Developer Note

Power Mac G4 Cube

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About This Note

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

This developer note is intended to help hardware and software developers design products that are compatible with the Macintosh products described here. If you are not already familiar with Macintosh computers or if you would simply like additional technical information, you should refer to Appendix A, "Supplemental Reference Documents,"

The information is arranged in four chapters and two appendixes:

- Chapter 1, "Introduction," gives a summary of the features of the Power Mac G4 Cube, describes the physical appearance of its enclosure, and describes key features of the system software.
- Chapter 2, "Architecture," describes the internal organization of the computer. It includes a functional block diagram and descriptions of the main components on the logic board.
- Chapter 3, "Devices and Ports," describes the built-in I/O devices and the external I/O ports.
- Chapter 4, "RAM Expansion," describes the RAM expansion slots and provides specifications for RAM expansion modules.
- Appendix A, "Supplemental Reference Documents," tells where to obtain more information about the technologies mentioned in this developer note.
- Appendix B, "Conventions and Abbreviations," lists the standard units and abbreviations used in this developer note.

Introduction

The Power Mac G4 Cube computer combines the power of the PowerPC G4 microprocessor with a stylish, compact enclosure.

Hardware Features

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

- **Microprocessor:** The G4 Cube has a PowerPC G4 microprocessor running at a clock frequency of 450 or 500 MHz depending on model. See "PowerPC G4 Microprocessor" (page 19).
- **Cache:** The G4 Cube has 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:** The G4 Cube has a 64-bit wide data bus and a 32-bit wide address bus with a 100 MHz bus clock. See "Main ICs and Buses" (page 19).
- **RAM:** The G4 Cube has three 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 slot. See "RAM Expansion" (page 53).
- **External video monitor:** The built-in graphics card supports both analog and digital external video monitors. See "Video Monitor Ports" (page 41).
- **Graphics acceleration:** The built-in graphics card provides 2D and 3D hardware graphics acceleration using an ATI RAGE 128 PRO or ATI RADEON graphics controller. See "Graphics Cards" (page 22).

- **Sound:** The G4 Cube supports digital audio input and output by way of the USB ports. See “Sound System” (page 50).
- **Hard disk:** The G4 Cube has as an internal Ultra DMA hard disk with a capacity of 20, 30, or 40 GB. See “Hard Disk Drive” (page 40).
- **DVD-ROM drive:** The G4 Cube has an 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. See “DVD-ROM Drive” (page 41).
- **USB ports:** The G4 Cube has two USB ports, described in “USB Ports” (page 29). The computer comes with a USB keyboard that has two additional USB ports; see “Keyboard” (page 47).
- **Ethernet:** The G4 Cube has a built in Ethernet port with an RJ-45 connector for 10Base-T or 100Base-T operation. Gigabit Ethernet (10-, 100-, or 1000-Base-T) is available as an option. See “Ethernet Port” (page 35).
- **Wireless LAN:** The G4 Cube has an internal wireless LAN module is available as a build-to-order option or as a user-installable upgrade. See “AirPort Card Wireless LAN Module” (page 38).
- **FireWire ports:** The G4 Cube has two external IEEE 1394a high-speed serial FireWire ports. See “FireWire Ports” (page 33).
- **Modem:** The G4 Cube comes with a built-in Apple 56 Kbps modem. The modem supports K56flex and V.90 modem standards. See “Internal Modem” (page 38).
- **Keyboard:** The G4 Cube comes with an Apple Pro keyboard, which has full-sized function and navigation keys. The keyboard is also a bus-powered USB hub with two USB ports. See “Keyboard” (page 47).
- **Mouse:** The G4 Cube comes with Apple Pro mouse, which has an optical sensor and operates as a low-speed (1.5 Mbps) USB device. See “Mouse” (page 50).
- **Energy saving:** Sleep, startup, and shutdown scheduling can be controlled with an Energy Saver control panel.
- **Size and weight:** The G4 Cube is 24.8 cm (9.8 inches) high, 19.5 cm (7.7 inches) wide, and 19.5 cm (7.7 inches) deep; it weighs 6.4 kg (14.0 pounds).

Features of the Enclosure

The Power Mac G4 Cube is small—only 8 inches square. It is also quiet; it is cooled by convection, so it has no fan.

The top of the Power Mac G4 Cube's enclosure has the slot for the DVD-ROM drive, the power button, and the power-on light. The power button is a touch sensitive switch with no moving parts.

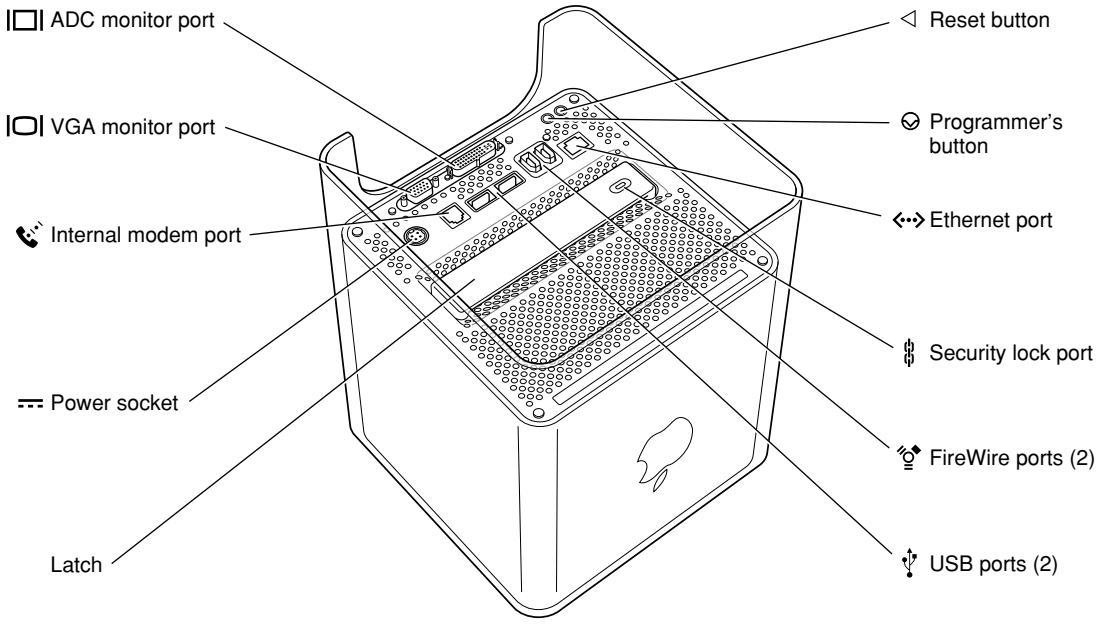
Touching the power button when the computer is running puts the computer into Sleep mode. To remind the user that the computer is still running, the power-on light pulsates slowly when the computer is in Sleep mode.

