



Theory of Operation

Early Macintosh Computers





Introduction

Logical troubleshooting involves knowing the function of each module in the computer to narrow the problem search. This document describes each module and its function, the logic board, power supply, disk drives, input devices, and video output.

Because this document ties certain features to the introduction of specific models, the following table lists the introduction dates of all computers discussed.





Macintosh	Date Introduced
128K	January 1984
512K	September 1984
Plus	January 1986
512Ke	April 1986
SE	March 1987
II	March 1987
IIx	October 1988
SE/30	January 1989
IIcx	March 1989
SE FDHD	August 1989





Macintosh	Date Introduced
IIci	September 1989
IIfx	March 1990
Classic	October 1990
IIsi	October 1990
LC	November 1990
Classic II	October 1991
Quadra 700	October 1991
Quadra 900	October 1991
LC II	March 1992
Color Classic	February 1993





System Startup

When a Macintosh computer starts up, the system begins a carefully synchronized sequence of events. For Macintosh SE and later computers, the system software performs a memory test to determine how much RAM is present and whether the RAM is good.

For Macintosh LC and later computers, the system then compiles memory maps describing the current memory configuration. A 24-bit map allows Macintosh software to use a 24-bit address mode. The 32-bit memory map enables Macintosh software created to use 32-bit memory with full 32-bit address space.





The memory management unit (MMU) is programmed, based on the 24- and 32-bit memory maps, to provide contiguous logical memory from the potentially noncontiguous physical segments.

Then the disk startup process begins. The system looks for a readable disk in the available disk drives in this order:

- 1 Internal floppy disk drive(s).
- 2 External floppy disk drive(s).
- 3 Startup device set in the control panel.
- 4 SCSI devices in declining order of device ID (from 6 to 0).

Note: If the battery is removed or the contents of parameter RAM are destroyed, the startup device defaults to the ID=0.





Logic Board

The Macintosh logic board is the heart of the computer system where all information processing takes place. The logic board contains the components described under the following subheadings.

Central Processing Unit (CPU) or Microprocessor

There is a Motorola 68000 microprocessor in the original Macintosh, Macintosh Plus, and Macintosh SE. It gets instructions from memory, translates them, and carries them out. It communicates with all components on the logic board and with all peripherals.





Beginning with the 68030 microprocessor, paged memory management support eliminates the need for a separate PMMU chip (found in the Macintosh II). Beginning with the Classic II, the 68030 microprocessor supports virtual memory capabilities.

Beginning with the Macintosh Quadra 700, the 68040 microprocessor has a math coprocessing unit and memory cache built in.

Math Coprocessor

The math coprocessor is sometimes called a floating-point unit (FPU). The math coprocessor performs floating point arithmetic computations in parallel with the microprocessor.





Random Access Memory (RAM)

RAM storage capability varies from 128 kilobytes on the original Macintosh to several megabytes on later models. It's on Single In-line Memory Modules (SIMMs) installed in sockets on the logic board. Each SIMM is a small printed circuit card.

The Macintosh IIfx reads and writes on separate data buses to allow memory reads and writes to occur simultaneously.

RAM Cache

RAM cache is for storing the most frequently used data and instructions to make them more quickly available for use. This increases the effective speed of main memory. The cache tag serves as a pointer for the CPU to locate information stored in the RAM cache.





Fast Memory Controller (FMC)

In the Macintosh IIx, the fast memory controller (FMC) is an integrated dynamic RAM and cache memory controller. It supports the MC68030 microprocessor's burst mode to access memory.

Parity Generator Chip (PGC)

The parity generator chip (PGC), an option on the Macintosh IIx and IIci logic boards, requires 9-bit DRAM SIMMs to work. With every read, the PGC generates an internal parity bit from each byte of the data bus and compares it to the bit read from the SIMM's parity bit. If the two parity bits don't agree, the PGC generates two outputs—one that indicates a parity error and one that interrupts the processor. After a parity error occurs, the system needs to be reset.





Read-Only Memory (ROM)

Read-only memory (ROM) is nonvolatile memory that contains operating code for the microprocessor. ROM contains such software as operating system support, diagnostics, self-tests, and the Macintosh ToolBox.

In later Macintosh computers, ROM also contains 32-bit QuickDraw routines, support for 32-bit addressing, the peripheral interface controllers, small computer system interface (SCSI) direct memory access (DMA), SuperDrive extensions, virtual memory (VM), built-in video, and parity.

With the Quadra, ROM contains routines to support math coprocessing, cache functions, sound capabilities and VRAM-based video, Ethernet, and a bootable RAM disk.





Versatile Interface Adapters

Introduced in the Macintosh and Macintosh Plus, the versatile interface adapter (VIA) is a dual-port parallel interface. The VIA chip converts serial data (from input devices) to parallel data, so the logic board can interpret information correctly. It provides an interface for the mouse and the keyboard.

