LESSON

3

Primary Storage: RAM

In this lesson, you will learn more about **primary storage devices** (**memory chips**) for the PC. There are two kinds of primary storage or memory chips: read only memory (ROM) and random access memory (RAM). As you learned in Lesson 1, the computer uses secondary storage for long term storage of data. The computer uses primary storage for short term storage of data that is needed, or will be needed, by the CPU. Data that needs to be stored for the long term is written to **secondary storage devices**, such as a hard disk or CD-ROM. Lessons 7 through 10 discuss how secondary storage works.

RAM plays a very important role in the operation of a computer. As operating systems become more sophisticated, and as application programs like Microsoft Office and Adobe Illustrator become more sophisticated, they require larger and larger amounts of RAM to operate efficiently, or even at all. Insufficient RAM is a major cause of poor computer performance. The design architecture and quality of RAM and ROM chips also influence the performance of a computer. Memory chips must be fast enough to keep up with the speed of the system bus and the CPU. They must also perform reliably under the stress of high demands placed on the system by particular applications.

If the RAM modules in a computer do not meet proper specifications, computer system performance declines. In some cases, computers cease to function or crash. Some PC applications, such as speech-to-text software and graphics applications (such as Photoshop), are especially CPU and RAM intensive because they require large amounts of information to be kept nearly instantly available to the CPU. Other functions, such as calculating the square root of a very large integer, may be CPU intensive but require little RAM. PC technicians must be aware of the kinds of applications being used on a computer when diagnosing problems.

A PC technician must also be familiar with the various performance features and packages used for RAM and ROM chips. As PC motherboard and CPU technology have evolved, ROM and RAM chips have been manufactured with a number of different shapes, sizes, and capabilities. Making the right choice when upgrading RAM can be complicated. Some kinds of memory chips are much more common than others, and replacing these commonly used memory chips is quite easy. Some PC motherboards can accommodate only one type of system memory; others can accommodate several types. Careful choices in purchasing memory for your computer may allow you to transfer it to another system or continue to use it after performing a motherboard upgrade.

The amount of RAM in a PC can greatly affect system performance. Generally, the more RAM installed in a computer, the faster it will read, write, and display information. A sufficient quantity of RAM can be more important to system performance than a faster CPU. Newer operating systems, such as Windows 2000, Windows XP, and Windows Server 2003, and newer graphics applications require much more RAM than earlier operating systems and older program versions.

The quality of RAM chips also can be an issue in system performance. Defective or poor quality RAM chips are a primary cause of application and system crashes. For reliable performance, memory chips must match the performance specifications of the motherboard.

Goals

In this lesson, you will learn about primary storage and about the different types and technologies of the ROM and RAM chips used in classic and contemporary PCs.

You will learn how to match memory modules to corresponding sockets and slots on the motherboard. You will also learn how the technologies of memory parity and error checking are used in PC memory to detect or correct errors. Additionally, you will learn how to read a RAM module label and typical advertisements for memory as well as evaluate and rate memory modules.

You will learn how to determine the amount of RAM on a computer, when to upgrade memory, and how to estimate the memory needed on a system. Finally, you will learn how to install and replace PC memory and how to troubleshoot memory-related system performance problems. You will also learn the basic methods used by Windows operating systems to manage PC memory.

Requirements

To complete this lesson, you will need administrative rights on a computer running a Windows-based operating system. For the step-by-step skills on installing RAM, you will need a computer to install a new DRAM module on as well as the new DRAM module. To complete the hands-on exercises you will need a computer with an Internet connection.

Lesson 3 Primary Storage: RAM

Skill	A+ Hardware Objective
1 Introduction to PC Memory	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
2. Learning about RAM	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.2** Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.
3. Identifying Types of RAM Technology	**4.2** Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.
4. Evaluating and Rating Memory	**4.2** Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.
5. Understanding Memory Parity and Error Correction	**4.2** Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.
6. Understanding an Advertisement for Computer Memory	**4.2** Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.
7. Preparing to Upgrade Memory	**1.2** Identify basic procedures for adding and removing field-replaceable modules for desktop systems. Given a replacement scenario, choose the appropriate sequences. **1.10** Determine the issues that must be considered when upgrading a PC. In a given scenario, determine when and how to upgrade system components. **4.2** Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.
8. Installing New RAM Modules	**1.2** Identify basic procedures for adding and removing field-replaceable modules for desktop systems. Given a replacement scenario, choose the appropriate sequences.

Lesson 3 Primary Storage: RAM (cont'd)

Skill	A+ Hardware Objective
9. Troubleshooting Memory Problems	**2.1** Recognize common problems associated with each module and their symptoms, and identify steps to isolate and troubleshoot the problems. Given a problem situation, interpret the symptoms and infer the most likely cause.
10. Memory Mapping in the First Megabyte	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.
11. Reading and Using Hexadecimal Numbers	Basic knowledge
12. Memory Mapping in Windows Operating Systems	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.
13. Working with UMBs and the HMA under MS-DOS and Windows 9.x	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.

skill 1 Introduction to PC Memory

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.

overview

In Lesson 2, you learned that microprocessors continuously retrieve, manipulate, and send binary data to and from other parts of the computer. Operating systems, applications, and data files contain large quantities of binary data—much more information than the CPU can store in its own internal memory registers. To work with large amounts of information very quickly, the CPU relies on two kinds of primary memory chips: ROM chips provide permanent storage space for instructions that must be fed to the CPU each time the computer starts. RAM chips provide an erasable electronic storage space that allows the CPU to quickly retrieve, process, and return data to other devices in the computer, such as display screens, printers, and network interfaces.

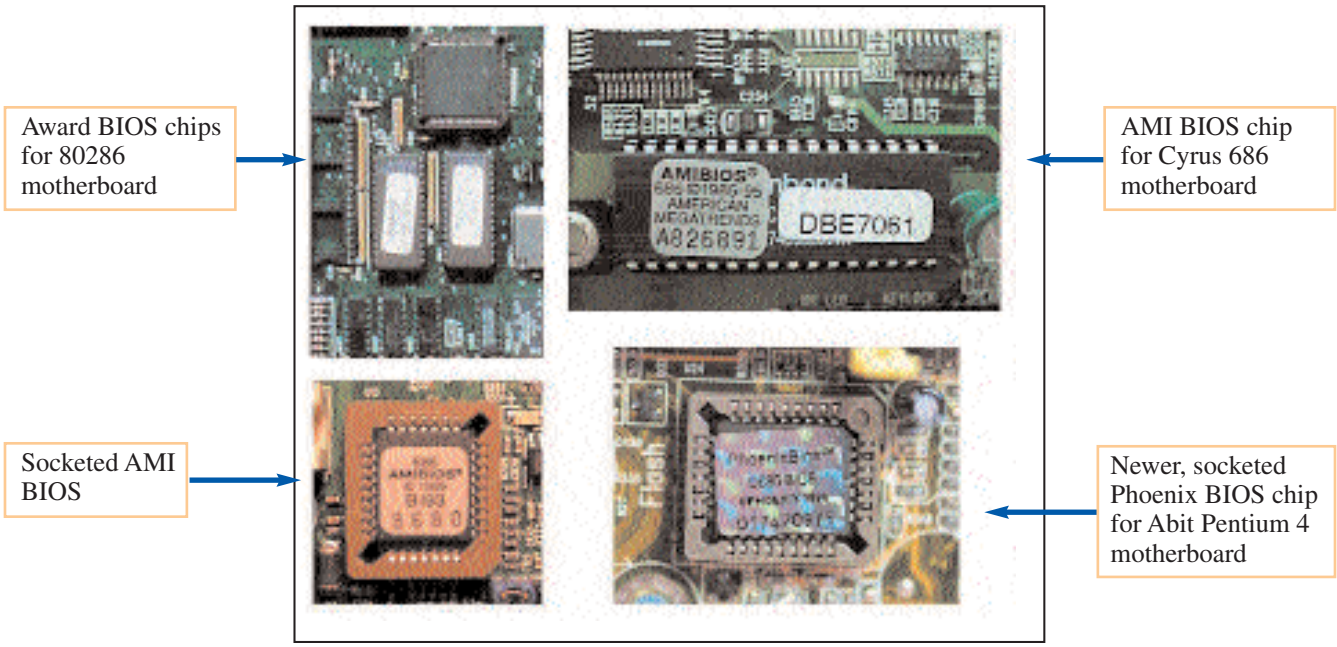
ROM stores data in memory chips soldered to or socketed on the motherboard. ROM data is permanently or semi-permanently recorded in the chip media and not affected by turning the computer off. A standard ROM chip is a collection of binary circuits encoded in silicon, prewired to be open or closed. The programming logic contained in these prewired circuits provides specific instructions to the CPU or other hardware devices that cannot be changed.

The ROM BIOS (Basic Input/Output System) is a ROM chip that contains instructions necessary to start a computer system. The instructions on ROM BIOS chips are burned into the chip at the factory. BIOS chips for older motherboards typically contained from 32 to 64 kilobytes of instructions. This BIOS was often distributed in pairs of socketed rectangular 32 KB chips that could be plugged into the motherboard and replaced when the manufacturer issued an upgrade. In Pentium motherboards, these gave way to single 64 KB socketed chips and eventually to tiny square chips, some containing as much as 2 MB of instruction code, socketed or soldered to the motherboard **(Figure 3-1)**. On contemporary motherboards, the BIOS is usually a Flash ROM chip that is upgraded electronically, rather than physically replaced. There are two kinds of ROM chips that can be reprogrammed electronically:

- **Electronically Programmable ROM (EPROM):** These chips can be reprogrammed through the use of a third-party electronic device that shines ultraviolet light through a glass window located on the top of the chip. This erases the chip and allows it to be reprogrammed.
- **Electrically Erasable Programmable ROM (EEPROM):** Also called Flash Memory, these chips can be reprogrammed through software that runs under a supported operating system. EEPROMs are erased by instructions that apply voltage to one of the pins. This technique is used to update Flash BIOS.

RAM stores data in memory chips that are usually removable and replaceable. In contemporary PCs, these chips are mounted on RAM modules inserted into dedicated slots on the motherboard. Some motherboards, particularly those in laptop systems, contain a certain amount of base RAM that cannot be removed or upgraded. RAM data is retained only as long as the computer is switched on. Once the computer is rebooted or shut down, the information stored in RAM disappears. You will learn more about RAM in the next skill.

Figure 3-1 System BIOS chips



skill 2 Learning about RAM

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

Random access memory (RAM) can be divided into two basic types, **dynamic RAM** (**DRAM**) and **static RAM** (**SRAM**). DRAM chips retain binary information with an electrical charge that dissipates after a few milliseconds (thousandths of a second, usually abbreviated as ms). Each DRAM chip is comprised of transistor memory cells that must be periodically recharged (or refreshed) by capacitors on the motherboard. In older PCs, the CPU regulated the refresh process. Modern motherboards include a separate refresh circuit handled by the memory controller chip in the system chipset.

More expensive SRAM chips hold data without requiring an electronic circuit that constantly refreshes the content. SRAM chips receive and transmit information at a faster rate than DRAM chips because they do not need to refresh their current state.

Static RAM is used for the fast L1, L2, and L3 memory caches that you learned about in Lesson 2. Recall that these caches improve system performance by forming a bridge between slower primary memory and the CPU. SRAM comes in two different types: more expensive **synchronous SRAM** and less expensive **asynchronous SRAM**. Synchronous SRAM runs in step with the CPU. A clock chip on the motherboard matches (or synchronizes) read and write cycles of a synchronous SRAM memory cache with the CPU. There are two types of synchronous RAM: burst and pipelined.

- **Burst SRAM** is the most expensive type of synchronous SRAM. It transmits binary data in two steps: first the chip sends the memory address of the data and then it transmits the actual content.
- **Pipelined burst SRAM** is a widely used, more economical type of synchronous SRAM. This type of cache memory uses overlapping address and data cycles that reduce the need for highest-speed access times. Pipelined burst SRAM requires more system clock cycles than standard burst SRAM to transfer the same amount of binary data to the CPU.

Asynchronous SRAM is the least expensive type of cache memory. It is slower than synchronous SRAM and does not need to have its read and write cycles synchronized with the CPU.

Video adapters use their own, customized RAM (VRAM and WRAM), which is different from the RAM types used for cache memory or main system memory. See Lesson 11 for more information about Video RAM.

Dynamic RAM (DRAM) chips are used for main memory storage. They hold operating system and application program code, plus user data read from disk or entered with the mouse and keyboard. DRAM chips are made in a number of different form factors. Dual Inline Pin Packages (DIPPs) were the design used on the original IBM PC and PC AT. DIPPs are individual, rectangular chips that plug into rows of sockets on the motherboard **(Figure 3-2)**. To make 1024 KB of RAM, the motherboard used an array of eight rows (because there are 8 bits in a byte) by 4 columns of 256-kilobit chips.

By the time of later 80286 motherboards, DRAM chips were mounted on boards, called "sticks." The original memory sticks were called **Single Inline Pin Packages** (**SIPPs**). Each stick had 30 pins that plugged into a corresponding 30-pin motherboard socket **(Figure 3-3)**.

RAM sockets or slots on a motherboard are arranged in groups called **memory banks**. When possible, the memory modules within a bank should be from the same manufacturer, with the same rated performance speed. SIPP modules are 8 bits wide. Therefore, on motherboards

tip

When installing RAM on a motherboard, each socket or slot in a bank must be filled before inserting RAM modules into the next bank.

Figure 3-2 Classic DRAM

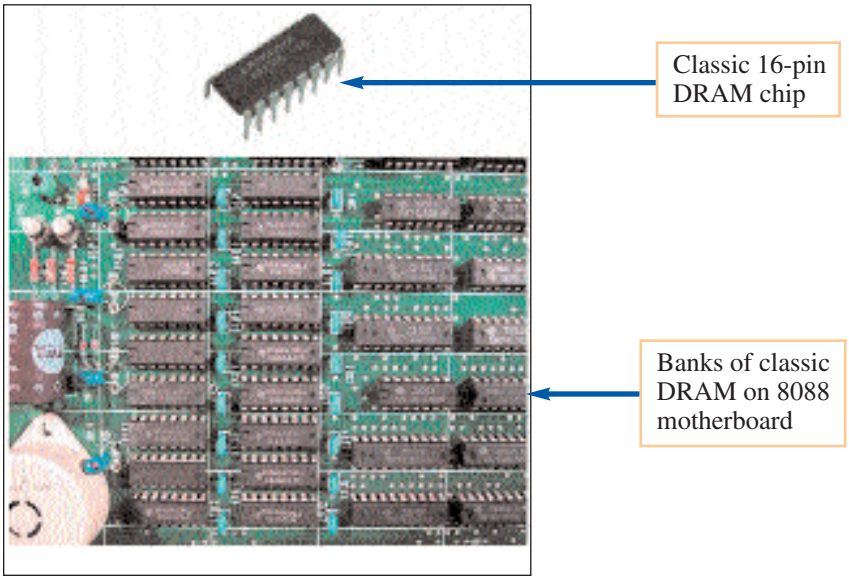
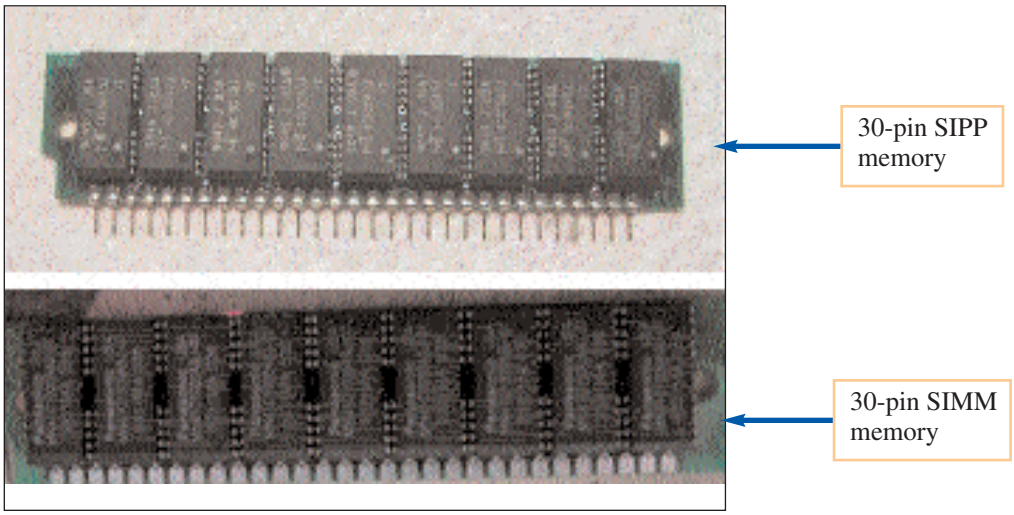


Figure 3-3 30-pin SIPP and SIMM memory sticks



skill 2 Learning about RAM (cont'd)

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

with a 16-bit external data bus, one SIPP memory bank consists of two RAM sockets (supporting 80286 and 80386SX CPUs). If the motherboard uses a 32-bit external data bus (80386DX, 80486DX, 80486DX/2, 80486DX/4 CPUs), then four RAM sockets are used for each bank of 8-bit, 30-pin SIPPs.

