LESSON 2

Microprocessors and the CPU

The CPU (central processing unit) is the most important chip in your computer. The CPU—like all computer chips—is a machine that executes programmed instructions written by programmers. The instructions that the CPU executes manipulate the data you send to it through the operating system (such as Windows XP or Linux) and application programs (such as Microsoft Word or Netscape Navigator).

The performance of a computer system depends on a number of factors. The system's CPU performance is obviously one factor, but the performance of other chips and components on the motherboard can be of equal or greater importance. To work efficiently, the CPU must be able to communicate with other components on the motherboard, and other parts of the computer. Therefore, the performance of the entire computer system depends, in part, on the capabilities of the motherboard's communication channels. As described in the following section, the CPU is typically just one of several chips. It is part of a **chipset** that performs the work of the computer system.

The majority of CPU chips installed in today's PCs are manufactured by Intel, or by its principal competitor, Advanced Micro Devices (AMD). International Business Machines (IBM) and other companies, such as Cyrix and Transmeta, Inc., have also offered alternatives to the standard Intel family of processors. The early Intel CPUs were all numbered models: 8088, 8086, 80286, 80386, and 80486. Intel named the successor to the 80486 the Pentium instead of 80586, partly to establish a brand name that could be distinguished in the market place from competing products produced by AMD. Following Intel's lead, AMD soon established its own branded chip names: K5, K6, Duron, and Athlon, for Intel-compatible CPUs.The newer generations of CPUs, such as Intel's Pentium 4 and Itanium and AMD's Athlon family, are much more powerful than earlier generation chips.

Goals

In this lesson, you will learn about the internal functions and operations of CPUs designed for Intel-compatible PCs. You will learn about clock cycles and how data is conducted through the motherboard though data paths called buses. You will also learn about the relationship of the CPU to other components on the motherboard, such as RAM and memory caches. You will learn about the different methods for cooling CPUs. Additionally, you will learn about the different features of popular CPU families and how to identify CPU chips by manufacturer and family. Finally, you will learn how to determine what type of CPU is in your computer, how to match a CPU to a motherboard, and how to remove and install a CPU on the motherboard.

Requirements

To complete this lesson, you will need a computer running a Windows-based operating system. To complete the step-by-step exercises, you will need a Windows-based computer for dismantling and removing the CPU; a replacement CPU for installing on the computer's motherboard; and a Socket 7 motherboard.

Lesson 2 Microprocessors and the CPU

Skill	***A+ Hardware Objective***
1. Identifying CPU Functions and Operations	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
2. Understanding CPU Performance Specifications	**4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
3. Identifying the CPU Chip Installed in a Computer	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
4. Identifying CPUs by Manufacturer, Model Name, and Marketing Generation	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
5. Identifying CPU Chips by Features and Performance Specifications	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
6. Understanding Features and Performance Specifications of First Through Fourth Generation CPUs	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
7. Understanding Features and Performance Specifications of Fifth Generation CPUs (The Classic Pentium and Its Competitors)	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
8. Understanding Features and Performance Specifications of Sixth Generation CPUs (Intel PII—PIII, AMD K6, K6-2/3)	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.

Lesson 2 Microprocessors and the CPU (cont'd)

Skill	A+ Hardware Objective
9. Understanding Features and Performance Specifications of Seventh Generation and Current CPUs	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
10. Identifying Standard CPU Packages	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
11. Identifying Standard CPU Sockets and Slots	**1.1** Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
12. Matching CPUs and Motherboards	**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. **4.1** Distinguish between the popular CPU chips in terms of their basic characteristics.
13. Understanding CPU Cooling Systems (Heat Sinks, Fans, Liquid Cooling)	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios. **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.
14. Installing a CPU and Heat Sink/Fan on a Motherboard with Slot Architecture	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under give scenarios. **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.
15. Installing a CPU and Heat Sink/Fan on a Motherboard with Socket Architecture	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under give scenarios. **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.
15. Working with Multiple Processors	**1.9** Identify procedures to optimize PC operations in specific situations. Predict the effects of specific procedures under given scenarios.

skill 1 Identifying CPU Functions and Operations

A+ Hardware objective

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

overview

An understanding of the principles of CPU operation will make you a better PC support technician. To begin with, let's look at the basic functions a CPU performs: When you save a document in a word processor or browse a page on the Internet with a Web browser, the keyboard and mouse translate your requests into a series of binary instructions and data. As discussed in Lesson 1, the motherboard sends this information to the CPU in strings of 1s and 0s (binary bits and bytes). The CPU receives information from RAM or ROM, executes instructions, manipulates data, and returns the results to RAM (**Figure 2-1**).

CPUs contain banks of tiny transistors embedded in a chip called a **processor die**. The transistors act as switches to store information. Each switch can be set to either a value of 1 (on) or 0 (off).

All Intel-compatible CPUs contain banks of these switches, with 16 switches per bank. Programmers refer to these switch banks as **registers**. Each register can be used to store two 8-bit bytes (or 16 bits) of information at any given time. The 16-bit data registers in a PC CPU are identified alphabetically, as AX, BX, CX, and DX (short for Accumulator, Base, Counter, and Data). Additional registers, called DI, SI, SP, and BP (short for Destination Index, Source Index, Stack Pointer, and Base Pointer), are used to create an index for the information stored in the data registers. Modern CPUs extend the size of the data registers to 32 bits or 64 bits, as we describe later in this lesson.

Data registers store temporary arithmetic values for current (or near current) data on which the CPU is about to operate.

The CPU also includes a set of special purpose registers. Of these, the most important is called the **program counter** (or IP register). The program counter stores the memory address of the next instruction the CPU will execute until it is time to transfer this request to the instruction register. The program counter then gets the memory address of the next instruction. (**Figure 2-2**).

Inside the CPU, several physical components cooperate to carry out user instructions. The **execution unit** interprets instructions received from programs loaded into the computer's RAM by the control unit. The **control unit** is part of the execution unit and directs data flow between the CPU and RAM installed on the motherboard. It can also receive instructions from the computer's ROM BIOS during the boot process. If the instructions received by the execution unit call for mathematical operations on stored data, the execution unit passes the data to the **arithmetic logic unit (ALU)**, which performs the necessary calculations. An ALU is part of the execution unit and is a set of electronic switches contained within the chip that can compare binary numbers, performing addition, subtraction, multiplication, and division operations. Before Intel developed its Pentium processor in 1994, each CPU contained only one ALU. Beginning with the Pentium series, all Intel CPUs have two ALUs, allowing them to execute two arithmetic operations at the same time.

The CPU includes a group of hard-wired computer code instructions called an instruction set. The **instruction set** allows the CPU to move binary information into and out of its registers, perform arithmetic calculations, and communicate with the computer's other hardware components. For the CPU to do this work, programmers use the chip's instruction set, issuing commands to read, write, manipulate, and display information. Operating systems and software applications are collections of these kinds of data-manipulating commands. The operating system and applications are usually stored on disk media. Some small, basic programs that are used to start and manage the computer are stored in the hardware of the computer's ROM BIOS. When the user makes a request to run a program, the program is read into

Figure 2-1 CPU to RAM

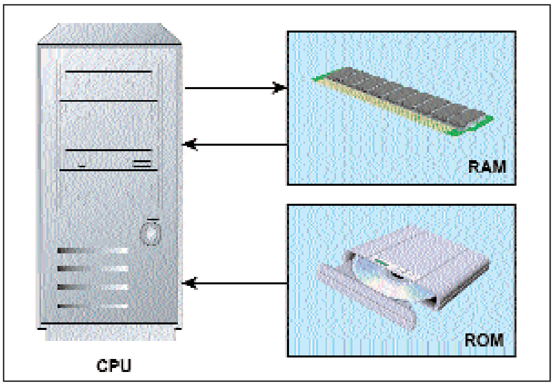


Figure 2-2 Parts of a CPU

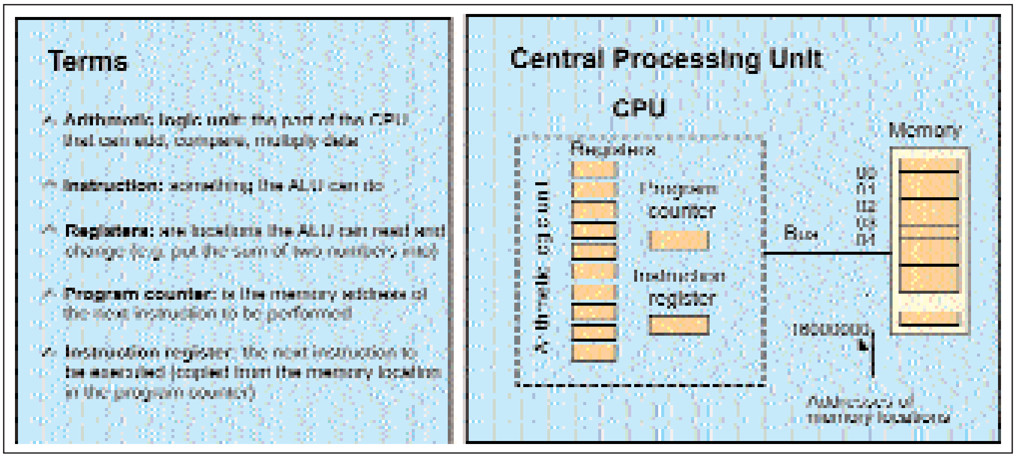
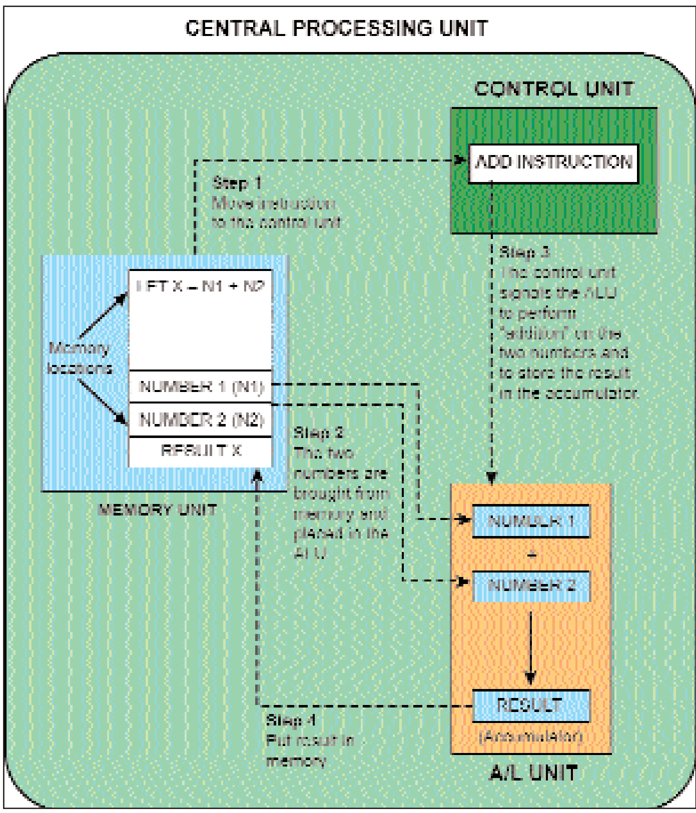


Figure 2-3 How the CPU works



The CPU receives instructions and information from RAM through a control unit; it calls on the execution unit and arithmetic logic unit to perform calculations and dispatch the results back to RAM

skill 1

Identifying CPU Functions and Operations (cont'd)

A+ Hardware objective

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

overview

RAM and transmitted, in smaller pieces, to the CPU. The procedure that reads information from a disk and stores it in RAM constitutes a program, in itself.

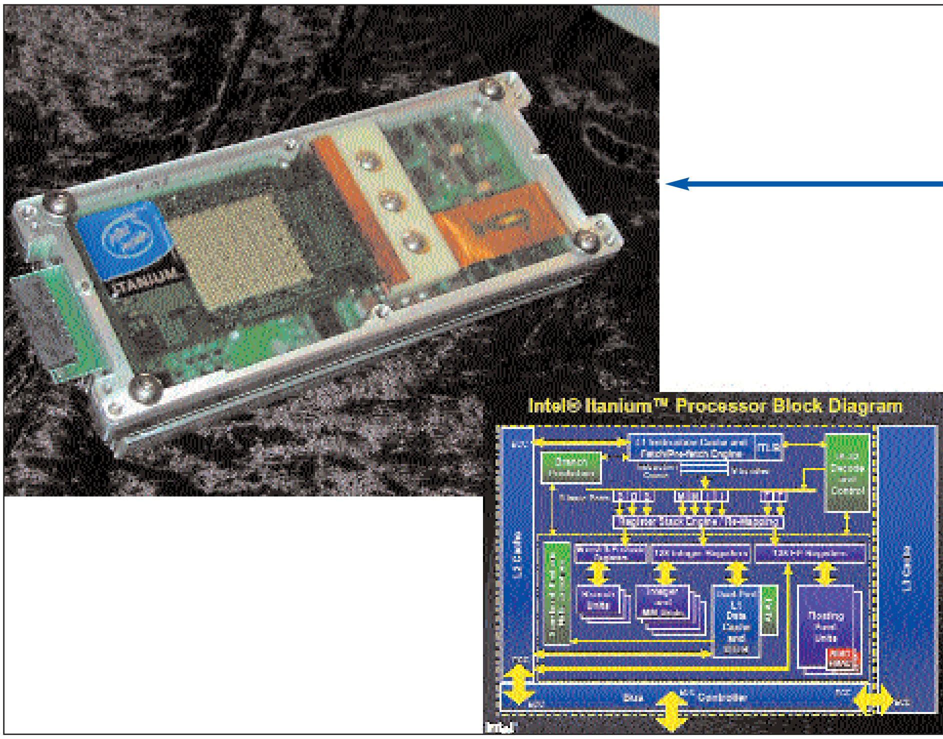
Microprocessors designed for Intel-compatible personal computers make use of a design architecture called **CISC (Complex Instruction Set Computing)**. CISC CPUs contain a large set of built-in instructions for manipulating binary data. The CISC model was developed at a time when available storage space, both in computer memory and on disk media, was at a premium. The CISC design allowed software programmers to streamline the size of their programs. Instead of specifying many lines of complicated code in applications, programmers could invoke functions built directly into the processor chip. Intel Pentium and AMD Duron/Athlon CPUs use nearly identical versions of a CISC instruction set called x86. Internally, the physical layout of the Intel and AMD processors is quite different, but they can all run the same operating systems and software applications.

By way of contrast, the CPUs manufactured for today's Macintosh computers contain a smaller instruction set, the **RISC (Reduced Instruction Set Computing)** model. The RISC model was popularized after research conducted in the 1990s in which computer scientists found that almost 80 percent of the work done by the computer was performed by about 20 percent of the instructions wired into a CISC processor. If the size of the CPU instruction set was reduced, the processor could execute the reduced set of instructions much more rapidly. The drawback of the RISC architecture is that when programs use instructions not available in the RISC chip instruction set, these instructions must be written into the program, moved to RAM, and then executed by the CPU.

Intel's latest design model for PC processors, the **Itanium (Figure 2-4)**, makes use of a new instruction set called **EPIC (Explicitly Parallel Instruction Computing)**. The EPIC instruction set has been tailored to optimize performance speed for applications compiled with the most recent software tools. Intel has radically redesigned the internal architecture for its most recent generation of CPUs, giving them a larger, 64-bit **memory address space**, larger data storage capacity, and improved performance speed.

