Developer Note

Power Mac G4 Computer

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Contents

Figures and Tables

About This Note

This developer note describes the Power Mac G4 computer. The note provides information about the internal design of the computer, its input-output and expansion capabilities, and issues affecting compatibility.

Note: This developer note has been updated to include information about the latest product configurations.

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, you should refer to Appendix A, "Supplemental Reference Documents."

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 G4 computer, describes the physical appearance of the enclosure, and lists compatibility issues of interest to developers.
- Chapter 2, "Architecture" (page 19), 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 31), describes the built-in I/O devices and the external I/O ports.
- Chapter 4, "Expansion" (page 55), describes the expansion slots on the logic board and provides specifications for the expansion modules.
- Appendix A, "Supplemental Reference Documents" (page 61), provides sources of additional information about the technologies used in the Power Mac G4 computer.

About This Note

- Appendix B, "Conventions and Abbreviations" (page 69), lists standard units of measure and other abbreviations used in this developer note.

CHAPTER 1

Introduction

The Power Mac G4 computer is the Macintosh desktop computer using the PowerPC G4 microprocessor. It is intended for use in content creation, desktop publishing, multimedia, and other activities that require high performance.

New Features

Here is a list of the features that are new to the Power Mac G4 computer.

- **Microprocessor clock speed:** The clock frequency in the single-processor configurations is either 733 or 933 MHz. The dual-processor configuration has a clock speed of 1 GHz. For more information, see "PowerPC G4 Microprocessor" (page 21).
- **RAM:** The standard configurations have either 256 or 512 MB of RAM installed. For more information, see "RAM Expansion" (page 55).
- **Graphics card:** Depending on the confguration, the graphics card has either 32, 64, or 128 MB of display RAM. All the cards support two monitors. For more information, see "Graphics Card" (page 29).

Hardware Features

Here is a list of the hardware features of the Power Mac G4 computer. The major features are described more fully later in this note.

- **Microprocessor:** PowerPC G4 microprocessor running at a clock frequency of 733, 933 MHz, or 1 GHz, depending on model and configuration. For more information, see "PowerPC G4 Microprocessor" (page 21).
- **Dual processor configurations:** The Power Mac G4 computer is available in a 1-GHz dual-processor configuration. For information about software and multiprocessing, see "Dual Processors and Mac OS 9" (page 15).
- **Memory caches:** The PowerPC G4 microprocessor used in the Power Mac G4 computer has an internal 256 KB level 2 cache. The 933-MHz and 1-GHz configurations also have an external 2 MB level 3 cache. For more information, see "Cache Memory" (page 22).
- **Processor system bus:** 64-bit wide data and 32-bit wide address, 133 MHz clock, supporting MaxBus protocol. For more information, see "Processor Bus" (page 23).
- **RAM:** Three DIMM slots for 168-pin PC133 DIMMs (dual inline memory modules) using SDRAM (synchronous dynamic random access memory) or ESDRAM (enhanced SDRAM) devices. A minimum of 256 MB of RAM is installed in one of the slots. For more information, see "RAM Expansion" (page 55).
- **ROM:** ROM-in-RAM implementation with 1 MB of boot ROM. For information about the ROM, see "Boot ROM" (page 25). For information about the ROM-in-RAM implementation, see the references listed in "ROM-in-RAM Architecture" (page 64).
- **Graphics card:** Depending on the confguration, the graphics card has either 32, 64, or 128 MB of display RAM. All the cards support two monitors. For more information, see "Graphics Card" (page 29).
- **Sound:** Built-in speaker, 3.5 mm headphone output jack, and 2.5 mm Apple speaker minijack. For more information, see "Sound System" (page 48).

- **Hard disks:** An internal Ultra DMA/66 hard disk occupies one of three drive bays in the bottom of the computer. Space is available in that bay for an additional Ultra DMA/66 device. Drives in the other two lower drive bays can be connected to an optional or user installed third-party PCI controller card. For more information, see "Disk Drives" (page 39).
- **SuperDrive (DVD-R/CD-RW drive):** Some configurations of the Power Mac G4 computer have a SuperDrive (DVD-R/CD-RW drive). For more information, see "SuperDrive" (page 39).
- **CD-RW drive:** Some configurations of the Power Mac G4 computer have a CD-RW drive. FOr more information, see "CD-RW Drive" (page 40).
- **DVD-ROM/CD-RW Combo drive:** A combination DVD-ROM/CD-RW drive is available as an option. For more information, see "DVD-ROM/CD-RW Drive" (page 41).
- **Zip drive:** All configurations can accept an optional 250 MB ATAPI Zip drive. For more information, see "Optional Zip Drive" (page 42).
- **USB ports:** Two USB ports, described in "USB Ports" (page 31). The keyboard that comes with the computer has two additional USB ports.
- **Ethernet:** All configurations include a built in Ethernet port for 10Base-T, 100Base-T, or 1000Base-T operation. For more information, see "Ethernet Port" (page 37).
- **AirPort Card:** An AirPort Card is available as a build-to-order option or as a user-installable upgrade. For more information, see "AirPort Card" (page 44).
- **FireWire ports:** The computer has two external IEEE 1394 high-speed serial FireWire ports, with transfer rates of 100, 200, and 400 Mbps and support for booting from a FireWire storage device. For more information, see "FireWire Ports" (page 33).
- **Modem:** The computer has a built-in Apple 56 Kbps modem. The modem supports K56flex and V.90 modem standards. For more information, see "Internal Modem" (page 43).
- **Keyboard:** The computer comes with an Apple Pro Keyboard, a full-size USB keyboard. The keyboard is also a bus-powered USB hub with two USB ports. For more information, see "Keyboard" (page 45).
- **Mouse:** The computer comes with an Apple Pro Mouse, a USB mouse with optical tracking. For more information, see "Mouse" (page 48).

- **PCI card expansion slots:** The Power Mac G4 computer has four expansion slots for PCI cards. For more information, see "PCI Expansion Slots" (page 59).
- **AGP-4x graphics card slot:** The computer is always shipped with an accelerated graphics card installed in this slot. For more information, see "Graphics Card" (page 29).
- **Voltage switch:** The models sold in some regions have a voltage switch that can be set to either 115 for voltages of 100–130 V or 230 for voltages of 200–250 V, depending on the voltage where the computer is installed. On machines with the switch, the voltage selection must be set manually. Machines without the switch have auto-ranging.
- **Fan speed control:** The speeds of the fans are thermally controlled and are automatically set as low as possilbe, to minimize noise. This is a function provided by the fans and is not under software control.
- **Energy saving:** Sleep scheduling can be controlled with an Energy Saver control panel.

Note: While in sleep mode, the computer emits no noise.

Features of the Enclosure

The Power Mac G4 computer's enclosure is a mini-tower design with opaque side panels and transparent handles.

The front of the computer's enclosure has the media slots for the optical media drive and the optional Zip drive, three buttons—power, reset, and NMI—and the power-on light.

The back panel includes the A/C power socket, the I/O ports, and the openings for PCI cards.

The user can get access to the main logic board to install PCI cards or additional memory by swinging the door down.