Because the pins on SIPP RAM chips could be easily bent or broken, memory vendors modified the package design to create **Single Inline Memory Module (SIMM)** sticks. The pins at the bottom of the SIPP memory stick were replaced by metal contacts (refer to **Figure 3-3**). A 30-pin SIMM stick slides into a memory slot on the motherboard in the same way that adapter cards slide into peripheral slots. The 30-pin SIMM design permitted each memory stick to contain from 256 KB to 4 MB of DRAM. As with SIPPS, 30-pin SIMMS modules have an 8-bit data width. One bank of 30-pin SIMMs uses two physical RAM slots if the motherboard uses a CPU with a 16-bit external data bus, and four RAM slots if the motherboard uses a CPU with a 32-bit external data bus.

tip

Although SIMMs memory sticks have contacts instead of pins; they are still commonly referred to as "*xx-pin*" modules (30-pin, 72-pin), rather than "*xx-contact*" modules. We will follow that convention in this book.

Observe in Figure 3-3 that the SIPP and SIMM memory sticks each contain nine DRAM chips, mounted on only one side of the stick. Eight of the chips on the stick cooperate. Each chip contributes one bit to each byte in the total system RAM. The ninth chip on each stick provides an extra bit called a **parity bit** to each byte. Parity bits do not store user data or program code. Instead, they are used for an error checking process that you will learn more about later in this lesson.

The 72-pin SIMM appeared with the arrival of Pentium and AMD K5 CPUs. The SIMM package design was changed to accommodate the 64-bit external data bus width of the new fifth generation CPUs. (Refer to **Table 2-4** in Lesson 2.) Using 72 contacts instead of 30 increased the amount of RAM that each SIMM stick could house. A 72-pin SIMM is 32-bits wide and each stick holds from 8 MB to 64 MB of RAM. Because the external data bus width of a Pentium motherboard is 64 bits, the motherboard uses two 32-bit RAM slots per memory bank. The SIMM sticks must be installed in a bank in pairs of the same RAM size, type, and speed **(Figure 3-4)**. The 72-pin SIMM is shipped in both single-sided designs (chips on only one side of the stick) and double-sided designs (chips on both sides of the stick). Some double-sided SIMMs really consist of two single-sided modules wired together.

A **Dual Inline Memory Module** (**DIMM**) is a newer memory package technology that places a larger number of contacts on each memory stick. DIMMs used on fifth and sixth generation motherboards have a 168-pin form factor. Variant DIMM form factors include 72-, 100-, and 144-pin Small Outline Dual Inline Memory Modules (SODIMMs) used in laptop computers and printers—and even smaller 144-pin MicroDIMMs used in sub-notebook laptops **(Figure 3-5)**. DIMMs are available in 8, 16, 32, 64, 128, 256, and 512 MB memory sizes. One advantage of the DIMM form factor is that each DIMM memory stick is 64 bits wide. Consequently, a DIMM memory bank on a motherboard consists of only one slot. If a motherboard has two DIMM slots, it can run with one slot empty, or both slots can be occupied with DIMM modules that have different RAM sizes.

The memory-stick form factors we have described up to this point are now considered to be **legacy technologies**. DIPP, SIPP, SIMM, and 168-pin DIMM memory sticks are not used on contemporary motherboards. Legacy RAM in 72-pin SIMM and 168-pin DIMM form factors is still sold by some vendors to support older computers.

Figure 3-4 72-pin SIMMs and empty 184-pin DIMM slot

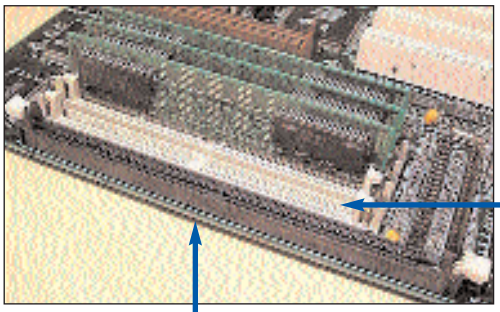
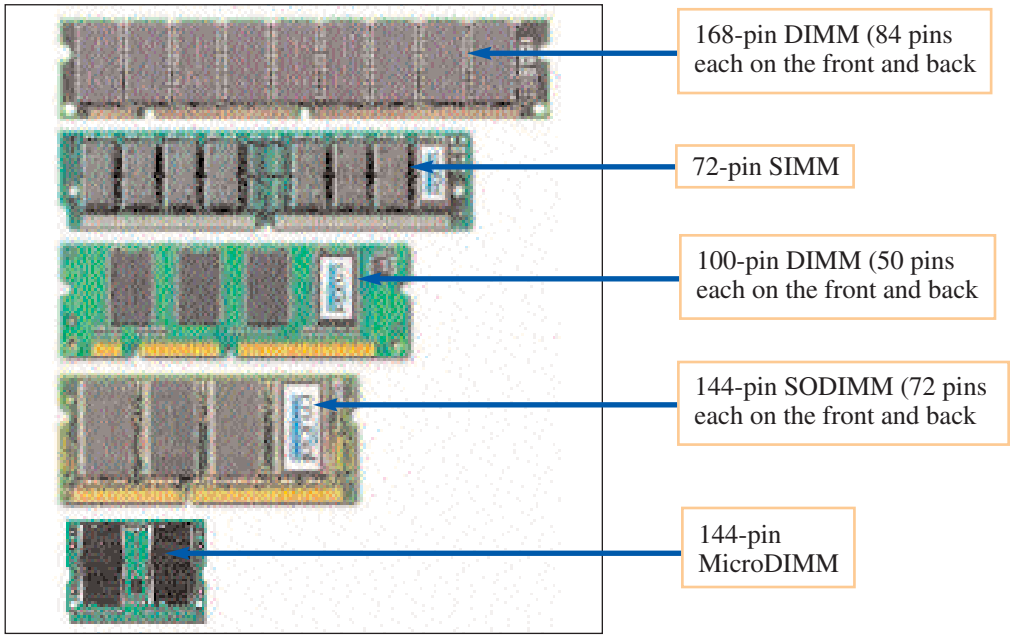


Figure 3-5 SIMM modules, DIMM, SODIMM, and MicroDIMM RAM modules



skill 2

Learning about RAM (cont'd)

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

Most modern desktop and laptop PCs use RAM sticks with one of the following form factors:

- **Double Data Rate Synchronous DRAM (DDR-SDRAM):** A 184-pin version of the DIMM package. It is used on modern motherboards that require a front side bus speed greater than 133 MHz.
- **Rambus Inline Memory Modules (RIMMs):** A 184-pin package design created by Rambus for its proprietary high-speed Rambus DRAM technology.

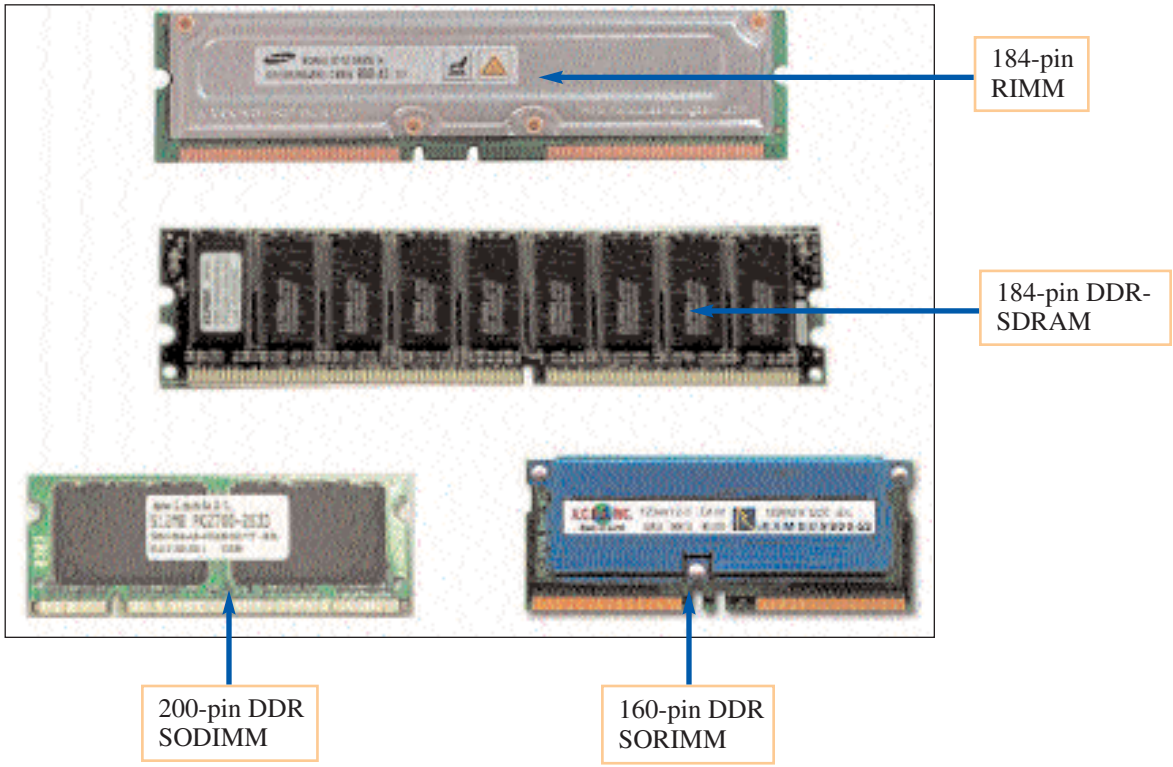
200-pin DDR SODIMM and 160-pin Small Outline RIMM (SORIMM) are variants of these packages used in recent Celeron and Pentium 4 laptop PCs **(Figure 3-6)**.

Here are some suggestions for identifying the difference between SIMM, DIMM, DDR-SDRAM, and RIMM memory sticks:

- 30-pin SIMMs are about the same size as 72-pin SIMMs, but they have a noticeably smaller number of metal contacts arranged in a single cluster.
- 72-pin SIMMs are smaller than 168-pin DIMMs. They have two clusters of metal contacts on the bottom, whereas the DIMMs use three clusters of contacts.
- 184-pin DDR-SDRAM sticks are about the same size as 168-pin DIMMs, but they have only two clusters of metal contacts at the bottom, not three.
- RIMMs (and SORIMMS) house the chips on the memory stick within a protective metal or plastic shield.

In this skill, you have learned about the two basic types of RAM (SRAM and DRAM), and how to match DRAM memory packages with corresponding RAM sockets and RAM slots on a motherboard. In the next skill, you will learn about the different performance technologies used in the RAM chips that populate these packages.

Figure 3-6 RIMM, DDR-SDRAM, DDR SODIMM, and SORIMM



skill 3 Identifying Types of RAM Technology

A+ Hardware objective

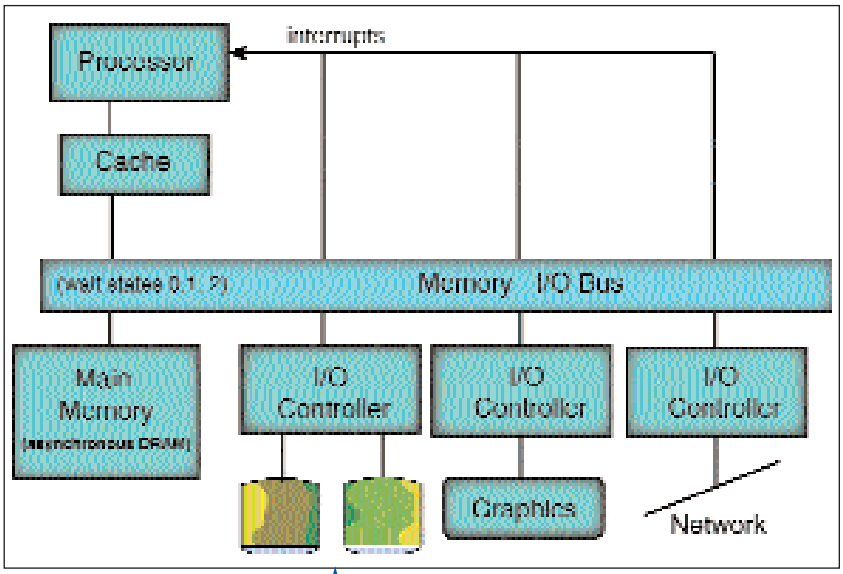
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

The form factors for dynamic RAM that we have discussed (DIPP, SIPP, SIMM, DIMM, DDR-SDRAM, and RIMM) have been used to contain a number of different memory chip technologies. With each new generation of CPUs and motherboards, PC system designers have created new DRAM chip technologies, each delivering faster, more reliable performance than its predecessors.

- **Conventional DRAM** was the early memory technology used with DIPP and SIPP memory modules on 8088, 80286, and 80386 motherboards. This type of DRAM is now obsolete.
- **Fast Page Mode (FPM) DRAM** first appeared on 30-pin SIMMs designed to work with 80486 CPUs. Slightly faster than conventional DRAM, FPM eliminated the requirement to specify the motherboard row and column locations of memory chips for each access. With FPM memory, the row address is sent just once for multiple accesses to memory chips in the same row. Despite its name, FPM memory is the slowest type designed for SIMM and DIMM form factors. 72-pin SIMMs and 168-pin DIMMs with FPM memory were used on 80486 and Pentium motherboards with clock speeds ranging from 16 MHz to 66 MHz.
- **Extended Data Output (EDO) DRAM** was developed for motherboards with clock speeds of 33 MHz to 66 MHz. Used on 72-pin SIMMs, 168-pin DIMMs, and 72/144-pin SODIMMs, EDO RAM needs to be refreshed less frequently than FPM RAM and delivers slightly faster performance. EDO memory must have support from the system chipset on the motherboard. It was largely replaced by SDRAM in the late 1990s, but because it was used so widely, EDO DRAM is still sold and found on some systems with older motherboards.
- **Burst EDO (BEDO) DRAM** was a refinement on EDO DRAM that allowed larger blocks of data to be read during a clock cycle. BEDO DRAM is faster than EDO DRAM, but still limited to a top system bus speed of 66 MHz. BEDO DRAM technology was not widely used, because Intel did not support it in their motherboards and chipsets.
- **Synchronous Dynamic RAM (SDRAM)** was the popular successor to EDO RAM. Used on 168-pin DIMMs and 72/144-pin SODIMMs, SDRAM runs at the same speed as the system clock. SDRAM is faster and more efficient than older, asynchronous types of DRAM. When memory chips are asynchronous, the CPU must wait during each memory refresh interval before it can pass new data to RAM. Motherboard chipsets accommodate this by including a pause in the system clock cycle called a **wait state**. SDRAM eliminated the requirement for wait states that slowed down earlier DRAM technologies **(Figure 3-7)**. The original design specification for SDRAM supported system clock speeds above 66 MHz; however, early SDRAM delivered erratic performance on 100 MHz motherboards. To insure acceptable performance, Intel created a series of memory standards: **PC66** (for a 66 MHz system bus), **PC100** (for a 100 MHz system bus), and **PC133** (for a 133 MHz system bus). Skill 4 in this lesson provides more details about speed considerations in matching RAM chips and motherboards.
- **Double Data Rate SDRAM (DDR-SDRAM)**, sometimes called SDRAM II, is an improved type of SDRAM, widely used on current motherboards. DDR-SDRAM requires a 184-pin memory slot with two clusters of contacts. DDR-SDRAM is synchronized with the system clock and transmits data to the CPU (through the L2 memory cache) twice during each clock cycle. This doubles the data transmission speed: A motherboard with a front side bus speed of 100 MHz uses 200 MHz DDR-SDRAM. The dual write cycle and fast performance speed of DDR-SDRAM allows it to operate on more recent motherboards with front side bus speeds of 200 MHz to 400 MHz. You may see

Figure 3-7 System bus and wait states



The memory controller on this motherboard can be configured to introduce 0, 1, or 2 wait states between main memory and the L2 cache

skill 3

Identifying Types of RAM Technology (cont'd)

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

the term "Dual Channel DDR" in advertisements for newer computer systems. This refers to the motherboard having two separate memory buses for the CPU, rather than to a change in DDR RAM technology.

more

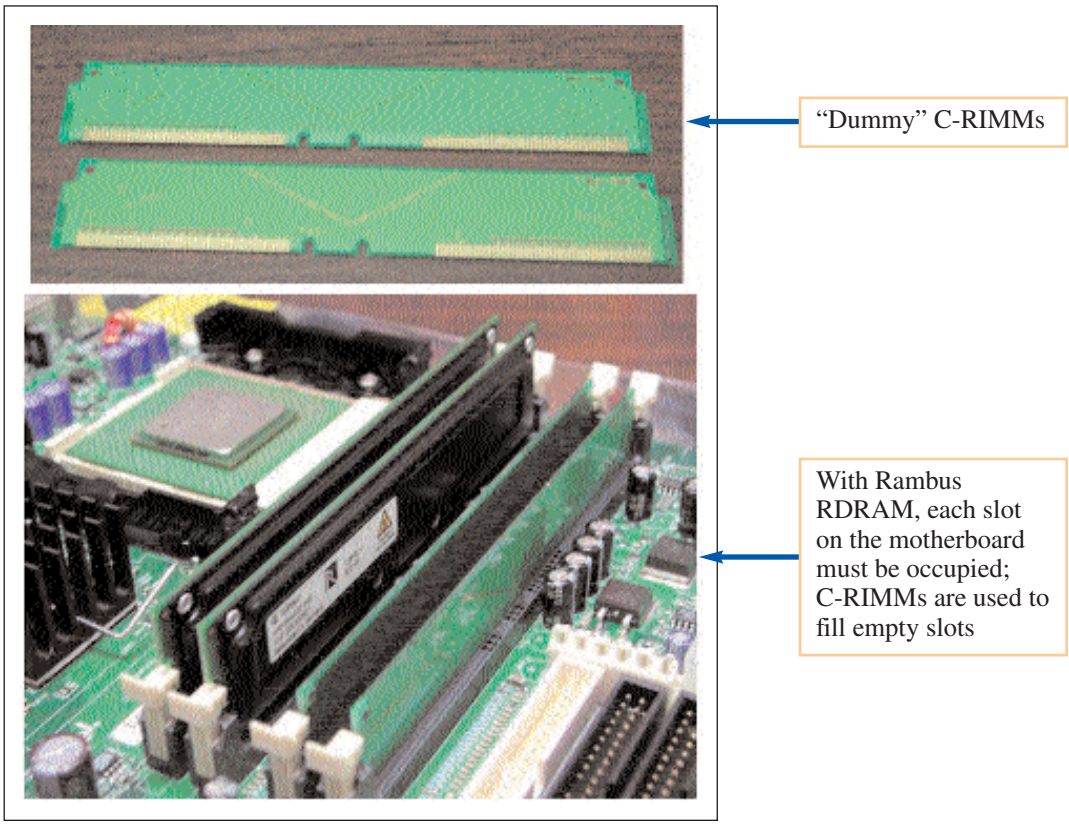
Synchronous Link DRAM (SLDRAM) is an obsolete memory technology that was developed as competition to standard SDRAM. It increased the number of memory banks a motherboard could access in one clock cycle from 4 to 16.