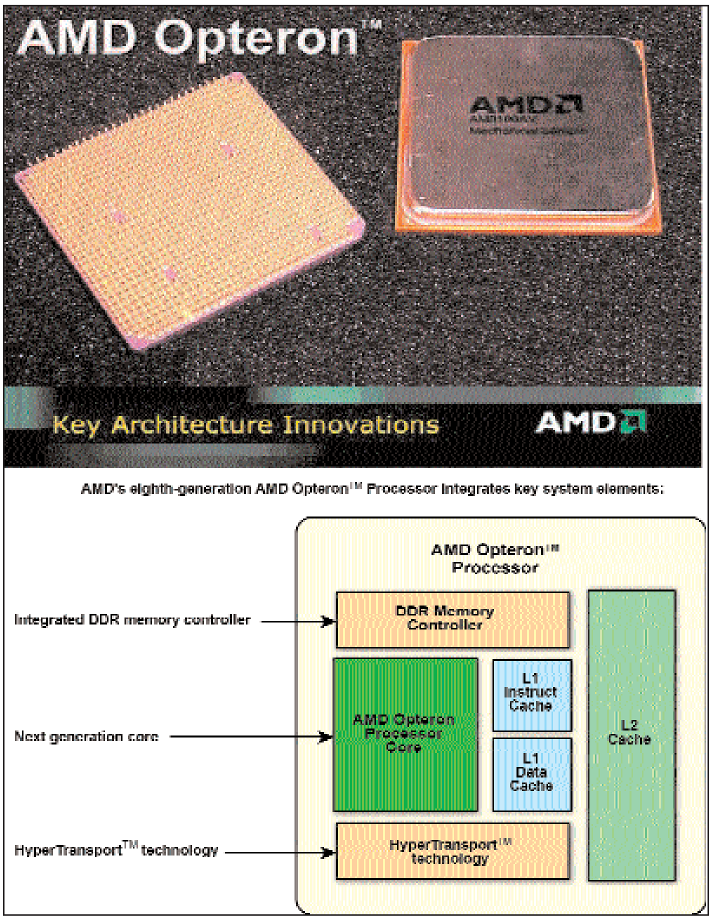
Intel's chief competitor, AMD, has also developed a new family of CPUs. AMD's new CPUs share some of the improved features of the Itanium, such as a larger memory address space. But AMD's **Opteron** and **Athlon 64** models continue to use the traditional CISC x86 instruction set **(Figure 2-5)**. This gives them the advantage of greater compatibility with existing PC operating systems and applications. Whereas PCs with Intel's new Itanium CPUs will require brand new 64-bit versions of all Windows operating systems, PCs with AMD's Athlon 64 processors will run the traditional 32-bit versions of Windows as well as the new versions. You will learn more about the features of the new 64-bit processors from Intel and AMD in Skill 5 in this lesson.

Figure 2-4 Intel Itanium CPU



Intel's new Itanium family of CPUs delivers faster performance through use of the new EPIC instruction set

Figure 2-5 AMD Opteron key architecture



skill 2 Understanding CPU Performance Specifications

A+ Hardware objective

4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

We measure the performance speed of the motherboard and the CPU in intervals of time called **clock cycles**. A **Hertz (Hz)** is a unit of measure that defines a single clock cycle in 1 second of time. One megahertz (1 MHz) is equal to one million cycles.

In early PCs, the flow of information from peripherals to expansion card to RAM to CPU took place at a uniform speed throughout the motherboard. The original IBM PC, released in 1981, executed 4.77 million instructions per second, one instruction per clock cycle, for a rated speed of 4.77 MHz. Today's CPUs are much faster, executing instructions at speeds measured in billions of cycles per second: 1 to 3 gigahertz (GHz). 3 gigahertz is equal to 3000 megahertz or 3 billion Hz. PC motherboards and their internal components (such as RAM chips, expansion slots, adapter cards, and input/output ports) have also increased their processing speed to keep pace with new developments in CPU technology.

CISC and RISC model processors are both designed to execute a fixed number of instructions within a clock cycle. Originally, a crystal chip called the **system clock** regulated the number of clock cycles that occurred within one second of time for all components on the motherboard. The path of traces (circuit paths) that conducted data through all parts of the motherboard was referred to as the **system bus**.

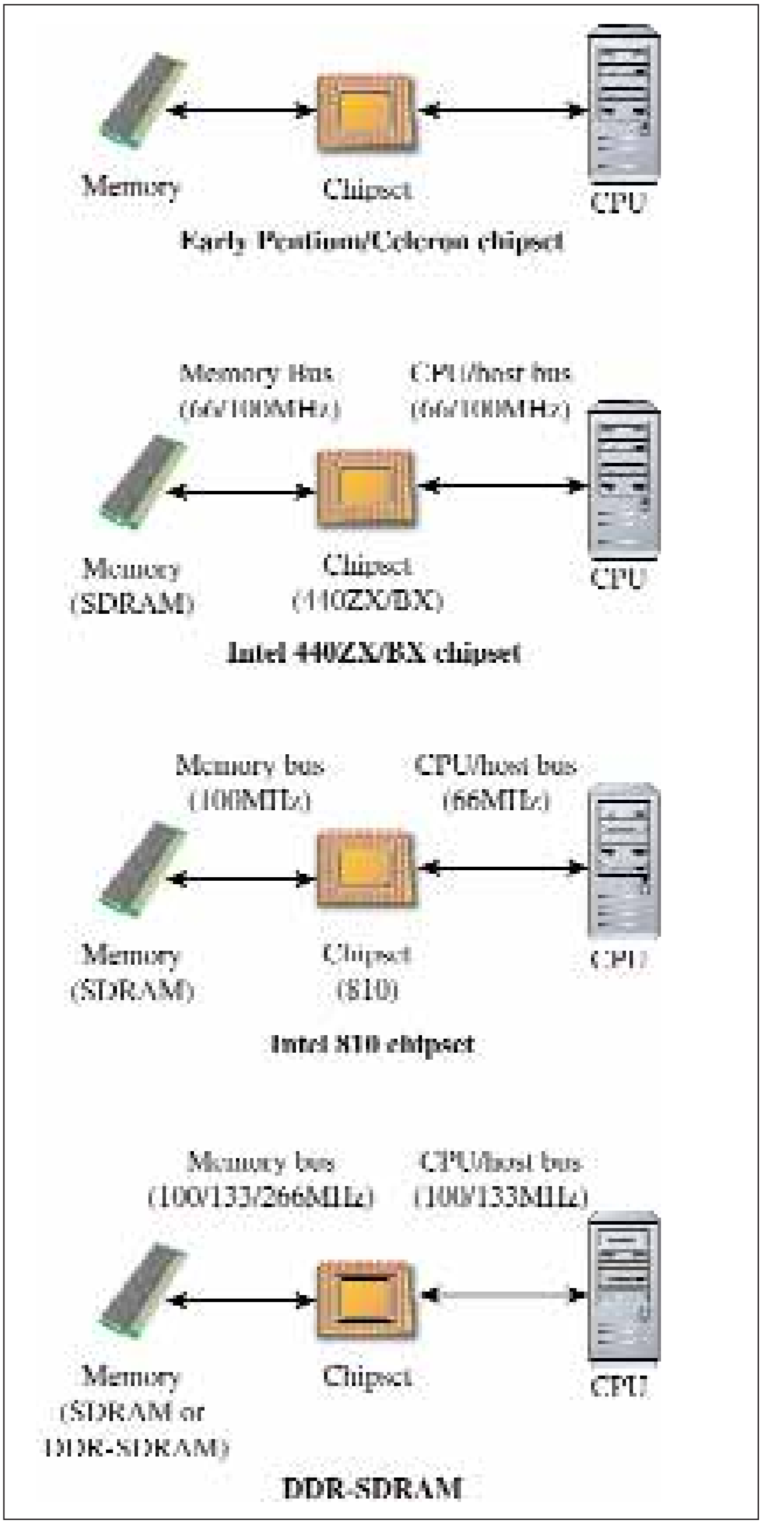
In today's computers, the CPU no longer operates at the same speed (or frequency) as other motherboard components. When Intel introduced the Pentium family of CPUs in 1994, the basic architecture of the PC motherboard was redesigned. The structure of the system bus was redefined to speed up the flow of data between the CPU and RAM. All motherboards that support Intel Pentium I, Pentium Pro, AMD K5/6, Cyrix 686, and subsequent microprocessors now include a feature called the **front side bus (FSB)**.

The front side bus frees the CPU from the necessity of communicating directly with slower motherboard components. It allows information to flow directly between the CPU and RAM in 64-bit chunks, at an increased system **clock speed** (frequency, also referred to as **processor speed**.) The increased frequency is implemented with a special chip called a **clock multiplier**. On some motherboards, the frequency of the front side bus can be varied to accommodate CPUs that run at higher and lower internal clock speeds (described in Skill 12).

The front side bus has two bus components. The **data bus** (or memory bus) carries programs and related data between the chipset that controls the bus connection and RAM. The **CPU/host bus** connects the managing chipset to the CPU. On modern motherboards, the memory bus and CPU/host bus may run at different clock speeds. Intel still refers to both buses, collectively, as the front side bus, because in its early implementation with Celeron/Pentium II/III chipsets, both buses ran at the same speed **(Figure 2-6)**.

The internal data path within the CPU itself is sometimes called the **back side bus (BSB)**. In current CPU models, the back side bus includes special RAM chips attached to the CPU to improve its performance (described in Skill 6).

Figure 2-6 Front side bus



On modern motherboards, the data bus and address bus may run at different clock speeds; Intel still refers to both buses, collectively, as the front side bus, because in its early implementation with Celeron/Pentium II/III chipsets, both buses ran at the same speed

skill 2

Understanding CPU Performance Specifications (cont'd)

A+ Hardware objective

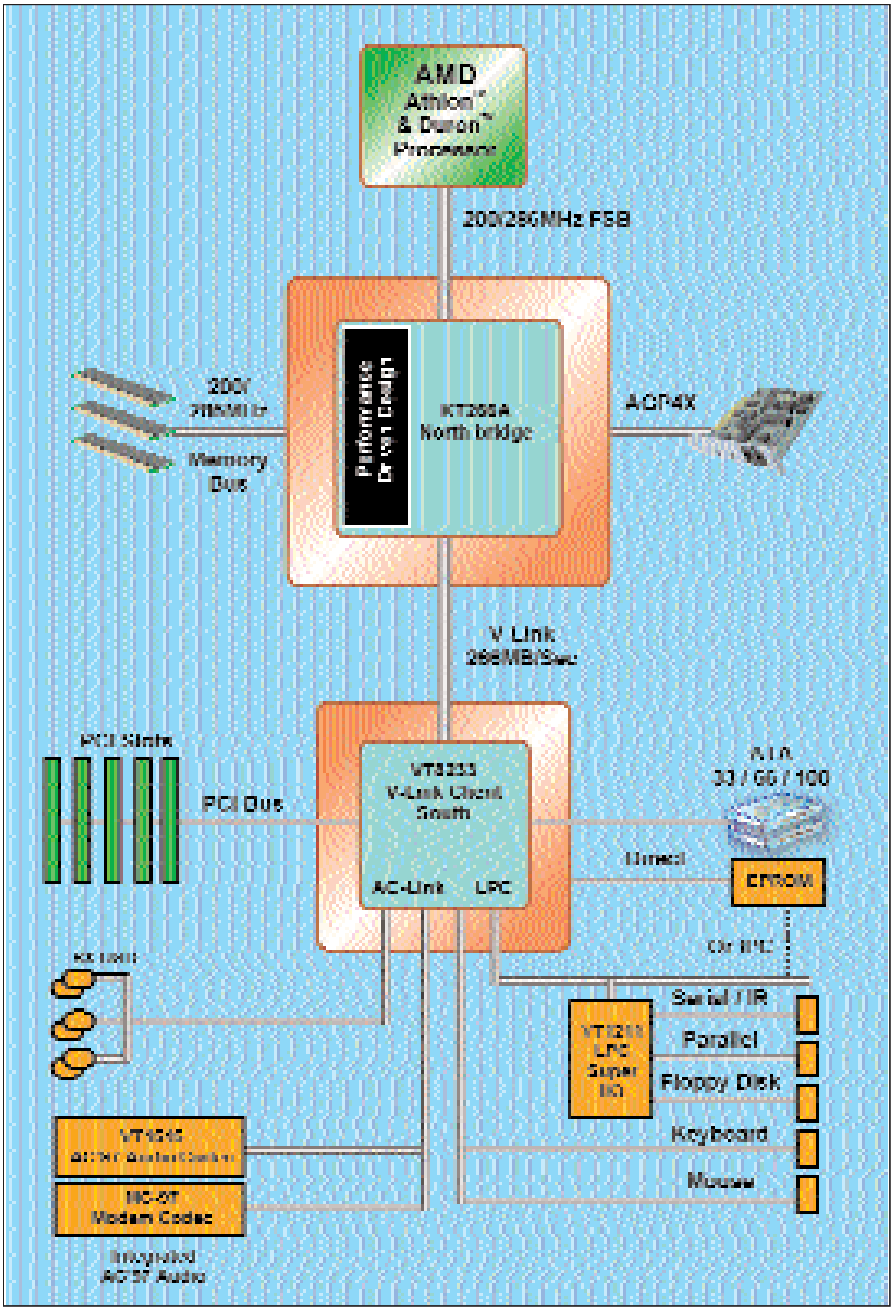
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

more

On pre-Pentium computers, the terms *system bus* and *host bus* were used to describe the data path connecting the CPU to the entire motherboard. On modern motherboards, *system bus* now refers to the FSB data path, which terminates with the RAM chips. A new set of chips, called the **North Bridge** and the **South Bridge**, regulate the flow of data from RAM to other motherboard components. The purpose of these changes was to increase the processing speed of the entire computer system; specifically to coordinate increasingly fast CPUs with other components on the motherboard. Some of these components can no longer work as fast as the CPU; therefore, Intel and other chip makers have taken steps to isolate the higher performance CPU from slowing performing components. Several years ago, Intel introduced a series of motherboard chipsets, referred to as the i800 family that, again, redefined the architecture of Pentium motherboards. Beginning with the i810 chipset, the connection between the front side bus and slower I/O buses on the motherboard is managed by using a hub interface architecture. The front side bus connects to the North Bridge, which is a series of chips that control the computer's memory and other fast components, such as an AGP display adapter. The North Bridge is connected to the South Bridge, a chip that communicates with slower motherboard components (such as expansion slots and I/O ports). In the Intel architecture, the North Bridge chips regulate the computer's RAM, and AGP video adapter (if present). The South Bridge chips regulate I/O ports (keyboard, serial, parallel, IDE, and USB), the PCI bus, and ISA expansion slots (if any) **(Figure 2-7)**.

Other manufacturers' chipsets differ slightly from Intel's. In some designs, the PCI bus extends to a path that connects the North Bridge and South Bridge chip controllers. But the end result is the same: Components that accept and return information at higher speeds connect to the front side bus at the North Bridge. Components that run at a slower speed connect at the South Bridge.

Figure 2-7 North Bridge and South Bridge



The CPU connects to faster system components, such as RAM and the AGP video bus, through the North Bridge; slower components, such as I/O ports and the sound card, connect through the South Bridge

skill 3

Identifying the CPU Chip Installed in a Computer

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics, of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

There are several techniques you can use to identify the CPU in your computer without opening the case.

- Read the documentation supplied with the computer. Specifications for the computer's internal components may appear on a page near the front or the back of the user manual. Alternatively, if the computer was custom-built by a small shop, the CPU type may appear in a parts list on the sales invoice.
- Examine the information displayed in your computer's boot process.
- View your computer's Properties sheet.
- Many free diagnostic utilities allow you to gain a more complete picture of your computer's hardware configuration. PC Wizard, which can be downloaded over the Internet at **http://www.cpuid.com/index.php**, provides a wealth of information about your PC. To download and install PC Wizard: connect to the Internet, open your web browser and enter **http://www.cpuid.com/index.php** in the browser's address window. Right-click the **Download PC Wizard** link, choose **Save target as** from the pop-up menu, and save the installation file to your My Documents folder. After the file has been downloaded, open the My Documents folder and launch the installation program. Follow the on-screen prompts. After PC Wizard is installed, launch the program and click the processor icon to gain information about the CPU installed in your computer **(Figure 2-8)**.
- As an alternative to detecting and identifying your computer's CPU with software, you can open the computer's case and inspect the CPU chip on the motherboard. Once you locate the CPU, the manufacturer's name and processor is usually stamped on the chip. You may need a magnifying glass and a flashlight to read this information.

how to

Gather information about your CPU from your computer's boot process and Properties sheet.

