New Technical Notes

Macintosh

Developer Support

Macintosh Memory Configurations

Hardware **M.HW.MemConfigs**

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This Technical Note describes the different possible memory configurations of all models of the Macintosh family that use Single In-line Memory Modules (SIMMs) as well as the non-SIMM memory upgrade options of the Macintosh Portable, Macintosh Classic, and Macintosh PowerBooks. (Special thanks to Brian Howard for the Macintosh Plus and original SE drawings, and for the inspiration for the other drawings.) This Note also describes the obstacles to using four megabit (Mbit) DRAM SIMMs in Apple Macintosh products to date.

Changes since April 1992: Corrected errors on the RAM configuration chart (page 2) and on the information for the IIci. Added information on the LC II, Quadra 950, PowerBook 145, 160, 180, PowerBook Duo 210 and 230, IIvx, IIvi and the Performa 600

Topics

- Memory Configurations for the full Macintosh line of CPUs
- Explanation of the problem with 4 Mbit DRAMs and the Macintosh Plus, SE, Classic, II and IIx

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Developer Technical Support receives numerous questions about the many different possible configurations of RAM on the different Macintosh models, so we'll attempt to answer these questions in this Technical Note, as well as to provide a showcase for some outstanding Macintosh Plus and SE artwork by Apple engineer Brian Howard. Interested readers should refer to the *Guide to the Macintosh Family Hardware*, Second Edition, which contains much more detail on the memory configurations and specifications for all Macintosh models released to date. For information on the newer Macintosh models not mentioned in the *Guide to the Macintosh Family Hardware,* please refer to the companion developer notes for those particular products.

RAM Configuration Chart

Caveat: The upper physical RAM totals expressed here assume the use and compatibility of 4, 16, and in some instances, 2 MB SIMMs. Since Apple has not yet thoroughly tested SIMMs larger than 1 MB, and in some instances 2 MB with our Macintosh line, these upper limits should be considered theoretical. At this point Apple cannot claim that these SIMM sizes will work, nor can we guarantee any information in this Tech Note that pertains to the use of 4 and 16 MB SIMMs (read: use them at your own risk).
All numbers are expressed in terms of megabytes (MB) unless otherwise noted.

	Permanent RAM	No. of SIMM slots	Allowable SIMM sizes	Physical RAM Totals	Req. Speed	TN Page
Plus	0	4	256K,1	512K,1,2,2.5,4	150 ns	3,4
SE	0	4	256K,1	512K,1,2,2.5,4	150 ns	3,5,6
Classic	1	2*	256K,1	1,2,2.5,4	150 ns	3,8
Classic II‡	2	2	1,2,4	2,4,6,10	100 ns	17
SE/30	0	8	256K,1,4,16	1,2,4,5,8…128†	120 ns	7,9
II	0	8	256K,1,4,16††	1,2,4,5,8…68†	120 ns	7,9
IIx	0	8	256K,1,4,16	1,2,4,5,8…128†	120 ns	7,9
IIcx	0	8	256K,1,4,16	1,2,4,5,8…128†	120 ns	7,12
LC‡	2	2	1,2,4,16	2,4,6,10	100 ns	8,10
LCII‡	**4**	**2**	**1,2,4,16**	**4,6,8,10**	**100 ns**	**8,10**
IIsi‡	1	4	256K,512K,1,2,4,16	1,2,3,5,9,17…65	100 ns	8,10
IIci‡	0	8	256K,512K,1,4,16	1,2,3,4,5,6,8,9,10, 12,16,17,18,20…128	80 ns	10,12
IIvx, IIvi‡	**4**	**4**	**256K,1,2,4,16**	**4,5,8,12,20…68**	**80 ns**	
Portable	1	0**	n/a	1,2,3,4,5,6,7,8,9***	100 ns	11,12
Portable (backlit)	1	0**	n/a	1,2,3,4,5,6,7,8***	100 ns	
Quadra 900‡	0	16	1,4,16	4,8,12,16,20,24…256	80 ns	15
Quadra 950‡	**0**	**16**	**1,4,16**	**4,8,12,16,20, 24…256**	**80 ns**	**15**
PowerBook 100	2	0**	n/a	2,4,6,8	100 ns	19
PowerBook 140‡	2	0**	n/a	2,4,6,8	100 ns	18
PowerBook 145‡	**2**	**0****	**n/a**	**2,4,6,8**	**100 ns**	**18**
PowerBook 160‡	**4**	**0****	**n/a**	**4,6,8,10,14**	**85 ns**	
PowerBook 170‡	2	0**	n/a	2,4,6,8	100 ns	18
PowerBook 180‡	**4**	**0****	**n/a**	**4,6,8,10,14**	**85 ns**	
PowerBook Duo210‡	**4**	**0****	**n/a**	**4,8,12…24**	**n/a**	
PowerBook Duo230‡	**4**	**0****	**n/a**	**4,8,12…24**	**n/a**	

All new products added in this revision are in bold type.

*The Macintosh Classic has 1 MB of RAM soldered onto the motherboard. Additional RAM can be added by using an expansion card. Apple Macintosh Classic 1 MB Memory Expansion Card has 1 MB of additional RAM and two SIMM connectors.

**The Macintosh Portable and the PowerBook computers allow you to add RAM by using an expansion card. These expansion cards can have from 1 MB to 4 MB of memory for the Portable; 1 MB to 3 MB for the backlit Portable; 2, 4, or 6 MB for the PowerBook 100, 140, 145 and 170; 2, 4, 6, 10 MB for the Powerbook 160 and 180; and 4, 8 MB for the PowerBook Duo 210 and 230.

***If the PDS slot is used for other peripherals, then the maximum amount of RAM (by using a RAM expansion card) is 5 MB for the Macintosh Portable, and 4 MB for the backlit Macintosh Portable.

‡These systems have ROMs that are capable of 32-bit addressing (when using the appropriate system software, such as System 7 or A/UX). The Macintosh can only address up to 8 MBs in 24-bit mode; therefore, when using more than 8 MB of RAM, you need to turn on 32-bit addressing.

†The Macintosh II, IIx, IIcx, and SE/30 can benefit from larger SIMM sizes and address more than 8 MB of RAM by using either A/UX or the 32-bit addressing software solution called MODE32™ in conjunction with System 7. This will allow addressing up to 128 MB on the IIx, IIcx, and SE/30, and up to 68 MB on the Macintosh II (four 1 MB SIMMs in Bank A, four 16 MB SIMMs in Bank B). If you use SIMMs larger than 1 MB on the Macintosh II or IIx, you must have a PMMU and special SIMMs with PAL™ logic on them. Please refer to pages 7 and 20 of this Tech Note for more information on these SIMMs. MODE32, by Connectix, has been made available at no charge to all Apple customers. For more information about MODE32, please contact the Apple Customer Assistance Center at 1-800-776-2333.

††SIMMs greater than 1 MB can only be in SIMM Bank B. Please refer to Page 7 for more Macintosh II information.

Warning: Because the video monitor is built in, there are dangerous voltages inside the cases of the Macintosh Plus, SE, Classic, Classic II, and SE/30 computers. The video tube and video circuitry may hold dangerous charges long after the computer's power is turned off. Opening the case of these computers requires special tools and may void your warranty. Installation of RAM in the SIMM sockets in these computers should be done by qualified service personnel only.

Macintosh Plus

The Macintosh Plus has the following possible configurations (see Figure 1):

512K, using two 256 Kbit SIMMs
1 MB, using four 256 Kbit SIMMs
2 MB, using two 1 Mbit SIMMs
2.5 MB, using two 1 Mbit SIMMs and two 256 Kbit SIMMs
4 MB, using four 1 Mbit SIMMs

It is important to place the SIMMs in the correct location when using a combination of SIMM sizes, as in the 2.5 MB example, and to make sure the right resistors are cut. Refer to Figure 1 for the correct location of the SIMMs, their sizes, and resistor requirements.

Macintosh SE

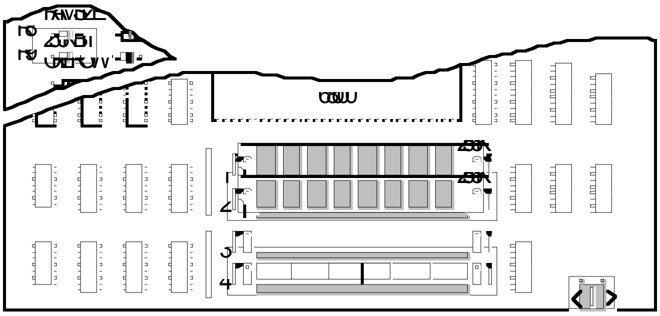
The Macintosh SE configurations (the original motherboard as well as the revised motherboard with a memory jumper selector) are the same as the Macintosh Plus, except physical locations on the motherboard are different. In addition, memory configurations with only two SIMMs (for example, 512K and 2 MB) use slots 3 and 4 on the revised SE motherboard instead of slots 1 and 2 like the original motherboard and Macintosh Plus. Refer to Figures 2 and 3 for the correct locations and settings.