Rambus DRAM (RDRAM), sometimes called Direct Rambus DRAM or Direct RDRAM, was developed by Rambus, Inc. as competition for SDRAM. RDRAM uses very high-speed memory chips (400 MHz to 1066 MHz) and a customized memory bus on the motherboard instead of the standard system bus. Recall from Lesson 2 that the front side bus uses a clock multiplier chip when it connects to the CPU (or to the L2 cache for more recent processors). Rambus DRAM uses additional clock multiplier chips to speed up the connection between system memory and the front side bus.

Because of a partnership that Intel formed with Rambus, Inc., a number of Pentium III and early Pentium 4 motherboards supported RDRAM as the only type of memory that could be installed. After 2001, the increasing popularity of DDR-SDRAM on motherboards designed for AMD Athlon CPUs caused Intel to revise its policy. DDR-SDRAM has largely replaced Rambus RDRAM on current motherboards. It should be noted that RDRAM can be faster than DDR-SDRAM, but it is also significantly more expensive. There have been several cycles of development for the Rambus DRAM, technology: Concurrent RDRAM, an early version, was replaced by a later version known as Direct Rambus DRAM (Direct RDRAM). One significant difference between Direct RDRAM and DDR-SDRAM is that Direct RDRAM has a narrower 16-bit data width on each RIMM instead of the standard DIMM 64-bit width. The performance of RDRAM relies upon the high clock frequency of the memory modules, and on the inclusion of multiple memory buses (as many as 4 or 8 between RAM and the CPU).

Another significant difference in using RDRAM on RIMM memory sticks is that all of the RIMM sockets on the motherboard must be filled to provide a continuous circuit for the memory to work. If there are more RIMM sockets on the motherboard than memory sticks, the extra sockets must be filled with special "dummy" modules called **Continuity-RIMMs (C-RIMMs) (Figure 3-8)**. The C-RIMMs do not contain memory chips; they are placed in sockets simply to preserve the continuity of the electrical circuit on the system bus.

Figure 3-8 **SRDRAM and C-RIMMs in their memory sockets**



skill 4 Evaluating and Rating Memory

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

The maximum speed of system RAM is defined by the system bus width and system bus speed of the motherboard. Recall that the system bus width is the number of data bits that can be transferred from RAM to the CPU during one clock cycle. Bus speed is the number of clock cycles that occur within 1 second of time. So, in theory, a 100 MHz, 64-bit system bus can send 8 bytes (64 divided by 8) of data to the CPU 100 million times during 1 second. This is a data transfer rate of roughly 800 MB per second.

The memory controller on a motherboard is part of the system chipset and responsible for regulating the performance of system RAM. It determines how much RAM can be installed on the motherboard and how fast data is transferred to and from RAM.

Recall that older conventional DRAM, 30-pin SIPPs, and 30-pin SIMMs are 8 bits wide. For a CPU with a 16-bit external data bus (such as an 80386SX), the memory controller requests information from two 8-bit memory modules during each clock cycle. A memory controller on a 32-bit 80486DX motherboard requests data simultaneously from four 8-bit memory modules.

Recall from Lesson 2 that modern 32-bit Intel Pentium and AMD Athlon CPUs use a 64-bit external data bus. This means that the memory controller passes data from RAM to the CPU in 64-bit blocks. Because 72-pin SIMMs modules are 32 bits wide, the memory controller requests information from two SIMMs modules at a time during each clock cycle.

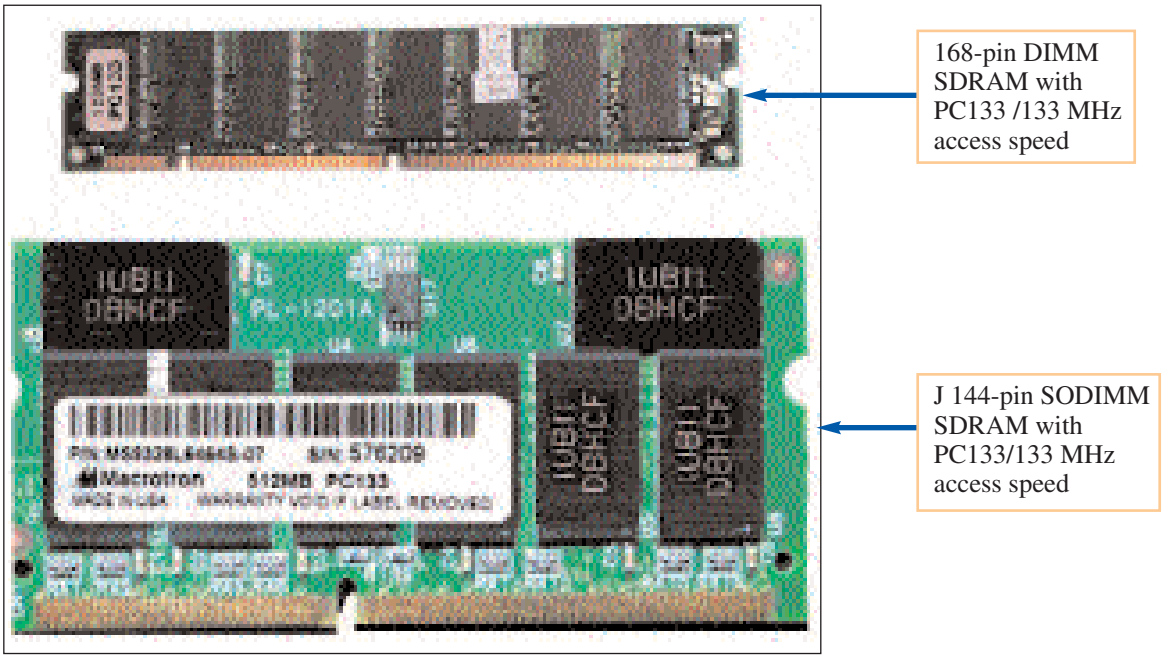
On a motherboard with 168-pin or 184-pin DIMMs, each memory stick is 64 bits wide and therefore the memory controller requests data from one DIMM module at a time. 184-pin RIMMs are an exception to this rule. They transfer information to the CPU only 16 bits at a time. Direct RDRAM compensates for this narrower bus width by operating at higher clock frequencies—2 to 4 times as fast as other DRAM technologies.

The performance speed of asynchronous DRAM is rated by access time measured in nanoseconds (millionths of a second, abbreviated as ns). The rated speed of an asynchronous DRAM module is the minimum number of nanoseconds required for one data refresh cycle or read/write operation to take place. The cycle is measured from the start of electronic access until the data reaches the CPU. Note that this is the speed of the DRAM module itself, not necessarily equivalent to the overall performance speed of all memory in the system. Synchronous DRAM access time is generally rated by internal clock speed (frequency) of the memory chips, measured in megahertz (MHz).

The access speed, in nanoseconds, of an asynchronous DRAM module may be found on a label for the memory stick; or it may be stamped on each chip in the module. The manufacturer name or serial number usually appears followed by a dash and a number, such as 5, 6, or 7, representing a speed of 50, 60, or 70ns **(Figure 3-9)**. For synchronous DRAM, the rated speed appears on the label as PC100 or PC133, representing a rated clock speed of 100 MHz or 133 MHz **(Figure 3-10)**.

Figure 3-9 Reading asynchronous SIMM memory chip labels

Figure 3-10 Reading synchronous DRAM memory chip labels



skill 4

Evaluating and Rating Memory (cont'd)

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

Table 3-1 shows you that conventional DRAM typically had rated access times of 80 to 150ns. FPM RAM was faster, and EDO/BEDO RAM was faster, still, with access times of 50 to 60ns. The 70 and 80ns chips were generally considered acceptable for motherboards running with a system bus speed of 60 MHz. Older Pentium systems running with a 66 MHz system bus required chips rated at 60 or 70ns. EDO RAM was considered ideal for these systems. A number of memory vendors apply conservative ratings to their DRAM. The memory chips often function under faster CMOS access settings than advertised. Many 66 MHz Pentium systems work properly with 70ns EDO RAM. However, you cannot rely on this capability with all DRAM vendors. Synchronous DRAM is significantly faster than asynchronous RAM, with access times measured at 6 to 10ns. However, Synchronous DRAM is usually rated by clock frequency, (matching the system clock speed), rather than by measuring access time in nanoseconds. 66 MHz SDRAM is suitable for use on a 66 MHz front side bus, 100 MHz SDRAM is used with a 100 MHz front side bus, 133 MHz SDRAM with a 133 MHz front side bus.

Early SDRAM had timing issues with 100 MHz and 133 MHz front side bus speeds. Intel responded by creating a series of performance standards that SDRAM must pass. PC66, PC100, and PC133 are the memory standards created by Intel that SDRAM must meet to be certified for use with each front side bus speed. Review **Figure 3-10**.

DDR-SDRAM modules are rated in several ways. One rating scheme uses the peak transfer rate of the module-the maximum amount of data that can be transferred in one second. A DDR-SDRAM module rated as PC2100 can deliver 2100 megabits of data in one second, PC2700 can transfer 2700 mbps. PCxxxx ratings for DDR-SDRAM can easily be converted to clock speed ratings—just divide the peak transfer rate by 8. A PC1600 RAM module has a clock speed of 1600/8 mbps or 200 MHz. A PC2700 RAM module has a clock speed of 2700/8 MHz, which is actually equal to 337.5, but labeled 333 MHz. Memory vendors may use either or both rating systems on labels for DDR-SDRAM (**Figure 3-11**).

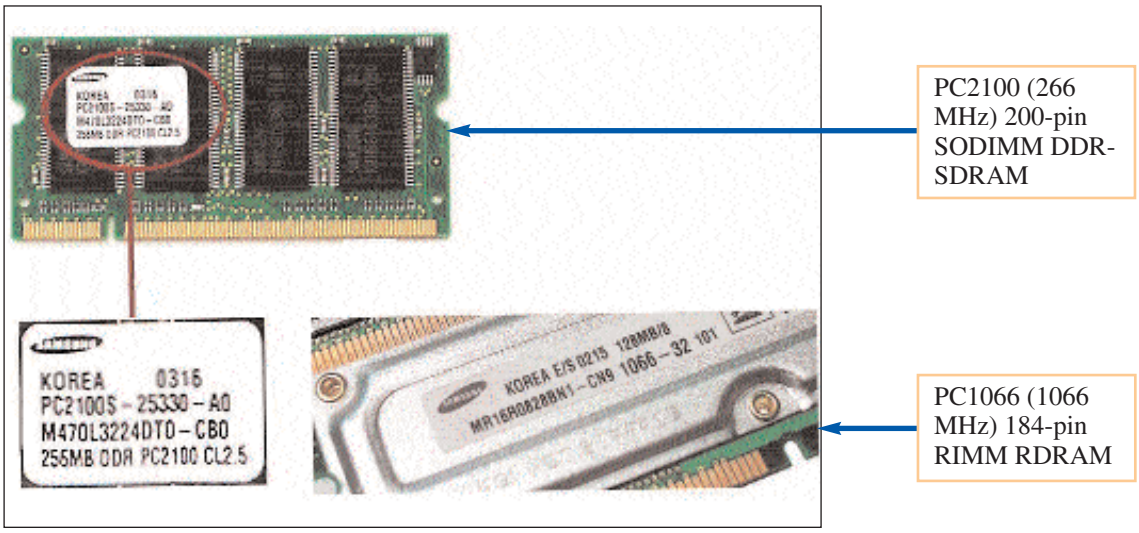
In practice, RAM does not always operate at the maximum speed of the system bus. The internal chip speed that we have discussed is regulated by the memory controller on the motherboard. The memory controller can limit DRAM performance speed to avoid hardware timing errors. The access speed ratings of memory chips represent the maximum speed the chips are capable of reaching. Column Access Strobe Latency, or **CAS Latency** (also referred to as CL) is another factor that affects memory performance. CAS Latency in nanoseconds or clock cycles) reflects the delay between reception of a read request from the memory controller and the time when RAM begins to respond with data output. The latency of asynchronous DRAM is set in CMOS by the memory controller and measured in nanoseconds. SDRAM has a built-in CAS Latency measured in clock cycles.

To make matters a bit confusing, Rambus DRAM performance speed is rated by clock frequency, but listed as PC600, PC700, PC800, or PC1066. PC800 RDRAM operates at an internal clock speed of 800 MHz, and transfers 16 bits (2 bytes) of information during each clock cycle. So the data transfer rate of PC800 RDRAM in mbps is 1600.

Table 3-1 DRAM Performance Statistics

Memory Technology	Typical System Speeds	Package	Chip Data Width Bus	Usual DRAM Speed (ns)	Usual DRAM Frequency (MHz)
Conventional	4.77–12	DIPP30-pin SIPP, 30-pin SIMM	8-bits	80–150	N/A
FPM	16–66	30-pin SIMM, 72-pin SIMM, 168-pin DIMM	32-bit 32-bit 64-bit	60–80	N/A
EDO	33–75	72-pin SIMM, 168-pin DIMM	32-bit 64-bit	50–60	N/A
BEDO	60–100	72-pin SIMM, 168-pin DIMM	32-bit 64-bit	50–60	N/A
SDRAM	60–100+	168-pin DIMM, 144-pin SODIMM	64-bit	6–12	66–150
DDR-SDRAM	200–400	184-pin DIMM, 200-pin SODIMM	64-bit	< 6	200–400
RDRAM	200–1066	184-pin RIMM, SORIMM	16-bit	< 6	800–1066

Figure 3-11 Reading DDR-SDRAM and RDRAM memory labels



skill 5

Understanding Memory Parity and Error Correction

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

Because PC memory is an electronic storage device, it is subject to the same kinds of errors that can occur in other electronic devices. Remember that DRAM stores the 1s and 0s that comprise binary data on small transistors that must constantly be recharged to preserve the information. A momentary fluctuation of voltage in a circuit can be sufficient to change a 1 to a 0 and corrupt the data being stored in memory.

Two kinds of errors can occur during memory reads. A **hard error** is one that occurs again and again, and typically indicates damaged hardware in the computer. A **soft error** is a misread that occurs only once, or intermittently. A DRAM chip can register a 1 instead of a 0 during one cycle, but correct itself during the next cycle. Soft errors are sometimes caused by bad memory chips, but they are often the result of incorrect timing settings in the CMOS or the temporary presence of static electricity.

Two technologies are commonly used in PC memory to detect or correct memory read/write errors: **parity checking** and **Error Correcting Code (ECC)**.

Parity checking is a system that detects 1-bit memory errors but does not correct them. Recall from Skill 2 in this lesson that memory modules can be designed to support either 8 or 9 bits per byte. **Parity memory** provides an extra ninth bit in each byte to check the accuracy of memory read and write operations. **Non-parity memory** does not include the ninth, error-checking bit. You can usually determine whether a memory module is parity or non-parity by counting the number of chips on it and dividing by 3. If the number of chips is divisible by three, the module is parity memory; otherwise, it is non-parity memory.

With parity memory, the PC records how many bits in each byte have a binary value of 1 and how many have a binary value of 0. This information is recorded each time a memory write operation takes place.

