

The Macintosh Memory Guide

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IT USED TO BE SO SIMPLE A LONG TIME AGO. BACK IN THE OLD DAYS THERE WAS ONLY ONE KIND OF MACINTOSH WHICH CAME WITH 128K OF BUILT-IN RAM.

AND THAT WAS IT.

BUT IT'S A DIFFERENT STORY TODAY. THE TWELVE DIFFERENT MACS IN COMMON USE REQUIRE SIMMS OF FIVE DIFFERENT BASIC TYPES, MOST OF WHICH COME IN EIGHT SIZES RANGING FROM 256K TO 16MB. NOT ONLY IS EACH MACINTOSH UNIQUE IN SOME WAY, WE ALSO HAVE SYSTEM 6 AND SYSTEM 7. 32-BIT ADDRESSING, 24-BIT ADDRESSING AND "DIRTY ROMS". VIRTUAL MEMORY AND PMMUS. DYNAMIC RAM, STATIC RAM, COMPOSITE SIMMS, RAM DISKS, RAM CACHES, RAM DRIVES AND NUBUS RAM CARDS! DO YOU REALLY HAVE TO BE A ROCKET SCIENTIST JUST TO UNDERSTAND THE MAC THESE DAYS?

WE DON'T THINK SO. EVERY DAY, CONNECTIX TALKS TO SCORES OF MAC USERS WITH QUESTIONS ABOUT MEMORY. WE'VE FOUND THAT MOST PEOPLE JUST NEED A FEW POINTERS AND THE PICTURE COMES INTO FOCUS. THIS BOOKLET COVERS PRETTY MUCH EVERYTHING YOU NEED TO KNOW ABOUT YOUR MAC — AT LEAST IN TERMS OF ITS MEMORY POTENTIAL.

WE HOPE YOU FIND THE GUIDE USEFUL AND WE WOULD LOVE TO HEAR WHAT YOU LIKED, OR MAYBE DIDN'T UNDERSTAND. MORE NEW MACS ARE ON THE WAY WITH THERE OWN UNIQUE MEMORY QUIRKS, SO YOUR COMMENTS WILL PROBABLY ONE DAY WIND UP IN A REVISED EDITION OF THE MACINTOSH MEMORY GUIDE. WE CAN BE REACHED AT 800/950-5880, INTERNATIONAL 415/571-5100, FAX 415/571-5195, APPLELINK CONNECTIX (OR USE THE THIRD PARTY CONNECTIX ICON READ/WRITE BOARDS), OR COMPUSERVE "GO MACAVEN", SECTION 8. BY THE WAY, YOU CAN GET A FREE COPY OF MODE32 AT EITHER THE APPLELINK CONNECTIX ICON OR THE COMPUSERVE CONNECTIX FORUM.

FINALLY, PLEASE FEEL FREE TO QUOTE FROM THIS MATERIAL AND REDISTRIBUTE IT, BUT DON'T FORGET TO ATTRIBUTE THE SOURCE AS CONNECTIX. IF YOU WOULD LIKE A NICELY PRINTED HARD COPY OF THE GUIDE JUST CALL OR WRITE US. IT'S ALSO FREE!

ENJOY!

ROY K. MCDONALD
PRESIDENT/CEO
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THE BASICS

THE TWO BASIC TYPES OF MEMORY

ALL YOUR FILES NORMALLY RESIDE ON A "MASS STORAGE DEVICE", TYPICALLY A HARD DRIVE. SUCH DEVICES HOLD TENS, HUNDREDS, OR EVEN THOUSANDS OF MEGABYTES OF INFORMATION. MOREOVER, THEY ARE NONVOLATILE, THAT IS, THEY RETAIN THIS INFORMATION EVEN WHEN POWER IS TURNED OFF. BUT THE CENTRAL PROCESSOR UNIT (CPU) WORKS MUCH FASTER THAN THE HARD DRIVE CAN SUPPLY INFORMATION, SO YOUR MAC ALSO HAS SOME FAST, VOLATILE MEMORY MADE OUT OF SEMICONDUCTORS. THIS IS YOUR RAM, RANDOM ACCESS MEMORY. WHEN YOU LAUNCH A PROGRAM FROM YOUR HARD DISK, SOME OR ALL OF THE APPLICATION SOFTWARE IS COPIED FROM THE HARD DRIVE INTO THE RAM, WHERE THE CPU CAN ACCESS IT AT HIGH-SPEED. WHEN YOU OPEN A DOCUMENT, THE SAME THING HAPPENS. WHEN YOU TRY TO SHUT DOWN YOUR COMPUTER WITH DOCUMENTS OPEN, THE MAC WILL ASK YOU IF YOU WANT TO SAVE THEM. IF YOU SAY YES, IT COPIES THE INFORMATION IN RAM BACK TO THE HARD DRIVE, WHERE THE MAC CAN "REMEMBER" IT EVEN AFTER POWER IS TURNED OFF.

RAM CAN USUALLY ACCESS A SPECIFIC PIECE OF DATA ABOUT 1000 TIMES FASTER THAN A HARD DRIVE CAN BUT IT DOES COST ROUGHLY 10 TIMES AS MUCH PER MEGABYTE. CONSEQUENTLY, A LOT OF EFFORT GOES INTO USING RAM AS SPARINGLY AS POSSIBLE. MANY MAC APPLICATIONS ARE "SEGMENTED" SO THAT ONLY PART OF THE SOFTWARE IS LOADED INTO RAM WHEN THE APPLICATION IS LAUNCHED. THE REST IS BROUGHT IN WHEN NEEDED. FOR EXAMPLE, MOST WORD PROCESSORS WILL ONLY LOAD THE SPELL CHECK ROUTINES AND THE DICTIONARY WHEN YOU REQUEST A SPELL CHECK. SOME APPLICATIONS CAN WORK WITH *DOCUMENTS* WHICH ARE PARTITIONED, SO THAT PART OF THE DOCUMENT IS IN RAM AND PART STAYS ON THE HARD DRIVE.

ALL OF THIS IS DONE SO THAT YOU CAN MAXIMIZE THE AMOUNT OF WORK THAT CAN BE ACCOMPLISHED WITHIN A GIVEN AMOUNT OF "APPLICATION MEMORY", WHICH IS USUALLY EQUAL TO THE AMOUNT OF RAM INSTALLED IN YOUR MAC. APPLICATION MEMORY IS THE SPACE YOUR COMPUTER USES TO RUN YOUR SYSTEM AND APPLICATIONS. YOU CAN SEE THIS DESCRIBED UNDER "ABOUT THIS MACINTOSH...". THE SIZE OF THIS SPACE LIMITS THE COMBINED SIZE OF THE SYSTEM AND ALL THE APPLICATIONS YOU CAN HAVE OPEN AT THE SAME TIME.

A TECHNIQUE CALLED VIRTUAL MEMORY (SEE VIRTUAL MEMORY BELOW) CAN EXTEND APPLICATION MEMORY BY SWAPPING INFORMATION BETWEEN THE HARD DRIVE AND RAM IN THE BACKGROUND, MAKING YOUR MAC WORK AS IF THERE IS MORE RAM IN THE MAC THAN YOU HAVE ACTUALLY INSTALLED. USING VIRTUAL MEMORY, YOU HAVE MORE APPLICATION MEMORY THAN PHYSICAL RAM.

SIMMS

EVERY MAC SINCE THE MAC PLUS HAS HAD SOCKETS TO HOLD MEMORY AND ALLOW FOR MEMORY EXPANSION. THE STANDARD WAY TO ADD MEMORY IS TO INSTALL SIMMS (SINGLE IN-

LINE MEMORY MODULES, IE. A LONG THIN STRIP OF PLASTIC WITH A SINGLE ROW OF RAM CHIPS ON IT.) INSTALLING SIMMS IS FAIRLY EASY; OFTEN THE HARDEST PART IS FIGURING OUT HOW TO OPEN UP THE MAC.

THERE ARE A FEW MAJOR CLASSES OF MACS IN TERMS OF MEMORY. THE COMPACT MACS INCLUDE THE PLUS, SE AND CLASSIC. THE MODULAR MACS ARE EVERYTHING ELSE, (INCLUDING THE SE/30, WHICH IS ESSENTIALLY A MAC IICX INSIDE A SMALLER BOX FROM THE POINT OF VIEW OF MEMORY). THE PORTABLE IS A SPECIAL CASE, AND THE CLASSIC, LC AND IISI VARY FROM THEIR BRETHREN IN SIGNIFICANT WAYS, DISCUSSED LATER.

FOR A COMPREHENSIVE SYSTEM-BY-SYSTEM DISCUSSION OF RAM CONFIGURATIONS, SEE THE REFERENCE GUIDE BELOW. BUT BASICALLY IT COMES DOWN TO COMPACT MACS AND TWO TYPES OF MODULAR MACS. COMPACT MACS HAVE 4 SIMM SOCKETS IN 2 "BANKS" OF TWO SOCKETS EACH. MODULAR MACS USUALLY HAVE EITHER 8 SIMM SOCKETS IN 2 BANKS OF 4 SOCKETS EACH OR HAVE 1-2MB OF RAM SOLDERED ON THE MOTHERBOARD, AND A SINGLE 2 OR 4 SOCKET BANK.

RULE #1 OF MAC MEMORY: *SIMM BANKS MUST EITHER BE COMPLETELY FULL, OR COMPLETELY EMPTY.*

SIMMS COME IN DIFFERENT SIZES. NOT LONG AGO THERE WERE ONLY TWO COMMON TYPES: 256K (ONE QUARTER MEGABYTE) AND 1MB (ONE MEGABYTE). TODAY THERE ARE 256K, 512K, 1MB, 2MB, 4MB, 8MB, AND 16MB SIMMS, AND RUMORS OF EVEN BIGGER ONES ON THE WAY.