Note
Holding down the power button for several seconds turns off the computer. This is not the recommended method because it doesn't engage the Shut Down Manager, so currently open documents are not saved. ◆

The power connector and the I/O ports are on the bottom panel, as shown in Figure 1-1. The reset button and the NMI button are also located on the bottom.

The transparent outer shell has an opening on the lower part of one side to allow space for the power and I/O cables. The I/O ports are on the part of the bottom panel that is nearest the opening.

Figure 1-1 Bottom view



System Software

The Power Mac G4 Cube comes with Mac OS 9 installed. For the latest information about Mac OS 9, see the references listed in "Mac OS 9" (page 60).

Like the system software on other Macintosh models since the introduction of the iMac, system software for the Power Mac G4 Cube has Open Firmware booting and Mac OS ROM in RAM. For more information, see the references in "ROM-in-RAM Architecture" (page 61) and "Open Firmware" (page 62).

Booting From External Drives

The Power Mac G4 Cube can boot from a USB storage device that follows the USB Mass Storage Class specification. For information about the USB specifications, see the references in "USB Interface" (page 64).

The Power Mac G4 Cube can boot from a FireWire storage device that implements SBP-2 (Serial Bus Protocol) with the RBC (reduced block commands) command set. For information about the FireWire specifications, see the references in "FireWire Interface" (page 64).

Target Disk Mode

The user has the option at boot time to put the computer into a mode of operation called Target Disk Mode (TDM). This mode is similar to SCSI Disk mode on a PowerBook computer equipped with a SCSI port, except it uses a FireWire cable instead of a special SCSI cable.

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

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

The G4 Cube can operate in Target Disk Mode as long as the other computer has a FireWire port and the FireWire version 2.3 or later software.

To put the G4 Cube into Target Disk mode, you restart the computer and holds down the T key until the FireWire icon appears on the display. You then connect a FireWire cable from the G4 Cube to the other computer. When the other computer completes the FireWire connection, a TDM icon appears on its display.

If you disconnect the FireWire cable or turn off the G4 Cube while in Target Disk Mode, an alert appears on the other computer asking you to reconnect the TDM volume.

To take the G4 Cube out of Target Disk Mode, you drag the TDM icon on the other computer to the trash, then turn off the G4 Cube.

For more information, see "Target Disk Mode" (page 61).

Computer Identification

Rather than reading the box flag or the model string and then making assumptions about the computer's features, applications that need to find out the features of the machine should use Gestalt calls to test for the features they require.

Asset management software that reports the kind of machine it is run on can obtain the value of the property at `Devices:device-tree:compatible` in the name registry. The model string is the first program-usable string in the array of C strings in the `compatible` field. For the Power Mac G4 Cube, the value of the model property is `PowerMac5,1`.

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.

Velocity Engine Acceleration

The Velocity Engine (also called 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 it makes possible. System software has also been modified to support low-level operations using the Velocity Engine.

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

- QuickTime: key codecs, including DV and photo JPEG

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

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

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

CHAPTER 2

Architecture

This chapter describes the architecture of the Power Mac G4 Cube 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.