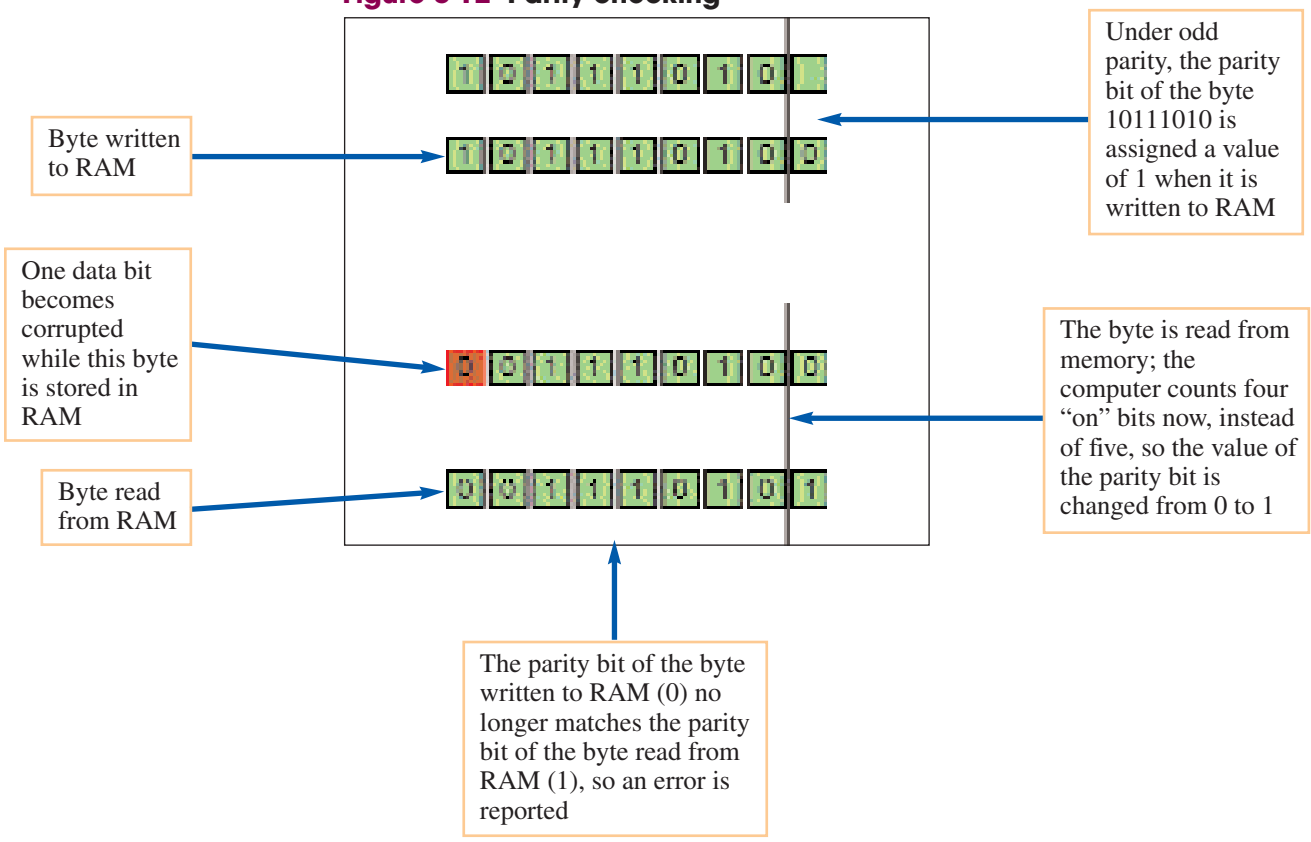
- Under odd parity, the parity bit insures that the number of "on" bits (1s) in each byte is odd. If the number of "on" bits in the 8 data bits is an even number, the parity bit is given a value of 1. If the number of "on" data bits is already odd, the parity bit is assigned a value of 0.
- Under even parity, the memory controller uses the parity bit to make the number of "on" bits in each byte an even number.

Later, when memory read operations take place, the memory controller checks the odd or even state of each byte, comparing it to the byte that was written to the same location. **Figure 3-12** shows how parity checking works: A byte with the content 10111010 is written to RAM. This byte has a total of five bits in the "on" position. Under odd parity, the ninth (parity) bit for this byte is assigned a value 0, because the number of "on" bits is already odd. In the figure, the first bit of this data-byte becomes corrupted while it is being stored in RAM. When the byte is read from memory, it has only four 1's instead of five. Consequently, the value of the parity bit is changed from 0 to 1, and the memory controller knows that it is not the same byte that was originally written to RAM.

The problem with parity checking as a data integrity safeguard is that it can discover only 1-bit errors in memory.

These errors are reported, but not corrected. Newer memory modules make use of an alternate technology called Error Correcting Code (ECC). ECC memory can detect multiple-bit memory errors and correct single-bit errors. ECC memory is supported on both SIMM and DIMM memory sticks, and is most commonly found on SDRAM and DDR-SDRAM modules. As with parity memory, the number of individual chips on an ECC module will usually be divisible by 3.

Figure 3-12 Parity checking



skill 5

Understanding Memory Parity and Error Correction (cont'd)

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

ECC memory applies several extra bits for error checking, instead of one. What happens when errors are found depends upon the design of the motherboard. Modern systems that use ECC automatically correct single-bit memory errors—which account for most of the errors that commonly occur in RAM read/write operations. Some motherboards can use ECC to correct multi-bit errors and exclude RAM modules that constantly report problems.

Non-parity and non-ECC memory chips are less expensive to manufacture; and a large number of computers on the market today are sold without either built-in error detection system. ECC memory is most commonly used on server systems, where data integrity is critical. Parity or ECC memory must be supported by the motherboard to work properly. Some motherboards support standard 8-bit memory or error-checking memory; but many motherboards support only one type of RAM. Systems that support error checking usually include a CMOS setting to switch it on or off (**Figure 3-13**).

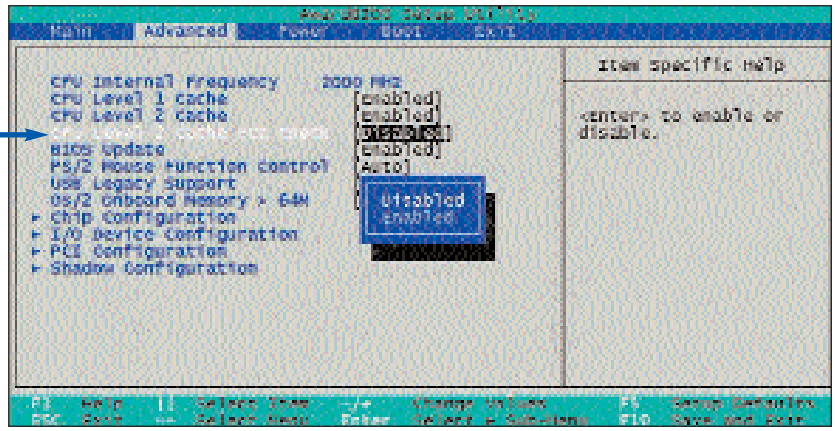
On systems that support both standard and error checking RAM, using both types at once is generally not the best practice. Combining parity and non-parity memory can cause the system to report parity errors at startup. The best procedure is to use identical modules within a bank.

caution

The ability to turn ECC checking on or off does not mean that a system will support standard 8-bit DRAM. Check your system documentation if you are in doubt about what memory types are supported.

Figure 3-13 Enabling or disabling ECC check in system BIOS

In this BIOS, support for ECC memory can be enabled or disabled by highlighting the "CPU Level 2 Cache ECC Check" option and pressing [Enter]



skill 6

Understanding an Advertisement for Computer Memory

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

Some memory vendors simplify your shopping job by organizing their products into categorized links. Others may provide a database where you can look up a particular computer system by manufacturer and model number **(Figure 3-14)**.

Table 3-2 is a facsimile of a typical memory advertisement that you might encounter on a vendor Web site or sales sheet. Memory modules are grouped by the form factor of the memory stick. Within each section, a number of different memory types and speeds may be available.

In the 72-pin SIMMs section of this ad, the modules are listed by memory technology (FPM and EDO). The section does not tell you directly how much RAM is contained on each module. Density, when given, is specified as two numbers in an A x B format. A density of 4x32 is read as "4 by 32."

The first number (4) specifies the memory depth of the module in MB. The second number (32) specifies the data bus width. (You already know that a 72-pin SIMM module has a data bus width of 32 bits.)

Some memory ads will tell you the total amount of RAM on a module as well as listing its density. Other ads expect you to figure out how much RAM is on the module from the density listing. The first entry in Table 3-2 shows that a 72-pin SIMM FPM memory module with an access speed of 60 nanoseconds and a density of 4x32 sells for $19.99.

To calculate the amount of RAM on a module from its density, divide the data-bit width (second number) by 8 and multiply this by the memory depth (first number).

- A 4x32 SIMM module has 4 MB x 32/8 or 16 MB of RAM.
- A 16x32 SIMM module has 16 MB x 32/8 or 64 MB of RAM.

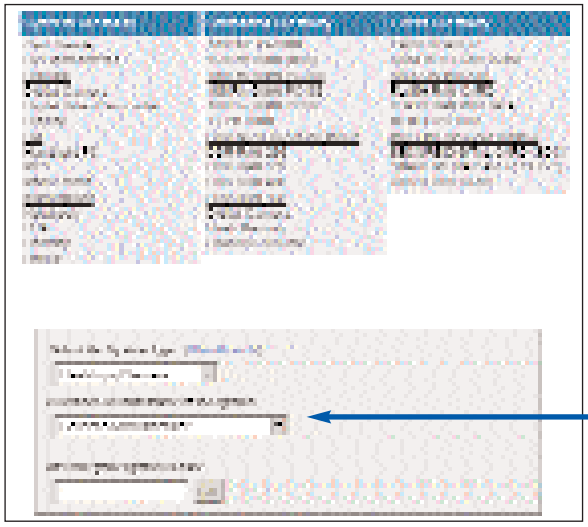
Some early SIMM modules included chips with a memory depth of less than 1 MB. The .25 or .5 MB depth of these chips was listed as "256" or "512," standing for KB instead of MB. A SIMM with a listed density of 256x32 actually contains .25 MB (256 KB) x 32/8 or 1 MB of RAM.

You may notice, further down in the table, that some memory modules are listed with densities of 16x36 or 16x72. Modules listed with a 36-bit or 72-bit bus width are parity or ECC RAM modules. The bus width includes the extra bits required for error checking. If a module is listed with a bus width of 32 or 64, you know that it is standard, non-error checking DRAM.

To determine how much RAM is contained on a parity or ECC DRAM module, you must round the bit width down to the data-bus width (32 or 64) before dividing by 8 and multiplying by the memory depth.

- An FPM SIMM with a density of 16x36 contains 16 MB x 32/8 or 64 MB of RAM. (The 36-bit bus width is rounded to a 32-bit data bus width.)
- A DIMM ECC SDRAM module with a density of 16x72 contains 16 MB x 64/8 or 128 MB. (The 72-bit bus width is rounded to a 64-bit data bus width.)
- A DIMM ECC SDRAM module with a density of 32x72 contains 32 MB x 64/8 or 256 MB.

Figure 3-14 Memory vendor online forms



This Web site form allows you to search for the type of memory used in a particular PC by manufacturer or model number

Table 3-2 PC Memory

72-PIN SIMM-FPM			
4x32-60	$19.99		
8x32-60	$28.99		
16x32-60	$40.99		
16x36-60	$115.99		
72-PIN SIMM-EDO			
4x32-60	$19.99		
8x32-60	$27.99		
16x32-60	$45.99		
32x32-60	$128.99		
144-Pin SODIMM			
32 MB	EDO	SODIMM	$22.99
64 MB	EDO	SODIMM	$45.99
168-Pin DIMMs			
64 MB	60ns	EDO 8x64, 3.3V	$59.50
64 MB	60ns	EDO 8x64, 5V	$59.50
64 MB	PC66	SDRAM	$22.99
128 MB	PC66	SDRAM	$40.99
64 MB	PC133	SDRAM	$22.99
128 MB	PC133	SDRAM	$35.99
128 MB	PC133	ECC SDRAM 16X72 Non Reg	$53.99
256 MB	PC133	ECC SDRAM 32X72 Reg	$115.99
512 MB	PC133	ECC SDRAM 64X72 Non Reg	$145.99

skill 6

Understanding an Advertisement for Computer Memory (cont'd)

A+ Hardware objective

4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

When you examine Table 3-2, observe that SDRAM modules are advertised by their Intel-certified performance speed: PC66, PC100, or PC133. DDR-SDRAM modules are advertised as PC2100 or PC2700 (their data transfer rate), and also by clock frequency (266 MHz, 366 MHz). Rambus RDRAM is rated by clock frequency, which is sometimes (confusingly) written as PC800 for 800 MHz or PC1066 for 1066 MHz.

For some memory types, the advertisement specifies additional information to avoid ambiguity. Some DIMM modules are distributed in both 3.3-volt and 5-volt versions. Some SDRAM modules are designed for use on motherboards that support ECC, and some are not. Additionally, some DRAM modules are marked as "Reg," **(registered memory)**, and some as "Non-Reg" **(non-registered memory)**.

When a PC starts up, it must detect the type of memory modules installed on the motherboard. Older PC motherboards use a system called **Parallel Presence Detect (PPD)**, which relays information to the memory controller chip through a series of circuits on the motherboard. RAM modules designed for PPD motherboards are classified as non-registered memory.

Serial Presence Detect (SPD) is a newer technology that uses an 8-pin EEPROM chip to store information about the size, speed, voltage, and pin configuration of each memory module on the motherboard. RAM modules designed for SPD motherboards are classified as registered memory.

tip

If you cannot determine from documentation whether your PC motherboard uses PPD or SPD memory detection, assume PPD, because PPD modules can be used on SPD motherboards.

more

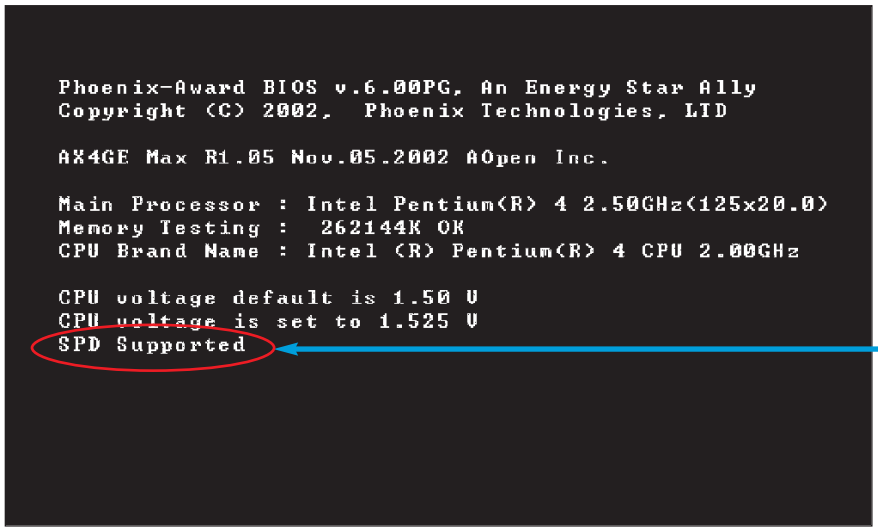
When you purchase new memory modules for a PC, you should first determine which of these two memory detection processes is used by the motherboard. The system documentation should provide this information. Some systems report the type of memory detection supported by the motherboard on the startup screen **(Figure 3-15)**. If no information is reported, the motherboard probably uses PPD and non-registered DRAM.

Not shown in Table 3-2 is a CAS Latency specification for SDRAM and DDR-SDRAM modules. Recall from Skill 4 that CAS Latency is a delay between the receipt of a memory read request and the time when the chip actually begins its data output. In some memory ads, you will find an additional specification of CL2, CL3, or CL5 for SDRAM that indicates a latency of 2, 3, or 5 clock cycles.

Table 3-2 PC Memory (cont'd)

184-Pin DDR-SDRAM				
128 MB	DDR	PC2100	266 MHz	$23.99
128 MB	DDR	PC2100	266 MHz ECC	$32.99
256 MB	DDR	PC2100	266 MHZ	$40.99
256 MB	DDR	PC2100	266 MHz ECC	$53.99
256 MB	DDR	PC2100	266 MHz ECC Reg	$66.99
256 MB	DDR	PC2700	333 MHz	$51.99
512 MB	DDR	PC2700	333 MHz	$89.99
512 MB	DDR	PC2700	333 MHz ECC Reg	$107.99
Rambus Direct RDRAM				
64 MB	Rambus	800 MHZ	$29.99	
128 MB	Rambus	800 MHZ	$51.99	
128 MB	Rambus	1066 MHZ	$52.99	
128 MB	Rambus	800 MHz ECC	$62.99	
256 MB	Rambus	1066 MHZ	$101.99	

Figure 3-15 Serial Presence Detect on startup screen



The startup screen of this PC shows that it supports SPD (Serial Presence Detect) RAM modules

skill 7 Preparing to Upgrade Memory

A+ Hardware objective

1.2 Identify basic procedures for adding and removing field-replaceable modules for desktop systems. Given a replacement scenario, choose the appropriate sequences.
1.10 Determine the issues that must be considered when upgrading a PC. In a given scenario, determine when and how to upgrade system components.
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

The more applications you open during a Windows session, the more memory is required to run them. When the system runs out of physical RAM, Windows uses space on the hard disk known as **virtual memory**. Because reading from and writing to the hard disk is much slower than accessing physical RAM, system performance tends to slow down as you open more applications (or document windows within a single program). Therefore, adding more physical RAM to a PC can make a significant improvement in its performance.

Most PCs are sold with one or more empty RAM banks on the motherboard. The key factor that controls the type of memory supported by a motherboard is the system chipset. The documentation for the motherboard should indicate what types of memory it can support. As you have learned in this lesson, memory modules are marketed in a variety of form factors, capacities, and speeds.

Upgrading memory is a process that you should approach in several stages:

- Estimate the amount of RAM that is optimal or recommended for the Windows operating system and applications that you use. Newer versions of Windows, such as Windows XP, require more RAM than Windows 98SE or Windows 2000 Professional for smooth performance. Newer versions of Microsoft Office and memory-intensive programs, such as Macromedia Dreamweaver or Adobe Photoshop, need more RAM than older versions of these programs.
- Determine how much RAM is currently installed on the system and the total amount that the system will support.
- Determine the type of RAM supported on the motherboard: identify the form factor (SIMMs, 168-pin DIMMs, 184-pin DIMMs, or RIMMs), and identify the memory type (EDO RAM, SDRAM, DDR-SDRAM, Direct RDRAM).
- Determine the speed (60ns, PC100, PC133, PC2100, PC1066), error checking support (none, parity, ECC), and RAM detection support (non-registered/PPD or registered/SPD) for currently installed memory modules.

tip
Before removing a SIMMs memory module, note which direction on the motherboard the label faces. This will make it easier to reinsert the module later on.