1. If your computer is running, shut it down and restart.
2. After you power on the computer to start the boot process, watch the diagnostic screens that appear before the Windows operating system loads **(Figure 2-8)**. Depending upon the manufacturer, you may see detailed information about the computer's BIOS, installed RAM, CPU, and hardware components; or you may see only a corporate splash screen.
3. If your computer displays diagnostic information, temporarily halt the boot process by pressing the Pause key on your keyboard.
4. After you record information from the screen, press the spacebar to resume the boot process.
5. In Windows 9.x, NT 4, and 2000, you can right-click My Computer on the desktop and choose Properties from the pop-up menu to gain partial information about the installed CPU. Windows XP provides a more complete information screen **(Figure 2-10)**.

Figure 2-8 PC Wizard CPU information screen

This diagnostic utility can be downloaded from: **http://www.cpuid.com/index.php**

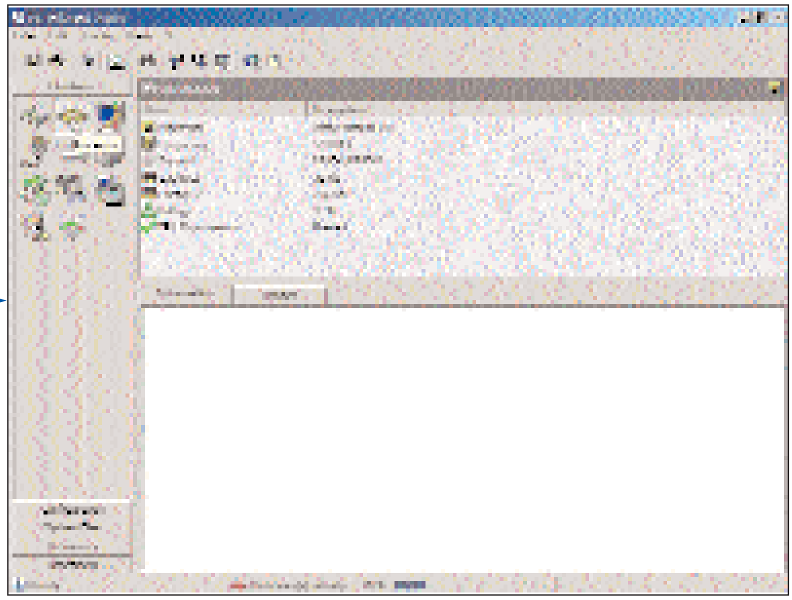
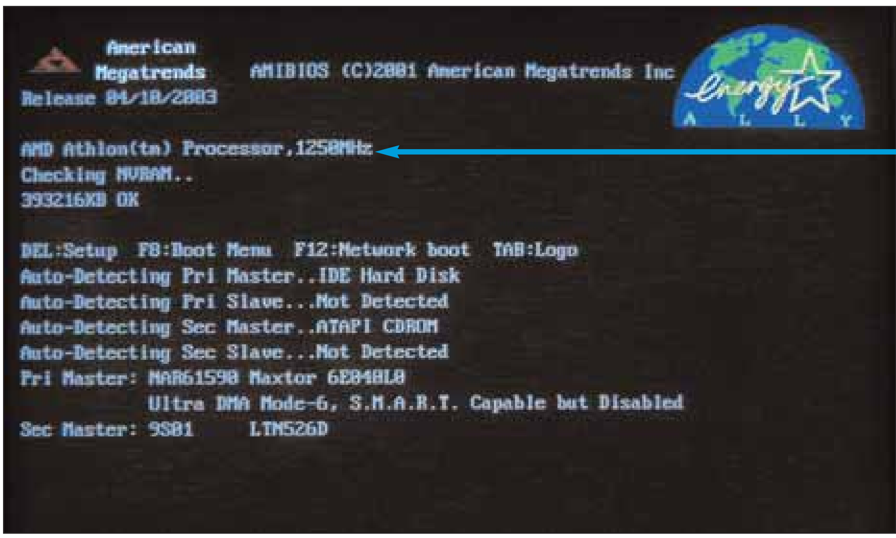


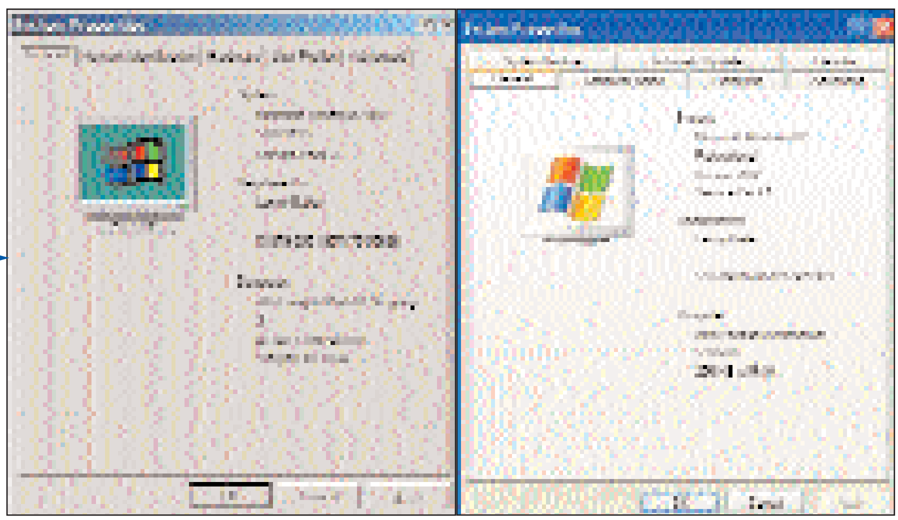
Figure 2-9 CPU information on PC startup screen



This computer has an AMD Athlon 1250MHz processor

Figure 2-10 Windows 2000 and XP System Properties

Windows 2000 System Properties (on the left) shows less specific information about your computer's CPU than Windows XP System Properties (on the right)



skill 4

Identifying CPU Chips by Manufacturer, Model Name, and Marketing Generation

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

The history of CPU production for personal computers is closely tied to two important companies: IBM (International Business Machines, Inc.) and Intel Corporation. Intel designed the first processor chips targeted for microcomputers in the 1970s. Intel eventually joined forces with IBM to create the popular IBM PC. The first IBM PC, marketed in 1981, ran on a very simple Intel CPU, called the 8088.

In 1965, Gordon Moore, then Chief Executive Officer of Intel Corporation, predicted that the number of transistors per integrated circuit in PC CPUs would double every 18 months. This formulation, called **Moore's Law**, turns out to have underestimated the rapid advances in CPU technology over the last quarter of the twentieth century. In the last few years, microprocessors have in fact been doubling in power almost every 12 months, although this rate of increase may slow down in the future.

To understand the incredibly rapid evolution of PC microprocessors since the Intel 8088, it can be useful to categorize microprocessor production into periods referred to as generations. The number of transistors used on each generation of microprocessors can be observed as a partial gauge of microprocessor power (**Table 2-1**). Intel's 8086 and 8088 processors made up the first generation (1978) of CPUs; the 80286 processor was the second generation; and 80386, the third generation, appeared in 1988. The number of transistors on microprocessors increased in this 10-year period from about 29,000 to 275,000. By the second generation, Intel had licensed the right to manufacture clones of its PC processors to another company, AMD (Advanced Micro Devices). The 80486 is considered to be the **fourth generation** of PC CPUs, introduced in 1990 with 1.2 million transistors.

In the fifth generation, Intel abandoned the x86 naming scheme, as you learned earlier, calling its new CPU the Pentium. Intel also withdrew permission, at this time, to license and distribute direct clones of its microprocessor products. AMD and other companies, such as IBM and Cyrix, responded by producing CPUs that were no longer exact clones of the Intel models. The CPUs manufactured by these rival companies had new names, such as AMD K5, and Cyrix 6X86; but they all used the x86 instruction set, allowing them to run the same operating systems. Microprocessors of this generation came with about 3 million transistors.

The sixth and seventh generations of PC microprocessors included new, improved Pentium families from Intel (Pentium Pro, Celeron, Pentium II, III, 4) and new AMD families (K6, K6-2, K6-3, Athlon, Duron, Athlon Thunderbird). By 2000, microprocessors contained about 40 million transistors; and the current Pentium 4 contains about 55 million transistors.

more

Can microprocessors and computer systems keep doubling in speed every 18 months forever? Is Moore's Law true for all time? The answer to these questions appears to be both yes and no. Two factors are behind Moore's Law: increasing the number of transistors per chip (the density of components), and increasing the clock speed of the processor. Increasing density depends in turn on how fine or small the circuits can be drawn on the silicon substrate. Using current technology, circuits are drawn at 1 micron (1/1000th of a millimeter); and there appears to be steady progress in shrinking the size of transistors and traces. Ultimately, transistors could be comprised of single molecules. So the number of transistors per chip continues to increase at about the same pace as before. However, recent progress in increasing the frequency of oscillations, or clock speed, appears to have slowed somewhat. Implementation of faster CPU clock speeds will likely slow somewhat more in the near future, because of the destructive impact of heat generated by high frequency oscillations. But even this barrier can be overcome by better heat dissipation, reducing the voltage of the chip, and by putting many CPUs on a single chip.

Table 2-1 Seven Generations of PC CPUs

PC	CPUs	Year	Number of transistors
First generation	Intel 8086 and 8088	1978–81	29,000
Second generation	Intel 80286AMD issued clones of these chips under Intel license	1984	134,000
Third generation	Intel 80386DX and 80386SX AMD issued clones of these chips under Intel license	1987–88	275,000
Fourth generation	Intel 80486SX, 80486 DX, 80486DX2 and 80486DX4 AMD issued clones of these chips under Intel license	1990–92	1,200,000
Fifth generation	Intel Pentium Cyrix 6X86 AMD K5 IDT WinChip C6	1993–95 1996 1996 1997	3,100,000 -- -- -- -- 3,500,000
Improved fifth generation	Intel Pentium MMX IBM/Cyrix 6x86MX IDT WinChip2 3D	1997 1997 1998	4,500,000 6,000,000 6,000,000
Sixth generation	Intel Pentium Pro AMD K6 Intel Pentium II AMD K6-2	1995 1997 1997 1998	5,500,000 8,800,000 7,500,000 9,300,000
Improved sixth generation	Intel Mobile Pentium II Intel Mobile Celeron Intel Pentium III AMD K6-3 Intel Pentium III CuMine	1999	27,400,000 18,900,000 9,300,000 29,000,000 28,000,000
Seventh generation	AMD original Athlon AMD Athlon Thunderbird Intel Pentium 4	1999 2000 2001	22,000,000 37,000,000 42,000,000

skill 5

Identifying CPU Chips by Features and Performance Specifications

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

Although counting transistors on a CPU chip is one way to gauge the power of modern microprocessors and to identify and distinguish the different models of CPUs, many other features are equally important in determining a CPU's features and overall performance. In this skill, we will be describing in some detail the features and performance of a broad range of CPU chips from 1978 to 2004, a period that encompasses essentially the entire history of personal computers. To understand the differences among the many different CPU chips produced in this period, you need a sense of speed, time, size, and distance in the world of CPUs. In addition, you need to understand the various features, besides numbers of transistors, that distinguish chips from one another.

Electrons on the surface of a chip travel at roughly the speed of light (approximately 127 million miles per second). Although the distances among components on a chip are truly microscopic, measured in millionths of an inch, electrons still take time to move from one component to another. Computer manufacturers gauge the speed of their chips and related components in bits per second, or some multiple of bits per second. Computer communication speeds for home cable or a DSL modem are measured in megabits per second (1 million bits per second, or 1 mb/sec).

The capacity of primary and secondary storage devices is measured in bytes. (Recall, from Lesson 1, that 1 byte, the basic unit of computer data storage, is composed of 8 bits.) The 8088 CPU designed for the first IBM PC had the capacity to address 1 megabyte (1 million bytes) of system memory. **Table 2-2** illustrates commonly used binary and decimal expressions used to characterize the data processing capacity of CPU chips and system memory.

One **kilobyte (KB)** is a binary unit of measure, roughly (but not exactly) equal to 1,000 bytes. Because units of measure in computers are based on the binary system, a kilobyte is actually 2^{10} (1,024) bytes, not 10^3 (1,000). Similarly, 1 megabyte (MB) = 2^{20} or 1,048,578 bytes. 1 gigabyte (GB) = 2^{30} or 1,073,741,824 bytes. Note that the abbreviations for kilobytes, megabytes, and gigabytes use capital letters. The convention used in this book is lowercase letters for bits (1 kilobit = 1 kb) and uppercase letters for bytes (1 kilobyte= 1 KB). You will find more information about commonly used measures of bits and bytes, kilobits and kilobytes, and larger units of binary measure in Lesson 3 (primary storage) and in Lesson 7 (secondary storage).

In addition to the sheer number of transistors on a chip, there are five other key features of the microprocessor that influence its ability to process data. After reviewing this set of features, you will understand that speeding up the communication paths that connect computer system components is an important element in increasing overall computer system speed, and therefore, performance power (**Figure 2-11**). In subsequent pages and tables (**Tables 2-3, 2-4**, and **2-5**), these five key features are illustrated, when we describe the different generations of CPU chips in detail.

- **Internal data bus width:** The larger the internal data bus width, the more data that can be moved on the surface of the chip, and the more data that can be processed in a single machine cycle. This translates directly into processing more bits per second. CPU internal data bus width increased from 16 bits in the first generation to 32 bits in the third generation. Internal data bus width remained fixed at 32 bits through the Pentium 4 and Athlon Thunderbird CPUs of the seventh generation. The internal data bus width increased to 64 bits in the most recent generation of AMD (Opteron/Athlon-64) and Intel (Itanium/Itanium 2) microprocessors. For this reason, they are frequently referred to as 64-bit processors.

