Developer Note

Power Mac G4 Computer

Technical Publications

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Figures and Tables

About This Note

This developer note describes the Power Mac® G4 computer. The note provides information about the features of the computer, the logic board architecture 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, you may wish to read the related technical manuals listed in the section "Supplemental Reference Documents."

Topics Described in This Note

The information is arranged in five chapters, an appendix, and an index:

- Chapter 1, "Introduction," gives a summary of the features of the Power Mac G4 computer, describes the physical appearance of the enclosure, and lists the available configurations and options. This chapter also includes a section describing compatibility issues that developers need to be aware of to take advantage of the features available with the Power Mac G4 computer.
- Chapter 2, "Architecture," describes the internal organization of the Power Mac G4 computer. It includes a functional block diagram and descriptions of the main components on the logic board.
- Chapter 3, "Input and Output Devices," describes the built-in input/output (I/O) devices and the external I/O ports.
- Chapter 4, "Expansion," describes the expansion slots on the logic board and provides descriptions of the expansion modules.
- Chapter 5, "Software," describes the system software that comes with the computer, with emphasis on the Open Firmware features and the software support for the new hardware features.
- Appendix A, "Conventions and Abbreviations," describes the typographical conventions and lists the abbreviations used in this note.

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.

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

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

3D Graphics

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

Information is available on the World Wide Web at

http://www.apple.com/opengl

Developer support and documentation is available at

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

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

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

RAM Expansion Modules

The Power Mac G4 computer uses PC100 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 is available from the Electronics Industry Association's website at

http://www.jedec.org/download/freestd/pub95/mo161C.pdf

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

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

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

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

PowerPC G4 Microprocessor

Information about the PowerPC™ G4 microprocessor used in the Power Mac G4 computer is available on the World Wide Web at

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

AltiVec

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 ontain a copy of the AltiVec PEM through the Motorola AltiVec site on the World Wide Web, at

http://www.mot.com/SPS/PowerPC/AltiVec/facts.html

Apple provides support for developers who are starting to use the AltiVec technology. Documentation, development tools, and sample code are now available on the World Wide Web, at

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

Mac OS 9

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

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

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

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

Open Firmware

The NewWorld software architecture implemented on the Power Mac G4 computer follows some of the standards defined by the Open Firmware IEEE 1274-1994 specification and the CHRP binding.

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

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

or you can order it by mail from

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

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

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

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

- *TN 1061: Open Firmware, Part I,* which introduces Forth programming, describes a typical device tree, and outlines a technique for debugging Open

Firmware drivers. It is available on the Technote website at
http://developer.apple.com/technotes/tn/tn1061.html

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

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

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

PCI Cards

For information about PCI expansion cards, refer to *Designing PCI Cards and Drivers for Power Macintosh Computers*. The Power Mac G4 computer supports version 2.1 of the PCI standard.

ATA Devices

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

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

USB Interface

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

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

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

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

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

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

FireWire Interface

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

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

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

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

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

http://www.1394ta.org/

CHAPTER 1

Introduction

The Power Mac G4 computer is a new Power Macintosh desktop computer using the PowerPC G4 microprocessor with a higher performance system bus and several improved I/O features. It is intended for use in content creation, desktop publishing, multimedia, and other activities that require high performance.

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 350, 400, or 450 MHz depending on model and configuration. For more information, see "PowerPC G4 Microprocessor" (page 28).
- **Cache:** 1 MB of backside level 2 (L2) cache on the processor module. The cache runs at half the clock frequency of the microprocessor.
- **Processor system bus:** 64-bit wide data and 32-bit wide address, 100 MHz clock, supporting MaxBus protocol. For more information, see "Processor Bus" (page 29).
- **RAM:** Four DIMM slots for 168-pin PC100 DIMMs (dual inline memory modules) using SDRAM (synchronous dynamic access memory) or ESDRAM (enhanced SDRAM) devices. A minimum of 64 MB of RAM is installed in one of the slots. For more information, see "RAM Expansion" (page 62).
- **ROM:** NewWorld ROM-in-RAM implementation with 1 MB of boot ROM. For information about the ROM, see "Boot ROM" (page 31). For information about the ROM-in-RAM implementation, see "ROM in RAM" (page 68).
- **Graphics acceleration:** A graphics card in the AGP slot provides 2D and 3D hardware graphics acceleration using the ATI RAGE 128 PRO graphics controller. For more information, see "AGP Graphics Card" (page 35).
- **Sound:** Supports 16 bits/channel stereo input and output on built-in 3.5 mm line-level stereo input and output jacks, one built-in speaker. For more information, see "Sound System" (page 53).

- **Hard disks:** One internal Ultra DMA / 66 hard disk; provision for adding either a second Ultra DMA / 66 disk or an ATA-3 storage device. For more information, see “Disk Drives” (page 46).
- **Expansion bays:** Three expansion bays, one of which is occupied by an Ultra DMA / 66 hard disk. Two bays are available for adding one internal 3.5 x 1-inch Ultra DMA / 66 or two ATA-3 devices, or other devices connected to a PCI controller card. For more information, see “Disk Drives” (page 46).
- **DVD-ROM drive:** ATAPI DVD-ROM drive providing support for 24x-speed CD-ROM and 6x-speed DVD-ROM media, as well as DVD-Video playback with DVD MPEG2 decode in software.
- **DVD-RAM drive:** Optional ATAPI DVD-RAM drive reads and writes 2.6 GB and 5.2 GB DVD-RAM media in addition to supporting 2x-speed DVD-ROM, 20x CD-ROM, and DVD-Video playback with DVD MPEG2 decode in software.
- **Zip drive:** 100 MB ATAPI Zip drive.
- **USB ports:** Two USB ports, described in “USB Ports” (page 40). The computer comes with a USB mouse and a USB keyboard that has two additional USB ports.
- **Ethernet:** Built in Ethernet port for a 10Base-T or 100Base-TX operation with an RJ-45 connector. For more information, see “Ethernet Port” (page 45).
- **Wireless LAN:** An internal wireless LAN module is available as a build-to-order option or as a user-installable upgrade. For more information, see “AirPort Card Wireless LAN Module” (page 50).
- **FireWire ports:** Two external and one internal IEEE 1394a high-speed serial FireWire ports, which support transfer rates of 100, 200, and 400 Mbps. For more information, see “FireWire Ports” (page 43).
- **Modem:** Slot for an optional built-in Apple 56 Kbps modem. The modem supports K56flex and V.90 modem standards. For more information, see “Internal Modem” (page 49).
- **Keyboard:** Apple USB keyboard with function keys and inverted-T arrow keys. It is also a bus-powered USB hub with two USB ports. For more information, see “Keyboard” (page 52).
- **Mouse:** Apple USB mouse operating as a low-speed (1.5 Mbps) USB device. For more information, see “Mouse” (page 53).

- **PCI card expansion slots:** Three slots for 33 MHz, 64-bit or 32-bit, 12-inch PCI cards. For more information, see “PCI Expansion Slots” (page 66).
- **AGP-2X graphics card slot:** The computer is always shipped with an accelerated graphics card installed in this slot. For more information, see “AGP Graphics Card” (page 35).
- **Startup button:** Startup and sleep are controlled from the Apple USB keyboard and a front power button.
- **Voltage switch:** 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. The voltage selection must be set manually.
- **Fan speed control:** The speed of the fan is thermally controlled and is automatically set to the lowest possible speed to minimize noise. This is a function provided by the fan and is not under software control.
- **Energy saving:** Sleep, startup, and shutdown scheduling can be controlled with an Energy Saver control panel.

