Power Mac G5 Developer Note

Hardware & Drivers > Apple Hardware

2003-08-20

Contents

5

Figures and Tables

7

Introduction to Power Mac G5 Developer Note

This developer note describes the all new 64-bit Power Mac G5 computer. The note provides information about the internal design of the computer, its input-output and expansion capabilities, and issues affecting compatibility.

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 simply like additional technical information, refer to Appendix A, "Supplemental Reference Documents," (page 55) for additional information.

Organization of This Document

The information is arranged in four chapters and two appendixes:

- Chapter 1, "Introduction," (page 11) gives a summary of the features of the Power Mac G5 computer, describes the physical appearance of the enclosure, and lists compatibility issues of interest to developers.

- Chapter 2, "Architecture," (page 17) describes the internal organization of the computer. It includes a functional block diagram and descriptions of the main components on the logic board.

- Chapter 3, "Input and Output Devices," (page 27) describes the built-in I/O devices and the external I/O ports.

- Chapter 4, "Expansion," (page 49) describes the expansion slots on the logic board and provides specifications for the expansion modules.

- Appendix A, "Supplemental Reference Documents," (page 55) provides sources of additional information about the technologies used in the Power Mac G5 computer.

- Appendix B, "Conventions and Abbreviations," (page 61) lists standard units of measure and other abbreviations used in this developer note.

Overview of Power Mac G5

The 64-bit desktop Power Mac G5 computer uses single and dual PowerPC G5 microprocessors and is intended for use in content creation, desktop publishing, multimedia, scientific and technical applications, and other activities that require high performance.

Hardware Features Summary

Here is a list of the hardware features of the Power Mac G5 computer. The major features are described more fully later in this note.

- **Microprocessors**: Three clock frequencies are available on the Power Mac G5 computer: single 1.6 GHz, single 1.8 GHz, and dual 2.0 GHz. For more information, see "PowerPC G5 Microprocessor" (page 19).

- **Memory caches**: The PowerPC G5 microprocessors used in the Power Mac G5 computer have an internal 512 KB level 2 cache.

- **Processor system bus**: The processor bus has 64-bit throughput (32-bit in and 32-bit out) with clock speeds of 800 MHz, 900 MHz or 1 GHz. For more information, see "Processor Bus" (page 20).

- **Memory bus**: The main memory bus is 128 bit 333 MHz or 400 MHz. For more information, see "Main Memory Bus" (page 20).

- **DDR SDRAM**: Eight DIMM slots for 184 pin DIMMs (dual inline memory modules) using unbuffered DDR (double data rate) SDRAM devices. A minimum of 256 MB of RAM is installed in pairs of slots, and the systems are capable of a maximum of 4 GB or 8 GB. For more information, see "Main Memory Bus" (page 20).

- **AGP 8x Pro card slot**: The computer has an AGP 3.0 8x Pro accelerated graphics card installed in this slot. For more information, see "Accelerated Graphics Port Bus" (page 21).

- **PCI expansion slots**: Three PCI or PCI-X slots are provided via the HyperTransport bus. In some Power Mac G5 configurations, the slots support PCI-X: one slot supports a maximum of 133 MHz and two slots support a maximum of 100 MHz. In other Power Mac G5 configurations, the three slots support 33 MHz PCI. For more information, see "PCI or PCI-X Expansion Slots" (page 21).

- **Hyper Transport bus**: A new high-speed bus architecture between the memory controller and device I/O. For more information, see "HyperTransport Technology" (page 23).

- **Graphics card**: The Power Mac G5 computer comes standard with one of the following graphics cards: NVIDIA GeForce FX 5200 Ultra with 64 MB RAM or ATI Radeon 9600 Pro with 64 MB RAM. Also available as a build-to-order option is the ATI Radeon 9800 Pro with 128 MB RAM. All cards have ADC and DVI-I connectors. For more information, see "Graphics Cards" (page 26).

- **Power supply**: The Power Mac G5 computer comes with either a 450 W or 600 W power supply.

- **Hard disks**: An internal 7200 rpm Serial ATA hard disk occupies one of two drive bays and functions as the default boot disk. Hard disk capacities are 80 GB and 160 GB with a 250 GB build-to-order option. For more information, see "Serial ATA Interface" (page 24).

- **SuperDrive (DVD-R/CD-RW drive)**: The Power Mac G5 computer has a SuperDrive drive connected to the Ultra DMA ATA/100 bus. For more information, see "SuperDrive" (page 34).

- **Combo (DVD-ROM/CD-RW) drive**: Instead of a SuperDrive, the Power Mac G5 computer has an optional build-to-order combination DVD-ROM/CD-RW drive connected to the Ultra DMA ATA/100 bus. For more information, see "Combo Drive" (page 34).

- **High-speed USB 2.0**: The computer has three external USB 2.0 ports: two on the rear of the enclosure and one on the front. All ports support both high-speed and classic USB speeds. For more information, see "USB Ports" (page 27).

- **Ethernet**: The computer has a built-in Ethernet port for 10Base-T/UTP, 100Base-TX, or 1000Base-TX Gigabit operation. The Ethernet port is auto-sensing and self-configuring to allow use of either a cross-over or straight-through cable. For more information, see "Ethernet Port" (page 32).

- **AirPort Extreme Card**: Available as a build-to-order option, the 54 Mbps AirPort Extreme Card provides a wireless LAN connection. For more information, see "Wireless LAN Module" (page 22).

- **Bluetooth** : Available as a build-to-order option, the fully-integrated Bluetooth module enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices. For more information, see "Bluetooth Technology" (page 37).

- **FireWire ports**: The computer has two FireWire 400 ports and one FireWire 800 port. For more information, see "FireWire Controllers" (page 24).

- **Modem**: The computer has a built-in Apple 56 Kbps modem. The modem supports K56flex and V.90 and V.92 modem standards. For more information, see "Internal Modem" (page 35).

- **Keyboard**: The computer comes with a full-size USB Apple Keyboard. The keyboard is also a bus-powered USB hub with two USB ports. For more information, see "Keyboard" (page 37).

- **Mouse**: The computer comes with a USB Apple Mouse, with optical tracking. For more information, see "Mouse" (page 39).

- **Boot ROM**: The Power Mac G5 computer comes with 1 MB of boot ROM.

- **S/PDIF digital audio**: The Power Mac G5 implements S/PDIF (Sony/Phillips Digital Interface) digital audio I/O via TOSLink optical input and digital output connectors on the rear panel. For more information, see "Sound System Overview" (page 25).

- **Analog audio line-in**: Rear panel analog audio line-in port for self-powered microphones or other audio equipment. For more information, see "Analog Audio Line-in" (page 42).

- **Analog audio line-out**: Rear panel analog audio line-out port for externally-powered speakers or other audio devices with line-level outputs. For more information, see "Analog Audio Line-out" (page 42).

- **Headphone and internal speaker**: The front panel includes a headphone mini-jack and the system includes an internal speaker. For more information, see "Analog Headphone Jack" (page 43).

- **DVI to video adapter**: The Power Mac G5 supports S-video and composite video from an optional adapter connected to the DVI port. For more information, see "DVI to Video Adapter" (page 47).

- **Voltage switching**: Auto-ranging voltage switching accepts 100 - 240V.

- **Fan speed control**: The speeds of the fans are thermally controlled and are automatically set as low as possible to minimize noise. System performance can be specified by a "high/reduced/automatic" pulldown option provided in the Energy Saver Control pane in System Preferences.

- **Energy saving**: Sleep scheduling can be controlled via the Energy Saver pane in System Preferences.

> **Note:** While in sleep mode, the computer emits no noise and the power light pulses slowly.

Features of the Enclosure

The Power Mac G5 computer's enclosure is a tower design. Figure 1-1 (page 13) illustrates the front of the enclosure and Figure 1-2 (page 14) illustrates the rear of the enclosure.

Figure 1-1   Power Mac G5 front view
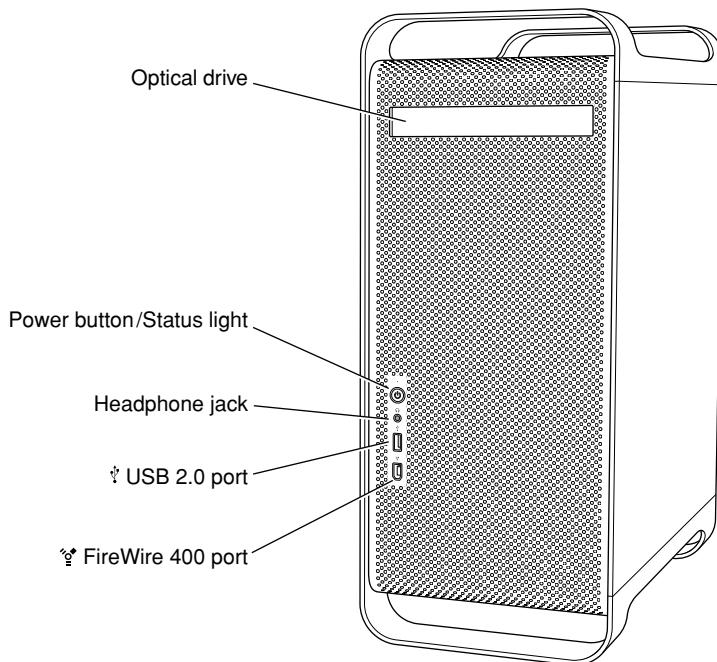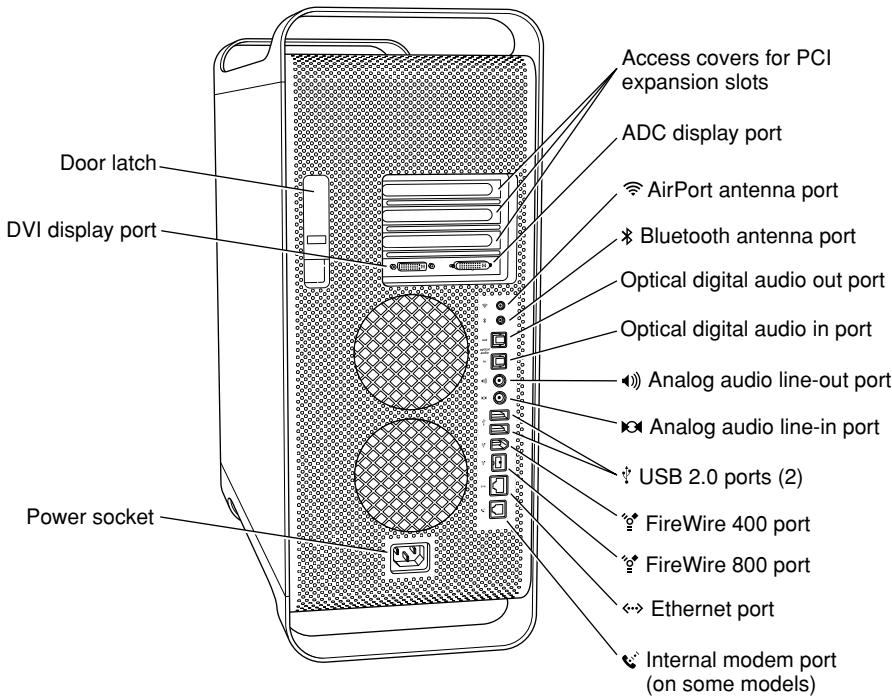
Figure 1-2   Power Mac G5 rear view

The enclosure has space for two hard disk drives and one optical device. See "Hard Disk Drives" (page 33).