RULE #2: *SIMM BANKS MUST ALWAYS BE FILLED WITH SIMMS OF ALL THE SAME SIZE.*

SIMMS COME IN DIFFERENT SPEEDS. THEY ARE RATED ACCORDING TO HOW FAST INFORMATION CAN BE RETRIEVED FROM THEM. THIS ACCESS SPEED IS DENOTED IN "NS" (NS- NANOSECOND, A BILLIONTH OF A SECOND). COMPACT MACS NEED 150NS. MOST MODULAR MACS NEED 120 OR 100NS, BUT THE IIFX AND THE IICI DEMAND 80NS. THE NS NUMBER CAN BE USUALLY BE FOUND ON THE RAM ITSELF; TAKE THE LAST ONE OR TWO DIGITS AFTER THE PART NUMBER AND MULTIPLY BY 10. YOU CAN USE FASTER SIMMS (LOWER NS NUMBER) THAN REQUIRED BUT THEY WILL USUALLY COST MORE AND WILL NOT IMPROVE PERFORMANCE. THE ONLY ADVANTAGE OF BUYING OVERRATED SIMMS IS THAT THEY MAY STILL BE COMPATIBLE IF YOU UPGRADE, OR IF YOU BUY A NEW MAC. YOU CAN MIX NS NUMBERS EVEN WITHIN A BANK, BUT THE SLOWEST ONE IS SUPPOSED TO BE TO BE FAST ENOUGH FOR THE GIVEN TYPE OF MAC. IN PRACTICE, WE HAVE FREQUENTLY USED 150NS SIMMS ON THE MAC II, IIX, IICX, AND SE/30 AND HAVE NEVER HAD A PROBLEM. HOWEVER, WE WOULD NOT RECOMMEND TRYING THAT ON A IICI OR IISI.

PHYSICALLY, MOST SIMMS ARE INTERCHANGEABLE. THE IIFX SIMMS HAVE OVER TWICE AS MANY CONNECTORS ON THEM, AND WILL ONLY FIT IN A IIFX, THOUGH. PORTABLE RAM IS COMPLETELY DIFFERENT — BECAUSE OF THE POWER LIMITATIONS DYNAMIC RAM (DRAM) CAN'T BE USED AND "STATIC RAM" IS REQUIRED INSTEAD. IT'S EXPENSIVE. A MORE ECONOMICAL

SOLUTION IS "PSEUDO-STATIC" RAM, WHICH CONSUMES A LITTLE MORE POWER BUT COSTS LESS.

WHEN YOU FACE THE FRONT OF MOST MODULAR MACS, THE BANK ON THE RIGHT IS BANK A, PROBABLY THE OPPOSITE OF WHAT YOU WOULD GUESS. ON COMPACT MACS, SE/30 AND IIFX, THE BANK TOWARDS THE BACK IS BANK A. (THE ENGINEERS WHO LAID THESE OUT ARE EVIDENTLY USED TO LOOKING AT THEIR MACS FROM THE BACK.)

RULE #3: IF YOU ONLY FILL ONE BANK WITH SIMMS, USE BANK A.

ALSO, YOU CAN USE SIMMS OF TWO DIFFERENT SIZES IN THE TWO BANKS AS LONG AS EACH BANK IS OF ONE SIMM TYPE. IF YOU DO THIS, REMEMBER

RULE #4: YOU SHOULD USUALLY PUT YOUR LARGER SIMMS IN BANK A.

NOTICE WE SAID USUALLY. IF YOU START WORKING WITH SIMMS THAT ARE BIGGER THAN 1MB, THINGS GET MORE COMPLICATED (MUCH MORE ON THIS LATER.) IN A FEW SPECIAL CASES, THIS RULE IS *REVERSED* IF YOU USE 2, 4, 8, OR 16MB SIMMS AND EITHER HAVE A MAC II, MAC IIX, OR USE ON-BOARD VIDEO ON A IICI. SEE THE REFERENCE GUIDE FOR DETAILS ON YOUR MAC.

RUNNING ON EMPTY

WHEN YOU TRY TO USE AN APPLICATION BUT DON'T HAVE ENOUGH MEMORY, TWO PROBLEMS MAY OCCUR. IF YOU ARE REALLY SHORT ON MEMORY, THE APPLICATION MAY SIMPLY REFUSE TO LAUNCH. THE MAC WILL DISPLAY A DIALOG BOX THAT SAYS "THE APPLICATION COULD NOT BE OPENED". WORSE, IT MAY LET YOU OPEN THE DOCUMENT BUT LATER QUIT IN THE MIDDLE OF THE SESSION DISPLAYING "APPLICATION HAS UNEXPECTEDLY QUIT". USUALLY YOU GET A WARNING BEFORE YOU LAUNCH IN SUCH AN CONFIGURATION, TELLING HOW MUCH RAM YOU OUGHT TO HAVE, VS. HOW MUCH IS ACTUALLY AVAILABLE. IF THE AMOUNT LEFT IS LESS THAN ABOUT 75% OF THE TOTAL NORMALLY REQUIRED, YOU ARE PROBABLY RISKING AN UNEXPECTED QUIT. ALL OF YOUR RECENT CHANGES (SINCE THE LAST SAVE) WILL BE LOST. BE SURE TO SAVE FREQUENTLY! SOME APPLICATIONS WARN YOU OF LOW MEMORY BY REVERSING SOME ELEMENTS OF THE SCREEN (WHITE ON BLACK INSTEAD OF BLACK ON WHITE).

THESE ARE ALL SIGNS THAT YOU NEED MORE MEMORY FOR THAT APPLICATION, BUT NOT NECESSARILY THAT YOU NEED MORE RAM. IF YOU ARE RUNNING MULTIFINDER (ALWAYS TRUE ON SYSTEM 7, OPTIONAL ON SYSTEM 6), IT MAY JUST BE NECESSARY TO INCREASE THE APPLICATION'S MULTIFINDER PARTITION. TO DO THIS, QUIT OUT OF THE APPLICATION INTO THE FINDER, CLICK *ONCE* ON THE APPLICATIONS ICON SO THAT IT IS SELECTED, THEN HIT ⌘-I (OR SELECT "GET INFO" UNDER THE FINDER "FILE" MENU). INCREASE THE NUMBER IN THE LOWER BOX IN THE LOWER RIGHT HAND CORNER (THE ONE LABELED "APPLICATION MEMORY SIZE") AND CLOSE THE INFO WINDOW. WHEN YOU LAUNCH THE APPLICATION YOU WILL NOW HAVE MORE OF YOUR APPLICATION MEMORY ASSIGNED TO THIS APPLICATION. IF YOU WANT TO RUN SEVERAL APPLICATIONS AT ONCE, AND THE COMBINED SIZE OF ALL THE APPLICATIONS PLUS THE

SYSTEM IS BIGGER THAN YOUR TOTAL APPLICATION MEMORY, YOU WILL NEED TO USE VIRTUAL MEMORY, INSTALL MORE RAM, OR RUN THE RISK OF OPENING AN APPLICATION WITH LESS THAN THE DESIGNATED PARTITION SIZE, POSSIBLY LEADING TO AN UNEXPECTED QUIT. THE SAME IS TRUE UNDER FINDER IF YOU WANT TO RUN A SINGLE APPLICATION WHICH, WHEN COMBINED WITH THE SYSTEM REQUIRES MORE APPLICATION MEMORY THAN YOU HAVE. UNDER FINDER, THE ONE OPEN APPLICATION ALWAYS GETS ALL AVAILABLE MEMORY SO THE PARTITION ADJUSTMENT PROCEDURE IS UNNECESSARY.

ROMS

ROMS (READ ONLY MEMORY) ARE CHIPS BUILT INTO THE MAC WHICH CONTAIN PART OF THE OPERATING SYSTEM. SINCE THEY ARE READ ONLY, NOTHING MORE CAN BE WRITTEN ON THEM, SO THEY ARE NOT USED AS MEMORY LIKE THE RAM AND HARD DRIVE. ROM IS NONVOLATILE AND CONTAINS THE INFORMATION YOUR MAC NEEDS IN ORDER TO REMEMBER HOW TO READ THE REST OF THE OPERATING SYSTEM THAT IS STORED ON THE HARD DRIVE IN YOUR SYSTEM FOLDER. SO, THE COMPUTER LEARNS A BIT FROM THE ROM, THEN MORE FROM THE SYSTEM FOLDER, AND THEN A LOT FROM THE REST OF THE HARD DRIVE. THIS REMINDED EARLY (PRE-APPLE) PROGRAMMERS OF THE EXPRESSION "LIFTING YOURSELF UP BY YOUR OWN BOOTSTRAPS". THAT'S HOW THE START UP PROCESS CAME TO BE KNOWN AS "BOOTING". THE MAIN IMPORTANCE OF ROMS, IN THE CONTEXT OF MAC MEMORY CONFIGURATIONS, IS THAT SOMETIMES THE OPERATING SYSTEM SOFTWARE LIMITS THE AMOUNT OF RAM THAT CAN BE USED. FOR EXAMPLE, THE MAC II, IIX, IICX, AND SE/30 NEED THE MODE32 SOFTWARE TO OVERCOME LIMITATIONS POSED BY THE ROMS WHEN USING SYSTEM 7 (SEE THE REFERENCE GUIDE).