You can usually determine the amount of RAM currently installed in a PC by watching for information on the initial boot screens, or, alternatively, by inspecting the General tab of System Properties in Windows **(Figures 2-8** and **2-9** in Lesson 2).

To determine the type, size, speed, and error-checking support of RAM installed in a computer, consult the system documentation. You may need to open the case to remove and inspect the currently installed RAM modules. Reread Skill 12 in Lesson 1 for instructions on opening the case. Be sure you are wearing an antistatic wrist strap before touching any internal components on the motherboard.

If your motherboard has SIMMs modules, you can remove one by tilting the module forward or backward (in the direction the slot naturally allows) by 45 degrees and then sliding the module out of its socket **(Figure 3-16)**. Do not force the module! Note that the SIMM may be held in place by two metal or plastic clips, one on either side of the slot. It may be necessary to gently push these clips open, using your fingers or a very small flathead screwdriver **(Figure 3-17)**.

Figure 3-16 Removing a SIMM module - I

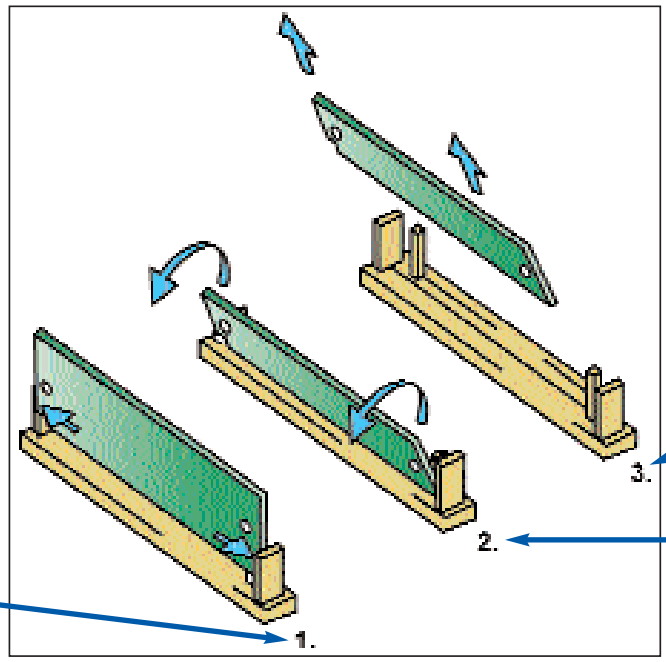
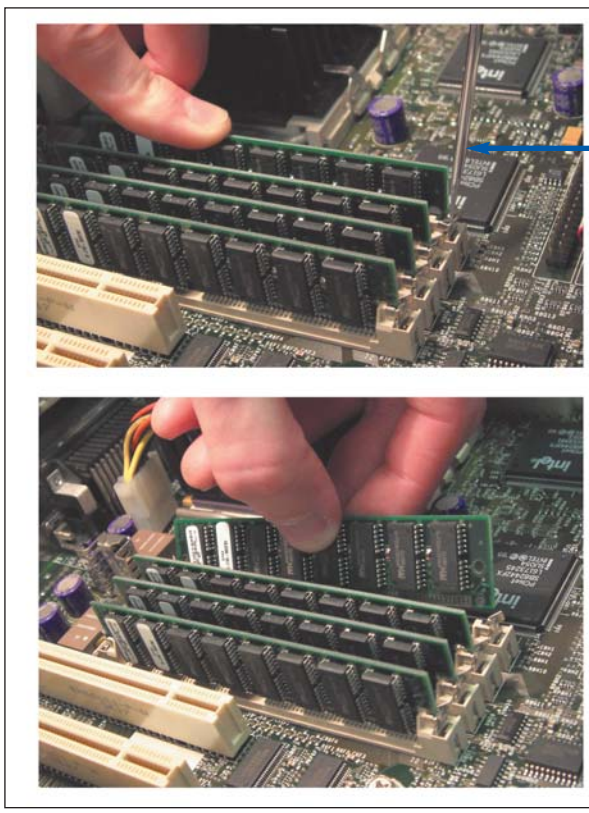


Figure 3-17 Removing a SIMM module - 2



skill 7

Preparing to Upgrade Memory (cont'd)

A+ Hardware objective

1.2 Identify basic procedures for adding and removing field-replaceable modules for desktop systems. Given a replacement scenario, choose the appropriate sequences.
1.10 Determine the issues that must be considered when upgrading a PC. In a given scenario, determine when and how to upgrade system components.
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

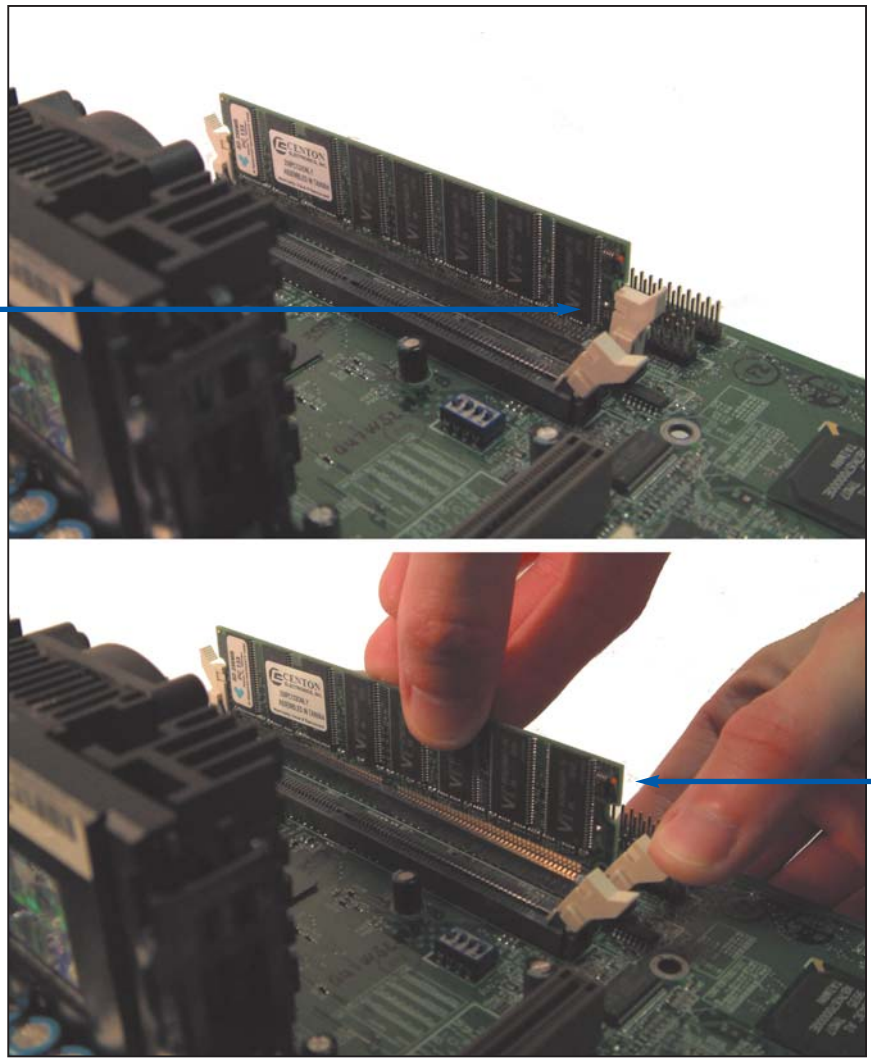
DIMM and RIMM modules are easier to remove. Push down the two guards on either side of the slot to release the module; then gently grasp the module at both edges with your finger tips and lift up to slide it out **(Figure 3-18)**.

Once you have removed the RAM modules from the motherboard, look for a label on each one that lists the manufacturer, memory size, and speed. If the label is missing any of this information, write down whatever serial number and manufacturer information it does display. You, or a memory vendor, may be able to find more complete information about the memory module on the Web. SIMM and DIMM modules are sold in both single-sided and double-sided chip configurations. You should try to maintain the same single-side or double-side chip configuration when buying new RAM modules for the system.

It may be necessary to replace old memory modules, in any event, if the RAM sizes accepted by the memory banks are incompatible with your desired upgrade. For instance, an older motherboard may have two SIMM memory banks, each with two RAM slots that accept SIMM modules up to 32 MB in size. If the first bank already has 32 MB, comprised of two 16 MB modules, you will need to replace these modules to upgrade the system to 128 MB of RAM. On this system, to install 128 MB of RAM, each of the four RAM slots must be filled with a 32 MB SIMM module. The existing 16 MB modules are too small and 64 MB modules are too large.

Additionally, all SIMMs modules on the system must use the same memory technology, supported by the motherboard (FPM, EDO, BEDO, or SDRAM). The modules installed in each bank must be identical (error-checking or standard DRAM), with the same rated access speed. All memory slots in the first bank (Bank 0) must be filled, before inserting SIMM modules in the second bank (Bank 1). Ideally, the modules in different memory banks should also be identical. Some older motherboards allowed FPM, EDO, and/or SDRAM to be mixed in different banks and others did not. Modern motherboards require the same memory type in each bank. It is possible, on some motherboards, to use modules with different access speed ratings in each bank, but this is generally not recommended.

Figure 3-18 Removing DIMMs and RIMMs



skill 7

Preparing to Upgrade Memory (cont'd)

A+ Hardware objective

1.2 Identify basic procedures for adding and removing field-replaceable modules for desktop systems. Given a replacement scenario, choose the appropriate sequences.
1.10 Determine the issues that must be considered when upgrading a PC. In a given scenario, determine when and how to upgrade system components.
4.2 Identify the types of RAM (random access memory), form factors, and operational characteristics. Determine banking and speed requirements under given scenarios.

overview

Some motherboards include both 72-pin SIMM and 168-pin DIMM memory banks. One type of DRAM or the other must be installed. The system cannot use both memory types simultaneously. Similarly, some motherboards support either SDRAM or DDR-SDRAM, but not both at the same time. **Figure 3-19** shows a motherboard equipped with both 168-pin DIMM and 184-pin DIMM memory slots.

168-pin and 184-pin DIMM modules have the advantage using single-slot banks. It is possible (and common practice) to install memory modules with different RAM sizes in each RAM slot. However, all the DIMM modules must use the same memory technology (ECC or non-ECC, EDO, SDRAM, or DDR-SDRAM). It is also advisable to use modules with the same access speed rating in each slot.

The metal contacts on RAM modules and the slots that hold them may be made of either tin or gold. To avoid chemical reactions between the two types of metal, the metal type used on the motherboard slots should be matched with metal type used on the DRAM contacts.

The voltage used by system RAM to operate must match the voltage supported by the motherboard. Some types of SDRAM and DDR-SDRAM designed for desktop PCs require 5 volts to operate (this is called **buffered SDRAM**) and others use 3.3 volts (this is called **unbuffered SDRAM**). Rambus RDRAM operates at 2.5 volts, as do SODIMMs and SORIMMs designed for most modern laptop computers. Your motherboard documentation should tell you the proper voltage setting for the DRAM it supports. Some motherboards have dual-voltage settings configured through onboard jumpers or CMOS settings. Most current motherboards that support DDR-SDRAM use buffered 5-volt modules.

Most manufacturers of DIMM and RIMM memory place notches in the memory sticks in different places to prevent you from putting the wrong type of RAM into a memory slot, or inserting the RAM module in the slot the wrong way. However, this is less typical of older 72-pin SIMMs modules, which should be inserted cautiously and have correct orientation in the slot verified before restarting a computer. All DRAM modules are sensitive to static electricity, so caution should be exercised when installing or removing them.

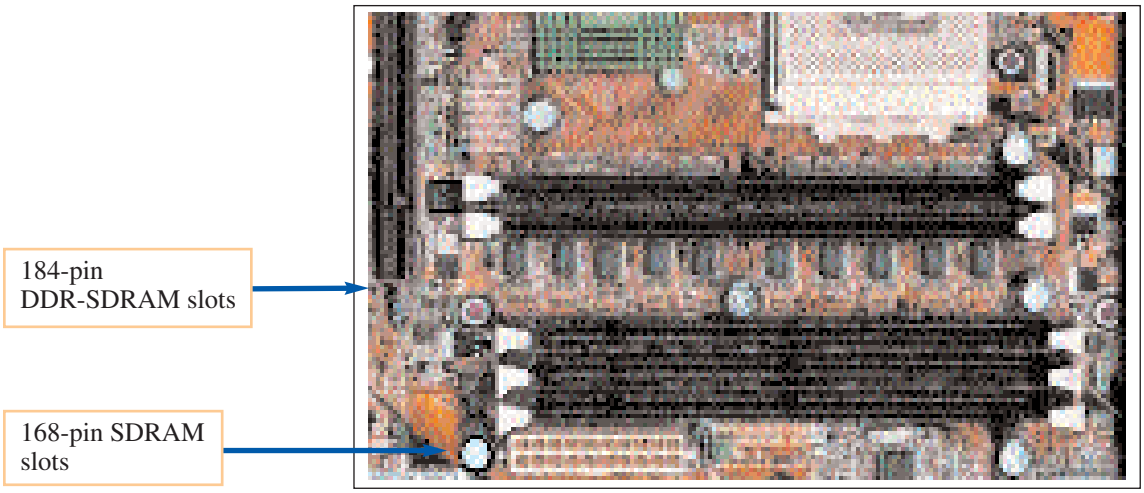
tip

All DRAM modules are sensitive to static electricity, so caution should be exercised when installing or removing them.

caution

Some poorly designed motherboards do not prevent SIMM modules from being inserted in the wrong direction. Make sure you have the correct orientation before inserting the SIMM. Inserting a SIMM module in the wrong direction may cause it to short out and damage the motherboard.

Figure 3-19 SDRAM-DDR-SDRAM compatible motherboard



skill 8 Installing New RAM Modules

A+ Hardware objective

1.2 Identify basic procedures for adding and removing field-replaceable modules for desktop systems. Given a replacement scenario, choose the appropriate sequences.

overview

After you have verified that you have the proper DRAM modules for your motherboard, installing them is the next step.

how to

Install new RAM modules.

1. Power down the computer, remove the power cord, and open the case. Be sure to wear an antistatic wrist strap.
2. Remove existing DRAM modules from the motherboard, as previously described, and put them in a safe place.
3. Take the first new DRAM module out of its antistatic storage bag and grip it with your fingers at either edge. Study the module and the RAM slot on the motherboard to see how the pins should align with the slot. The location of holes or notches in the module, location of the label, or placement of chips on the module may provide clues.
4. For SIMM modules, remember that Bank 0 must be completely filled, if you intend to place any DRAM in Bank 1. For DIMM and RIMM modules, make sure that the two guards at either end of the slot are in the open, pushed down position. Gently slide the DRAM module into the proper memory slot at a 60-degree angle, and then rotate it to an upright position. If you have inserted the module correctly, you should hear a click as it locks into position **(Figure 3-20)**.
5. Motherboards that use the 184-pin RIMM form factor must have all memory banks on the motherboard filled, either with Rambus RDRAM modules or C-RIMM dummy modules. To install two RDRAM modules on a system with two memory banks, one RDRAM module and one C-RIMM are installed in each bank. If you are installing a new RDRAM module in Bank 1, remove the C-RIMM and replace it with the new RDRAM module **(Figure 3-21)**.
6. Verify that the DRAM modules you have installed are firmly in place. Place your finger on each module and try to wiggle it, gently, from side to side. If the module is installed correctly, it will remain in place.
7. If you have removed any RAM modules from the motherboard, store them in antistatic bags to preserve their integrity. You can often find a use for older RAM modules later.
8. After completing the installation of upgrade RAM modules, reconnect the power cable and any other cables or components that you removed.
9. Boot the PC to verify that the new memory is recognized. You can leave the case cover off while you do this to troubleshoot physical connection problems.
10. If the PC fails to start or does not count the proper amount of installed RAM during startup, you will have to perform some troubleshooting procedures outlined in the next skill.