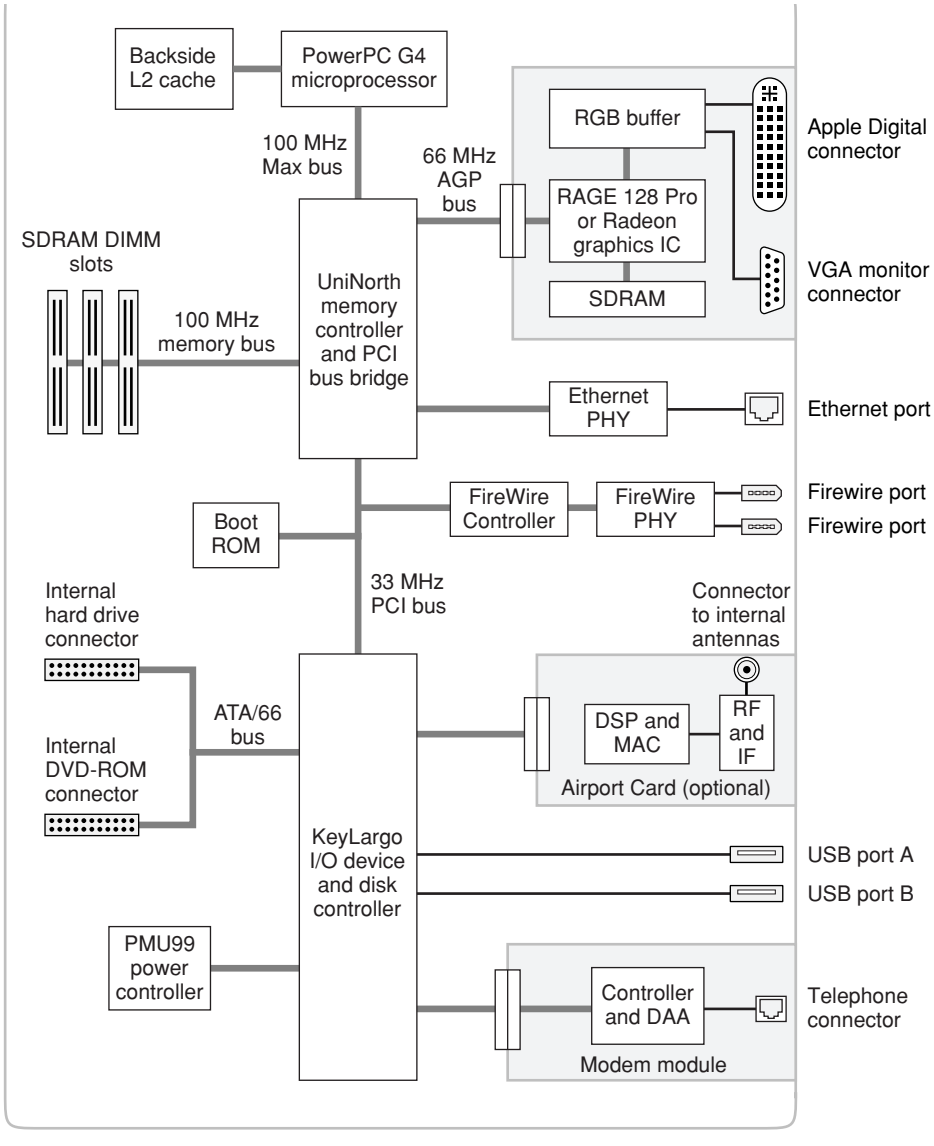
Block Diagram and Buses

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

Block Diagram

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

Figure 2-1 Simplified block diagram



Main ICs and Buses

The architecture of the Power Mac G4 Cube is designed around the PowerPC G4 microprocessor and two custom ICs: the Uni-N memory controller and bus bridge, and the KeyLargo I/O device controller. Those three ICs occupy the center of the block diagram.

The PowerPC G4 microprocessor is connected to the Uni-N memory controller and bus bridge IC by a MaxBus bus with 64 data lines and a bus clock speed of 100 MHz. The Uni-N IC has other buses that connect with the KeyLargo IC, the main system RAM, and the graphics IC. The buses implemented by the Uni-N IC are summarized in Table 2-1, which is in the section "Memory Controller and Bus Bridge".

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

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

Processor and Cache

The PowerPC G4 microprocessor and the backside L2 cache are located on the processor card.

PowerPC G4 Microprocessor

The processor in the Power Mac G4 Cube is a PowerPC G4 microprocessor running at a clock frequency of 450 or 500 MHz.

The PowerPC G4 microprocessor uses a pipelined system bus that is more efficient than the system bus on the PowerPC G3 microprocessors. The 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 more information, see the references shown in "PowerPC G4 Microprocessor" (page 59).

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 Cube does not use jumpers to control the clock speeds of the processor and cache. ◆

Memory Controller and Bus Bridge

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

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

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

Name of bus	Destinations	Width of data path	Bus clock speed
Maxbus	Microprocessor	64 bits	100 MHz
Memory bus	System RAM	64 bits	100 MHz
PCI bus	KeyLargo IC and Boot ROM	32 bits	33 MHz
AGP bus	Graphics IC	32 bits	66 MHz (AGP or AGP2)

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

System RAM

The memory subsystem in the Power Mac G4 Cube supports three slots for 168-pin DIMMs (dual inline memory modules). The data bus to the RAM and DIMM is 64 bits wide, and the memory interface is synchronized to the MaxBus interface at 100 MHz. For more information, see “RAM Expansion” (page 53).

Boot ROM

The boot ROM is connected to the Uni-N IC by way of the PCI bus plus additional control signals. The boot ROM is a 1 M by 8 bit device.

FireWire Controller

The PCI bus supports an IEEE 1394 FireWire controller IC with a maximum data rate of 400 megabits (50 megabytes) per second. The Uni-N IC provides DB-DMA support by way of the PCI bus for the FireWire interface.

The FireWire controller IC implements the FireWire link layer. The physical layer IC (PHY) implements the electrical signaling protocol of the FireWire interface. The PHY supports two FireWire ports by way of the external connectors on the bottom panel.

The computer can accept 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.

Ethernet Controller

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

The controller is connected to a PHY interface IC that is capable of operating in either 10-BaseT or 100-BaseTX mode. The PHY installed with the Gigabit Ethernet option can also operate in 1000-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 35).

Graphics Cards

The computer comes with a graphics card installed in the AGP slot. Two graphics cards are available: the ATI RAGE 128 PRO graphics card and the ATI RADEON graphics card.

RAGE 128 PRO Graphics Card

The ATI RAGE 128 PRO card is a graphics accelerator card that supports the highest resolutions available on all Apple displays.

RAGE 128 PRO Graphics Card Specifications

The RAGE 128 PRO graphics card has the following specifications:

- ATI's RAGE 128 PRO graphics IC
- 16 MB SDRAM
- VGA connector for an analog video monitor
- ADC connector for either an analog or digital monitor, plus USB and power
- support for up to 1920 by 1200 pixels on an analog monitor
- support for up to 1600 by 1200 pixels on a digital monitor

For more information about the features of the graphics card and the monitors it supports, see "Video Monitor Ports" (page 41).

RAGE 128 PRO Graphics Card Display Memory

The display memory on the RAGE 128 PRO graphics card consists of 16 MB of 140 MHz SDRAM devices configured to make a 128-bit data bus. The display memory cannot be expanded by the user.

The RAGE 128 PRO 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 1200 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 41).

RADEON Graphics Card

The ATI RADEON graphics card has the capabilities of the RAGE 128 PRO cards plus more powerful 3D features for advanced 3D games and complex 3D modeling and rendering.

RADEON Graphics Card Specifications

The RAGE 128 PRO graphics card has the following specifications:

- ATI's RADEON graphics IC
- 32 MB DDR SDRAM
- VGA connector for an analog video monitor
- ADC connector for either an analog or digital monitor, plus USB and power
- support for up to 1920 by 1200 pixels on an analog monitor
- support for up to 1600 by 1200 pixels on a digital monitor

For more information about the features of the graphics card and the monitors it supports, see "Video Monitor Ports" (page 41).

