Developer Note

Apple iMac Computer

Developer Note

Technical Publications
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About This Developer Note

This developer note is a concise description of the iMac™ computer, with the emphasis on the features that are new or different from those of other Macintosh desktop computers.

This developer note is intended to help hardware and software developers design products that are compatible with the 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 section "Supplemental Reference Documents".

Contents of This Note

The information in this note is arranged in five chapters.

- Chapter 1, "Introduction," introduces the iMac computer and describes its features.

- Chapter 2, "Architecture," describes the internal logic of the computer, including the main ICs.

- Chapter 3, "Devices and Ports," describes the I/O ports and the built-in I/O devices.

- Chapter 4, "RAM Expansion," describes the expansion features of interest to developers. It includes development guides for the RAM expansion modules.

- Chapter 5, "Software," describes the system software that comes with the computer, with emphasis on the new Open Firmware features.

Supplemental Reference Documents

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

PowerPC G3 Microprocessor

For more information about the PowerPC 750™ microprocessor used in the iMac computer, developers may wish to refer to the standard reference, *PowerPC 740/750 Microprocessor Implementation Definition Book IV.* Information about the PowerPC 750 and other G3 microprocessors is also available on the World Wide Web at

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

Mac OS

For a description of the version of the Mac OS that comes with the new models, developers should refer to the Technote for Mac OS 8.1. The technote is available on the Technote web site at

http://developer.apple.com/technotes/tn/tn1121.html

ATA Devices

For the latest information about the system software for ATA devices such as the IDE drive, see *Technote #1098, ATA Device Software Guide Additions and Corrections,* available on the world wide web at

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

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

The technotes are also available on the reference library issues of the developer CD.

USB Devices

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

http://developer.apple.com/dev/usb/

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

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

Open Firmware

Three Technotes provide an introduction to Open Firmware on the Macintosh platform. They are:

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

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

TN 1062: Open Firmware, Part II, available on the Technote web site at

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

TN 1044: Open Firmware, Part III, available on the Technote web site at

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

The New World software architecture described in Chapter 5, "Software," follows some of the standards defined by the Open Firmware IEEE 1274-1995 specification and the CHRP binding.

The basis for the bootinfo file format and use is the document *PowerPC*^{TM} *Microprocessor Common Hardware Reference Platform (CHRP*^{TM}*) 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. A bootinfo file can be extended to contain non-Open Firmware information, such as "Trampoline" code and the ToolBox ROM Image.

Other Open Firmware references of possible interest include:

IEEE 1275-1994 Standard for Boot (Initialization, Configuration) Firmware: Core Requirements and Practices

IEEE Std 1275-1994 Standard for Boot (Initialization, Configuration) Firmware (Version 1.7)

Open Firmware Recommended Practice: Device Support Extensions (Version 1.0)

Open Firmware Recommended Practice: Interrupt Mapping (Version 0.9)

Introduction

The Apple iMac computer is a new consumer-oriented desktop computer. This chapter summarizes the features of this new computer and points out issues affecting compatibility.

Features

Here is a list of the features of the iMac computer. Each feature is described in more detail in a later chapter.

- **Processor:** The iMac has a PowerPC G3 microprocessor running at a clock speed of 233 MHz. For more information, see "G3 Microprocessor" (page 23).

- **Cache:** The iMac has a backside L2 cache consisting of 512 KB of fast static RAM. The clock speed for the backside cache is half the clock speed of the microprocessor. For more information, see "Backside Cache" (page 23).

- **Memory:** The iMac has two standard SO-DIMM expansion slots for SDRAM modules. The computer comes with 32 MB of SDRAM installed. RAM is expandable up to 128 MB total, using presently available memory devices. For more information, see "Main RAM Expansion" (page 48).

- **Hard disk storage:** The iMac has a built-in hard disk drive with a capacity of 4 GB. For more information, see "Hard Disk Drive" (page 34).

- **CD-ROM drive:** The iMac has a built-in CD-ROM drive with 24X speed.

- **Display:** The iMac has a built-in 15-inch color monitor (13.8-inch viewable diagonal). The monitor can display with resolutions of 640 by 480, 800 by 600, or 1024 by 768 pixels. For more information, see "Video Display" (page 34).

- **Video RAM:** The iMac comes with 2 MB of video SGRAM, which supports millions of colors on displays up to 800 by 600 pixels and thousands of colors on a display with 1024 by 768 pixels. The computer has one expansion slot for a second 2 or 4 MB SGRAM DIMM, which allows the computer to display millions of colors on a display with 1024 by 768 pixels. For more information, see "Video RAM Expansion" (page 53).

- **Graphics acceleration:** The video circuits provide built-in 2D and 3D acceleration using an ATI Rage IIc IC.

- **USB ports:** The computer has two USB ports for keyboard, mouse, and other USB devices, described in "USB Ports" (page 28).

- **Modem:** The computer has a built-in modem with 56 Kbps data rate. For more information, see "Internal Modem" (page 39).

- **Ethernet:** The computer has a built in Ethernet port for a 10Base-T and 100Base-TX operation with an RJ-45 connector. For more information, see "Ethernet Port" (page 39).

- **Infrared link:** The computer has an IrDA infrared link capable of transferring data at up to 4 Mbits per second. For more information, see "Infrared Communication Link" (page 35).

- **Sound:** The computer has a built-in microphone and two stereo speakers as well as line-level stereo input and output jacks and two stereo headphone jacks. For more information, see "Sound System" (page 35).

- **Keyboard:** The Apple USB keyboard is a new design that operates as a USB device. The keyboard includes function keys and inverted-T cursor motion keys. It is also a bus-powered USB hub with two USB ports. For more information, see "Keyboard" (page 32).

- **Mouse:** The Apple USB mouse is a new design that operates as a USB device. For more information, see "Mouse" (page 33).

- **Size and weight:** The iMac computer is 39.5 cm (15.8 inches) high, 38.0 cm (15.2 inches) wide, and 44.0 cm (17.6 inches) deep; it weighs 17.3 kg (38.1 pounds).

Case and External Features

The Apple iMac computer is housed in a two-tone plastic case that includes the display. The separate keyboard and mouse are also designed in two-tone plastic.

The top of the case includes a built-in handle for carrying the computer. The handle can also be used to secure the computer using a cable and lock.

Figure 1-1 shows a front view of the computer.

Figure 1-1   Front view

Microphone

CD-ROM drive

Power button
on computer

Infrared window

Headphone jacks (2)

Stereo speaker

Stereo speaker

Apple USB
keyboard

Open button on CD-Rom drive

Power button on keyboard

Apple USB mouse
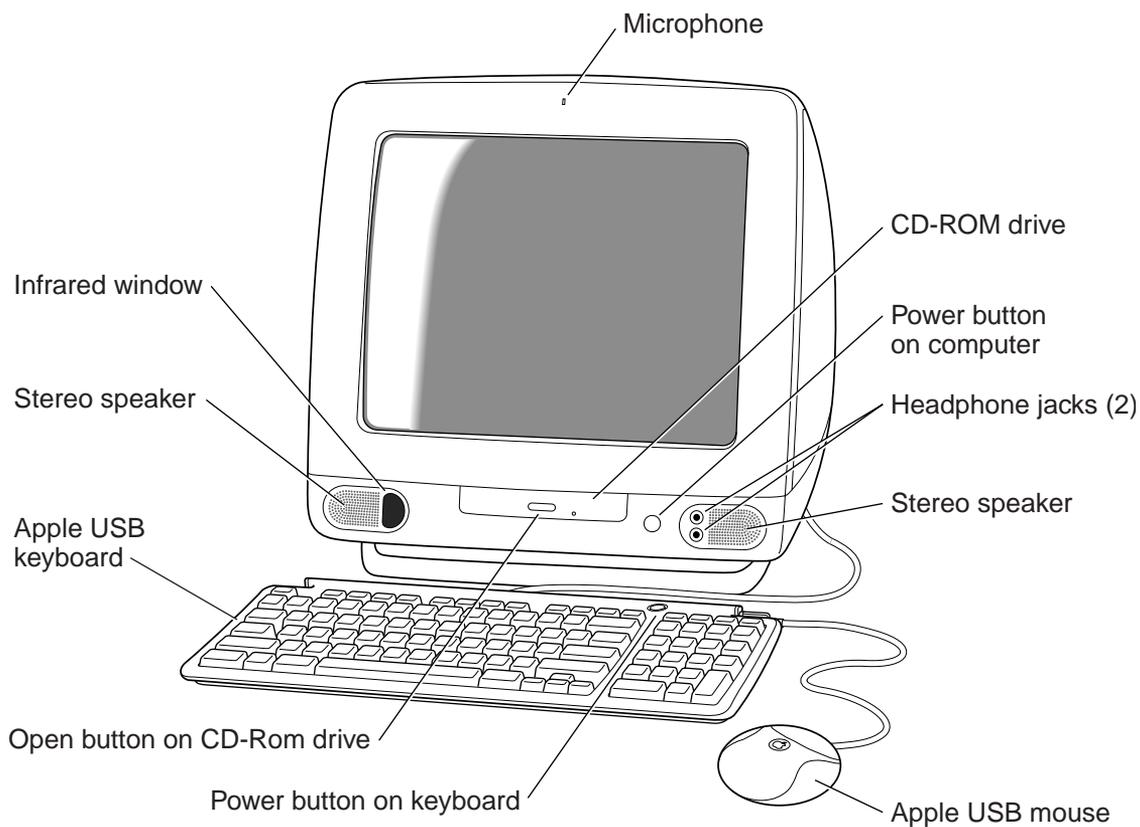
The front of the case is dominated by the 15-inch display. The front also
includes, below the display, the following features:

- CD-ROM drive opening, in the center, with a drawer eject button

- Stereo speakers, one on either side

- Infrared window, next to the speaker on the left side

- Two headphone jacks, next to the speaker on the right side

- Power button, green when on, amber in Sleep mode, located between the CD
  drive and the headphone jacks

Figure 1-2 Side view showing I/O bay
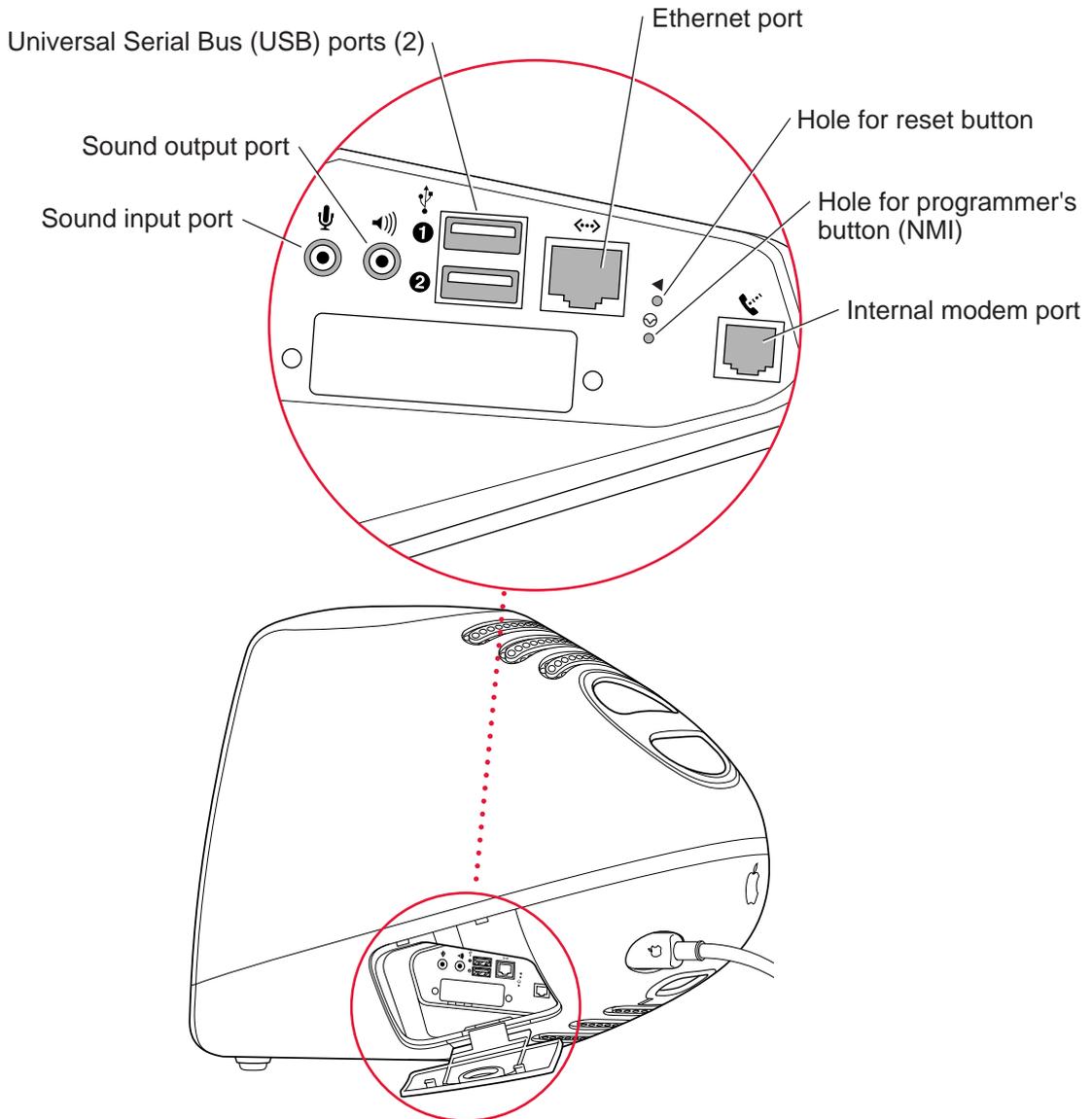
The back of the case contains the receptacle for the power cord and a small folding handle for use in removing the access cover on the bottom of the case.

The right side of the case, as viewed from the front, contains the I/O bay behind a hinged cover. Figure 1-2 is a side view showing the I/O bay with its cover open.

The I/O bay contains the following features:

- Sound input and output jacks

- Two USB ports

- Ethernet port

- Modem connector

- Access to programmer's buttons through two small openings (upper one for reset, lower one for NMI)

The bottom of the case has a hinged support that can be used to tilt the front of the computer upward by about 17 degrees.

The back portion of the bottom of the case is a removable plastic cover, retained by a screw, that can be removed to allow access to the main logic board and drive assembly. That entire assembly can be removed for installation of expansion RAM.

Compatibility Issues

While the iMac computer has many new features, there should be no compatibility problems with applications that operate correctly with earlier Macintosh models. Compatibility issues for expansion and peripheral devices are listed here.

System Software

The iMac computer has newly designed system software that provides Open Firmware booting and Mac OS ROM in RAM. The system software is described in Chapter 5. For software compatibility information, see "Compatibility" (page 59).

Main RAM Expansion Modules

For expansion of main RAM, the iMac computer uses standard SO-DIMMs that contain SDRAM devices. These are similar to the SO-DIMMs used in the Macintosh G3 PowerBook Series. For more information, see "Main RAM Expansion" (page 48).

IMPORTANT

The main RAM DIMMs in the iMac must be SO-DIMMs
that use SDRAM devices. SO-DIMMs that use EDO or
SGRAM devices will not work. ▲

Video RAM Expansion Modules

For expansion of video RAM, the iMac computer accepts one standard SO-DIMM that contains SGRAM devices. This is the same as the video expansion SO-DIMMs used in the the Power Macintosh G3 computers. For more information, see "Video RAM Expansion" (page 53).

IMPORTANT

The video RAM DIMMs in the iMac must be SO-DIMMs
that use SGRAM devices. SO-DIMMs that use EDO or
SDRAM devices will not work. ▲

USB Ports and Devices

The USB ports take the place of the ADB and serial I/O ports found on earlier Macintosh computers. Software shims have been added to allow existing applications designed to work with ADB mice and keyboards to work with the equivalent USB devices. See "USB Compatibility Issues" (page 30).

Architecture

The components at the heart of the iMac computer reside on two printed-circuit boards: the main logic board and the processor module. The Figure 2-1 is a block diagram showing the major components on those boards. The components shown are described in the sections that follow.

Figure 2-1   Block diagram
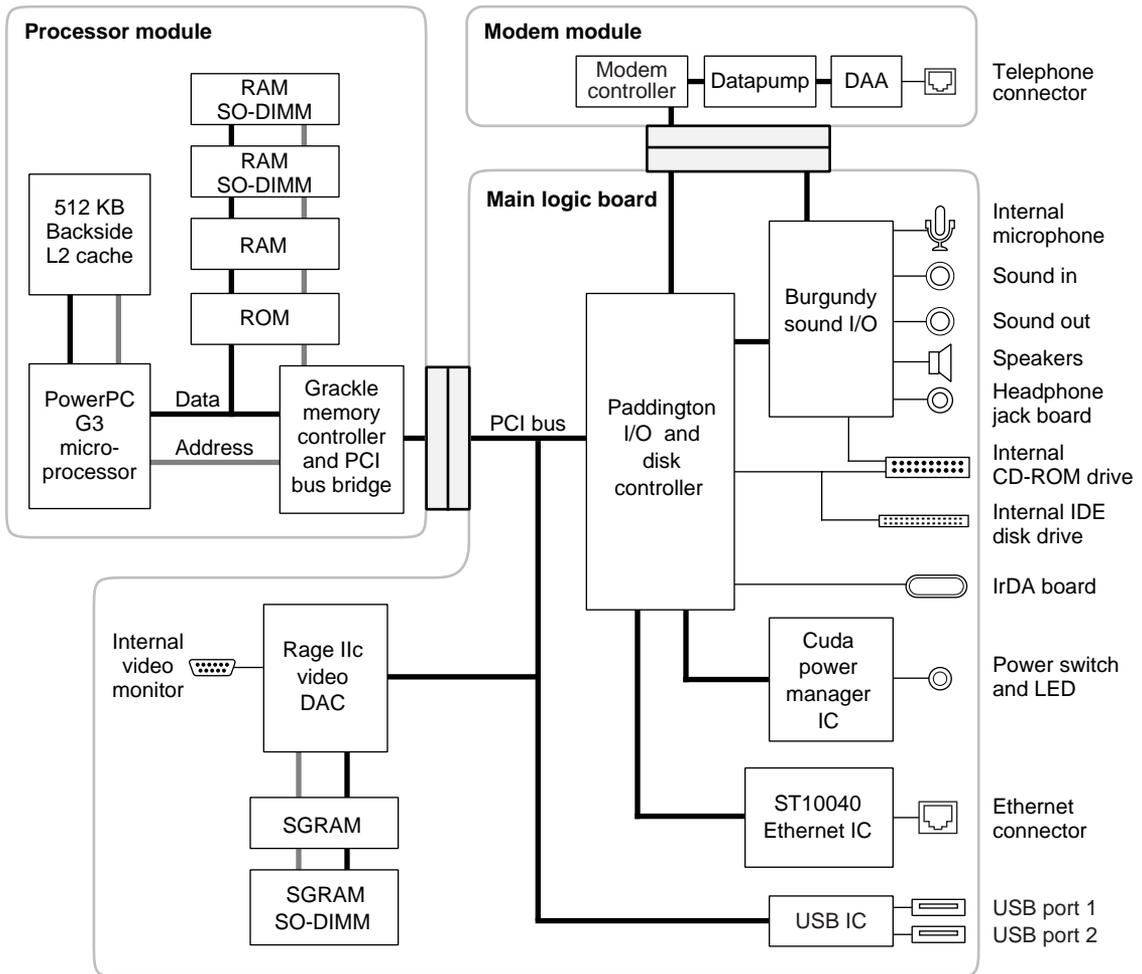
Processor module