Macintosh Classic

The Macintosh Classic has the following possible configurations (see Figure 4):

1 MB, using eight 128 Kbit DRAMs soldered to the motherboard
2 MB, using the memory expansion card and setting the jumper to "SIMM NOT INSTALLED"
2.5 MB, using two 256 Kbit SIMMs on the memory expansion card and setting the jumper to "SIMM INSTALLED"
4 MB, using two 1 Mbit SIMMs on the memory expansion card and setting the jumper to "SIMM INSTALLED"

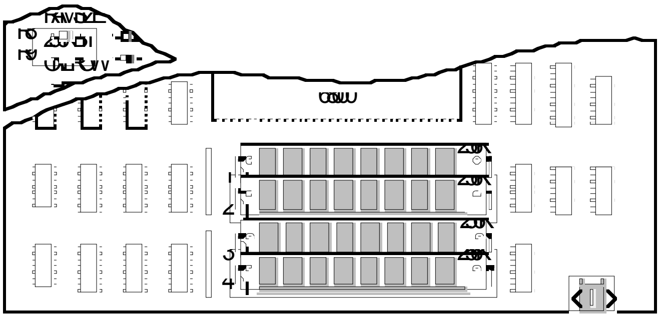
When adding SIMMs to the memory expansion card, use either two 256 Kbit or two 1 Mbit parts rated at 120 ns or faster.



System memory size: 512K

SIMM configuration
- Row 1 (SIMMs 1 & 2): 256K
- Row 2 (SIMMs 3 & 4): Not installed

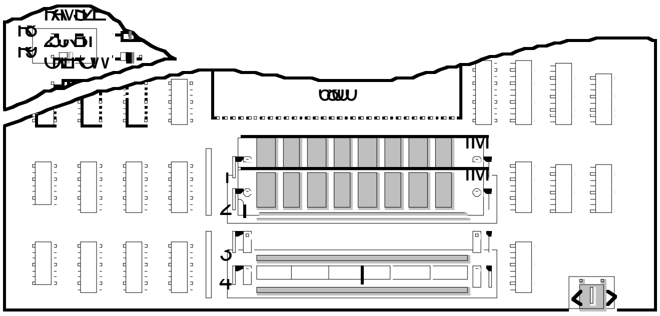
RAM SIZE resistors
- 256K only (R8): Installed
- One row (R9): Installed



System memory size: 1MB

SIMM configuration
- Row 1 (SIMMs 1 & 2): 256K
- Row 2 (SIMMs 3 & 4): 256K

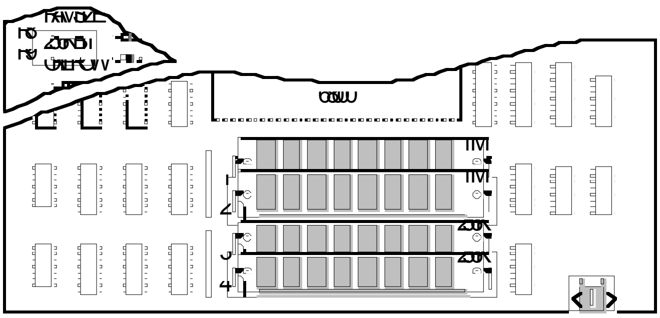
RAM SIZE resistors
- 256K only (R8): Installed
- One row (R9): Not installed



System memory size: 2MB

SIMM configuration
- Row 1 (SIMMs 1 & 2): 1MB
- Row 2 (SIMMs 3 & 4): Not installed

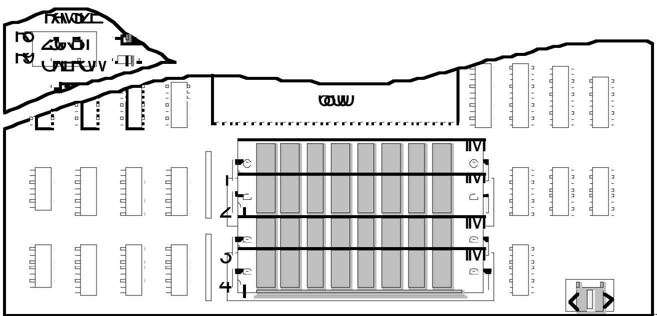
RAM SIZE resistors
- 256K only (R8): Not installed
- One row (R9): Installed



System memory size: 2.5MB

SIMM configuration
- Row 1 (SIMMs 1 & 2): 1MB
- Row 2 (SIMMs 3 & 4): 256K

RAM SIZE resistors
- 256K only (R8): Not installed
- One row (R9): Not installed



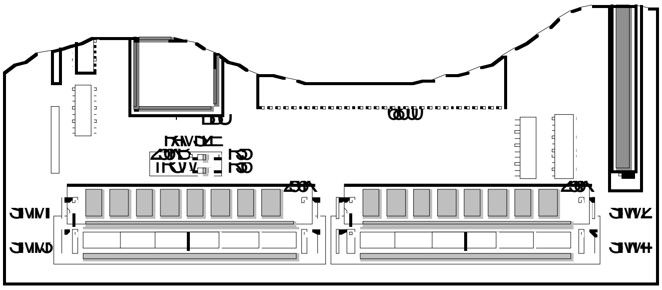
System memory size: 4MB

SIMM configuration
- Row 1 (SIMMs 1 & 2): 1MB
- Row 2 (SIMMs 3 & 4): 1MB

RAM SIZE resistors
- 256K only (R8): Not installed
- One row (R9): Not installed

(SIMMs must be 150 ns RAS access time or faster, and must be the same speed within a row)

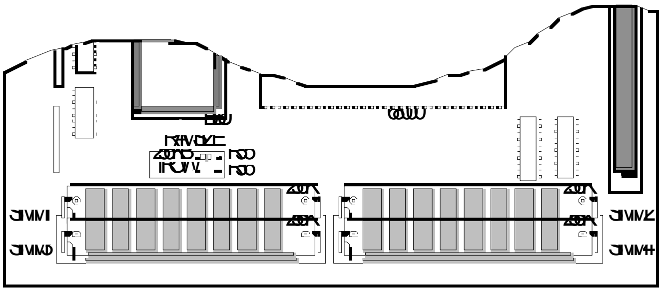
Figure 4 Macintosh Plus Memory Configurations



System memory size 512K

SIMMs Configuration
Row 1 (SIMMs 1 & 2) 256K
Row 2 (SIMMs 3 & 4) Not installed

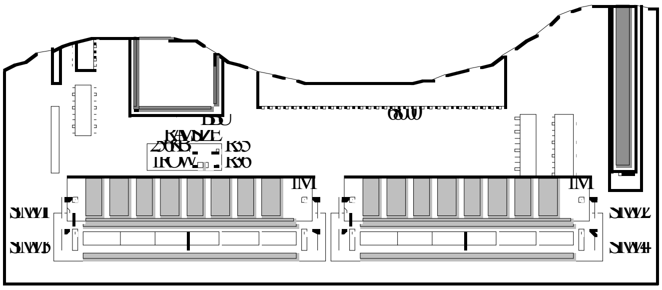
RAM SIZE Resistors
256K Bit (R35) Installed
One Row (R36) Installed



System memory size 1 MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2) 256K
Row 2 (SIMMs 3 & 4) 256K

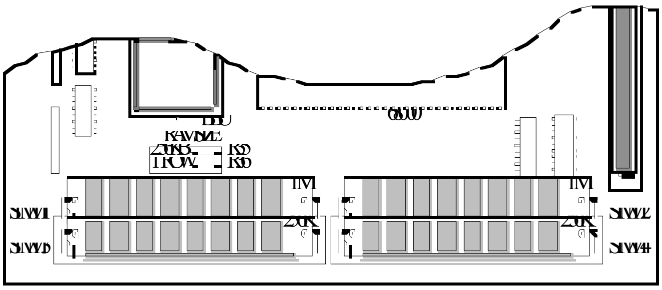
RAM SIZE Resistors
256K Bit (R35) Installed
One Row (R36) Not installed



System memory size 2 MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2) 1 MB
Row 2 (SIMMs 3 & 4) Not installed