Table 2-2 Binary and Decimal Measures

Binary Measures

Unit	Power of 2	Bytes
Kilobyte	2^{10}	1, 024
Megabyte	2^{20}	1, 048, 576
Gigabyte	2^{30}	1, 073, 741, 824
Terabyte	2^{40}	1, 099, 511, 627, 776
Petabyte	2^{50}	1, 125, 899, 906, 842 ,624
Exabyte	2^{60}	1, 152,921, 504, 606, 846, 976
Zettabyte	2^{70}	1, 180, 591, 620, 717, 411, 303, 424
Yottabyte	2^{80}	1, 208, 925, 819, 614, 629, 174, 706, 176

Decimal Measures

Prefix	Power of 10	Units	Number
Kilo-	10^3	Thousands	1, 000
Mega-	10^6	Millions	1, 000, 000
Giga-	10^9	Billions	1, 000, 000, 000
Tera-	10^{12}	Trillions	1, 000, 000, 000, 000
Peta-	10^{15}	Quadrillions	1, 000, 000, 000, 000, 000
Exa-	10^{18}	Quintillions	1, 000, 000, 000, 000, 000, 000
Zetta-	10^{21}	Sextillions	1, 000, 000, 000, 000, 000, 000, 000
Yotta-	10^{24}	Septillions	1, 000, 000, 000, 000, 000, 000, 000, 000

skill 5 Identifying CPU Chips by Features and Performance Specifications (cont'd)

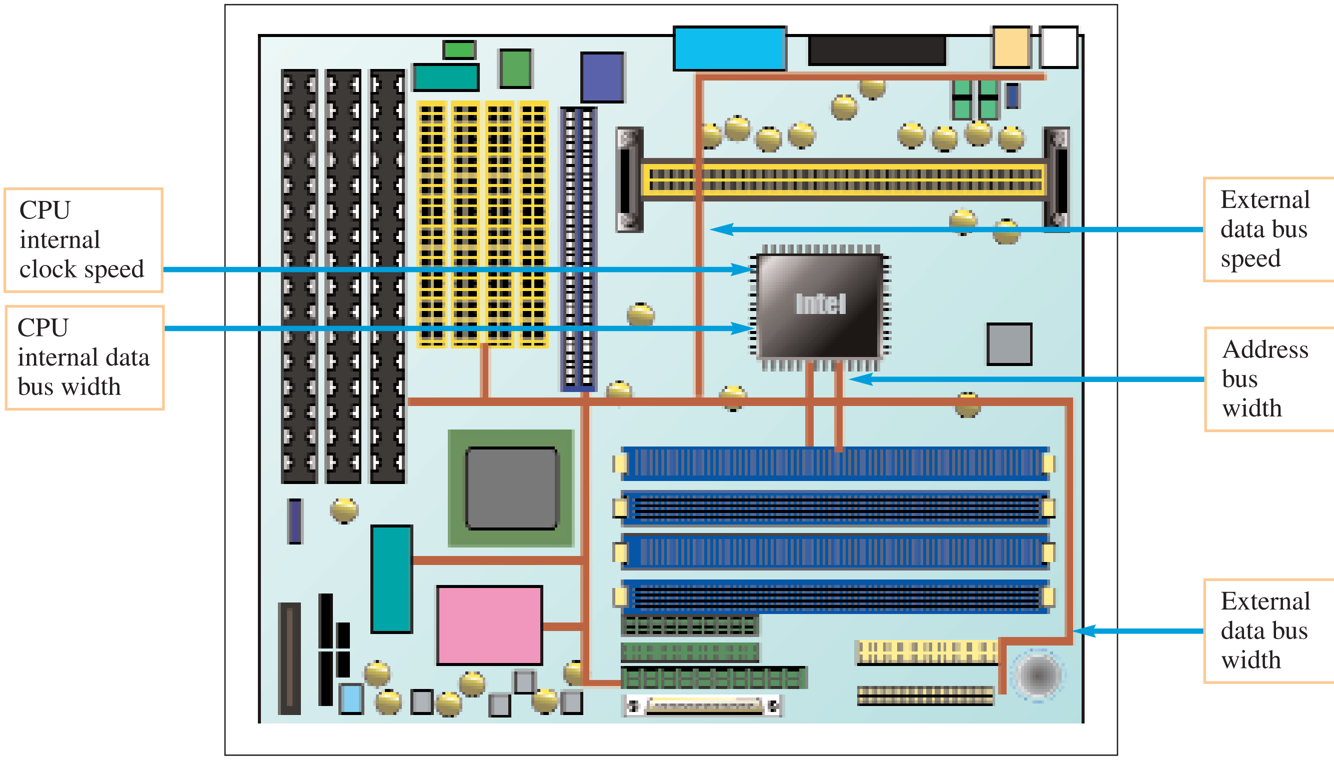
A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

- **External data bus width:** The larger the external data bus width, the more data that can be moved from RAM to the CPU in a single cycle. External data bus width increased from 8 bits in the first generation to 16 bits in the second generation and to 32 bits in the third generation. It jumped to 64 bits in the fifth generation, and remained constant until the 128-bit specification in the current (eighth) generation of AMD and Intel microprocessors.
- **Address bus width:** Address bus width (the largest amount of RAM that the CPU can address) increased from 20 bits (2^{20} storage states, or 1 MB) in the first generation to 24 bits (16 MB) in the second generation and 32 bits (4 GB) in the third generation. The address bus width has increased to 64 bits in the current (eighth) generation of AMD and Intel microprocessors.
- **Internal clock speed:** Measured in MHz (millions of instruction cycles per second or GHz (trillions of instructions per second). The faster the internal clock speed of the microprocessor, the more data it can process per unit time. CPU internal clock speed increases greatly from generation to generation. First-generation CPUs operated at below 100 megahertz, whereas current CPUs operate in the low single digit gigahertz range. There is a wide variation in the internal clock speed of individual CPU models within each processor family. Early Pentium IV processors operated at 1 gigahertz whereas later models operate at over 3 gigahertz.
- **External bus (system bus) speed:** Measured in MHz. The faster the external system bus, the more data can be processed by the system per unit time. External bus speed is dependent on motherboard and memory performance characteristics, as well as CPU design.

Figure 2-11 Performance related features of a CPU



skill 6

Understanding Features and Performance Specifications of First Through Fourth Generation CPUs

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

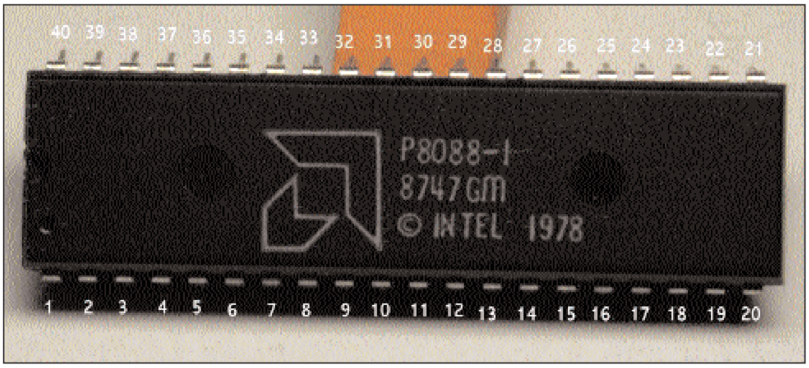
The 8088 and a similar processor, the 8086, belonged to the first generation of Intel microprocessors designed for IBM PCs. The 8088 was a 16-bit processor, internally, with a 20-bit external address bus. This means that the eight general registers of the 8088 could each contain 16 bits of binary instructions or data in one clock cycle. Because each bit could have two states: on and off, the total amount of information the CPU could process in one clock cycle was 8 x $2^{16,}$ or 64 kilobytes. When it came time to send processed data to RAM, the 8088 used 20 sets of external address trace wires, giving it a 20-bit memory address space **(Figure 2-12)**. Although the CPU could operate on a maximum of 64 kilobytes of information at a time, the total amount of RAM that it recognized to store information was 8 x 2^{20} bits, or 1 megabyte. The IBM PC XT (Extended Technology), marketed in 1983, added a 10 MB hard disk to the package, but also used an 8088 CPU with its 1 MB memory address space.

In 1981, the IBM computer designers thought that 1 MB was more memory address space than PC users would ever need! But, only three years later, software programmers were designing applications that taxed the limits of the original IBM PC and PC-XT. Intel's second generation of microprocessors appeared in 1984, with the debut of the 80286 CPU inside the IBM PC AT (Advanced Technology). In addition to executing more instruction cycles per second than the 8088, the 80286 CPU was designed with a 24-bit address space, giving it the ability to address 8 x 2^{24} bits, or 16,777,216 bytes (16 MB) of RAM (Figure 2-13). The 80286 also included an enhanced instruction set that would allow it to run a new operating system. MS-DOS, the operating system supplied by Microsoft for IBM PCs, was limited to run in the 8088's single megabit of memory address space. OS/2, the new operating system to be issued by Microsoft and IBM in partnership, would address the full 16 megabytes provided by the 80286 to run applications. Unfortunately for IBM, Microsoft deserted the partnership before OS/2 could come to market, pouring its energy into a competing product called Microsoft Windows. The 80286 CPU ran existing MS-DOS applications faster than PCs based on the 8088; but the chip's inability to address more than 16 megabytes of RAM failed to provide much benefit to most computer users, who continued to use MS-DOS as their operating system.

Intel's third generation 80386 CPU was a significant milestone in PC performance (Figure 2-14). Invented in 1985, this processor boasted a 32-bit (8 x 2^{32}, or 4 gigabyte) memory address space, and an improved 32-bit instruction set that allowed users to run multiple MS-DOS operating sessions in memory, simultaneously. The first computer systems to use the 80386 CPU were manufactured by Compaq, in 1986. The 80386 was the first Intel CPU to use instruction pipelining (sometimes referred to as superscalar processing), which allows the processor to start working on the next instruction before the previous one is complete.

Intel manufactured several different types of 80386 chips with different features. The initial 80386DX had the 32-bit memory address bus and 32-bit bus for internal instruction processing. The 80386SX was a special stripped-down CPU that Intel issued to accommodate manufacturers of inexpensive motherboards. The 80386SX chip retained the internal 32-bit instruction set, but it was designed with a 16-bit external memory address bus. This meant that computers with 386SX processors and less-expensive motherboards could recognize only 16 MB of RAM. The ability to run more than one instance or copy of MS-DOS gave users the practical ability to multitask applications. A document might be printed in one DOS session at the same time that a modem program downloaded a file in another session. The multitasking capability of the 80386 CPU was not implemented specifically in Microsoft's MS-DOS. It was enabled by third-party software applications such as DESQview, produced by Quarterdeck Office Systems. Microsoft eventually appropriated a good portion of the Quarterdeck technology and included it in the Windows 3.0 and 3.1 operating systems

Figure 2-12 Intel 8088 CPU



The 8088 CPU included 20 pairs of connectors, which allowed it to address 20 memory address circuits

Figure 2-13 Intel 80286 CPU

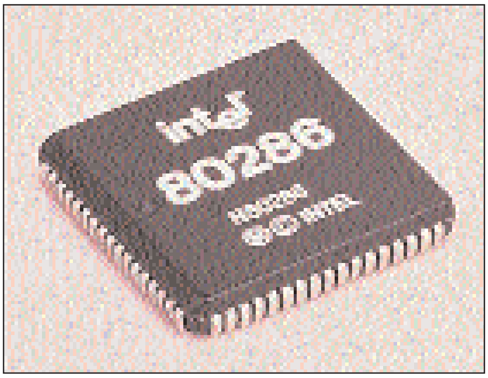
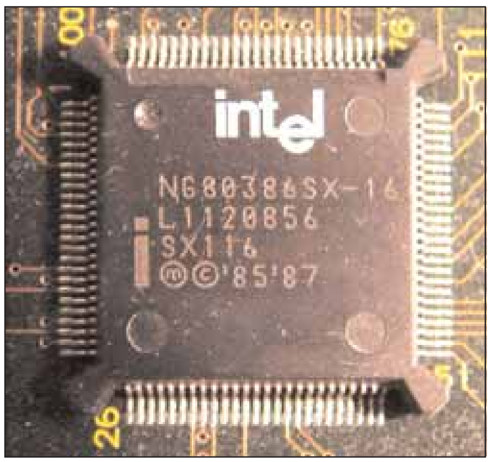


Figure 2-14 Intel 80386SX CPU



skill 6

Understanding Features and Performance Specifications of First Through Fourth Generation CPUs (cont'd)

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

of the early 1990s. The success of Microsoft's Windows operating system highlighted a number of PC performance bottlenecks that were less obvious under MS-DOS. Some, but not all, of these bottlenecks could be overcome by improved CPU design technology. Improvements in the motherboard data buses were also required.

The Intel 80486DX CPU, issued in 1989, used the same 32-bit registers as the 80386, but ran twice as fast (**Figure 2-15**). The original 80486 had an internal clock speed of 33 MHz, compared to the 16 MHz clock speed of the original 80386. Some versions of the 486 also included an integrated component called a **floating point unit (FPU)** to perform high-speed mathematical calculations. In previous Intel CPUs, from the 8088 to the 80386, high-speed arithmetic was executed in a separate chip called a math coprocessor.Intel's lower-cost 80486SX CPU did not have an FPU, but unlike the 80386SX, it did include a full 32-bit external data bus.

more

Intel designed other special versions of its 80486 processors in the 1990s. These clock doubled and clock tripled CPUs (called the 80486 DX/2 and 80486 DX/4) ran, internally, at two or three times the clock speed used to communicate with RAM. For a short period of time, the 80486 DX/2 and 80486 DX/4 processors satisfied users who ran the Windows 3.1 operating system. But simply increasing the CPU's internal performance speed failed to overcome a number of other performance bottlenecks. Video cards were too slow; so a new bus (called a local bus) was invented to accommodate faster ones. Intel's 80486 DX/4 100 MHz processor, which could execute internal instructions at an impressive speed of 100 MHz, was limited to a speed of 33 MHz when required to export data and instructions to RAM and adapter cards on the expansion bus (**Table 2-3**).

Special, fast-RAM memory caches were another improvement incorporated into Intel's 80486 CPUs. A **memory cache** is a small quantity of RAM that runs at a faster speed than ordinary system RAM. The CPU communicates with cache RAM at a faster rate than with ordinary RAM. The RAM used in a memory cache is usually a special type called Static RAM (or SRAM). The RAM used for ordinary system memory is Dynamic RAM (DRAM). You will learn more about how to identify different types of RAM and their uses in Lesson 3.

Memory caches improve the performance of a computer by serving as a midpoint for the CPU to store and retrieve binary data. The memory cache allows the CPU to perform more data retrieval cycles per second than would be possible if it had to read and write directly to slower system RAM (**Figure 2-16**).

A memory cache can be built into the die that forms a CPU chip; it can be mounted on the housing that connects the CPU to the motherboard; or it can be mounted on the motherboard itself (**Figure 2-17**).

- When the memory cache is part of the CPU die, it is called an **internal cache**, also known as an **L1 (Level 1) cache** or **primary cache**.
- When the memory cache is located outside of the CPU chip, it is generally called an **external cache**, also referred to as a secondary cache or **L2 (Level 2) cache**. The L2 cache is usually larger than the L1 cache. On some CPUs, the L2 cache is a set of chips mounted on the processor housing, rather than chips mounted on the motherboard. On more recent AMD models, the L2 cache may be embedded directly in the processor die

Figure 2-15 Intel 80486DX and 80486SX CPUs

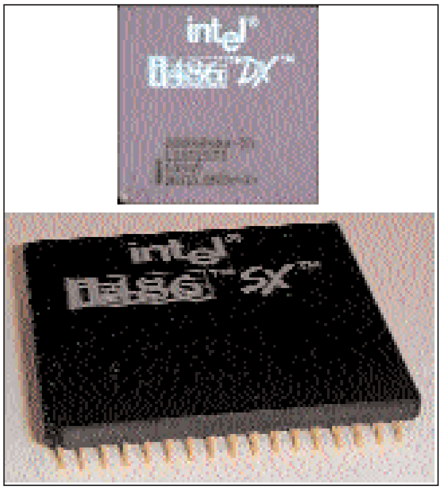
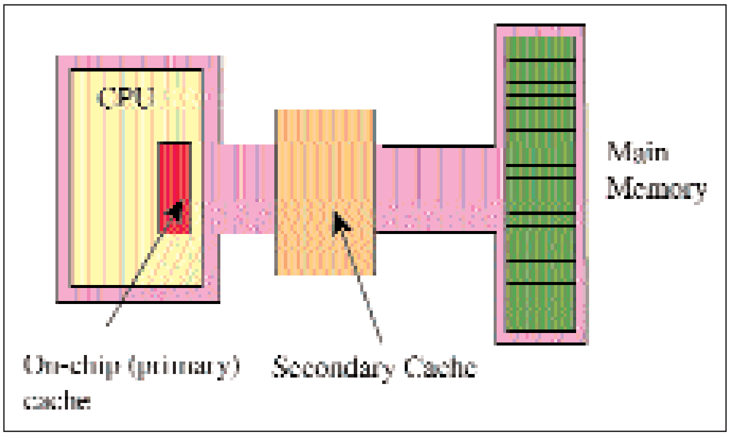