The lower part of the enclosure has space for additional storage devices. See "Fixed-Media Drives" (page 42).

System Software

The Power Mac G4 computer comes with Mac OS X 10.1 and Mac OS 9.2.2 installed. Mac OS X is the default operating system.

Here are a few items of interest about the system software on the Power Mac G4 computer.

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 machine should use the Name Registry and Gestalt calls to test for the features they require.

Asset management software that reports the kind of machine it is run on can obtain the value of the property at `Devices:device-tree:compatible` in the name registry. The model string is the first program-usable string in the array of C strings in the `compatible` field. For the Power Mac G4, the value of the model property is `PowerMac3,5`.

Dual Processors and Mac OS 9

To gain a performance advantage on dual-processor configurations, applications that run in Mac OS 9 must be modified to use Multiprocessing Services, an API that allows applications to create tasks that run independently on one or more processors.

Multiprocessing Services allows you to create preemptive tasks within an application. The application still operates in a cooperative multitasking environment with respect to other applications.

Multiple processor support is transparent in Multiprocessing Services. If multiple processors are available, Multiprocessing Services divides the tasks among the available processors. If only one processor is available, Multiprocessing Services schedules all the tasks with that processor.

Multiprocessing Services allows you to determine the number of processors available before creating any tasks.

To obtain more information, including interfaces and libraries, documentation, demonstration applications, and sample code, refer to the references in "Multiprocessing Services" (page 62).

Power Saving Modes

The Power Manager is designed to implement a common power management strategy across all Macintosh models.

Processor States

The following processor states are defined:

- Run Multiple: The system is running at maximum processing capacity. In a single processor system the processor is running at full speed. In a multi-processor system all processors are running at full speed.
- Run Single: One processor is running at maximum processing capacity. In a single processor system, this is the same as Run Multiple. In a multi-processor system, only one processor is running at full speed; all other processors are in sleep mode with their caches flushed and their states saved.
- Idle One: The system is idling. All clocks are running and the system can return to running code within a few nanoseconds. In a single processor system, the main processor is stopped in Doze mode. Cache coherency is maintained in this level of idle. In a multi-processor system, all other processors will be sleeping as described in Run Single.
- Idle Two: The system is in power saving mode. This mode is entered only when a system has been in Idle One state for a substantial period of time (a half second or so) with no activity. In a single processor system, the main processor cache is flushed, and the processor is put into sleep mode—the external processor bus clock is stopped. The delay in coming out of this state is on the order of a millisecond. Cache coherency is maintained by the flush on entry. In a multi-processor system, the other processors will be sleeping as described in Run Single.

System Modes

The Macintosh system has two power saving modes.

- Partial Sleep: The power to the disk drive motors and the display is turned off, but the power supply and fans are still on. The computer can still respond to network activity.
- 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 clocks in the system are suspended except for the 32.768Khz timebase crystal on the PMU99 IC. This mode allows the computer to meet the 5W sleep requirement while providing the ability to start up without rebooting.

Velocity Engine Acceleration

The Velocity Engine (also known as AltiVec) is the vector processing unit in the PowerPC G4 microprocessor. Some system software has been modified to take advantage of the accelerated processing that the Velocity Engine makes possible. System software has also been modified to support low-level operations using the Velocity Engine.

The software areas that have been modified to take advantage of Velocity Engine acceleration are

- QuickTime: key codecs, including DV and photo JPEG

The software areas that have been added or modified for low-level Velocity Engine support are

- Nanokernel: the floating-point vector denormal handler
- Process Manager: context switching
- Block Move routines

The following vector libraries are included: vBasicOps, vectorOps, vBigNum, and vMathLib.

CHAPTER 1

Introduction

CHAPTER 2

Architecture

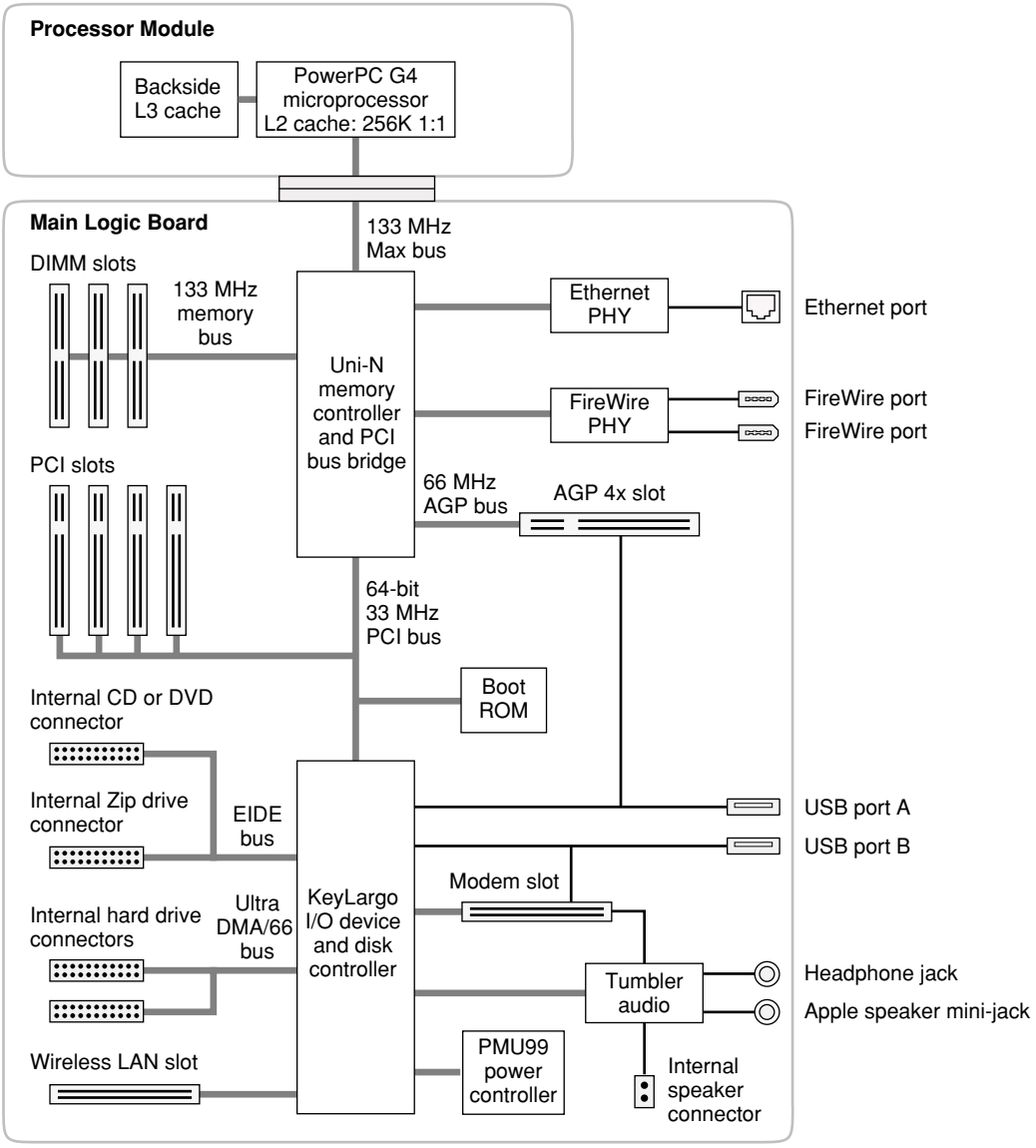
This chapter describes the architecture of the Power Mac G4 computer. It includes information about the major components on the logic boards: the microprocessor, the other main ICs, and the buses that connect them to each other and to the I/O interfaces.