In the Macintosh II and later models, the versatile interface adapters became two chips known as VIA1 and VIA2 that provide for software compatibility.

The VIA1 chip provides the system with most of the signals from the 68000-based Macintosh configuration. It also allows access to Apple Desktop Bus interrupt and a synchronous modem signal. In the Macintosh IIci, the VIA1 chip supports parity. In the Macintosh Quadra 700, the VIA1 chip supports A/UX software and initialization.





The VIA2 chip decodes NuBus slot interrupts, a SCSI interrupt, and the Apple sound chip interrupt. It also powers the unit off, blocks NuBus accesses to RAM, and determines errors that occur in NuBus transactions.

In later models it detects an external speaker or amplifier, disables the 68030 or 68040 instruction and data cache, flushes and disables cache, tests the parity circuit, and controls the direct-access frame buffer (for built-in video) and built-in Ethernet support.

Built-in Video Chip

The built-in video chip provides support for the color lookup table (CLUT). It identifies the type of monitor connected by the grounding pattern on the pins.





The video chip includes versatile interface adapter chips, VIA1 and VIA2. The VIA2 contains registers for inputs and outputs, video control, testing modes, and interrupt handling.

VRAM

Video RAM can be installed in the Macintosh LC and LC II. This allows the video frame buffer to use VRAM instead of RAM. Video data can be fetched from VRAM without interrupting CPU access to main memory or to I/O devices.





Disk Controller Chip

Integrated Woz Machine (IWM)

The IWM is a self-contained disk controller card on one integrated circuit (IC). This IC supports the internal and external disk drives in the original Macintosh, Macintosh Plus, early Macintosh SE, and Macintosh II computers. It simplifies the microprocessor's task of reading and writing.

Sanders-Woz Integrated Machine (SWIM)

Macintosh SE/30 and later Macintosh computers use the SWIM chip. In addition to IWM functionality, it enables the Apple SuperDrive (Floppy Drive High Density or FDHD) disk drive to exchange data between Apple and MS-DOS systems.





Serial Communications Controller (SCC)

The SCC handles the information received and sent from serial ports on the computer. Serial ports are mainly used for connecting to networks, printers, and modems.

Programmable Array Logic (PAL)

Programmable array logic (PAL) chips are customized ICs that perform control and synchronizing functions for the rest of the main logic board.





Real-Time Clock

Beginning with the Macintosh LC, a real-time clock on a microcontroller chip contains parameter RAM (PRAM). PRAM stores the configuration of ports, the clock setting, and other data that must be preserved when system power isn't available.

Oscillator

This is a timing device on early Macintosh computers that generates the master clock pulse. The master clock pulse is broken down into various timing clocks needed by chips on the main logic board.





Battery

Beginning with the Macintosh SE, the battery is installed in a holder for replacement without cutting and soldering. The battery provides power to the system clock and calendar.

Peripheral Interface Controllers

Low-level communications with external devices were handled by the main CPU in early Macintosh computers. The Macintosh IIx includes dedicated I/O processors called input/output processors (IOPs). To increase performance in the Macintosh IIx, these communications are handled by three IOPs implemented as standalone peripheral interface controllers (PICs). These PICs support the serial communications controller (SCC), SWIM disk controller, and Apple Desktop Bus interface.





Sound

Sound Output

The sound chip supports the internal speaker connector and the external sound jack.

Sound Input

The sound input port became available with the Macintosh Classic II. A stereo mini-phone jack allows recording sound digitally and mixing an external audio source with computer-generated sound.





Small Computer System Interface (SCSI) Bus

The Apple SCSI manager controls the high-speed parallel port that supports up to seven daisy-chained SCSI devices. The Macintosh computer is always address 7. The hard drive, if present, is address 0. The Apple SCSI interface differs from the industry SCSI standard in two ways:

- A DB-25 connector is used instead of the standard 50-pin “D” connector to attach external SCSI devices. The Apple SCSI System Cable is available to convert the connector to the standard.
- Power for termination resistors is not provided. If the attached SCSI device does not have the required terminator resistor, the external device must either include a built-in terminator or provide power for an external terminator.





Direct memory access (DMA) support was added to the SCSI chip on the Macintosh IIx. Data transfers and bus arbitration could be handled independently from the microprocessor.

Apple Desktop Bus (ADB)

Beginning with the Macintosh SE, ADB is the method and protocol for connecting computers with input devices. The ADB issues commands that control the flow of data to connected devices.





NuBus Interface

NuBus expansion slots allow attaching Apple standard peripherals. The slot is a 96-pin DIN connector. The following are examples of cards that go into a NuBus slot:

- Video cards
- Coprocessor cards
- RAM cards
- Ethernet, Token Ring, and other network interface cards
- Data acquisition cards
- Add-on SCSI port cards

The NuBus interface has three major states of communication:

- Processor to NuBus, which happens whenever the microprocessor generates a physical slot address. If a device responds, the data is transferred.