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 Power Mac G4 computer’s enclosure has the slots for the DVD-ROM or DVD-RAM drive and the optional Zip drive, the power button, the reset button, the NMI button, and the power-on light.

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

The user can get access to the main logic board to add memory or PCI cards by opening the case and swinging the door down.

An internal 56 Kbps modem card can be installed as an option at the time of purchase. The modem is compatible with V.34 and V.90 protocols.

Compatibility Issues

The Power Mac G4 computer incorporates several changes from earlier models. This section describes key issues you should be aware of to ensure that your hardware and software work properly.

Software Issues

Like other recent Macintosh computers, the Power Mac G4 computer uses the RAM-in-ROM approach with Open Firmware booting. Software developers should follow the recommended practices for the new approach.

System Software

The system software that comes with the Power Mac G4 computer is Mac OS 9 with extensions and control panels required for product-specific features. Features specific to the Power Mac G4 computer are described in “Mac OS ROM Image File” (page 72). For a general description of the Mac OS 9 release, refer to the Technote for Mac OS 9. The technote is available on the Technote website at

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

Machine Identification

With the RAM-in-ROM system software, it is no longer possible to use the box flag to identify the computer model. For guidelines about machine identification, see “Computer Identification” (page 73).

Booting From External Drives

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

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

G4 computer includes USB Mass Storage Support 2.0, a class driver that supports devices that meet the USB Mass Storage Class specification.

Expansion Issues

The expansion features of the Power Mac G4 computer are similar to those of the Power Macintosh G3 1999 computer.

Internal Storage Devices

Standard configurations of the Power Mac G4 computer include two unused expansion bays in the bottom of the enclosure. The expansion bays accommodate 1.6-inch-high 3.5-inch devices. Power connectors are provided for both expansion bays. For more information, see “Disk Drives” (page 46).

RAM Expansion

The main logic board uses JEDEC-standard SDRAM DIMM cards that are 64-bit bus, nonparity, 168-pin, 3.3-volt, unbuffered, and PC100 compliant. The speed of the devices must be 125 MHz (8 ns) or faster.

IMPORTANT

DIMMs with registers or buffers, DIMMs with PLLs, and DIMMs with EDO RAM are not supported in the Power Mac G4 computer. ▲

The maximum supported height of SDRAM DIMM cards is 2 inches. The maximum number of devices supported on a DIMM is 16 SDRAM devices. For more information, see “RAM Expansion” (page 62).

No L2 Cache Expansion

The backside L2 cache is integrated into the microprocessor module. Cache expansion is not supported.

Proprietary Modem Slot

The 70-pin modem connector in the Power Mac G4 computer is the same as the connector on the modem slot in the blue-and-white Power Macintosh G3 computers. The modem slot is a proprietary design specifically for Apple modem cards.

Digital A/V Connections

Composite and S-Video connectors are not available on the Power Mac G4 computer. Digital video input and output features of the Power Mac G4 computer are provided by the FireWire ports and the USB ports.

The Power Mac G4 computer does not include RCA jacks for analog stereo audio input and output. The built-in 3.5 mm sound input and sound output connectors can be used for analog stereo audio input and output. Digital audio input and output is supported by the FireWire interface. For information about the analog sound connectors, see “Sound System” (page 53). For information about the FireWire interface, see “FireWire Ports” (page 43).

AC Power Issues

Users should be made aware of the following power issues.

Line Voltage Switch

The power supply is not self-configuring for different input voltages. The voltage switch is delivered preconfigured for the input voltage of the region in which the unit is originally purchased. If the computer is moved to another location where the input voltage is different, a voltage switch must be adjusted to accommodate the voltage change. The switch has two positions that support voltage ranges of 100 to 130 V or 220 to 270 V.

Monitor Power Socket

The monitor power socket is not switched. Any time power is connected to the power supply, power is available on the monitor power socket. A monitor that does not support energy saving features that is connected to the monitor power socket will not power off when the computer is shut down. Monitors that do not support energy saving features have to be switched manually.

Legacy I/O Issues

The Power Mac G4 computer does not include certain I/O features found on previous Macintosh computers.

No SCSI Ports

The Power Mac G4 computer does not include built-in internal or external SCSI device connectors. Adding an internal or external SCSI device requires the use of a SCSI PCI card. Ultra2 SCSI (LVD) drives and PCI controller cards are available as options at the time of purchase.

No LocalTalk Serial Ports

The Power Mac G4 computer does not include RS-422 LocalTalk serial ports found on earlier Macintosh models. Serial I/O for external USB devices is provided by two USB ports. USB adapters are available from third parties to support Macintosh-compatible legacy serial devices.

No ADB or Serial Ports

The USB ports take the place of the ADB and serial I/O ports found on earlier Macintosh computers. Software shims have been implemented in the system software to allow existing applications that use ADB devices to work with USB devices.

The Power Mac G4 computer uses a USB keyboard and mouse similar to the USB keyboard and mouse introduced with the iMac computer.

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/

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.

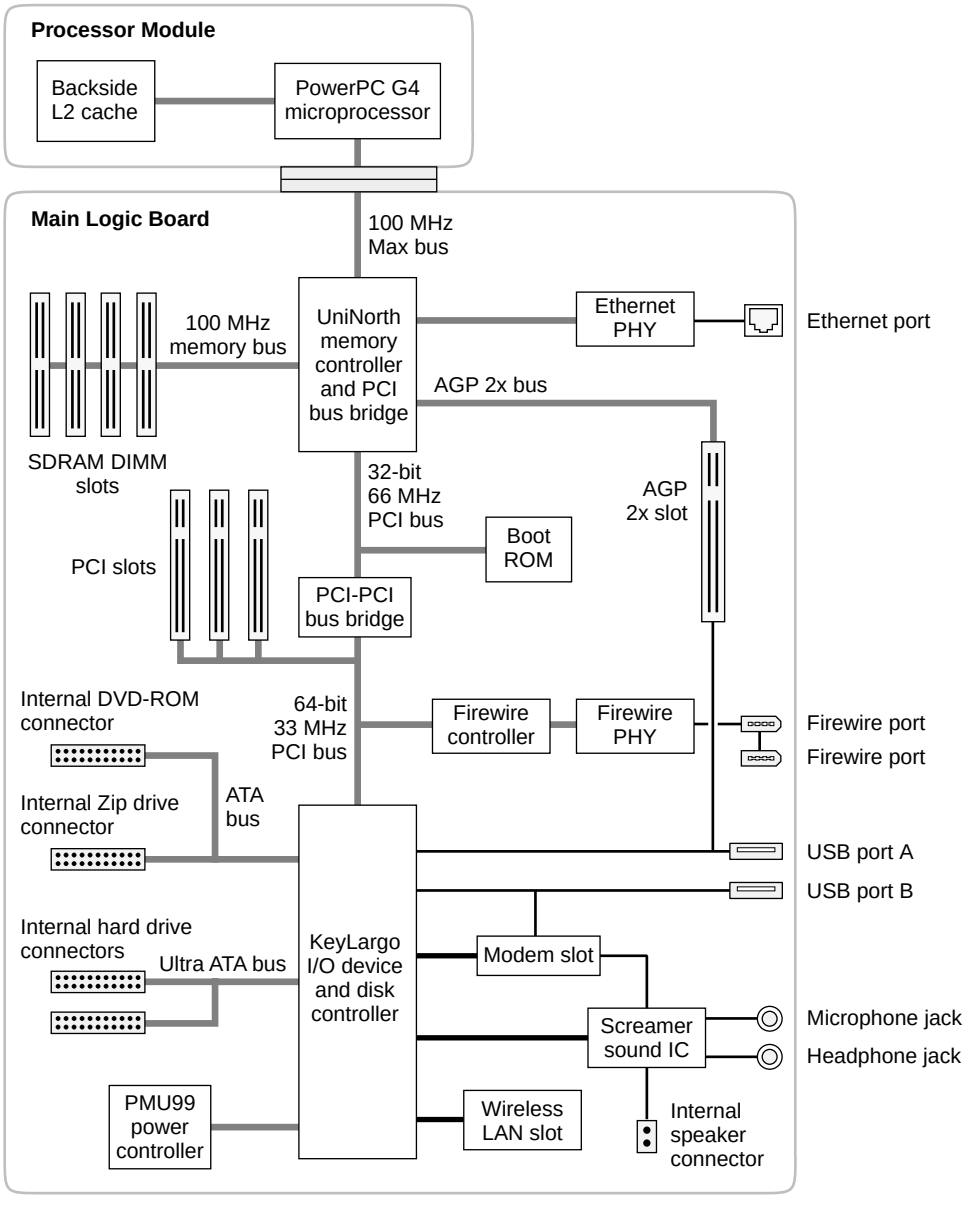
The architecture of the Power Mac G4 computer is based on the PowerPC G4 microprocessor and two new custom ICs: the Uni-N memory controller and bus bridge, and the KeyLargo I/O controller.