Block Diagram and Buses

Figure 2-1 is a simplified block diagram of the Power Mac G4 computer. The diagram shows the main ICs and the buses that connect them together.

The architecture of the Power Mac G4 is based on the PowerPC G4 microprocessor and two custom ICs: the Uni-N memory controller and bus bridge, and the KeyLargo I/O controller.

Figure 2-1 Simplified block diagram



The Power Mac G4 has four separate buses, not counting the processor's dedicated interface to the backside cache.

- Processor bus: 133-MHz, 64-bit bus connecting the processor module to the Uni-N IC
- Memory bus: 133-MHz, 64-bit bus connecting the main memory to the Uni-N IC
- AGP 4x bus: 66-MHz, 32-bit bus connecting the AGP graphics card to the Uni-N IC
- PCI bus: 33-MHz, 64-bit bus connecting the KeyLargo I/O controller, the boot ROM, and the PCI slots to the to the Uni-N IC

The remainder of this chapter describes the architecture in three sections centered around the processor module, the Uni-N memory controller and bridge IC, and the KeyLargo I/O controller IC.

Processor Module

The processor module is a separate logic board that contains one or two G4 microprocessors and their external memory caches (if any).

The processor module is connected to the main logic board by way of 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 G4 Microprocessor

The PowerPC G4 microprocessor used in the Power Mac G4 computer has many powerful features, including a pipelined system bus, called MaxBus, that is more efficient than the system bus on the PowerPC G3 microprocessors.

The PowerPC G4 used in the Power Mac G4 computer has the following features:

- 32-bit PowerPC implementation
- superscalar PowerPC core

- Velocity Engine (AltiVec technology): 128-bit-wide vector execution unit
- high bandwidth MaxBus
- fully symmetric multiprocessing capability
- dual 32 KB instruction and data caches (level one)
- built-in 256 KB backside L2 cache
- support for up to 2 MB backside L3 cache
- on-chip L3 tag storage

To find more information, see the reference at "PowerPC G4 Microprocessor" (page 62).

Cache Memory

In addition to the 256-KB L2 cache built into the PowerPC G4 microprocessor, the 933-MHz and 1-GHz configurations also have an external level 3 (L3) backside cache. The L3 cache consists of 2 MB of high-speed SRAM. The ratio of the clock speeds of the microprocessor and cache is 4:1; the clock speeds are shown in Table 2-1.

Table 2-1 L3 cache clock speeds

Microprocessor clock frequency	L3 cache clock frequency
933 MHz	233 MHz
1 GHz	250 MHz

Note: The Power Mac G4 computer does not use jumpers to control the clock speeds of the processor and cache.

Dual Processors

The 1-GHz configuration of the Power Mac G4 computer has a processor card that contains two PowerPC G4 processors, each with its own external L3 cache. The dual-processor configuration allows applications that support multitasking to about double their performance. For more information, see “Dual Processors and Mac OS 9” (page 15).

Uni-N Bridge and Memory Controller

The Uni-N custom IC is at the heart of the Power Mac G4 computer. It provides the bridging functionality between the processor, the memory system, the PCI-based I/O system, the AGP graphics slot, and the FireWire and Ethernet interfaces.

Processor Bus

The processor bus is a 133-MHz, 64-bit bus connecting the processor module to the Uni-N IC. In addition to the increased bus clock speed, the bus uses MaxBus protocols, supported by the Uni-N IC, for improved performance.

The MaxBus protocol includes enhancements that improve bus efficiency and throughput over the 60x bus. The enhancements include

- out of order completion
- address bus streaming
- intervention

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 DRAM read can pass a slow PCI read, potentially enabling the processor to do more before it has to wait on the PCI data.

Address bus streaming allows a single master on the bus to issue multiple address transactions back-to-back. This means that a single master can post addresses at the rate of one every two clocks, as opposed to one every three clocks, as it is in the 60x bus protocol.

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. In previous systems, the first processor must write the modified data to memory and then the second processor can read the correct values from memory. With intervention, the first processor sends the data directly to the second processor, reducing latency by a factor of ten or more.

Main Memory Bus

The main memory bus is a 133-MHz, 64-bit bus connecting the main memory to the Uni-N IC.

Main memory is provided by up to three PC133 DIMMs. Supported DIMM sizes are 128, 256, and 512 MB. The memory slots will accept three 512-MB DIMMs for a maximum memory size of 1.5 GB.

For more information about memory DIMMs, see "RAM Expansion" (page 55).

Accelerated Graphics Port Bus

The accelerated graphics port (AGP) bus is a 128-MHz, 32-bit bus connecting the AGP graphics card to the Uni-N IC. The AGP bus provides faster access to main memory than previous designs using the PCI bus. The bus is an AGP-4x bus with twice the performance of the AGP-2x bus, supporting peak transfers of 512 MB/s.

The AGP bus is a superset of the PCI bus, with the addition of separate address lines so it does not multiplex address and data when running in AGP mode. Having a separate address bus allows the AGP bus to pipeline addresses, thereby improving performance.

To further improve the performance of the AGP bus, the Uni-N 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 Uni-N to translate a linear address space for AGP transactions into physical addresses in main memory.

PCI Bus

The PCI bus connects the Uni-N IC to the boot ROM, the KeyLargo I/O controller, and the PCI slots. The PCI bus is a 33-MHz, 64-bit bus for the highest possible PCI card performance.

The Uni-N 1.5 IC used in the Power Mac G4 computer supports a new PCI feature called Write Combining. This feature allows sequential write transactions involving the Memory Write or Memory Write and Invalidate commands to be combined into a single PCI transaction. The memory write transactions being combined must be to sequential, ascending, and non-overlapping PCI addresses. Placing an eieio or sync command between the write commands will prevent any write combining.

Boot ROM

The boot ROM consists of 1 MB of on-board flash EPROM. 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.

Ethernet Controller

The Uni-N IC includes an Ethernet media access controller (MAC). As a separate I/O channel on the Uni-N IC, it can operate at its full capacity without degrading the performance of other peripheral devices. The Uni-N IC provides DMA support for the Ethernet interface.

The MAC implements the link layer. It is connected to a PHY interface IC that provides 10-BaseT, 100-BaseT, or 1000-BaseT operation over a standard twisted-pair interface. The operating speed of the link is automatically negotiated by the PHY and the bridge or router to which the Ethernet port is connected. For information about the port, see “Ethernet Port” (page 37).

FireWire Controller

The Uni-N IC includes an IEEE 1394 FireWire controller that implements the FireWire link layer. The controller supports a maximum data rate of 400 Mbits (50 MBytes) per second.

