack that accepts line-level stereo signals. It also accepts a stereo miniplug-to-RCA cable adapter for connecting stereo equipment to the computer.

The audio line in signal connections are

- tip: audio left channel
- ring: audio right channel
- sleeve: audio ground

Modem Activity Sound Signals

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

Sound Outputs

The sound system sends sound output signals to the built-in speakers and the headphone out port.

Headphone Out

The headphone out is located on the left side of the computer. The headphone out provides enough current to drive a pair of low-impedance headphones. It can also be used as a line-level output.

The headphone out has the following electrical characteristics:

- impedance suitable for driving standard 32-ohm headphones
- output level 2.0 V peak-to-peak (1.41 V RMS)
- signal-to-noise (SNR) 90 dB unweighted (typical)
- total harmonic distortion (THD) 0.01% or less

Internal Speakers

The computer has two internal speakers, one on either side of the keyboard. The computer turns off the sound signals to the speakers when an external device is actively connected to the headphone out and during power management.

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 sound circuitry.

When recording sound from a microphone, applications that may be affected by feedback should disable sound play-through by calling the Sound Manager functions.

Expansion Features

This chapter describes the expansion features of the 17-inch PowerBook G4's RAM expansion slots and the PC Card/CardBus slot.

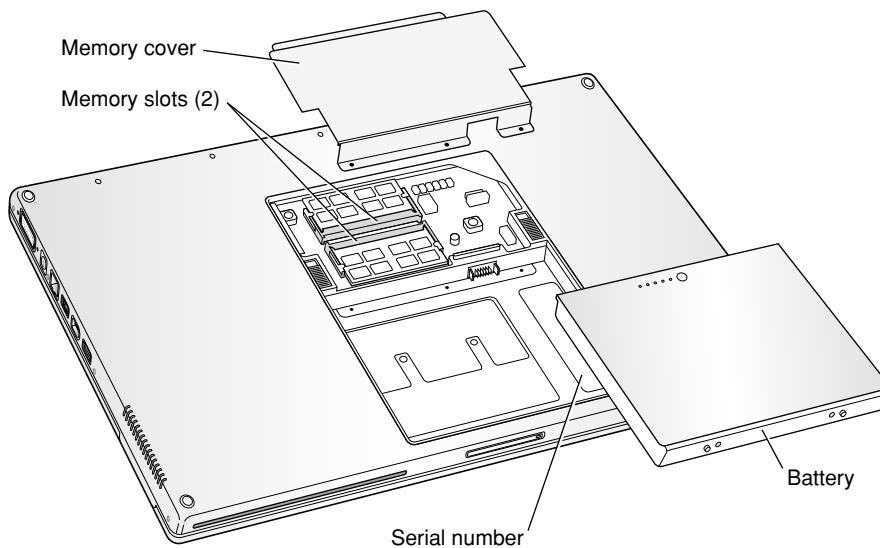
RAM Expansion Slots

The 17-inch PowerBook G4 ships with 512 MB of factory-installed SDRAM. The computer has two RAM expansion slots that accommodate standard SO (small outline) DIMMs using DDR SDRAM devices. The expansion slots are accessible for user installation of an additional SO-DIMM. Available as build to order options are 1 GB and 2 GB RAM.

The address logic for the RAM slots supports up to 2 GB total RAM. Using the highest-density devices currently available, an SO-DIMM can contain up to 1 GB of RAM, so the two RAM expansion slots can accommodate up to 2 GB total RAM.

Accessing the RAM Slots

The user can access the RAM expansion slots by removing the memory slot cover on the back of the computer, as shown in [Figure 4-1](#) (page 56). For complete instructions on accessing and replacing the RAM memory, refer to the *17-inch PowerBook G4 Getting Started* guide that came with the computer.

Figure 4-1 Removing RAM expansion slot cover

Mechanical Design of DDR RAM SO-DIMMs

The RAM expansion modules used in the 17-inch PowerBook G4 are PC2700 DDR333 RAM 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 DDR SO-DIMM. The specification number is JEDEC JESD95. To obtain a copy of the specification, see the references listed at [“RAM Expansion Modules”](#) (page 63).

The specification defines SO-DIMMs with nominal heights of 1.0, 1.25, 1.5, and 2.0 inches. The 17-inch PowerBook G4 can accommodate SO-DIMMs with heights of 1.25 inches or less.