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

- **Processor bus:** 100-MHz, 64-bit bus connecting the processor module to the Uni-N IC
- **Memory bus:** 100-MHz, 64-bit bus connecting the main memory to the Uni-N IC
- **AGP bus:** 66 or 132-MHz, 32-bit bus connecting the AGP graphics card to the Uni-N IC
- **PCI bus:** 66-MHz, 32-bit bus connecting the boot ROM and the PCI-PCI bridge IC to the Uni-N IC; 33-MHz, 64-bit bus connecting the KeyLargo I/O controller and the PCI slots to the PCI-PCI bridge IC

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

Figure 2-1 Simplified block diagram



Processor Module

The processor module is a separate PC card that contains the G4 microprocessor and the backside L2 cache.

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 processor in the Power Mac G4 computer is a PowerPC G4 microprocessor running at a clock frequency of 350, 400, or 450 MHz.

The PowerPC G4 microprocessor uses a new pipelined system bus that is more efficient than the system bus on the PowerPC G3 microprocessors. The new bus design, called MaxBus, allows for much greater efficiency of bus utilization than was possible with the previous design.

Features of the PowerPC G4 include:

- 32-bit PowerPC implementation
- superscalar PowerPC core
- AltiVec technology: 128-bit-wide vector execution unit
- dual 32 KB instruction and data caches (the same as PowerPC G3)
- support for up to 2 MB backside L2 cache
- on-chip L2 tag storage (twice as much as PowerPC G3)
- high bandwidth MaxBus (also compatible with 60x bus)
- fully symmetric multiprocessing capability

For technical details, see the PowerPC web pages at

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

Level2 Cache

The backside level2 (L2) cache consists of 1 MB of high-speed SRAM. The clock frequency of the L2 cache is one half the clock frequency of the PowerPC G4 microprocessor.

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

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 Ethernet interface.

Processor Bus

The processor bus is a 100-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 multiprocessor systems. If one processor modifies some data, that data first gets stored “dirty” 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 dirty 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 100-MHz, 64-bit bus connecting the main memory to the Uni-N IC.

Main memory is provided by up to four PC100 DIMMs. Supported DIMM sizes are 16, 32, 64, 128, 256, and 512 MB. Four 512-MB DIMMs make a total of 2 GB, which is the maximum supported memory size.

For more information, see “RAM Expansion” (page 62).

Note
At present, the Mac OS supports up to 1 GB of memory for applications. Future releases of the Mac OS will support the full 2 GB. ◆

Accelerated Graphics Port Bus

The accelerated graphics port (AGP) bus is a 66 or 132-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 AGP bus is a superset of the PCI bus, but it has separate address lines so it does not multiplex address and data as PCI does. 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 Buses and Bridge

The Power Mac G4 computer has two PCI buses. The first PCI bus is a 66-MHz, 32-bit bus from the Uni-N IC. The second PCI bus is a 33-MHz, 64-bit bus to the KeyLargo I/O controller and the PCI slots. The PCI-PCI bridge IC provides the conversion between the two PCI buses. The rationale behind this arrangement has to do with reducing the number of pins on the Uni-N IC.

The PCI-to-PCI bridge IC is a DEC 21154-66 device. In addition to bridging between the two PCI buses, it provides performance enhancing features such as write buffering, memory read-ahead buffering, and transaction optimization.

The PCI-to-PCI bridge IC also provides arbitration for the 33 MHz secondary PCI bus. This arbiter is a two-tier round-robin arbiter. The low-priority tier gets one slot in the high-priority round-robin arbitration scheme. Placement of devices in the arbitration scheme is under software control, so any device may be placed in either the high-priority tier or the low-priority tier. For more details of the arbiter, see the DEC 21154-66 databook.

Boot ROM

The boot ROM contains the Open Firmware boot code.

To minimize the number of pins on Uni-N, the boot ROM is connected to the 66 MHz PCI bus. The boot ROM uses the thirty two PCI AD lines and four PCI byte enable lines for address and data. Uni-N has separate pins for Chip Enable, Output Enable, and Write Enable signals to keep the ROM from interfering with proper PCI bus operation.

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, to load an operating system, and to provide common hardware access services.

The components that comprise what is referred to as the Mac OS Toolbox are no longer in the on-board firmware ROM. The Mac OS Toolbox image file, called Mac OS ROM, is copied from the boot device (hard disk or CD-ROM) into RAM before the Mac OS begins operation. For more information about this ROM-in-RAM approach, see “ROM in RAM” (page 68).

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 DB-DMA support for the Ethernet interface.

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

FireWire Controller

The PCI bus supports an IEEE 1394a FireWire controller with a maximum data rate of 400 Mbits (50 MBytes) per second. The controller implements the FireWire link layer. A physical layer IC, called a PHY, implements the electrical signaling protocol of the FireWire interface. The PHY supports three FireWire ports. Two of the ports go to external connectors on the rear panel of the base unit. The third port is available for devices inside the case.

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

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

- DAV channel to the sound IC

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

Interrupt Support

The interrupt controller for the Power Mac G4 system is an MPIC cell in the KeyLargo IC. In addditition 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 40).

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 as a master and a second hard drive as a slave.

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 computer, the KeyLargo IC provides an enhanced IDE (EIDE) interface. The EIDE interface supports the DVD drive and an optional Iomega Zip removable media drive.