Table 2-3 Binary and Decimal Measures

	Internal Speed (MHz)	External Speed (MHz)	Internal Data Bus Width	External Data Bus Width	Address Bus Width	Internal Cache
8086	4.77	4.77	16-bit	16-bit	20-bit	No
8088	4.77	4.77	16-bit	8-bit	20-bit	No
80286	8–20	8-16	16-bit	16-bit	24-bit	No
80386DX	16–33	16-33	32-bit	32-bit	32-bit	No
80386SX	16–25	16-25	32-bit	16-bit	24-bit	No
80486DX	25–66	25-33	32-bit	32-bit	32-bit	8KB
80486DX/2	25–66	25-33	32-bit	32-bit	32-bit	8KB
80486DX/4	25–100	25-33	32-bit	32-bit	32-bit	16KB
80486SX	16–25	16-25	32-bit	32-bit	32-bit	8KB

Figure 2-16 L1 and L2 cache



skill 6

Understanding Features and Performance Specifications of First Through Fourth Generation CPUs (cont'd)

A+ Hardware objective

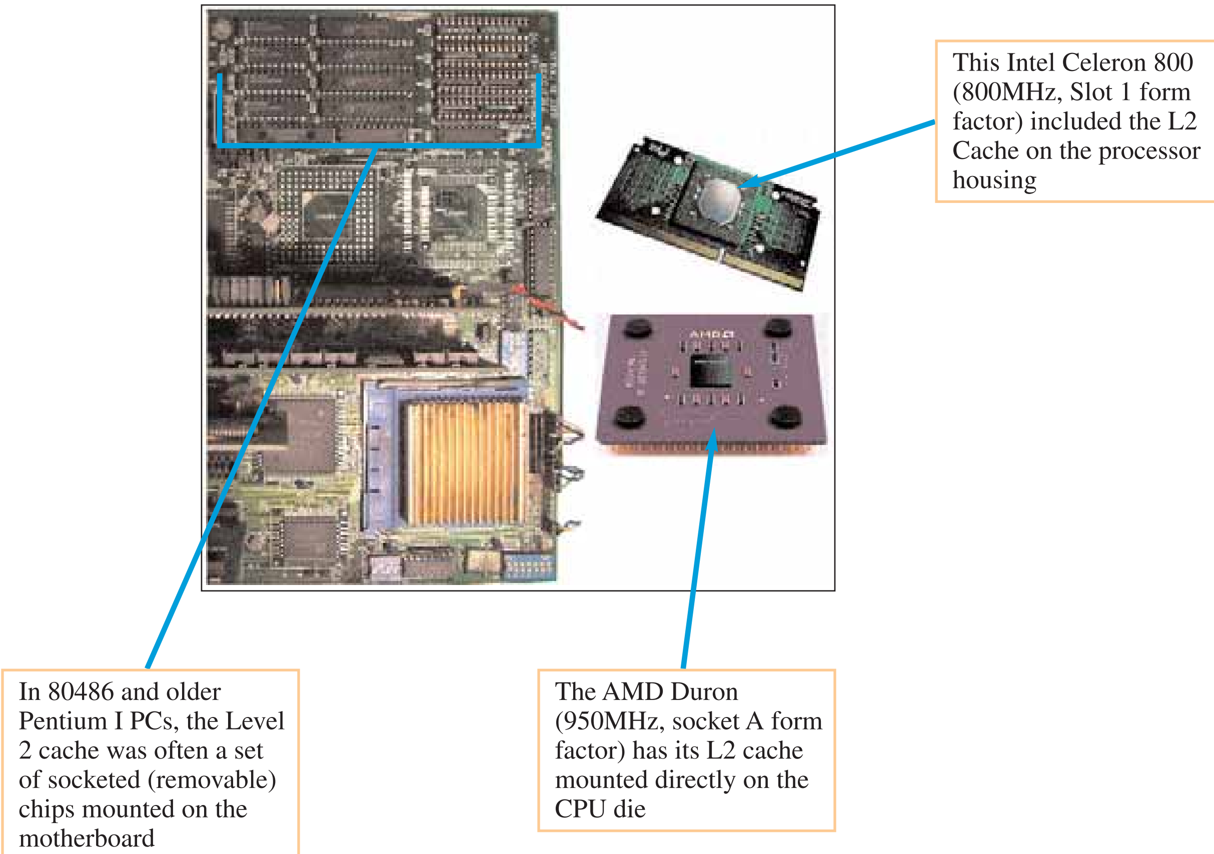
1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

more

along with the L1 cache (**Figure 2-17**). With these CPUs, the L2 cache is also part of the back side bus.

- Early L2 caches designed to work with 80486 CPUs used one of two design technologies: A **write-through cache** would immediately send all data to RAM as it was received from the CPU. A **write-back cache** would store data and write it to RAM at periodic, delayed intervals. The write-back technology was more expensive, but delivered better performance. On modern Pentium motherboards, the L2 cache always uses the write-back design.
- On systems that contain an L2 cache on the processor housing, there may be an additional external cache referred to as **L3 (Level 3) cache**, usually mounted directly on the motherboard.

Figure 2-17 L2 caches



skill 7

Understanding Features and Performance Specifications of Fifth Generation CPUs (The Classic Pentium and Its Competitors)

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

Intel's contribution to the fifth generation of PC processors was the Pentium I family, also referred to as classic Pentiums (**Figure 2-18**). Introduced in March of 1993, the first Pentium CPU ran at an internal and external clock speed of 60 MHz. Internal instructions were executed at the same speed used for communication with RAM through the front side bus. The size of the internal cache in the classic Pentium family was doubled from 8 KB to 16 KB. The Pentium had an additional 1.9 million transistors, when compared to the 80486DX. CPUs in the classic Pentium family have a 32-bit address bus and a 64-bit external data bus.

Some of the physical chip characteristics changed in the faster Pentium versions released later in this cycle. The Pentium CPUs released in 1994 had clock speeds of 75 to 200 MHz and had a slightly different package design to fit into a new motherboard socket. You will learn how to identify CPU package designs and motherboard socket/slot form factors later in this lesson. Intel experimented in 1995 with a chip called the Pentium Pro, designed to deliver faster performance for the Windows operating system. The Pentium Pro included an L2 cache directly inside of the chip; but it had limited popularity because of its slow performance in running MS-DOS applications.

In January of 1997, Intel changed the internal design of the Pentium family, introducing a new technology called MMX (Multimedia Extensions). The new MMX instruction set improved the performance of graphical applications like Photoshop (and other photo editors), and of multimedia software for games and video. Pentium MMX CPUs were manufactured at clock speeds of 166, 200, 233, and 266 MHz.

To allow processor upgrades of earlier motherboards, Intel distributed a class of Pentium chips, called Pentium OverDrive. Internally, these were Pentium CPUs; but they were altered to accommodate unusual sockets and motherboards by appearing to the motherboard chipset as an earlier CPU model. Intel no longer manufactures or supports Pentium OverDrive CPUs.

Intel's competitors, AMD and Cyrix, distributed CPU products from 1995 to 1996 that were pin-compatible with Intel CPUs. The AMD and Cyrix CPUs could be inserted into the same motherboard sockets designed for the Pentium I (**Figure 2-19**). The AMD K5 and Cyrix 6x86 had different internal design structures than the Pentiums. They used higher or lower internal clock speeds than the Intel Pentium; but they ran the DOS and Windows operating systems with comparable performance.

more

One of the more infamous manufacturing faults in the history of chips was a bug discovered in the floating point units (FPUs) of some Intel Pentium processors manufactured in 1994. When the FPU was called on to perform certain calculations, errors would appear in numbers that contained more than three decimal places. This issue occurred only on Pentium CPUs with internal clock speeds of 60 to 100 MHz.

There are several ways to test a Pentium CPU to determine if it has the Pentium flaw. You can use Microsoft Excel to make the following calculations:

Divide 962,306,957,033 by 11,010,046

Correct answer: 87,402.6282027341

Incorrect answer: 87,399.5805831329

You can also test for this flaw by entering the following formula in Microsoft Excel:

= 4195835-((4195835/3145727)*3145727)

If the FPU works properly, you should see a returned result of 0.

Figure 2-18 Classic Pentium CPU

Figure 2-19 AMD K5 and Cyrix 6x86 CPUs

skill 8

Understanding Features and Performance Specifications of Sixth Generation CPUs (Intel PII—PIII, AMD K6, K6-2/3)

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

tip

A good summary of the development and features of Intel CPUs, up to the Pentium family is available, online, at http://www.computerhope.com/help/cpu.htm.

In 1995, the sixth generation of CPUs began to appear. These chips offered major improvements in processing power, being designed to satisfy the growing demand for faster graphics and multimedia performance in games, videos, and sound applications. In addition, these chips were the first to meet the challenges of the rapidly growing population of Internet and World Wide Web consumers. Sixth generation CPUs included new, improved Pentium families from Intel (Celeron, Pentium II, III, and 4) and new AMD families (K6, K6-2, K6-3, Athlon, Duron).

With the Pentium II family, Intel attempted to combine the best features of the Pentium I MMX and Pentium Pro. The L1 cache size was increased to 32 KB and the CPU was placed in a new package, called **Single Edge Contact Cartridge (SECC) (Figure 2-20)**. The SECC technology allowed the use of an onboard 512 KB L2 cache, made up of pipeline Burst SRAM. **Burst SRAM** is a type of cache that retrieves (or pre-fetches) memory content, anticipating the information that the CPU will ask for before the CPU actually requests it. This permits one memory value in the cache to be accessed at the same time that another memory value is accessed in RAM.

The Pentium II was the first Intel CPU designed to fit into a slot on the motherboard, rather than a socket. Pentium II CPUs with clock speeds of 350 MHz and above also used a faster 100 MHz front side bus, which increased the PC's overall performance speed.

Intel's Celeron series began as a less expensive Pentium based on the Pentium II. The original Celerons used a Slot-1 processor packaging called **Single Edge Processor Package (SEPP)**. This packaging was similar to the Pentium II SEC design, but lacked a protective covering for the processor. The early Celeron 266 MHz and 300 MHz models lacked an L2 cache. These Celerons ran at the lower 66 MHz front side bus speed of the Pentium I generation. Those specifications made early Celerons poor performers compared to the competing AMD K6 processor line.

The next series of Celerons was designed with a dual-form factor. These Celerons were distributed in both a SEP package and a new plastic pin grid array (PPGA) socket form factor (**Figure 2-21**). Although limited to the 66 MHz FSB speed, these Celerons ran at internal clock speeds from 300 to 700 MHz and included large amounts of L2 cache memory (**Table 2-4**).

While Intel was marketing its Pentium II's and Celerons, AMD released the K6-2, which ran with higher internal and external clock speeds than the K6. AMD included its own "3Dnow" multimedia instruction set to compete with Intel's MMX. The K6-3 processor used the K6-2 core with 256 KB of L2 cache directly embedded on the processor die.

Intel's Pentium III family improved the MMX (multimedia) support of previous Pentiums by adding 70 new Streaming SIMD (Single Instruction Multiple Data) Extensions (SSEs) (**Figure 2-22**). Of the new SSE extensions, 50 were designed to improve floating-point performance. The Pentium III instruction set also contains eight new 128-bit floating-point registers. The CPU retains a 32 KB Level 1 cache and includes 512 KB of Level 2 cache. Intel distributed both Slot-1 and socketed versions of Pentium III CPUs.

Newer generations of Celeron, (sometimes referred to as Celeron II), have appeared based on Intel's Pentium III, and Pentium 4 processor families. These newer Celerons use yet another form factor and run at internal clock speeds up to 1.2 GHz with a 100 MHz front side bus.

AMD's Athlon classic, released in 1999, had an internal clock speed of 500 MHz (**Figure 2-22**). The Athlon (sometimes referred to as the AMD K7), contained nine execution pipelines and an enhanced 3dNow technology. Because Intel had copyrighted its Slot 1 motherboard technology, AMD developed an alternative, which it called **Slot A**. AMD's Athlon marked a significant division in the motherboard technology required to support CPUs from the two rival processor vendors. AMD designed a new system bus for the Athlon that operated at 200 MHz. AMD also released the Athlon, later on, in a new socketed version, called Socket A.

Table 2-4 Fifth and Sixth Generation CPU Performance Specs

	Internal Speed (MHz)	Front Side Bus Speed (MHz)	Internal Data Bus Width	External Data Bus Width	Address Bus Width	Internal Cache (L1)	Internal Cache (L2)
Intel Pentium I	60-233	60-66	32-bit	64-bit	32-bit	16 KB	Off-chip (Varies)
Intel Pentium I MMX	133-233	66	32-bit	64-bit	32-bit	16 KB	Off-chip (Varies)
Intel Pentium Pro	166-200	66	32-bit	64-bit	32-bit	16 KB	256 KB-512 KB
Intel Celeron (Pre-PIII)	266-700	66	32-bit	64-bit	32-bit	32 KB	0-512 KB
AMD K6	166-266	66	32-bit	64-bit	32-bit	32 KB	Off chip (Varies)
Intel Pentium II	266-700	66-100	32-bit	64-bit	32-bit	32 KB	256 KB-512 KB
Cyrix 6x86MX	133–188	60-75	32-bit	64-bit	32-bit	32 KB	Off-chip (varies)
AMD K6-2	200-400	66-100	32-bit	64-bit	32-bit	64 KB	Off-chip (varies)
AMD K6-3	400-600	95-100	32-bit	64-bit	32-bit	64 KB	256 KB
Intel Pentium III	450-1250	100-133	32-bit	64-bit	32-bit	32 KB	256 KB-512 KB

Figure 2-20 Intel Pentium II 333 MHz CPU

Figure 2-21 Intel Celeron 300 and 466 MHz CPUs

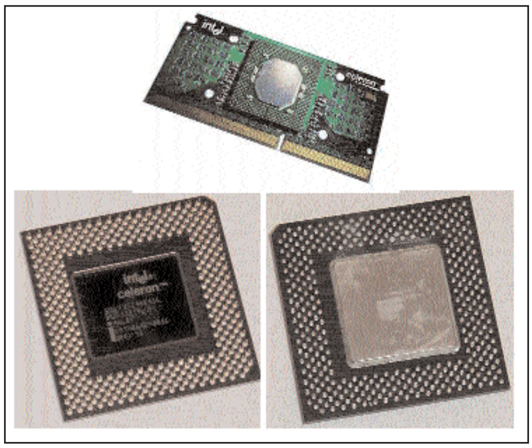
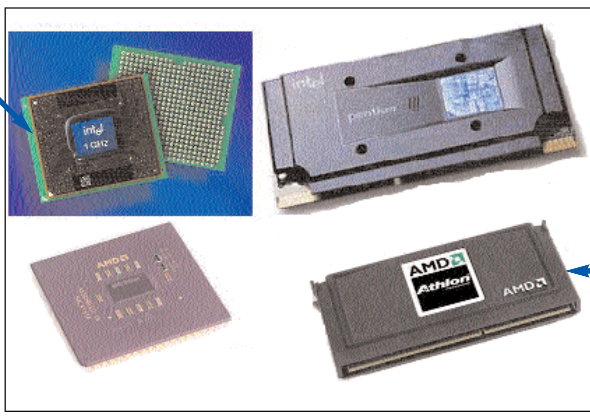


Figure 2-22 Intel Pentium III and Athlon CPUs

Intel Pentium III CPU and cartridge package



AMD Athlon CPU and cartridge package

skill 9

Understanding Features and Performance Specifications of Seventh Generation and Current CPUs

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

The seventh generation of chips began to appear in 1999. These newer chips responded to two trends in the use of PCs by consumers around the world. PCs were increasingly being used as entertainment centers, processing very large sound and video files; and PCs were increasingly used as search and shopping tools, spurred on the growth of electronic commerce. The seventh generation CPUs broke through the gigahertz clock speed barrier and introduced a whole set of innovations, based on parallelism. Parallelism is a design concept that places multiple processing units on a single chip, breaking data and instructions into two or more streams that can be processed simultaneously. Intel's Pentium 4 family included major design improvements (**Figure 2-23**). Changes in the CPU's internal logic allowed this family to operate at significantly higher internal clock speeds, and also to process more instructions per clock cycle. The changes in the Pentium 4 family include:

- **Hyper threading:** Software applications can address the physical processor as if it were actually two logical processors, allowing for simultaneous execution of multiple tasks.
- **Hyper pipelining:** The pipeline depth of the P4 CPU was increased from 10 to 20 stages (see instruction pipelining), allowing for more efficient execution of repetitive software instructions.
- **Level 1 execution trace cache:** In P4 CPUs, the L1 cache is divided into a section that holds data and the **execution trace cache**—a section that stores pre-decoded instructions for faster execution.
- **Rapid execution engine:** A feature that allows the Pentium 4's ALUs to perform arithmetic calculations at twice the core clock speed of the CPU.
- **Level 2 advanced transfer cache:** A high-speed cache integrated directly onto the CPU die that operates at the CPU's internal clock speed—with a 256-bit data bus.
- **SIMD Extensions 2 (SSE2):** A revised version of the SSE instruction set, including 76 new SIMD instructions. The 128-bit bus width of the cache allows more robust performance on CPU-intensive multimedia tasks, such as 3-D graphic rendering and streaming video.