WILL MORE MEMORY MAKE MY MAC FASTER?

ONE ADVANTAGE OF HAVING MORE MEMORY IS SIMPLY THAT YOU CAN OPEN UP MORE APPLICATIONS AT THE SAME TIME. TIME SAVED NOT OPENING AND CLOSING DOCUMENTS AND APPLICATIONS ADDS UP FAST. IF YOU NEED TO OPEN UP MORE APPLICATIONS THAN YOUR APPLICATION MEMORY CAN HOLD, YOU MUST EITHER INSTALL MORE RAM OR INCREASE YOUR VIRTUAL MEMORY USAGE. OTHERWISE THERE JUST ISN'T ENOUGH SPACE IN THE MEMORY MAP TO DO THE WORK YOU ARE TRYING TO DO.

THERE ARE ALSO CIRCUMSTANCES WHERE ADDING RAM IS A GOOD IDEA BECAUSE IT WILL ACTUALLY SPEED UP PROCESSING OF TASKS. A CLASSIC EXAMPLE IS IF YOU ARE USING AN APPLICATION LIKE PHOTOSHOP WHICH CAN WORK WITH A DOCUMENT THAT IS MOSTLY ON THE HARD DRIVE BY TAKING A PIECE OF IT AT A TIME INTO RAM ACCORDING TO THE AMOUNT OF AVAILABLE MEMORY. EACH TIME THAT DATA IS SWAPPED IN AND OUT OF RAM YOUR MAC BECOMES "I/O LIMITED". THIS MEANS THAT THE CPU IS WAITING AROUND FOR EXTERNAL DATA TRANSFERS TO OCCUR BEFORE IT CAN DO ANY USEFUL WORK. IF YOU ADD RAM IN SUCH A SITUATION, THE AMOUNT OF DISK ACTIVITY CAN BE REDUCED AND THE I/O LIMITATIONS WILL OCCUR LESS FREQUENTLY. IF YOU USE SYSTEM 7 VM, OR CONNECTIX VIRTUAL, AND OPEN APPLICATIONS THAT ARE LARGER THAN THE AMOUNT OF PHYSICAL RAM NOT TAKEN UP BY THE

SYSTEM, THEN YOU ARE I/O LIMITED BY THE VIRTUAL MEMORY SWAPPING IN A SIMILAR FASHION.

ONE WAY TO OVERCOME THE I/O BOTTLENECK IS TO USE A VERY FAST DISK, LIKE A RAM DISK (SEE RAM CACHES, RAM DISKS, AND RAM DRIVES, BELOW). WHEN YOU USE A RAM DISK, INFORMATION IS AVAILABLE AS FAST AS THE CPU CAN ACCEPT IT SO I/O LIMITS ARE ESSENTIALLY REMOVED.

BUT A LOT OF THE TIME THE REASON YOUR MAC IS SLOWER THAN YOU WANT IS BECAUSE YOU ARE "CPU-LIMITED", IE. THE DATA IS ALL AVAILABLE, BUT THE CPU JUST TAKES A LONG TIME TO PROCESS IT. IF THIS IS THE PROBLEM, MORE RAM WON'T HELP — YOU NEED TO SPEED UP YOUR CPU. THE FIVE MAIN WAYS TO DO THIS ARE 1) ADD A THIRD-PARTY CPU ACCELERATOR 2) INSTALL AN APPLE CPU UPGRADE, 3) ADD A CACHE CARD (IICI, IISI) 4) ADD A MATH COPROCESSOR (WHICH WILL SPEED UP MATHEMATICAL CALCULATIONS ONLY) OR 5) BUY A NEW, FASTER MAC. BY THE WAY, UNLESS YOU SPEED YOUR MAC UP BY AT LEAST 20% IT WILL BE HARD TO NOTICE, EVEN THOUGH LESSER IMPROVEMENTS WILL SAVE YOU TIME.

BREAKING THE 8 (4) MEGABYTE BARRIER

THINGS ARE PRETTY SIMPLE ON A MODULAR MAC AS LONG AS YOU DON'T NEED MORE THAN 8MB OF MEMORY, OR ON A COMPACT MAC IF YOU ARE SATISFIED WITH 4MB. IN THIS CASE JUST FOLLOW THE FOUR SIMM RULES AND MAKE SURE YOUR SIMMS ARE FAST ENOUGH FOR THE MAC YOU ARE USING (SEE THE REFERENCE GUIDE IF YOU ARE NOT SURE.) BUT IF YOU ARE DOING HIGH-END GRAPHICS, ANIMATION, CAD, MODELLING, OR ANY OF THE PLETHORA OF MEMORY-INTENSIVE MAC JOBS, THEN YOU MAY NEED TO KNOW HOW TO BREAK THE EIGHT (4) MEGABYTE BARRIER.

THE TWO BASIC WAYS TO DO THIS ARE TO USE 32-BIT ADDRESSING OR ENHANCED 24-BIT ADDRESSING. THE 32-BIT ADDRESSING MODE ALLOWS YOUR MAC TO USE UP TO 128MB OF RAM, WHILE THE STANDARD 24-BIT MODE ONLY ALLOWS YOU TO ACCESS UP TO 8MB OF RAM. THE ENHANCED 24-BIT MODE EXTENDS THIS FROM 8MB TO 14MB. THE ADVANTAGE OF 24-BIT ADDRESSING MODE IS THAT IT IS COMPATIBLE WITH THE FULL RANGE OF MACINTOSH SOFTWARE, WHEREAS ONLY "32-BIT CLEAN" APPLICATIONS AND INITs WILL RUN IN THE MORE POWERFUL 32-BIT MODE.

32-BIT ADDRESSING

THIS IS A NEW STANDARD FEATURE OF SYSTEM 7 THAT INCREASES THE AMOUNT OF APPLICATION MEMORY YOU CAN ADDRESS (USE). *IT HAS ABSOLUTELY NOTHING TO DO WITH 32-BIT QUICK DRAW, 32-BIT COLOR, OR HOW MANY COLORS CAN SHOW ON YOUR SCREEN OR VIDEO IMAGE!*

AN ADDRESS IS A UNIQUE SERIAL NUMBER WHICH SPECIFIES THE LOCATION OF EACH BYTE OF INFORMATION IN APPLICATION MEMORY. EVERY MODULAR MAC SINCE THE MAC II HAS BEEN BUILT WITH HARDWARE THAT CAN USE 32 BITS (A BINARY NUMBER 32 DIGITS LONG, EG.

11010010010100100101010111011) FOR ADDRESSES BUT, UNTIL RECENTLY, ONLY THE FIRST 24 BITS HAVE BEEN USED BY THE OPERATING SYSTEM. (FOR A DETAILED HISTORY OF THIS ISSUE, SEE A BRIEF HISTORY OF MAC MEMORY ADDRESSING, BELOW.) THIS "24-BIT MODE" LIMITED THE MAC TO USING A MAXIMUM OF 16MB OF ADDRESSABLE MEMORY, OF WHICH THE LOWER 8MB WAS ASSIGNED TO APPLICATION MEMORY, AND THE UPPER 8MB WAS ASSIGNED TO NUBUS CARDS, ROMS, AND VARIOUS OTHER DEVICES.

WHEN 32-BIT ADDRESSING IS TURNED ON, ALL 32 DIGITS ARE USED FOR ADDRESS INFORMATION, MEANING THAT UP TO 4 BILLION LOCATIONS (4 GIGABYTES) CAN BE UNIQUELY IDENTIFIED. THIS TOTALLY ELIMINATES THE 8 MEGABYTE BARRIER. THERE ARE STILL SOME HARDWARE LIMITATIONS IN THE SIMM SOCKET DESIGN, SO "ONLY" 128 MEGABYTES OF PHYSICAL MEMORY (EIGHT 16MB SIMMS) CAN BE INSTALLED ON A STANDARD MODULAR MAC. THAT'S THE MAXIMUM PHYSICAL RAM YOU CAN USE AS APPLICATION MEMORY UNDER 32-BIT ADDRESSING. AND, BECAUSE OF MEMORY FRAGMENTATION (SEE 24-BIT FRAGMENTATION, BELOW) ONLY THE FIRST QUARTER OF THE MEMORY MAP, IE. ONE GIGABYTE (1024 MEGABYTES), CAN BE USED FOR VIRTUAL MEMORY.

STILL, FOR MOST PEOPLE, 128MB OF PHYSICAL RAM, EXTENDABLE TO AS MUCH AS 1024MB OF VIRTUAL MEMORY IS PLENTY. THE EASIEST WAY TO GET THIS IF YOU USE A MAC IISI, IICI, OR IIFX, IS TO RUN SYSTEM 7 WITH 32-BIT ADDRESSING TURNED ON (LOOK IN THE MEMORY CONTROL PANEL). IF YOU HAVE AN EARLIER MODULAR MAC (II, IIX, IICX, OR SE/30) RUNNING SYSTEM 7, JUST INSTALL MODE32 AND YOU CAN DO EXACTLY THE SAME THING. SYSTEM 6 USERS OF ALL SEVEN MAC SYSTEMS CAN GET 32-BIT MODE BY INSTALLING CONNECTIX OPTIMA. HOWEVER, OPTIMA IS NOT COMPATIBLE WITH MULTIFINDER, SO ONLY FINDER MAY BE USED. 32-BIT ADDRESSING IS NOT AVAILABLE ON COMPACT MACS, BUT COMPACT VIRTUAL 3.0 SUPPORTS 16MB OF PHYSICAL OR VIRTUAL MEMORY IF A 68030 ACCELERATOR IS INSTALLED. (SEE EXTENDING MEMORY ON COMPACT MACS, BELOW.)