To access the main logic board to install PCI or PCI-X cards or additional memory, refer to "Expansion" (page 49). For full details regarding opening and accessing the computer, refer to the *Power Mac G5 Take Apart* document provided by Apple Care support.

⚠️ **Warning:** Opening the enclosure side panel impacts the thermal performance of the computer. Do not run the enclosure with the side panel open. If the air deflector inside the enclosure is removed, the fans will turn off and the system will take action to prevent over-heating.

System Software

The Power Mac G5 computer ships with Mac OS X 10.2.7 installed as the default operating system. The classic environment can be used to run Mac OS 9 applications.

To retrieve information from the I/O Registry, use the APIs in the header file IOKit/IOKitLib.h.

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 I/O Registry calls to test for the features they require.

Asset management software that reports the kind of computer it is run on can obtain the value of the property at `Devices:device-tree:compatible` in the IODeviceTree plane of the I/O Registry. The model string is the first program-usable string in the array of C strings in the `compatible` field. For the Power Mac G5, the value of the model property is `PowerMac7,2`.

Power Management

A common power management strategy is implemented across all Macintosh models. The basics of Apple's power management techniques are described in the following paragraphs.

Processor and Bus Slewing

To lower power consumption, heat generation, and fan noise, the Power Mac G5 computer incorporates an automatic power management technique called bus slewing. Bus slewing is designed to run at high processor and bus speeds and high voltage when the demand on the processor is high, and to run at low processor and bus speeds and low voltage when the demand on the processor is low. Switching between different processor/bus speeds and voltages is achieved by a gradual transition that does not impact system or application performance and operates seamlessly to the user. In slewing, the bus runs at half the speed of the processor.

The ranges of the slewed processor speeds are listed below:

Configuration	Processor range
1.6 GHz	1.3 GHz to 1.6 GHz
1.8 GHz	1.3 GHz to 1.8 GHz
2.0 GHz	1.3 GHz to 2.0 GHz

In addition, the Power Mac G5 computer allows the user to control bus slewing mode. The options for specifying either high, reduced, or automatic processor and bus speeds are located at System Preferences>Energy Saver>Options; then select Automatic, Highest, or Reduced.

If the Power Mac G5 computer detects a system temperature that is too high, due to high ambient temperatures or other factors, it will automatically enter bus slewing mode regardless of the selected setting.

Processor States

The following processor states are defined:

■   Run: The system is running at maximum processing capacity with all processors running at full speed.

■   Idle: The system is idling; this is the default state. All clocks are running and the system can return to running code within a few nanoseconds. If the system has no work to do, it will be in idle mode.

System Modes

The Macintosh system has the following power-saving modes. If the system does not support full sleep, it will use the less efficient doze mode.

- Run: The system is fully functional in normal operating mode with all components powered and operating.

- Doze: The power to the disk drive motors and the display is turned off, but the power supply and fans are still on. PCI cards that don't support full system sleep (some SCSI cards, some graphics cards) will cause the machine to doze rather than fully sleep.

- Full sleep: The main power supply is shut down. A trickle supply provides auxiliary power to the PCI slots and keeps the DRAM state preserved for a quick recovery. All processors are powered off with their state preserved in DRAM. All non-essential clocks in the system are suspended. This mode allows the computer to meet Energy Star sleep requirements while providing the ability to start up without rebooting. This system may be awakened by administrative network packets, keyboard or mouse activity, USB device removal, or PMU scheduled wakeup.

- Off: The Power Mac G5 computer meets FEMP (Federal Energy Management Program) requirements and supports FireWire ports functioning as repeaters when operating on AC power.

Velocity Engine Acceleration

The Velocity Engine is the vector processing unit in the PowerPC G5 microprocessor. System software has been modified to take advantage of the accelerated processing that the Velocity Engine makes possible and to support low-level operations using the Velocity Engine.

For complete information on the Velocity Engine, refer to the following Apple website:

http://developer.apple.com/hardwaredrivers/ve/index.html
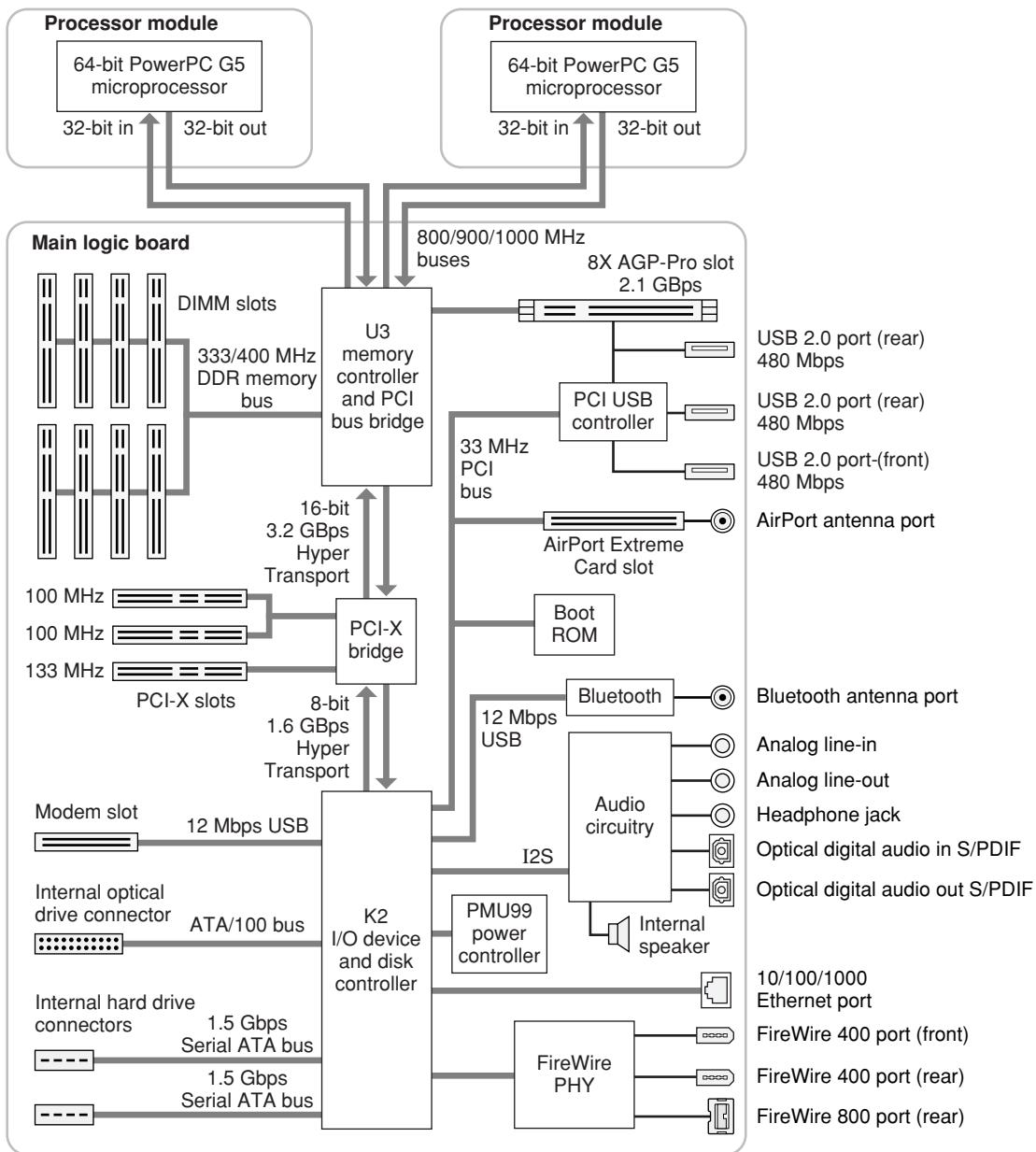
Architecture

This chapter describes the architecture of the Power Mac G5 computer. It includes information about the major components on the logic boards: 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

Figure 2-1 (page 18) is a simplified block diagram of the Power Mac G5 computer. The diagram shows the main ICs and the buses that connect them together.

The architecture of the Power Mac G5 computer is based on the PowerPC G5 microprocessor, and two custom ICs: the U3 memory controller and bus bridge and the K2 I/O controller.

Figure 2-1 Simplified block diagram

The Power Mac G5 computer has the following data buses, not counting the processor's dedicated interface to the backside cache.

■ Processor bus: 800/900/1000 MHz, 64-bit (32-bit in and 32-bit out) data throughput per processor connecting the processor module to the U3 IC

■ Dual processor systems have two independent 64-bit (32-bit in and 32-bit out) processor buses

■ Memory bus: 333 or 400 MHz, 128-bit bus connecting the main DDR SDRAM memory to the U3 IC

■ 8x AGP Pro bus: 266/533 MHz, 32-bit bus connecting the AGP graphics card to the U3 IC

- PCI or PCI-X bridge bus: supports three 64-bit PCI-X slots (two 100 MHz and one 133 MHz) or three 33 MHz PCI slots

- Internal PCI bus: 33 MHz, 64-bit bus supports the K2 I/O controller, the boot ROM, the AirPort Extreme Card slot, and the USB controllers

- Serial ATA (S-ATA) buses: support 1.5 Gbps internal hard drive connectors

- Ultra DMA ATA/100 bus: supports internal optical drive

- HyperTransport: high-speed, bidirectional, point-to-point link for integrated circuits supports bidirectional data rates up to 3.2 GBps

The remainder of this chapter describes the architecture of the processor module, the U3 memory controller and bridge IC, the K2 I/O controller IC, and the USB controllers.

Processor Module

The processor module is a separate logic board that contains one PowerPC G5 microprocessor. Dual microprocessor configurations contain two identical PowerPC G5 processor modules.

The processor module is connected to the main logic board by a 300-pin connector. To achieve the required level of performance, the signal lines that connect the processor module and the main logic board are carefully matched in length, loading, and impedance.

PowerPC G5 Microprocessor

The PowerPC G5 used in the Power Mac G5 computer has the following features:

- 64-bit PowerPC implementation with 42-bit physical memory addressing

- core runs at twice the bus speed

- superscalar execution core supporting more than 200 in-flight instructions

- two independent double-precision floating point units

- Velocity Engine: 128-bit-wide vector execution unit

- 64K L1 instruction cache, 32K L1 data cache per processor

- fully symmetric multiprocessing capability

- built-in 512 KB backside L2 cache per processor

- two independent, unidirectional 800 MHz to 1 GHz frontside buses each supporting up to 8 GBps data throughput per processor

For more information, see the reference at "PowerPC G5 Microprocessor" (page 55).

U3 Bridge and Memory Controller

The U3 custom IC is at the heart of the Power Mac G5 computer. It provides the bridging functionality among the processors, the memory system, HyperTransport bus to the PCI-based I/O system, and the AGP slot.

Processor Bus

The processor bus is a 800 MHz, 900 MHz, or 1 GHz bus connecting the processor module to the U3 IC. The bus has 64-bit wide data and 36-bit wide addresses.