A physical layer (PHY) IC connected to the Uni-N IC implements the electrical signaling protocol of the FireWire interface. The PHY supports two FireWire ports by way of the external connectors on the rear panel.

The PHY is powered as long as the computer is connected to AC power. While the PHY is operating, it acts as a repeater from one port to another so that the FireWire bus remains connected. For more information, see "FireWire Ports" (page 33).

KeyLargo I/O Controller

The KeyLargo custom IC is the third major component of the architecture. It provides all the I/O functions except Ethernet and FireWire. The KeyLargo IC provides two USB root hubs, an Ultra DMA/66 interface, an EIDE interface, and support for the communication slot and the sound IC.

DMA Support

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

- Ultra DMA/66 interface
- EIDE interface
- communication slot interface
- I2S channel to the sound subsystem

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

Interrupt Support

The interrupt controller for the Power Mac G4 system is an MPIC cell in the KeyLargo IC. In addition to accepting all the KeyLargo internal interrupt sources, the MPIC controller accepts external interrupts from dedicated interrupt pins and serial interrupts from the Uni-N serial interrupt stream. The signals from the Uni-N IC are synchronized to the operation of the MPIC circuitry, so there is no additional interrupt latency on the Uni-N interrupts.

USB Interface

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

The two external USB connectors support USB devices with data transfer rates of 1.5 Mbps or 12 Mbps. For more information, see “USB Ports” (page 31).

Internally, the second port of one controller is routed to the USB signal pair on the AGP slot. The second port of the other controller is routed to the modem slot for an internal USB modem.

The USB ports comply with the Universal Serial Bus Specification 1.0 Final Draft Revision. The USB register set complies with the Open Host Controller Interface (OHCI) specification.

Ultra DMA/66 Interface

The KeyLargo IC implements a single Ultra DMA/66 hard disk interface. This interface supports the boot drive and can accommodate a second hard drive.

For information about the drive bays, see “Fixed-Media Drives” (page 42).

The KeyLargo IC provides DB-DMA (descriptor-based direct memory access) support for the Ultra DMA/66 interface.

Enhanced IDE Interface

In the Power Mac G4, the KeyLargo IC provides an enhanced IDE (EIDE) interface. The EIDE interface supports the removable media drives mounted behind the front panel: the optical drive and an optional Iomega 250 MB Zip drive.

For information about specific drives, see "Removable-Media Drives" (page 39).

The KeyLargo IC provides DB-DMA (descriptor-based direct memory access) support for the EIDE interface.

Modem Slot Support

The KeyLargo IC has a traditional Macintosh serial port that is connected to the modem slot. The KeyLargo IC also provides digital audio to the slot in the form of an I2S port that shares pins with the serial port.

The KeyLargo IC 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 datapump, and the interface to the telephone line (DAA). For more information about the modem, see "Internal Modem" (page 43).

Wireless LAN Module

The interface between the wireless LAN module and the KeyLargo IC is similar to a PC Card interface.

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

The wireless LAN module is based on the IEEE 802.11 standard. The wireless LAN module transmits and receives data at up to 11 Mbps and is compatible with older systems that operate at 1 or 2 Mbps. For information about its operation, see "AirPort Card" (page 44).

Sound Circuitry

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

The Tumbler circuitry includes a signal processing IC that handles the equalization and volume control functions, a codec IC that performs A-to-D and D-to-A conversion, and a digital power amplifier that drives the Apple speaker minijack.

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

For a description of the features of the sound system, see "Sound System" (page 48).

Power Controller

The power management controller in the Power Mac G4 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 Saving Modes" (page 16).

Graphics Card

Depending on the configuration, the Power Mac G4 computer comes either an ATI or an Nvidia graphics card installed in the 4x AGP slot. The main features of the graphics cards are as follows:

Graphics IC	Video RAM	Connectors
ATI RV200	32 MB DDR	ADC and VGA
Nvidia NV17	64 MB DDR	ADC and VGA

EIther graphics card can support two monitors at the same time.

The display memory on the AGP graphics card is separate from the main memory. The display memory consists of 32 or 64 MB of DDR devices configured to make a 128-bit data bus. The display memory cannot be expanded by the user.

The digital flat-panel display can have pixel depths of 8, 16, or 32 for a display up to 1600 by 1024 pixels. The analog monitor display can have pixel depths of 8, 16, or 32 bpp for all displays up to 1920 by 1200 pixels.

For more information about the features of the graphics card and the monitors it supports, see "Video Monitor Ports" (page 50).

Input and Output Devices

This chapter describes the Power Mac G4 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 G4 computer has two external Universal Serial Bus (USB) ports on the back. The USB ports are used for connecting the keyboard and mouse as well as additional I/O devices such as printers, scanners, and low-speed storage devices.

Each USB port is connected to a separate USB root hub, allowing both USB ports to support 12 Mbps devices at the same time with no degradation of their performance. (USB port 2 is shared internally with the USB signals to the ADC monitor.)

For more information about USB on Macintosh computers, please refer to Apple Computer's Mac OS USB DDK API Reference and the other sources listed in "USB Interface" (page 67).

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 shows the connector and Table 3-1 shows the signals and pin assignments.

Figure 3-1 USB connector

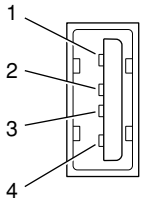


Table 3-1 Signals on the USB connector

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

The Power Mac G4 provides power for the USB ports at 5 V and up to 500 mA on each port. The ports share the same power supply; a short circuit on one will disable both ports until the short has been removed.

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

The Macintosh system software supports all four data transfer types defined in the USB specification.

Waking Up From Sleep

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

This functionality is part of the USB-suspend mode defined in the USB specification. Information about the operation of USB-suspend mode on Macintosh computers is included in the Mac OS USB DDK API Reference, available on the World Wide Web at http://developer.apple.com/techpubs/hardware/DeviceManagers/usb/usb.html

Booting from USB Storage Devices

The Power Mac G4 can boot from a USB storage device that follows the USB Mass Storage Class specification.

Class drivers are software components that are able to communicate with many USB devices of a particular kind. If the appropriate class driver is present, any number of compliant devices can be plugged in and start working immediately without the need to install additional software. The Mac OS for the Power Mac G4 computer includes a class driver that supports devices that meet the USB Mass Storage Class specification.

FireWire Ports

The Power Mac G4 computer includes two external FireWire (IEEE 1394) ports on the rear panel of the enclosure. The FireWire ports

- support serial I/O at 100, 200, and 400 Mbps (megabits per second)
- provide 15 watts of power when the computer system is on
- support up to 62 devices

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

The FireWire hardware and software provided with the Power Mac G4 are capable of all asynchronous and isochronous transfers defined by IEEE standard 1394.

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

For more information about FireWire on Macintosh computers, please refer to the Apple FireWire website and the other sources listed in "FireWire Interface" (page 67).

FireWire Connector

The FireWire connector has six pins, as shown in Figure 3-2. The connector signals and pin assignments are shown in Table 3-2.