ENHANCED 24-BIT ADDRESSING

AS WE MENTIONED ABOVE, THE DISADVANTAGE OF 32-BIT ADDRESSING IS THAT NOT ALL APPLICATIONS, EXTENSIONS, AND OTHER SOFTWARE IS COMPATIBLE WITH THIS MODE. THE ALTERNATIVE IS TO STAY IN THE MUCH-MORE-COMPATIBLE 24-BIT MODE AND USE MAXIMA. 24-BIT MODE IS THE STANDARD ADDRESSING MODE OF SYSTEM 6 AND IS ALSO WHAT YOU GET UNDER SYSTEM 7 WHEN 32-BIT ADDRESSING IS OFF, OR NOT AVAILABLE. IN STANDARD 24-BIT MODE ONLY 8MB OUT OF THE TOTAL AVAILABLE 16MB IS ALLOWED TO BE USED AS APPLICATION MEMORY. MAXIMA EXTENDS 24-BIT ADDRESSING BY ADDING SOME OF THE UPPER 8MB INTO APPLICATION MEMORY, WHILE STILL USING 24 DIGIT LONG ADDRESSES. MAXIMA EXTENDS ADDRESSING IN 24-BIT MODE TO 14MB AND TURNS THE REST INTO A PROTECTED, NONVOLATILE RAM DISK (SEE RAM CACHES, RAM DISKS, AND RAM DRIVES, BELOW). SYSTEM 6 USERS ARE ALWAYS IN 24-BIT MODE UNLESS CONNECTIX OPTIMA IS INSTALLED. SO, IF YOU DON'T USE OPTIMA, MAXIMA IS A MUST FOR HIGH RAM CONFIGURATIONS UNDER SYSTEM 6.

NOTE THAT ANY OF THE 24-BIT MEMORY OVER EIGHT MEGABYTES WILL BE *FRAGMENTED* (SEE 24-BIT FRAGMENTATION, BELOW), WITH THE RESULT THAT NO SINGLE APPLICATION CAN USE ALL

14 MEGABYTES UNDER MULTIFINDER. IN 32-BIT MODE, ALL OF THE MEMORY UP TO ONE GIGABYTE IS CONTIGUOUS SO THAT EACH APPLICATION CAN ACCESS ALL THE APPLICATION MEMORY.

EXTENDING MEMORY ON COMPACT MACS

COMPACT MACS CAN USE 16MB OF PHYSICAL RAM (FOUR 4MB SIMMS) IF THE MAC IS EQUIPPED WITH A COMPATIBLE 68030 ACCELERATOR CARD AND COMPACT VIRTUAL 3.0 IS INSTALLED. THIS IS ACCOMPLISHED IN 24-BIT MODE AND DOES NOT REQUIRE USING VIRTUAL MEMORY. (COMPACT VIRTUAL WILL ALSO CREATE 16MB OF VIRTUAL MEMORY ON A COMPACT MAC WITH FOUR OR LESS MEGABYTES OF RAM.) THERE IS NO SUPPORT FOR 32-BIT MODE ON THESE MACS. IF YOU NEED MORE THAN 16MB IT'S TIME TO UPGRADE TO A MORE POWERFUL MAC.

68030- ACCELERATOR CARDS ARE AVAILABLE TODAY FOR THE MAC PLUS, SE, AND CLASSIC. THEY HAVE STREET PRICES IN THE RANGE OF \$350 TO \$850. THE LESS EXPENSIVE VERSIONS MAINLY PROVIDE VIRTUAL MEMORY COMPATIBILITY, SINCE THE "ACCELERATION" IS USUALLY ONLY 20-40%. THE MORE EXPENSIVE VERSIONS CAN TRIPLE (OR MORE) THE SPEED OF TYPICAL OPERATIONS. YOU GET WHAT YOU PAY FOR. YOU OFTEN ALSO GET COMPACT VIRTUAL FOR *FREE* SINCE IT'S BUNDLED WITH MANY 68030-ACCELERATORS!

VIRTUAL MEMORY

VIRTUAL MEMORY IS A TECHNIQUE THAT ALLOWS YOU TO TRANSFORM SOME OF YOUR (INEXPENSIVE) HARD DRIVE SPACE INTO (MORE VALUABLE) APPLICATION MEMORY. IT MEANS THAT YOU CAN USE MORE APPLICATION MEMORY THAN THE AMOUNT OF PHYSICAL RAM YOU HAVE INSTALLED IN YOUR MAC. FOR EXAMPLE, A MAC IICX WITH 5MB OF RAM CAN EASILY BE SET TO HAVE 13MB OF APPLICATION MEMORY USING VIRTUAL MEMORY (EVEN WITH 32-BIT ADDRESSING TURNED OFF) WHICH MEANS YOU COULD HAVE 2MB OF RAM TAKEN UP BY THE OPERATING SYSTEM, AND STILL OPEN THREE 3MB APPLICATIONS AND ONE 2MB APPLICATION.

VIRTUAL MEMORY IS SLOWER THAN A COMPARABLE AMOUNT OF REAL RAM, BUT NOT NECESSARILY BY MUCH. VIRTUAL MEMORY WORKS BY KEEPING SOME OF THE INFORMATION NORMALLY STORED IN RAM IN A SPECIAL FILE ON THE HARD DRIVE KNOWN AS THE SWAPPING FILE. IT WORKS ESPECIALLY WELL WITH MULTIFINDER, SINCE THE FOREGROUND APPLICATION CAN BE GIVEN MOST OF THE REAL RAM AND THE BACKGROUND APPLICATIONS CAN BE "SWAPPED OUT" TO THE HARD DRIVE, READY TO BE COPIED UP TO RAM WHENEVER THEY ARE BROUGHT TO THE FOREGROUND. IN THIS CASE THE IMPORTANT PARAMETER IS THE RATIO BETWEEN THE AMOUNT OF REAL RAM NOT BEING USED BY THE SYSTEM (IE., THE PHYSICAL RAM MINUS 2MB OR SO) AS COMPARED TO THE SIZE OF THE LARGEST SINGLE APPLICATION YOU WANT TO RUN. AS LONG AS THEY ARE NEARLY EQUAL, VIRTUAL MEMORY SHOULD NOT NOTICEABLY SLOW DOWN YOUR COMPUTER.

CONNECTIX FIRST BROUGHT THIS TECHNOLOGY TO THE MACINTOSH IN 1988 WITH OUR AWARD-WINNING PRODUCT, VIRTUAL, AND TODAY VM IS A STANDARD FEATURE OF SYSTEM 7. WE STILL

THINK VIRTUAL 3.0 IS WORTH HAVING, THOUGH, AND RECOMMEND ITS USE IF YOU FIND YOU NEED VIRTUAL MEMORY FREQUENTLY. VIRTUAL PROVIDES 14MB OF VIRTUAL MEMORY IN 24-BIT MODE WHILE SYSTEM 7 VM USUALLY ONLY OFFERS 13MB (12MB ON THE IISI). VIRTUAL IS OPTIMIZED FOR SPEED, AND IT CAN BE CONFIGURED TO USE UP MUCH LESS HARD DRIVE SPACE THAN VM. (VM ALWAYS REQUIRES 1MB OF HARD DRIVE SPACE FOR EACH MEGABYTE OF APPLICATION MEMORY, REGARDLESS OF THE AMOUNT OF PHYSICAL RAM INSTALLED.) FINALLY, MANY PRODUCTS WHICH ARE NOT COMPATIBLE WITH VM TODAY WORK WITH VIRTUAL 3.0 (EG, SYSTEM 6, ACCELERATED COMPACT MACS, SOME HARD DRIVE DRIVERS.)

BY THE WAY, IF YOU DO USE SYSTEM 7 VM, YOU CAN SLIGHTLY IMPROVE ITS PERFORMANCE BY MAKING SURE THAT THE SWAP FILE IS CONTIGUOUS. THE BEST WAY TO DO THIS IS TO OPTIMIZE YOUR DRIVE WITH ONE OF THE MAJOR HARD DRIVE UTILITIES. CONNECTIX VIRTUAL OPTIMIZES ITS OWN SWAP FILE AUTOMATICALLY.

TO USE VIRTUAL MEMORY ON THE MAC YOU NEED A PAGED MEMORY MANAGEMENT UNIT (PMMU). THIS IS BUILT INTO THE 68030 PROCESSOR. SO THE SE/30, IIX, IICX, IICI, IISI, AND IIFX CAN RUN VIRTUAL MEMORY WITHOUT MODIFICATION. THE MAC II IS BASED ON THE 68020 PROCESSOR WHICH HAS NO PMMU, SO IT NEEDS A MEMORY COPROCESSOR CALLED THE MC73 PMMU. APPLE OFFERS THESE FOR \$499 BUT YOU CAN GET THE SAME PART FROM CONNECTIX FOR \$179. THE LC IS ALSO BASED ON THE 68020, BUT HAS NO SOCKET FOR A PMMU. THE ONLY WAY TO RUN VIRTUAL MEMORY ON AN LC WOULD BE TO INSTALL A 68030 OR 68040 ACCELERATOR. 68040 ACCELERATORS ARE AVAILABLE FOR THE LC TODAY. 68030'S ARE REPORTED TO BE UNDER DEVELOPMENT BUT, AS OF THIS WRITING, NONE HAVE BEEN RELEASED. COMPACT MACS CAN RUN CONNECTIX'S COMPACT VIRTUAL IF THEY ARE UPGRADED WITH A 68030 ACCELERATOR, AND VIRTUAL PROVIDES 16MB OF VIRTUAL MEMORY ON THESE SYSTEMS. SYSTEM 7 VM DOES NOT WORK WITH ACCELERATED MAC PLUS, SE OR CLASSIC.