The processor module contains the high-speed components:

- G3 microprocessor
- 512 KB backside cache memory
- main memory (minimum of 32 MB)
- system ROM (1 MB)
- memory controller and the PCI bus bridge IC

The devices on the processor module communicate with the main logic board by way of the PCI bus.

This section includes a description of the microprocessor, the backside cache, and the memory controller IC. For a description of the SO-DIMMs that contain the main memory, please see Chapter 4, "Expansion."

G3 Microprocessor

The latest family of PowerPC microprocessor designs is called "G3," for "generation three." The G3 microprocessors have several features that contribute to improved performance, including:

- larger on-chip (L1) caches, 32 KB each for instruction cache and data cache
- a built-in cache controller and cache tag RAM for the second level (L2) cache
- a separate backside bus for the L2 cache, providing faster clock speed and overlapped bus transactions
- a microprocessor core optimized for Mac OS applications

The G3 microprocessor in the iMac runs at a clock speed of 233 MHz.

Backside Cache

The controller and tag storage for the backside cache are built into the microprocessor chip. The cache controller includes bus management and control hardware that allows the cache to run at a sub-multiple of the

processor's clock speed, rather than at the clock speed of the main system bus. In the iMac, the clock speed of the backside cache is half that of the microprocessor.

The data storage for the backside L2 cache consists of 512 KB of fast static RAM on the processor module.

Memory Controller and PCI Bridge

The memory controller and PCI bus bridge IC is a Motorola MPC106, also called Grackle. The Grackle IC provides the bus bridge between the processor bus used on the processor module and the PCI bus used for the ICs on the main logic board. The Grackle IC also contains the memory controller for the main memory.

The main memory bus runs at a clock speed of 66.67 MHz. The internal PCI bus runs at 33.33 MHz. To enhance performance, the Grackle IC supports concurrent transactions on the main memory bus and the PCI bus.

Information about the Grackle IC is available on the World Wide Web at

http://www.mot.com/SPS/PowerPC/products/semiconductor/support_chips/106.html

Main Logic Board

All the I/O interfaces and the video display system are on the main logic board. The controller ICs on the main logic board are connected to the PCI bus, which also communicates with the processor module.

I/O Controller IC

The I/O controller IC in the Macintosh iMac computer is an ASIC called Paddington. The Paddington IC is an integrated I/O controller and DMA engine for use in Power Macintosh computers with a PCI bus.

The Paddington IC contains the PCI bus arbiter. It also provides the interface and control signals for

■ the video display subsystem

- the built-in modem

- the infrared link

- the Ethernet port

- the sound ASIC

- the internal IDE hard drive

- the internal CD-ROM drive

- the power manager IC

The Paddington IC is similar to the Heathrow IC used in the Power Macintosh G3 computers and Macintosh PowerBook G3 computers. The main difference is that the Paddington IC supports 100Base-TX Ethernet as well as 10Base-T.

USB Controller

The USB controller is a standard IC with two USB connectors. The register set complies with the Open Host Controller Interface (OHCI) specification.

Video Display Subsystem

The display subsystem consists of a graphics controller ASIC, 2 MB of SGRAM on the main logic board, and a connector for an additional 2 MB or 4 MB of SGRAM on an SO-DIMM. For information about the SGRAM SO-DIMM, see Chapter 4, "Expansion."

The graphics controller IC is an ATI Rage IIc. It contains 2D and 3D acceleration engines, a digital video port, front-end and back-end scalers, a CRT controller, and a PCI bus interface with bus master capability.

For information about the display and supported resolutions, see Chapter 3, "Devices and Ports."

Built-in Modem

The built-in hardware modem is a separate module that is connected to the SCC port A of the Paddington IC. The module contains a modem controller IC, a datapump, and the interface to the telephone line (DAA).

Infrared Link Module

The infrared link module is a separate printed circuit board that is connected to SCC port B of the Paddington IC.

The maximum IrDA data transfer rate is 4 Mbit/sec.

Devices and Ports

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

■ "USB Ports"

■ "Keyboard"

■ "Mouse"

■ "Hard Disk Drive"

■ "Video Display"

■ "Infrared Communication Link"

■ "Sound System"

■ "Ethernet Port"

■ "Internal Modem"

USB Ports

The iMac computer has two Universal Serial Bus (USB) ports that are used to connect the keyboard and mouse as well as additional I/O devices such as printers, scanners, and low-speed storage devices.

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

http://developer.apple.com/dev/usb/

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

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

USB Connectors

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

Figure 3-1   USB Type A port and connector
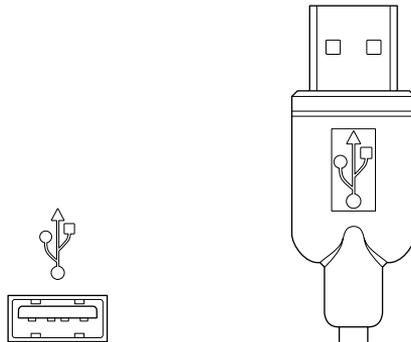
Table 3-1   Pin assignments on the USB port

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

The iMac computer provides 5-volt power at 500 mA for each of the two ports.

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 operations requires the use of shielded cables.

Transfer Types Supported

The USB specification defines four data transfer types:

■ Control transfers, used for device configuration and initialization.

■ Bulk transfers, used for printers, scanners, modems, and other devices that require accurate delivery of data with relaxed timing constraints.

■ Interrupt transfers, used for human interface device (HID) class devices such as keyboards and mice, as well as devices that report status changes, such as serial or parallel adaptors and modems.

■ Isochronous transfers, used for on-time delivery of data. Isochronous data transactions are best suited for audio or video data streams.

Version 1.0 of the Macintosh USB system software provides functions that support only control, bulk, and interrupt transfer types.

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 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 iMac computer, 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 iMac computer and will be included in the Mac OS ROM image on future Power Macintosh systems that have USB ports. For more information about the Mac OS ROM image, refer to Chapter 5, "Software." ◆

Serial Port Compatibility

The first release of the MacOS USB DDK does not include a universal Serial/
USB shim that would allow processes that use the Communications Toolbox
CRM to use a USB serial device. At the introduction of the iMac computer, any
USB Serial Class Driver will need to implement its own Serial/USB shim.

The first release of the Mac OS USB DDK does not include a universal Serial/
USB shim that would allow processes that use the Communications Toolbox
CRM to find and use a USB modem device. At the introduction of the iMac
computer, any USB modem device would need to implement its own
communication shim to interface between the CRM and its USB
Communication class driver. For more information, please refer to the Mac OS
USB DDK, which is available from the Apple Developer DDK page on the
World Wide Web, at

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

Macintosh-To-Macintosh Connections

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 iMac
computers is through the built-in Ethernet port.

USB Storage Devices

The Macintosh USB software does not support booting from an external USB
storage device.

USB Controller

The iMac computer 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 will not be supported
by the Macintosh USB system software.

Keyboard

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.

Keyboard Layout

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 3-2 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 3-2 ANSI keyboard layout

Keyboard and USB

The Apple USB keyboard is designed to work with the iMac 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. ▲

Power to the computer can be turned on using the keyboard power button. A proprietary circuit allows the power control circuitry on the main logic board to detect a power-button press and turn on the power.

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 in the computer's I/O bay, behind small holes (accessible by means of an unfolded paper clip).

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 Apple USB mouse is designed to work with the iMac computer by way of the USB ports. The mouse case is round and has the same two-tone color design as the case of the iMac computer.

Note
Despite rumours you may have heard, the Apple USB mouse does not have an internal light source—it doesn't glow. ◆

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.

Hard Disk Drive

The iMac computer has an internal hard disk drive. The drive uses the extended IDE (integrated drive electronics) interface, which is also referred to as the ATA interface. The implementation of the ATA interface on these computers is a subset of the ATA/IDE specification, ANSI proposal X3T10/0948D, Revision 3 (ATA-3).

The software that supports the internal hard disk is the same as that in previous Macintosh PowerBook models with internal IDE drives and includes DMA support. For the latest information about that software, see *Technote #1098, ATA Device Software Guide Additions and Corrections,* available on the world wide web at

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

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

Video Display

The built-in video display uses a 15-inch CRT (13.8-inch viewable diagonal). The CRT uses shadow-mask technology and has a dot pitch of 0.28 mm. The display is multi-scan and supports three resolutions. Table 3-2 lists the resolutions and the pixel depths supported with either the standard 2 MB of SGRAM or with expanded SGRAM.