The Power Mac G5 system controller is built with the same state-of-the-art 130-nanometer, SOI technology as the PowerPC G5 processor. This super-efficient point-to-point architecture provides each subsystem with dedicated bandwidth to main memory. The Power Mac G5 uses separate processor boards with each PowerPC G5 processor; two processor boards are used for dual processor systems. The U3 I/O implements two independent processor interfaces. The processors range from 1600 to 2000 MHz in clock rate and connect to the U3 I/O through the Apple Processor Interface (API). The processor clock is derived from a PLL which multiplies the reference clock by preset intervals of 6 or 8 times.

Out-of-order completion allows the memory controller to optimize the data bus efficiency by transferring whichever data is ready, rather than having to pass data across the bus in the order the transactions were posted on the bus. This means that a fast DDR SDRAM read can pass a slow PCI read, potentially enabling the processor to do more before it has to wait on the PCI data.

Intervention is a cache-coherency optimization that improves performance for dual-processor systems. If one processor modifies some data, that data first gets stored only in that processor's cache. If the other processor then wants that data, it needs to get the new modified values.

Main Memory Bus

The Power Mac G5 computer main memory bus connects the main memory to the U3 IC via the 64-bit data bus. The DDR SDRAM DIMM specifications for the standard configurations are shown in Table 2-1 (page 20).

Table 2-1   Memory Bus Standard Specifications

DDR memory bus speed	333 MHz	400 MHz
DIMM size	128 MB	256 MB
max total mem	4 GB	8 GB
number of DIMM slots	4	8
DIMM spec	PC2700	PC3200

Standard supported DIMM sizes are 128, 256, and 512 MB, and capable of 1 GB. The DIMMs must be unbuffered and installed in pairs of the same size.

For more information about memory DIMMs and installation, see "RAM Expansion" (page 49).

Accelerated Graphics Port Bus

The accelerated graphics port (AGP 8x Pro) bus is a 266/533 MHz, 32-bit bus connecting the AGP card to the U3 IC. DDR data is transmitted at both edges of the clock for peak transfers of 2.1 GBps.

The AGP bus is an enhanced PCI bus with extra functionality to burst texture data and other graphics across the port up to 8 times faster than a 66 MHz PCI port. The Power Mac G5 computer's AGP implementation is compatible with version 3 of the AGP specification and with the Pro version of AGP. AGP 3.0 enables deeply pipelined memory read and write operations and demultiplexing of address and data on the bus.

To further improve the performance of the AGP bus, the U3 IC supports a graphics address remapping table (GART). Because the virtual memory system organizes main memory as randomly distributed 4 KB pages, DMA transactions for more than 4 KB of data must perform scatter-gather operations. To avoid this necessity for AGP transactions, the GART is used by the AGP bridge in the U3 to translate a linear address space for AGP transactions into physical addresses in main memory.

For more information on the graphics cards installed in the AGP slot, refer to "Graphics Cards" (page 26).

> **Note:** The AGP bus is 1.5 V only and is not backward compatible. Older AGP cards will not work in the Power Mac G5 computer.

Internal PCI Bus

An internal 33-MHz, 64-bit PCI bus connects the K2 I/O controller to the boot ROM, the AirPort Extreme Card slot, and the USB controller. The U3 IC used in the Power Mac G5 computer supports the PCI write combining feature. This feature allows sequential write transactions involving the Memory Write or Memory Write and Invalidate commands to be combined into a single PCI transaction. For memory write transactions to be combined, they must be sequential, ascending, and non-overlapping PCI addresses. Placing an `eieio` or `sync` command between the write commands prevents any write combining.

For more information on the PCI bus, refer to "PCI or PCI-X Expansion Slots" (page 52).

PCI or PCI-X Expansion Slots

The Power Mac G5 computer provides three PCI or PCI-X slots via the HyperTransport bus. In some configurations of the Power Mac G5, one slot runs at a maximum of 133 MHz and two slots run at a maximum of 100 MHz. In other configurations of the Power Mac G5 computer, all three slots run at 33 MHz. Each slot has room for a full size 12.335-inch or short 6.926-inch card. The slots are numbered from 2 to 4 on back panel, on the PCB, and in the Apple System Profiler. To satisfy cooling power supply requirements, a total of 90 W is allocated to the three PCI or PCI-X slots and the AGP Pro slot.

The connectors to the PCI or PCI-X slots are 3.3 V keyed and support 32-bit and 64-bit buses. The connectors include a PME signal which allows a PCI card to wake the computer from sleep.

> **Note:** 5 V keyed or signalling cards do not work in the Power Mac G5 computer.

The slots (12.335 inch) have a capture feature which is at the end of the slot. If a card exceeds the short length it is recommended that the long length be used rather than an intermediate length, to assure the card stays secure if and when the system is in shipment.

The 133 MHz slot can support a maximum burst bandwidth of 1064 MBps, based on 64 bits times 133 MHz. The two 100 MHz slots can support a combined bandwidth of 800 MBps. It is recommended that the highest bandwidth card be inserted in slot 4.

For more information, refer to "PCI or PCI-X Expansion Slots" (page 52).

Wireless LAN Module

The optional AirPort Extreme wireless LAN module connects via the PCI interface.

The AirPort Extreme Card wireless LAN module contains a media access controller (MAC), a digital signal processor (DSP), and a radio-frequency (RF) section. The module has an antenna port on the rear of the computer.

The AirPort Extreme Card is based on 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 earlier 2 Mbps systems. For information about its operation, see "AirPort Extreme Card" (page 35).

The build-to-order Bluetooth connectivity comes off the K2 IC; see "Bluetooth Technology" (page 37) for more information.

Modem Slot Support

The K2 IC supports the modem and provides DB-DMA (descriptor-based direct memory access) support for the modem slot interface.

The internal hardware modem is a separate module that contains a modem controller IC, a data pump, and the interface to the telephone line (DAA). For more information about the modem, see "Internal Modem" (page 35).

Boot ROM

The boot ROM consists of 1 MB of on-board flash EEPROM. The boot ROM includes the hardware-specific code and tables needed to start up the computer using Open Firmware, to load an operating system, and to provide common hardware access services.

HyperTransport Technology

The DDR HyperTransport is an advanced chip-to-chip communications technology that provides a high-speed, high-performance, point-to-point link for integrated circuits. HyperTransport provides a universal connection that reduces the number of buses within a system.

The HyperTransport bus between the U3 IC and the PCI-X bridge is 16 bits wide, supporting total of 3.2 GBps bidirectional throughput. Between the PCI-X bridge and the K2 IC, the bus width is 8 bits, supporting total of 1.6 GBps bidirectional throughput.

For more information on the HyperTransport technology, go to the World Wide Web at

http://www.hypertransport.org

PCI USB Controller

The Power Mac G5 CPU uses a PCI USB controller ASIC with one Enhanced Host Controller Interface (EHCI) function and two Open Host Controller Interface (OHCI) functions. The controller has a total of four ports available to support the internal AGP slot and three external USB ports. If connected to classic-speed USB devices, the two rear panel ports are connected to separate OHCI controllers.

These four 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 Ports" (page 27).

K2 I/O Controller

The K2 custom IC provides all the I/O functions. These functions are described in the following sections.

DMA Support

The K2 IC provides DB-DMA (descriptor-based direct memory access) support for the following I/O channels:

■   Ultra ATA/100

■   Communication slot interface

■   I2S channel to the sound subsystem

■   Serial ATA

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.

Ethernet Controller

The K2 IC includes an Ethernet media access controller (MAC) and PHY. As a separate I/O channel on the K2 IC, it can operate at its full capacity without degrading the performance of other peripheral devices.

The MAC implements the link layer. It is connected to a PHY that is internal to K2 and provides 10Base-T/UTP, 100Base-TX, or 1000Base-TX operation over a standard twisted-pair interface. The Ethernet port is auto-sensing and self-configuring to allow use of either a cross-over or straight-through cable. The operating speed of the link is automatically negotiated by the PHY and the bridge, router, hub, switch, or other Mac or PC to which the Ethernet port is connected. For information about the port, see "Ethernet Port" (page 32).

FireWire Controllers

The K2 IC includes a FireWire controller that supports both IEEE 1394b (FireWire 800) with a maximum data rate of 800 Mbps (100 MBps) and IEEE 1394a (FireWire 400) with a maximum data rate of 400 Mbps (50 MBps). The IC is backwards-compatible with 1394a (FireWire 400). The K2 IC provides DMA (direct memory access) support for the FireWire interface.

The controller in the K2 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 ports. For more information, see "FireWire Ports" (page 28).

Interrupt Support

The interrupt controller for the Power Mac G5 system is an MPIC cell in the K2 IC. In addition to accepting K2 internal interrupt sources, the MPIC controller accepts internal interrupts from U3 and dedicated interrupt pins.

USB Interface

The K2 IC has two independent USB OHCI controllers. One is used for the optional modem module and one for the build-to-order Bluetooth interface.

The external USB interface is via the PCI USB controller; see "PCI USB Controller" (page 23).

Serial ATA Interface

Based on the Serial ATA 1.0 specification, Serial ATA (S-ATA) is a disk-interface technology that delivers up to 1.5 Gbps of performance to each independent drive bus on the Power Mac G5 computer. It provides a scalable, point-to-point connection that allows multiple ports to be aggregated into a single controller. Serial ATA uses a thin, point-to-point cable connection that enables easy routing within a system, avoiding master/slave, daisy-chaining, and termination issues and enabling better airflow within a system.

The K2 IC implements two Serial ATA revision one ports, each of which accommodates one independent internal hard drive.

For information about the drive bays, see "Hard Disk Drives" (page 33).

Ultra DMA ATA/100 Interface

In the Power Mac G5 computer, the K2 IC provides an Ultra DMA ATA/100 interface to support the optical drive. For information about specific drives, see "Disk Drives" (page 33).

Sound System Overview

The sound circuitry is connected to the K2 IC by a standard I2S (inter-IC sound) bus. The K2 IC provides DB-DMA (descriptor-based direct memory access) support for the I2S port.

The Power Mac G5 circuitry consists of two main components: an analog audio CODEC IC and a digital audio CODEC IC. The analog audio CODEC IC includes an A/D converter, a D/A converter, and digital audio processing functions. The digital audio processing functions include output equalization, dynamic range compression, and volume control. The equalization and dynamic range control functions are set to fixed values to equalize the internal speaker. Those functions are bypassed for signals sent to the audio output jacks.

The codec functions include one stereo input pair, two stereo output pairs (line out and headphone out), and one mono output that drives the internal speaker.

Stereo signals from the audio input jack are routed to an analog line input buffer that drives the internal A/D converter. The output of the A/D converter is routed to the K2 IC over the I2S bus.

Digital audio data from the K2 IC is routed to the D/A converter on the analog audio CODEC over the I2S bus. The analog audio output from the D/A is routed to separate amplifiers that drive the line output, headphone output, and internal speaker.

The digital audio CODEC IC includes an S/PDIF (Sony/Phillips Digital Interface) digital audio receiver, a sample rate converter (SRC), a phase-locked loop (PLL), and an S/PDIF digital audio transmitter.

The S/PDIF input can operate in synchronous and asynchronous modes. In synchronous mode, the PLL in the digital audio CODEC locks on to the incoming S/PDIF data rate and drives the audio system clocks in the Power Mac G5, allowing bit-accurate data processing of the S/PDIF input data. In asynchronous mode, the incoming S/PDIF data passes through the SRC, where it is converted to the output sample rate of the Power Mac G5, allowing the Power Mac G5 to play audio at a fixed output sample rate while accepting S/PDIF input data over a wide frequency range. The S/PDIF input data is routed to the K2 IC over the I2S bus.