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 I^2S 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 49).

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 Wireless LAN Module” (page 50).

Sound IC Support

The KeyLargo IC has a traditional DAV port that connects to the Screamer sound IC. The KeyLargo IC provides DB-DMA (descriptor-based direct memory access) support for the DAV port.

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

Audio data from the CD-ROM drive are sent through the KeyLargo IC's DMA channel and then to the Screamer IC for conversion to analog signals.

For a description of the features of the sound system, see "Sound System" (page 53).

Power Controller

The power management controller in the Power Mac G4 computer is a custom IC called the PMU99. It supports new modes of power management that provide signficantly lower power consumption than previous systems. For more information, see "Power Manager" (page 74).

AGP Graphics Card

The computer comes with an AGP graphics card installed. The graphics card has the following specifications:

- ATI's RAGE 128 PRO graphics IC
- 16 MB SDRAM on 128-bit, 125-MHz SDRAM bus
- 3-row mini DB-9/15 connector for analog video monitor
- support for up to 1280 by 1024 pixels at 32 bpp on analog monitor
- 24-pin standard digital-only DVI connector for digital monitor.
- support for up to 1024 by 768 pixels on digital monitor

For more information about the features of the graphics card and the monitors it supports, see "Video Monitor Ports" (page 55).

Graphics Controller IC

The ATI RAGE 128 PRO graphics controller IC on the accelerated graphics card contains the logic for the video display. The ATI RAGE 128 PRO graphics controller includes the following features:

- advanced 128-bit rendering engine
- architecture optimized to support high-speed SDRAM video memory
- display memory controller, built-in drawing coprocessor, video scaler, color space converter, clock generator, and true color palette video DAC (digital-to-analog converter)
- video CLUT (color lookup table)
- integrated support for digital flat panel monitors
- hardware graphics acceleration with a 16-bit Z-buffer
- accelerated QuickDraw 3D rendering up to six times that of software-only acceleration
- true color palette DAC supporting pixel clock rates to 200 MHz for 1600 by 1200 resolution at 90 Hz
- graphics and video line buffer for superior video scaling and playback quality
- hardware cursor up to 64 x 64 x 2
- DDC1 and DDC2B+ for plug-and-play monitor support
- graphics control accessible through the QuickDraw, QuickDraw 3D, QuickDraw 3D RAVE, and QuickTime components APIs

A separate data bus handles data transfers between the ATI RAGE 128 PRO graphics controller and the display memory. The display memory data bus is 64 bits wide, and all data transfers consist of 64 bits at a time. The RAGE 128 PRO IC breaks each 64-bit data transfer into several pixels of the appropriate size for the current display mode—4, 8, 16, 24, or 32 bits per pixel.

The ATI RAGE 128 PRO graphics controller uses several clocks. Its transactions are synchronized with the AGP bus. Data transfers from the frame-buffer RAM are clocked by the MEM_CLK signal. Data transfers to the CLUT and the video output are clocked by the dot clock, which has a different rate for different display monitors.

The 2D graphics accelerator is a fixed-function accelerator for rectangle fill, line draw, polygon fill, panning/scrolling, bit masking, monochrome expansion, and scissoring.

Display Memory

The display memory on the AGP graphics card is separate from the main memory. The display memory consists of 16 MB of 125 MHz/8ns SDRAM devices configured to make a 64-bit data bus. The display memory cannot be expanded by the user.

The graphics card has 16 MB of video memory, allowing the analog monitor display to have pixel depths of 8, 16, or 32 bpp for displays up to 1280 by 1024 pixels and 8 or 16 bpp for displays up to 1920 by 1080 pixels. The digital flat-panel display can have pixel depths of 8, 16, or 32 for a display up to 1600 by 1024 pixels.

For information about the monitor connector and display resolutions, see “Video Monitor Ports” (page 55).

Architecture

CHAPTER 3

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 that are used for connecting the keyboard and mouse as well as additional I/O devices such as printers, scanners, and low-speed storage devices.

The USB ports are connected to separate USB root hubs, allowing both USB ports to support 12 Mbps devices at the same time with no degradation of their performance.

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 "About This Note" (page 11).

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 pin assignments.

Figure 3-1 USB connector

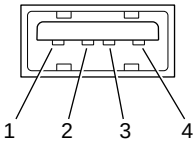


Table 3-1 Pin assignments on the USB connector

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

The Power Mac G4 computer provides power for the USB ports at 5 V and up to 500 mA on each port. The ports have individual overcurrent protection; an overcurrent condition on one port leaves the other functional.

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 Power Mac G4 computer comes with version 1.3 of the Macintosh USB system software, which supports all four data transfer types defined in the USB specification.

USB Features

Features of the USB ports include power saving modes and the ability to start up the computer from an USB mass-storage device.

“Power Off During Sleep”

“USB Storage Devices”

Power Off During Sleep

In the Power Mac G4 computer, the USB port can be completely powered down during Sleep mode. USB devices must be able to start up again when the computer wakes up from Sleep mode. 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

In addition to restarting themselves out of Sleep mode, USB devices can also provide a remote wakeup function for the computer. The USB root hub in the computer is set to support remote wakeup whenever a device is attached to or disconnected from the bus. The mouse and keyboard that come with the computer use this method to wake the computer on a key press or mouse motion.

USB Storage Devices

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

Class drivers are software components that are able to communicate with many USB devices of a particular kind. If the appropriate class driver is present, any number of compliant devices can be plugged in and start working immediately without the need to install additional software. The Mac OS for the Power Mac G4 computer includes USB Mass Storage Support 2.0, a class driver that supports devices that meet the USB Mass Storage Class specification.

USB Compatibility Issues

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

ADB Compatibility

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

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

Keyboards other than the Apple USB keyboard can be used with the Power Mac G4 computer, but they will be treated as having an ADB device ID of 2.

IMPORTANT

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

Note
The ADB/USB shim is built into the Mac OS ROM image on the Power Mac G4 computer, as it is on all Power Macintosh systems that have USB ports. ◆

Serial Port Compatibility

Mac OS 9 includes a serial shim, called SerialShimLib, that enables processes that use the Communications Toolbox CRM to find and use a USB modem device. For more information about the shim, and a sample modem driver that shows how to use it, please refer to the Mac OS USB DDK, available from the Apple Developer Development Kits page on the World Wide Web, at

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

Apple also provides a USB Communication Class driver, so modem vendors whose devices comply with the USB Communication Class specification do not need to write their own vendor-specific USB class drivers. See "USB Drivers" (page 76).

Not for Networking

USB is a serial communications channel, but it does not replace LocalTalk functionality on Macintosh computers; you cannot connect two Macintosh computers together using the USB. The best method for networking Power Mac G4 computers is through the built-in Ethernet port.

FireWire Ports

The Power Mac G4 computer includes two external FireWire IEEE 1394a ports on the rear panel of the enclosure and one inside the computer. 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
- accept external power input on the bus when the computer is off

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

IEEE standard 1394a. Developers of FireWire peripherals are required to provide device drivers.

It is possible to connect two computers to each other using a FireWire cable, but no software is provided to make use of such a connection.