Table 3-2   Display resolutions and pixel depths

Resolution	Vertical rate	Pixel depth (2 MB SGRAM)	Pixel depth (4 or 6 MB SGRAM)
640 by 480	117.233 Hz	32 bits	32 bits
800 by 600	94.97 Hz	32 bits	32 bits
1024 by 768	75.03 Hz	16 bits	32 bits

Infrared Communication Link

The iMac computer has a direct infrared (IR) communication link connected internally to serial port B. When the computer is placed within range of another device with an IR interface, it can send and receive serial data using the IrDA protocol. The other device can be an IrDA-equipped Macintosh PowerBook or some other device that complies with the Infrared Data Association (IrDA) standard. The minimum range of the IR link is approximately 2 inches, and the maximum range is 1 meter.

The IR link in the iMac computer supports IrDA at up to 4.0 Mbps. The IrDA modulation method complies with the IrDA physical layer standard, which can be found at ftp://irda.org.

Sound System

The 16-bit stereo audio circuitry provides high-quality sound input and output through the built-in microphone and speakers. The user can also connect external input and output devices by way of the sound input and output jacks.

The sound system is based on the Burgundy codec IC along with input and output amplifiers and signal conditioners. The sound system supports sample sizes up to 16 bits at a sample rate of 44.1 kHz.

Sound Inputs

The sound system accepts inputs from three possible sources:

■ built-in microphone

■ external stereo sound input jack

■ sound from internal CD player

Built-in Microphone

The sound signal from the built-in microphone goes through a dedicated preamplifier that raises its signal level to the nominal level of the codec circuits in the Burgundy IC.

External Sound Input

The external sound input jack is a 3.5-mm mini phone jack located in the I/O bay on the right side of the computer. The sound input jack accepts line-level stereo signals or an Apple PlainTalk microphone. It also accepts a stereo miniplug-to-RCA cable adapter for connecting stereo equipment to the computer.

The sound input jack has the following electrical characteristics:

■ input impedance: nominal 3300 ohms

■ maximum level: nominal 1 V rms (2.8 V peak-to-peak)

Sound Outputs

The sound system sends computer-generated sounds to the built-in speakers, the sound output jack, and the headphone jacks. The sound system provides user-selectable SRS® 3D stereo enhancement.

Internal Speakers

The computer has two internal speakers. The computer turns off the sound signals to the internal speakers under the following conditions:

■ when headphones are plugged into either headphone jack

■ when a plug is inserted into the sound output jack

■ during power cycling

External Sound Output

The external sound output jack is a 3.5-mm mini phone jack located in the I/O bay on the right side of the computer. It accepts a stereo miniplug-to-RCA cable adapter for connecting stereo equipment to the computer.

The sound output jack has the following electrical characteristics:

■ output impedance: nominal 180 ohms

■ maximum level: nominal 1 V rms (2.8 V peak-to-peak)

Headphone Jacks

Two headphone jacks are located on the front of the computer next to the right speaker. Each sound output jack provides enough current to drive a pair of low-impedance headphones.

The headphone jacks have the following electrical characteristics:

■ output impedance: nominal 13 ohms

■ maximum level: 1.4 V rms (4.0 V peak-to-peak)

Headphones should have an impedance not lower than the recommended minimum impedance of 32 ohms. Headphones with lower impedance can be used, but with some degradation in performance.

Sound Specifications

The frequency response of the sound circuits, not including the microphone and speakers, is within plus or minus 1 dB from 4 Hz to 20 kHz.

Total harmonic distortion plus noise (THD+N) as a percentage of full scale for various outputs are shown in Table 3-3.

Table 3-3   Distortion specifications

Connector and level	Total harmonic distortion and noise
Line input	0.03%
Line output	0.03%
Headphone jack, open circuit	0.03%
Headphone jack, 32-ohm headphones, −20 dBFS level	0.1%
Headphone jack, 32-ohm headphones, −1.5 dBFS level	1.0%

The signal-to-noise ratios (SNR) for various inputs and outputs are shown in Table 3-4. The values shown are unweighted; values with A weighting would be about 8 dB higher.

Table 3-4   Noise specifications

Connector and level	Signal-to-noise ratio
Line output	92 dB
Headphone jacks	86 dB
Line input	85 dB
Internal CD	82 dB

Ethernet Port

The iMac computer has a built-in 10/100 Mbps Ethernet port. The user can connect it 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 in the I/O bay on the right side of the computer.

The Ethernet interface in the iMac computer conforms to the ISO/IEC 802.3 specification, where applicable.

Internal Modem

The iMac computer comes with a built-in modem. The connector for the modem is an RJ-11 connector in the I/O bay on the right side 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.

RAM Expansion

This chapter tells how to gain access to the expansion slots in the iMac computer and describes the two types of RAM expansion: main RAM expansion and video RAM expansion.

The Expansion Slots

To get access to the expansion slots, the user must open up the bottom of the computer and remove the main logic board and processor module assembly.

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

Removing the Logic Board Assembly

The steps in removing the logic board assembly are:

1. Place the computer face down on a soft cloth.

2. Remove the retaining screw and the bottom cover.

3. Unfasten the cables attached to the logic board assembly.

4. Remove the retaining screws.

5. Pull out the logic board assembly.

The following sections describe the steps.

Placing the Computer Face Down

To remove the logic board from the computer, the user must first gain access to the bottom of the computer by placing the computer face down on a soft cloth, as shown in Figure 4-1.

Figure 4-1   Bottom view showing bottom cover handle
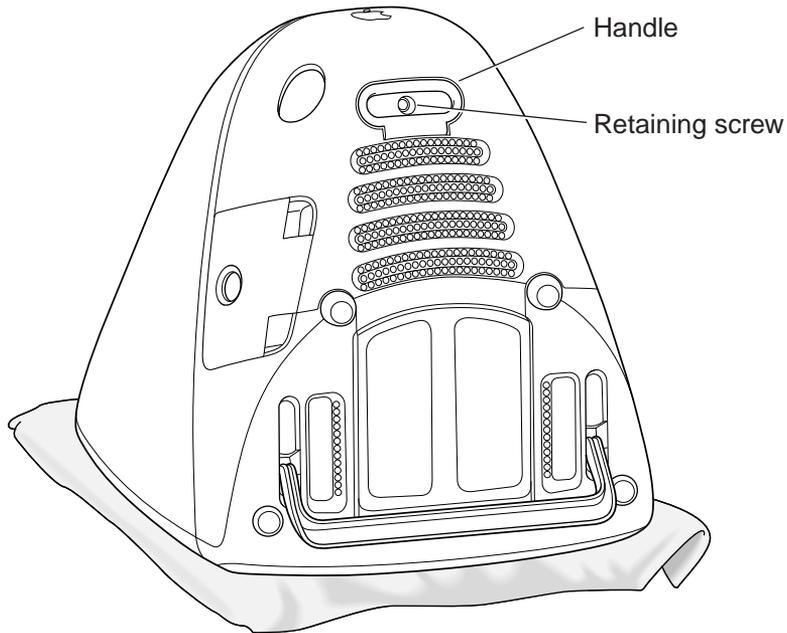
Removing the bottom cover

The bottom cover is held in place by a retaining screw located on the bottom cover and accessible through the opening in the handle. After removing the screw, the user can remove the cover by pulling up and out on the handle.

Unfastening the Cables

Several signal cables are connected to the back of the logic board assembly, as shown in Figure 4-2. Those must be disconnected and freed from their clamps. Once the cables and clamps are disconnected, the user should position the cables to either side of the logic board assembly, as shown in Figure 4-3.

Figure 4-2   Cables connected to the logic board assembly
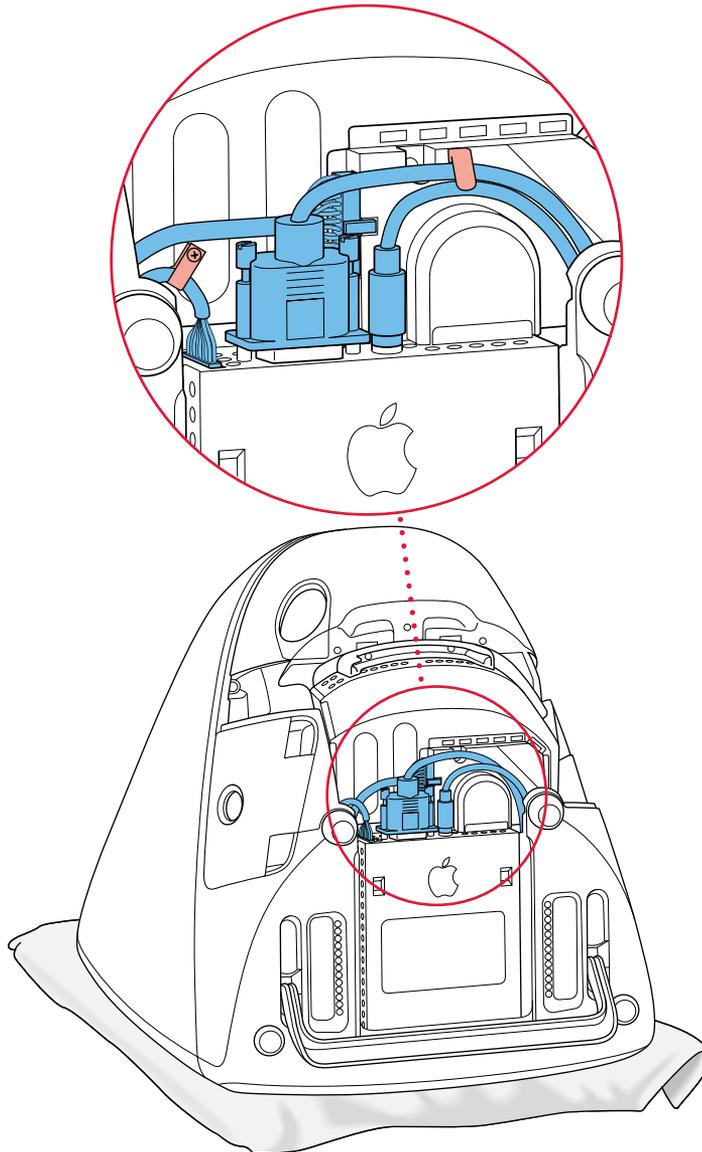
Removing the Retaining Screws

A slot-shaped handle is located at the back end of the logic board assembly. The retaining screws are located inside the slot in the handle, as shown in Figure 4-3.