Digital audio data from the K2 chip is routed to the S/PDIF output transmitter in the digital audio CODEC over the I2S bus. The Power Mac G5 sends and receives S/PDIF audio data over TOSLink optical connectors.

Analog audio I/O is not independent of digital audio I/O on the Power Mac G5. Audio input can come from either the line input or the S/PDIF input, but not both at the same time. Audio output can be played simultaneously on the line output, headphones output, and S/PDIF output. However, these audio streams are not independent.

For more detail on the audio, see "Audio" (page 40).

Power Controller

The power management controller in the Power Mac G5 computer is a microcontroller called the PMU99. It supports new modes of power management that provide significantly lower power consumption than previous systems. For more information, see "Power Management" (page 15).

Graphics Cards

The Power Mac G5 computer comes with a graphics card installed in the AGP 3.0 8x Pro slot. The supported graphics cards are shown below:

Graphics IC	Video SDRAM	Connectors
NVIDIA GeForce FX 5200 Ultra	64 MB DDR	ADC and DVI-I
ATI Radeon 9600 Pro	64 MB DDR	ADC and DVI-I
ATI Radeon 9800 Pro (build-to-order)	128 MB DDR	ADC and DVI-I

All graphics cards support dual displays in either extended desktop or video mirroring mode, and support digital resolutions up to 1920x1200 pixels and analog resolutions up to 1600x1200 pixels.

The display memory on the AGP card is separate from the main memory. The display memory consists of 64 or 128 MB of DDR devices configured to make a 128-bit data bus. The display memory cannot be expanded by the user.

For more information about the features of the graphics cards and the monitors they support, see "Video Monitor Ports" (page 44).

Fan Controller

The Power Mac G5 system employs advanced thermal management to keep acoustic noise to a minimum. The system is divided into discrete zones, each with independently controlled fans bringing in cool air from the front of the enclosure, directing it through ducts and exhausting it out the rear. Temperature and power consumption are monitored by the operating system which communicates with the Fan Control Unit, which in turn controls and monitors fan operation. Note that if Mac OS X is not booted, thermal management must be provided by the alternate development operating system.

Input and Output Devices

This chapter describes the Power Mac G5 computer's built-in I/O devices and the ports for connecting external I/O devices. Each of the following sections describes an I/O port or device.

USB Ports

The Power Mac G5 computer has two external Universal Serial Bus (USB) 2.0 ports on the back and one on the front of the enclosure and an internal connection to the AGP slot for the Apple display. The external USB ports are off of the USB controller connected to the PCI bus, bridged by K2. In addition, there are two USB 1.1 ports on the keyboard. The USB ports are used for connecting the keyboard and mouse as well as additional I/O devices such as printers, scanners, and storage devices.

All USB ports are fully compliant with the USB 2.0 specification, including support for high-speed (480 Mbps) devices using an Enhanced Host Controller Interface (EHCI). Ports are automatically routed to a companion OHCI controller when a classic-speed (full-speed or low-speed) USB device is attached to a root hub port.
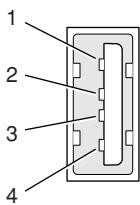
Each USB rear port is connected to a separate USB root hub in classic speeds, allowing the USB ports to support 12 Mbps devices at the same time with no degradation of their performance. The USB root hubs are also connected to the internal USB modem and to the USB port on the ADC monitor connector.

The three external USB ports and the port supporting the Apple display comply with the Universal Serial Bus Specification 2.0. The two ports on the keyboard comply with the Universal Serial Bus Specification 1.1 Final Draft Revision. For low-speed and full-speed devices, the USB register set complies with the Open Host Controller Interface (OHCI) specification. For high-speed devices, the USB register set complies with the Enhanced Host Controller Interface (EHCI) specification.

For more information about USB on Macintosh computers, please refer to Apple Computer's *Accessing Hardware from Applications* and the other sources listed in "USB Interface" (page 58).

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 28) shows the connector and Table 3-1 (page 28) shows the signals and pin assignments.

Figure 3-1   USB connector

Table 3-1   Signals on the USB connector

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

The Power Mac G5 computer provides 5 V power for the USB ports and up to 500 mA on each port. The power is provided in both run and sleep mode. The ports share the same power supply; a short circuit on one disables all ports until the short has been removed.

The USB ports support all USB 2.0 speeds: high-speed (480 Mbps) and classic USB speeds of full-speed (12 Mbps) and low-speed (1.5 Mbps). High-speed operation requires the use of shielded cables.

The Macintosh system software supports all four data transfer types defined in the USB specification, as well as split transactions for classic-speed devices attached to high-speed hubs.

Waking Up From Sleep

As defined in the USB-suspend mode of the USB specification, USB devices can provide a remote wakeup function for the computer (resume signalling). The USB root hub in the computer is set to support remote wakeup whenever a device is attached to the bus. The device wakes the computer by sending a RESUME event to the USB root hub. The mouse and keyboard that come with the computer use this method to wake the computer on a key press or mouse click.

FireWire Ports

The Power Mac G5 computer has one FireWire 800 port based on IEEE 1394b and two FireWire 400 IEEE 1394a ports. Each FireWire port

- supports booting the system from a mass storage device

- supports target disk mode

- provides bus repeating capability as long as the computer is connected to AC power

■   provides power for FireWire devices both in run and sleep mode (useful for charging the iPod)

The three FireWire ports share a single power supply that can provide up to 15 watts total. The three ports are all on the same FireWire bus and can connect to up 62 other FireWire devices.

The FireWire hardware and software provided with the Power Mac G5 computer are capable of all asynchronous and isochronous transfers defined by IEEE standards 1394a and 1394b.

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

> **Note:**   FireWire cables are not included with this product and must be purchased independently, if required.

For more information about FireWire on Macintosh computers, please refer to the Apple FireWire website and the other sources listed in "FireWire Interface" (page 58).

FireWire 800 Connector

The FireWire 800 port on the Power Mac G5 computer 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 1394a (FireWire 400) devices with 6-pin or 4-pin connectors. With the appropriate cable, the 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 in the package.

The 9-pin FireWire 800 connector is shown in Figure 3-2 (page 29). Its connector signals and pin assignments are shown in Table 3-2 (page 29).

Figure 3-2   9-pin FireWire 800 connector
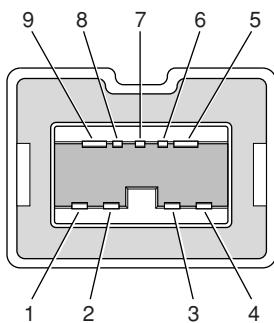
Table 3-2   Signals on the 9-pin FireWire 800 connector

Pin	Signal name	Description
1	TPB–	Twisted-pair B Minus

Pin	Signal name	Description
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 25 V DC)
9	TPB (R)	Twisted-pair B Ground Reference

VP (pin 8) provides up to 15 W power, shared with the other FireWire connectors. The voltage on the power pin is approximately 25 V.

The 9-pin FireWire port is capable of operating at 100, 200, 400, and 800 Mbps, depending on the device it is connected to. 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 Power Mac G5 computer 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 400 Connector

The FireWire 400 ports 1 and 2 use the six-pin connectors shown in Figure 3-3 (page 30). The connector signals and pin assignments are shown in Table 3-3 (page 31).

Figure 3-3   6-pin FireWire 400 connector
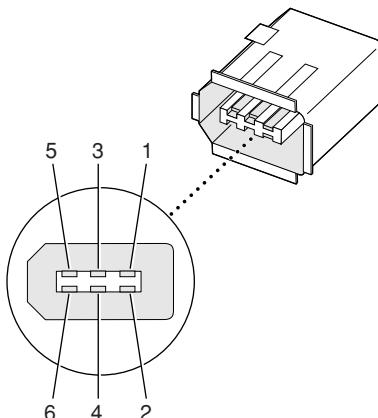
Table 3-3   Signals on the 6-pin FireWire 400 connector

Pin	Signal name	Description
1	Power	Power (approximately 25 V DC)
2	Ground	Ground return for power and inner cable shield
3	TPB–	Twisted-pair B Minus
4	TPB+	Twisted-pair B Plus
5	TPA–	Twisted-pair A Minus
6	TPA+	Twisted-pair A Plus
Shell	—	Outer cable shield

The power pin provides up to 15 W total power, shared with the other FireWire connectors. The voltage on the power pin is approximately 25 V.

Pin 2 of the 6-pin FireWire connector is ground return for both power and the inner cable shield. In a FireWire cable with a 4-pin connector on the other end, the wire from pin 2 is connected to the shell of the 4-pin connector.

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.

Booting from a FireWire Device

The Power Mac G5 computer can boot from a FireWire storage device that implements SBP-2 (Serial Bus Protocol) with the RBC (reduced block commands) command set.

For additional information about the FireWire interface and the Apple API for FireWire device control, see the references shown in "FireWire Interface" (page 58).

Target Disk Mode

The user has the option at boot time to put the computer into a mode of operation called Target Disk Mode (TDM). When the Power Mac G5 computer is in Target Disk Mode and connected to another Macintosh computer by a FireWire cable, the Power Mac G5 computer operates like a FireWire mass storage device with the SBP-2 (Serial Bus Protocol) standard. Target Disk Mode has two primary uses:

- high-speed data transfer between computers

- diagnosis and repair of a corrupted internal hard drive

The Power Mac G5 computer can operate in Target Disk Mode as long as the other computer has a 1394a or 1394b FireWire port and either any version of Mac OS X or Mac OS 9 with FireWire software version 2.3.3 or later.

To put the Power Mac G5 computer into Target Disk Mode, restart the computer and hold down the T key until the FireWire icon appears on the display. Then connect a FireWire cable from the Power Mac G5 to the other computer. When the other computer completes the FireWire connection, a hard disk icon appears on its desktop.

If you disconnect the FireWire cable or turn off the Power Mac G5 computer while in Target Disk Mode, an alert appears on the other computer.

To take the Power Mac G5 out of Target Disk Mode, drag the hard disk icon on the other computer to the trash, then press the power button on the Power Mac G5 computer until the computer powers down.

Ethernet Port

The Power Mac G5 computer has a built-in Ethernet port that supports 10/100/1000 Mbps transfer rates. In operation, the actual speed of the link is auto-negotiated between the Ethernet PHY device that is internal to the K2 IC and the bridge, router, hub, switch, or other Mac or PC to which it is connected. The Ethernet port is auto-sensing and self-configuring to allow connection via either a cross-over or straight-through cable.

Both CAT 5 unshielded twisted pair (UTP) and shielded twisted pair (STP) cables work with the Ethernet port. An STP cable is recommended for noisy environments or run of greater than 100 meters.

> **Note:** When connecting a Power Mac G5 computer directly to another computer without using an Ethernet hub, a crossover cable is not required; circuits in the PHY detect the type of connection and switch the signal configuration as required.

The connector for the Ethernet port is an RJ-45 connector on the back of the computer. Table 3-4 (page 32) shows the signals and pin assignments for 10Base-T/UTP and 100Base-TX operation. Table 3-5 (page 33) shows the signals and pin assignments for 1000Base-TX operation.

Table 3-4   Signals for 10Base-T/UTP and 100Base-TX 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
8	–	Not used

Table 3-5   Signals for 1000Base-TX Gigabit 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-TX operation, you must use 4-pair cable (Category 5 or 6).