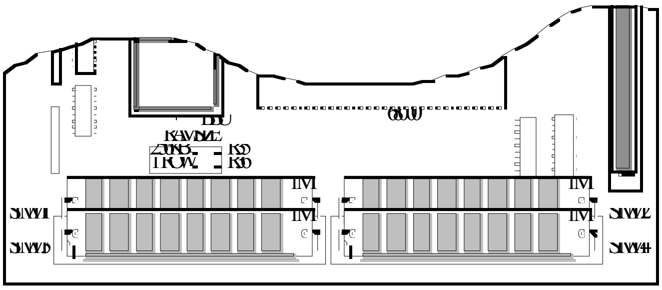
RAM SIZE Resistors
256K Bit (R35) Not installed
One Row (R36) Installed



System memory size 2.5 MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2) 1 MB
Row 2 (SIMMs 3 & 4) 256K

RAM SIZE Resistors
256K Bit (R35) Not installed
One Row (R36) Not installed



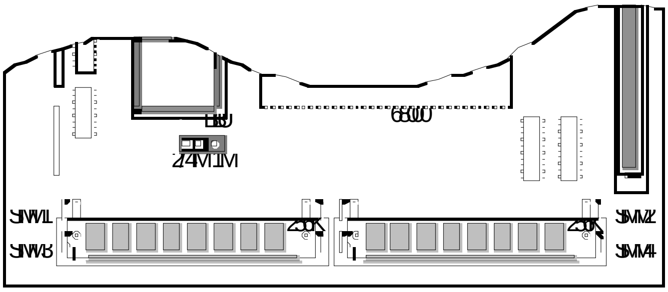
System memory size 4 MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2) 1 MB
Row 2 (SIMMs 3 & 4) 1 MB

RAM SIZE Resistors
256K Bit (R35) Not installed
One Row (R36) Not installed

(SIMMs must be 150 ns RAS access time or faster, [illegible])

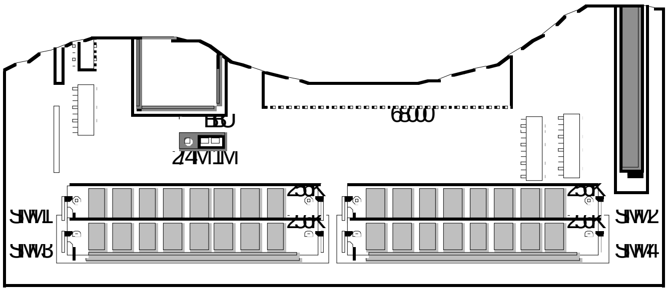
Figure 2—Various SE Memory Configurations



System memory size: 512K

SIMMs Configuration
Row 1 (SIMMs 1 & 2): Not installed
Row 2 (SIMMs 3 & 4): 256K

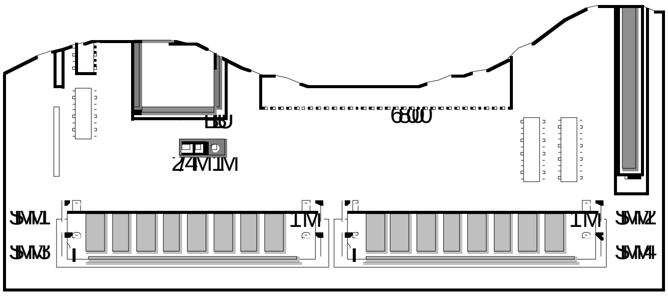
Jumper on 2/4M



System memory size: 1MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2): 256K
Row 2 (SIMMs 3 & 4): 256K

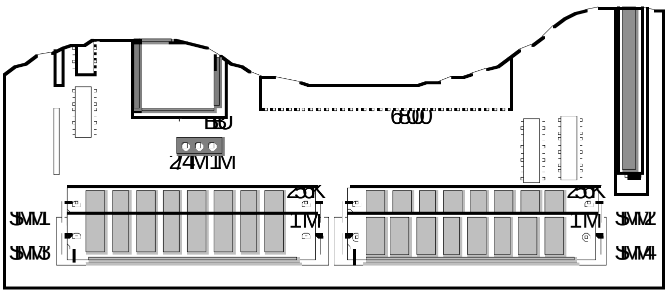
Jumper on 1M



System memory size: 2MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2): Not installed
Row 2 (SIMMs 3 & 4): 1MB

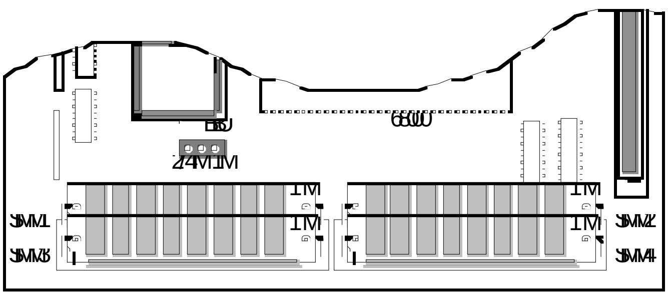
Jumper on 2/4M



System memory size: 2.5MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2): 256K
Row 2 (SIMMs 3 & 4): 1MB

Jumper off



System memory size: 4MB

SIMMs Configuration
Row 1 (SIMMs 1 & 2): 1MB
Row 2 (SIMMs 3 & 4): 1MB

Jumper off

(SIMMs must be 150ns RAS-access time or faster, [illegible] narrow)

Figure 3-4 Macintosh SE (with jumper) Memory Configurations

Macintosh SE/30, II, IIx, and IIcx

Since these machines use a 32-bit data bus with eight-bit SIMMs, you must always upgrade memory four SIMMs at a time. The eight SIMM connectors are divided into two banks of four SIMM slots, Bank A and Bank B.

On the Macintosh SE/30, Bank A is located next to the ROM SIMM while Bank B is next to the 68882 coprocessor. On the Macintosh II and IIx, Bank A is the bank closest to the edge of the board, while on the Macintosh IIcx, Bank A is the bank closest to the disk drives and power supply. Refer to Figure 5 for the proper locations of Banks A and B on the SE/30, II, and IIx, and refer to Figure 6 for the proper locations on the IIcx.

Unlike the Macintosh Plus and the Macintosh SE, the Macintosh II and IIx have no resistors to cut and no jumpers to set; you need only install the SIMMS in the correct banks and you'll be up and running. You can implement the following configurations:

1 MB, using four 256 Kbit SIMMs in Bank A
2 MB, using eight 256 Kbit SIMMs in Banks A and B
4 MB, using four 1 Mbit SIMMs in Bank A
5 MB, using four 1 Mbit SIMMs in Bank A and four 256 Kbit SIMMs in Bank B
8 MB, using eight 1 Mbit SIMMs in Banks A and B
>8 MB: see the 32-bit addressing information below

Again, it is important to make sure the right size SIMMs are in the right bank; when you are using a combination of SIMMs, the larger SIMMs (in terms of Mbits) must typically be in Bank A (see the exception below). When you are using only four SIMMs, they must be in Bank A as well.

32-Bit Addressing With the Macintosh SE/30, II, IIx, and IIcx

The Macintosh SE/30, II, IIx, and IIcx ROMs are not capable of 32-bit addressing. These models can overcome this limitation, however, by using the appropriate system software. A/UX is a 32-bit operating system, as is System 7 when used in conjunction with MODE32 or when used on a Macintosh with 32-bit clean ROMs.

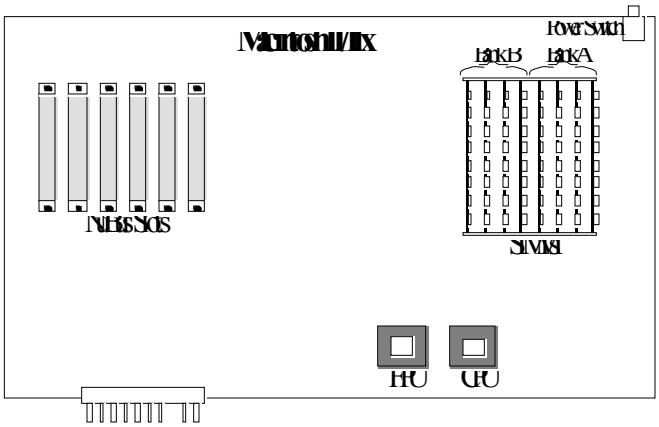
To have more than 8 MB of RAM in a Macintosh II or IIx, special 120 ns PAL SIMMs are required. These SIMMs incorporate PAL logic chips that overcome problems caused by the refresh logic on the Macintosh II and IIx. In addition, a PMMU is required on the Macintosh II. Please refer to the end of this Note ("4 MBit DRAMs in Revolt") for more information on this subject.