Figure 4-3   Logic board assembly handle and retaining screws
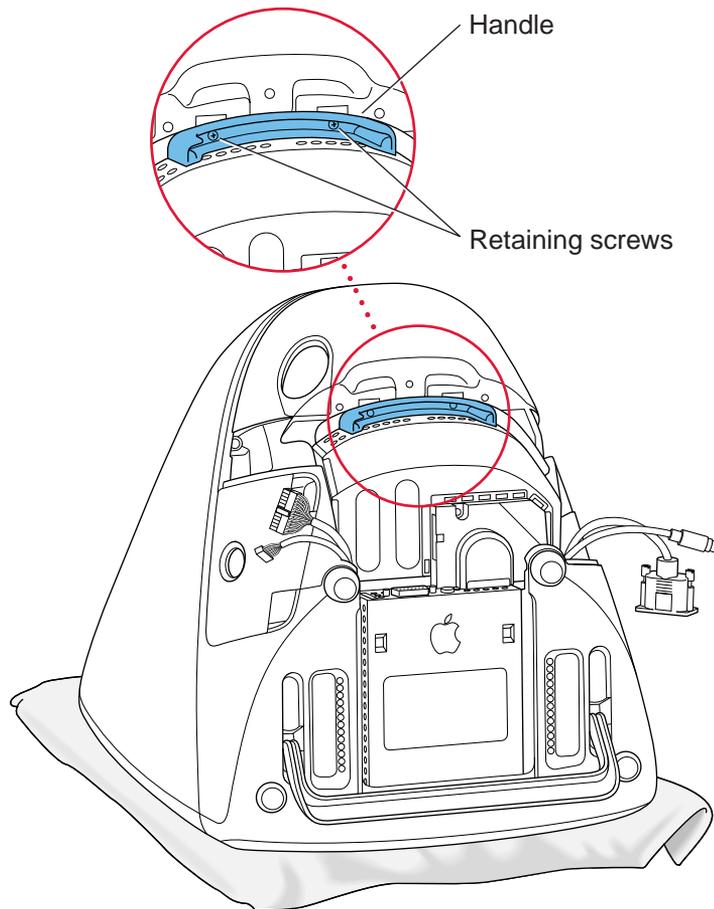
Removing the Logic Board Assembly

With the retaining screws removed and the cables positioned to the sides, the user can remove the logic board assembly by pulling upward on the handle, as shown in Figure 4-4.

Figure 4-4   Removing the logic board assembly
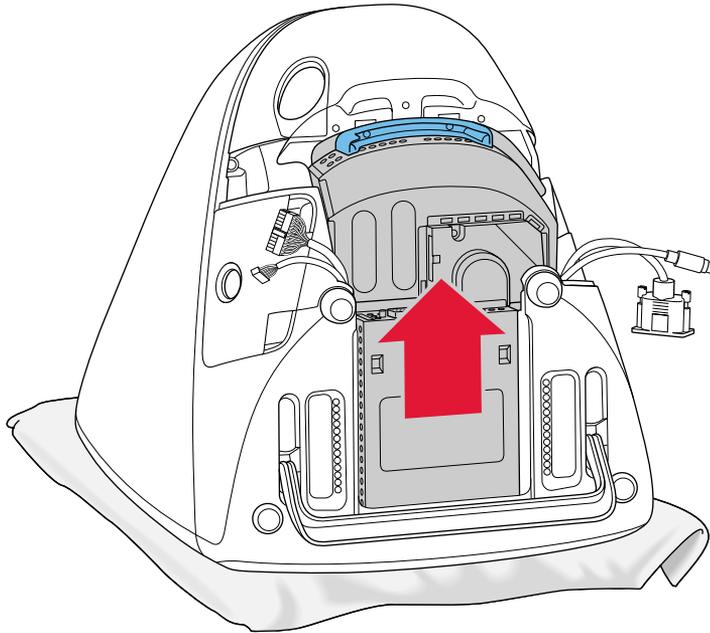
IMPORTANT

While removing and reinstalling the logic board assembly, you should take care to align the door of the CD drive with the opening in the front of the case. ▲

Removing the EMI Shield

Once the logic board assembly is free of the case, you can see the EMI shield, which covers the processor module. To gain access to the main RAM expansion slots, you must remove the EMI shield, as shown in Figure 4-5.

Figure 4-5 EMI shield
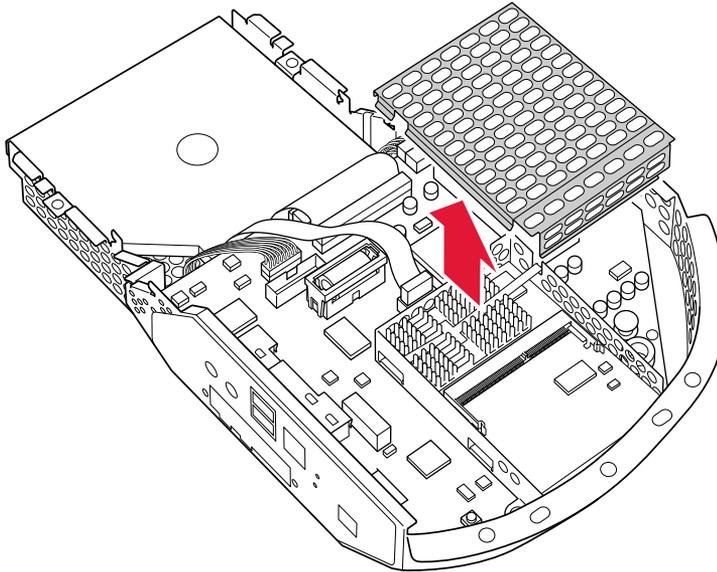
Locations of the Expansion Slots

Figure 4-6 shows the location of the two main RAM expansion slots and the video RAM expansion slot.

One of the main RAM expansion slots is on the bottom of the processor module and is normally occupied by the factory-installed SO-DIMM. The other main RAM expansion slot is on the top of the processor module and is available for a user-installed SO-DIMM.

Figure 4-6 Locations of the RAM expansion slots

Video RAM slot

Main RAM top slot

Main RAM bottom slot
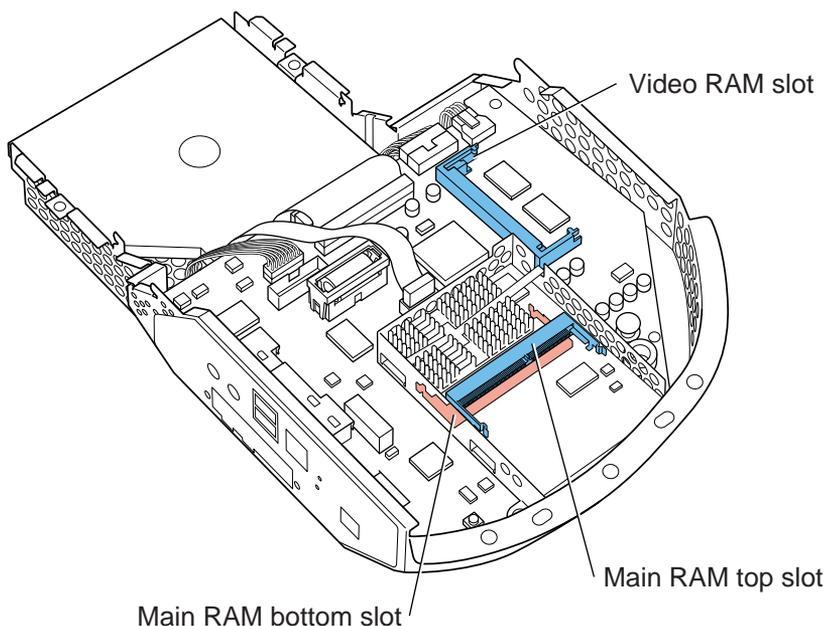
Main RAM Expansion

The iMac computer has two RAM expansion slots that accommodate standard SO (small outline) DIMMs using SDRAM devices.