The Ethernet interface in the Power Mac G5 computer conforms to the ISO/IEC 802.3 specification, where applicable, and complies with IEEE specifications 802.3i (10Base-T/UTP), 802.3u-1995 (100Base-TX), and 802.3ab (1000Base-TX).

Disk Drives

The Power Mac G5 computer has one 5.25 inch bay for optical drive access through the front panel and two 3.5 inch bays for internal hard disk drives. The optical drive is connected to the Ultra ATA/100 bus; the factory installed drive runs at 33 MHz. The standard configuration of the Power Mac G5 provides a SuperDrive, however a build-to-order Combo drive can be selected as a configure-to-order option.

Hard Disk Drives

The enclosure has two drive carriers with two 3.5 inch bays for fixed-media mass storage devices. The drive carrier has data and power connectors for the boot drive. The two drives on the independent Serial ATA buses implement revision one ports. For references to S-ATA website information, refer to .

SCSI Drive

SCSI drives and SCSI PCI controller cards are available from third party providers. The Power Mac G5 computer supports external SCSI drives only.

SuperDrive

The Power Mac G5 computer has a tray-loading SuperDrive (combination DVD-R and CD-RW drive). The SuperDrive can read and write DVD media and CD media, as shown in Table 3-6 (page 34). The DVD-R/CD-RW drive also provides DVD-Video playback. (The G5 microprocessor provides the MPEG 2 decoding.)

Table 3-6   Media read and written by the SuperDrive

Media type	Reading speed (maximum)	Writing speed
DVD-R	8x (CLV)	4x/2x/1x (CLV) depending on media type
DVD-ROM	8x (CAV max)	_
CD-R	32x (CAV max)	16x (CLV)
CD-RW	32 (CAV max)	10x (CLV) high speed CD-RW disc
CD or CD-ROM	32x (CAV max)	–

The Apple SuperDrive writes to DVD-R 4.7 gigabyte General Use media. These discs are playable in most standard DVD players and computer DVD-ROM drives. For a list of players tested by Apple for playability, refer to

http://www.apple.com/dvd/compatibility/

For compatibility information regarding recordable DVD formats, refer to

http://dvddemystified.com/dvdfaq.html#4.3

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

Combo Drive

As a build-to-order option, the Power Mac G5 computer can have a tray-loading combination DVD-ROM and CD-RW drive.

The Combo drive can read DVD media and read and write CD media, as shown in Table 3-7 (page 34). The DVD-ROM/CD-RW drive also provides DVD-Video playback. (The G5 microprocessor provides the MPEG 2 decoding.)

Table 3-7   Media read and written by the Combo drive

Media type	Reading speed	Writing speed
DVD-R	4.8x (CAV max)	–
DVD-ROM	12x DVD5 (CAV max) 8x DVD9 (CAV max)	–
CD-R	32x (CAV max)	32x (ZCLV)

Media type	Reading speed	Writing speed
CD-RW	20x (ZCAV max)	10x (CLV, for high speed media)
CD or CD-ROM	32x (CAV max)	–

Digital audio signals from the Combo drive can be played through the sound outputs under the control of the Sound Manager.

Internal Modem

The Power Mac G5 computer has an internal modem module. The external I/O connector for the modem is an RJ-11 connector installed on the rear panel of the computer. The modem has the following features:

- modem bit rates up to 56 Kbps, supporting V.90 and V.92 modem standards
- fax modem bit rates up to 14.4 Kbps

The modem appears to the system as a USB device that responds to standard AT commands. The modem provides a sound output for monitoring the progress of the modem connection.

AirPort Extreme Card

The Power Mac G5 computer supports the optional AirPort Extreme Card, an internal wireless LAN module. The AirPort Extreme Card is available as a build-to-order option or as a user-installable upgrade through the Apple Store.

By communicating wirelessly with a base station, the AirPort Extreme Card 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, and a standard telephone line using the built-in 56 Kbps modem that is available on some base stations.

When the AirPort Extreme option is included in the factory order, an external AirPort Extreme antenna is provided in the accessory kit and must be installed on the AirPort Extreme antenna port on the rear of the enclosure.

Complying with the IEEE 802.11g standard, AirPort Extreme transmits and receives data at rates up to 54 Mbps. Airport Extreme is also compatible with other devices that follow the IEEE 802.11b standard, including PC's. For more information about Wi-Fi and compatibility, see the reference at "Wireless Networks" (page 58).

> **Note:** As is the case with the existing IEEE 802.11b standard, actual data throughput will be lower than the indicated maximum connection speeds.

Data Security

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

- The system uses direct-sequence spread-spectrum (DSSS) technology that uses a multibit 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 or MAC addresses (Ethernet or AirPort IDs) to verify each client's identity before granting access to the network.

- When communicating with a base station, AirPort Extreme uses up to 128-bit encryption to encode data while it is in transit.

- The AirPort Extreme Base Station can be configured to use NAT (Network Address Translation), protecting data from would-be Internet hackers.

- The AirPort Extreme Base Station can authenticate users by their unique MAC addresses (AirPort IDs), preventing unauthorized computers from logging into a network. Network administrators can take advantage of RADIUS compatibility, used for authenticating users over a remote server.

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

AirPort Extreme Hardware

The AirPort Extreme Card is a 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.

The AirPort Extreme wireless interface is on the PCI bus.

AirPort Extreme Software

Software that is provided with the AirPort Extreme Card includes

- AirPort Setup Assistant (located in the Applications/Utilities folder), is an easy-to-use program that guides the user through the steps necessary to set up the AirPort Extreme Card 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 - Menu-Extra pulldown, which is enabled by a checkbox in System Preferences.

- AirPort Admin Utility (located in the Applications/Utilities folder), is 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

Available as a fully-integrated, build-to-order option, Bluetooth is an 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

Bluetooth is available as a build-to-order option, which is installed by Apple at the time of purchase as a fully integrated module. Accessing the Bluetooth capabilities without purchasing the integrated module will require a third-party dongle.

When the Bluetooth option is included on the factory order, the Bluetooth antenna is provided in the accessory kit and must be installed on the Bluetooth antenna port on the rear of the enclosure.

For more information on Bluetooth technology, refer to "Bluetooth" (page 59).

Keyboard

The Power Mac G5 computer comes with an Apple Keyboard. It is a full-size keyboard with function keys and separate numeric keypad and editing sections.

The keyboard has an attached 1-meter cable and comes with a 1-meter extender cable for installations where the computer is located on the floor or away from the immediate desktop area.

Keyboard Features

Here is a list of the features of the Apple Keyboard.

- sloped design
- 109 keys (on the ANSI versions)
- 16 function keys
- 6 editing keys (Page Up, Page Down, Home, End, Forward Delete, and Help)
- USB HID Consumer Page Usage multimedia control keys
- full travel, standard pitch keys on alphanumeric, editing, and keypad sections, including function keys and cursor-position keys
- localized worldwide: 33 versions, standard layouts (including: ANSI, JIS, ISO)

- LED indicator on the Num Lock key
- USB hub functionality with two USB 1.1 sockets

Note: There is no power key on this keyboard.
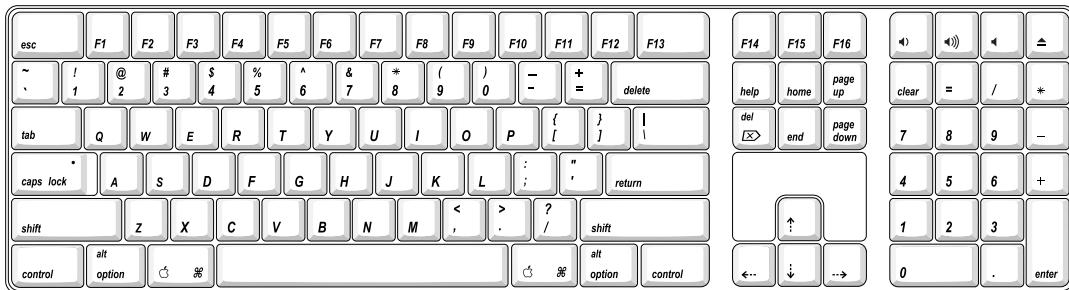
Keyboard Layout

There are localized versions of the Apple Keyboard for use in different parts of the world. The three standards used are ANSI (US and North America), JIS (Japan), and ISO (Europe).

Applications can determine which keyboard is connected by calling the Gestalt Manager and checking for the corresponding value of the `gestaltKeyboardType` selector.

Figure 3-4 (page 38) shows the keyboard layout for the ANSI keyboard.

Figure 3-4   ANSI keyboard layout

MultiMedia Control Keys

The keyboard has six multimedia keys: Volume Up, Volume Down, Mute, Brightness Up (F15), Brightness Down (F14), and Eject. Theses keys provide direct control of the features on the computer by way of the USB.

Keyboard and USB

The Apple Keyboard is designed to work with the computer by way of the USB ports. The keyboard has a captive cable with a USB Type A connector. The keyboard is a bus-powered USB hub with two USB Type A ports.

⚠ **Warning:** A bus-powered hub as defined in the USB specification does not provide enough power to support a second bus-powered hub. A second bus-powered hub must be connected to a USB port on the computer or other self-powered hub, not to a port on the keyboard.

Apple provides a HID class driver for the Apple Keyboard, which supports the USB boot protocol. Other keyboards intended for use on the Macintosh platform must support the HID boot protocol, as defined in the USB Device Class Definition for Human Interface Devices (HIDs).

Programmer's Switches

Key combinations for programmer's switches that used the Power button on earlier models now use the Eject key. Here are the key combinations for the Power Mac G5 computer.

- Control-Command-Eject: restart immediately (reset)

- Control-Command-Option-Eject: shut down immediately

- Control-Eject: display the dialog for shutdown, restart, and sleep

The key combinations are decoded in software and may not be available under some crashed conditions.

NMI without Programmer's Switch

Current Macintosh computers do not have a programmer's switch, which allowed users to generate a non-maskable interrupt (NMI). The paragraphs below describe how to generate an NMI from a remote session for systems that do not have a physical programmer's switch.

Starting with Mac OS X 10.1.2, the OS will promote and recognize the `DB_NMI` bit in the "boot-args" property of the "chosen" node from Open Firmware. When the `DB_NMI` bit is set, the user can generate a non-maskable interrupt (NMI) by pressing the system's power button. This replaces the power button's sleep or wake response. The system reads the state of the bit at boot time from the `boot-args` configuration variable. For more information about the debug flags, please see *Inside Mac OS X: Kernel Programming*.

To set the `DB_NMI` bit, enter the following command at the Terminal to display the current debug flag settings.

```
% nvram boot-args
```

Add the parameter `debug=0x4`, as follows.

```
% sudo nvram boot-args="<current settings> debug=0x4"
```

After rebooting, press the power button for approximately 3 seconds to generate an NMI.

> **Note:** If the power button is pressed for more than five seconds, the system will immediately power off.

The power button will retain this functionality until Mac OS X is restarted without the `DB_NMI` bit set. To clear this bit, issue the `nvram` command omitting `debug=0x4` parameter, as follows.

```
% sudo nvram boot-args=""
```

> **Note:** The debug flags bit will be cleared if you use System Preferences to change the startup disk. It may also be cleared if you perform an installation that requires a restart.