Figure 3-20 Installing SIMMs and DIMMs

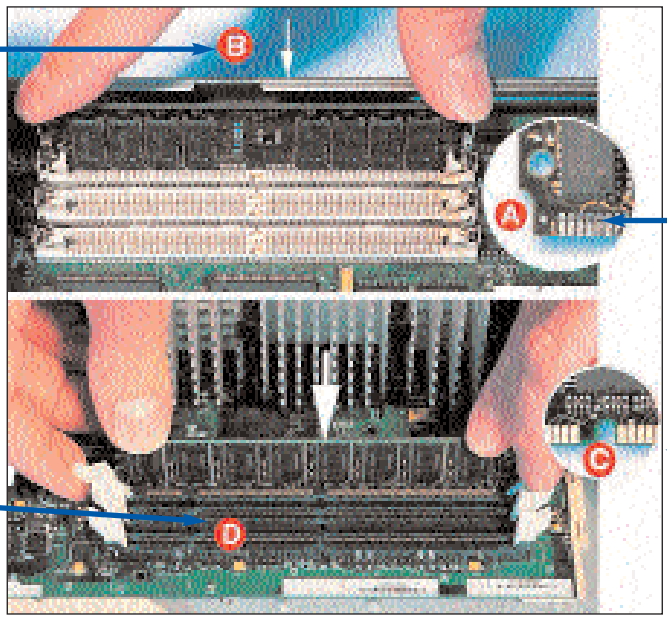
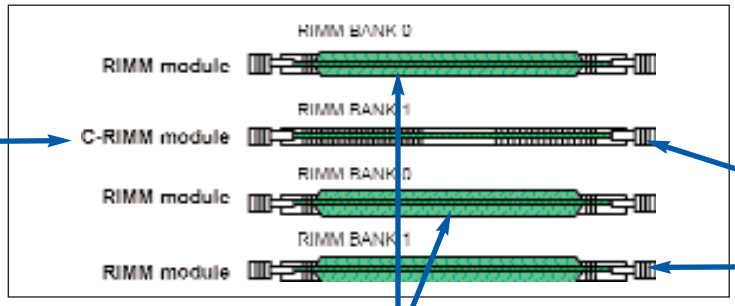


Figure 3-21 Installing Rambus RDRAM



skill 9 Troubleshooting Memory Problems

A+ Hardware objective

2.1 Recognize common problems associated with each module and their symptoms, and identify steps to isolate and troubleshoot the problems. Given a problem situation, interpret the symptoms and infer the most likely cause.

overview

Memory-related performance problems on a PC can usually be traced to a few basic causes. If you turn on the PC, see nothing on the monitor, but hear a series of beeps from the speaker, the problem is probably caused by one of the following:

- Improperly seated RAM modules on the motherboard
- RAM that is too slow for the system
- RAM modules of an unsupported memory type
- Different speeds or memory types in the same memory bank
- Unfilled slots in a memory bank
- Defective memory chips on a RAM module

Different BIOS manufacturers use different beep error codes to indicate various startup problems. The PC speaker cables must be properly attached to their jumpers on the motherboard for you to hear the speaker (described later in Lesson 5). Your system documentation should explain the beep startup code for your PC. **Table 3-3** shows typical memory-related beep codes for some common BIOS brands.To resolve this kind of problem, check each installed RAM module on the motherboard. Remember that for 72-pin SIMMs, Bank 0 must be filled before inserting a SIMMs module in Bank 1. Rambus RDRAM requires empty slots to be filled with C-RIMM modules. Run your thumb over each RAM module to see if it is firmly in place. If any module wiggles in place, verify that it has been inserted the right way into its slot and press down on it with your thumb to lock it into position. If this does not resolve the problem, it may be necessary to remove each module, verify that it is a type and speed supported by the motherboard and reinsert it.

Sometimes, after performing a RAM upgrade, a PC will start up, but may experience other problems:

- The amount of RAM shown on the startup screen or in the Windows System Properties is incorrect.
- The system starts to boot, but halts or crashes in loading the operating system.

Be sure to watch the startup screens on the monitor to see if any error messages are displayed before the operating system begins to load. Mixing single-sided and double-sided RAM in the same memory bank sometimes causes incorrect reporting of system RAM. In general, if you have multiple DIMMs with different memory sizes, the module with the largest amount of RAM should be inserted in Bank 0. System errors displayed at startup may be caused by an incorrect CMOS configuration, or by using memory modules with different speeds and/or different error-checking support **(Figure 3-22)**. In some cases, a system vendor will recommend the use of RAM modules sold by a specific manufacturer. (You will find more troubleshooting tips related to startup problems in Lesson 5, Skill 12.).

"Blue screen" crashes in which a blue screen appears and the computer freezes after starting the system and application errors within a Windows operating system may be related to mismatched memory modules, or caused by defects in an individual module **(Figure 3-23)**.

tip

In some PCs, when new, faster DRAM chips are installed, the CMOS must be manually reconfigured to match the speed of the new memory. In other systems, the CMOS automatically readjusts the memory controller when new DRAM modules are inserted. Check for an upgrade section in your system documentation to get more information.

Table 3-3 Common Memory Error Beep Codes

BIOS Manufacturer/Beep Code	Meaning
Award BIOS	
Continuous single beeps	RAM failure
Two short beeps	General, non-fatal startup error
AMI BIOS	
One beep	Memory refresh failure
Two beeps	Parity error
Three beeps	Base 64 K memory error
Phoenix BIOS	
1-3-1-1 beep pattern	DRAM refresh problem
1-3-4-1 beep pattern	RAM failure on a specific address line

Figure 3-22 BIOS memory error

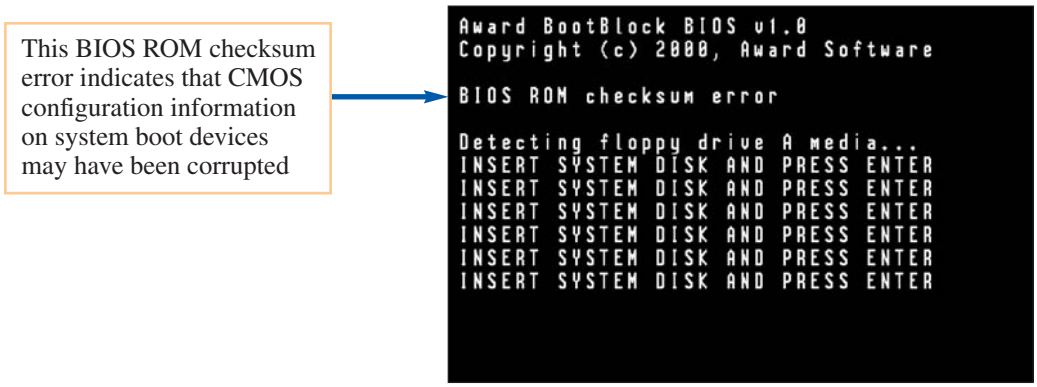
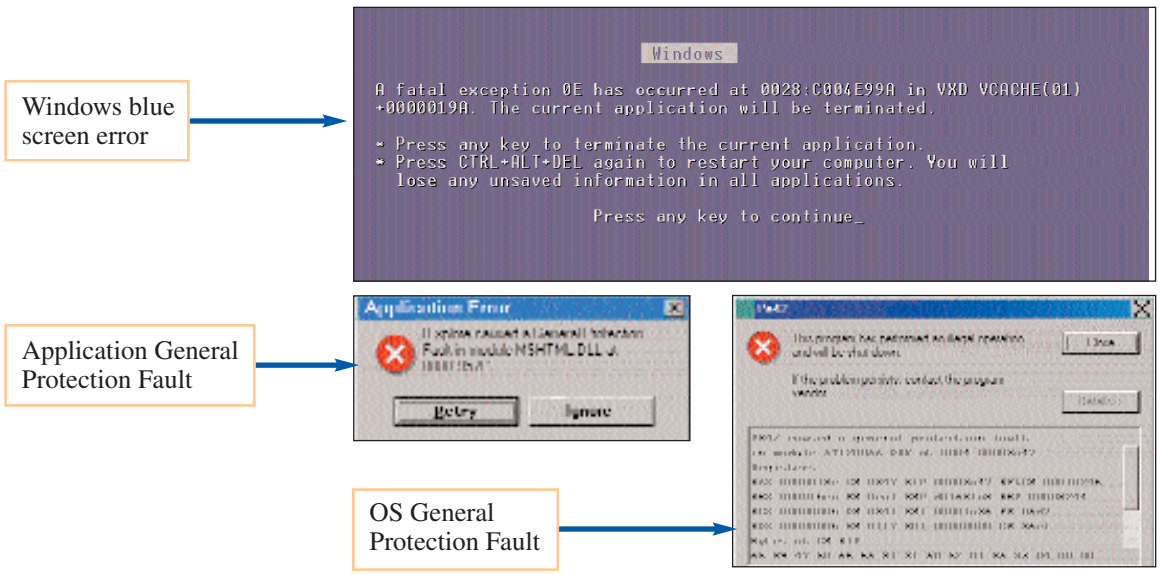


Figure 3-23 Windows memory errors



skill 9

Troubleshooting Memory Problems *(cont'd)*

A+ Hardware objective

2.1 Recognize common problems associated with each module and their symptoms, and identify steps to isolate and troubleshoot the problems. Given a problem situation, interpret the symptoms and infer the most likely cause.

overview

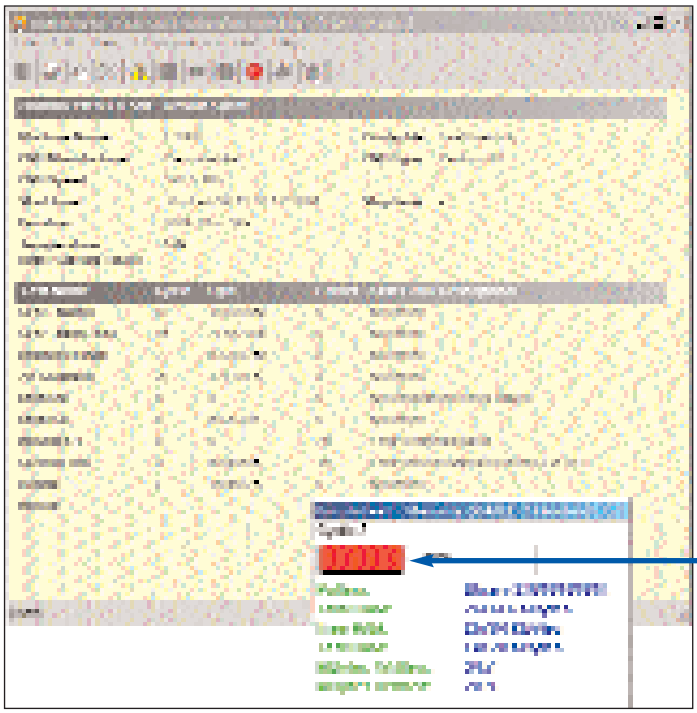
If simply removing and reinstalling RAM does not resolve a problem, one of the following procedures may work:

- Clean the edge connectors on RAM modules with a soft cloth before reinserting them. Over time, the gold or tin contacts can become coated with oil or dust.
- Perform a flash upgrade on the system BIOS, using either the current or a newer version. See Lesson 5 for details on how to perform a Flash BIOS upgrade.
- Try swapping in a set of known good RAM modules from a PC that uses the same kind of memory; or test the RAM modules that are generating errors by plugging them into a different PC. If memory errors clear up with different RAM or persist with the same RAM in a different PC, you have good reason to suspect one or more of the original modules may be defective.

If the PC will boot into DOS or Windows, running a software memory diagnostic utility may allow you to locate a specific defective RAM module. Some system vendors, such as IBM and Dell, provide diagnostic utilities specific to the computers they manufacture. On some computers, a set of diagnostic tests may be built into the computer's CMOS options. You can also do a search on the Web using "memory testing utilities" as a search string to find downloadable memory testing software. Memtest-86 **(http://www.memtest86.com/)** is a free memory testing utility that runs only under MS-DOS. To use MemTest, you must install it on a floppy diskette and boot the computer from the floppy. See the Projects on Your Own section at the end of this lesson for more details on how to download and install Memtest.

If a PC can be booted into a Windows operating system, a utility like BurnIn Test (http://www.passmark.com/products/bit.htm) can perform memory diagnostics that may reveal intermittent problems (**Figure 3-24**).

Figure 3-24 BurnInTest memory diagnostics



BurnInTest performs system diagnostics, including read/write tests of installed RAM

skill 10

Memory Mapping in the First Megabyte

A+ Hardware objective

1.9 Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.

overview

MS-DOS, the first operating system designed for IBM and Intel-compatible PCs, operated within a single megabyte (1024 KB) of RAM. Within that megabyte, the first 640 KB (known as **conventional memory**) was allocated to running the operating system, device drivers, and applications. The memory addressed from 640 KB to 1024 KB (called **reserved memory**) was set aside for hardware instruction code. The instructions in a computer's BIOS and in firmware attached to hardware devices (such as video adapters, network cards, and disk controllers), is permanently stored in ROM chips that always retain the information.

In early PCs, the CPU read BIOS and other permanent hardware instructions directly from onboard ROM chips. Under MS-DOS, these instructions were logically mapped to the **memory address space** between 640 KB and 1024 KB. This did not necessarily imply that there were RAM chips keyed to those addresses. Memory address space is simply the potential location for stored information. Recall that a modern CPU can address 4 GB of memory, but most PCs have far less physical RAM installed on the motherboard. To improve performance in later PCs, a system called **shadowing** was invented. When ROM is shadowed on a PC, the CPU reads information from it, once only. The information is then transferred to faster RAM chips keyed to the 640 KB-1024 KB reserve memory address space. The process of keying specific ROM or RAM chips to logical memory addresses is called **memory mapping (Figure 3-25)**.

Eventually, the 640 KB allocated by MS-DOS to run applications turned out to be insufficient. PCs began to require more and more device drivers for network connectivity and new types of hardware. The conventional memory consumed by device drivers was unavailable to run large, complicated DOS applications. In the meantime, the address space used by ROM BIOS and firmware code in reserved memory was significantly less than the available total of 384 KB. About 200 KB of the reserved memory address space was usually still unmapped. So DOS programmers decided to use the surplus address space between 640 KB and 1024 KB to load device driver code. Naturally, this required a full 1024 KB of RAM to be installed on the motherboard, instead of only 640 KB.

When programmers learned how to load device driver code into this memory region, they began to call it **upper memory** (or high memory), instead of reserved memory. Contiguous chunks of RAM used to store DOS code between 640 KB and 1024 KB were named **upper memory blocks (UMBs)**. Loading some device drivers in high memory freed up conventional memory, allowing more and larger applications to run below 640 KB.

Figure 3-26 shows how hardware instruction code is stored in upper memory and assigned to specific memory address locations. To convert unused upper memory address space into upper memory blocks that can store DOS system code, two special DOS device drivers must be loaded at boot-time in a startup file called **config.sys**. See Skill 13 in this lesson for more details.

Figure 3-25 Shadowing reserved memory

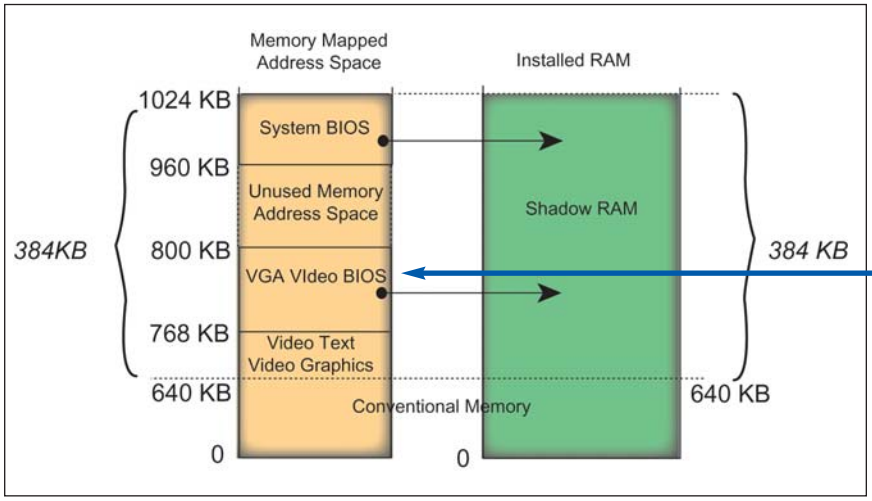
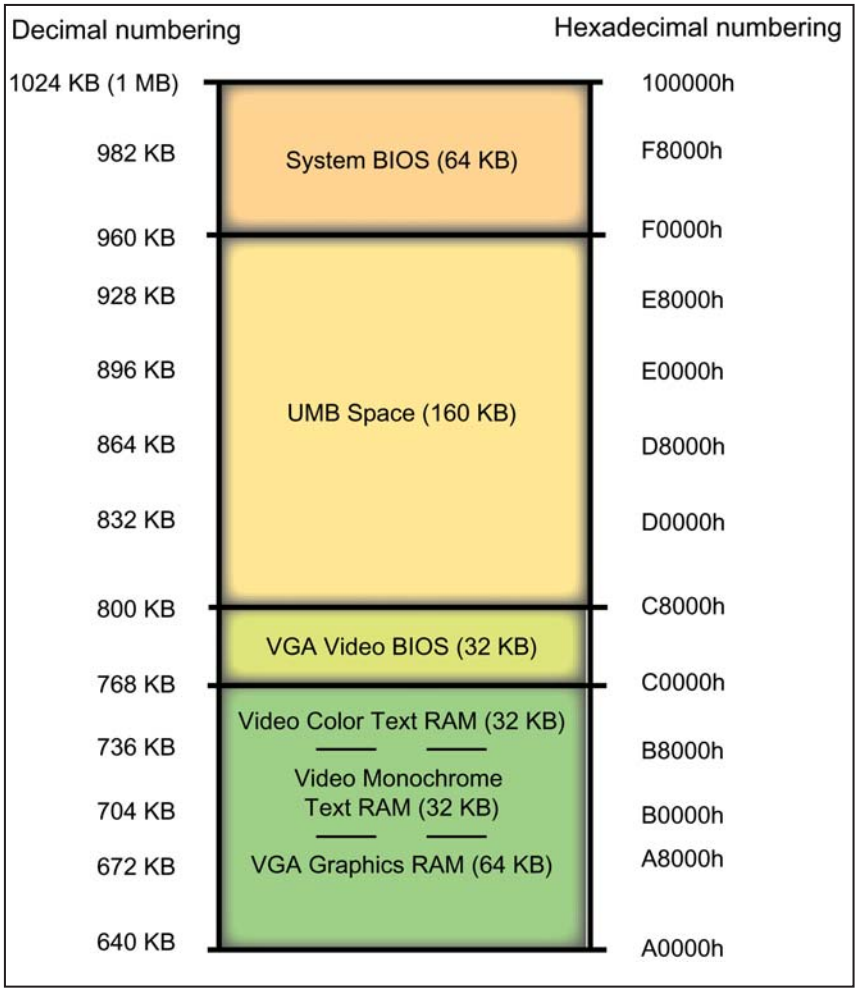


Figure 3-26 Map of upper memory



skill 11

Reading and Using Hexadecimal Numbers

A+ Hardware objective

Basic knowledge

overview

The memory addresses shown in **Figure 3-26** are given in both the decimal and **hexadecimal** numbering systems. You learned in Lesson 1 that the PC uses the 1s and 0s of the binary numbering system to convert information into electrical circuits. The hexadecimal system counts numbers in groups of 16, instead of 10 (as the decimal system), or 2 (as the binary system). PC programmers find it convenient to count in increments of 16 instead of 10 because the binary electrical circuits on a PC are often grouped in multiples of 16. (Recall that the Intel 8088 CPU used in the first IBM PC had a 16-bit internal bus width.)