Figure 3-2 FireWire connector

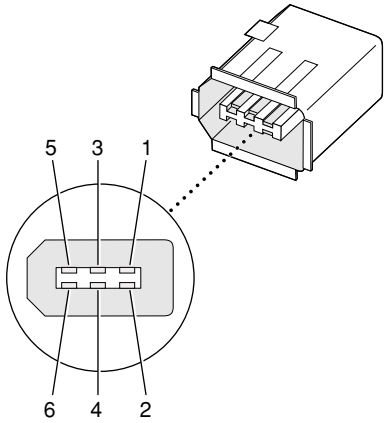


Table 3-2 Signals on the FireWire connector

Pin	Signal name	Description
1	Power	Approximately 25 V DC
2	Ground	Ground return for power and inner cable shield
3	TPB-	Twisted-pair B, differential signals
4	TPB+	
5	TPA-	Twisted-pair A, differential signals
6	TPA+	
Shell	—	Outer cable shield

The power pin provides up to 15 W total power on both 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, such as the one included with the computer, 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 G4 can boot from a FireWire storage device that implements SBP-2 (Serial Bus Protocol) with the RBC (reduced block commands) command set. Detailed information is available from Developer Technical Support at dts@apple.com.

For additional information about the FireWire interface and the Apple APIs for FireWire device control, see the references shown in “FireWire Interface” (page 67).

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 G4 computer is in Target Disk Mode and connected to another Macintosh computer by a FireWire cable, the Power Mac G4 operates like a FireWire mass storage device with the SBP-2 (Serial Bus Protocol) standard. Target Disk Mode has two primary uses:

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

The Power Mac G4 computer can operate in Target Disk Mode as long as the other computer has a FireWire port and either Mac OS X (any version) or Mac OS 9 with FireWire software version 2.3.3 or later.

To put the Power Mac G4 computer into Target Disk mode, you restart the Power Mac G4 and hold down the T key until the FireWire icon appears on the display. You then connect a FireWire cable from the Power Mac G4 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 G4 computer while in Target Disk Mode, an alert appears on the other computer.

To take the Power Mac G4 out of Target Disk Mode, you drag the hard disk icon on the other computer to the trash, then press the power button on the Power Mac G4 computer.

For more information about Target Disk Mode, see the section "Target Mode" in Technote 1189, The Monster Disk Driver Technote. For information about obtaining the Technote, see "Apple Technotes" (page 61).

Ethernet Port

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

Note: When connecting a Power Mac G4 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 3-3 shows the signals and pin assignments for 10Base-T and 100Base-T operation. Table 3-4 shows the signals and pin assignments for 1000Base-T operation.

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

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

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

Pin	Signal name	Signal definition
5	–	Not used
6	RXN	Receive (negative lead)
7	–	Not used
8	–	Not used

Table 3-4 Signals for 1000Base-T operation

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

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

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

Disk Drives

The Power Mac G4 computer has two bays for storage devices with removable-media access through the front panel and three bays for storage devices with fixed media.

Removable-Media Drives

The removable-media drives are connected by way of an EIDE (ATA-3) interface.

The optical drive and Zip drive, when installed, occupy both device locations on the IDE channel. The devices operate in an IDE Device 0/1 configuration. The optical drive is Device 0 (master), and the Zip drive is Device 1 (slave). If the Zip drive is not factory installed in the system, a power and data cable is available for adding a Zip drive to the EIDE bus in the Zip drive bay. The device must be device-select jumpered as Device 1 (slave).

The EIDE bus supports PIO Mode 4 and DMA Mode 2 data transfers.

SuperDrive

Some configurations of the Power Mac G4 computer have a SuperDrive (combination DVD-R and CD-RW drive). The SuperDrive has a tray for loading the disc.

The SuperDrive can read and write DVD media and CD media, as shown in Table 3-5 (page 40). The DVD-R/CD-RW drive also provides DVD-Video playback with DVD MPEG2 decode.

Table 3-5 Media read and written by the SuperDrive

Media type	Reading speed	Writing speed
DVD-R	4x (CAV)	2x (CAV)
CD-R	16x (CAV)	12x (CLV)
CD-RW	16x (CAV)	4x (CLV)
CD or CD-ROM	24x	–

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

The SuperDrive is an ATAPI drive and is device-select jumpered as Device 0 (master) in an ATA Device 0/1 configuration.

CD-RW Drive

Some configurations of the Power Mac G4 computer have an internal CD-RW drive. The drive has a tray for loading the disc.

The drive can read CD and CD-ROM media and read and write CD-R and CD-RW media, as shown in Table 3-6 (page 41).

Table 3-6 Media read and written by the CD-RW drive

Media type	Reading speed	Writing speed
CD-R	32x	24x
CD-RW	32x	10x
CD or CD-ROM	32x	–

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

The CD-RW drive is an ATAPI drive and is device-select jumpered as Device 0 (master) in an ATA Device 0/1 configuration.

DVD-ROM/CD-RW Drive

A combination DVD-ROM and CD-RW drive is available as an option. The drive has a tray for loading the disc.

The drive can read DVD media and read and write CD media, as shown in Table 3-7 (page 41). The DVD-ROM/CD-RW drive also provides DVD-Video playback with DVD MPEG2 decode.

Table 3-7 Media read and written by the DVD-ROM/CD-RW drive

Media type	Reading speed	Writing speed
DVD-ROM	8x (CAV)	–

Table 3-7 Media read and written by the DVD-ROM/CD-RW drive (continued)

Media type	Reading speed	Writing speed
CD-R	32x (CAV)	12x (CLV)
CD-RW	20x (CAV)	8x (CLV)
CD or CD-ROM	32x (CAV)	–

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

Optional Zip Drive

As an option, the Power Mac G4 can have an internal Iomega 250 MB Zip drive. It is an ATAPI drive connected as device 1 in an IDE Device 0/1 configuration on the IDE channel of the main logic board. If the Zip drive option is not installed at the time of purchase, data and power connectors are provided to add an ATAPI Zip drive to the system. The device should be device-select jumpered as device 1 (slave).

Fixed-Media Drives

The lower part of the enclosure has three drive bays for fixed-media mass storage devices. The enclosure includes data and power connectors for the boot drive and a second internal drive on the Ultra DMA/66 interface. It also has a power connector for a third internal drive connected to an optional PCI controller card.

The boot drive occupies one of the lower bays and is connected by way of an Ultra DMA/66 (ATA-5) interface. The Ultra DMA/66 cable assembly also has data and power connectors for a second 3.5 x 1-inch drive, which can be stacked on top of the boot drive.

The drives on the Ultra DMA/66 bus operate in a Device 0/1 configuration. The boot drive is device-select jumpered as Device 0 (master). Normally, an additional Ultra DMA/66 drive should be jumpered as Device 1 (slave). If necessary, the device configurations of the drives could be reversed, but in any case, the two drives on the Ultra DMA/66 bus must be configured complementarily.

The Ultra DMA/66 bus supports PIO Mode 4, DMA Mode 2, and Ultra DMA Mode 4 data transfers.

The other two lower bays are available for devices connected to a separate PCI controller card. An Ultra SCSI 160 drive and Ultra SCSI 160 PCI controller card are available as a configuration option.

None of the lower drive bays can be modified to support removable-media drives.