Mouse

The Power Mac G5 computer comes with an Apple Mouse. The mouse case is made of polycarbonate plastic.

The Apple Mouse uses optical tracking in place of the traditional rolling ball. It works on almost any surface, though nonreflective, opaque surfaces without repetitive patterns work best.

Audio

The Power Mac G5 computer supports a sound system with both digital and analog audio. The new digital capability features Sony/Phillips Digital Interface (S/PDIF) input and output using optical connectors. S/PDIF technology results in a clean audio signal with no added noise to or from an external audio device.

Under the control of the system software, the sound circuitry digitally creates and records sounds. The Power Mac G5 computer can receive input only from either the analog input or the digital input. However, it can output simultaneously to digital and analog devices: the internal speaker, the headphone jack, the audio output jack, and the S/PDIF output connector.

By default, when components are plugged into the headphone jack or the rear line-out, the sound system mutes the internal speaker.

The headphones, rear line-out jack, and S/PDIF output are only muted when selected in the System Preferences. Muting and sound options are set in System Preferences:Sound:Output. Selecting the "Allow Line Out and Digital when headphones are attached" checkbox allows operation of the analog and digital output ports when headphones are attached, enabling monitoring of the optical digital transport.

The analog and digital sound circuitries are not independent. Different audio streams cannot be played to the analog and digital circuitry. The selection of digital or analog output is performed through Sound pane in System Preferences.

The sound circuitry and audio device drivers handle audio data in multiple formats. Both digital and analog sound circuitry handle audio input and output data at sample rates of 32.0 kHz, 44.1 kHz, and 48.0 kHz at sample depths of 16 bits and 24 bits.
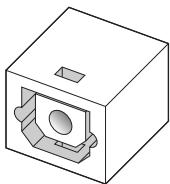
If audio data sampled from another computer at a lower rate is played as output on the Power Mac G5, the Core Audio (Mac OS X's OS Level Audio API) transparently up-samples the data to the currently set sampling frequency prior to sending the audio data to the sound circuitry. To maximize audio fidelity, the Core Audio samples are stored as 32-bit floating point. The Sound Manager exists as a Carbon compatibility layer, but developers are encouraged to move their applications to Core Audio for maximum performance and fidelity, because the Sound Manager is capable of representing samples only as 16-bit values.

For more information about audio API's on Mac OS X, visit the Apple audio technologies developer web page at

http://developer.apple.com/audio/

Optical S/PDIF Audio

Digital data is transmitted to and from the digital audio I/O using optical cables. The physical connectors, commonly referred to as TOSLink, are for both input and output and conform to IEC60874-17. The TOSLink friction-lock type F-05 connectors are available from pro-audio, musician's supply, hi-fi and other retailers. The 7.5 mm digital optical TOSLink input and output connectors, shown in Figure 3-5 (page 41), are located on the back of the enclosure.

Figure 3-5   Digital optical S/PDIF connector

The digital I/O circuitry can either perform input clock recovery on an incoming data stream or can sample using the internal clock. If samples are clocked using the internal clock, the data is run through the sample-rate converter on the digital circuitry. To enable bit-accurate copies, the external clock should be enabled in Audio MIDI Setup. Developers of applications that need this capability will need to provide access to the input clock recovery control.

Audio signals from the audio input jack are converted to digital data internally. All audio is handled digitally inside the computer, including audio data from the CD or DVD drive and from devices connected to the USB and FireWire ports. Audio data is converted to analog form for output to the internal speaker, the headphones, line output jacks, or external speakers.

For details on the S/PDIF digital input and output electrical specifications, refer to "Digital Optical Input/Output Specifications" (page 41).

The Power Mac G5 computer also has the ability to lock its internal audio hardware to the incoming audio stream to synchronize the audio subsystem to an external device supplying the audio stream. This function allows audio and video to play in sync with the external audio or video device. The data format for signals transmitted over the optical cable is S/PDIF protocol IEC 60958-3.

The Power Mac G5 computer's audio subsystem has built-in sample-rate conversion (SRC) that allows the incoming audio to have a different rate than the playback audio, enabling the audio to come in the digital-in connector. For the best digital input quality in its purest form, set the audio clocking preference to "External Clock."

External Clocking

When the Power Mac G5 computer is set to "External" clocking, the computer audio circuitry will track and follow the incoming digital sampling rate and lock the internal audio hardware to the sampling rate of the external device. The external clock must be stable enough to be locked onto, otherwise the digital circuit will signal an error and the driver will fall back to using the internal clock.

Internal Clocking

When the Power Mac G5 computer is set for "Internal" clocking, the computer audio circuitry will run using the computer's internal clock. Incoming digital audio is automatically sample-rate converted to the selected output sample rate using the sample rate converter in the audio chip. The sample rate converter is high quality and does not use CPU bandwidth for audio conversion.

Digital Optical Input/Output Specifications

Based on playback of a 1 kHz, -1dBFS 24-bit sine wave playback, 24-bit 44.1 kHz output sample rate (unless otherwise specified below) the digital sound input and output have the following electrical characteristics (nominal specifications):

- Fsi – input sample rates (external clock mode): 32 kHz, 44.1 kHz or 48 kHz

- Fsi – input sample rate (internal clock mode): 16 kHz – 96 kHz

- bits per sample: 16-bit or 24-bit

- SNR (external clock mode): >130 dB

- SNR (internal clock mode, 16 kHz < Fsi < 96 kHz): < -110 dB

- THD+N (external clock mode): < -130 dB (0.00001%)

- THD+N (internal clock mode, 16 kHz < Fsi < 96 kHz): < -110 dB (0.0003%)

Analog Audio Line-in

The Power Mac G5 has a stereo audio line-in jack on the back panel. The audio inputs are designed to accept high-level audio signals: 2.2 Vrms or +8 dbu, which is the standard output level from CD and DVD players. The output level of some consumer audio devices is lower, often 0.316 Vrms or −10 dbV. Sound recordings made on the Power Mac G5 with such low-level devices have more noise than those made with high-level devices. The user may obtain better results by connecting an amplifier between the low-level device and the computer's audio input jack.

The audio input jack is a 3.5 mm miniature phone jack with the signals connected as follows:

Tip	Left-channel audio
Ring	Right-channel audio
Sleeve	Audio ground

Based on a 1 kHz, 2VRMS sine wave input, 24-bit 44.1 kHz input format, 0 db input gain and no weighting, the line input has the following electrical characteristics :

- maximum input voltage: 2.2 Vrms (+8 dBu)

- input impedance: > 47 kilohms

- bits per sample: 16-bit or 24-bit

- channel separation: greater than 75 dB

- frequency response: 20 Hz to 20 kHz, +0.5 dB/−3.0 dB

- THD+N distortion: below < −85 dB (no weighting)

Analog Audio Line-out

The Power Mac G5 has a stereo output jack on the back of the enclosure. The audio output jack is suitable for connecting amplified external speakers.

The audio output jack is a 3.5 mm miniature phone jack with the signals connected as follows:

Tip	Left-channel audio

Ring	Right-channel audio
Sleeve	Audio ground

> **Note:** For best results, line-out devices should be plugged into the line-out jack. Headphone impedance is 32 ohms and line-out impedance is 1 kilohm.

Based on a 1 kHz, -1 dBFS sine wave playback, 24-bit 44.1 kHz output format, -1 db output level and 100 kilohm load no weighting, the line output has the following electrical characteristics (nominal specifications):

- output voltage: 1.4 Vrms (+4 dBu)
- source impedance: less than 24 ohms
- bits per sample: 16-bit or 24-bit
- channel separation: > 65 dB
- THD+N distortion: < −80 dB (0.01%) no weighting
- frequency response: 20 Hz to 20 kHz, +0.5 dB/−3.0 dB

Analog Headphone Jack

The Power Mac G5 has a stereo headphone jack on the front of the enclosure. The headphone jack is suitable for connecting a pair of headphones or amplified external speakers. When a plug is inserted into the headphone jack, the internal speaker is muted.

The headphone jack is a 3.5 mm miniature phone jack with the signals connected as follows:

Tip	Left-channel audio
Ring	Right-channel audio
Sleeve	Audio ground

> **Note:** The rear line-out is not designed to power headphones. Headphone impedance is 32 ohms and line-out impedance is 1 kilohm.

Based on a 1 kHz sine wave playback, 24-bit 44.1 kHz output format, -1 dB output level and 100 kilohm load no weighting, (unless otherwise specified) the headphone output has the following electrical characteristics (nominal specifications):

- output voltage: 1.4 Vrms, (+4 dBu)
- output impedance: 24 ohms
- bits per sample: 16-bit or 24-bit
- channel separation: > 65 dB
- frequency response: 20 Hz to 20 kHz, +0.5 dB/−3.0 dB

- THD+N distortion: < −80 dB (0.01%)

- output power (into 32 ohms): 20 mW

Video Monitor Ports

Depending on the configuration, the Power Mac G5 computer comes with either an ATI or an NVIDIA graphics card installed. The main features of the graphics cards are as follows:

Graphics IC	Video SDRAM	Connectors
NVIDIA GeForce FX 5200 Ultra	64 MB DDR	ADC and DVI-I
ATI Radeon 9600 Pro	64 MB DDR	ADC and DVI-I

The ATI Radeon 9800 Pro with 128 MB DDR, ADC/DVI-I graphics card is available as a build-to-order option.

All of the graphics cards support dual displays in either extended desktop or video mirroring mode; for more detail, see "Dual Display Extended and Mirror Modes" (page 48).

The following sections describe the video connectors on the graphics cards.

Apple Display Connector

The graphics cards have an Apple proprietary connector called the ADC (Apple display connector). The connector carries both digital and analog video signals as well as USB and control signals and power for an external monitor. Figure 3-6 (page 44) shows the contact configuration; Table 3-8 (page 44) and Table 3-9 (page 45) list the signals and pin assignments.

The maximum current available from the 25 V supply for the external monitor is 3.6 A.

Figure 3-6   Apple display connector
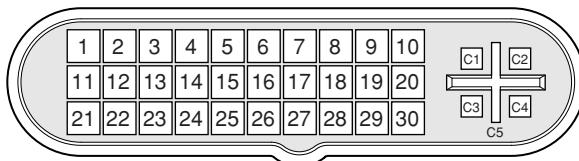
Table 3-8   Digital signals on the Apple display connector

Pin	Signal name	Pin	Signal name
1	25 V Supply	16	TMDS Data1/3 Shield
2	25 V Supply	17	TMDS Data3−
3	LED	18	TMDS Data3+

Pin	Signal name	Pin	Signal name
4	TMDS Data0−	19	DDC CLock
5	TMDS Data0+	20	Clock Return
6	TMDS Data0/5 Shield	21	USB Data+
7	TMDS Data5−	22	USB Data−
8	TMDS Data5+	23	USB Return
9	DDC Data	24	TMDS Data2−
10	Vsync	25	TMDS Data2+
11	25 V Return	26	TMDS Data2/4 Shield
12	25 V Return	27	TMDS Data4−
13	Soft Power	28	TMDS Data4+
14	TMDS Data1−	29	Clock+
15	TMDS Data1+	30	Clock−

Table 3-9   Analog signals on the Apple display connector

Pin	Signal name
C1	Analog Blue Video
C2	Analog Green Video
C3	Analog Horizontal Sync
C4	Analog Red Video
C5	Analog RGB Return and DDC 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 58).