About PMMUs: Not all PMMUs are alike.

The original 68020-based Mac II requires a Motorola 68851 Paged Memory Management Unit, (PMMU) in order to run System 7.0 VM, A/UX, Connectix Virtual, or Connectix MAXIMA, unless the Mac II has been upgraded with a 68030 or 68040 processor. The Mac II incorporates a motherboard socket specifically designed for this memory coprocessor.

The current (and final) shipping version of the Paged Memory Management Unit is the Mask 73 Motorola MC68851RC16A. This is the version which Apple carries on its parts list. Surplus parts of earlier versions (Masks) may be available but some earlier PMMU parts may not work properly.

The Connectix product, MC73 PMMU, includes the current (Mask 73) version of the processor, a grounding strap, and a detailed installation manual.

The Mask number can be identified by looking at the second line on the chip. The first or second digit on this line should be a letter "B". The Mask number is found in the two digits that follow the "B". All parts shipped by Motorola since March, 1989 are Mask 73. Earlier generations (in reverse chronological order) were Mask 36, 96, and 87. These are *not recommended* for use with the Macintosh.

PMMUs are also available in different speed ratings. This is designated by the number after the letters RC on the first line. The Mac II is clocked at 16MHz, so it needs a 16MHz PMMU. Do not buy a PMMU with an RC number less than that. So, for example an MC68851 RC16A is a good part, but an XC68851 RC12 is not. Some RC12 parts are available on the market for a low price, but these are likely to produce intermittent crashes after days, weeks, or months of use.

You may also check the date the PMMU was produced by looking at the last four digits of the last line on the chip. These are printed in YY-WW (Year-Year, Week-Week) notation. So, for example, 9035 indicates the chip was manufactured in the 35th week of 1990.

24-BIT FRAGMENTATION

In 24-bit mode, the extended memory created by VM, Virtual or MAXIMA is *fragmented* at the 8 Megabyte point by the ROMs. (In 32-bit mode the fragmentation occurs at 1024MB, one gigabyte, and so, practically speaking is not an issue at present.) Fragmentation can limit the size of the largest single application you can run using MultiFinder, so you might have 13 or 14MB of application memory, but not be able to open a single 8MB file.

System 6 MultiFinder and the System 7 Process Manager can not assign a fragmented block of memory to any one program, and this means that while running in 24-bit mode the largest zone for any one application is slightly less than 8 Megabytes. The largest available block of memory is shown in the "About this Macintosh" (System 7) or "About the Finder" (System 6) window.

If you run an application under System 6 in Finder, then all of the memory in the machine (up to 14 Megabytes minus the size of the System) will be given to that application. Even then, the available memory is fragmented and some limitations still apply. For example, you can have a 6 Megabyte picture buffer, and a 6 Megabyte "undo" buffer but, using many applications, you can't have a single 12 Megabyte picture.

NuBus cards can further fragment memory, but you can arrange your slot cards to minimize the effect. On a Mac II, IIfx, IIfx, or IIfx you should right-justify your cards so they are all together towards the floppy drive. If you have a Mac IIfx, left justify the cards, away from the power supply and disk.

RAM CACHES, RAM DISKS, AND RAM DRIVES

WE DESCRIBED EARLIER HOW INFORMATION HAS TO BE BROUGHT FROM THE HARD DRIVE INTO THE RAM BEFORE IT CAN BE USED BY THE CPU. ONCE EXECUTED, THESE INSTRUCTIONS ARE FORGOTTEN BY THE CPU. USUALLY, IF THEY ARE NEEDED AGAIN THEY MUST ONCE MORE BE COPIED FROM THE HARD DRIVE. BUT INSTRUCTIONS ARE OFTEN USED REPEATEDLY IN SHORT INTERVALS ("LOOPS" IN THE PROGRAM, FOR EXAMPLE). SO THE MAC CONTAINS A BUILT-IN RAM CACHE WHERE THE MOST RECENTLY USED INSTRUCTIONS CAN BE STORED IN SIMM RAM. THIS SPEEDS UP ACCESS IN THE FREQUENT CASES WHERE RECENTLY USED INSTRUCTIONS ARE NEEDED AGAIN RIGHT AWAY. YOU CAN ADJUST THE SIZE OF THIS CACHE IN THE CONTROL PANEL. HOWEVER, INCREASING THE RAM CACHE BEYOND SOME POINT, TYPICALLY 256K, YIELDS DIMINISHING RETURNS, AND BECOMES A WASTE OF POTENTIAL APPLICATION MEMORY. THE RAM CACHE IS USUALLY WORTH USING BUT DON'T EXPECT DRAMATIC RESULTS. USUALLY IT SPEEDS THINGS UP NO MORE THAN 5-15%.

THE FINAL DATA TRANSFER STEP IS WHEN THE INFORMATION IS COPIED FROM THE RAM INTO AN INTERNAL "REGISTER" IN THE CPU. THIS ALSO TAKES TIME AND CAN SLOW DOWN YOUR MAC. AGAIN, HOWEVER, THE NEXT INSTRUCTION THAT NEEDS TO BE EXECUTED IS FREQUENTLY ONE THAT HAS JUST RECENTLY BEEN USED. THE MAC IICI AND SOME IISI MATH COPROCESSOR CARDS SUPPORT AN ADD-ON RAM CACHE WHICH CAN REMEMBER THE MOST RECENTLY USED

INSTRUCTIONS. IT STORES THEM IN A MEMORY LOCATION THAT CAN BE ACCESSED BY THE CPU EVEN FASTER THAN DATA HELD IN NORMAL RAM. IT CAN PRODUCE SUPRISINGLY BIG SPEED IMPROVEMENTS, OFTEN IN THE RANGE OF 15-30%. AND SINCE YOU ADD RAM, THIS CACHE DOES NOT REDUCE THE AMOUNT OF AVAILABLE APPLICATION MEMORY. THE IIFX HAS A BUILT-IN CACHE CARD WITH 64K OF MEMORY.

A RAM DISK IS A PORTION OF THE INSTALLED RAM WHICH IS NOT USED FOR APPLICATION MEMORY, AND INSTEAD IS CONFIGURED TO WORK LIKE A HARD DRIVE. RAM DISKS TYPICALLY LOOK LIKE A HARD DRIVE ON THE DESKTOP, AND INFORMATION CAN BE ADDED, ACCESSED, MODIFIED, OR REMOVED IN EXACTLY THE SAME WAY AS ANY HARD DRIVE, BUT AT RAM SPEEDS. THE TRADITIONAL PROBLEM WITH RAM DISKS IS THAT THE CONTENTS ARE ERASED WHENEVER POWER IS TURNED OFF. THE MAXIMA RAM DISK SOLVES THIS PROBLEM BY MAINTAINING A COPY OF THE RAM DISK CONTENTS ON THE HARD DRIVE, THUS PRESERVING THE INFORMATION WHENEVER THE SYSTEM IS SHUT DOWN. IT THEN AUTOMATICALLY COPIES THIS INFORMATION BACK UP FROM THE HARD DRIVE INTO THE RAM DISK WHEN THE MAC IS REBOOTED. AN UNUSUAL FEATURE OF THE MAXIMA RAM DISK IS THAT ITS CONTENTS WILL ALSO SURVIVE A CRASH OR A RESTART, AS LONG AS POWER IS NOT INTERRUPTED.

A RAM DRIVE IS A SCSI DEVICE, IE. IT IS CONNECTED TO THE MAC IN THE SAME WAY AN EXTERNAL HARD DRIVE IS. INSTEAD OF HAVING A SPINNING PLATTER LIKE A HARD DRIVE, IT CONTAINS LOTS OF RAM. RAM DRIVES ARE EXPENSIVE BUT THEY CAN BE A LOT FASTER THAN THE VERY FASTEST ORDINARY HARD DRIVES. THEY ARE USUALLY NOT AS FAST AS RAM DISKS BUILT OUT OF SIMM RAM SINCE THEY ARE SLOWED DOWN BY THE DATA TRANSFER THROUGH THE SCSI CONNECTION, ALTHOUGH THE LATEST GENERATION IS OF 8-BIT SCSI-2 DRIVES ARE INCREDIBLY FAST.

LaserWriter SIMMs

Your LaserWriter uses SIMMs to store information about fonts and to work as a buffer in accepting data from your Macintosh. The buffer allows the Mac to send a large stream of data faster than the rate the printer can print, and then send another stream when the first one is almost used up. LaserWriter SIMMs have 64 connectors just like a IIfx and, in fact, you can use the RAM interchangeably. However, the IIfx requires 80ns RAM, while the LaserWriter only needs 100ns.

The LaserWriter II NT comes with 2MB and cannot be expanded further. The LaserWriter II NTX has three RAM expansion banks, each of which is comprised of 4 sockets. The standard II NTX comes with 2MB in the form of eight 256K SIMMs located in Banks 0 and 1. Larger configurations can be achieved as follows:

3MB: Add four 256K SIMMs to Bank 2.

5MB: Replace the four 256K SIMMs in Bank 0 with 1MB SIMMs. Leave four 256K SIMMs in Bank 1.

6MB: Oddly enough, not possible.

8MB: Place eight 1MB SIMMs into Banks 0 and 1.

9MB: Take the 8MB setup and add four 256K SIMMs to Bank 2.