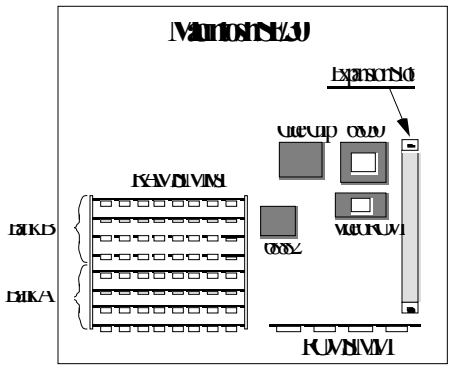
Due to an undocumented feature in the ROM firmware shipped with the original Macintosh II, a Macintosh II with original ROMs is limited to using SIMMs no larger than 1 MB in Bank A. Large SIMMs can only be put in Bank B (that is, 4 and 16 MB SIMMs)*. Remember that if Bank B is to be used at all, Bank A must be populated first. As a result of

this limitation, the largest memory configuration on an unmodified Macintosh II using 1 MB SIMMs in Bank A and 4 MB SIMMs in Bank B is 20 MB. This problem is avoided if you've installed the SuperDrive upgrade kit, which includes a set of Macintosh IIx ROMs. The Macintosh IIx ROMs can handle 4 MB SIMMs, and expect the presence of a SWIM chip in place of the old IWM.

The theoretical maximum memory that a Macintosh SE/30, IIx, IIcx (and II with IIx ROMs) can address is 128 MB using 16 MB SIMMs.

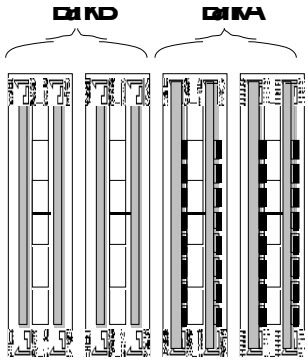
* Please remember that the use of large SIMM sizes with the Macintosh hardware line has not yet been tested thoroughly. It is mentioned here for your consideration and should be considered theoretical until we have been able to further test all of these possible configurations.

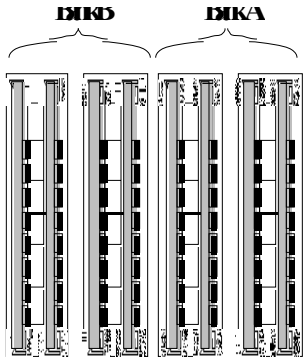


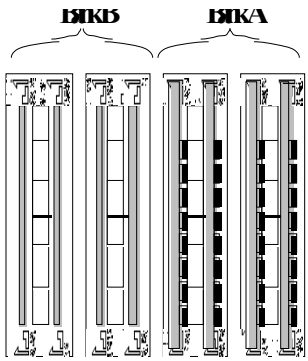


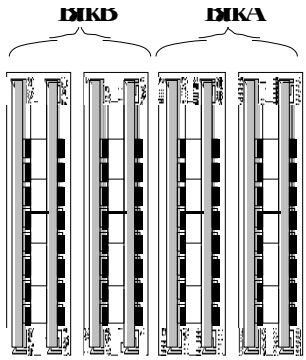
(SIMMs must be 120 ns or faster access time, or faster, and these are specified with a row).

Macintosh IIx, IIx, and Macintosh SE/30 memory configurations are identical.









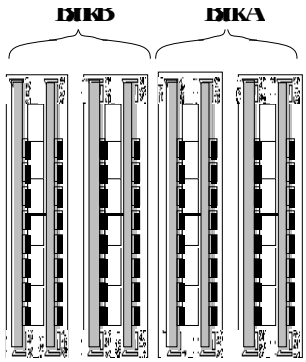


Figure 3 Macintosh SE/30, IIx, and IIx memory configurations

Macintosh LC and LC II

The Macintosh LC and LC II uses a 16-bit data bus with 8-bit SIMMs, so upgrades must always be performed two SIMMs at a time. The LC and the LC II have two SIMM connectors that are used as a single additional RAM bank (see Figure 4). The LC has 2 MB already soldered to the main logic board and the LC II has 4 MB already soldered to the main logic board. The Macintosh LC and LC II requires 100 ns or faster SIMMs. The following memory configurations can be implemented by installing SIMM pairs in this additional bank:

LC

- 2 MB, using four 1 Mbit x 4 DRAMs soldered to the main logic board
- 4 MB, using two 1 Mbit SIMMs in the SIMM connectors
- 6 MB, using two 2 Mbit SIMMs in the SIMM connectors
- 10 MB, using two 4 Mbit SIMMs in the SIMM connectors

LC II

- 4 MB , using eight 1 Mbit x 4 DRAMs soldered to the main logic board
- 6 MB, using two 1 Mbit SIMMs in the SIMM connectors
- 10 MB, using two 4 Mbit SIMMs in the SIMM connectors*

*The LC II can address a maximum of 10 MB of RAM. When the SIMM slots are filled with 4 MB SIMMs the lower 2 MB of DRAM on the logic board can't be addressed.

Macintosh IIsi

The Macintosh IIsi is similar to the SE/30, II, IIx, and IIcx in that it uses a 32-bit data bus with 8-bit SIMMs; you must always upgrade memory four SIMMs at a time. The IIsi differs in that it only has one SIMM bank instead of two (see Figure 4). There is 1MB soldered on the main logic board. The IIsi requires 100 ns or faster SIMMs. The following memory configurations can be implemented:

- 1 MB soldered on the main logic board
- 2 MB, using 256K SIMMs in the SIMM connectors
- 3 MB, using 512K SIMMs in the SIMM connectors
- 5 MB, using four 1 Mbit SIMMs in the SIMM connectors
- 9 MB, using four 2 Mbit SIMMs in the SIMM connectors
- 17 MB, using four 4 Mbit SIMMs in the SIMM connectors

If future 16 Mbit DRAMs are compatible with the current refresh frequency, then the IIsi will support 16 Mbit SIMMs, enabling a RAM configuration of 65 MB (4 x 16 MB + 1 MB).

Macintosh IIci

The Macintosh IIci main logic board layout is somewhat different from the IIcx, but the location of the RAM SIMMs is unchanged. Bank A is still the bank closest to the disk drives. Refer to Figure 6 for the proper locations of Banks A and B on the IIci.

The IIci has a much improved RAM interface and allows a great deal more freedom when installing SIMMs. Banks A and B are interchangeable, meaning that when mixing two sizes of RAM, the larger SIMMs do not necessarily have to go in Bank A. In fact, for best performance when using on-board video, Apple recommends that the smaller SIMMs be installed in Bank A. Note, however, that if on-board video is used, then RAM ***must*** be present in Bank A.

The IIci requires that SIMMs be 80 ns or faster and the same speed within a bank. You can implement the following memory configurations with 256K, 1 MB, and 2 MB SIMMs:

1 MB using four 256 Kbit SIMMs in Bank A or in Bank B*
2 MB using eight 256 Kbit SIMMs in Banks A and B
4 MB using four 1 Mbit SIMMs in Bank A or in Bank B*
5 MB using four 256 Kbit SIMMs in Bank A and four 1 Mbit SIMMs in Bank B**
5 MB using four 1 Mbit SIMMs in Bank A and four 256 Kbit SIMMs in Bank B
8 MB using eight 1 Mbit SIMMs in Banks A and B
9 MB using four 256 Kbit SIMMs in Bank A and 2 Mbit SIMMs in Bank B
12 MB using four 1 Mbit SIMMs in Bank A and 2 Mbit SIMMs in Bank B
16 MB using eight 2 Mbit SIMMs in Banks A and B

* The 1 MB and 4 MB configurations using only Bank B are not compatible with on-board video, since Bank A must contain memory when using on-board video.
** The first 5 MB configuration (with 256 Kbit SIMMs in Bank A) is recommended for 5 MB configurations using on-board video.

Parity RAM

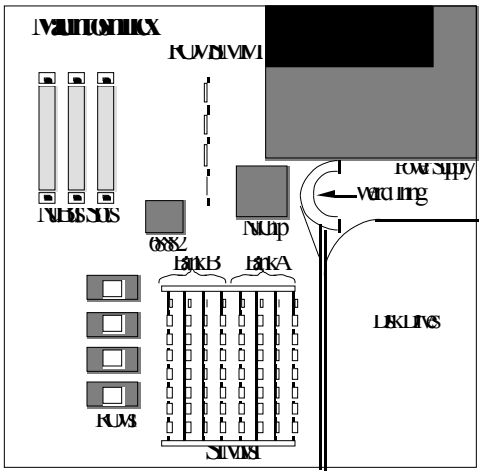
Some specially ordered versions of the Macintosh IIci are equipped with a PGC chip and support parity for RAM error detection. These machines require parity RAM. The SIMMs for these machines are nine bits wide instead of eight, so there is generally an extra RAM IC on the SIMM. There is no difference in the installation of 256K x 9 or 1M x 9 SIMMs.