Intel's family of Pentium III Xeon and Pentium 4 processors use an **advanced transfer cache (ATC)** directly mounted on the CPU die. The cache runs at the same clock speed as the CPU. The most recent Pentium 4 CPUs operate at internal clock speeds over 3 GHz per second. Intel refers to the following features: new L1 execution trace cache, rapid execution engine, L2 advanced transfer cache, and SSE2 instruction set, collectively, as **NetBurst** technology.

Intel has been, and continues to be, the leading innovator and producer of PC CPUs since the 1970s. But, as an A+ technician, you may also encounter CPUs produced by several other manufacturers. The AMD families of CPUs continue to evolve along with Intel's CPUs, sometimes exceeding the power of Intel's latest chips. The processors of AMD's Athlon family have also gone through a number of revisions and improvements. The Athlon Thunderbird, released in June of 2000, included support for modern DDR-RAM (described in Lesson 3) and is still in popular use. The Athlon Palomino, also referred to as the Athlon 4, is a low power, low-demand processor that was originally issued for laptop computers, and later renamed **Athlon XP** (**Figure 2-23**). This current AMD CPU includes full support for Intel's SSE instruction set. Because the XP actually performs more work per clock cycle than Intel's Pentiums, this CPU family operates at slower clock speeds than indicated by the model numbers. For instance: the Athlon XP 1900 runs at an internal clock speed of 1600 MHz and the XP 2400 at 2000 MHz (**Table 2-5**). AMD also manufactures an alternative, lower-cost CPU family called **Duron** that competes directly against Intel's Celeron. Duron CPUs include a 128 KB L1 cache and 64 KB L2 cache embedded on the processor die.

Figure 2-23 Intel Pentium 4 and Athlon XP CPUs

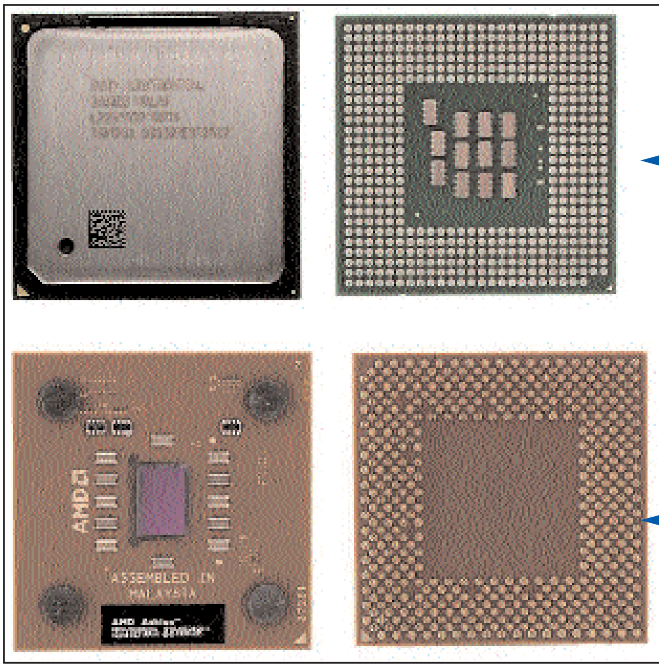


Table 2-5 Seventh Generation and Beyond CPU Performance Specs

	Internal Speed (MHz)	Front Side Bus Speed (MHz)	Internal Data Bus Width	External Data Bus Width	Address Bus Width	Internal Cache (L1)	Internal Cache (L2)
AMD Athlon Classic (Athlon Professional)	500-1400	100-200	32-bit	64-bit	32-bit	128 KB	256 KB-512 KB
Intel Celeron II (Post PIII)	800-2400	100	32-bit	64-bit	32-bit	20 KB-32 KB	256 KB (ATC)
AMD Duron	600-1300	200	32-bit	64-bit	32-bit	128 KB	64 KB
Intel Pentium 4	1300-3600	100-800	32-bit	64-bit	32-bit	20 KB--32 KB	256 KB-1024 KB (ATC)
Transmeta Crusoe	333-1000	66-133	32-bit	64-bit	32-bit	96 KB-128 KB	0 KB-512 KB
AMD Athlon XP	1333-3200	266-400	32-bit	64-bit	32-bit	128 KB	256 KB-512 KB
64-Bit CPUs							
AMD Athlon-64 (K8)	3200-3400	400*	64-bit	128-bit	64-bit	128 KB	1024 KB
Intel Itanium	733-1.8*	400*	64-bit	256-bit	64-bit	32 KB	96 KB-256 KB (+2-4 MB L3)

* = Estimated specification

ATC = Advanced Transfer Cache

skill 9

Understanding Features and Performance Specifications of Seventh Generation and Current CPUs *(cont'd)*

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

Both Intel and AMD manufacture mobile versions of their CPU families designed for notebook computers. These chips are designed with smaller form factors and lower power requirements than the desktop versions. The Intel Centrino processor is based on a new technology that combines a Pentium M (mobile) processor and a wireless networking interface.

In addition to Intel and AMD, several other manufacturers make CPUs that are Intel-compatible and are designed to run Windows operating systems. For instance, IBM is the world's largest manufacturer of CPU chips, but consumes most of its production output for its own line of mainframe and mid-range RISC Unix-based computers. In the PC marketplace, IBM has typically sought partnerships with Intel-competitors, occasionally manufacturing its own branded PC CPUs. IBM partnered with Cyrix to develop the 6x86 CPU family in the 1990s. More recently IBM partnered with Apple Computer to produce a family of RISC PowerPC processors for Apple Macintosh computers.

Transmeta is a company known for designing low-power CPUs, most suitable to notebook, tablet, and handheld computers. Transmeta produces Pentium 4-compatible CPUs for popular notebook PCs manufactured by Sony, Fujitsu, Hitachi, and other vendors. Because they operate on a lower voltage than competing processors, the Transmeta Crusoe **(Figure 2-24)** and Efficeon processors also reduce the need for CPU cooling systems such as fans and heat sinks, which are, themselves, a significant power drain on laptop batteries.

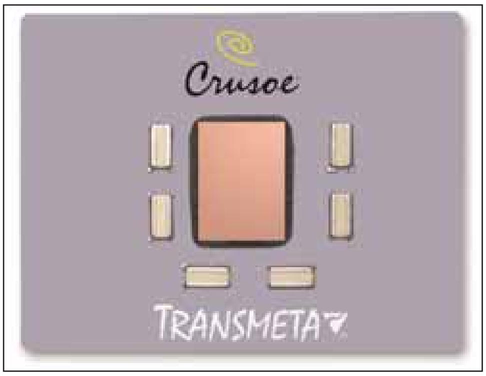
The eighth generation of chips is already being manufactured, but because of their expense, they have not yet come into widespread use in consumer or business PCs. The AMD Athlon 64 (K8) and the Intel Itanium are both 64-bit processors with multiple processors on a single chip. Both have 64-bit front and back side buses, although the Itanium has a much larger address bus of 256 bits, versus the K8 128-bit address bus. AMD was the first to market with their internal bus 64-bit chip. Moreover, AMD made a wise choice in making the K8 compatible with existing Windows and other 32-bit applications. Intel's Itanium got off to a weak start in the marketplace because its Itanium 64-bit chip could not run 32-bit programs, and users are required to rewrite their application software to use this chip. Intel changed course in 2004 and has announced it will be producing a 32-bit compatible 64-bit chip.

more

The design specs for more recent CPUs and motherboards sometimes make it difficult to tell the difference between an L1 and an L2 cache. The term **discrete L2 cache** describes the external cache that was used on some of Intel's Pentium III CPUs. The discrete L2 cache was installed on the processor housing and used a 64-bit bus to connect to main memory and ran at half the internal clock speed of the CPU.

When you read specifications on CPU performance, you may encounter some confusing terminology and marketing claims with respect to "Front Side Bus" and "System Bus." The two terms are often used interchangeably, but you may see current Pentium 4 or Athlon XP chips described as having a front side bus speed of 200 MHz and a system bus speed of 200x4 (or 800) MHz. This is because newer motherboards now support RAM chips that can send data to the system bus four times per clock cycle. We discuss these issues in Lesson 4.

Figure 2-24 Transmeta Crusoe CPU



skill 10 Identifying Standard CPU Packages

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

In studying how the CPU connects to the motherboard in a PC, the two key elements to identify are the **CPU package** and the **CPU socket** or **slot** on the motherboard that the package plugs into. In this skill, you will identify packages. The next skill discusses corresponding motherboard slot and socket interfaces for each package.

The CPU package is the part that houses or mounts the microprocessor chip. Packages for modern CPUs come in two basic designs: The first type extrudes a series of pins from the bottom of the processor chip to plug into a matching socket on the motherboard. The second type mounts the CPU on an interface card that is inserted into a slot on the motherboard. **Figure 2-22** provides side-by-side examples of both package types. The layout and number of pins in the socket design, or the size of the card in the slot design, varies from model to model with the various Intel and AMD CPU families. The earliest Intel 8088 and 80286 models used a package design called Dual Inline Pin Package (DIPP), which consisted of two rows of pins on either side of the processor. The DIPP package was soon replaced by a larger-sized **Pin Grid Array (PGA)**. The PGA package, used in 80286 through 80486 CPU generations, provided more efficient cooling system by distributing pins evenly along the bottom of the processor chip **(Figure 2-25)**. Early Pentium and Pentium-compatible families (Intel Pentium I/Pentium Pro, AMD K5/K6, Cyrix 6x86) used a design called **Staggered Pin Grid Array (SPGA)**; the number of pins in each row was increased and the rows were staggered over the socket to fit more pins into a smaller space.

More recent CPU families (Intel Pentium III, AMD Athlon/Duron) use an improved version of the SPGA package called **Plastic Pin Grid Array (PPGA) (Figure 2-26)**. The PPGA package replaced the ceramic base of the earlier SPGA with a new high-thermal plastic. The **Flip Chip Pin Grid Array (FC-PGA)** and revised version (FC-PGA2) are packages that resemble the PPGA externally, but contain internal wiring improvements **(Table 2-6)**.

Some CPUs are packaged to be installed in special slots on the motherboard. Socketed PPGA or FC-PGA processors can be installed on a Slot-1 motherboard through the use of a special slot-to-socket (or **slocket**) expansion card. Slocket converters usually include a set of jumpers or switches that allows the user to select between individual processor models, internal, and front side bus clock speeds. Intel's CPU packages developed for the copyrighted Slot-1/Slot-2 motherboard architecture include:

- **Single Edge Contact Cartridge (SECC):** Used for individual models in the Pentium I, II, and III families.
- **Single Edge Processor Package (SEPP):** Used for early Celerons.
- **Single Edge Contact Cartridge, version 2 (SECC2):** An improved package used for individual models in the Pentium III, and Pentium 4 families **(Figure 2-26)**.

Intel's new Itanium and Itanium 2 CPUs plug into a new **Pin Array Cartridge (PAC)**. AMD's 64-bit Opteron and Athlon-64 CPU families are housed in proprietary AMD CPU packages with 940 pins.

Table 2-6 Seventh Generation and Beyond CPU Performance Specs

CPU Package	Description	Used by CPUs
DIPP	20-24 pins	Intel 8088, 80286
PGA	169-238 pins	Intel 80286-80486
SPGA	273-387 pins	Intel Pentium I/Pentium Pro; AMD K5/K6, Cyrix 6x86
PPGA	370 pins	Intel PII, PIII, AMD K6-2/K6-3
PGA603	603 pins	Intel PII, PIII Xeon
SEPP	242 contacts	Intel Celeron
SECC	242 contacts (330 contacts for Intel PII, III Xeon models)	Intel PII, PIII
SECC2	242 contacts	Intel PII, PIII
FC-PGA	370 pins	Intel PIII,
FC-PGA2	370 pins (423 pins for Intel P4)	Intel PIII, P4, AMD Athlon XP
OOI/OLGA	Organic Land Grid Array 423 pins	Intel P4

Figure 2-25 Early CPU packages

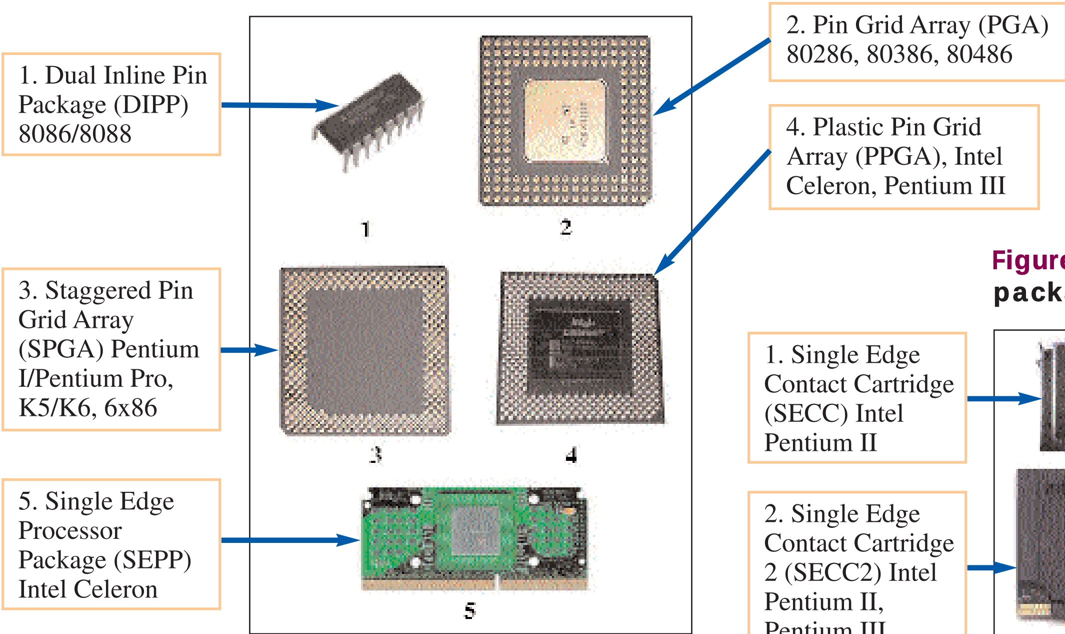
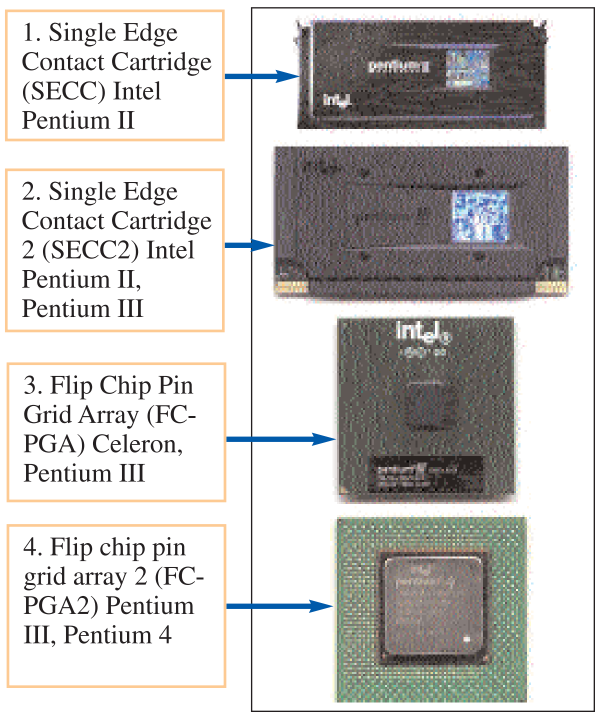


Figure 2-26 Modern CPU packages



skill 11 Identifying Standard CPU Sockets and Slots

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

caution

When inserting a CPU into a socket, make certain that you have lined pin 1 with socket hole 1. Look for bevels, dots, or notches to guide you.