FireWire Connector

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

Figure 3-2 FireWire connector

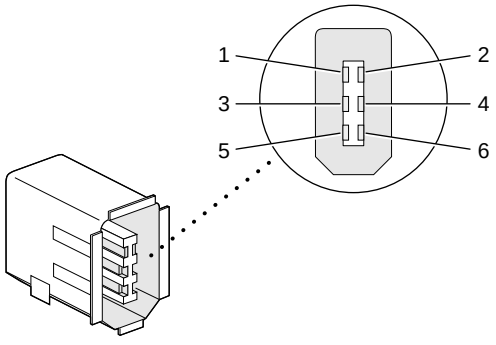


Table 3-2 Pin assignments on the FireWire connector

Pin	Signal name	Description
1	Power	Unregulated DC; 30 V no load
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 unregulated, ranging from 20 V under a typical load to 30 V under no load. The power pin also accepts external power at 8 to 33 V, in conformity with the P1394a draft standard, to keep the FireWire bus connected when the computer is turned off.

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

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

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

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

or send electronic mail to

firewire@apple.com

Ethernet Port

The Power Mac G4 computer has a built-in 10/100 Mbps Ethernet port. The actual speed of the link is auto-negotiated between the computer's PHY device and the network bridge or router to which it is connected.

The connector for the Ethernet port is an RJ-45 connector on the back of the computer. Table 3-3 shows the signals and pins on the connector. The computer does not have a connector for a fiber-optic cable.

Table 3-3 Signals on the Ethernet connector

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

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

Disk Drives

The Power Mac G4 computer has an Ultra DMA / 66 (ATA-5) interface and an ATA-3 interface for internal mass storage and removable media 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. The enclosure has data and power connectors for the internal ATAPI DVD-ROM or DVD-RAM drive and an internal ATAPI Zip drive. Those drives are connected to the ATA-3 interface.

The enclosure includes three drive bays for mass storage devices. One bay is occupied by the boot drive. A drive in one of the other bays can be connected to the second drive connector on the Ultra DMA / 66 cable assembly or to an

optional or user installed third-party PCI controller card. None of the drive bays can be modified to support removable drive bay kits.

The Ultra DMA / 66 bus supports PIO Mode 4, DMA Mode 2, and Ultra DMA Mode 2 data transfers. The ATA-3 bus supports PIO Mode 4 and DMA Mode 2 data transfers.

The ATA-3 channel supports two ATA devices. The devices are configured in a ATA Device 0 / 1 configuration. The ATAPI DVD-ROM and Zip drive, when installed, occupy both device locations on the ATA-3 channel. The ATAPI DVD-ROM 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 ATA-3 bus in the Zip drive bay. The device must be device-select jumpered as Device 1 (slave).

The Power Mac G4 computer does not include a 1.44 MB floppy drive.

Ultra DMA/66 Hard Disk

The logic board supports an internal hard disk that uses the standard Ultra DMA / 66 (ATA-5) interface. The Power Mac G4 computer comes with an Ultra DMA / 66 hard disk or a Wide Ultra 2 hard disk installed in the third drive bay.

The internal hard disk has a 40-pin connector and a separate 4-pin power connector. An 80-conductor high-density cable with a 40-pin connector is attached to the main logic board. To provide improved signal quality, the 80-conductor cable has ground lines separating the signals on the 40-pin connector. The power cable is attached directly to the power supply.

DVD-ROM Drive

The Power Mac G4 computer has an internal 6x-speed DVD-ROM drive. The DVD-ROM drive supports the following disc formats:

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

The DVD-ROM drive is an ATAPI drive and is connected as device 0 in an ATA Device 0/1 configuration on the ATA-3 channel of the main logic board. To provide improved signal quality, the ATA bus has an 80-conductor cable with ground lines separating the signals.

A four-conductor cable carries the analog audio output of the DVD drive to the main logic board for playback of audio CDs.

Optional DVD-RAM Drive

As an option, the Power Mac G4 computer has an internal 2x-speed DVD-RAM drive in place of the DVD-ROM drive. The DVD-RAM drive supports the following disc formats.

- Reading and writing:
  - DVD-RAM media in Type 1 cartridge, one- or two-sided
  - DVD-RAM media in Type 2 catridge, one sided
- Reading only:
  - DVD-RAM bare one-sided disc, reading only
  - DVD-R (3.9 GB, disc-at-once only)
  - DVD-ROM (One- or two-layer, one- or two-sided)
  - CD-ROM (Modes 1 and 2)
  - CD-ROM XA (Mode 2, Forms 1 and 2)
  - CD-Audio (CD-DA data through IDE bus)
  - Photo CD (single and multiple sessions)
  - CD-RW
  - CD-R (fixed and variable packets)
  - CD-I (Mode 2, Forms 1 and 2), CD-I Ready, CD-I Bridge
  - Video CD (White Book disc)
  - CD-EXTRA CD (Blue Book disc)

The DVD-RAM drive takes the place of the DVD-ROM drive and is connected in the same way: as device 0 in an ATA Device 0/1 configuration on the ATA-3 channel of the main logic board. To provide improved signal quality, the ATA bus has an 80-conductor cable with ground lines separating the signals.

A four-conductor cable carries the analog audio output of the DVD drive to the main logic board for playback of audio CDs.

ATAPI Zip Drive

The internal Iomega Zip drive is an ATAPI drive. It is connected as device 1 in an ATA Device 0/1 configuration on the EIDE 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).

Optional Ultra2 SCSI (LVD) Drive

An optional Ultra2 SCSI low-voltage differential (LVD) drive and Ultra2 SCSI (LVD) PCI controller card are available as a configuration option. The Ultra2 SCSI (LVD) interface provides data transfer rates of up to 80 MB per second. Additional information about the Ultra2 SCSI (LVD) interface can be found at

http://www.quantum.com/src/whitepapers/

Internal Modem

The Power Mac G4 computer has a dedicated slot for an internal modem module. The module is available as a build-to-order option or as a user-installable upgrade. 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.

Note
This developer note does not provide electrical or mechanical specifications for the modem slot.

AirPort Card Wireless LAN Module

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.

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

The AirPort Card transmits and receives data at up to 11 Mbps. It is also interoperable with some older wireless LANs, as specified in “Hardware Components” (page 50).

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

Data Security

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

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

Hardware Components

The AirPort Card is a wireless LAN module based on the IEEE 802.11 standard and using direct-sequence spread-spectrum (DSSS) technology. It is

interoperable with PC-compatible wireless LANs that conform to the 802.11 standard and use DSSS.

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

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

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

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

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

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

Software Components

Software that is provided with the AirPort Card includes

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

Keyboard

The Power Mac G4 computer comes with an Apple USB keyboard. The keyboard has an attached 2-meter cable for installations where the computer is located on the floor or away from the immediate desktop area.

Keyboard Layout

The Apple USB keyboard has a total of 82 keys, including 12 function keys, a numeric keypad and a set of 4 cursor-control keys. The cursor-control keys are in the inverted-T arrangement.

There are versions of the Apple USB keyboard with different key layouts for three standards used in different parts of the world: 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:

- `gestaltUSBCosmoANSIKbd` (value = 198)
- `gestaltUSBCosmoJISKbd` (value = 200)
- `gestaltUSBCosmoISOKbd` (value = 199)

Figure 3-3 ANSI keyboard layout

Keyboard and USB

The Apple USB 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 Apple USB keyboard. ▲

The standard NMI and reset key combinations are available, but the keys 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.