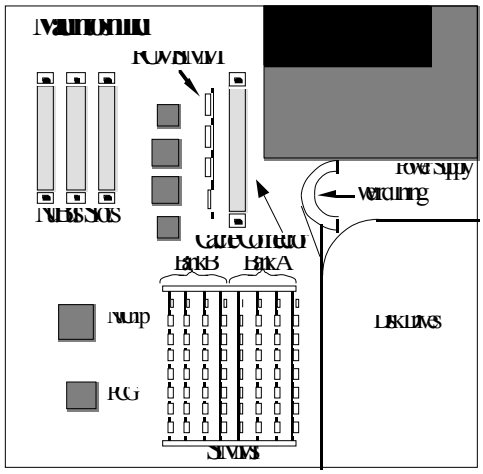
Macintosh Portable

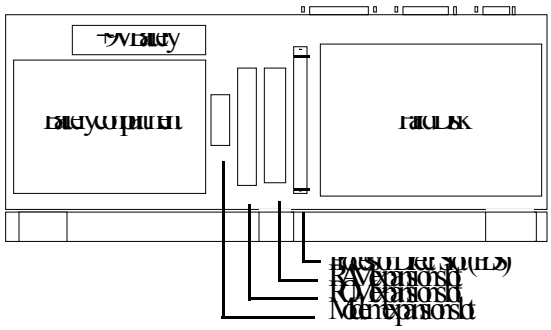
Memory expansion on the Macintosh Portable is different from other members of the Macintosh family since the Portable uses memory expansion cards in place of SIMMs. The base Portable is equipped with 1 MB of RAM on the motherboard and has one RAM expansion card slot. Third-party developers may produce higher-capacity expansion boards (2 MB to 8 MB).

Since the Portable has only one RAM expansion slot, you may use only one memory expansion board at a time. This limit means that a 1 MB expansion board would have to be completely replaced by a higher-capacity board when it became available.

Total RAM for the Portable will always be 1 MB plus the size of your one RAM expansion board (if installed). Refer to Figure 6 for the location of the RAM expansion slot.







Macintosh IIfx

The Macintosh IIfx main logic board layout has its SIMMs located in the same general area as the IIx, but they are oriented transversely. Bank A is the bank closest to the rear of the machine; bank B is closest to the main processor. Refer to Figure 7 for the proper memory bank locations.

The IIfx has a RAM SIMM interface similar to that of the IIcx, et al.: when you are using a combination of SIMMs, the larger SIMMs (in terms of Mbits) must be in Bank A. When you are using only four SIMMs, they must be in Bank A as well. The description in the *Guide to the Macintosh Family Hardware*, Second Edition, inaccurately states the larger SIMMs can be placed in either bank.

The IIfx requires that SIMMs be 80 ns RAS-access time or faster and the same speed within a bank. The IIfx uses 64-pin RAM which is not standard Macintosh RAM. You can implement the following memory configurations with 1 and 4 MB SIMMs (256K address-depth SIMMs are not supported):

4 MB using four 1 Mbit SIMMs in Bank A
8 MB using eight 1 Mbit SIMMs in Banks A and B
16 MB using four 4 Mbit SIMMs in Bank A
20 MB using four 4 Mbit SIMMs in Banks A and four 1 Mbit SIMMs in Bank B
32 MB using eight 4 Mbit SIMMs in Banks A and B

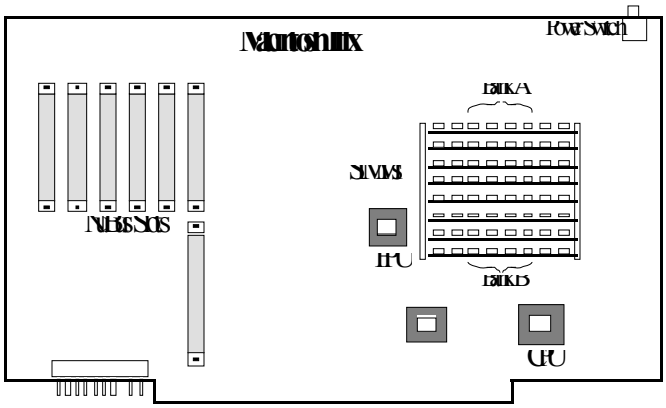
Parity RAM

Parity RAM requirements are as follows: if using 1 MB or 4 MB SIMMs, the RAM speed must be 60 ns. However, the parity circuit programmable array that goes on the motherboard as well as the parity PALs that go on the SIMMs are proprietary to Apple—their equations are not expected to be released to developers. Because of this proprietary design, Apple does not recommend third-party development of parity products.

RAM SIMM Drawings

The IIfx has 64-pin SIMMs, which are different from previous Macintosh models. Developers can request mechanical drawings and electrical specifications of the IIfx RAM SIMM modules from DTS. Please send the request with a mailing address and include the words “IIfx SIMM information request” in the title of the electronic mail request or letter to facilitate handling.

Warning: To avoid degradation of signal quality, it is critical to adhere to the strict timing parameters of the IIfx and to use a good layout that takes high-speed circuits into account.