RADEON Graphics Card Display Memory

The display memory on the RADEON graphics card consists of 32 MB DDR SDRAM devices configured to make a 128-bit data bus. The display memory cannot be expanded by the user.

The DDR RAM on the RADEON graphics card has a peak bandwidth of 4.8 gigabytes per second, which is double the throughput of standard video RAM.

The RADEON graphics card has 32 MB of video memory, allowing the analog monitor display to have pixel depths of 8, 16, or 32 bpp for all display sizes up to 1920 by 1200 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 41).

I/O Device Controller

The I/O controller IC in the Power Mac G4 Cube is a custom IC called KeyLargo. It is an integrated I/O controller and DMA engine for use in Power Macintosh computers with a PCI bus.

The KeyLargo IC provides the interface and control signals for the following devices:

- the internal hard drive
- the CD-ROM or DVD-ROM drive
- the USB ports
- the built-in modem
- the power manager microcontroller
- the optional wireless LAN module

DMA Support

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

- Ultra DMA IDE interface to the internal hard drive and the CD-ROM drive or DVD-ROM drive
- modem slot interface to the built-in modem

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

Interrupt Support

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

USB Interface

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

USB port 2 (the connector closest to the FireWire connectors) is also connected to the USB pins on the ADC connector. USB devices connected to an ADC monitor share the root hub with USB port 2.

The two external USB connectors support USB devices with data transfer rates of 1.5 Mbps or 12 Mbps. For more information about the connectors, see "USB Ports" (page 29).

USB devices connected to the Power Mac G4 Cube are required to support USB-suspend mode as defined in the USB specification. Information about the operation of USB-suspend mode on Macintosh computers is included in the *Mac OS USB DDK API Reference*. To obtain that document or Apple's USB DDK, see the references shown in "USB Interface" (page 64).

The USB ports on the Power Mac G4 Cube comply with the Universal Serial Bus Specification 1.1 Final Draft Revision. The USB controllers comply with the Open Host Controller Interface (OHCI) specification.

Ultra DMA Interface

In the Power Mac G4 Cube, the KeyLargo IC provides an Ultra DMA IDE (integrated drive electronics) channel that is connected to the internal hard disk drive and the CD-ROM or DVD-ROM drive. The KeyLargo IC provides DB-DMA (descriptor-based direct memory access) support for the Ultra DMA interface.

The Ultra DMA IDE interface, also called Ultra-DMA/66 and ATA-5, is an improved version of the EIDE interface.

The internal hard disk drive is connected as device 0 (master) in an ATA Device 0/1 configuration; the CD-ROM drive or DVD-ROM drive is an ATAPI drive and is connected as device 1 (slave).

Modem Support

The KeyLargo IC has a Macintosh serial port that is the interface to the modem connector. The KeyLargo IC provides DB-DMA support for the modem interface. The modem provides analog call progress signals, which are digitized by the sound codec and output by way of the USB ports.

The internal hardware modem is a separate module that contains the modem ICs (controller and datapump) and the interface to the telephone line (DAA). For more information about the modem, see "Internal Modem" (page 38).

USB Sound Support

Sound signals are handled as digital data and are sent and received by way of the USB ports. Even the startup sounds (boot beep, chimes) are sent through the USB ports. For a description of the features of the sound system, see “Sound System” (page 50).

Power Controller

The power management controller in the Power Mac G4 Cube is a microcontroller called the PMU99. Its operation is managed by the Power Manager software. For more information, see “Power Manager” (page 61).

Wireless LAN Module

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

The 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 enclosure.

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 38).

Devices and Ports

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

USB Ports

The Power Mac G4 Cube has two 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. See “USB Interface” (page 25).

For more information about USB on Macintosh computers, please refer to Apple Computer’s *Mac OS USB DDK API Reference* and the other sources listed in “USB Interface” (page 64).

USB Connectors

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

Figure 3-1 USB Type A port and pins

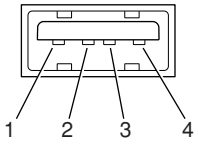


Table 3-1 Signals on the USB port

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

The Power Mac G4 Cube provides 5-volt power to the USB ports. The maximum total current available is 500 mA on each port.

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

The Power Mac G4 Cube comes with version 1.4.3 or later 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.

“Connect and Resume”

“USB Storage Devices”

“USB Controller”

Connect and Resume

The KeyLargo IC sends a signal to the computer to wake from Sleep mode on connect, disconnect, and resume events from compatible USB devices that support the USB-suspend mode. Information about the operation of USB-suspend mode on Macintosh computers is included in the *Mac OS USB DDK API Reference*. To obtain that document or Apple's USB DDK, see the references shown in "USB Interface" (page 64).

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

USB Controller

The Power Mac G4 Cube uses an Open Host Controller Interface (OHCI) controller for USB communication. Some early USB devices (most notably keyboards) can't interoperate with an OHCI controller. Those devices are not supported by the Macintosh USB system software.

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"

"Serial Port Compatibility"

"Not for Networking"

ADB Compatibility

Apple is providing 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 Cube, but they will be treated as having an ADB device ID of 2.

IMPORTANT
The ADB/USB shim does not support other types of ADB devices. ▲

Note
The ADB/USB shim is built into the Mac OS ROM image on the Power Mac G4 Cube, as it is on all Macintosh computers that have USB ports. For more information about the Mac OS ROM, see the references in "ROM-in-RAM Architecture" (page 61). ◆

Serial Port Compatibility

Mac OS 8.6 includes a Serial shim, called SerialShimLib, that enables processes that use the Communications Toolbox CRM to find and use a USB 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. For more information, see the references in "USB Interface" (page 64).

Game Controllers

USB game controllers are supported by the InputSprocket component of the Apple Games Sprockets software architecture. For information about InputSprocket software and the InputSprocket APIs, see the references in "USB Interface" (page 64).