- NuBus to processor bus for access between NuBus and RAM, NuBus and ROM, and NuBus and I/O. Two control functions are performed for this process—one tracks the changes on NuBus, and the other lets the processor tell NuBus what to do next.
- NuBus time-out, required to prevent access to empty slots. Such access would hang the system.

Every NuBus card should contain a ROM that provides information to the operating system at startup. The ROM information ensures that drivers are properly installed and that the card is initialized and recognized by the system.





The Macintosh IIx has two Bus Interface Units (BIUs) that interface between NuBus and the microprocessor. They contain the control circuitry and latches for the address and data buses. Also, the NuBus clock generator generates the NuBus clock signal and monitors NuBus control signals on the Macintosh IIx. The NuBus interface in the Macintosh Quadra 700 allows direct communications between two NuBus cards.

Processor-Direct Slot (PDS)

The processor-direct slot (PDS) provides direct access to the microprocessor bus. This direct access to the CPU rather than through the NuBus interface increases throughput for the connected device.





General Logic Unit (GLU)

The general logic unit (GLU) chip performs support functions for the microprocessor in the Macintosh II, IIx, and IIcx. It provides address decoding, chip select, RAM refresh, CPU, SCC, and VIA clock signal generation and NuBus, VIA, SCC, power, and NMI switch interrupt handling.

Operating System Support (OSS) Chip

Some of the support functions the operating system support (OSS) chip performs include I/O device decoding and timing, interrupt prioritization and masking, a 56-bit system counter, bus timeout logic, and interface support for the real-time clock chip.





Power Supply

The power supply converts the AC voltage to DC voltage for use by the entire system. It operates on standard line voltage and outputs various DC voltages used by the logic board, video display, fan, internal disk drives, peripheral ports, NuBus slots, and processor-direct slots.

Power Control

The Macintosh II, IIx, IIcx, IIfx, IIsi, LC, LC II, and Quadra 900 have a hardware-on/software-off circuit to control the power supply.

The Macintosh IIcx, IIci, and Quadra 700 use a switch-and-shut-down circuit to control the power supply. The circuit controls the power supply through the power failure warning signal on the NuBus interface.





On the Macintosh Ilcx, Ilci, Ilsi, LC, LC II, and Quadra 700 the rear-panel power switch can be locked in the ON position. This allows the computer to restart as soon as it detects AC power. If a power failure shuts off the computer, it will start up as soon as power comes back on.

Fuses

Some logic boards have resettable fuses that protect the external SCSI, Ethernet, and ADB connectors.





Video Output

Analog Board

The analog board contains circuits for both the horizontal and vertical signals fed to the cathode-ray tube (CRT). The flyback transformer delivers high voltage directly to the CRT through the anode connector.





Cathode-Ray Tube (CRT)

The CRT provides the high-resolution video display. The flyback transformer on the analog board connects to the anode to apply high voltage to the CRT.

The analog board connects to the neck and yoke to supply various voltages and signals to the CRT to create the video display. A separate video board on the neck of the CRT provides video amplification and overvoltage protection.





Disk Drives

Floppy Drives

Internal disk drives connect to the logic board through internally installed connectors. External drives connect to ports on the logic board.

Reading and writing operations are controlled by the disk controller chip on the logic board. The data passes through this chip on its way from the logic board to the disk in the drive or from the disk drive to the logic board.

Beginning with some Macintosh SE computers, the 1.4 MB SuperDrive (Floppy Drive High Density or FDHD) became available.





SCSI Hard Drive

The internal SCSI hard drive connects to the logic board through the internal SCSI connector. Other SCSI devices may be daisy-chained through the external SCSI port.





Input Devices

Mouse

Original Macintosh and Macintosh Plus Mouse

The mouse connects to a nine-pin connector on the main logic board. The assemblies inside the mouse send a series of pulses to the SCC and the VIA. These chips interpret and translate the information so that the logic board can use it.





ADB Mouse

Macintosh computers after the Macintosh Plus use an ADB mouse that connects to the keyboard or other ADB port on the computer. The mouse is the only ADB device that doesn't have a port for daisy-chaining to other devices and must be the last device in a chain. The mouse has no microprocessor.

Keyboard

Original Macintosh and Macintosh Plus Keyboard

The keyboard connects to the logic board through a four-wire coil with a telephone-type connector. The keyboard has its own microprocessor, which is used to implement a serial bus for communicating with the logic board.





The keyboard data is sent in serial form to the VIA, where it is converted into parallel data and translated so that the logic board can use it.

ADB Keyboards

Macintosh computers after the Macintosh Plus use keyboards that connect to the ADB port. All devices made for the ADB have a microprocessor (except the mouse) that makes them intelligent devices. This means they can issue commands on the ADB and transmit and receive data to and from other ADB devices. All ADB devices communicate with the logic board via a mini DIN-4 connector.