Apple provides a HID class driver for the Apple USB 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).

Mouse

The Power Mac G4 computer comes with an Apple USB mouse.

The mechanism inside the Apple USB mouse is similar to that in the Apple Desktop Bus Mouse II. The mouse ball is removeable for cleaning; the ring that allows access to the ball can be locked by inserting an unfolded paper clip into a small hole and turning the ring clockwise.

Sound System

The sound system for the Power Mac G4 computer supports 44.1 kHz 16-bit stereo sound output and input, available simultaneously.

Like other Macintosh computers, the sound circuitry and system software can create sounds digitally and either play the sounds through speaker inside the enclosure or send the sound signals out through the sound output jack. The Power Mac G4 computer also records sound from several sources: an analog stereo sound source connected to the line-level sound input jack, analog single-channel sound from the modem card in the internal modem slot, a PlainTalk microphone, or analog stereo from a compact disc in the DVD-ROM drive. With each sound input source, sound playthrough can be enabled or disabled.

Sound Output

The Power Mac G4 computer has one built-in speaker and a 3.5 mm mini jack for stereo sound output on the back of the enclosure.

The output jack is suitable for connecting a pair of headphones or amplified external speakers. Inserting a plug into the sound output jack disconnects the internal speaker.

The sound output jack has the following electrical characteristics:

- output sound signal-to-noise ratio (SNR) <90 dB unweighted (typical) when sound playback is from system hard disk drive or main memory
- output sound SNR <80 dB unweighted (nominal) when playback is from CD
- overall output sound SNR <90 dB unweighted (typical)

Sound Input

The Power Mac G4 computer provides a stereo sound input jack on the back of the enclosure for connecting an external PlainTalk microphone or a line-level sound source. The sound input jack accepts a standard 3.5 mm stereophonic phone plug (two signals plus ground).

The sound input jack has the following electrical characteristics:

- input impedance: 20 kΩ
- maximum input level without distortion: 2.5 V peak to peak (Vpp) maximum
- line-level microphone voltage range of 0.28 V to 2.1 V peak to peak
- input SNR <90 dB unweighted (typical) for recording to system hard disk drive or system main memory

Digitizing Sound

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

The preferred sound sampling rate for output is specified in the Monitors & Sound control panel when the sound input is not in use. The preferred output sampling rate is overridden by the setting of the input sampling rate, because the input and output sampling rates are physically locked together. The sound output sampling rate is always 44.1 kHz.

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

Video Monitor Ports

The Prototype 5 computer comes with an accelerated graphics card installed. The card provides an analog port for an external video monitor and a digital port for a digital flat-panel monitor.

Digital Monitor Connector

The connector for the digital video monitor is a standard digital-only DVI connector. Figure 3-4 shows the contact configuration and Table 3-4 lists the signal assignments.

Figure 3-4 Digital monitor connector

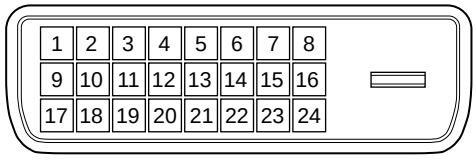


Table 3-4 Signals on the digital monitor connector

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	n. c.	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–

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 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

Analog Monitor Connector

The connector for the video monitor 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 3-5 lists the signal pin assignments.

Figure 3-5 Analog monitor connector

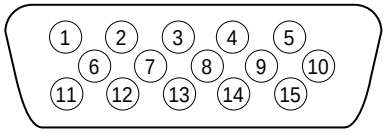


Table 3-5 Signals on the analog monitor connector

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

Monitor Adapter

A monitor adapter is required for connecting an older Apple monitor cable to the computer. The adapter enables the computer to recognize a wide range of monitor types. The adapter does not come with the computer. The Apple part number for the adapter is 590-1120.

Display Resolution Modes

When power is applied, the monitor is initially set for a display size of 640 by 480 pixels. With a multisync monitor the user can switch the monitor resolution on the fly by using the BitDepth and Resolution modules in the control strip or the Monitors & Sound control panel.

Table 3-6 shows the display resolution, vertical and horizontal scan rates, and maximum pixel depths supported by the accelerated graphics card. The 16 MB of video RAM on the accelerated graphics card supports pixel depths up to 32 bits per pixel at all resolutions.

Table 3-6 Supported display resolutions

Display resolution	Vertical scan rate	Horizontal scan rate
512 by 384	70 Hz	31.488 kHz
640 by 480	60 Hz	31.469 kHz
640 by 480	67 Hz	35.00 kHz
640 by 480	72 Hz	37.861 kHz
640 by 480	75 Hz	37.500 kHz
640 by 480	85 Hz	43.269 kHz
640 by 870	75 Hz	68.85 kHz
800 by 600	56 Hz	35.156 kHz
800 by 600	60 Hz	37.879 kHz
800 by 600	72 Hz	48.077 kHz
800 by 600	75 Hz	46.875 kHz

Table 3-6 Supported display resolutions (continued)

Display resolution	Vertical scan rate	Horizontal scan rate
800 by 600	85 Hz	53.674 kHz
832 by 624	74.5 Hz	49.725 kHz
1024 by 768	60 Hz	48.363 kHz
1024 by 768	70 Hz	56.476 kHz
1024 by 768 (VESA)	75 Hz	60.023 kHz
1024 by 768 (19” RGB)	75 Hz	60.241 kHz
1024 by 768	85 Hz	68.677 kHz
1152 by 870	75 Hz	68.681 kHz
1280 by 960	75 Hz	75.000 kHz
1280 by 1024	60 Hz	63.981 kHz
1280 by 1024	75 Hz	79.976 kHz
1280 by 1024	85 Hz	91.146 kHz
1600 by 1200	60 Hz	75 kHz
1600 by 1200	65 Hz	81.250 kHz
1600 by 1200	70 Hz	87.500 kHz
1600 by 1200	75 Hz	93.750 kHz
1920 by 1080	60 Hz	70.313 kHz
1920 by 1080	71 Hz	84.375 kHz

Graphics Acceleration Display Modes

Table 3-7 shows the display modes for QuickDraw 3D acceleration. (QuickDraw 2D acceleration is supported in all modes.)

Table 3-7 Supported graphics acceleration display modes

Display resolution	Pixel depth	Vertical scan rates	QuickDraw 3D acceleration
512 by 384	8	70 Hz	No
512 by 384	16, 32	70 Hz	Yes
640 by 480	8	60 Hz, 67 Hz, 72 Hz, 75 Hz, 85 Hz	No
640 by 480	16	60 Hz, 67 Hz, 72 Hz, 75 Hz, 85 Hz	Yes
640 by 480	32	60 Hz, 67 Hz, 72 Hz, 75 Hz, 85 Hz	Depends on application's window size
640 by 870	16	75 Hz	No
800 by 600	8, 32	56 Hz, 60 Hz, 72 Hz, 75 Hz, 85 Hz	No
800 by 600	16	56 Hz, 60 Hz, 72 Hz, 75 Hz, 85 Hz	Depends on application's window size
832 by 624	8, 32	75 Hz	No
832 by 624	16	75 Hz	Depends on application's window size
1024 by 768	8, 16	60 Hz, 70 Hz, 75 Hz	No
1152 by 870	16	75 Hz	No
1280 by 980	8	75 Hz	No
1280 by 1024	8	60 Hz, 75 Hz	No

CHAPTER 4

Expansion

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

RAM Expansion

The main logic board has four 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.