Ultra DMA/66 Hard Disk

The boot disk in the Power Mac G4 computer is installed in one of the lower bays and connected by way of the Ultra DMA/66 (ATA-5) interface.

Optional Ultra SCSI 160 Drive

An Ultra SCSI 160 drive and Ultra SCSI 160 PCI controller card are available as a configuration option. The Ultra SCSI 160 is a low-voltage differential (LVD) interface and provides data transfer rates of up to 160 MB per second.

Internal Modem

The Power Mac G4 computer has an internal modem module. The external I/O connector for the modem is an RJ-11 connector installed on the rear of the computer. The modem has the following features:

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

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

AirPort Card

The Power Mac G4 computer supports the AirPort Card, an internal wireless LAN module. The AirPort 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 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 Base Station has connectors for a wired LAN, a DSL or cable modem, and a standard telephone line using its built-in 56k modem.

AirPort transmits and receives data at speeds up to 11 Mbps, comparable to wired networking speeds. Airport is Wi-Fi Certified, which means it is fully 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 68).

Data Security

AirPort 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 multi-bit spreading code that effectively scrambles the data for any receiver that lacks the corresponding code.
- The system can use a table of authentic network client ID values to verify each client's identity before granting access to the network.
- When communicating with a base station, AirPort uses up to 128-bit encryption to encode your data while it is in transit.
- The AirPort Base Station can be configured to act as a firewall, protecting your data from would-be Internet hackers.

- The AirPort Base Station can authenticate users by their unique Ethernet IDs, preventing unauthorized machines from logging into your network. Network administrators can take advantage of RADIUS compatibility, used for authenticating users over a remote server. Smaller networks can offer the same security using a local look-up table located within the base station.

AirPort Hardware

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

Two AirPort antennas are built into the computer's cover, on either side of the flat-panel display . One antenna is always used for transmitting. Either of the two antennas may be used for receiving. Using a diversity technique, the AirPort Card selects the antenna that gives the best reception.

AirPort Software

Software that is provided with the AirPort Card includes

- AirPort Setup Assistant, an easy-to-use program that guides you through the steps necessary to set up the AirPort Card or set up an AirPort Base Station.
- AirPort Application, an application that allows users to switch between wireless networks and to create and join peer-to-peer networks.
- AirPort Admin Utility, a utility for advanced users and system administrators. With it the user can edit the administrative and advanced settings needed for some advanced configurations.

Keyboard

The Power Mac G4 computer comes with a Apple Pro Keyboard. It is a full-size keyboard with function keys and separate 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 Pro Keyboard.

- Slope settable to either 0 or 6 degrees
- 108 keys (on the ANSI versions)
- 15 function keys
- 6 editing keys (Page Up, Page Down, Home, End, Forward Delete, and Help)
- USB HID Consumer Page Usage control keys (Volume Up, Volume Down, Mute, and Eject)
- Full travel, standard pitch keys on alphanumeric, editing, and keypad sections, including function keys and cursor position keys
- Localized worldwide: 33 versions, 3 standard layouts (ANSI, JIS, ISO)
- LED indicators in the Caps Lock and Num Lock keys
- USB hub functionality with two USB sockets

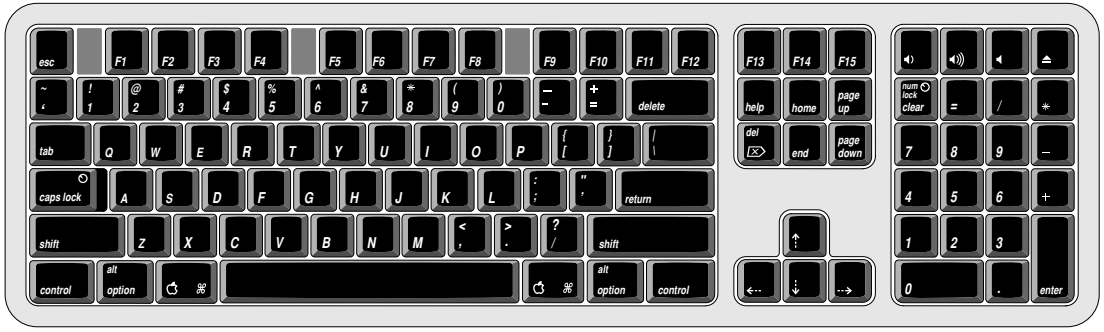
Note: There is no power key on this keyboard.

Keyboard Layout

There are localized versions of the Apple Pro Keyboard for use in different parts of the world. The three standards used are ANSI (US and North America), JIS (Japan), and ISO (Europe). Figure 3-3 shows the keyboard layout for the ANSI keyboard. Applications can determine which keyboard is connected by calling the Gestalt Manager and checking for the corresponding value of the `gestaltKeyboardType` selector:

- `gestaltUSBAndyANSIKbd` (value = 204)
- `gestaltUSBAndyISOKbd` (value = 205)
- `gestaltUSBAndyJISKbd` (value = 206)

Figure 3-3 ANSI keyboard layout



Multi-Media Control Keys

The keyboard has four multi-media keys: Volume Up, Volume Down, Mute, and Eject. The provide direct control of the those features on the computer by way of the USB.

Keyboard and USB

The Apple Pro 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 the second USB port on the computer, not to a port on the keyboard.

Apple provides a HID class driver for the Apple Pro 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 button. Here are the key combinations for the Power Mac G4 computer.

- Control-Command-Eject: restart immediately (reset)
- Control-Command-Option-Eject: shut down immediately
- Control-Eject: display the dialog box for shutdown, restart, and sleep
- Command-Eject: drop into MacsBug, if MacsBug is installed (Mac OS 9)

The key combinations are decoded in software and may not be available under some crashed conditions. Therefore, NMI and reset switches are also available on the front of the computer.

Mouse

The Power Mac G4 computer comes with an Apple Pro Mouse. The mouse case is made of polycarbonate plastic like the computer.

The Apple Pro Mouse is a new design that uses optical tracking in place of the traditional rolling ball. It works on almost any surface, though non-reflective, opaque surface without repetitive patterns work best.

Sound System

The sound circuitry and system software can create and record sounds digitally and play the sounds through the speaker inside the enclosure and send audio signals out through the headphone jack and the Apple speaker minijack.

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. Sound data is converted to analog form only for output to the internal speaker, the headphone jack, and the Apple Speaker minijack.

The sound circuitry handles audio data as 44.1 kHz, 16-bit samples. If audio data sampled at a lower rate on another computer is played as output, the Sound Manager transparently upsamples the data to 44.1 kHz prior to sending the audio data to the Tumbler sound circuitry.

Headphone Jack

The Power Mac G4 has a 3.5 mm mini jack for stereo sound output on the back 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 speakers and the Apple speakers are muted.

The sound output through the headphone jack has the following electrical characteristics:

- output level 2.0 V peak-to-peak (0.7 V RMS)
- impedance suitable for driving standard 32-ohm headphones
- signal-to-noise (SNR) 90 dB unweighted (typical)
- total harmonic distortion (THD) 0.03% or less

Apple Speaker Minijack

The Apple speaker minijack is a stereo 2.5-mm miniature jack. It has a smaller diameter than the headphone jack so that the user cannot inadvertently plug headphones into it.