IMPORTANT

RAM expansion SO-DIMMs for the iMac must use SDRAM devices. If the user installs an SO-DIMM that uses EDO or SGRAM devices, the computer will beep several times when the user attempts to restart the computer. ▲

An SO-DIMM for the iMac can contain either 16, 32, or 64 MB of memory.

Total RAM capacity using devices currently available is 128 MB and is limited by the space available for the SO-DIMMs. The bottom slot can accommodate a 1.5-inch SO-DIMM. The top slot can accommodate a 2.0-inch SO-DIMM.

Note
Future devices with higher density may allow expansion beyond the current 128-MB limit.

Mechanical Design of RAM SO-DIMMs

The mechanical characteristics of the RAM expansion SO-DIMM are given in the JEDEC specification for the 144-pin 8-byte DRAM SO-DIMM. The specification number is JEDEC MO-190; it is available from the Electronics Industry Association's web site, at

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

The specification defines SO-DIMMs with nominal heights of 1.0, 1.25, 1.5, or 2.0 inches. The iMac computer can accommodate two SO-DIMMS, one with a height up to 1.5 inches and the other with a height up to 2.0 inches.

IMPORTANT
The JEDEC specifications for the heights of the SO-DIMMs gives a plus-or-minus 0.15 mm tolerance. In the iMac, the specified heights for the SO-DIMMs are maximum heights.

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

Electrical Design of RAM SO-DIMMs

The electrical characteristics of the RAM SO-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 web site, at

http://www.jedec.org/download/jep21-j.pdf

The specification defines several attributes of the DIMM, including storage capacity and configuration, connector pin assignments, and electrical loading. The specification supports SO-DIMMs with either one or two banks of memory.

The JEDEC specification for the SO-DIMM defines a Serial Presence Detect (SPD) feature that contains the attributes of the module. SO-DIMMs for use in the iMac are required to have the SPD feature. Information about the required values to be stored in the presence detect EEPROM is in section 4.1.2.5 and Figure 4.5.6–C (144 Pin SDRAM SO–DIMM, PD INFORMATION) of the JEDEC standard 21-C specification, release 7.

Because the SO-DIMM connector has only two clock lines, and each clock line is limited to only 4 loads, an SO-DIMM with more than 8 SDRAM devices must have buffers on the clock lines. The buffers must be zero-delay type, such as phase-lock loop (PLL), which regenerates the clock signals. For example, the computer can support a 128-MB SO-DIMM using 16 devices and a PLL clock buffer.

SDRAM Devices

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 100 MHz or greater, corresponding to a cycle time of 10 ns or less.

The devices are programmed to operate with a CAS latency of 3. At that CAS latency, the access time from the clock transition must be 7 ns or less. The burst length must be at least 4 and the minimum clock delay for back-to-back random column access cycles must be a latency of 1 clock cycle.

Configuration of RAM SO-DIMMs

Table 4-1 shows the sizes of the RAM expansion modules that can be used in the iMac computer and the different sizes of SDRAM devices that make up those modules.

Table 4-1   Sizes of RAM expansion modules and devices

Device size	Device configuration	Number of devices per bank	Size of each bank
16 Mbits	2M x 4 x 2	16	32 MB
16 Mbits	1M x 8 x 2	8	16 MB
16 Mbits	512K x 16 x 2	4	8 MB
64 Mbits	8M x 4 x 2	16	128 MB
64 Mbits	4M x 4 x 4	16	128 MB
64 Mbits	4M x 8 x 2	8	64 MB
64 Mbits	2M x 8 x 4	8	64 MB
64 Mbits	2M x 16 x 2	4	32 MB
64 Mbits	1M x 16 x 4	4	32 MB
64 Mbits	1M x 32 x 2	2	16 MB
64 Mbits	512K x 32 x 4	2	16 MB

The iMac accepts either one or two SO-DIMMs. Any of the supported SO-DIMM sizes can be installed in either slot, subject to the limits on the dimensions of the SO-DIMMS. The memory controller configures the combined memory of the SO-DIMMs into a contiguous array of memory addresses.

Note
The iMac does not support memory interleaving, so installing two SO-DIMMs of the same size does not result in any performance gain.

Address Multiplexing

Signals A[0] – A[13] on each RAM SO-DIMM make up a 14-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 iMac computer by size, configuration, and sizes of row and column addresses.

IMPORTANT

The iMac supports only the types of SDRAM devices specified in Table 4-2. Other types of DRAM devices should not be used with this computer. ▲

Table 4-2 Types of DRAM devices

Device size	Device configuration	Size of row address	Size of column address
16 Mbits	2M x 4 x 2	11	10
16 Mbits	1M x 8 x 2	11	9
16 Mbits	512K x 16 x 2	11	8
64 Mbits	8M x 4 x 2	13	10
64 Mbits	4M x 4 x 4	12	10
64 Mbits	4M x 8 x 2	13	9
64 Mbits	2M x 8 x 4	12	9
64 Mbits	2M x 16 x 2	13	8
64 Mbits	1M x 16 x 4	12	8
64 Mbits	1M x 32 x 2	13	7
64 Mbits	512K x 32 x 4	12	7

RAM SO-DIMM Electrical Limits

Each RAM SO-DIMM must not exceed the following maximum current limits on the +3 V supply:

Active   1.2 A (8 devices at 150 mA each)

Sleep   6 mA per bank

The maximum current specified for active operation generally rules out the use of 4-bit-wide SDRAM devices in a RAM expansion card. Such a card would have 16 such devices, and the 1.2 A maximum current would allow only about 75 mA per device. To stay within the current limits, RAM expansion cards should use only 8-bit or 16-bit SDRAM devices.

Video RAM Expansion

The iMac computer includes 2 MB of SGRAM for video on the main logic board. The video RAM can be expanded up to 6 MB with an additional 2 or 4 MB of SGRAM on a 144-pin SO-DIMM (small outline dual inline memory module). The mechanical design of the SGRAM SO-DIMM is defined by the JEDEC MO-190 specification. The SGRAM SO-DIMM specification can be downloaded at

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

The devices on the DIMM must be 3.3 V SGRAM devices. The speed of the SGRAM devices must be 100 MHz or greater, corresponding to a cycle time of 10 ns or less. The 100 MHz/10ns SGRAM SO-DIMM specification provides suitable margins for compatibility with the iMac architecture.

Increasing the size of the installed video RAM from 2 MB to 4 or 6 MB increases the maximum color depth available at the highest monitor resolutions.

Any additional video RAM that isn't used for the current display mode is available to QuickDraw 3D applications for more data storage, such as textures, which results in faster 3D graphics performance. A more detailed explanation of video RAM and QuickDraw 3D graphics performance can be found in Chapter 5 of the *Power Macintosh 5500/6500 Developer Note*, where the use of the video frame buffer for front frame buffer, back frame buffer, optional Z buffer, and available texture memory are described.

Software

The Apple iMac computer is different from previous Macintosh computers in that it has no single, large ROM that contains the toolbox software, the 68K emulator, hardware initialization, and the nanokernel. A small ROM provides hardware initialization functions and provides a mechanism to load the Mac OS Toolbox ROM image into RAM. The new software architecture that is centered around ROM-in-RAM and its ramifications has the code name NewWorld.

Why Make This Change?

Historically, the Macintosh ROM has been structured as one monolithic ROM, known as the ToolBox ROM, that contains both low level and high level software. That is, the ROM contains the hardware-specific code needed by the computer at power-up time as well as higher level Mac OS ToolBox software. Examples of hardware-specific code are drivers, feature tables, diagnostics, and hardware initialization code. Examples of higher level software are high-level ToolBox managers, QuickDraw, SCSI Manager, and so on.

As features have been added to the Mac OS software, some of the higher level code expanded beyond the practical limits provided by ROMs, so the ROM has been augmented and modified by system software such as the System file and the Enabler. In this way the functionality of the ROM has been spread out among the ROM, the Enabler, and disk-based system software. This intertwining of low-level and high-level code spread out from ROM to disk has made it difficult and time consuming to release new computers.

One way to address this problem is to separate the system software into two logically distinct pieces. One piece holds most of the hardware-specific components needed to boot the computer, while the other contains boot-time ToolBox routines and components that are common to many Macs. With this scheme, much of the hardware-specific code is isolated in the Boot ROM, and the ToolBox and system software code can be made abstract and generic. This approach has several benefits.

• When hardware changes are needed, only the hardware-specific code in the Boot ROM has to be modified, greatly decreasing turnaround time for new product releases, and reducing testing time and expenses.

• The high-level ToolBox and system software does not need to change often. When making a new build as a result of changing hardware-dependent code, there is high confidence that the high-level software has not been changed.

• Not changing the higher level software as often simplifies things for many groups inside Apple, including testing, system software, software configuration management, developer support, and publications. Third-party developers can also benefit from this.

What Has Changed

Hardware-specific code that performs the computer's start-up activities resides in firmware (ROM). That code fits into one ROM called the Boot ROM. The Boot ROM includes the hardware specific code and tables needed to start up the computer, to load an OS, and to provide common hardware access services.

All higher level software resides somewhere else. For now, think of it residing in what has been historically known as the Mac OS ToolBox ROM, but with much of the old hardware-specific code moved into the Boot ROM. As before, the ToolBox ROM can still be augmented by Enablers, the System file, and extensions.