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 Cube computers is through the built-in Ethernet port or by using AirPort Cards.

FireWire Ports

The Power Mac G4 Cube has two external FireWire IEEE 1394 ports. The features of the FireWire ports are:

- Support serial I/O at 100, 200, and 400 Mbps (megabits per second)
- Share up to 12 watts of power when the computer system is on
- Support up to 62 devices

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

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

Users can connect two computers to each other using a FireWire cable and exchange data by using Target Disk Mode, as described in “Target Disk Mode” (page 15).

FireWire Connector

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

Figure 3-2 FireWire connector

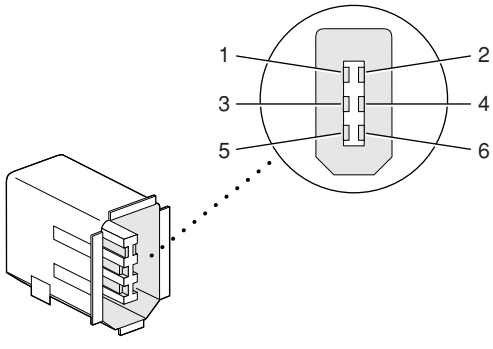


Table 3-2 Signals on the FireWire connector

Pin	Signal name	Description
1	Power	unregulated DC; 18-28 V no load
2	Ground	Ground return for power and inner cable shield
3	TPB-	Twisted-pair B, differential signals
4	TPB+	Twisted-pair B, differential signals
5	TPA-	Twisted-pair A, differential signals
6	TPA+	Twisted-pair A, differential signals
Shell	—	Outer cable shield

When the computer is on, the power pin provides a maximum voltage of 28 V (no load) and up to 12 W total power (shared by both connectors). Maximum current is 0.5 A and is controlled by an auto-resetting fuse.

The power pin can accept external power at 8 to 33 V, in conformity with the 1394 standard, to keep the FireWire bus operational when the computer is turned off.

Pin 2 of the 6-pin FireWire connector is ground for both power and 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, see the references in “FireWire Interface” (page 64).

Ethernet Port

The Power Mac G4 Cube has a built-in 10/100Base-T Ethernet port. A Gigabit Ethernet port that supports 10/100/1000Base-T operations is available as an option.

10/100Base-T Ethernet Port

The user can connect the Ethernet port to either a 10Base-T or a 100Base-TX hub; the port will automatically sense which type of hub is connected.

The connector for the Ethernet port is a an RJ-45 connector located on the I/O panel. Table 3-3 shows the signals and pin assignments on the connector.

Table 3-3 Signals on the Ethernet connector

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

The Ethernet interface in the Power Mac G4 Cube conforms to the ISO/IEC 802.3 specification, where applicable.

Optional Gigabit Ethernet Port

The optional Gigabit Ethernet port supports 10Base-T, 100Base-T, and 1000Base-T transfer rates. In operation, the actual speed of the link is auto-negotiated between the computer's PHY device and the network bridge or router to which it is connected.

The connector for the Gigabit Ethernet port is an RJ-45 connector on the back of the computer. Table 3-4 shows the signals and pin assignments for 10Base-T and 100Base-T operation. Table 3-5 shows the signals and pin assignments for 1000Base-T operation.

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

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

Table 3-5 Signals for 1000Base-T operation

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

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

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

Internal Modem

The Power Mac G4 Cube comes with a built-in modem. The telephone connector for the modem is an RJ-11 connector on the I/O panel.

The modem has the following features:

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

The modem appears to the system as a serial port that responds to the typical AT commands. The modem provides digital sound output for monitoring call progress by way of USB speakers.

AirPort Card Wireless LAN Module

The Power Mac G4 Cube supports the AirPort Card, Apple's 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 email 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".

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 56k hardware modem.

Data Security

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

- The AirPort Card 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 AirPort Card software 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 AirPort Card software 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 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 direct-sequence spread-spectrum (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.

Hard Disk Drive

The internal hard disk drive has a storage capacity of 20, 30, or 40 GB. The drive uses the Ultra DMA ATA interface, which is also referred to as the ATA-5 interface. The transfer rate is 66 MB per second, which is sometimes referred to as ATA-66 or UDMA Mode 4. The internal hard disk drive is connected as device 0 (master) in an ATA Device 0/1 configuration.

The software that supports the internal hard disk is the same as that in previous Macintosh models with internal ATA drives and includes DMA support. To obtain information about that software and about the ANSI standard for the Ultra DMA ATA interface, see “ATA Devices” (page 63).

DVD-ROM Drive

The Power Mac G4 Cube has an internal 6x-speed DVD-ROM drive. The drive has a slot for loading and unloading the disk.

The DVD-ROM drive supports the following disc formats:

- DVD-RAM bare one sided disc, 2.6 GB per side, reading 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, Photo CD, CD-RW, CD-R, CD-Extra
- CD-I (Mode 2, Forms 1 and 2), CD-I Ready, CD-I Bridge
- Video CD

▲ **WARNING**
Only 77 mm or 120 mm circular discs work in the slot loading DVD-ROM drive. Inserting an unusually sized or shaped disc may damage the drive. ▲

The DVD-ROM drive is an ATAPI drive and is connected as device 1 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.

Video Monitor Ports

The Power Mac G4 Cube comes with an accelerated graphics card installed. The card provides an Apple display connector (ADC) for an Apple intelligent monitor and a VGA connector for an analog video monitor.

Note
Two graphics cards are available, the ATI RAGE 128 PRO card and the ATI RADEON card. Both have the same connectors and support the same types of monitors. For information about the cards, see "Graphics Cards" (page 22). ◆

Apple Display Connector

The Apple Display Connector (ADC) carries both digital and analog video signals. It also carries USB and control signals along with power for an external monitor such as the 17-inch Apple Studio Display, the 15-inch plat-panel Apple Studio Display, or the 22-inch Apple Cinema Display.