WARNING
Some types of headphones and other audio devices have a 2.5-mm plug. The user should be warned not to plug such devices into the Apple speaker minijack. Doing so could cause damage to the devices.

The Apple Speakers include an internal ROM that enables the computer to identify the speakers. Speakers other than the Apple Speakers should not be connected to the Apple Speaker jack.

Video Monitor Ports

Depending on the configuration, the Power Mac G4 computer comes either an ATI or an Nvidia graphics card installed. The main features of the graphics cards are as follows:

Graphics IC	Video RAM	Connectors
ATI RV200	32 MB DDR	ADC and VGA
Nvidia NV17	64 MB DDR	ADC and VGA

Either graphics card can support two monitors at the same time.

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

Apple Display Connector

The graphics card has an Apple proprietary connector called the ADC (Apple display connector). It carries both digital and analog video signals as well as USB and control signals and power for an external monitor. Figure 3-4 shows the contact configuration; Table 3-8 and Table 3-9 list the signals and pin assignments.

The maximum current available from the 25-V supply for the external monitor is 4.0 A.

Figure 3-4 Apple display connector

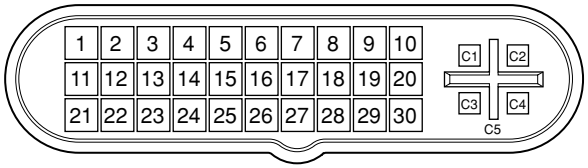


Table 3-8 Digital signals on the Apple display connector

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+
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 68).

VGA Connector

In addition to the ADC connector, the graphics card also has a VGA connector. The VGA connector is a three-row DB-9/15 (also called mini sub D15) connector for use with a VGA, SVGA, or XGA monitor. Figure 3-5 shows the pin configuration and Table 3-10 lists the signals and pin assignments.

Figure 3-5 Analog monitor connector

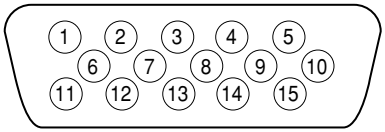


Table 3-10 Signals on the video connector

Pin	Signal name	Description
1	RED	Red video signal
2	GREEN	Green video signal
3	BLUE	Blue video signal
4	n.c.	No connect
5	GND	Ground
6	RED_RTN	Red video signal return
7	GREEN_RTN	Green video signal return
8	BLUE_RTN	Blue video signal return
9	n.c.	No connect
10	GND	Ground
11	n.c.	No connect
12	SDA	I2C data
13	HSYNC	Horizontal synchronization signal
14	VSYNC	Vertical synchronization signal
15	SCL	I2C clock

Expansion

This chapter describes the expansion features of the Power Mac G4 computer: the RAM expansion slots and the PCI expansion slots.

RAM Expansion

The main logic board has three RAM expansion slots for SDRAM DIMMs. At least one of the RAM expansion slots contains a factory installed SDRAM DIMM.

The SDRAM DIMMs can be installed one or more at a time. The system supports linear memory organization; no performance gains are seen when two DIMMs of the same size are installed. Any supported size DIMM can be installed in any DIMM slot, and the combined memory of all of the DIMMs installed is configured as a contiguous array of memory.

The maximum memory size supported by the Power Mac G4 computer is 1.5 GB.

DIMM Specifications

The RAM expansion slots accept 168-pin SDRAM DIMMs that are 3.3 volt, unbuffered, 8-byte, nonparity, and PC133 compliant.

Important
PC100 DIMMs will not work in the Power Mac G4 computer.

The DIMMs can be implemented with either SDRAM or ESDRAM devices. ESDRAM devices provide higher performance for random read and write operations, but SDRAM devices are generally available in larger sizes.

Important
DIMMs with any of the following features are not supported in the Power Mac G4: registers or buffers, PLLs, ECC, parity, or EDO RAM.

Mechanical Specifications

The mechanical design of the SDRAM DIMM is defined by the JEDEC MO-161-D specification. To find this specification on the World Wide Web, refer to "RAM Expansion Modules" (page 66).

The maximum height of DIMMs for use in the Power Mac G4 computer is 2.00 inches.

Electrical Specifications

The electrical design of the SDRAM DIMM is defined by the JEDEC standard 21-C specification. To find this specification on the World Wide Web, refer to "RAM Expansion Modules" (page 66).

The presence detect serial EEPROM specified in the JEDEC standard is required and must be set to properly define the DIMM configuration. Details about the required values for each byte on presence detect EEPROM can be found in sections 4.5.4 and 4.1.2.5 of the JEDEC standard 21-C specification.

Important
For a DIMM to be recognized by the startup software, the Serial Presence Detect (SPD) feature must be programmed properly to indicate the timing modes supported by the DIMM.

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

DIMM Configurations

The largest DIMM supported is a two-bank DIMM of 512 MB using 256 Mbit SDRAM devices. The minimum bank size supported by the memory controller is 2 MB, and the largest is 256 MB. The maximum number of devices per DIMM is 16.

Table 4-1 shows information about the different sizes of SDRAM devices used in the memory modules. The memory controller supports 64 Mbit, 128 Mbit, and 256 Mbit 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 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 RAM expansion DIMMS and devices

Size of DIMM	SDRAM device size	Device configuration	Devices per bank	Size of each bank
32 MB	64 Mbits	1 M x 32 x 2	2	16 MB
32 MB	64 Mbits	512 K x 32 x 4	2	16 MB
64 MB	64 Mbits	2 M x 16 x 2	4	32 MB
64 MB	64 Mbits	1 M x 16 x 4	4	32 MB
64 MB	128 Mbits	1 M x 32 x 4	2	32 MB
128 MB	128 Mbits	2 M x 16 x 4	4	64 MB
128 MB	64 Mbits	4 M x 8 x 2	8	64 MB
128 MB	64 Mbits	2 M x 8 x 4	8	64 MB
128 MB	256 Mbits	2 M x 32 x 4	2	64 MB

Table 4-1 Sizes of RAM expansion DIMMS and devices (continued)

Size of DIMM	SDRAM device size	Device configuration	Devices per bank	Size of each bank
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

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 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
64 Mbits	4 M x 8 x 2	13	9
64 Mbits	2 M x 8 x 4	12	9
64 Mbits	2 M x 16 x 2	13	8
64 Mbits	2 M x 16 x 2	11	10
64 Mbits	1 M x 16 x 4	12	8
64 Mbits	1 M x 32 x 2	11	9
64 Mbits	512 K x 32 x 4	11	8
128 Mbits	4 M x 8 x 4	12	10
128 Mbits	2 M x 16 x 4	12	9
128 Mbits	1 M x 32 x 4	12	8

Table 4-2 Address multiplexing modes for SDRAM devices (continued)

Device size	Device configuration	Size of row address	Size of column address
256 Mbits	8 M x 8 x 4	13	10
256 Mbits	4 M x 16 x 4	13	9
256 Mbits	2 M x 32 x 4	13	8

PCI Expansion Slots

The Power Mac G4 computer has four expansion slots using the industry-standard peripheral component interconnect (PCI) bus.