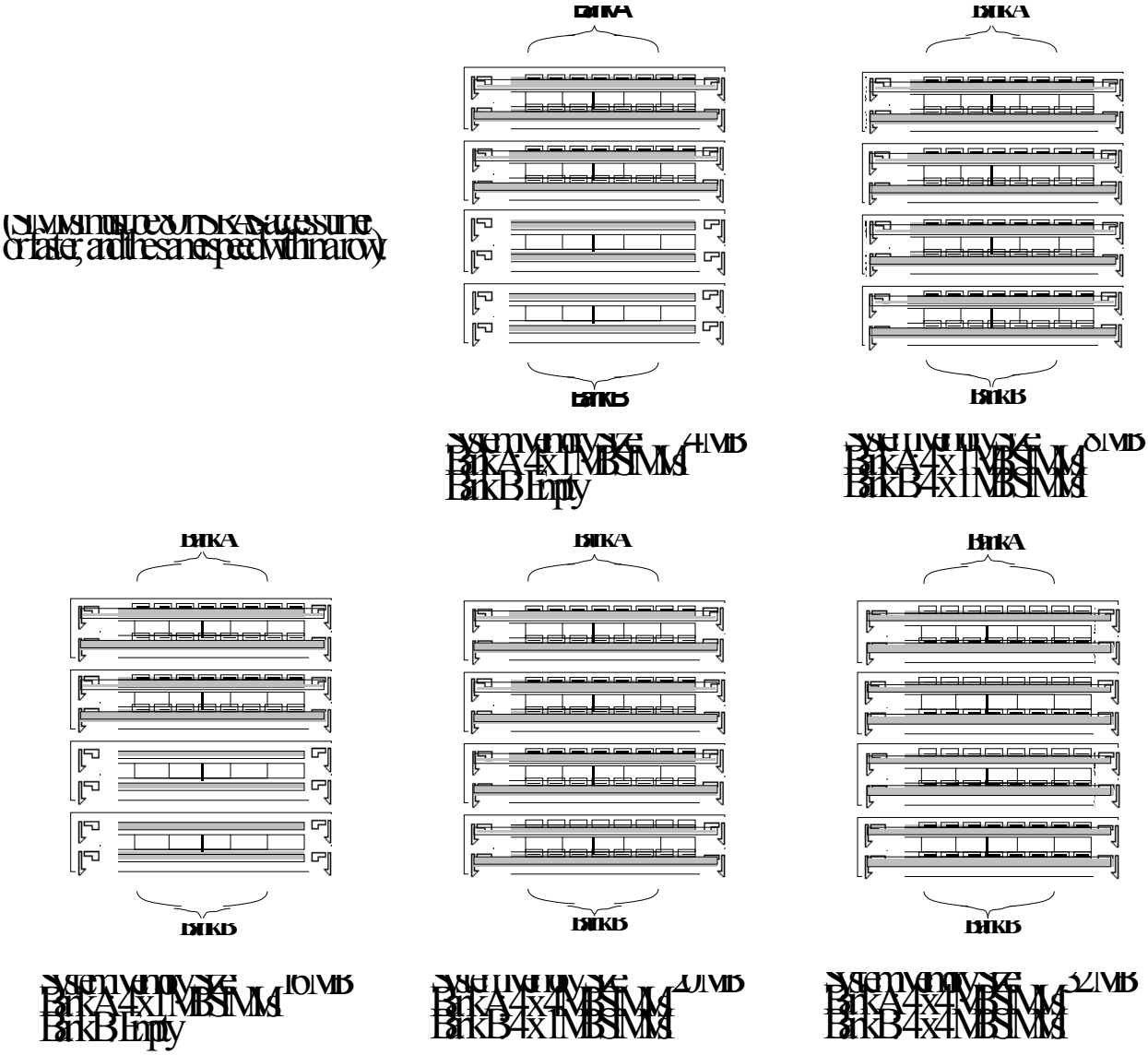


Figure 7—Macintosh IIfx Memory Configurations

Macintosh Quadra 900 and 950

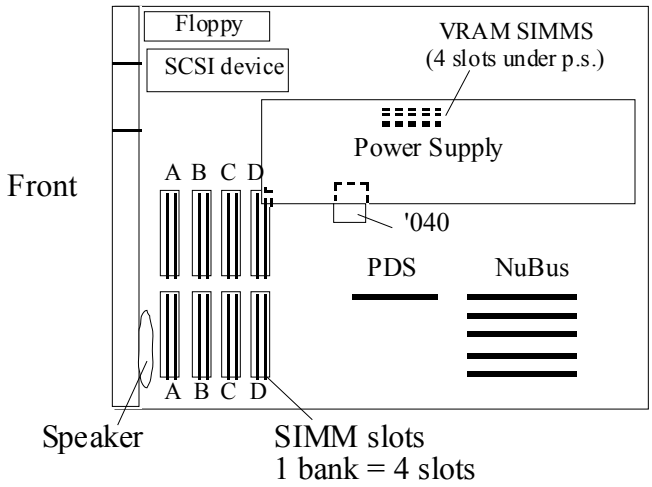


Figure 8 - View of the Macintosh Quadra 900/950 With Case Open

The memory control unit (MCU) controls four banks of dynamic RAM, for a total of 16 SIMM slots. Each bank accepts standard 80 ns SIMMs containing 1 MB, 4 MB, and perhaps 16 MB SIMMs (256K and 2 MB are not supported), giving total memory sizes from 4 MB to 16 MB for each bank (64 MB if 16 MB SIMMs work). Therefore, the Macintosh Quadra 900/950 could have a total of 64 MB when using currently available 4 MB SIMMs. 16 MB SIMMs have not been thoroughly tested on the Quadra 900/950 and therefore cannot be listed as a possible configuration. The Macintosh Quadra 900/950 can also use 60 ns SIMMs, but the MCU is programmed for 80 ns DRAM, so a 60 ns SIMM wouldn't improve the speed.

If one slot in a given bank is filled, then all slots in that particular bank must be populated with the same size and speed SIMM. The order that the banks are populated does not matter (for example, it is acceptable to have four 1 MB SIMMs in Bank B, and four 4 MB SIMMs in Bank D).

Note: When large amounts of DRAM are installed, the memory check upon startup is lengthy and can cause users to think that the machine isn't functioning. There is no software indication that the machine is running memory checks.

Macintosh Quadra 700

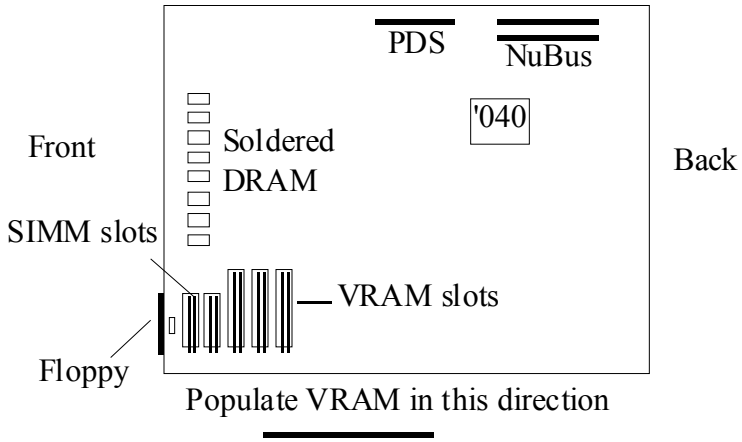


Figure 9 - View of the Macintosh Quadra 700 With Case Open

The Quadra 700 has 4 MB soldered on the main logic board and one bank with four SIMM connectors. The Quadra 700 accepts standard 80 ns SIMMs containing 1 MB, 4 MB, and perhaps 16 MB (256K and 2 MB are not supported), giving total memory sizes from 4 MB to 16 MB. Therefore the Macintosh Quadra 700 could have a total of 20 MB when using SIMMs that are currently available. 16 MB SIMMs have not been tested on the Quadra 700 and therefore cannot be listed as a possible configuration. The Macintosh Quadra 700 can also use 60 ns SIMMs, but the MCU is programmed for 80 ns DRAM, so a 60 ns SIMM wouldn't improve the speed. If one slot in a given bank is filled, then all slots in the bank must be populated. It is not possible to mix the speed of RAM SIMMs on the Quadra 700. The Quadra 700 can implement the following memory configurations:

4 MB soldered on the main logic board
8 MB, using 1 Mbit SIMMs in the SIMM connectors
20 MB, using 4 Mbit SIMMs in the SIMM connectors

Note: Due to the location of the SIMM slots on the Macintosh Quadra 700, it is unlikely that third- party vendors will be able to develop 16 MB SIMMs that work on this machine. The placement of the SIMM slots (under the hard drive) is unfortunate, but necessary due to the logic board architecture.

Macintosh Classic II

The Macintosh Classic II has 2 MB soldered on the main logic board and 2 SIMM connectors that support up to 10 MB of RAM. The Classic II requires 100 ns or faster SIMMs. It can accommodate 1, 2, or 4 MB SIMMS for the following possible system configurations:

2 MB soldered on the main logic board
4 MB, using 1 Mbit SIMMs in the SIMM connectors
6 MB, using 2 Mbit SIMMs in the SIMM connectors
10 MB, using 4 Mbit SIMMs in the SIMM connectors

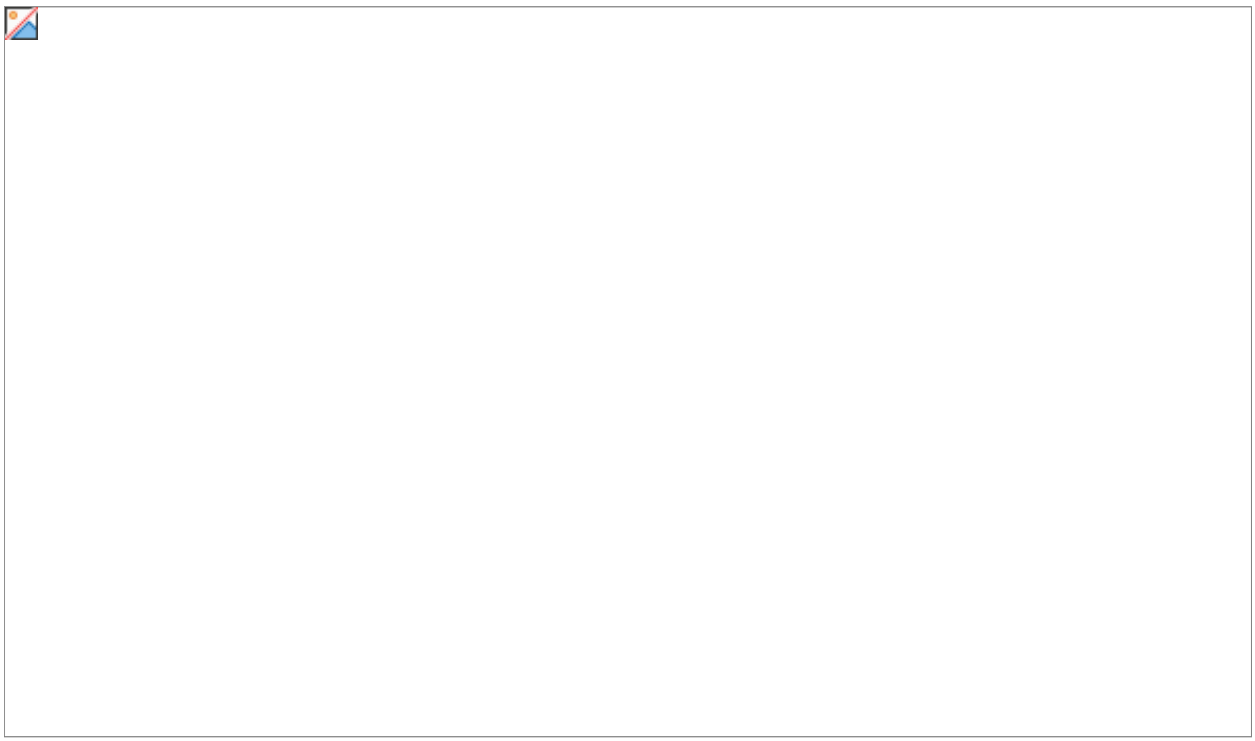


Figure 10 - Macintosh Classic II

Macintosh PowerBook 140, 145, and 170

The Macintosh PowerBook 140, 145, and 170 ship with 2 MB of PSRAM (pseudo-static) on the daughter board. The RAM is arranged physically as four 4 Mbit chips of 512K x 8-bits each. Additionally, an expansion slot allows RAM to be expanded to a total of 8 MB. All three PowerBook systems use 100 ns PSRAM. The Macintosh PowerBook 140 and 145 has one wait state (four clock cycles). The Macintosh PowerBook 170 has two wait states (five clock cycles). PSRAM needs to be refreshed, and the refresh is accomplished by circuitry in the CPU Glue Logic ASIC. The refresh requirement causes a 2% reduction in performance over SRAM. However, PSRAM uses less current in sleep mode and costs less than SRAM.