Figure 3-3 shows the contact configuration; Table 3-6 and Table 3-7 list the signals and pin assignments.

Figure 3-3 Apple Display Connector

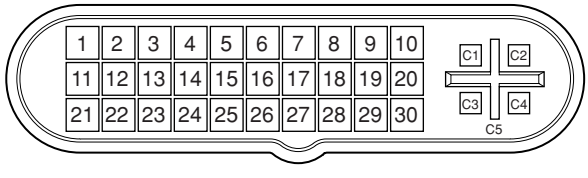


Table 3-6 Digital signals on the Apple display connector

Pin	Signal name	Pin	Signal name
1	28-V Supply	16	TMDS Data1/3 Shield
2	28-V Supply	17	TMDS Data3–
3	LED	18	TMDS Data3+
4	TMDS Data0–	19	DDC CLock
5	TMDS Data0+	20	Clock Return
6	TMDS Data0/5 Shield	21	USB Data+
7	TMDS Data5–	22	USB Data–

Table 3-6 Digital signals on the Apple display connector (continued)

Pin	Signal name	Pin	Signal name
8	TMDS Data5+	23	USB Return
9	DDC Data	24	TMDS Data2–
10	Vsync	25	TMDS Data2+
11	28-V Return	26	TMDS Data2/4 Shield
12	28-V Return	27	TMDS Data4–
13	Soft Power	28	TMDS Data4+
14	TMDS Data1–	29	Clock+
15	TMDS Data1+	30	Clock–

Table 3-7 Analog signals on the Apple display connector

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

The maximum current available from the 28-V supply for the external monitor is 4.0 A.

The Soft Power signal puts the monitor into a low-power mode when the computer is in Sleep mode.

The graphics data sent to the digital monitor use transition minimized differential signaling (TMDS). TMDS uses an encoding algorithm to convert bytes of graphics data into characters that are transition-minimized to reduce EMI with copper cables and DC-balanced for transmission over fiber optic cables. The TMDS algorithm also provides robust clock recovery for greater skew tolerance with longer cables or low cost short cables. For additional

information about TMDS, see the references in "Digital Visual Interface" (page 65).

Digital Display Resolutions

Table 3-8 shows the resolutions supported on the digital interface. The 16 MB of video RAM on the accelerated graphics card supports pixel depths up to 32 bits per pixel at all resolutions.

Not all resolutions are available on all monitors.

Table 3-8 Digital display resolutions

640 by 480	1024 by 768
800 by 500	1280 by 800
800 by 512	1280 by 1024
800 by 600	1600 by 1024
1024 by 640	1600 by 1200

VGA Monitor Connector

The VGA monitor connector is a three-row DB-9/15 (also called mini sub D15) connector for use with a VGA, SVGA, or XGA monitor. Figure 3-4 shows the pin configuration and Table 3-9 lists the signals and pin assignments.

Figure 3-4 VGA monitor connector

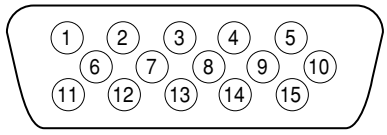


Table 3-9 Signals on the video connector

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

The SDA and SCL signals use I^2C protocols to transmit Extended Display Identification Data (EDID) from the display to the computer. The specifications for the SDA and SCL signals are included in the Display Data Channel (DDC) Standard published by the Video Electronics Standards Association (VESA). To

obtain more information see “Video Electronics Standards Association” (page 65).

VGA Monitor Adapter

A monitor adapter is required for connecting an older Apple monitor cable to the computer’s VGA connector. 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.

Analog Display Resolutions

Table 3-10 shows the display resolutions, vertical scan rates, and maximum pixel depths supported on analog (CRT) monitors. 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 during operation by using the Monitors control panel or the BitDepth and Resolution modules in the control strip.

Table 3-10 Analog display resolutions

Display resolution	Vertical scan rate	Pixel depth	Display resolution	Vertical scan rate	Pixel depth
640 by 480	60 Hz	32	1024 by 768 (VESA)	75 Hz	32
640 by 480	67 Hz	32	1024 by 768 (19″ RGB)	75 Hz	32
640 by 480	72 Hz	32	1024 by 768	85 Hz	32
640 by 480	75 Hz	32	1024 by 768	90 Hz	32
640 by 480	85 Hz	32	1024 by 768	100 Hz	32
640 by 480	90 Hz	32	1024 by 768	120 Hz	32
640 by 480	100 Hz	32	1152 by 870	75 Hz	32
640 by 480	120 Hz	32	1280 by 960	75 Hz	32
640 by 870	75 Hz	32	1280 by 1024	60 Hz	32

Table 3-10 Analog display resolutions (continued)

Display resolution	Vertical scan rate	Pixel depth	Display resolution	Vertical scan rate	Pixel depth
800 by 600	56 Hz	32	1280 by 1024	75 Hz	32
800 by 600	60 Hz	32	1280 by 1024	80 Hz	32
800 by 600	72 Hz	32	1600 by 1200	60 Hz	32
800 by 600	75 Hz	32	1600 by 1200	65 Hz	32
800 by 600	85 Hz	32	1600 by 1200	70 Hz	32
800 by 600	90 Hz	32	1600 by 1200	75 Hz	32
800 by 600	100 Hz	32	1600 by 1200	85 Hz	32
800 by 600	120 Hz	32	1920 by 1080	60 Hz	32
832 by 624	75 Hz	32	1920 by 1080	72 Hz	32
1024 by 768	60 Hz	32	1920 by 1200	76	32
1024 by 768	70 Hz	32			

Keyboard

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

The keyboard has an attached 1-meter cable.