Slots and sockets are the physical connectors on a PC motherboard that allow the CPU to be attached (**Table 2-7**). The number and pattern of pin holes in a CPU socket correspond exactly with the number and pattern of pins on the CPU packages designed for it that you learned about in the previous skill. A CPU slot accepts a processor mounted on a card, working in the same way as an expansion card slot.

Before the 80486, the CPU was often soldered into its motherboard socket, or otherwise difficult to remove. Intel's standardized sockets included a new feature called **ZIF (zero insertion force)**. ZIF sockets include a release side-lever that tightens the socket connection when down and loosens it when up so that the CPU can be easily removed or replaced **(Figure 2-27)**. (An earlier version called **LIF** or **Low Insertion Force** did not include the release lever.)

CPU sockets generally have a square shape. In most designs, the corner of the socket where pin 1 of the CPU is inserted has a beveled edge that helps you identify how to insert the CPU into the socket. The CPU, itself, usually has a dot or notch on the corner that contains pin 1. Accidentally rotating the processor by 90 degrees and inserting pin 1 into the wrong hole on the socket can have disastrous consequences, producing electrical short circuits that ruin the CPU or the motherboard. Some CPU sockets are keyed with an asymmetric pin layout to prevent accidental insertion of pin 1 at the wrong corner.

The socket interfaces for Intel CPUs manufactured before the 80486 are usually referred to as 8088 socket, 80286 socket, and 80386 socket. Beginning with 80486 CPU packages, Intel began to standardize CPU socket and slot architecture. Initially, the CPUs of AMD and Cyrix could fit into Intel's standardized sockets. Intel has attempted over the years to develop a proprietary socket and pin package that would prevent substitution of competitor products with some success. More recently, AMD has developed its own socket and slot standards because the internal structure of its CPUs has diverged from Intel models. Today it is difficult if not impossible to swap Intel and AMD chips on the same motherboard because of incompatible packaging and sockets.

Socket 1, Socket 3, and Socket 6 were used to connect various 80486 models. Standards for this series of CPUs were complicated by the wide number of individual models with different numbers of pins on the package.

Socket 4 and Socket 5 connected early Pentium 60 and 66 MHz CPUs; but the most common socket design for Pentium I motherboards was Socket 7 **(Figure 2-28)**. Socket 7 supported 321-pin CPU packages, and was the first to use the Staggered Pin Grid Array form factor. An improved version called **SuperSocket 7** was designed for Pentium MMX CPUs and also accepted K6 and 6x86 models from Intel's competitors AMD and Cyrix. The Socket 7 and SuperSocket 7 form factors are pin-compatible. Socket 7, designed for early Intel Pentium I CPUs, is limited to a front side bus speed of 66 MHz. SuperSocket 7 supports a front side bus speed of 100 MHz. Faster Intel Pentium I, AMD K6/K6-II, and Cyrix 686 CPUs can run on a Socket 7 motherboard; but they require SuperSocket 7 support to perform at their factory-rated speeds. Socket 8 was a 387-pin form factor, designed for the Pentium Pro.

Table 2-7 CPU Sockets and Slots

Motherboard Interface	# of Pins or Contacts	CPU Package	Used by CPUs
Pre-Socket	20–168	DIPP/PGA	DIPP/PGA Intel 8086/8088 to 80386
Socket 1	169	PGA	Intel 80486DX/DX2/DX4/SX/SX2
Socket 2	238	PGA	Intel 80486DX/DX2/DX4/SX/SX2, Pentium
Socket 3	237	PGA	Intel 80486DX/DX2/DX4/SX/SX2, Pentium I
Socket 4	273	PGA	Pentium I 60/66 MHz
Socket 5	320	SPGA	Pentium I 75 -133 MHz
Socket 6	235	PGA	80486 DX4
Socket 7 and SuperSocket 7 *	321	SPGA	Pentium I 75-233, Intel Pentium MMX, AMD K5, K6, K6-II, K6-III, Cyrix 6x86, Transmeta Crusoe
Socket 8	387	SPGA	Intel Pentium Pro, Pentium II
Socket 370/Socket FC-PGA	370	PPGA	Intel Pentium II, III, Celeron
Slot 1	242	SECC/SEPP	Intel Celeron, Pentium II, Pentium Pro
Slot A	242	AMD	AMD Athlon
Socket A (Socket 462)	462	PPGA	AMD Athlon, Duron, Spitfire
Slot 2	330	SECC/SECC2	Pentium II Xeon, Pentium III Xeon
Socket 423	423	FC-PGA	Intel Pentium 4
Socket 478	478	FC-PGA2	Intel Pentium 4
Socket 603	603	603PGA	Intel Pentium 4 Xeon (Foster)
Socket 754	754	AMD Proprietary	AMD Athlon-64
Socket 940	940	AMD Proprietary	AMD Opteron
PAC418	418	PAC	Intel Itanium
PAC 611	611	PAC	Intel Itanium 2

Figure 2-27 ZIF sockets

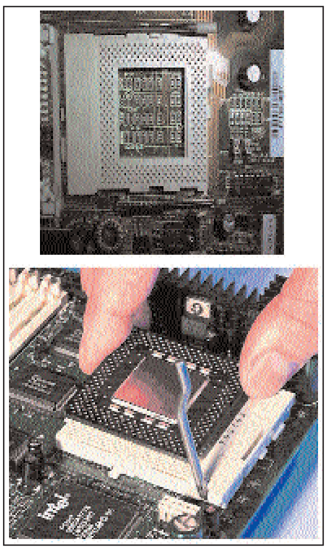
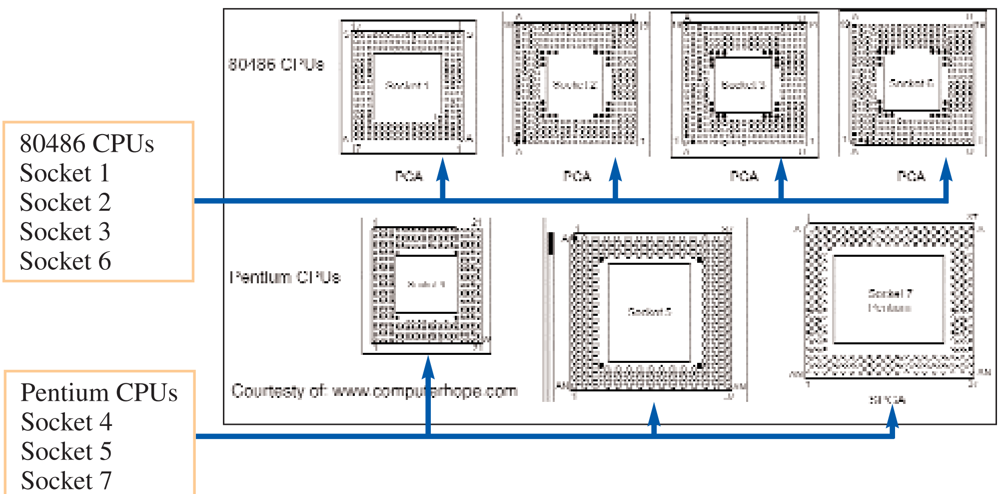


Figure 2-28 Early CPU socket form factors



skill 11

Identifying Standard CPU Sockets and Slots (cont'd)

A+ Hardware objective

1.1 Identify the names, purpose, and characteristics of system modules. Recognize these modules by sight or definition.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

Intel introduced the Slot 1 form factor for its Pentium II CPU family, which mounted both processor chip and L2 cache in a plastic cartridge attached to an expansion card **(Figure 2-29)**. Intel's patent on the Slot 1 technology prevented AMD and Cyrix from using it for their competing CPUs. AMD responded by developing its own Slot A motherboard form factors for its new Athlon processors. From this point on, the motherboard interfaces for Intel, AMD, and other vendors' processor products are mostly incompatible. Users who want to upgrade the motherboard or CPU in a PC must be sure to match the processor with a motherboard that supports that CPU manufacturer's products.

Intel's Slot 2 **(Figure 2-30)** is a 330-contact version of the Slot 1 interface, designed for Xeon processors. Intel's Pentium Xeon CPUs include a combination of Pentium Pro and Pentium II/III/4 features and are designed to deliver robust performance on high-end workstations and servers. One significant difference between Slot 1 and Slot 2 is that Slot 2 allows the CPU to communicate with the L2 cache at the CPU's full clock speed. Slot 1 limits communication between the L2 cache and CPU to half the CPU's internal clock speed.

Intel and AMD eventually discovered that placing secondary cache memory directly on the CPU die was less expensive than mounting separate chips on the processor housing. This discovery resulted in a return to socket-based CPUs for both companies.

The Socket 370, Socket A, and Socket 423 CPU interfaces were developed when Intel and AMD both learned to place secondary cache memory directly on the CPU die instead of requiring separate chips mounted on the processor housing **(Figure 2-31)**. Socket 370 takes the basic Socket 7 design and adds extra pin rows on all four sides, accepting CPUs that use PPGA and FC-PGA package. Socket A, designed for Athlon and Duron CPUs, uses 462 pins. Socket 423 (423 pins) was the first interface developed for Intel Pentium 4 CPU packages.

Newer Pentium 4 CPUs (with clock speeds greater than 2 GHz) have a smaller footprint than older models and use the 478-pin Socket 478 interface. Socket 478 is the standard interface for current 32-bit Pentium 4 processors on motherboards designed for desktop computers.

Intel's 64-bit Itanium and Itanium-2 CPUs use the new PAC418 (418-pin) and PAC611 (611-pin) sockets. AMD's 64-bit Athlon-64 and Opteron CPUs use Socket 754, and Socket 940 which are proprietary AMD interfaces with 754 and 940 pins, respectively **(Figure 2-32)**.

Figure 2-29 Intel Slot 1 and Pentium II CPU

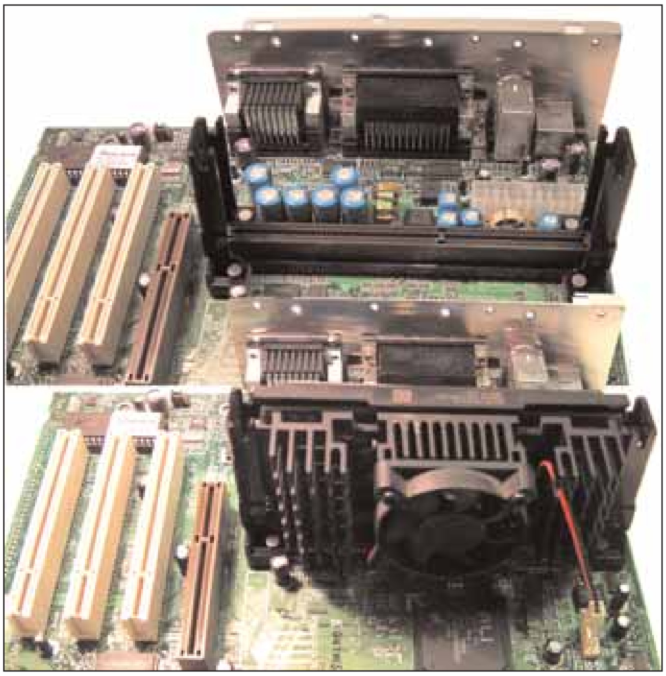


Figure 2-30 Intel Slot 2 - without CPU and with CPU

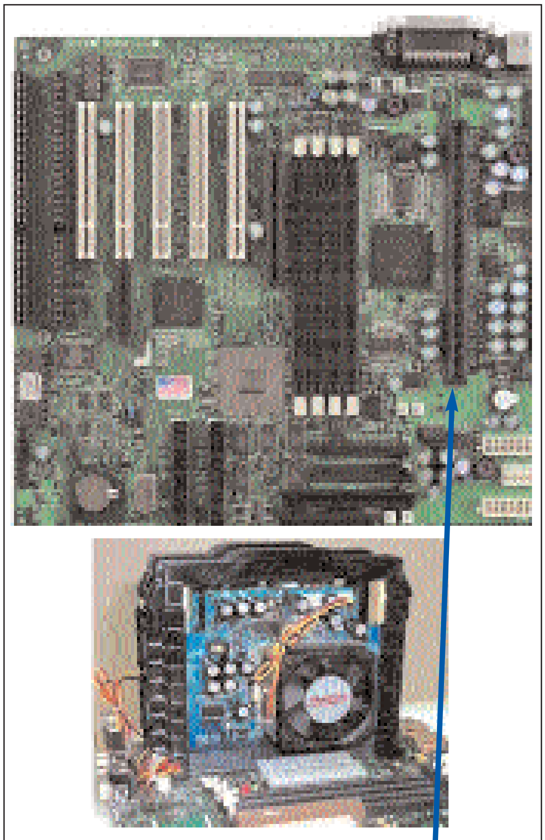


Figure 2-31 Socket 370, Socket A, and Socket 478

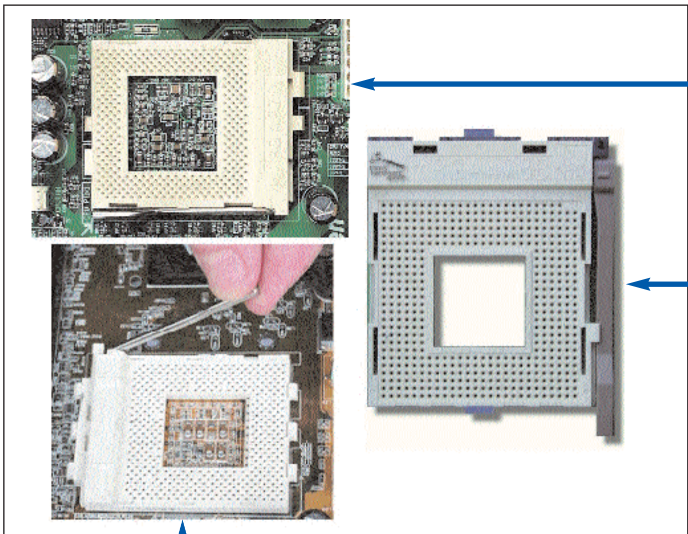
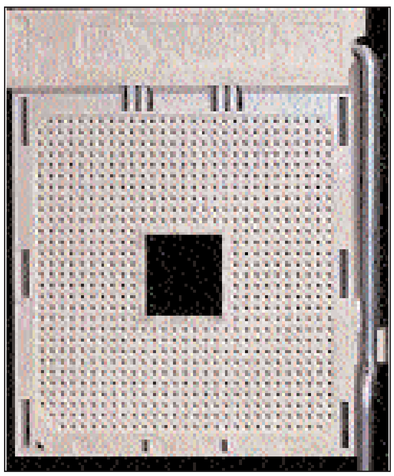


Figure 2-32 AMD Socket 754



skill 12

Matching CPUs and Motherboards

A+ Hardware objective

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.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

tip

If the documentation for your computer's motherboard is missing, you may be able to download it from the Internet. Open the computer case, if necessary, to determine the manufacturer and model number for the motherboard. Then use a search engine to find the manufacturer's Web site. Many computer and motherboard vendors post system documentation on their web sites.