The PowerBook computers contain a 70-pin RAM expansion connector (slot) that supports RAM expansion card sizes of 2, 4, and 6 MB. Apple offers a 2 MB and 4 MB memory card.

Since the PowerBooks have only one RAM expansion slot, you may use only one memory expansion card at a time. This means if you are upgrading from 4 MB to 6 MB, for example, you will have to remove the current 2 MB expansion card and replace it with the 4 MB expansion card.

Note: If a RAM expansion card is designed correctly, it will work in the PowerBook 100, 140, 145, and 170 computers. The 68030-based PowerBooks have a 32-bit data bus whereas the 68HC000-based machine (the PowerBook 100) has only a 16-bit data bus. If the expansion card is designed as a 32-bit device it will only work in the PowerBook 140, 145, and 170, but if the data lines and chip select lines are in the correct location on the card, users can use the same card in either machine without loss of performance. The separated chip select lines are necessary for the 68HC000-based machine because it can get access to only 16 bits at a time. The Macintosh PowerBook 140, 145, and 170 do not require separated chip select lines because both have a 32-bit data bus; therefore the lines are tied back together on the computer’s main logic board.

The Apple PowerBook RAM cards will work in all three PowerBook systems. If purchasing RAM from third-party vendors, make sure it will work in the 68HC000–based portable as well.

RAM wait states: access to the RAM from the main processor requires 100 ns PSRAM and two processor wait states (five clock cycles per RAM access). The CPU Glue Logic custom chip includes special circuitry that performs the refresh function.

Battery backup: both main and expansion RAM memories are backed up when the computer is in the sleep mode. This means that when the computer is not in use, the contents of the memory array are retained as long as the battery remains charged.

Note: Unlike the Macintosh PowerBook 100 and Macintosh Portable, when the battery is

removed from the PowerBook 140, 145, and 170, the contents of RAM are lost. The user must shut down the unit before replacing the battery. The backup battery in the Macintosh PowerBook 140, 145 and 170 computers supply power only to the RTC chip (the clock).

Macintosh PowerBook 100

The system comes with 2 MB of PSRAM (pseudo-static RAM). The RAM is arranged as four 4 Mbit chips of 512 by 8 bits each. The memory chips have an access and cycle time of 100 ns. There are no processor wait states to RAM unless the requested location in the pseudo-static RAM is being refreshed.

The system RAM can be expanded via a 70-pin RAM expansion connector. The expansion slot can be filled with card sizes of 2 MB, 4 MB, or 6 MB. The system will automatically determine the card's memory size. These memory expansion cards can be used with the Macintosh PowerBook 140, 145 and 170 computers.

Since the PowerBook 100 has only one RAM expansion slot, you may use only one memory expansion card at a time. This means if you are upgrading from 4 MB to 6 MB, for example, you will have to remove the current 2 MB expansion card and replace it with the 4 MB expansion card.

System RAM is always powered; therefore RAM disks will be saved even after shutdown (similar to the Macintosh Portable). RAM will be maintained by three lithium batteries during a main battery exchange.

Macintosh PowerBook 160 and 180

The PowerBook 160 and 180 include 4 MB of 85 ns pseudostatic RAM on the secondary logic board, consisting of eight 512K x 8-bit chips. In addition, the RAM expansion slot supports up to 10 MB of PSRAM, for a total of 14 MB. The secondary logic board contains a 70-pin RAM expansion connector (slot) that supports RAM expansion cards from 2 MB to 10 MB in size. The PowerBook 160/180 RAM expansion slot provides almost twice the physical design envelope of previous PowerBook computers, making it easier to implement high capacity expansion cards.

RAM expansion cards designed for the PowerBook 100/140/145/170 are generally compatible with the PowerBook 160 and PowerBook 180, but impose limitations on performance and maximum RAM expansion.

As with earlier members of the PowerBook family, only 4 Mbit (512K x 8-bit) PSRAM chips are used for expansion RAM. The maximum power budget for RAM expansion is 2 watts (400 mA at +5V).

For purposes of this discussion, there are two types of RAM expansion cards:

- Compatible - cards designed for the PowerBook 100/140/145/170 are compatible with the PowerBook 160/180, but are limited in terms of physical size and maximum RAM expansion (6MB). These cards also Impose an extra wait state in the PowerBook 180.

- Fast - cards designed specifically for the PowerBook 160/180 can take advantage of a larger physical board size and can contain up to 10 MB of RAM. These cards must use 85 ns PSRAM chips.

Note: It is possible to design a hybrid card that is compatible with all current PowerBook models without imposing an extra wait state on the PowerBook

180. Such a card would require extra circuitry to operate correctly in all models, and would still be subject to the size and capacity limitations of compatible cards.

Since the PowerBook 160 and 180 has only one RAM expansion slot, you may use only one memory expansion card at a time. This means if you are upgrading for example from 6 MB to 8 MB you will have to remove the current 2 MB expansion card and replace it with the 4 MB expansion card.

PowerBook Duo 210 and 230

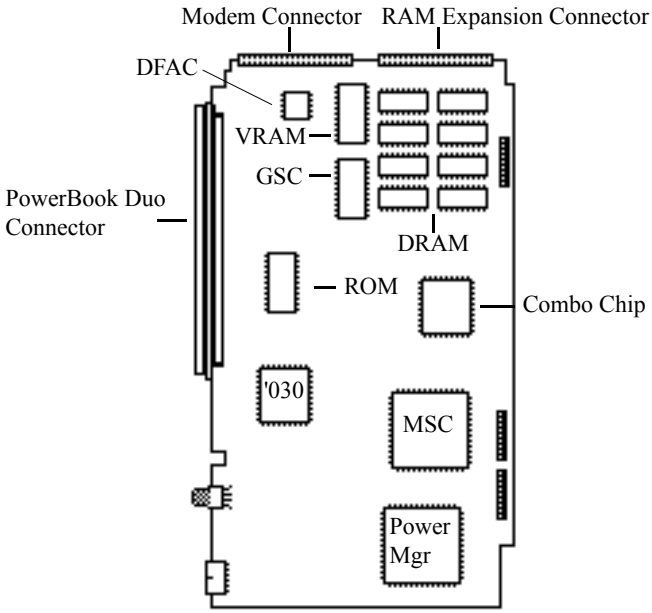


Figure 11 - Macintosh PowerBook Duo 210 and 230

The PowerBook Duo 210 and 230 has 4 MB of DRAM on the main logic board. The DRAMs are arranged in dual 2 MB banks, which are soldered to the main logic board. They have an access time of 80 ns for the Duo 210 and 70 ns for the Duo 230. A typical DRAM bank contains four 512K x 8-bit DRAMs, providing two megabytes of basic memory.

The main logic board has an expansion slot that accommodates the memory expansion card. The one designed by Apple is a plug-in unit with space for 16 DRAMs. The card plugs into the side of the main logic board and extends memory capacity by 4 or 8 MBs. Using 16 Mbit DRAMs, third-party developers can design memory expansion cards that expand the DRAM capacity up to 24 MBs.

Since the PowerBook Duo 210 and 230 has only one RAM expansion slot, you may use only one memory expansion card at a time. This means if you are upgrading for example from 8 MB to 12 MB you will have to remove the 4 MB expansion card and replace it with the 8 MB expansion card.