12MB: (Largest possible) Place twelve 1MB SIMMs into Banks 0, 1 and 2.

Adding RAM to a LaserWriter II NTX increases the space available to store fonts and can speed up printing in many cases.

REFERENCE GUIDE

HERE IS A SYSTEM BY SYSTEM DESCRIPTION OF THE MAIN ISSUES RELATING TO MEMORY CONFIGURATIONS ON THE ELEVEN MOST COMMON MACS. "LOW MEMORY" RELATES TO CONFIGURATIONS USING 1MB SIMMS OR SMALLER. ON COMPACT MACS THIS MEANS UP TO 4MB TOTAL, AND ON MODULAR MACS IT MEANS UP TO 8MB. "VIRTUAL MEMORY" MEANS CONFIGURATIONS USING EITHER CONNECTIX VIRTUAL 3.0, OR SYSTEM 7 BUILT-IN VM. "HIGH MEMORY" COVERS CONFIGURATIONS USING 2, 4, 8, OR 16 MB SIMMS.

MAC PLUS: FOUR SOCKETS IN TWO BANKS OF TWO EACH. 150NS SIMMS REQUIRED.

LOW MEMORY: UP TO 4MB CAN BE INSTALLED USING FOUR 1MB SIMMS. TO ADD RAM TO A MAC PLUS YOU NEED TO CUT ONE RESISTER ON THE MOTHERBOARD. IF YOU'RE STILL USING A PLUS AND, ESPECIALLY, IF YOU WANT TO RUN SYSTEM 7, IT'S PROBABLY TIME TO FILL IT UP WITH RAM.

VIRTUAL MEMORY: THE 68000 CPU IN THE MAC PLUS HAS NO PAGED MEMORY MANAGEMENT UNIT (WHICH IS REQUIRED TO RUN VIRTUAL MEMORY). IF YOU ADD A 68030 ACCELERATOR, THIS WILL CONTAIN A BUILT-IN PMMU, BUT SYSTEM 7 VM WILL STILL NOT WORK. USE CONNECTIX COMPACT VIRTUAL 3.0 TO CREATE 16 MB OF VIRTUAL MEMORY ON THE ACCELERATED MAC PLUS.

HIGH MEMORY: THE ONLY SOLUTION IS A 68030 ACCELERATOR AND CONNECTIX VIRTUAL 3.0. ON MOST ACCELERATORS YOU CAN THEN INSTALL FOUR 4MB SIMMS TO HAVE A TOTAL OF 16MB OF APPLICATION MEMORY.

MAC SE: FOUR SOCKETS IN TWO BANKS OF TWO EACH. 150NS SIMMS REQUIRED.

LOW MEMORY: SAME AS MAC PLUS

VIRTUAL MEMORY: SAME AS MAC PLUS

HIGH MEMORY: SAME AS MAC PLUS

MAC CLASSIC: ONE SPECIAL SOCKET AND 1MB OF RAM SOLDERED ON THE MOTHERBOARD. 150NS SIMMS REQUIRED.

LOW MEMORY: THE SOCKET CAN BE FILLED WITH A SPECIAL ADAPTER CARD WITH 1MB OF RAM WHICH ALSO CARRIES SOCKETS TO HOLD TWO MORE SIMMS. THESE LAST TWO SOCKETS ARE A BANK; THEY MUST BOTH BE FILLED OR BOTH BE EMPTY. A TOTAL OF 4MB CAN BE INSTALLED WITH 1MB SIMMS.

VIRTUAL MEMORY: SAME AS PLUS.

HIGH MEMORY: SAME AS PLUS.

MAC PORTABLE: FOUR SOCKETS IN ONE BANK. 1MB BUILT-IN RAM. SPECIAL STATIC OR PSEUDO-STATIC, (SEE SIMMS, ABOVE) RAM REQUIRED.

LOW MEMORY: UP TO 5MB

VIRTUAL MEMORY: THE 68000 CPU IN THE MAC PORTABLE HAS NO PAGED MEMORY MANAGEMENT UNIT (WHICH IS REQUIRED TO RUN VIRTUAL MEMORY). THERE IS CURRENTLY NO UPGRADE PATH TO PROVIDE A PMMU TO THE PORTABLE AND THERE MAY NEVER BE ONE.

HIGH MEMORY: NOT AVAILABLE.

MAC II: EIGHT SOCKETS IN TWO BANKS OF FOUR EACH. 120NS SIMMS REQUIRED. SPECIAL "PAL" SIMMS REQUIRED FOR 4MB SIMMS OR LARGER.

LOW MEMORY: MEMORY CONFIGURATIONS FROM 1 TO 8 MEGABYTES ARE ACHIEVED FOLLOWING THE USUAL RULE FOR MODULAR MACS: EACH BANK OF 4 SOCKETS MUST BE EITHER COMPLETELY FILLED WITH 4 SIMMS OF THE SAME SIZE, OR LEFT COMPLETELY EMPTY. (BANK A MUST ALWAYS BE FILLED.)

VIRTUAL MEMORY: THE MAC II IS EQUIPPED WITH A MOTOROLA 68020 CPU (NOT THE 68030 OF THE MORE RECENT SYSTEMS.) BECAUSE OF THIS IT NEEDS A MEMORY COPROCESSOR TO RUN VIRTUAL MEMORY — THE MOTOROLA MC68851RC16A PAGED MEMORY MANAGEMENT UNIT (PMMU). THIS PART IS AVAILABLE THROUGH MOST MAC RESELLERS UNDER THE NAME MC73 PMMU. THE SOLE PURPOSE OF THE PMMU IS TO ALLOW USE OF SYSTEM 7 VM, A/UX, VIRTUAL, AND MAXIMA ON THE MAC II. IT DOES NOT OTHERWISE AFFECT PERFORMANCE AND SHOULD NOT BE CONFUSED WITH THE MOTOROLA 68882 MATH COPROCESSOR, WHICH IS DESIGNED TO ACCELERATE MATHEMATICAL COMPUTATION.

HIGH MEMORY: This is probably the most complex case. Three distinct issues all limit Mac II memory configurations over 8MB.

1) The Mac II ROMs are not compatible with 32-bit addressing so some extra software must always be added in order to access more than 8 megabytes. Under System 7, the best solution is usually MODE32, which overcomes this limitation by enabling standard 32-bit addressing (see 32-bit addressing, above). 32-bit addressing is also available under System 6 by using OPTIMA (although OPTIMA is not compatible with MultiFinder). In either System 6 or 7, MAXIMA can be used to enhance the 24-bit addressing mode, allowing up to 14MB to be addressed.

2) Special SIMMs are required on the Mac II (and IIx). The special design incorporates the usual eight 4-megabit DRAM chips as well as a PAL or equivalent logic chip. A logic chip is needed to overcome problems caused by the refresh logic on the Mac II (and IIx). These two systems were designed before 4MB SIMMs became available and turned out not to be compatible with the final standard design of 4MB SIMMs. (Do not confuse these special SIMMs with the somewhat similar 9-chip "parity" SIMMs used for government and other applications, where the 9th chip is also DRAM. Parity SIMMs will not overcome the memory problem.) Many vendors now offer compatible SIMMs for the Mac II and IIx, though they do cost a little more than standard SIMMs. Be sure to specify what Mac you use when you buy 4 (or 2 or 8 or 16) MB SIMMs. These special SIMMs are also compatible with the IIcx, IICI, IISI, and SE/30, (but not the IIfx) although they are not required on these systems.

3) On standard Mac II's Bank A cannot use SIMMs larger than 2MB. 4, 8, and 16MB SIMMs must only be put in Bank B. Also, Bank A must be filled with SIMMs of 2MB or less if Bank B is to be used. Bank A is the set of four sockets to the right as you face the front of the Macintosh. This is a problem unique to the Mac II, and is caused by problems in the Mac II ROMs which is not overcome by adding MODE32 or MAXIMA. However, you can fix this one problem by installing the HDFS SuperDrive upgrade kit, which includes a set of Mac IIx ROMs. As a result of this limitation the largest memory configuration available on unmodified Mac IIs using 1MB and 4MB SIMMs is 20MB: four 1MB SIMMs in Bank A and four 4MB SIMMs in Bank B. When Mac IIx ROMs are added the maximum amount of memory the computer will support is 128MB, using eight 16MB SIMMs.

MAC IIX: EIGHT SOCKETS IN TWO BANKS OF FOUR EACH. 120NS SIMMS REQUIRED. SPECIAL "PAL" SIMMS REQUIRED FOR 4MB SIMMS OR LARGER.

LOW MEMORY: SAME AS MAC II

VIRTUAL MEMORY: THE 68030 CPU IN THE MAC IIX HAS A BUILT-IN MEMORY MANAGEMENT UNIT (WHICH IS NEARLY IDENTICAL TO THE CIRCUITRY IN A PMMU). THEREFORE, THE MAC IIX CAN RUN VIRTUAL MEMORY WITHOUT REQUIRING ANY ADDITIONAL HARDWARE.

HIGH MEMORY: UP TO 128MB OF PHYSICAL RAM MAY BE INSTALLED ON A MAC IIX (EIGHT 16MB SIMMS). A COMMON HIGH MEMORY CONFIGURATION IS EIGHT 4MB SIMMS FOR A TOTAL OF 32MB. IN SYSTEM 7 MODE32 AND/OR MAXIMA SOFTWARE MUST BE ADDED AND SPECIAL SIMMS ARE REQUIRED (SEE ABOVE - MAC II, HIGH MEMORY, POINTS 1 AND 2. POINT 3 DOES *NOT* APPLY TO MAX IIX.) UNDER SYSTEM 6 USE MAXIMA OR OPTIMA.