Prior to the iMac, all Macintosh computers required a ROM component that contained the Mac OS Toolbox software. The NewWorld approach sidesteps this requirement by copying an image of the Mac OS ToolBox into RAM before the Mac OS begins operation. The area of RAM that contains the ToolBox image is excluded from the available memory space in RAM, and is marked as read-only. Once the Mac OS begins operation, a ToolBox image in RAM and an actual ToolBox ROM behave in the same way.

No new or different software interfaces are directly accessible from Mac OS. During the boot process, software contained in the Mac OS ToolBox ROM file communicates with Open Firmware to collect information about the hardware, using the Open Firmware Client Interface.

Note
Open Firmware is a central component of the NewWorld architecture. For reference material about Open Firmware, see "Open Firmware" (page 11). ◆

Most of the changes are completely transparent to Mac OS. Only the Startup Disk control panel is affected: it includes added code to modify the Open Firmware's configuration variables in the NV-RAM.

Features of the New Approach

Because the iMac has new hardware features that are different from other Macintosh computers, new software features are needed in addition to the NewWorld requirements for other Macintosh computers. This list includes features that implement the NewWorld approach along with features that support the new hardware features of the iMac computer.

■ Power-on Self Test (POST) software, which resides in the Boot ROM, provides hardware initialization and diagnostic functions.

■ Open Firmware, which resides in ROM, completes hardware initialization, provides a description of the hardware, loads initial OS software, and transfers control to that software.

■ Run-Time Abstraction Services (RTAS), which resides in ROM, is instantiated into RAM through an Open Firmware method called by the OS. RTAS provides functions that are available to the OS at any time to access platform-specific hardware, such as the real-time clock and NV-RAM.

■ Mac OS ROM image, a file that contains the ToolBox ROM code and other high-level software that resides in the ToolBox ROM on other Macintosh computers.

■ 10Base-T/100Base-TX Ethernet device driver, in the Boot ROM.

■ Device driver for the USB hub, Apple USB keyboard, and Apple USB mouse, in the Mac OS ROM image.

In addition to the above new features, changes have been made to the source base for the components of the Mac OS ROM to abstract it from the hardware. These changes are designed to reduce bring-up time and effort, improve reliability of the Mac OS ROM components, and reduce testing time, by moving the changes necessary for a new computer to the Boot ROM. Some of the hardware components accessed through this new abstracted software are the interrupt controller, ADB, USB, SCSI, ATA (IDE), sound, and Ethernet.

The NewWorld architecture has a ToolBox ROM image that is high-level enough to be used on many different Macintosh computers. Although the iMac is the first Macintosh computer to use it, this new architecture is intended for use on all future Macintosh computers.

Performance

Performance of an iMac computer using ROM in RAM should exceed performance measurements for other Macintosh computers with comparable CPUs and speeds due to improved interrupt handling with the New World approach. In addition, performance is improved due to executing code that normally exists in ROM in RAM, because the RAM devices operate faster than the ROM devices normally used.

RAM Footprint

The iMac is the first Macintosh computer to have its Toolbox ROM image stored in RAM. This removes approximately 3 megabytes of RAM from Mac OS usage. In effect, a system with 32 megabytes of RAM appears to have only 29 megabytes available. Some portion of the missing 3 megabytes is offset by having fewer patches in RAM. Other mechanisms are being explored in an attempt to minimize the impact of ROM-in-RAM.

User Experience

Setting the boot volume from the Startup Disk control panel makes all the changes to the boot process that are necessary to operate with a ToolBox image in RAM. The control panel user interface remains unchanged for this release.

Data Structures and Files

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

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. The format of the NV-RAM partition is defined in the Open Firmware CHRP Binding. The partition is accessed using RTAS.

Compatibility

A Mac OS ToolBox image that is in write-protected RAM will appear to be a ROM to all MacOS software and applications. Because the image of the ToolBox

in RAM appears to be a ROM, the ROM-in-RAM approach is completely compatible with all application and system software.

The Mac OS ToolBox image is kept in a file in the System Folder on the specified boot device. In order to avoid problems with internationalizing the name, the file is located by file type instead of by name.

In order for Open Firmware to retrieve the ToolBox image file, it must be able to read the selected boot device. If the ToolBox image file is on a partition that is on a RAID, encrypted, striped, or otherwise non-standard device, Open Firmware must be able to read from these devices in order to boot Mac OS. Two possible solutions to this problem are to have a standard partition available on the device that contains the ToolBox image file, or to provide Open Firmware methods to read the file.

The main incompatibility that ROM-in-RAM approach introduces is that memory is not mapped one-to-one, as it has been for previous PCI-based Macs. 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 calls the `LogicalToPhysical` or `PrepareMemoryForIO` functions when it needs a physical memory address—will continue to work.

Boot ROM Contents

The Boot ROM contains the code needed to start up the computer, initialize and examine the hardware, provide a device tree to describe the hardware, provide hardware access services (RTAS), and control to the OS. The Boot ROM can be grouped into the following major pieces.

POST Code

This is the code executed when the computer first boots. This encompasses many of the traditional Mac ROM operations and is based on the hardware initialization code used in the past: setup and initialization of the processor and ASICs, a boot beep, an error beep, diagnostics, and transfer to Open Firmware.

A small debugging Mini-Nub is part of this section. It allows prodding and poking with some MacsBug-like commands. Getting into the Debugger Nub is not possible using standard user interface input, however.

Failure to boot in POST causes the error beep, optionally entering the Mini-Nub.

Open Firmware

The Open Firmware component of NewWorld is based on the CHRP version of Open Firmware, also known as Open Firmware 3.0. This is the most robust and full-featured Open Firmware used by Apple to date. This version of Open Firmware contains several notable changes from the Open Firmware found in the first and second generation PCI Macintosh computers:

■ Open Firmware is capable of reliably reading files from block devices.

■ Open Firmware builds an expanded device tree that holds every facet of hardware information needed by an operating system.

■ Open Firmware contains code that mimics the `StartSearch` code in the ToolBox ROM and provides a Mac-like user interface during startup.

■ Open Firmware creates an interrupt tree that is interlaced through the Device Tree to provide a mechanism to describe the interrupt layout of the computer.

If a boot failure occurs in Open Firmware, Open Firmware attempts to provide a Macintosh-like experience.

Mac OS `'ndrv'` Drivers

The Boot ROM may also contain Mac OS drivers that are hardware-specific and needed at boot time; they are organized as `'ndrv'` drivers. Drivers needed at boot time (video drivers, network drivers, or disk drivers) need to be loaded from the Device Tree.

RTAS

RTAS (Run-Time Abstraction Services) can be thought of as a BIOS. RTAS code handles hardware accesses needed by an OS, making it possible for multiple operating systems to get hardware services without having to know the specifics. RTAS handles hardware-specific services such as NV-RAM (containing parameter RAM), time services (the real time clock), PCI configuration cycles, power management, and the code needed to restart and shutdown.

RTAS is relocateable code; its location in RAM is determined by the OS, and it remains functional after the OS boots.

Note
RTAS is part of the system software. It is not needed by applications, which use operating system APIs. ◆

Toolbox Image File Contents

The Toolbox image file (also called the bootinfo file) contains three main components, each of which is made up of smaller components: the pieces that are part of the bootinfo specification, the Trampoline code, and the ToolBox ROM Image itself.

Most changes needed for a new CPU occur in the Boot ROM, not in the bootinfo file. Changes to the ToolBox ROM Image should be limited to new manager software and support for hardware that is common to many Macintosh computers (ATA interface modules, user interface modules, and the like).

The bootinfo file exists on the boot device and has a localizable name. Identification information that leads to the file's path is stored in NV-RAM and the search algorithm for a usable bootinfo file parallels the search mechanism across SCSI, ATA, etc., used in the former startup disk routine. By default, the file is located by using the directory ID of the "blessed folder" in the boot block of each HFS or HFS Plus partition, and then searching for a file with a file type of 'tbxi'. Searching by file type is done to allow localization of the file. Non-localized, the name of the bootinfo file is "Mac OS ROM".

Open Firmware Script

The bootinfo components normally do not need to be changed for each new product. The Open Firmware script is automatically modified at build time to have the correct offsets within the bootinfo file to the other two main components.

Trampoline Code

The Trampoline code is the component of the NewWorld architecture that handles the transition between Open Firmware and the ToolBox ROM Image. It retrieves all necessary information about the system from Open Firmware, instantiates RTAS, decompresses the ToolBox ROM Image, locates the Mac OS NV-RAM partition, formats the system information into tables and data structures for Mac OS, terminates Open Firmware, moves information in memory to safe locations, and transfers control to the ToolBox ROM Image.

ToolBox ROM Image

The NewWorld version of the ToolBox ROM Image is similar to the old ToolBox ROM in that it has a similar layout and contains many of the same components as it did before.

The ToolBox ROM Image includes code that contains hardware-specific support, including ADB, VIA, Cuda/Egret, MESH SCSI, Heathrow/CHRP/ UltraDMA ATA AIMs. In the future, they can be moved out of the ToolBox ROM Image when there is a mechanism to load them from a boot volume at boot time.

NewWorld Boot Process

Following is a high level view of the execution path take when a NewWorld-based computer boots.

1. The POST code runs (preliminary diagnostics, boot beep, initialization, and setup), with possible intervention in the Mini Nub.