DIMM Specifications

The RAM expansion slots accept 168-pin SDRAM DIMMs that are 3.3 volt, unbuffered, 8-byte, nonparity, and PC100 compliant. The speed of the SDRAM devices must be rated at 125 MHz (8 ns) or faster.

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 computer: 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.The specification can be found on the World Wide Web at

http://www.jedec.org/download/freestd/pub95/mo-161d.pdf

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. The specification is available from the Electronics Industry Association's website, at

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

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.

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.

IMPORTANT

RAM modules for the Power Mac G4 must conform to the PC100 specification. In particular, they must behave correctly when the CKE signal is low, as defined in the specification. ▲

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.

Note

With four DIMMs of 512 MB each, the Power Mac G4 computer can accommodate 2 GB of memory. At present, the Mac OS supports up to 1.5 GB of memory, with 999 MB maximum for each application. Future releases of the Mac OS will support the full 2 GB. ◆

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 third column in Table 4-1 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. The last column shows the memory size of the largest DIMM with that device size that the computer can accommodate.

Table 4-1 Sizes of RAM expansion devices and modules

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

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
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 main logic board uses the industry-standard peripheral component interconnect (PCI) bus for an I/O expansion bus. It is a 33 MHz bus with 64-bit multiplexed address and data.

The Power Mac G4 computer also has an AGP graphics slot, which is labeled 1. It accommodates standard 32-bit, 66 MHz AGP-2X cards. The computer is always configured with a graphics card installed in slot 1, so that slot is not available for PCI card expansion unless the graphics card is removed. For information about the graphics card, see “AGP Graphics Card” (page 35).

Expansion slots 2, 3, and 4 accommodate 33 MHz +5 V PCI cards with either 32-bit or 64-bit address and data buses. 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 PCI slots support all the required PCI signals and certain optional PCI signals. The secondary PCI slots support the optional 64-bit bus extension signals and cache support signals.

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

To install or remove a PCI 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 in question.

IMPORTANT

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

For more information about the PCI expansion slot, refer to *Designing PCI Cards and Drivers for Power Macintosh Computers.*

CHAPTER 5

Software

This chapter summarizes the ROM-in-RAM design of the software and describes the changes that have been made to support the Power Mac G4 computer.

The version of the Mac OS that comes with the Power Mac G4 computer is Mac OS 9.

ROM in RAM

The system software in the Power Mac G4 computer uses the ROM-in-RAM approach also used in the iMac and the Power Macintosh G3 Series 1999 computer. With the ROM-in-RAM approach, also called the NewWorld design, a small ROM contains the code needed to initialize the hardware and load an operating system. The rest of the system code that formerly resided in the Mac OS ROM is loaded into RAM from disk or from the network.

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

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

Aspects of the New Approach

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

RAM Footprint

The Power Mac G4 computer has its Mac OS ROM image stored in RAM. The area of RAM that contains the Mac OS ROM image is excluded from the available memory space and is marked as read-only. This removes approximately 3 megabytes of RAM from availability for other uses. In effect, a

system with 64 megabytes of RAM appears to have only 61 megabytes available.

Startup Disk Control Panel

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

IMPORTANT

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

Data Structures and Files

The Mac OS ROM image is contained in a new file, named "Mac OS ROM", that is kept in the System Folder. The Mac OS ROM image is the same as it would be if it were an actual Mac OS ROM, containing the high-level software, the kernel software, and the 68K emulator.

Memory Mapping

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

IMPORTANT

Designers of DMA device drivers should refer to *Designing PCI Cards and Drivers for Power Macintosh Computers* for information about using the `PrepareMemoryForIO` function to set up mapping for physical and logical addresses. The relevant section is on pages 219–229. For device drivers running with the NewWorld software, the sentence on page 227 that says "Certain DMA transactions require both mapping tables" should be interpreted to mean "All DMA transactions require both mapping tables." ▲

Boot Process

The boot process for the Power Mac G4 computer is similar to that for other Macintosh computers that use the ROM-in-RAM approach. The PowerPC processor executes its reset vector as defined by the Hardware Initialization code. This code runs diagnostics tests, and when enough hardware initialization has been performed to run Open Firmware, the boot beep sound is played and Open Firmware begins executing. The Open Firmware module probes the system's I/O buses to determine the device configuration and builds a device tree describing the hardware it finds.

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

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

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

Some of the Mac OS ROM boot code is written in 68K code. In order to run the 68K ROM, the PowerPC Nanokernel is loaded, and the emulator task is started. The emulator begins executing code in the 68K ROM. This code uses the device tree provided by Open Firmware to install device drivers, Macintosh OS

Services (referred to as Toolbox Managers), and finally the ROM loads the rest of the operating system from the startup device.

Boot ROM Contents

The boot ROM image serves as the container for the CPU specific software required for loading the Mac OS.

Hardware Initialization Code

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

The hardware initialization code on the Power Mac G4 computer is different from that on earlier Power Macintosh models because of the new ICs (Uni-N and KeyLargo). Additional diagnostics are run out of the ROM in emulation.

Functions of the hardware initialization code include

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

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

Open Firmware

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

Functions of the Open Firmware code include

- configuration of the Uni-N and KeyLargo ICs
- construction of the device tree
- probing of the devices and inclusion of some device drivers
- selection of the boot device

On the Power Mac G4 computer, the Open Firmware code has been extended so that the device tree describes the new hardware features of the computer. The Open Firmware code also includes FCode drivers for the new hardware channels: UltraDMA66, FireWire, and USB.

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

Interrupts

The KeyLargo IC has an interrupt controller (MPIC) for the interrupts generated within the IC. The interrupt layout is determined by information in the device tree. An interrupt tree overlays the other information in the device tree and determines how the interrupts are configured.

Mac OS ROM Image File

The Mac OS ROM image file (also called the bootinfo file) is named Mac OS ROM. It includes

- a Mac OS Loader program

- a compressed Mac OS ROM image including
  - 68K Macintosh Toolbox code and data resources
  - PowerPC shared libraries
  - Nanokernel, the Mac OS 9 kernel
  - 68LC040 Emulator

The Nanokernel and the 68LC040 Emulator are low-level Mac OS initialization components that were part of BootPowerPC code in previous CPU ROMs. They are now included in the Mac OS ROM image.

Complementarily, CPU-specific hardware initialization code has been relocated into the boot ROM as described in the previous section.

System Software Modifications

The following sections describe the parts of the Mac OS ROM image that have been changed for the Mac OS 9 release to support features of the Power Mac G4 computer.

Computer Identification

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

IMPORTANT

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

Asset management software that reports the kind of machine it is run on can obtain the value of the property at `Devices:device-tree:compatible` in the name

registry. The model string is the first program-useable string in the array of C strings in the `compatible` field. For the Power Mac G4 computer, the value of the model property is `PowerMac3,1`.

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

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

Power Manager

The Power Manager has been redesigned to reduce power consumption in Sleep mode. The new version, Power Manager 2.0, is a native Mac OS manager designed to implement common power management policy across all Macintosh models by means of the new Power Plugin component.