Important: The 17-inch PowerBook G4 can not accept a 1.5 or 2-inch SO-DIMM.

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

Electrical Design of DDR RAM SO-DIMMs

SO-DIMMs for the 17-inch PowerBook G4 are required to be PC2700 compliant. For information about the PC2700 specifications, see the references at [“RAM Expansion Modules”](#) (page 63).

The electrical characteristics of the DDR RAM SO-DIMM are given in section 4.5.6 of the JEDEC Standard 21-C, release 7 (JESD-21C). To obtain a copy of the specification, see the references listed at [“RAM Expansion Modules”](#) (page 63).

The JEDEC and Intel 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.

Important: The memory controller on the 17-inch PowerBook G4 uses separate CKE signals for each bank, as called out in the JEDEC specification. SO-DIMMs that have all the CKE pins connected together do not operate properly.

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 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 (200-pin DDR SDRAM SO–DIMM, PD INFORMATION) of the JEDEC standard 21-C specification, release 7.

Important: For a DIMM to be recognized by the startup software, the SPD feature must be programmed properly to indicate the timing modes supported by the DIMM.

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.

DDR SDRAM Devices

The DDR SDRAM devices used in the RAM expansion modules must be self-refresh type devices for operation from a 2.5 V power supply. The data rate of the DDR SDRAM devices must be 333 MHz.

The devices are programmed to operate with a CAS latency of 2.5 or 3. At these CAS latencies, the access time from the clock transition must be +/- 0.6 ns or less for data strobes and +/- 0.7 ns for data lines. 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 RAM module is 6 mA/128 MB (48 mA per RAM module) ;see the section “RAM SO-DIMM Electrical Limits” (page 58). Developers should specify DDR SDRAM devices with low power specifications so as to stay within that limit.

Configuration of DDR RAM SO-DIMMs

Table 4-1 (page 57) shows information about the different sizes of DDR 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 DDR SDRAM devices making up the memory modules.

Table 4-1 Sizes of RAM expansion modules and devices

SO-DIMM size	SO-DIMM configuration (MB x bits)	Number of devices	Device configuration (MB x bits)	Number of banks
128 MB	16 x 64	8	16 x 8	1
128 MB	16 x 64	8	8 x 16	2
256 MB	32 x 64	16	16 x 8	2
256 MB	32 x 64	8	32 x 8	1

SO-DIMM size	SO-DIMM configuration (MB x bits)	Number of devices	Device configuration (MB x bits)	Number of banks
256 MB	32 x 64	8	16 x 16	2
512 MB	64 x 64	8	64 x 8	2
512 MB	64 x 64	16	32 x 8	2
1 GB	128 x 64	16	64 x 8	2

Note: The 17-inch PowerBook G4 does not use 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 DDR SDRAM devices. [Table 4-2](#) (page 58) lists the types of devices that can be used in the 17-inch PowerBook G4 by size, configuration, and sizes of row, column, and bank addresses.

Important: The 17-inch PowerBook G4 supports only the types of DDR SDRAM devices specified in [Table 4-2](#) (page 58). Other types of devices should not be used with this computer.

Table 4-2 Types of DRAM devices

Device size	Device configuration (bytes x bits x banks)	Row address bits	Column address bits
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
512 Mbits	16 M x 8 x 4	13	11
512 Mbits	8Mx16x4	13	10

RAM SO-DIMM Electrical Limits

Each RAM SO-DIMM must not exceed the following maximum current limits on the 2.5 V supply:

Active: 1.2 A (8 devices at 150 mA each)

Sleep: 6 mA/128 MB (48 mA per RAM module)

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 Intrepid memory controller does not support 4-bit-wide SDRAM devices in any RAM expansion module.

PC Card/CardBus Slot

The PC Card/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.

Note: The PC Card/CardBus slot does not provide 12 V power.