2. Open Firmware initializes and begins execution, including building the device tree and the interrupt trees;

3. Open Firmware loads the Toolbox image file, based on defaults and NV-RAM settings;

4. Open Firmware executes the Forth script in the bootinfo file, which contains instructions to read both the Trampoline code and the compressed ToolBox ROM Image and place them into a temporary place in memory;

5. The Forth script transfers control to the Trampoline code, which functions as the transition between Open Firmware and the beginning of the Mac OS execution;

6. The Trampoline code decompresses the ToolBox ROM Image, gathers information about the system from Open Firmware, creates data structures based on this information, terminates Open Firmware, and rearranges the contents of memory to an interim location in physical memory space;

7. The Trampoline code transfers control to the `HardwareInit` routine in the ToolBox ROM Image;

8. The `HardwareInit` routine copies data structures to their correct places in memory, and then calls the NanoKernel;

9. The NanoKernel fills in its data structures and then calls the 68K Emulator;

10. The 68K Emulator initializes itself, then transfers control to the startup initialization code;

11. The startup initialization code begins execution, initializing data structures and Managers, and booting the Mac OS.

All functions found in the old ToolBox ROM are present in the NewWorld boot process, but occur at different times and places. To accomplish this, the code in the ToolBox ROM Image and POST is simplified, while the Trampoline code addresses the new functionality.

What Is Different

Even though ROM-in-RAM involves a fundamental change to the construction of the product-specific part of the Mac OS, the changes in the code and its execution are not that large. Many components are in changed locations, but their functions with respect to boot time and run time have not greatly changed. Many Mac OS components remain untouched.

Interrupt Handling

Interrupt handling is very different with the NewWorld approach. The interrupt code has been rewritten to allow for dynamic creation of the interrupt layout. The new code has two features that did not exist in the old code. One is

that interrupt latency has been reduced to such an extent as to make it negligible. The other is that the interrupt handling code no longer requires changes to support a new machine, unless it has new interrupt controller hardware. The description of the interrupt layout is now part of an Open Firmware interrupt tree that is interlaced within the Open Firmware device tree. The Trampoline code uses this interrupt tree to build the Mac OS native interrupt tree.

Outmoded Resources

Prior to NewWorld, many resources in the ROM exist in the System Folder as well, often as replacements that fix or enhance those in the ROM, but sometimes because the ROM resources have not yet been removed from the ROM. With the NewWorld approach, any resources that are not needed early in the boot sequence are no longer in the ToolBox ROM Image, and only the resources from the System Folder are in use.

RAM Footprint

NewWorld puts the ToolBox ROM Image in RAM, and marks it read-only. Although the image is 4 megabytes in size, not all of it is in use. The portion that is not used is returned to Mac OS for use as part of system RAM. At the time this document was written, less than 3 megabytes of the 4 megabyte ToolBox ROM Image are in use, allowing more than 1 megabyte to be returned to Mac OS.

RTAS

Certain hardware devices differ from machine to machine, but provide similar functions. RTAS (Run-time Abstraction Services) provides such hardware-specific functions, including functions for accessing the real-time clock, non-volatile RAM (NV-RAM), restart, shutdown, and PCI configuration cycles. The I/O primitives for these functions in the ToolBox ROM Image for NewWorld use RTAS.

NV-RAM

Instead of using hard-coded offsets to locations in NV-RAM for Mac OS NV-RAM and other information, the Trampoline code breaks NV-RAM into

variable-sized partitions that are used by Mac OS, Open Firmware, and any other client. PRAM resides in the Mac OS partition. The partitioning scheme is part of the CHRP specification.

NanoKernel

The previous version of the NanoKernel has code that is processor-specific to create data structures. Under NewWorld, the Trampoline code creates these data structures from information in the Open Firmware Device Tree.

NanoKernel is typically no longer changed to support a new CPU. Support for new processors has moved to POST, which is responsible for configuring all processor-specific registers. Run-time cache control is part of RTAS.

Startup Disk Control Panel

Open Firmware now bears responsibility for locating a startup device. This is very different from previous Mac OS systems where the Mac OS ROM had responsibility for locating the startup device. On the iMac computer, the Mac OS ROM image itself comes from the startup disk, so decisions regarding startup device must be made earlier in the startup process. Open Firmware recreates as much as possible the user experience of earlier systems but the implemention is very different.

Previous systems stored the user's selected startup device in PRAM. The startup device was set in PRAM when the user selected a device in the Startup Disk control panel. This device was honored by the Mac OS ROM unless the selected device was unavailable or was overridden by the user.

The startup disk routine for the iMac, rather than setting Mac OS PRAM, sets an Open Firmware config variable called `boot-device`. This setting is honored by Open Firmware unless the selected device was unavailable or was overridden by the user.

The following keys can be used to override the selected startup device.

- Key combination Command-Option-Shift-Delete: ignore the boot-device setting and scan for alternate devices.

- C key: force the internal CD-ROM drive to be the startup device

- D key: force the internal hard disk to be the startup device

Once Open Firmware locates a startup device and successfully loads a Mac OS ROM, image it passes information about the chosen device in the `bootpath` variable. This information, rather than that previously set in PRAM, is subsequently used by the Mac OS ROM to locate the device containing the startup System Folder.

IMPORTANT

The previous API for controlling the startup device selection, using `_GetDefaultStartup` and `_SetDefaultStartup`, is not effective on the iMac. ▲

Open Firmware and the Device Tree

NewWorld relies heavily on a functioning Open Firmware with a complete device tree.

Interrupt Layout

The interrupt layout is determined by information in the device tree. An interrupt tree overlays the other information in the device tree to describe how the interrupts are configured. The Trampoline code traverses this device tree interrupt tree and builds data structures that are used to dispatch interrupts. The device tree interrupt tree is defined in the *Open Firmware Recommended Practice: Interrupt Mapping*. It is not necessary to change any of the interrupt dispatching code, either 68K or native. All the necessary information is retrieved from the device tree.

This interrupt dispatch code has drastically reduced latency times as compared to all previous PCI Macintosh computers.

Machine Identification

Applications can find out which machine they are running on by calling the Gestalt Manager. The gestaltMachineType value returned for the iMac is 406 (196 hexadecimal).

Because NewWorld uses the same Universal and ProductInfo tables for all computer models that it runs on, those computers all have the same Box Flag. All those computers use the same enablers, and no patches are made to the

ToolBox ROM Image, so sharing the same Box Flag is not an issue for those areas.

IMPORTANT

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

Asset management software that reports the kind of machine it is run on should check the name registry for the value of the property at `Devices:device-tree:model`. For the current iMac, the property value is `iMac,1`.

Abbreviations

Standard units of measure used in this note include:

A	amperes	MB	megabytes
dB	decibels	Mbps	megabits per second
GB	gigabytes	Mbit	megabits
Hz	hertz	MHz	megahertz
KB	kilobytes	mm	millimeters
kg	kilograms	ns	nanoseconds
kHz	kilohertz	V	volts
mA	milliamperes	VDC	volts direct current

Other abbreviations used in this note include:

$n	hexadecimal value n
10Base-T	an Ethernet standard for data transmission at 10 Mbits per second
100Base-TX	an Ethernet standard for data transmission at 100 Mbits per second
68K	the 68000 family of microprocessors
ADB	Apple Desktop Bus
AIM	ATA Interface Module
ANSI	American National Standards Institute
API	application programming interface
ASIC	application-specific integrated circuit
ATA	AT attachment
BIOS	basic input/output system
CAS	column address strobe, a memory control signal
CD	compact disc
CD-ROM	compact disc read-only memory

CHRP	Common Hardware Reference Platform
CPU	central processing unit
CRM	Communications Resource Manager
CRT	cathode ray tube, a video display device
DAA	data access adapter (a telephone line interface)
DAC	digital-to-analog converter
DIMM	Dual Inline Memory Module
DMA	direct memory access
EDO	extended data out
EEPROM	electrically eraseable programmable ROM
G3	Generation 3, the third generation of PowerPC microprocessors, including the PPC 740 and PPC 750
GND	ground
HFS	hierarchical file system
HID	human interface device, a class of USB devices
IC	integrated circuit
IDE	integrated device electronics
IEC	International Electrotechnical Commission
I/O	input and output
IR	infrared
IrDA	Infrared Data Association
ISO	International Organization for Standardization
JEDEC	Joint Electron Device Engineering Council
JIS	Japanese Industrial Standards
L1	level 1 or first level, a type of CPU cache
L2	level 2 or second level, a type of CPU cache
LED	light emitting diode
Mac OS	Macintosh Operating System
MESH	the name of an Apple custom IC
modem	modulator-demodulator, a data communications interface for use with analog telephone lines

Abbreviations

NMI	nonmaskable interrupt
NV-RAM	nonvolatile random-access memory
OHCI	Open Host Controller Interface
OS	operating system
PCI	Peripheral Component Interconnect, an industry-standard expansion bus
PLL	phase-locked loop
POST	power-on self test
RAM	random-access memory
RAID	random array of inexpensive disks
RCA	Radio Corporation of America
rms	root mean square
ROM	read-only memory
RTAS	run-time abstraction services
SCC	Serial Communications Controller
SCSI	Small Computer System Interface
SDRAM	synchronous dynamic RAM
SGRAM	synchronous graphics RAM; used for display buffers
SNR	signal to noise ratio
SO-DIMM	small outline dual inline memory module
SPD	Serial Presence Detect, a feature of the SO DIMM
USB	Universal Serial Bus, an industry-standard expansion bus
VCC	positive supply voltage (voltage for collectors)
VIA	versatile interface adapter

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