So how does this work? The decimal system (base 10) has 9 counting symbols plus 0 as a placeholder **(Table 3-4)**. Every time you reach a multiple of 10, a 0 is inserted as a placeholder and you move over a column to the left—from units to tens (10x1) to hundreds (10x10) to thousands (10x10x10) to continue counting. The binary system (base 2) has 1 counting symbol plus 0 as a placeholder. Every time you reach a multiple of 2, a 0 is inserted as a placeholder and you move over a column to the left, from units to twos (2x1) to fours (2x2) to eights, (2x2x2) and so on.

The hexadecimal system (base 16) has 15 counting symbols plus 0 as a placeholder. When you get to the number 10, the capital letter A is used as a new symbol; B is 11, C is 12, D is 13, E is 14, and F is 15 **(Table 3-5)**. The number 16 is written in hexadecimal as 10h (1 in the 16's place and 0 in the units place, with the h to tell you that this is a hexadecimal number). A 17 in the decimal system is 11h in hexadecimal (1 in the 16's place and 1 in the units place. Every time you reach a multiple of 16, a 0 is inserted as a placeholder and you move over a column to the left-from units to 16's (16x1) to 256's (16x16) to 4096's (16x16x16).

Although it is difficult at first to think in multiples of 16 instead of multiples of 10, it becomes easier after you work with PCs for awhile. You will automatically know that 16x16x16x16 (or 65,536) in decimal is equal to 1000h. In the meantime, for quick conversions between decimal and hexadecimal numbers, you can use the Windows Calculator, located in the Accessories group.

Table 3-4 Decimal, Binary, and Hexadecimal Places

Decimal places:				
10^4	10^3	10^2	10^1	10^0
10,000s	1000s	100s	10s	1s
Binary places:				
2^4	2^3	2^2	2^1	2^0
16s	8s	4s	2s	1s
Hexadecimal places:				
16^4	16^3	16^2	16^1	16^0
65536s	4096s	256s	16s	1s

Table 3-5 Decimal and Hexadecimal Equivalents

Decimal	Hexadecimal	Decimal	Hexadecimal
1	01h	17	11h
2	02h	18	12h
3	03h	19	13h
4	04h	20	14h
5	05h	21	15h
6	06h	22	16h
7	07h	23	17h
8	08h	24	18h
9	09h	25	19h
10	0Ah	26	1Ah
11	0Bh	27	1Bh
12	0Ch	28	1Ch
13	0Dh	29	1Dh
14	0Eh	30	1Eh
15	0Fh	31	1Fh
16	10h	32	20h
100	64h	1000	03E8h
65, 536 (640x1024)	A000	655, 360 (65, 536x1024)	A0000

skill 11

Reading and Using Hexadecimal Numbers (cont'd)

A+ Hardware objective

Basic knowledge

how to

Use the Windows Calculator to convert the number of bytes expressed in hexadecimal as A0000h bytes to its decimal equivalent.

1. Click the **Start** button, go to the **Programs**, point to the **Accessories** group, and click on **Calculator**.
2. Open the **View** menu in Calculator and switch to the **Scientific Calculator**.
3. Select the **Hex** radio button, then enter the hexadecimal value **A0000** in the data window **(Figure 3-27)**.
4. Click the **Dec** radio button. The decimal value for A0000h (655,360) will appear in the data window.
5. To convert 655,360 bytes to kilobytes, divide by 1024, because 1024 bytes = 1 kilobyte.
6. Click the **divide** function (slash to the right of the 9) and enter **1024**. Click the = button to see that 655,360 bytes= 640 kilobytes.

You can repeat this procedure with the Windows Calculator to verify that all of the hexadecimal memory addresses shown on the left side of **Figure 3-26** are equivalent to the decimal memory addresses (expressed in kilobytes) shown on the right side.

(Remember to divide by 1024 after converting from hex to decimal.)

Figure 3-27 Entering a hexadecimal value into Windows Calculator

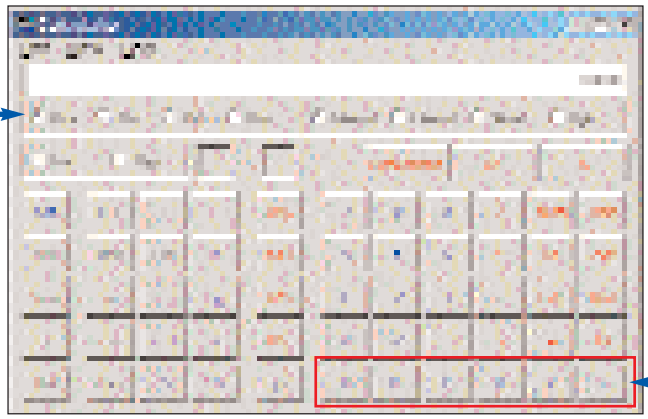


Figure 3-28 Windows Calculator converts hex to decimal

skill 12

Memory Mapping in Windows Operating Systems

A+ Hardware objective

1.9 Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.

overview

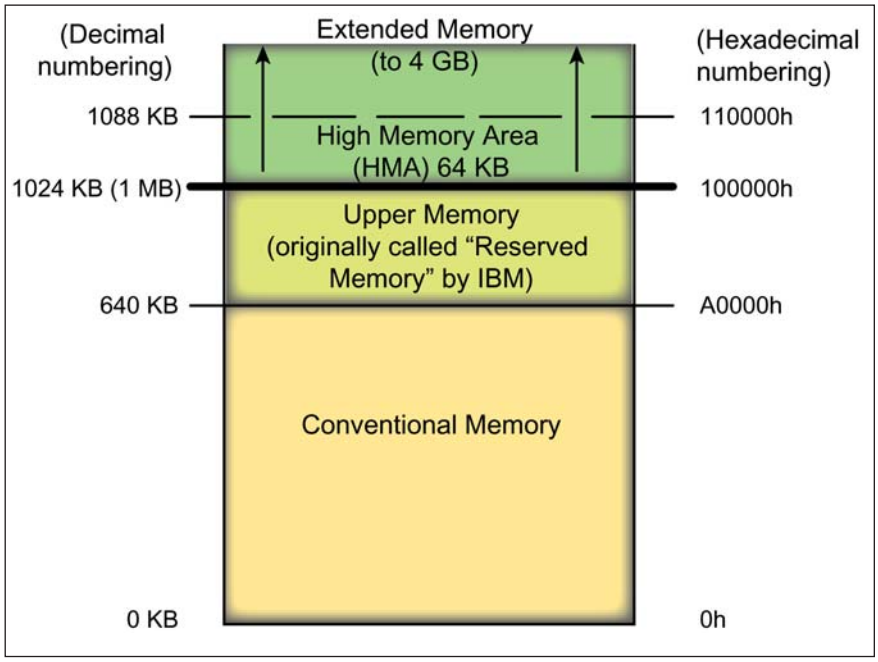
Extended memory (sometimes called XMS memory) is the RAM on the motherboard used to fill the memory address space above 1 MB. The first 64 KB of extended memory has a special name. Although MS-DOS sees only the first megabyte of RAM, programmers working for Quarterdeck Office Systems made an interesting discovery about PC memory in the late 1980s. The Quarterdeck programmers discovered that they could trick MS-DOS into recognizing the first 64 kilobytes of extended memory as if it were within the standard 1 MB MS-DOS address space. Microsoft soon appropriated this technology and coined the name **High Memory Area (HMA)** to refer to this 64 KB memory block **(Figure 3-29)**. DOS programmers developed a technique for loading operating system code into the HMA in addition to loading device drivers into upper memory blocks. The ability to use UMBs and the HMA to store DOS system files was a significant technology advance at this time. Users no longer had to choose between connecting to a network and working on a large spreadsheet. Instead, they could do both simultaneously.

When a PC runs the MS-DOS operating system, the CPU operates under a set of instructions called **real mode**, limited to 1 MB of memory address space. Recall from Lesson 2 that all PCs with an 80286 CPU or higher can address more than 1 MB of RAM even when the operating system cannot do so. PCs with these CPUs address memory above 1 MB by switching the CPU into an enhanced instruction mode called **protected mode**.

Microsoft Windows 3.x and all subsequent versions of the Windows operating system (including Windows 9.x, Windows NT, Windows 2000, Windows XP, and Windows Server 2003) use the protected mode instruction set. Windows 3.x refers to all the release versions of Windows that begin with 3: Windows 3.0, Windows 3.1, and Windows for Workgroups 3.11. Similarly, Windows 9.x refers to all the release versions of Windows that begin with a 9: Windows 95, Windows 98, Windows 98SE, and Windows Millennium Edition (ME)—which is considered part of the 9.x series.

Windows 3.x and Windows 9.x are based on an underlying DOS core. This means that when a PC boots these operating systems, the CPU initially runs in real mode, loading MS-DOS system files. This feature preserves compatibility with older MS-DOS applications and device drivers. When it is time for the Windows graphical interface to load, the CPU switches into protected mode to address the extended memory installed on the motherboard. More recent versions of Windows, such as Windows NT 3.x, Windows NT4, Windows 2000, Windows XP, and Windows Server 2003, do not have an underlying DOS core. The CPU switches directly into protected mode to load these operating systems.

Figure 3-29 PC memory map



skill 13

Working with UMBs and the HMA under MS-DOS and Windows 9.x

A+ Hardware objective

1.9 Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.

overview

When a PC boots into the MS-DOS or Windows 9.x operating systems, three core system files are loaded from the boot drive: IO.SYS, MSDOS.SYS, and COMMAND.COM.

- IO.SYS contains input/output instructions for the operating system to access hardware, read and write to disk media, and create new files.
- MSDOS.SYS contains internal information about system file locations and other operating system defaults.
- COMMAND.COM contains instructions that allow the user to launch application programs and perform basic file management tasks.

After the computer loads IO.SYS and MSDOS.SYS, but before loading COMMAND.COM, DOS searches for an optional configuration file called CONFIG.SYS on the boot drive. If this file is found, DOS reads it, loading specified device driver files and setting up specified operating system defaults.

Under MS-DOS and Windows 9.x, two device driver files must be loaded to manage upper and HMA memory. HIMEM.SYS is the device driver that allows DOS to recognize the HMA. It also prepares the system for Windows 9.x to switch the CPU from real to protected mode. Under Windows 9.x operating systems, this essential device driver is loaded even if the user has not created a CONFIG.SYS configuration file. EMM386.EXE is the device driver that allows DOS to load other device drivers and small utility programs into UMBs. A command to load EMM386.EXE must be entered, specifically, into the CONFIG.SYS configuration file to activate UMBs.You can create a new CONFIG.SYS file (or edit an existing CONFIG.SYS file) under MS-DOS and Windows 9.x by performing the following steps.

how to

Create a new CONFIG.SYS file.

1. From the A-prompt or C-prompt under MS-DOS, issue the following command: **EDIT C:\CONFIG.SYS (Figure 3-30)**.
2. Enter the following statements in the text editor, each on its own line:
   DEVICE=HIMEM.SYS
   DEVICE=EMM386.EXE NOEMS
   DOS=HIGH
   DOS=UMB
3. Save the file by pressing **ALT+F** on the keyboard, followed by **S**.
4. Quit the text editor by pressing **ALT+F**, followed by **X**. The DOS=HIGH statement tells MS-DOS to load portions of COMMAND.COM into the HMA instead of using conventional memory to contain it. The DOS=UMB statement allocates upper memory blocks to load other device drivers and small DOS utility programs. **Remember that this procedure is supported only under MS-DOS and Windows 9.x**. Later versions of Windows, such as Windows 2000 Professional, Windows XP, and Windows Server 2003 do not use the MS-DOS operating core to manage PC memory.
5. Once these statements have been entered into the CONFIG.SYS file, device drivers may be loaded "high" into UMBs by substituting the syntax **Devicehigh =** for **Device =**. For instance, if a statement to load a DOS driver for the CD-ROM drive appears in CONFIG.SYS as

   DEVICE = OAKCDROM.SYS /d:mscd0000

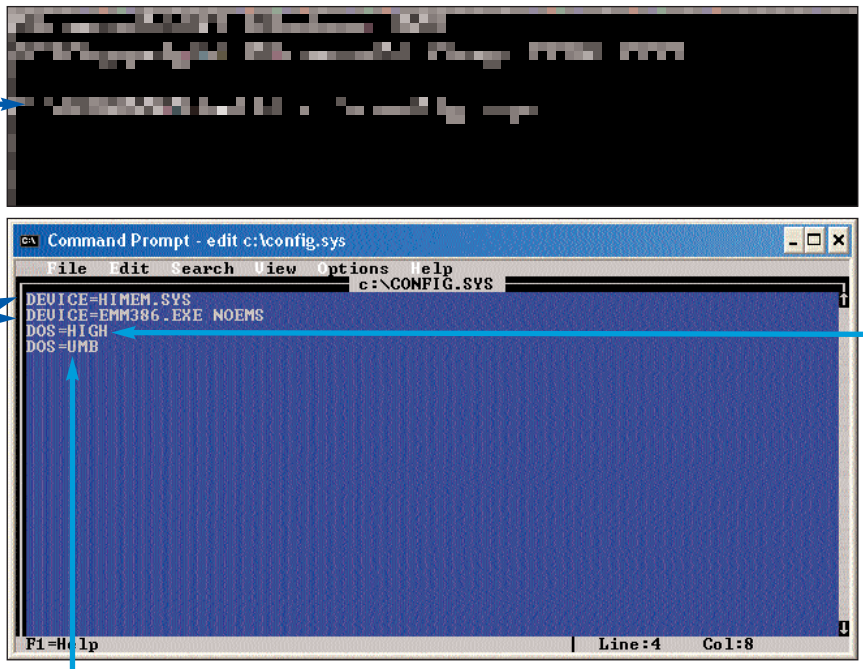
   you can tell the operating system to load this driver into a UMB by changing the statement to:

   DEVICEHIGH = OAKCDROM.SYS /d:mscd0000.

tip

In Windows 9.x, you can open an MS-DOS session by clicking Start, then clicking the MS-DOS icon on the **Programs** menu.

Figure 3-30 Editing config.sys



skill 13

Working with UMBs and the HMA under MS-DOS and Windows 9.x (cont'd)

A+ Hardware objective

1.9 Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.

overview

MS-DOS and Windows 9.x have the capacity to load small utility programs, such as a program to activate an MS-DOS mouse driver or assign a drive letter to a CD-ROM drive, by entering commands into a startup file called **AUTOEXEC.BAT**. AUTOEXEC.BAT is an MS-DOS configuration file that is loaded in the boot process after CONFIG.SYS and COMMAND.COM, but before the command that switches the CPU into protected mode to load the Windows 9.x graphical interface.

To load small utility programs into upper memory blocks, the "Loadhigh" command must be inserted before the instruction to launch a program in AUTOEXEC.BAT. For instance, AUTOEXEC.BAT may contain instructions to activate a mouse and assign a CD-ROM drive letter as follows:

MOUSE.COM

MSCDEX /d:mscd0000

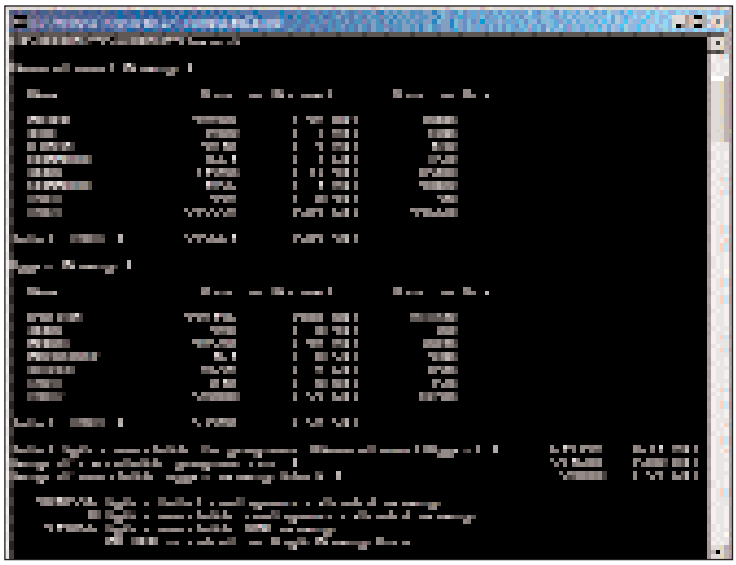
To load these programs into UMBs, the AUTOEXEC.BAT file must be opened in a text editor and modified. Perform the following steps.

how to

Load small utility programs into UMBs.