MAC IICX: EIGHT SOCKETS IN TWO BANKS OF FOUR EACH. STANDARD 120NS SIMMS REQUIRED.

LOW MEMORY: SAME AS MAC II.

VIRTUAL MEMORY: SAME AS MAC IIX.

HIGH MEMORY: UP TO 128MB OF PHYSICAL RAM MAY BE INSTALLED ON A MAC IICX (EIGHT 16MB SIMMS). A COMMON HIGH MEMORY CONFIGURATION IS EIGHT 4MB SIMMS FOR A TOTAL OF 32MB. IN SYSTEM 7 MODE32 AND/OR MAXIMA SOFTWARE MUST BE ADDED, BUT STANDARD SIMMS MAY BE USED. (SEE ABOVE- MAC II, HIGH MEMORY, POINT 1. POINTS 2 AND 3 DO *NOT* APPLY TO THE MAX IICX.) UNDER SYSTEM 6 USE MAXIMA OR OPTIMA.

MAC SE/30: SAME AS MAC IICX.

MAC IICI: EIGHT SOCKETS IN TWO BANKS OF FOUR EACH. IN PRICIPLE, STANDARD 80NS SIMMS REQUIRED. IN PRACTICE, YOU CAN OFTEN GET AWAY WITH 100NS RAM. HOWEVER, IF YOU USE AN ADD-ON CACHE CARD (SEE PAGE RAM CACHES, RAM DISKS, AND RAM DRIVES, BELOW) YOU REALLY NEED TO USE 80NS RAM IN THE SIMM SOCKETS.

LOW MEMORY: SAME AS MAC II.

VIRTUAL MEMORY: SAME AS MAC IIX.

HIGH MEMORY: UP TO 128MB OF PHYSICAL RAM MAY BE INSTALLED ON A MAC IICI (EIGHT 16MB SIMMS). HOWEVER, A UNIQUE LIMITATION OCCURS ON THE MAC IICI. BANK A IS SHARED BETWEEN THE ON-BOARD VIDEO AND SIMMS, SO USING 2, 4, 8, OR 16MB SIMMS IN BANK A CAN ACTUALLY SLOW THE MAC DOWN QUITE A LOT. MOREOVER, INTERMITTENT CRASHES OCCUR IF 2, 4,8, OR 16MB SIMMS ARE PUT IN BANK A OF A MAC IICI, IF THE ON-BOARD VIDEO IS USED. (THIS ISSUE IS NOT RELATED TO THE ABOVE CACHE CARD ISSUE.) SO, IF YOU USE THE ON-BOARD VIDEO, PUT YOUR LARGE SIMMS IN BANK B, AND BE SURE TO PUT SOME SMALLER SIMMS (1MB OR LESS) IN BANK A. IF YOU DO NOT USE ON-BOARD VIDEO, FOLLOW THE USUAL RULE: PUT YOUR LARGEST RAM IN BANK A. THE MAC IICI WAS THE FIRST MAC TO CONTAIN 32-BIT COMPATIBLE ROMS, SO NO ADDITIONAL SOFTWARE IS REQUIRED TO ADDRESS HIGH MEMORY IN SYSTEM 7. UNDER SYSTEM 6 USE MAXIMA OR OPTIMA.

MAC IISI: FOUR SOCKETS IN ONE BANK. 1MB OF RAM SOLDERED ON THE MOTHERBOARD. STANDARD 100NS SIMMS REQUIRED.

LOW MEMORY: THE BANK MAY EITHER BE EMPTY, OR FILLED WITH FOUR SIMMS, WHICH MUST ALL BE OF THE SAME SIZE. LOW MEMORY CONFIGURATIONS OF 1, 2, OR 5MB ARE THEREFORE POSSIBLE USING NO SIMMS, 256K SIMMS OR 1MB SIMMS IN THE SIMM BANK.

VIRTUAL MEMORY: SAME AS MAC IIX EXCEPT THAT SYSTEM 7 VM CAN ONLY PROVIDE 12 MB INSTEAD OF THE USUAL 13 MB IN 24-BIT ADDRESSING MODE. CONNECTIX VIRTUAL PROVIDES 14 MB IN 24-BIT MODE, AS USUAL.

HIGH MEMORY: UP TO 65MB OF PHYSICAL RAM MAY BE INSTALLED ON A MAC IISI (1MB SOLDERED ON THE MOTHERBOARD PLUS FOUR 16MB SIMMS). A COMMON CONFIGURATION IS 17MB (1MB BUILT-IN PLUS FOUR 4MB SIMMS). THE MAC IISI HAS 32-BIT COMPATIBLE ROMS, SO NO ADDITIONAL SOFTWARE IS REQUIRED TO ADDRESS HIGH MEMORY IN SYSTEM 7. UNDER SYSTEM 6 USE MAXIMA OR OPTIMA.

MAC IIFX: EIGHT SOCKETS IN TWO BANKS OF FOUR EACH. SPECIAL IIFX-COMPATIBLE 80NS SIMMS REQUIRED.

LOW MEMORY: THE MAC IIFX REQUIRES FASTER RAM THAN THE OTHER SYSTEMS (80NS). THE SIMM SOCKETS HAVE 64 CONNECTORS INSTEAD OF THE USUAL 30 SO STANDARD SIMMS WILL NOT FIT IN A IIFX. MEMORY CONFIGURATIONS UP TO 8 MEGABYTES ARE ACHIEVED FOLLOWING THE USUAL RULE FOR MODULAR MACS: EACH BANK OF 4 SOCKETS MUST BE EITHER COMPLETELY FILLED WITH 4 SIMMS OF THE SAME SIZE, OR LEFT COMPLETELY EMPTY.

VIRTUAL MEMORY: SAME AS MAC IIX.

HIGH MEMORY: UP TO 128MB OF PHYSICAL RAM MAY BE INSTALLED ON A MAC IIFX (EIGHT 16MB SIMMS). A COMMON HIGH MEMORY CONFIGURATION IS EIGHT 4MB SIMMS FOR A TOTAL OF 32MB. THE MAC IIFX HAS 32-BIT COMPATIBLE ROMS, SO NO ADDITIONAL SOFTWARE IS REQUIRED TO ADDRESS HIGH MEMORY IN SYSTEM 7. UNDER SYSTEM 6 USE MAXIMA OR OPTIMA.

MAC LC: ONE BANK OF TWO SOCKETS. 2MB OF RAM SOLDERED ON THE MOTHERBOARD. 100NS SIMMS REQUIRED.

LOW MEMORY: SAME AS IISI

VIRTUAL MEMORY: ONLY POSSIBLE IF YOU ADD A 68040 ACCELERATOR (AVAILABLE TODAY) OR A 68030 ACCELERATOR (SOME IN DEVELOPMENT, NONE RELEASED YET.) THE LC IS BASED ON THE 68020 CPU (SEE MAC II VIRTUAL MEMORY) BUT HAS NO SOCKET TO HOLD A PMMU.

HIGH MEMORY: MAXIMUM OF 10 MB (!). THE ROMS SUPPORT STANDARD 32-BIT ADDRESSING, BUT THE MOTHERBOARD IS HARD-WIRED TO SUPPORT A MAXIMUM OF 10MB OF MEMORY. BECAUSE THERE IS NO SUPPORT FOR A PMMU, MAXIMA CANNOT BE USED. TO ADDRESS OVER 8MB YOU MUST USE 32-BIT ADDRESSING- EITHER SYSTEM 6 AND OPTIMA, OR SYSTEM 7. ALL IN ALL, THE LC IS NOT A GOOD CHOICE FOR HIGH MEMORY APPLICATIONS.

A BRIEF HISTORY OF MAC MEMORY ADDRESSING

Addressing modes affect how you use your computer because they determine the amount of application memory you can use on your system. Application memory is the space your system works in when it runs applications, the memory you can see described under "About This Macintosh...". The size of this space limits the total combined size of all the applications you can have open at the same time. The System also uses up application memory.

The amount of RAM that can be "addressed" (used) as application memory on your system is limited by the total number of different memory addresses (locations) that the Macintosh can identify, each with a unique serial number. This identification is performed by sending 1's and 0's down a parallel set of data lines called an address bus.

This address bus became an important limitation during the course of the evolution of the Macintosh. Apple's Macintosh system software was first developed on the Lisa and Mac 128 computers, both of which used the Motorola 68000 microprocessor. Although the internal architecture of the machine used 32-bit address and data paths, this microprocessor only had a 24 line address bus, so no address higher than 2^{24} (≈ 16 million) was accessible. So, the top byte (the top eight bits) out of the total of 32 was not used by the 24-bit addressing scheme. And, to put it in technical jargon, the 24-bit addressing mode of the Macintosh only supported 16 megabytes of internal addresses.

THE EIGHT MEGABYTE BARRIER

This 24-bit/16 megabyte limitation was accentuated by another design decision made in the early Mac architecture. Of those 16 megabytes, only the lower 8 were allocated to supporting RAM addresses, hence the "8 megabyte barrier" familiar to users of modular Macintoshes. The remaining upper 8 megabytes were allocated to addressing the motherboard, video monitors, ROMs, input/output ports like SCSI and AppleTalk, and, mainly, the NuBus slots, each of which was given a full megabyte.