Keyboard Features

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

- Slope settable to either 0 or 6 degrees
- 108 keys (on the ANSI versions)
- 15 function keys, programmable by the user
- 6 editing keys (Page Up, Page Down, Home, End, Forward Delete, and Help)

- USB HID Consumer Page Usage control keys (Volume Up, Volume Down, Mute, and Eject)
- Full travel, standard pitch keys on alphanumeric, editing, and keypad sections, including function keys and cursor position keys
- Localized worldwide: 33 versions, 3 standard layouts (ANSI, JIS, ISO)
- LED indicators in the Caps Lock and Num Lock keys
- USB hub functionality with two USB sockets

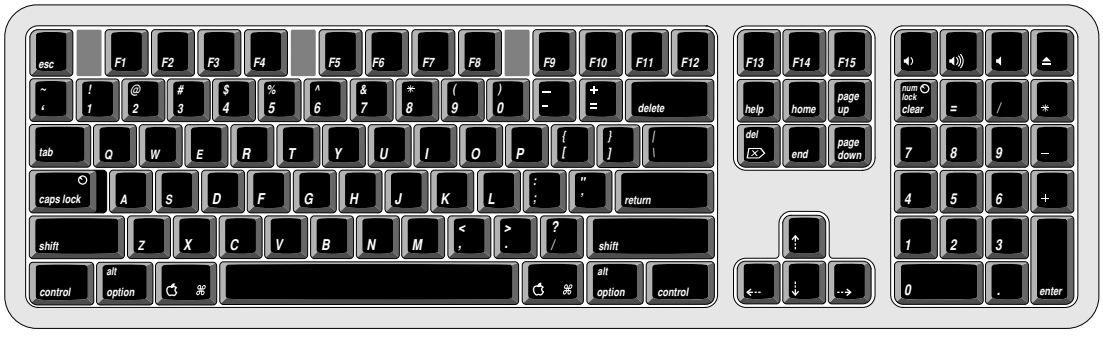
Note
There is no power key on this keyboard. ◆

Keyboard Layout

There are localized versions of the Apple Pro Keyboard for use in different parts of the world. The three standards used are ANSI (US and North America), JIS (Japan), and ISO (Europe). Figure 3-5 shows the keyboard layout for the ANSI keyboard. Applications can determine which keyboard is connected by calling the Gestalt Manager and checking for the corresponding value of the `gestaltKeyboardType` selector:

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

Figure 3-5 ANSI keyboard layout



Programming the Function Keys

The function keys (F1–F15) can be programmed by the user through the Keyboard Control Panel. Operations that can be assigned include

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

Multi-Media Control Keys

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

Keyboard and USB

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

The USB ports on the Apple Pro Keyboard do not support USB speakers.

▲ **WARNING**
A bus-powered hub as defined in the USB specification does not provide enough power to support a second bus-powered hub. A bus-powered hub must be connected to a USB port on the computer or on a fully powered hub, not to a port on the keyboard. ▲

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

Programmer's Switches

Key combinations for programmer's switches that used the Power button on earlier models now use the Eject button. Here are the key combinations for the Power Mac G4 Cube.

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

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

Mouse

The Power Mac G4 Cube comes with an Apple Pro Mouse. The Apple Pro Mouse is a new design that uses optical tracking in place of the traditional rolling ball. It works on almost any surface, though non-reflective, opaque surface without repetitive patterns work best.

Sound System

The Power Mac G4 Cube has the following sound features:

- Separate stereo speakers and digital amplifier module
- Headphone jack (on the digital amplifier module)
- Sound input and output through the USB and FireWire ports.

Amplifier and Speakers

The Power Mac G4 Cube comes with a pair of stereo speakers and a separate digital audio amplifier. The connection from the computer to the amplifier is a single cable that carries USB signals and power. Power is provided by the USB

ports on the G4 Cube or on an Apple display that uses the Apple display connector (ADC).

The digital amplifier module supplies up to 10 W per channel.

The speakers have a frequency response of 80 Hz to 20 kHz.

Headphone Jack

A headphone jack is located on the digital audio amplifier module. The headphone jack is a stereo mini-jack for connecting a pair of low-impedance headphones. It can also be used to drive a 10K-ohm audio line input.

The recommended minimum impedance is 32 ohms. Headphones with lower impedance can be used, but with some degradation in performance.

Digital Audio

The Power Mac G4 Cube supports third-party digital audio peripherals connected to the USB ports. For information about USB audio class devices, see the references at “USB Interface” (page 64).

RAM Expansion

This chapter tells how to gain access to the expansion slots in the Power Mac G4 Cube computer and describes the RAM expansion modules.

RAM Expansion Slots

The Power Mac G4 Cube has three RAM expansion slots. The slots accept standard PC-100 168-pin DIMMs (dual inline memory modules) using SDRAM devices. A DIMM for a Power Mac G4 Cube can contain either 32, 64, 128, 256, or 512 MB of memory.

To get access to the RAM expansion slots, you must remove the computer core from the outer shell. After shutting down the computer, you turn it upside down and place it on a soft cloth to avoid scratching the case. When you press down on the handle, the handle rises gently into its extended position. Then you can grasp the handle and lift the core from the outer shell.

When the computer core is out of its enclosure, the portion of the main logic board that contains the three RAM expansion slots is visible along one corner, to the left of the video graphics card. One slot is normally occupied by the factory-installed RAM DIMM. The other RAM expansion slots are available for user-installed DIMMs.

IMPORTANT

The user should be reminded to observe the usual precautions to avoid damage to the electronic components due to static electricity. ▲

RAM Expansion Modules

The RAM expansion modules for the Power Mac G4 Cube computer are 168-pin SDRAM DIMMs that are 3.3 volt, unbuffered, 8-byte, non-parity, and PC-100 compliant. The speed of the SDRAM devices must be rated at 125 MHz (8 ns) or faster.

IMPORTANT

RAM expansion DIMMs for the Power Mac G4 Cube must be PC-100 compliant and use SDRAM devices. If the user installs only DIMMs that use EDO or SGRAM devices, the computer will flash the power indicator several times when the user attempts to restart the computer. If the user mixes different types of DIMMs, the computer will use only the PC-100 SDRAM devices and ignore the others. ▲

Mechanical Design of RAM DIMMs

The mechanical characteristics of the RAM expansion DIMM are given in the JEDEC specification for the 168-pin 8-byte DRAM DIMM. The specification number is JEDEC MO-161-D. To obtain the specification, see the references at “RAM Expansion Modules” (page 63).