Supplemental Reference Documents

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

For information about older models of Macintosh computers, refer to the developer notes archive at

<http://developer.apple.com/documentation/Hardware/hardware2.html>

Apple Technical Notes

Apple Technical Notes answer many specific questions about the operation of Macintosh computers and the Mac OS. The notes are available on the Technical Note website at

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

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/>

PowerPC G4 Microprocessor

Information about the PowerPC G4 microprocessor is available on the World Wide Web at

http://e-www.motorola.com/webapp/sps/site/prod_summary.jsp?code=MPC7447A&nodeId=018rH3bTdG8653

Velocity Engine

Velocity Engine is Apple's name for the AltiVec vector processor in the PowerPC G4 microprocessor. Apple provides support for developers who are starting to use the Velocity Engine in their applications. Documentation, development tools, and sample code are available on the World Wide Web, at

<http://developer.apple.com/hardware/ve/index.html>

AltiVec Technology Programming Environments Manual (AltiVec PEM) is a reference guide for programmers. It contains a description for each instruction and information to help in understanding how the instruction works. You can obtain a copy of the AltiVec PEM through the Motorola AltiVec site on the World Wide Web, at

<http://e-www.motorola.com/webapp/sps/site/overview.jsp?nodeId=03M943030450467M0ymK5Nf2>

Mac OS X

Mac OS X version 10.3.3 is installed by default on the 17-inch PowerBook G4. For access to Apple's developer documentation for Mac OS X, see the Apple Developer Connection (ADC) website at

<http://developer.apple.com/documentation/MacOSX/MacOSX.html>

O'Reilly & Associates publishes a series of books about Mac OS X development. The books in this series have been technically reviewed by Apple engineers and are recommended by the Apple Developer Connection.

I/O Kit

The I/O Kit is part of Darwin, the operating system foundation for Mac OS X. The documentation for I/O Kit is available on Apple's Darwin website at

<http://developer.apple.com/documentation/Darwin/Darwin.html>

Open Firmware

The software architecture implemented on current Macintosh computers follows the standard defined by the Open Firmware IEEE 1274-1994 specification. Three Technical Notes provide an introduction to Open Firmware on the Macintosh platform. They are:

TN1061: Open Firmware, Part I, available at

<http://developer.apple.com/technotes/tn/tn1061.html>

TN1062: Open Firmware, Part II, available at

<http://developer.apple.com/technotes/tn/tn1062.html>

TN1044: Open Firmware, Part III, available at

<http://developer.apple.com/technotes/tn/tn1044.html>

Other Technical Notes provide additional information about Open Firmware on the Macintosh.

TN2000: PCI Expansion ROMs and You, at

<http://developer.apple.com/technotes/tn/tn2000.html>

TN2001: Running Files from a Hard Drive in Open Firmware, at

<http://developer.apple.com/technotes/tn/tn2001.html>

TN2004: Debugging Open Firmware Using Telnet, available at

<http://developer.apple.com/technotes/tn/tn2004.html>

RAM Expansion Modules

The mechanical characteristics of the DDR RAM SO-DIMM are given in JEDEC specification number JESD95. The specification can be found by using the search string JESD95 on the Electronics Industry Association's website at

<http://www.jedec.org/DOWNLOAD/default.cfm>

The electrical characteristics of the RAM SO-DIMM are given in JEDEC Standard 21-C. The specification can be found by using the search string JESD-21C on the Electronics Industry Association's website at

<http://www.jedec.org/DOWNLOAD/default.cfm>

The DDR RAM DIMMs are required to be PC2700 compliant. Information about the PC2700 specifications is available from Intel's website at

<http://developer.intel.com/technology/memory/>

ATA Devices

ATA (AT Attachment), also referred to as integrated drive electronics (IDE), is a standard interface used with storage devices such as hard disk drives. For more information on ATA, refer to the following Apple website at

<http://developer.apple.com/documentation/Hardware/DeviceManagers/ata/ata.html>

ATA Manager 4.0 supports driver software for internal IDE drives and includes DMA support. For the latest information about ATA Manager 4.0, see Technical Note TN1098, 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 Technical Note TN1098 includes a link to a downloadable copy of *ATA Device Software Guide*.