Virtual and MAXIMA became the first products to cross the 24-bit mode 8 megabyte barrier by collecting unused space in the upper 8 MB and allowing the system to use it in the same way as the original lower 8 MB of application RAM. Modular Macs with one NuBus card running a video monitor were able to address up to 14 megabytes of application memory using this approach. Under System 7, the VM virtual memory does a similar trick. But, to access more than 8 megabytes of real RAM in 24-bit mode, you still need to use MAXIMA.

The 24-bit addressing mode did not seem like a big limitation on the earliest Macs which had only 128 K of RAM. So the unused top byte was put to use by enterprising software engineers to signify various other things. For example, setting the high-order bits of an address could help "tag" (identify) that memory as being temporarily write protected. Thus the hexadecimal address \$80001234 represents the same memory location as \$00001234, but is just tagged differently. This convention was assumed throughout the operating system, the ROM code, and by the applications which were developed to run on the Mac. And, as you will see, this led to problems later.

ENTER THE MAC II

Eventually, the 8 megabyte barrier started to become a significant limitation and Apple began a program to convert the Macintosh hardware, software, and firmware (ROMs) to the 32-bit mode. With 32 lines for addresses, the Macintosh would have 2^{32} memory locations, capable of supporting an astonishing 4 gigabytes (4096 megabytes) of application memory. For the foreseeable future, the internal limitations of RAM addressing would cease to exist. (Unfortunately this memory is also fragmented — at the one gigabyte level. As a result, "only" one gigabyte of application memory can be accessed under System 7 32-bit mode. Since, historically, upper level Mac memory needs have doubled every year this should become an issue sometime around 1998!)

The first step of this conversion program was to incorporate a new microprocessor. With the introduction of the Motorola 68020-based Mac II (and the later 68030-based systems), the Macintosh CPU graduated to a 32-bit address bus. The hardware was able to make all 32-bits of each address significant. Apple continues to ship products based on the old 68000 for reasons of economy, but all of the high end systems have been 32-bit hardware compatible since the introduction of the Mac II.

Now there was a new problem. Some of the high-order address bits had been set for non-address purposes, so

whenever the hardware used those particular "tagged" addresses the program would fetch information from an incorrect location; i.e. although the hardware was now 32-bit clean, the system, the embedded code in the ROMs, and much of the application software was not. At this point Apple started to clean up their system software and ROM designs, and tried to impress upon third party developers the importance of following Apple guidelines, so that the software everyone wrote would work in a full-time 32-bit clean environment when the ROMs and System were ready.

THE NEW ROMS

The second step of the conversion program was the new "32-bit clean" ROM designs which were incorporated in the IICI, IIfx, IIsi, and LC. These were first released in 1989 and are capable of accepting full 32-bit addresses. Systems equipped with these ROMs can run in 32-bit mode under System 7.0 and later systems, provided that the applications and INITs are 32-bit clean.

The function of MODE32 is to make this 32-bit mode available for users of Mac II-family computers that were released before the 32-bit clean ROMs were introduced, i.e. the SE/30, II, IIx, and IICx. MODE32 contains software that makes these ROMs 32-bit clean.

Apple's third step was to convert the operating system itself to run in this mode, a feature which is provided as the 32-bit mode option in System 7. One can guess that in some future System the 24-bit option will disappear entirely and 32-bit mode will be the only standard. Connectix offers a product called OPTIMA, which creates a 32-bit mode for System 6, but only using Finder.

The next few years will be a transitional period because the last step in moving to 32-bit mode involves the application software. Only "32-bit clean" applications can be used in 32-bit mode -- all others will cause a system crash. Apple made 32-bit mode optional in System 7 because many applications today are incompatible with 32-bit mode and it will probably be a while before the full software base converts. When you want to run applications and/or INITs that are not 32-bit clean, you must switch your system to the 24-bit mode, at which stage you may want to use MAXIMA to enhance the 24-bit mode.

Bad Memory

When you power up your Mac (perform a "cold start"), it begins by performing a comprehensive memory test. Basically it tries to write information to all the address locations in the entire installed RAM and then performs an operation (called an XOR) on the contents to see if it produces the correct result. It then writes the opposite pattern (0's where there were 1's before and vice versa) and tests again. If it gets correct results both times, it validates the RAM. When you do a Restart (a "warm boot") without interrupting power, a much more limited test is performed.

In either case, if the Mac finds a problem before it validates enough memory to run the monitor, it gives the four note chime, colorfully known as the Chimes of Death. If it finds a problem after it validates enough memory to run the monitor, you get the Unhappy Mac image on the screen (along with some arcane codes that might tell a programmer something about what went wrong).

There are several possible explanations. If you have just changed the RAM configuration in your Mac, or have just moved the Mac, it probably means the RAM is not securely seated in the SIMM sockets. Try wiggling each SIMM a little and gently pressing it a little harder into the socket. If this doesn't help, *carefully* remove the SIMMs and put them back in. If you still have problems, make sure you followed the 4 SIMM Rules, have the right RAM for your machine (eg. PAL SIMMs for a II or IIx if they are over 1MB), and don't have any obvious other

culprits (like a loose add-on accelerator card.) If you get this far, you probably have at least one defective SIMM. If possible, try to boot you Mac with a different set of RAM and then use a process of swapping and elimination to find the bad SIMM. By the way, SIMMs don't go bad often and when they do it is usually because they have recently been physically handled.

It is possible for software to cause memory problems, too, although this is extremely rare. If your RAM seems to be OK, try turning off as many INITs as possible, reinstalling your System and running a virus checker.

Glossary

<i>application</i>	Memory which is actually available for use either by an application or the operating <i>memory</i> system, and which will be recognized by standard operating system calls.
<i>bank</i>	A set of SIMM sockets that are logically connected- they must all be filled with the same size RAM, or all be empty.
<i>boot</i>	The process of starting-up a computer by loading essential environment and operating system information into the computer's memory. Changes in many operating system parameters can only take effect at boot time. In this booklet, it is also often used to refer to the " Restart " process.
<i>byte</i>	8 bits, enough information to hold a value between 0 and 255, which is enough to specify one alphanumeric character (letter, number, or symbol).
<i>CPU</i>	Central Processor Unit. A chip on the motherboard which does most of the calculations and manages the operating system.
<i>compact Mac</i>	Mac Plus, SE and Classic.
<i>contiguous</i>	When referring to RAM memory, an unbroken series of available addresses.
<i>fragmented</i>	Not contiguous; broken into logically and physically separate pieces.
<i>high memory</i>	In this manual, over 8 megabytes for Modular Macs, over 4MB for Compacts.
<i>kilobyte</i>	1024 bytes. Roughly the amount of information in half a typewritten page.
<i>low memory</i>	In this manual, under 8 megabytes for Modular Macs, under 4MB for Compacts.
<i>mask</i>	The design version of a semiconductor.
<i>MB</i>	Megabyte. Loosely, a million bytes. Precisely, 1024 kilobytes.
<i>megabyte</i>	1,048,576 bytes. Enough space to hold about 200 copies of this booklet.
<i>memory map</i>	Describes what information or devices may be found at any particular memory address.
<i>modular Mac</i>	As used in this manual, Mac II-series, LC, and SE/30.
<i>motherboard</i>	The large printed circuit board in your Mac which contains the main processor and most of the other electronic components.
<i>nanosecond</i>	One billionth of a second. Some Macs can perform simple operations like moving a byte of data in 100 nanoseconds or less.
<i>nonvolatile</i>	The ability to retain information without external power applied. Hard drives, floppy diskettes, and ROMs are nonvolatile so their contents are preserved when the Mac is off.

operating system The software that runs the Macintosh. It is mainly what makes a Mac a Mac. System 6 or System 7 plus the ROM software makes up the entire operating system.

PAL Programmable Array Logic chip. A general purpose semiconductor that can be programmed after leaving the chip factory for a wide variety of uses. (Can be replaced by a Gate Array, or other logic chip to perform the same function.)

RAM Random Access Memory, meaning any location or address chosen at random can be accessed as quickly as any other. Often contrasted to sequential access memory, where the access time varies according to the location. A tape is sequential access because it is faster to get data from the beginning of a tape than the middle if the tape has just been rewound. SIMMs are a particular design type of RAM.

RAM disk A logical structure made from semiconductor memory which emulates the functioning of a disk drive as closely as possible. Since most semiconductor memory (RAM) is volatile, most RAM disks are also volatile.

Restart This usually refers to the selection in the Finder under the "**Special**" menu of the item which re-boots the computer without an intermediate interruption of power.

ROM Read Only Memory. A chip inside your Mac containing software which is part of your operating system. Its contents cannot be altered.

Startup Disk The disk which appears as the topmost disk on the desktop. It contains the System and Finder which are currently in use.

Shutdown The orderly transition of your Mac to a powered-off state.

SIMM Single In-line Memory Module. The standard configuration of RAM used on a Mac.

socket A connector on the motherboard which holds a single SIMM.

virtual memory A memory technology which creates more application memory than the amount of installed physical RAM. Uses hard drive space.

volatile Loses information when power is interrupted. (See **nonvolatile**.)

wait state A delaying processor cycle during which no memory is accessed, used to allow slower memory to be used with a faster processor.

24-bit mode The standard addressing mode of System 6, where only 24 bits are used to designate addresses. Limits address space to 16 MB, of which only 8MB is normally available for application memory. This mode occurs under System 7 if 32-bit addressing is turned off.

32-bit mode The new addressing mode available in System 7 (or System 6 if OPTIMA is installed.) Because 32 bits are used to designate address information, up to 128 MB of physical RAM or up to 1024 MB (one gigabyte) of virtual memory can be used under 32-bit addressing. Also called 32-bit addressing.