The maximum height of DIMMs for use in the Power Mac G4 Cube is 1.38 inches.

Electrical Design of RAM DIMMs

The electrical characteristics of the RAM DIMM are given in section 4.5.6 of the JEDEC Standard 21-C. To obtain the specification, see the references in “RAM Expansion Modules” (page 63).

The specification defines several attributes of the DIMM, including storage capacity and configuration, connector pin assignments, and electrical loading.

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 to be stored in the presence detect EEPROM can be found in sections 4.5.4 and 4.1.2.5 of the JEDEC standard 21-C specification.

The RAM DIMMs are required to be the PC-100 compliant. To obtain the PC-100 specification, see the references in “RAM Expansion Modules” (page 63).

The SDRAM devices used in the RAM expansion modules must be self-refresh type devices for operation from a 3.3-V power supply. The speed of the SDRAM devices must be 125 MHz or greater, corresponding to a cycle time of 8 ns or less, as required by the PC-100 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.

Table 4-1 shows information about the different sizes of SDRAM devices used in the memory modules. The memory controller supports 64, 128, 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 DIMMs

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	128 MB
64 Mbits	1 M x 16 x 4	4	32 MB	128 MB

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

64 Mbits	1 M x 32 x 2	2	16 MB	128 MB
64 Mbits	512 K x 32 x 4	2	16 MB	128 MB
128 Mbits	8 M x 8 x 2	8	128 MB	256 MB
128 Mbits	4 M x 8 x 4	8	128 MB	256 MB
128 Mbits	4 M x 16 x 2	4	64 MB	256 MB
128 Mbits	2 M x 16 x 4	4	64 MB	256 MB
128 Mbits	2 M x 32 x 2	2	32 MB	256 MB
128 Mbits	1 M x 32 x 4	2	32 MB	256 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

The Power Mac G4 Cube accepts one, two, or three DIMMs. Any of the supported DIMM sizes can be installed in any slot. The memory controller configures the combined memory of the DIMMs into a contiguous array of memory addresses.

Note
The Power Mac G4 Cube does not support memory interleaving, so installing a pair of DIMMs of the same size does not result in any performance gain. ◆

RAM Addressing

Signals A[0] – A[12] and BA[0] – BA[1] on each RAM DIMM make up a 15-bit multiplexed address bus that can support several different types of SDRAM devices. Table 4-2 lists the types of devices that can be used in the Power Mac G4 Cube by size, configuration, and sizes of row and column addresses.

IMPORTANT
The Power Mac G4 Cube supports only the types of SDRAM devices listed in Table 4-2. Other types of DRAM devices should not be used with this computer. ▲

Table 4-2 Address multiplexing modes for SDRAM devices

Device size	Device configuration	Size of row address	Size of column address
64 Mbits	4 M x 8 x 2	13	9
64 Mbits	2 M x 8 x 4	12	9
64 Mbits	2 M x 16 x 2	13	8
64 Mbits	2 M x 16 x 2	11	10
64 Mbits	1 M x 16 x 4	12	8
64 Mbits	1 M x 32 x 2	11	9
64 Mbits	512 K x 32 x 4	11	8
128 Mbits	8 M x 8 x 2	13	10
128 Mbits	4 M x 8 x 4	12	10
128 Mbits	4 M x 16 x 2	13	9
128 Mbits	2 M x 16 x 4	12	9
128 Mbits	2 M x 32 x 2	13	8
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

APPENDIX A

Supplemental Reference Documents

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

Apple Technical Publications

Complete information about the system software for Macintosh computers is available on the World Wide Web at

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

The Apple technotes are available on the Technote website at

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

PowerPC G4 Microprocessor

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

http://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 obtain 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

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

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. 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

Power Manager

The Power Manager has been redesigned to reduce power consumption in Sleep mode. 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.

Although the previous public Power Manager interfaces will be maintained for application compatibility, you should use the new API in your applications. Information about the API changes for Power Manager 2.0 is provided by Technote 1190, which can be obtained from the website at

http://developer.apple.com/technotes/tn/tn1190.html

Target Disk Mode

For more information about Target Disk Mode, see the section "Target Mode" in Technote 1189, *The Monster Disk Driver Technote*. You can get the Technote from the website at

http://developer.apple.com/technotes/tn/tn1189.html

ROM-in-RAM Architecture

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

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

Open Firmware

The NewWorld software architecture implemented on the current Macintosh computers 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

RAM Expansion Modules

The Power Mac G4 Cube 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. Information about the PC100 specification is available from Intel's website at

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

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.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

Macintosh computers support audio input and output over USB in conformance with the *Universal Serial Bus Device Class Definition for Audio Devices.* That document is available on the World Wide Web, at

http://www.usb.org/developers/devclass_docs.html#approved

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/

Digital Visual Interface

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

Video Electronics Standards Association

More information about Extended Display Identification Data (EDID) and the DDC interface on the VGA connector is available from the Video Electronics Standards Association web site:

http://www.vesa.org/standards.html

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
ADC	Apple Display Connector
AGP	accelerated graphics port
ATA	advanced technology attachment
ATAPI	advanced technology attachment, packet interface
AV	audiovisual
CAS	column address strobe
CDDA	compact disc digital audio
CD-ROM	compact disc read-only memory
CLUT	color lookup table
CRM	Communications Resource Manager
DAC	digital to analog converter
DBDMA	descriptor-based direct memory access
DDC	display data channel
DDR	double data rate
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 4, 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	polled input/output
RAM	random-access memory
RAS	row address strobe
RAVE	Rendering Acceleration Virtual Engine
RBC	reduced block commands
RGB	a video signal format with separate red, green, and blue components
RISC	reduced instruction set computing
ROM	read-only memory
SBP	Serial Bus Protocol
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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