Macintosh IIvx, IIvi, and the Performa 600

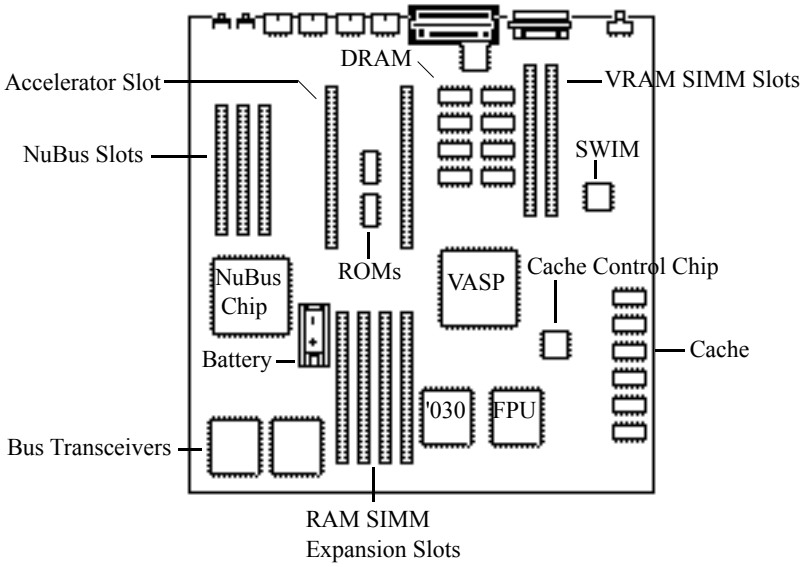


Figure 12 - Macintosh IIvx

The Macintosh IIvx comes standard with 4 MBs (eight 1 Mbit x 4-bit dynamic RAM ICs) of RAM soldered on the main logic board. There are four SIMM connectors which allows up to 68 MB of additional RAM to be added. The Macintosh IIvx uses the same 30-pin RAM SIMMs used in most other Macintosh models. The Macintosh IIvx accepts 256K, 1 MB, 2 MB, 4 MB, and 16 MB SIMMs, single- or double-sided. When adding additional RAM, all four slots must be filled and all SIMMs must be the same size and speed. The IIvx requires 80 ns RAM. The Macintosh IIvx accepts the following memory configurations:

4 MB soldered on the main logic board
5 MB, using 256K SIMMs in the SIMM connectors
8 MB, using 1 Mbit SIMMs in the SIMM connectors
12 MB, using 2 Mbit SIMMs in the SIMM connectors
20 MB, using 4 Mbit SIMMs in the SIMM connectors
68 MB, using 16 Mbit SIMMs in the SIMM connectors

Software determines the amount of RAM installed at system startup, and configures the system appropriately. Because RAM is tested and sized before the video system is initialized, the screen will appear blank during this phase of the boot process. Users with large amounts of RAM installed will experience a delay before the desktop pattern appears.

4 Mbit DRAMs in Revolt

When the Macintosh II was originally designed, Apple engineers intended for it to accept large amounts of memory in the form of 4 MB and 16 MB DRAM SIMMs. That was in 1986, when 1 Mbit DRAM was difficult to find and the higher-density chips did not yet exist. The engineers anticipated the pinouts of the yet to be introduced 4 MB SIMMs and provided all the necessary hardware and address multiplexing to allow installation of these parts when they became available.

4 MB SIMMs do not work as advertised in most cases. This is the story of the Revolt of the 4 MB DRAM SIMMs.

Preliminary Notes

Before diving into the problem with 4 Mbit DRAMs, there is some preliminary ground that must be covered.

First, there are a couple ways to construct a 4 MB SIMM. Using old technology, it is possible to cram together 32 DRAM ICs of 1Mbit x 1 density. Using new technology, it only takes eight 4M x 1 ICs, resulting in a much smaller, lower-power module. If a 4 MB SIMM is of the large, so-called composite type (that is, it is constructed of 32 1 Mbit ICs), then everything is fine except on the original Macintosh II. Please refer to page 7 of this Tech Note for more information on Macintosh II RAM.

With the FDHD/SuperDrive upgrade kit installed, the Macintosh II is on equal footing with the Macintosh IIx. That is, SIMMs made exclusively of the new 4 Mbit ICs still will not work, regardless of whether you are using a Macintosh II or IIx; therefore, for the remainder of this discussion, *Macintosh II* is used to refer to not only the original Macintosh II, but also the IIx.

Subsequent Macintosh models have revised ROMs that recognize 4 MB SIMMs.

The 4 Mbit Problem

DRAM ICs are now available in 4 Mbit density, but they come with a very nasty surprise. JEDEC, the committee overseeing the standardization of new solid-state devices, has added an additional built-in test mode to high-density DRAMs. The test mode is invoked by a sequence of electrical signals that was ignored by earlier-generation DRAM. The crux of the situation is this: under certain conditions, the Macintosh II unwittingly activates this new test mode and large amounts of memory become very forgetful.

More Specifically . . .

Those who are interested in the specific phenomenon occurring within the memory ICs should consult the detailed technical data supplied by the DRAM manufacturers. This Note

only explains how the Macintosh II offends this new feature of the 4 Mbit DRAM, and hence, what might be done to work around the problem.

The Macintosh II uses /CAS-before-/RAS refresh cycles to keep RAM up to date on its contents. For 1 Mbit DRAM, the state of the /W control line is ignored during this type of refresh cycle. This is not the case any longer. DRAM of the 4 Mbit variety goes off into test mode if /W is asserted (low, so that the RAM thinks it is write-enabled) during a /CAS-before-/RAS refresh cycle. The problem with the Macintosh II is that /W is the same signal as the MPU R/W line, and if the MPU is writing to an I/O address or a NuBus™ card concurrently

with a refresh cycle, all the conditions are right for a waltz into test mode. Unfortunately, this condition is not all that unusual, since video card accesses qualify.

Please note: SIMMs constructed with an on-board PAL are not necessarily Macintosh II-specific. SIMMs constructed in this manner should work without modification in any usage calling for 4 MB SIMMs (except in the unlikely event that the new test mode is required).

The Salvage Process

All is not necessarily lost, and although the situation is ugly, there is still a way to use 4 Mbit DRAM ICs to construct 4 MB SIMMs that work in the Macintosh II. A solution lies in the addition of a ninth IC to the SIMM. Programmed with suitable logic, a high-speed (-D or -E suffix) PAL on the SIMM itself can recognize and intercept /CAS-before-/RAS refresh cycles and set /W appropriately before any damage is done. More or less, the PAL becomes an intelligent buffer between the MPU read/write line and the DRAM write-enable lines. When the PAL senses a refresh cycle commencing, it holds /W high, ensuring that the ICs are not corrupted by the potentially dangerous processor-generated R/W signal.

What's the Point?

You have overcome all the problems discussed in this section and have working 4 Mbit SIMMs installed in your Macintosh. You probably have at least 20 MB of RAM. What can you do with all of it? Create lots of huge 32-bit PICTs and edit them all simultaneously? Model and animate Bay Area weather patterns in Mathematica™? Yes! But, you have to use the appropriate system software to address this memory. Also, if you're running in 32-bit addressing mode, the applications that you desire to use need to be 32-bit clean. For more information on 32-bit cleanliness and addressing, please see Technical Notes #212 and #213.

Under System 7.0, applications can finally access additional physical memory over and above 8 MB. As mentioned previously in this Tech Note, the 32-bit addressing mode of System 7 requires either a Macintosh with 32-bit clean ROMs (listing is on page 2), or else the 32-bit software solution provided by the MODE32 system extension. A/UX is an alternative that can use up to 256K of RAM on Macintosh computers that support A/UX. Many manufacturers of large SIMMs also offer RAM disks. This is a volatile form of storage, but can certainly be useful for I/O intensive operations.

Other Permutations

The problem with 4 Mbit DRAM is not limited to 4 MB SIMMs. It is the 4 Mbit density of the individual RAM ICs that causes problems with certain machines. There exist 1 MB SIMMs constructed of only two 1M x 4 (4 Mbit) ICs. These do not work in a Macintosh II or IIx, any more than 4 MB SIMMs constructed of eight 4M x 1 ICs.

A few machines, namely the Macintosh Plus, Macintosh SE, and Macintosh Classic, depend on video accesses to refresh all of their DRAM. As the video circuitry accesses sequential locations through the video frame buffer, it simultaneously refreshes row after row of memory, eventually refreshing all 512 rows. Memory at the 4 Mbit density, however, is arranged as 1024 rows and there are not sufficient video accesses to refresh all 1024 rows. Chunks of memory simply go blank. Thus for a different reason, 4 Mbit DRAM parts are also not compatible with these older Macintosh hardware designs.

Executive Summary

Owners of the Macintosh Plus, SE, Classic, II, or IIx are all likely to have problems with any 1 MB SIMM carrying only two ICs, or any 4 MB SIMM carrying only 8 ICs. Any SIMM constructed in one of these ways likely uses 4 Mbit density DRAM ICs and does not account for problems with the 4 Mbit test mode nor the video refresh strategy of older Macintosh designs.

Further Reference:

- *Inside Macintosh*, Volume V-1, Compatibility Guidelines
- *Guide to the Macintosh Family Hardware*, Second Edition
- Macintosh IIsi, LC, and Classic Developer Notes
- Macintosh Classic II, Macintosh PowerBook Family, and Macintosh Quadra Family Developer Notes
- Macintosh PowerBook 160 and 180, Macintosh PowerBook Duo 210 and 230, and Macintosh IIvx Developer Notes
- Macintosh Technical Notes #212 and #213