With the Power Manager 2.0, the secondary PCI bus can be completely powered down, including the PCI bridge. To support this feature, power management support has been added to allow the Expansion Manager to install sleep / wake routines that save and restore configuration header information for PCI devices. Developers of PCI drivers should update their software to include power management sleep / wake callbacks to save and restore their PCI card state on sleep / wake. Those new drivers need to set a new driver description bit to indicate that they can operate with the new power management architecture.

IMPORTANT

Because the power is turned off in Sleep mode, any PCI card that does not support the new power management architecture will prevent the computer from entering Sleep mode.

With new power management architecture the following states are defined:

- **Run Single:** One processor is running at maximum processing capacity.
- **Idle One:** The system is idling. All clocks are running and the system can return to running code within a few nanoseconds. The processor is stopped in Doze mode. Cache coherency is maintained in this level of idle.

- **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. 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.
- **Doze:** The power to the disk drive motors and the display is turned off, but the power supply and fan are still on. The computer can still respond to network activity.
- **Sleep:** The system is completely shut down, with only the DRAM state preserved for quick recovery. The processor is powered off with its state preserved in DRAM. All clocks in the system are suspended except for the 32.768 Khz timebase crystal on the PMU99 IC. This mode allows desktop systems to meet 5W sleep requirements while providing the ability to start up without rebooting.

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

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

Suspend and Resume

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

IMPORTANT

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

The Energy Saver control panel has a checkbox that lets the user specify whether or not to save memory before the system goes into Sleep mode. The default is yes. The Energy Setting control strip module has two new items: one saves memory to disk and goes to sleep; the second saves memory and shuts off.

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

Sleep and wake queues are executed for Suspend and Resume.

ATA Manager 4.0

Mac OS 9 includes ATA Manager 4.0, which has a modular design similar to that of SCSI Manager 4.3. This modularity provides the flexibility to have multiple ATA controllers working at the same time—for example, those for the UltraDMA66 and EIDE interfaces. ATA Manager 4.0 supports both controllers together by including ATA Interface Modules (AIMs) for both.

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

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

ATA plug-ins are responsible for

- handling each request
- error handling
- returning errors

USB Drivers

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

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

USB Mass Storage Support 1.3 includes the following class drivers:

- Audio Class driver: Supports USB audio devices such as speakers and microphones.
- Mass Storage Class driver: Supports booting from a USB storage device that follows the USB Mass Storage Class specification. Mass Storage Class drivers do not support CD, CD-R, or other read-only media types.
- Communication Class driver: Supports USB communication devices that support the Abstract Control Model subclass.
- Printer Class driver: Supports USB printers. The LaserWriter 8 driver can communicate through this driver to any Postscript-based printer.
- HID driver: Provides support in InputSprockets for all HID-class devices (such as joysticks and game controllers) and for most force-feedback devices.
- Keyboard and Mouse driver: Supports all USB keyboards and mouse devices that support boot protocol (HID Class, Subclass 1).
- HUB Class driver: Supports all USB compliant hubs.

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

Other New Drivers

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

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

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

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

Legacy Drivers

The absence of serial ports, ADB ports, a SCSI port, IRTalk, and a floppy drive, and the addition of the USB and FireWire ports, may affect the behavior and

appearance of various system components. Modifications for such changes are in Mac OS 9 itself.

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

Floppy Disk Legacy

The Power Mac G4 computer has no built-in floppy disk drive, so the existing `.Sony` driver has been disabled using the same techniques as in the iMac software. MFM floppy disks can be supported by a USB-based LS-120 disk drive developed by a third party.

ADB Legacy

The Power Mac G4 computer has no ADB ports. The ADB Manager, however, is still present to retain compatibility with programs that require it.

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

SCSI Legacy

Although there is no SCSI connector on the Power Mac G4 computer, the high-level SCSI interfaces remains in the system. That allows for possible support for SCSI devices using a USB-to-SCSI adapter. Such an adapter would take the USB commands coming from the USB port and convert them into SCSI commands to send to the drive. A SCSI driver would also need to be written that would take the SCSI commands coming from the system and embed them in USB commands that would be sent to the device through the adapter.

AltiVec Acceleration and Support

AltiVec is a vector processing unit that is new with the G4 microprocessor. Some system software has been modified to take advantage of the accelerated processing that is possible with AltiVec. System software has also been modified to support low-level AltiVec operations.

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

- QuickTime: key codecs, including DV, photo JPEG, MPEG, and MPEG-2
- QuickDraw: the 2D acceleration API, which has many blit loops

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

- Nanokernel: exception handling and context switching
- Process Manager: context switching
- Block Move routines

Software

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.

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:

$*n*	hexadecimal value *n*
ADB	Apple Desktop Bus
AGP	accelerated graphics port
ATA	advanced technology attachment
ATAPI	advanced technology attachment, packet interface
AV	audiovisual
CAS	column address strobe
CD-ROM	compact disc read-only memory
CLUT	color lookup table
DAC	digital to analog converter
DBDMA	descriptor-based direct memory access
DDC	display data channel
DIMM	dual inline memory module
DIN	Deutsche Industrie Norm
DLPI	Data Link Provider Interface
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
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 3, the fourth generation of PowerPC microprocessors, incorporating AltiVec technology
GCR	group code recording
HID	human interface device, a class of USB devices
I^2C	same as IIC
I^2S	same as IIS
IC	integrated circuit
IEEE	Institute of Electrical and Electronics Engineers
IEEE 1394	the official specification for FireWire
IIC	inter-integrated circuit (an internal control bus)
IIS	inter IC sound bus
I/O	input/output
IR	infrared
IrDA	Infrared Data Association
ISO	International Organization for Standardization
JEDEC	Joint Electronics Devices Engineering Council
L2	level 2, used in reference to level of cache
LAN	local area network
MAC	media access controller
Mac OS	Macintosh Operating System
MESH	Macintosh enhanced SCSI hardware
MMU	memory management unit
MPEG	Motion Picture Experts Group
NTSC	National Television Standards Committee (the standard system used for broadcast TV in North America and Japan)
OHCI	Open Host Controller Interface
PAL	Phase Alternating Line system (the standard for broadcast TV in most of Europe, Africa, South America, and southern Asia)
Pel	pixel element; an individual red, green, or blue value of an RGB pixel

PCI	Peripheral Component Interconnect
PGA	pin grid array
PHY	physical layer
PIO	parallel input output
RAM	random-access memory
RAS	row address strobe
RAVE	Rendering Acceleration Virtual Engine
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
SCSI	Small Computer System Interface
SCC	serial communications controller
SDRAM	synchronous dynamic random access memory
SECAM	the standard system used for broadcast TV in France and the former Soviet countries
SIMM	single inline memory module
SGRAM	synchronous graphics random access memory
SO-DIMM	small outline dual inline memory module
SRAM	static random access memory
S-video	a type of video connector that keeps luminance and chrominance separate; also called a Y/C connector
USB	Universal Serial Bus
TMDS	transition minimized differential signaling
VESA	Video Electronics Standards Association
VRAM	video RAM; used for display buffers
Y/C	a type of video connector that keeps luminance and chrominance separate; also called an S-video connector
YUV	a video signal format with separate luminance and chrominance components

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