1. Using a text editor, open the **AUTOEXEC.BAT** file.
2. Change:
   MOUSE.COM
   MSCDEX /d:mscd0000
   To:
   LOADHIGH MOUSE.COM
   LOADHIGH MSCDEX /d:mscd0000
3. Reboot the computer.
4. After your PC has booted into DOS or Windows, you can display a report of the operating system's memory usage by running the **MEM** command from a DOS command prompt.
5. If you are running Windows, open a command prompt session. Click the **Start** button, and point to **Run**. Enter **COMMAND.COM** in the Run box and click **OK**.
6. At the command prompt, type the word **MEM** and press **[Enter]**. Different versions of Windows will display slightly different screens, but all will show you the total and available amounts of conventional and extended memory.
7. In Windows 2000 and Windows XP, if you type the command **MEM /C**, the screen will display all of the applications loaded into conventional and upper memory, along with their size in decimal and hexadecimal **(Figure 3-30)**.

Figure 3-31 Displaying memory usage with MEM



Summary

- Random access memory (RAM) is an erasable electronic storage space. The CPU uses RAM as a workspace to read and write operating system, application, and user document data.
- Read only memory (ROM) stores PC hardware instructions in memory chips that retain the information when the computer is switched off. EPROM chips can be programmed at the factory only once. EEPROM chips can be reprogrammed with software that runs under MS-DOS.
- Flash ROM uses EEPROM technology to allow some hardware instructions (such as the system BIOS) to be updated as necessary.
- Dynamic RAM (DRAM) chips must be periodically refreshed with an electrical charge to retain stored information. Dynamic RAM is typically used as main system memory.
- Static RAM (SRAM) chips hold data without requiring an electronic circuit to constantly refresh content. SRAM is faster and more expensive to manufacture than DRAM, commonly used in PCs as CPU cache memory.
- Synchronous SRAM runs in step with the CPU and is the most desirable memory technology for an L2 CPU cache. Asynchronous SRAM is less expensive and does not operate at the same frequency as the CPU.
- Older RAM modules were packaged and sold in DIPP, 30-pin SIPP, 30-pin SIMM, and 72-pin SIMM form factors. Modern RAM modules are packaged and sold in 168-pin DIMM, 184-pin DIMM, and 184-pin RIMM form factors. (RAM for laptop PCs is packaged in 144-pin and 200-pin SODIMMs, or 160-pin SORIMMs.)
- RAM sockets on a motherboard are arranged in groups called banks. When installing RAM on a motherboard, each socket or slot in a bank must be filled before inserting RAM modules in the next bank. (When possible, the memory modules within a bank should be from the same manufacturer, with the same rated performance speed.)
- The number of slots within a RAM bank on a motherboard depends upon the bus width of the RAM modules that will be inserted into each slot.
- A number of different memory technologies have been used in Dynamic RAM chips designed for PC motherboards. These include (in order of development): conventional mode DRAM, FPM RAM, EDO RAM, Burst EDO RAM, SDRAM, DDR-SDRAM, and Rambus RDRAM.
- Modern PCs use either DDR-SDRAM (on 184-pin DIMMs or 200-pin SODIMMs) or Rambus RDRAM (on 184-pin RIMMs or 160-pin SORIMMs).
- The performance speed of Asynchronous DRAM is measured in nanoseconds (ns). Synchronous DRAM runs at the speed of the system bus. Its performance speed is measured in MHz or rated by the three Intel standards: PC66 (66 MHz), PC100 (100 MHz), or PC133 (133 MHz).
- DDR-SDRAM sends data to the CPU twice during each clock cycle. Its performance speed is specified in MHz or by a PCxxxx rating. The performance speed in MHz can be found by dividing the PC rating by 8 and rounding off to a number equal to twice the system bus speed. (PC2700 DDR-SDRAM, runs roughly at a frequency of 2700/8 = 337 MHz. This number is rounded off to 333 MHz—twice the clock frequency of the 166 MHz system bus.)
- Rambus RDRAM sends data to the CPU twice during each clock cycle. An additional clock multiplier on the system bus may allow data to reach the L2 cache four times during each clock cycle. The PC rating for Direct RDRAM directly corresponds with its clock frequency, in contrast to the PC rating for DDR-SDRAM. (PC800 RDRAM runs at a clock frequency of 800 MHz on a motherboard with a system bus speed of either 400 MHz x 2 or 200 MHz x 4.)
- Parity and ECC are two error-checking technologies used in PC DRAM.
- PC memory problems can be caused by improperly installed RAM modules or by mixing modules with inconsistent memory technologies, edge-connector metals, performance speeds, or error-checking technologies. Problems may also result from empty slots within a memory bank, an outdated system BIOS, incorrect settings in CMOS, or defective RAM modules.
- MS-DOS uses the real mode instruction set of a CPU. It addresses 1 MB of RAM, traditionally dividing it into 640 KB of conventional memory and 384 KB of reserved memory
- Microsoft Windows 9.x and MS-DOS versions 5 and 6.xx include the ability to load device drivers and small utility programs into upper memory blocks mapped from reserved memory addresses.
- The hexadecimal (base 16) numbering system is used by PC programmers to work with hardware addresses and memory addresses.
- All PCs with Intel 80286 or higher CPUs can address more than 1 MB of RAM through the protected mode instruction set built into these microprocessors. Memory addressed above 1 MB is called extended memory.
- MS-DOS and Windows 9.x must load three system files, IO.SYS, MSDOS.SYS, and COMMAND.COM, to operate. Two optional configuration files, CONFIG.SYS and AUTOEXEC.BAT, can also be loaded to modify operating system defaults.
- The first 64 KB of extended memory (known as the High Memory Area) can be recognized by MS-DOS if the HIMEM.SYS device driver is loaded at boot time.
- Device drivers and small utility programs can be loaded into upper memory blocks if the EMM386.EXE device driver is loaded at boot time.

- HIMEM.SYS and EMM386.EXE are loaded by placing DEVICE= statements in the CONFIG.SYS file. (Windows 9.x will load HIMEM.SYS automatically if no CONFIG.SYS file exists.)
- The 3.x and 9.x versions of Windows load the core MS-DOS system files in real mode at boot time. These versions of Windows switch the CPU into protected mode when the graphical interface is loaded.
- Windows NT 3.x and 4.x, Windows 2000, Windows XP, and Windows Server 2003 do not use an MS-DOS core. These operating systems load directly into protected mode at boot time.

Key Terms

Asynchronous SRAM
Autoexec.bat
Buffered SDRAM
Burst EDO (BEDO) DRAM
Burst SRAM
CAS Latency (CL)
Config.sys
Continuity RIMMS (C-RIMMS)
Conventional DRAM
Conventional memory
Double Data Rate Synchronous DRAM (DDR-SDRAM)
Dual Inline Memory Module (DIMM)
Dynamic RAM (DRAM)
Electronically erasable progammable ROM (EEPROM)
Electronically programmable ROM (EPROM)
Error Correcting Code (ECC)
Extended Data Output DRAM (EDO DRAM)
Extended memory (XMS memory)
Fast Page Mode DRAM (FPM DRAM)
Hard error
Hexadecimal
High Memory Area (HMA)
Legacy technology
Memory address space
Memory bank
Memory chips
Memory mapping
Non-parity memory
Non-registered memory
Parallel Presence Detect (PPD)
Parity checking
Parity memory
Parity bit
PC100
PC133
PC66
Pipelined burst SRAM
Primary storage device
Protected mode
Rambus DRAM (RDRAM)
Rambus Inline Memory Module (RIMM)
Real mode
Registered memory
Reserved memory
Secondary storage device
Serial Presence Detect (SPD)
Shadowing
Single Inline Memory Module (SIMM)
Single Inline Pin Package (SIPP)
Soft error
Static RAM (SRAM)
Synchronous Dynamic RAM (SDRAM)
Synchronous link DRAM (SLDRAM)
Synchronous SRAM
Unbuffered SDRAM
Upper memory
Upper memory blocks (UMBs)
Virtual memory
Wait state

Test Yourself

1. Name four ways that the size and quality of RAM installed in a computer can affect the way the PC works.
a. _____.
b. _____.
c. _____.
d. _____.

2. Most SRAM on current motherboards is usually found within the housing for the CPU.
a. True
b. False

3. All the following are true about EEPROM chips except:
a. They are a type of ROM.
b. They retain program instructions when power to the PC is switched off.
c. They are erased by shining an ultra-violet light through a special window on the chip.
d. They are also called flash memory.

4. What is the fastest SRAM used for L2 CPU caches?
a) Asynchronous SRAM
b) Burst SRAM
c) Fast Mode SRAM
d) Pipelined burst SRAM

5. What is the main difference between DRAM and SRAM?
a. DRAM operates at faster clock speeds than SRAM.
b. The content of DRAM needs to be refreshed periodically by the memory controller.
c. SRAM can store vast amounts of data.
d. SRAM is less expensive than DRAM.

6. Memory is not stored on which type of memory modules?
a. DIMMs
b. SIMMs
c. PIMMs
d. RIMMs

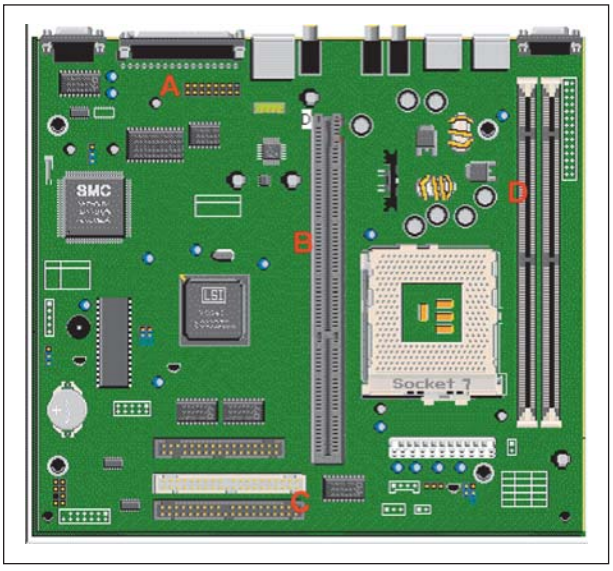
7. Which of the following statements best describes the process used to refresh PC system memory?
   a. An electric charge is periodically sent to each DRAM cell.
   b. Memory modules must be periodically removed from the PC and cleaned.
   c. The contents of physical RAM are periodically written to a hard disk and re-read into the memory chips.
   d. A software device driver optimizes the memory mapping of physical RAM.

8. The earliest SIPPs and SIMMs memory modules had _____ pins or contacts.
   a. 30
   b. 64
   c. 72
   d. 168

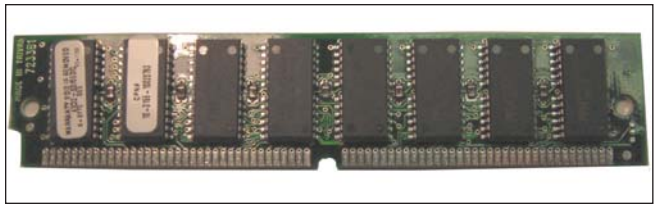
9. Which of the following was the earliest memory technology used in SIMMs modules?
   a. EDO
   b. Direct Rambus
   c. FPM
   d. SDRAM

10. 72-pin SIMMs have a data width of _____ bits.
   a. 8
   b. 16
   c. 32
   d. 64

11. Indicate the area on the motherboard diagram where you would install a DRAM memory module.
   a. _____
   b. _____
   c. _____
   d. _____



12. What type of RAM module is shown here?
   a. 168-pin DIMM
   b. DIPP
   c. 72-pin SIMM
   d. 30-pin SIMM



13. Which of the following four DRAM speed ratings indicates the fastest access time?
   a. PC100
   b. PC133
   c. 60ns
   d. 80ns

14. Which of the following DRAM technologies is likely to deliver the fastest memory performance?
   a. EDO RAM
   b. BEDO RAM
   c. Synchronous DRAM
   d. DDR-SDRAM

15. On a motherboard that uses odd parity, what value will the parity bit of the byte "10110010" have?
   a. 0
   b. 1
   c. None
   d. 8

16. What are the extra clock cycles inserted by the memory controller chip to allow older RAM modules to catch up with the CPU called?
   a. Wait states
   b. Delay states
   c. System states
   d. Latency stalls

17. The data path for SDRAM on DIMM modules is _____ bits wide.
   a. 16
   b. 32
   c. 64
   d. 128

18. What is 266 MHz DDR-SDRAM also called?
   a. PC100
   b. PC266
   c. PC2100
   d. PC2700

19. When installing one Rambus RDRAM module, if the motherboard has two RIMM slots, the second slot _____.
a. Should be left empty
b. Should be filled with a C-RIMM module
c. Should be filled with a SIMM module
d. Should be filled with a SODIMM module

20. In C-RIMMs, what does the C stand for?
a. Correcting
b. Concurrent
c. Continuity
d. Cache

21. If the motherboard does not specify the method used at boot time to detect the type of memory installed, assume _____.
a. CL
b. PPD
c. SPD
d. ECC

22. A memory ad lists 32x72 SDRAM DIMMs modules at $120 each. Each module contains _____ MB of _____ DRAM.
a. 64 MB of standard SDRAM
b. 128 MB of ECC SDRAM
c. 256 MB of standard SDRAM
d. 256 MB of ECC SDRAM

23. If you are using DDR 333 MHz memory in your PC, what should be the front side bus speed of the motherboard?
a. 100 MHz
b. 166 MHz
c. 200 MHz
d. 400 MHz

24. Your computer uses 184-pin DDR-SDRAM, and has a 128 MB module inserted in Memory Bank 0. You add a 64 MB module to Bank 1 and reboot the computer. The POST test still reports 128 MB of RAM. What is the most probable reason that the added memory is not recognized? (Select the best choice.)
a. The 64 MB module should be in Bank 0.
b. The BIOS is outdated.
c. The new module is not seated properly in its slot.
d. DDR-SDRAM modules must always contain the same amount of RAM. You should have added another 128 MB module instead of a 64 MB module.

25. The first 640 KB of memory on a PC is called _____ memory.
a. Conventional
b. Primary
c. Lower
d. Main

26. The hexadecimal address F0000h is equivalent to _____ in decimal.
a. 64 KB
b. 640 KB
c. 960 KB
d. 1024 KB

27. The VGA video BIOS on the display controller is usually mapped to the hexadecimal address area _____ in reserved memory.
a. F0000h–100000h
b. C0000h–D0000h
c. B0000h–C0000h
d. A0000h–B0000h

28. For DOS programs and device drivers to run in upper memory, the _____ and _____ device drivers must be loaded in the DOS CONFIG.SYS file. (Fill in the blanks.)

29. The memory above 1 MB, recognized by 80286 and higher CPUs, is called _____ memory.
a. Middle
b. Upper
c. Conventional
d. Extended

30. What is the High Memory Area (HMA)?
a. The first 64 KB of conventional memory (0–64 KB), used to store device driver information
b. The first 64 KB of extended memory (1024–1088 KB), sometimes used to store portions of the MS-DOS COMMAND.COM file
c. The last 64 KB of conventional memory (576–640 KB), used to store application data
d. The first 64 KB of reserved memory (640–704 KB), used to store video graphical data

Projects: On Your Own

1. Test the RAM in your computer. Download and install a DOS memory testing utility, such as Memory Test 86 **(http://www.memtest86.com/)** or find another using a search engine on the Web. Once you have downloaded the memt.zip package, you will also need to download and install a Zip archive unpacker, such as WinZip, available at **(http://www.winzip.com)**.
   a. After installing WinZip, use it to open the memt.zip package and unpack the files to a directory on your hard disk.
   b. Locate a formatted floppy diskette and run MemTest's RAWRITE installation utility to install MemTest86 on the floppy diskette. See the README.TXT file included in the package for more details.
   c. Reboot the computer from the floppy diskette and the MemTest utility will automatically start up and begin to test your computer's installed memory.
   d. See if you can find additional PC testing software online through use of an Internet search engine. AMIDIAGs is an older, industry-standard testing suite created by the American Megatrends, Inc. BIOS manufacturer. To find a download source for this package, enter "download AMIDIAGS" in a Web search engine. Currently, AMIDIAG is available at **http://www.amidiag.com/support/dl.cfm**.
2. Go to a local computer store or weekend computer show and check out the prices for the RAM on sale there.
   a. Look at the motherboards on sale in the store and try to determine whether they use SDRAM, DDR-SDRAM, or Rambus RDRAM. See if you can answer the following questions:
      i. Which type of RAM appears to be the most popular?
      ii. How much RAM are the motherboards designed to hold (minimum and maximum)?
      iii. On average, how many slots and banks are present on motherboards designed for each RAM type? (Are there odd numbers or even numbers of slots?)
   b. Inspect the documentation for some of the motherboards and see if you can determine exactly what kind of memory they take (memory technology, access speed, error checking status, registered or unregistered).
   c. After looking at a few motherboards, choose one and bring it to a salesperson. Ask the salesperson what kind of RAM the motherboard uses and see whether the answer you get agrees with your own determination.
   d. Write down the prices for SDRAM, DDR-SDRAM, and Rambus RDRAM in a few sizes and speeds. When you get home, go online and compare those prices with nationally advertised prices for RAM at chain stores, such as Fry's or Circuit City, or an online memory vendor, such as The Chip Merchant **(http://www.thechipmerchant.com)** or Provantage **(http://www.provantage.com)**. You can find other memory vendors on the Web using a search engine.

Problem Solving Scenarios

1. You work for a nonprofit organization that has a number of older PCs with Pentium Socket 7 motherboards. These systems have four RAM slots for 72-pin SIMMs. Currently, each system has 2x32 EDO SIMMs installed in two of the slots, with 16 MB of RAM reported. You are asked to upgrade each PC to 64 MB of RAM. How should you proceed? (Can you use the RAM modules already installed in the computers? What size and type of new RAM modules will you need to buy? How should they be installed?)