Information about the ATA standards is available at the Technical Committee T13 AT Attachment website, at

<http://www.t13.org/>

USB Interface

For more information about USB on Macintosh computers, refer to Apple Computer's *Accessing Hardware from Applications* at

<http://developer.apple.com/documentation/Hardware/DeviceManagers/usb/usb.html>

For full specifications of the Universal Serial Bus 2.0, refer to the USB Implementers Forum on the World Wide Web, at

<http://www.usb.org/developers/docs>

FireWire Interface

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

<http://developer.apple.com/firewire/index.html>

The IEEE 1394 standards are available from the IEEE. Ordering information can be found on the World Wide Web at

<http://shop.ieee.org/store>

You may also find useful information at the 1394 Trade Association's website:

<http://www.1394ta.org/>

Digital Visual Interface

For information about transition minimized differential signaling (TMDS) used with digital video monitors, see the specification, Digital Visual Interface DVI Revision 1.0, available on the website of the Digital Display Working Group (DDWG) at

<http://www.ddwg.org/>

Wireless Networks

More information about Wi-Fi and wireless networks using the IEEE 802.11 standards is available on the website of the WiFi Alliance, at

<http://www.wirelessethernet.org/OpenSection/index.asp>

Bluetooth

For more information regarding Bluetooth technology, refer to the following locations on the World Wide Web.

Bluetooth specification:

<http://www.bluetooth.org/spec/>

Bluetooth SIG:

<http://www.bluetooth.org>

Bluetooth developer tools on the Apple web site at:

<http://developer.apple.com/devicedrivers/bluetooth/>

A P P E N D I X A
Supplemental Reference Documents

Abbreviations

Here are lists of abbreviations used in this developer note.

Abbreviations and Standard Units

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

Other abbreviations used in this note include:

10Base-T	an Ethernet standard for data transmission at rates up to 10 Mbits per second
100Base-T	an Ethernet standard for data transmission at rates up to 100 Mbits per second
1000Base-T	an Ethernet standard for data transmission at rates up to 1000 Mbits per second

Abbreviations

AGP	accelerated graphics port
AIM	ATA Interface Module
ANSI	American National Standards Institute
API	application programming interface
ASIC	application-specific integrated circuit
ATA	AT attachment
CAS	column address strobe, a memory control signal
CD	compact disc
CD-ROM	compact disc read-only memory
CLV	constant linear velocity
CPU	central processing unit
CRT	cathode ray tube, a video display device
DAA	data access adapter (a telephone line interface)
DAC	digital-to-analog converter
DDC	display data channel
DIMM	Dual Inline Memory Module
DB-DMA	descriptor-based direct memory access
DDK	device developer's kit
DDR	double data rate, a type of SDRAM
DFS	dynamic frequency shift
DMA	direct memory access
DVI	Digital Visual Interface
EDO	extended data out
EHCI	Enhanced Host Controller Interface — USB 2.0 controller standard
EIDE	enhanced integrated device electronics
G4	Generation 4, the fourth generation of PowerPC microprocessors, incorporating AltiVec technology
GND	ground
HFS	hierarchical file system

Abbreviations

HCRP	hardcopy cable replacement profiler
HID	human interface device, a class of USB devices
IC	integrated circuit
IDE	integrated device electronics
IEC	International Electrotechnical Commission
IIC	inter-IC control bus
IIS	inter-IC sound bus
I/O	input and output
ISM	industrial, scientific, and medicine
ISO	International Organization for Standardization
JEDEC	Joint Electron Device Engineering Council
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
MDI	Medium Dependent Interface
MDI-X	Medium Dependent Interface with Cross-Over
modem	modulator-demodulator, a data communications interface for use with analog telephone lines
NMI	nonmaskable interrupt
NOP	no operation
NVRAM	nonvolatile random-access memory
OFDM	orthogonal frequency-division multiplexing
OHCI	Open Host Controller Interface — USB 1.1 controller standard
OS	operating system
PCI	Peripheral Component Interconnect, an industry-standard expansion bus
PLL	phase-locked loop
RADIUS	Remote Authentication Dial-In User Service
RAM	random-access memory

Abbreviations

RCA	Radio Corporation of America
rms	root mean square
ROM	read-only memory
SBP	Serial Bus Protocol
SCSI	Small Computer System Interface
SDK	software developer's kit
SDR	Single Data Rate
SDRAM	synchronous dynamic RAM
SNR	signal to noise ratio
SO-DIMM	Small Outline Dual Inline Memory Module
SPD	Serial Presence Detect, a feature of the SO-DIMM
TMDS	transition minimized differential signaling
USB	Universal Serial Bus, an industry-standard expansion bus
VCC	positive supply voltage (voltage for collectors)
VPN	virtual private network
WEP	Wired Equivalent Privacy
Wi-Fi	Logo used by the Wireless Ethernet Compatibility Alliance for certification of interoperability of 802.11 products
WLAN	wireless LAN
ZCLV	zone constant linear velocity