The computer's case has five openings in the back for access to I/O connectors on cards in the four expansion slots and the AGP slot. The openings and the corresponding slots are listed in Table 4-3.

Table 4-3 Identifying the expansion slots

Number on case opening	Slot type	Label on PCB
1	AGP-4x	J16 and J9 (aligned)
2	PCI	J17
3	PCI	J12
4	PCI	J11
5	PCI	J10

The expansion slots accept 33 MHz PCI cards with either 32-bit or 64-bit address and data buses. The PCI cards can use power at +5 V, +3.3 V, or both. The slots accept standard 6.88-inch and 12.283-inch PCI cards as defined by the PCI Local Bus Specification, Revision 2.1. The cards are required to use the standard ISA fence described in the specification.

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-4x slot carry the 3.3V_AUX power and PME signals to allow an expansion card to wake the computer from Sleep mode.

The maximum total power available for all four PCI slots and the AGP-4x slot is 80 watts. The AGP-4x slot can account for up to 20 watts of that total.

To install or remove a PCI expansion card, the user first opens the door of the enclosure. Then the user removes the blank PCI fence for the appropriate slot, inserts the card in the slot, and screws the card's fence into place to secure the card. The user then closes the enclosure door and turns on the computer. In order to use the new PCI card, a driver must be installed. The driver installation procedure is documented by the manufacturer of the PCI card.

Important
The user should first shut down the computer before removing or installing PCI expansion cards. The Power Mac G4 does not support PCI hot-plugging functionality. The main logic board has a red light to warn the user that power is present.

APPENDIX A

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/techpubs/hardware/hardware2.html

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

http://developer.apple.com/techpubs/macos8/mac8.html

Apple Technotes

Apple Technotes answer many specific questions about the operation of Macintosh computers and the Mac OS. The technotes are available on the Technote website at

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

PowerPC G4 Microprocessor

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

http://e-www.motorola.com/webapp/sps/library/docu_lib.jsp

Velocity Engine (AltiVec)

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

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

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

http://e-www.motorola.com/webapp/sps/library/docu_lib.jsp

Multiprocessing Services

Some configurations of the Power Mac G4 computer have dual microprocessors. The Multiprocessing Services API allows your application to create tasks that run independently on one or more processors. The Multiprocessing 2.1 SDK includes

interfaces and libraries, documentation, demonstration applications, and sample code. You can download the SDK from Apple's developer site on the World Wide Web at

http://developer.apple.com/macos/multiprocessing.html

3D Graphics

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

Information is available on the World Wide Web at

http://www.apple.com/opengl

Developer support and documentation is available at

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

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

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

Mac OS 9.2.2

For a description of the version of the Mac OS that comes with the new models, you should refer to the technote for Mac OS 9.2.2. Other technotes contain information about the NewWorld software architecture and the API changes for Power Manager 2.0. The technotes are available on the Technote website at

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

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

http://developer.apple.com/techpubs/macos8/mac8.html

Mac OS X

For access to Apple's developer documentation for Mac OS X, see the website at

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

Two introductory books are available: *Mac OS X: An Overview for Developers*, and *Inside Mac OS X: System Overview*. Both are available on the Mac OS X website at

http://developer.apple.com/macosx/gettingstarted/

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. The first Mac OS X titles, *Learning Carbon* and *Learning Cocoa*, are avilable now. In addition to the book series, the O'Reilly Network provides news and articles for Macintosh Developers on the World Wide Web at

http://www.oreillynet.com/mac

ROM-in-RAM Architecture

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

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

With the ROM-in-RAM approach, memory is not mapped one-to-one as it was for earlier PCI-based Macintosh computers. This could be a compatibility issue with some software. For more information see Technical Q&A DV 33, *PrepareMemoryForIO for the New World*, available on Apple's Q&A website at

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

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 G4 computer uses PC133 compliant, 168-pin SDRAM DIMMs. The mechanical characteristics of the DIMM are given in the JEDEC specification for the 168-pin 8-byte DRAM DIMM. The specification number is JEDEC MO-161; the specification can be found by using the search string MO161 on the Electronics Industry Association's website at

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

The electrical characteristics of the DIMM are given in section 4.5.6 of the JEDEC Standard 21-C, release 7. 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

The RAM DIMMs are required to be PC133 compliant. Information about the PC133 specification is available from Intel's website at

http://developer.intel.com/technology/memory/pcsdram/

ATA Devices

ATA Manager 4.0 supports driver software for internal IDE drives and includes DMA support. For the latest information about ATA Manager 4.0, see Technote #1098, *ATA Device Software Guide Additions and Corrections*, available on the world wide web at

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

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

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

http://www.t13.org/

USB Interface

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

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

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

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

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

http://www.usb.org/developers/home.php3

FireWire Interface

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

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

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

http://standards.ieee.org/reading/ieee/std_public/description/busarch/1394-1995_desc.html

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 web site of the Digital Display Working Group (DDWG) at

http://www.ddwg.org/index.html

Wireless Networks

More information about Wi-Fi and wireless networks using the IEEE 802.11 standard is available on the web site of the Wireless Ethernet Compatibility Alliance, at

http://www.wirelessethernet.org/index.html

APPENDIX B

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.

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.

APPENDIX B

Conventions and Abbreviations

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

A	amperes	mA	milliamperes
dB	decibels	µA	microamperes
GB	gigabytes	MB	megabytes
Hz	hertz	MHz	megahertz
in.	inches	mm	millimeters
k	1000	ms	milliseconds
K	1024	µs	microseconds
KB	kilobytes	ns	nanoseconds
kg	kilograms	Ω	ohms
kHz	kilohertz	sec.	seconds
kΩ	kilohms	V	volts
lb.	pounds	W	watts

Other abbreviations used in developer notes include these:

ADC	Apple digital connector
AGP	accelerated graphicsport
ATA	advanced technology attachment
ATAPI	advanced technology attachment, packet interface
AV	audiovisual
CAS	column address strobe
CD-ROM	compact disc read-only memory
DBDMA	descriptor-based direct memory access
DDC	display data channel
DDR	double data rate, a type of SDRAM
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 writeable
DVI	Digital Visual Interface
EDO	extended data out DRAM device type
EIDE	extended IDE
EMI	electromagnetic interference
ESDRAM	enhanced synchronous dynamic random-access memory
FWIM	FireWire interface module
G3	Generation 3, the third generation of PowerPC microprocessors, including the PPC 740 and PPC 750
G4	Generation 4, the fourth generation of PowerPC microprocessors, incorporating AltiVec technology
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 1274	the official specification for Open Firmware
IEEE 1394	the official specification for FireWire
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
PCI	Peripheral Component Interconnect

PHY	physical layer
PIO	polled 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
ROM	read-only memory
SBP	Serial Bus Protocol
SPD	Serial Presence Detect
SCSI	Small Computer System Interface
SCC	serial communications controller
SDRAM	synchronous dynamic random access memory
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	Logo used by the Wireless Ethernet Compatibility Alliance for certification of interoperability of 802.11 products

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