DVI Connector

In addition to the ADC connector, supported graphics cards also have a DVI-I (DVI with analog) connector. With a DVI to ADC adapter, available separately and shown in Figure 3-7 (page 46), the DVI port on the Power Mac G5 computer can also support any Apple flat panel display.
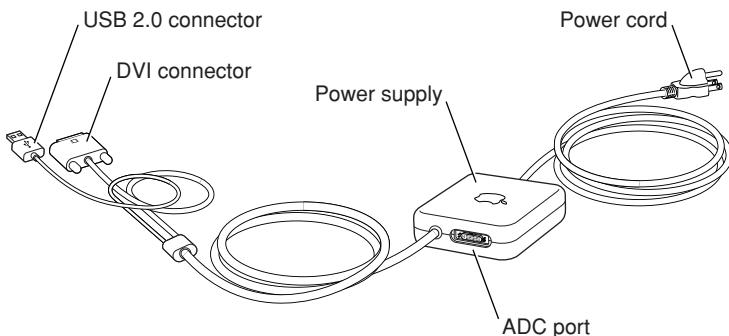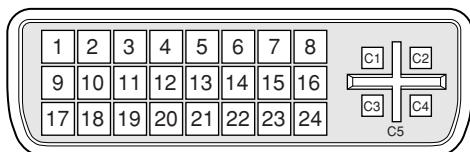
Figure 3-7   DVI to ADC adapter

Figure 3-8 (page 46) shows the contact configuration for the DVI-I connector; Table 3-10 (page 46) lists the signals and pin assignments.

Figure 3-8   DVI-I connector

Table 3-10   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–
C1	Analog red	C4	Analog horizontal sync

Pin	Signal name	Pin	Signal name
C2	Analog green	C5	Analog ground (analog R, G, B return)
C3	Analog blue		

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 information about TMDS, see the reference listed in "Digital Visual Interface" (page 58).

> **Note:** The Power Mac G5 computer includes a DVI-I to VGA adapter.

DVI to Video Adapter

The Power Mac G5 computer supports an optional DVI to S-video/composite adapter that provides S-video and composite output to a PAL or NTSC video monitor or VCR. When a display is connected by way of the video adapter, the computer detects the type of adapter and enables the composite and S-video outputs. The settings for the resolutions and standards (NTSC or PAL) are then selectable in the System Preferences Displays pane.

> **Note:** The DVI-I to video adapter does not come packaged with the Power Mac G5 computer and must be purchased separately.

The video output connector is a 7-pin S-video connector. Figure 3-9 (page 47) shows the arrangement of the pins and Table 3-11 (page 47) shows the pin assignments on the composite out and S-video connector.

Figure 3-9   S-video connector
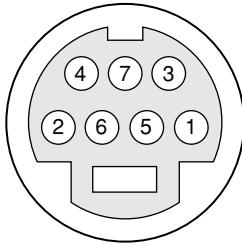
Table 3-11   Pin assignments for the S-video output connector

Pin number	S-video output connector
1	Analog GND
2	Analog GND

Pin number	S-video output connector
3	Video Y (luminance)
4	Video C (chroma)
5	composite video
6	Unused
7	Unused

The Power Mac G5 computer provides video output at picture sizes and frame rates compatible with the NTSC and PAL standards; the picture sizes are listed in Table 3-12 (page 48). Those picture sizes produce under-scanned displays on standard monitors.

Table 3-12   Picture sizes for S-video output

Picture size	Pixel depth
800 by 600	24 bpp
832 by 624	24 bpp
1024 by 768	24 bpp

Dual Display Extended and Mirror Modes

The Power Mac G5 is equipped with an ADC port for connecting an Apple display and a DVI-I port for a second digital display. Through these two ports, the Power Mac G5 supports dual displays in both extended desktop and video mirroring modes. Extended desktop mode lets users distribute work across two displays, increasing the amount of visible desktop space. Video mirroring mode displays the same information on both monitors, enabling the control of a presentation on one display, while allowing an audience to watch the presentation on a second display or projector. The Power Mac G5 can power two Apple Cinema HD Displays at a cumulative pixel resolution of 3840x1200.

To switch between extended desktop and video mirroring modes, enable the "Mirror Displays" option on the Arrangement tab in the Displays pane of System Preferences.

The scaling function is available when both monitors (main via ADC and second via DVI-I) are operating and the mirror mode is selected. Either monitor 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 resolutions match. 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.

Expansion
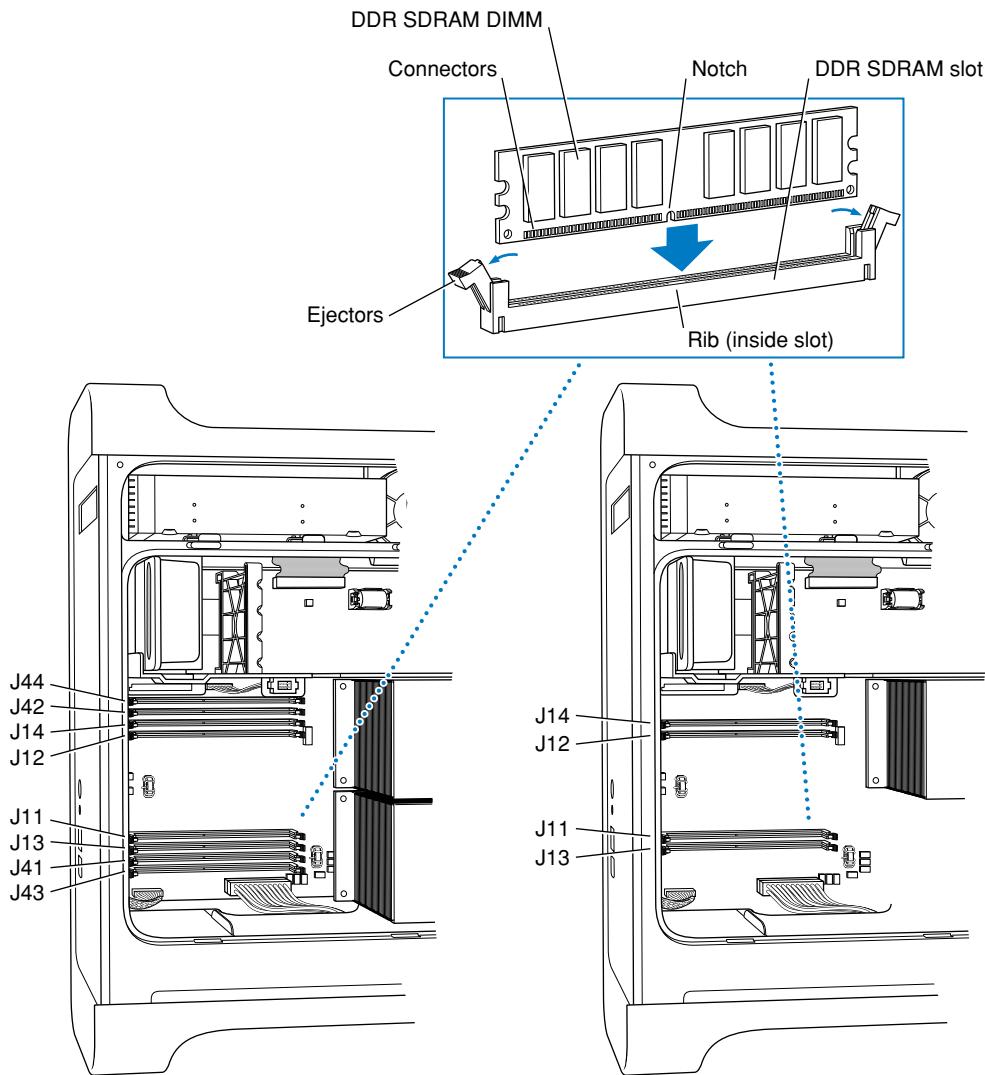
This chapter describes the expansion features of the Power Mac G5 computer: the DDR SDRAM expansion slots and the PCI or PCI-X expansion slots.

RAM Expansion

The main logic board of some configurations of the Power Mac G5 computer has four pairs of DDR SDRAM expansion slots for unbuffered DDR400 (PC3200) dual in-line memory modules (DIMMs) for a maximum memory of 8 GB. The main logic board of other configurations of the Power Mac G5 computer has 2 pairs of DDR SDRAM expansion slots for unbuffered DDR333 (PC2700) dual in-line memory modules (DIMMs) for a maximum memory of 4 GB.

Each DIMM can contain 256 and 512 MB (also is capable of 128 MB, 1 GB, and has future expansion ability of 2 GB) of double data rate synchronous dynamic RAM (DDR SDRAM). At least one pair of the RAM expansion slots contains factory installed DIMMs.

Additional DIMMs must be installed in pairs of the same size. The slot pairs are numbered: J11 and J12, J13 and J14, J41 and J42, and J43 and J44; see for slot locations and numbering for both the 8-slot and 4-slot configurations. When installing additional memory, populate starting with the lowest slot pair numbers. The combined memory of all of the DIMMs installed is configured as a contiguous array of memory.

Figure 4-1   DIMM installation

For all microprocessor speeds and for both DDR400 (PC3200) and DDR333 (PC2700) SDRAM DIMMs, the Power Mac G5 supports CAS latencies of 2, 2.5, 3, 4, and 5.

DIMM Specifications

The RAM expansion slots accept 184-pin DDR SDRAM DIMMs that are 2.5 volt, unbuffered, 8-byte, nonparity, and DDR400-compliant (PC3200) or DDR333-compliant (PC2700).

> **Important:** DDR266 (PC2100) or slower DIMMs do not work in the Power Mac G5 computer.

> **Important:** DIMMs with any of the following features are not supported in the Power Mac G5 computer: registers or buffers, PLLs, ECC, parity, or EDO RAM.

Mechanical Specifications

The mechanical design of the DDR SDRAM DIMM is defined by the JEDEC specification JESD21-C, MODULES4_20_4, Release 11b. To find this specification on the World Wide Web, refer to "RAM Expansion Modules" (page 57).

The maximum height of DIMMs for use in the Power Mac G5 computer is 2 inches.

Electrical Specifications

The electrical design of the SDRAM DIMM is defined by the JEDEC specification JESD21-C, MODULES4_20_4, Release 11b. To find this specification on the World Wide Web, refer to "RAM Expansion Modules" (page 57).

The Serial Presence Detect (SPD) EEPROM specified in the JEDEC standard is required and must be set to properly define the DIMM configuration. The EEPROM is powered on 3.3 V. Details about the required values for each byte on the SPD EEPROM can be found on pages 68–70 of the JEDEC specification.

> **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.

DIMM Configurations

The largest DIMM supported is a two-bank DIMM of 2 GB using 512 Mbit DDR SDRAM devices. The maximum number of devices per DIMM is 16.

> **Important:** Power is delivered to the Power Mac G5 during sleep mode, so do not remove DIMMs while in sleep mode. A red light adjacent to the DIMM is illuminated when power is present.

Table 4-1 (page 52) shows information about the different sizes of DDR SDRAM devices used in the memory modules. The memory controller supports 64 Mbit, 128 Mbit, 256 Mbit, and 512 Mbit DDR SDRAM devices. The device configurations include three specifications: address range, word size, and number of banks. For example, a 1 M by 16 by 4 device addresses 1 M, stores 16 bits at a time, and has 4 banks.

The first column in Table 4-1 (page 52) shows the memory size of the largest DIMM with that device size that the computer can accommodate. The third column specifies the number of devices needed to make up the 8-byte width of the data bus. The fourth column in the table shows the size of each bank of devices, which is based on the number of internal banks in each device and the number of devices per bank.

Table 4-1   Sizes of DDR SDRAM expansion DIMMS and devices

Size of DIMM	SDRAM device size	Device configuration	Devices per bank	Size of each bank
128 MB	128 Mbits	4 M x 8 x 4	8	64 MB
128 MB	256 Mbits	2 M x 16 x 4	4	64 MB
256 MB	128 Mbits	4 M x 8 x 4	8	128 MB
256 MB	256 Mbits	4 M x 16 x 4	4	128 MB
512 MB	256 Mbits	8 M x 8 x 4	8	256 MB
1 GB	512 Mbits	16 M x 8 x 4	8	512 MB

RAM Addressing

Signals A[0–12] on each SDRAM DIMM make up a 13-bit multiplexed address bus that can support several different sizes of SDRAM devices. Table 4-2 (page 52) shows the address multiplexing modes used with the devices.

Table 4-2   Address multiplexing modes for SDRAM devices

Device size	Device configuration	Size of row address	Size of column address
128 Mbits	4 M x 8 x 4	12	10
128 Mbits	2 M x 16 x 4	12	9
256 Mbits	8 M x 8 x 4	13	10
256 Mbits	4 M x 16 x 4	13	9
512 Mbits	8 M x 8 x 4	14	10

PCI or PCI-X Expansion Slots

The Power Mac G5 provides three PCI or PCI-X slots via the HyperTransport bus. In some configurations of the Power Mac G5, one slot runs at a maximum of 133 MHz and two PCI-X slots run at a maximum of 100 MHz. Other configurations of the Power Mac G5 computer access all three PCI slots at 33 MHz. Each slot has room for a full size 12.335-inch or short 6.926-inch card.

The PCI-X configuration conforms to the PCI-X Specification 10B. The PCI configuration conforms to the PCI Specification 2.3.

The computer's case has four openings in the back for access to I/O connectors on cards in the three expansion slots and the AGP slot. The numbering on the casing is 1 through 4 and corresponds to the label on the PCB. Number one is the AGP slot and numbers two through four are the PCI or PCI-X slots.

The expansion slots accept PCI or PCI-X cards with either 32-bit or 64-bit address and data buses. The expansion slots support universal and +3.3 V cards, but not 5 V signalling. The cards are required to use the standard ISA fence described in the specification.

> **Note:** 5 V keyed or signalling cards do not work in the Power Mac G5 computer.

The expansion slots support all the required PCI signals and certain optional PCI signals. The PCI slots support the optional 64-bit bus extension signals and cache support signals.

The PCI slots and the AGP Pro 8x slot carry the 3.3 V_AUX power and PME signals to allow an expansion card to wake the computer from sleep mode.

A standard AGP 3.0 8x card consumes up to 30 W. Some of the higher powered AGP Pro style cards will consume a higher amount of that power, depending on the card specifications. These cards may also physically require the usage of one of more of the PCI or PCI-X slot spaces. In such a case, the power available for the physically available PCI or PCI-X slots is reduced to compensate for the increased AGP Pro power usage over the 30W. Hence, the AGP 3.0 8x Pro slot can account for up to 75 watts of that total, depending on which card is installed. The total power available for the AGP Pro slot and the three PCI or PCI-X slots is 90 W.

> **Important:** Before removing or installing PCI expansion cards, shut down the computer and unplug the AC power cord. The Power Mac G5 computer does not support PCI hot-plugging functionality. When the computer is powered-on or asleep, the main logic board has a red LED to warn that power is present.

To install or remove a PCI or PCI-X expansion card: turn off power to the computer, flip out the enclosure latch, open the side panel, remove the clear plastic air deflector, and remove the fan units. Remove the blank PCI fence for the appropriate slot, insert the card in the slot, and screw the card's fence into place to secure the card.

> ⚠ **Warning:** When the system power is on or the system is asleep, a red light will illuminate if the plastic air deflector is removed. Do not continue if the red light is on. Power-off the system before continuing.

For detailed instructions on accessing the expansion slots, refer to the *Apple Take Apart* document for the Power Mac G5 computer.

In order to use the new PCI or PCI-X card, a driver must be installed. The driver installation procedure is documented by the manufacturer of the PCI card.

For more information on PCI or PCI-X, visit the worldwide web at

http://www.pci-sig.org

Supplemental Reference Documents

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

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/

PowerPC G5 Microprocessor

Information about the PowerPC G5 microprocessor is available on the World Wide Web at

http://www-306.ibm.com/chips/techlib/techlib.nsf/techdocs/AE818B5D1DBB02EC87256DDE00007821

Velocity Engine

Velocity Engine is Apple's vector processor in the PowerPC G5 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 Apple website, at

http://developer.apple.com/hardwaredrivers/ve/index.html

Motorola's implementation of Apple's Velocity Engine is named AltiVec. The *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 documentation site on the World Wide Web, at

http://www.freescale.com/webapp/sps/site/overview.jsp?nodeId=02VS0l81285Nf2

3D Graphics

Developers of 3D graphics for games should know about OpenGL for Macintosh, a 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/

Mac OS X

Initially, the Power Mac G5 computer ships with Mac OS X 10.2 installed as the default operating system. The classic environment can be used to run Mac OS 9 applications 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

and

http://developer.apple.com/documentation/Carbon/Reference/Multiprocessing_Services/

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.

Open Firmware

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

TN 1061: *Open Firmware, Part I*, available on the Technote web site at

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

TN 1062: *Open Firmware, Part II*, at

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

TN 1044: *Open Firmware, Part III*, at

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

Other Technotes provide additional information about Open Firmware on the Macintosh.

TN 2000: *PCI Expansion ROMs and You*, at

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

TN 2001: *Running Files from a Hard Drive in Open Firmware*, at

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

TN 2004: *Debugging Open Firmware Using Telnet*, at

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

RAM Expansion Modules

The Power Mac G5 computer uses (DDR333) PC2700-compliant or (DDR400) PC3200-compliant, 184-pin DDR SDRAM DIMMs.

The electrical and mechanical characteristics of the DIMM are given in JEDEC Standard 21-C. The specification can be found by using the search string JESD21-C on the Electronics Industry Association's website at

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

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

The web page for Technical Note 1098 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/

Ethernet

For information on Ethernet specifications and design guides, go to the World Wide Web at

http://standards.ieee.org/

Serial ATA

For information on Serial ATA specifications and design guides, go to the World Wide Web at

http://www.serialata.org

USB Interface

For more information about USB on the Macintosh computer, 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, refer to the USB Implementation 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 1394a and 1394b standards are available from the IEEE; you can order these documents electronically from the IEEE Standards Department website at

http://shop.ieee.org/store

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

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 standard is available on the website of the Wireless Ethernet Compatibility Alliance, at

http://www.wi-fi.org

Bluetooth

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

Bluetooth specification:

http://www.bluetooth.com/

Bluetooth SIG:

http://www.bluetooth.org

Bluetooth developer tools on the Apple web site at:

http://developer.apple.com/hardwaredrivers/bluetooth/

Conventions and Abbreviations

This developer note uses the following typographical conventions and abbreviations.

Typographical Conventions

> **Note:** A note like this contains information that is of interest but is not essential for an understanding of the text.

> **Important:** A note like this contains important information that you should read before proceeding.

> ⚠ **Warning:** A note like this contains a warning about a situation that could cause a system crash or loss of data.

Abbreviations

When unusual abbreviations appear in this developer note, the corresponding terms are also spelled out. Standard units of measure and other widely used abbreviations are not spelled out.

Here are the standard units of measure used in developer notes:

A	amperes	mA	milliamperes
dB	decibels	A	microamperes
Gb	gigabits	Mb	megabits
GB	gigabytes	MB	megabytes
Hz	hertz	MHz	megahertz
in.	inches	mm	millimeters
k	1000	ms	milliseconds
K	1024	s	microseconds
KB	kilobytes	ns	nanoseconds

kg	kilograms		ohms
kHz	kilohertz	sec.	seconds
k	kilohms	V	volts
lb.	pounds	W	watts

Other abbreviations used in developer notes include these:

ADC	Apple Display Connector
AGP	accelerated graphics port
ATA	advanced technology attachment
ATAPI	advanced technology attachment, packet interface
AV	audio visual
CAS	column address strobe
CAV	constant angular velocity
CD-ROM	compact disc read-only memory
CLV	constant linear velocity
DB-DMA	descriptor-based direct memory access
DDC	display data channel
DDR	double data rate, a type of SDRAM where data is clocked on rising and falling clock edges
DIMM	dual inline memory module
DIN	Deutsche Industrie Norm
DMA	direct memory access
DRAM	dynamic random-access memory
DVD	12 cm optical storage system with 4 GB capacity
DVD-ROM	DVD read-only memory
DVD-RAM	DVD that is both readable and writable
DVI	Digital Visual Interface
EDO	extended data out DRAM device type
EHCI	Enhanced Host Controller Interface, USB 2.0 specification
EIDE	extended IDE

EMI	electromagnetic interference
G5	Generation 5, the fifth generation of PowerPC microprocessors, incorporating Velocity Engine technology
GBps	data throughput rate — giga bytes per second
Gbps	data throughput rate — giga bits per second
HID	human interface device, a class of USB devices
I2C	same as IIC
I2S	same as IIS
IC	integrated circuit
IDE	integrated device electronics
IEEE	Institute of Electrical and Electronics Engineers
IEEE 1275	the official specification for Open Firmware
IEEE 1394a	the official specification for FireWire 400 (400 Mbps)
IEEE 1394b	the official specification for FireWire 800 (800 Mbps)
IIC	inter-IC (an internal control bus)
IIS	inter-IC sound bus
I/O	input/output
ISO	International Organization for Standardization
JEDEC	Joint Electronics Devices Engineering Council
L2	level 2 (refers to level of cache)
L3	level 3 (refers to level of cache)
LAN	local area network
MAC	media access controller
Mac OS	Macintosh Operating System
MBps	data throughput rate — mega bytes per second
Mbps	data throughput rate — mega bits per second
OFDM	orthogonal frequency-division multiplexing
OHCI	Open Host Controller Interface, USB 1.1 specification
PCI	Peripheral Component Interconnect

PHY	physical layer
PIO	programmed input/output
RADIUS	Remote Authentication Dial-In User Service
RAM	random-access memory
RAS	row address strobe
RBC	reduced block commands
RGB	a video signal format with separate red, green, and blue components
RISC	reduced instruction set computing
rms	root mean square
ROM	read-only memory
S-ATA	serial ATA bus for hard disk drives
SBP	Serial Bus Protocol
SPD	Serial Presence Detect
SCSI	Small Computer System Interface
SCC	serial communications controller
SDR	single data rate
SDRAM	synchronous dynamic random access memory
SO-DIMM	small outline - dual inline memory module
SRAM	static random access memory
USB	Universal Serial Bus
TMDS	transition minimized differential signaling
VESA	Video Electronics Standards Association
VRAM	video RAM; used for display buffers
Wi-Fi	Wireless- Fidelity. Used by the Wireless Ethernet Compatibility Alliance for certification of interoperability of 802.11 products