You have already learned in this lesson that different CPU families come in a number of sizes and packages, operating at different internal frequencies (clock speeds). You have also learned that individual CPUs may use different external clock speeds to communicate with system RAM. Additionally, individual CPUs vary in their motherboard voltage requirements.

Some PC motherboards are designed to accommodate more than one CPU model, allowing users to upgrade the computer by installing a faster processor. As a PC technician, you may be required to perform such an upgrade. The CPU must be matched with the motherboard in terms of the following:

- **Slot or socket type:** Some CPU sockets and slots accept more than one type of CPU package. For instance, many Socket 370 motherboards can use either a Pentium III or Celeron CPU.
- **Clock speed of the front side bus (or external data bus):** On some motherboards that support more than one CPU type, it may be necessary to configure this setting manually. You will need to consult the PC manufacturer's manual.
- **Multiplier:** Because the internal frequency of a CPU is faster than the speed of the system bus on modern PCs, the motherboard uses a special chip called a **clock multiplier** to synchronize the transfer of data between the CPU and RAM. Some newer PCs use more than one multiplier chip when required to synchronize data transmission between RAM, system bus, and AGP video bus.
- **Voltage settings**: Early Intel and AMD CPUs (including AMD 80486 processors and the first Intel Pentium CPU) used 5 volts. CPU manufacturers have reduced CPU voltage requirements with each new processor generation in an effort to reduce heat generation and reduce the size of heat sinks and fans. Some current CPUs operate on as little as 1 to 1.7 volts.

To configure a motherboard for use with a particular CPU, you should always refer to the documentation provided by the motherboard manufacturer. The documentation provides specific details about supported CPU types, bus speeds, and voltages, and how to choose appropriate settings. This is one of the reasons that IT professionals need to save all of the documentation that comes with a computer.

The following is a simple formula for determining the appropriate multiplier and front side bus settings for a particular CPU/motherboard combination:

Internal CPU frequency = front side bus speed x multiplier

For instance, if your computer has an Intel Pentium III 900 MHz Coppermine CPU, then the motherboard uses a front side bus speed of 100 MHz with a multiplier of 9. If the motherboard supports an upgrade to a Pentium III 1.0 GHz Coppermine CPU, the front side bus speed should be reconfigured to 133 MHz and the multiplier set to 7.5 to accommodate the faster processor. **Table 2-8** illustrates some standard specifications for a number of common CPUs.

With some motherboard/CPU combinations, it may be possible to use alternate bus speed/multiplier settings, as long as the end result matches the CPU's internal frequency. For instance, an FSB setting of 100 MHz with a multiplier of 10 might be used for a Pentium III 1.0 GHz CPU if the CPU and motherboard specifications permit this.

Table 2-8 Internal and External Clock Speeds, Multipliers, and Voltages for Common CPUs

CPU Package	Internal Clock	System Bus Speed	Clock Multi-plier Speed	Core Voltage	L2 Cache	Cache Frequency	Intel Architecture (Nickname)	Size (in microns)
PGA/Socket 7								
Pentium 60	60 MHz	60 MHz	1	5.0V	Off-chip	60 MHz	P5	.8
AMD K5	75 MHz	50 MHz	1.5	3.30V	Off chip	50 MHz	K5	0.5
Pentium 75	75 MHz	50 MHz	1.5	3.30V	Off chip	50 MHz	P54C	0.6
Pentium 90	90 MHz	60 MHz	1.5	3.30V	Off-chip	60 MHz	P540	0.6
Pentium 120	120 MHz	60 MHz	2.0	3.30V	Off-chip	60 MHz	P540	0.6
Pentium 133	133 MHz	66 MHz	2.0	3.30V	Off-chip	66 MHz	P540	0.6
Pentium 150	150 MHz	60 MHz	2.5	3.30V	Off-chip	60 MHz	P540	0.6
Pentium 166	166 MHz	66 MHz	2.5	3.30V	Off-chip	66 MHz	P540	0.6
Pentium 200	200 MHz	66 MHz	3.0	3.30V	Off-chip	66 MHz	P540	0.6
Cyrix 6x86	200 MHz	75 MHz	2.0	3.30V	Off-chip	75 MHz	M1	0.6
Pentium MMX 166	166 MHz	66 MHz	2.5	2.80V*	Off-chip	66 MHz	P55C	0.35
Pentium MMX 233	233 MHz	66 MHz	3.5	2.80V*	Off-chip	66 MHz	P55C	0.35
K6 166	166 MHz	66 MHz	2.5	2.00V*	Off-chip	66 MHz	K6	0.35
K6 233	333 MHz	66 MHz	3.0	3.30V*	Off-chip	66 MHz	K6	0.30
K6 300	300 MHz	66 MHz	4.0	2.20V*	Off-chip	66 MHz	K6	0.20
PGA/Socket 8								
Pentium Pro 200	200 MHz	66 MHz	3.5	3.30V	256 KB	66 MHz	P6	0.35
SEPP/Slot 1								
Celeron 266	266 MHz	66 MHz	4.0	2 00V	None	None	Covington	0.30
Celeron300A	300 MHz	66 MHz	4.5	2 00V	120 KB	300 MHz	Mendocino	0.20
Celeron 333	333 MHz	66 MHz	5.0	2.00V	120 KB	333 MHz	Mendocino	0.20
Celeron 433	433 MHz	66 MHz	6.0	2.00V	120 KB	433 MHz	Mendocino	0.20
SECC/Slot1								
Pentium II 233	233 MHz	66 MHz	3.5	2.80V*	512 KB	117 MHz	Klamath	0,35
Pentium II 266	266 MHz	66 MHz	4.0	2.80V*	512 KB	133 MHz	Klamath	0,35
Pentium II 300	300 MHz	66 MHz	4.5	2.80V*	512 KB	150 MHz	Klamath	0.35
Pentium II 333	333 MHz	66 MHz	5.0	2.00V*	512 KB	167 MHz	Deschutes	0.25
Pentium II 400	400 MHz	100 MHz	4.0	2.00V*	512 KB	200 MHz	Deschutes	0.25
Pentium II 450	450 MHz	100 MHz	4.5	2.00V*	512 KB	225 MHz	Deschutes	0.25
AMD/Slot A								
Athlon 500A	500 MHz	100 MHz (x2)	5.0	1.60V	Off-chip	250 MHz	K7 512KB	0.18
Athlon 550A	550 MHz	100 MHz (x2)	5.5	1.60v	Off-chip 512 KB	275 MHz	K7	0.18
Athlon 800A	800 MHz	100 MHz (x2)	8.0	1.70V	Off-chip 512 KB	320 MHz	K7	0.18

skill 12 Matching CPUs and Motherboards (cont'd)

A+ Hardware objective

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.
4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

overview

On motherboards that support only one CPU type, the bus speed and multiplier settings may be locked and you will be unable to change them. On motherboards that support more than one CPU type, either the front side bus speed or the multiplier setting (or both settings) can be adjusted. Many current motherboards configure system bus speed, clock multiplier, and voltage settings for the CPU automatically once the CPU has been inserted into the motherboard. Some motherboards require these settings to be user-configured through the CMOS setup program in the computer's BIOS (**Figure 2-33**). You will find more detailed information about CMOS setup options in Lesson 5.

On some motherboards, particularly older models, front side bus speed and CPU voltage settings must be adjusted manually through the use of **jumpers** and **dipswitches**. Jumpers and dipswitches are mechanical devices for regulating circuits on the motherboard (or on an expansion card). Jumpers are plastic-covered metal clips that slip over jumper pins and create a closed circuit. Dipswitches are small switches that can be turned either on or off to close and open circuits. Both devices are used to create alternate device configurations in the field by users or technicians. Some older CPUs are **dual-voltage CPUs**, requiring different voltage settings for internal and external operation. **Single-voltage CPUs** operate internally and externally at the same voltage. **Figure 2-35** illustrates how to configure the **voltage regulator module (VRM)** on a Socket 7 motherboard for a Pentium I 133 MHz CPU.

Modern motherboards usually regulate voltage to the CPU automatically. Multipliers and bus speeds are set by the BIOS or configured by the use of small dipswitches (**Figure 2-36**).

caution

Improper voltage configuration on a motherboard can ruin a CPU. If you're not sure of the proper settings, consult the technical support department of the motherboard vendor.

how to

Configure a Socket 7 motherboard designed for Intel Classic Pentium CPUs.

1. Configure the front side bus speed. Identify the correct jumper pin set to configure the front side bus speed in the motherboard documentation (referred to as the "external clock speed" in the documentation for this motherboard). The documentation identifies JP5 as the correct jumper pin set.
2. Locate jumper pin set JP5 on the motherboard (**Figure 2-34**). Notice that the pins are arranged in rows numbered 1 to 3, and columns labeled A, B, C, and D.
3. Configure the front side bus speed to 66 MHz by placing jumpers over pins 2A and 3A, 1B and 2B, 2C and 3C, and 1D and 2D (darkened outline in **Figure 2-34**).
4. Identify the correct clock multiplier. For a 133 MHz CPU and 66 MHz front side bus speed, the clock multiplier should be 2.0.
5. Locate the correct jumper pin set to configure the clock multiplier. For this motherboard, the documentation identifies JP7 as the "internal clock speed selector."
6. Place jumpers over the pins identified in the documentation. In this case, using the settings for 2.0X. These settings will jump pins 2A and 3A, and 1B and 2B (**Figure 2-34**). There is no jumper for pins in column C.
7. Configure the voltage for the CPU. Identify in the documentation the correct jumper pin set. For this motherboard, the documentation identifies JP6 as the correct jumper pin set (called "CPU core voltage selectors" in this example).
8. Locate jumper pin set JP6 on the motherboard (**Figure 2-35**).
9. Set the CPU voltage to 3.3 volts by using the settings for Core Vcc of 3.3 volts. Place a jumper over the pins highlighted in **Figure 2-35**.

Table 2-8 Internal and External Clock Speeds, Multipliers, and Voltages for Common CPUs (cont'd)

CPU Package	Internal Clock	System Bus Speed	Clock Multiplier Speed	Core Voltage	L2 Cache	Cache Frequency	Intel Architecture (Nickname)	Size (in microns)
Athlon 1000A	1000 MHz	100MHz (x2)	10.0	1.80V	Off-chip 512KB	333 MHz	K7	0.18
SECC2/Slot 1								
Pentium III 450	450 MHz	100 MHz	4.5	2.00	512 KB	300 MHz	Katmai	0.25
Pentium III 600	600 MHz	133 MHz	4.5	1.65V	256 KB	600 MHz	Coppermine	0.18
Pentium III 900	900 MHz	100 MHz	9.0	1.70V	256 KB	900 MHz	Coppermine	0.18
Pentium III 1.0 GHz	1000 MHz	133 MHz	7.5	1.70V:	256 KB	1000 MHz	Coppermine	0.18
SECC2/Slot 2								
Pentium II Xeon	450 MHz	100 MHz	4.5	2.0V	512 KB	450 MHz	Drake	.25
Pentium III Xeon	1000 MHz	133 MHz	7.5	1.5V	256 KB	1000 MHz	Cascades	0.18
PPGA/FC-PGA/Socket 370								
Celeron 533A	533 MHz	66 MHz	8.0	1.SOV	128 KB	533 MHz	Coppermine	0.18
Celeron 566	566 MHz	66 MHz	8.5	1.50V	128 KB	566 MHz	Coppermine	0.18
Celeron 600	600 MHz	66 MHz	9.0	1.50V	128 KB	600 MHz	Coppermine	0.18
Pentium III 650	650 MHz	100 MHz	6.5	1.65v	256 KB	650 MHz	Coppermine	0.18
Pentium III 700	700 MHz	100 MHz	7.0	1.6SV	512 KB	700 MHz	Coppermine	0.18
Pentium III 866	866 MHz	133 MHz	6.5	1.65V	256 KB	866 MHz	Coppermine	0.18
Pentium III 1.0 GHz	1000 MHz	133 MHz	7.5	1.70V	256 KB	1000 MHz	Coppermine	0.18
PPGA/FC-PGA/Socket 423								
Pentium 4 1.3 GHz	1300 MHz	100 MHz (x4)	3.5*	1.70V	256 KB	1300 MHz	Willamette	0.18
PPGA/FC-PGA2/Socket 478								
Pentium 4 2.8 GHz	2800 MHz	133 MHz (x4)	5.5*	1.5V	512 KB	2800 MHz	Northwood	0.13
Pentium 4 3.4 GHz	3400 MHz	200 MHz (x4)	4.5	1.5V	512 KB	3400 MHz	Prescott	0.09
AMD/Socket A								
Athlon MP 2800+	2130 MHz	133 MHz (x2)	16	1.75V	512 KB	2130 MHz	Thunderbird	.13
AMD/Socket 754								
Athlon 64 2800+	1800 MHz	400 MHz	4.5	1.5V	512 KB	1800 MHz	K8	.13

1 micron = one millionth of a meter, or 1/1,000,000 meters. This length is also referred to as a micrometer.

* These are dual-voltage CPUs, which require separate core voltage and external voltage settings. The required external voltage settings may vary from 3.3V to 4.3V. System documentation should be consulted.

** On some Pentium 4 motherboards, there are two clock multipliers, one for the system bus-to-CPU-connection (indicated in the Multiplier column) and one for the connection of DDR2 or RAMBUS Direct RAM-to the system bus connection (indicated in parentheses in the System Bus column). For example: for the Pentium 4 2.8GHz Northwood CPU, the front side bus speed (133 MHz) is multiplied by 4 and then, again by 5.5 to match the 2.8 GHz internal clock speed of the CPU. See Lesson 3 for more details.

skill 12

Matching CPUs and Motherboards

(cont'd)

A+ Hardware objective

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.

4.1 Distinguish between the popular CPU chips in terms of their basic characteristics.

how to

10. Set the motherboard CPU voltage. Our Pentium 133 processor is a single-voltage CPU (P54C). As described in the documentation for this motherboard, the correct jumper pin set is JP8.
11. Locate jumper pin set JP8 on the motherboard. Set the motherboard for this CPU to 3.3 volts by placing plastic jumpers over the highlighted pins in **Figure 2-35**.

Figure 2-33 CMOS settings for front side bus speed

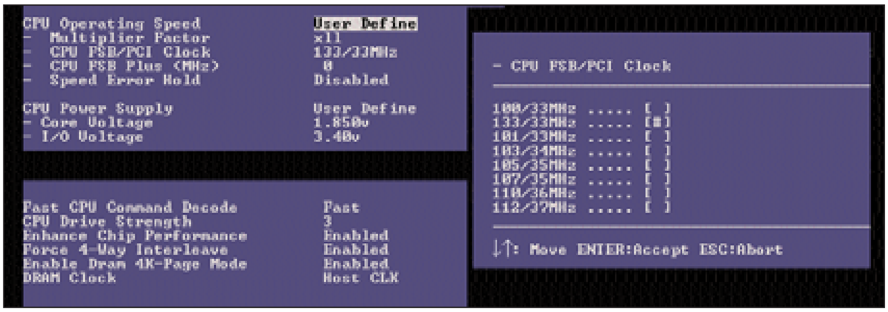


Figure 2-34 FSB and multiplier jumper settings

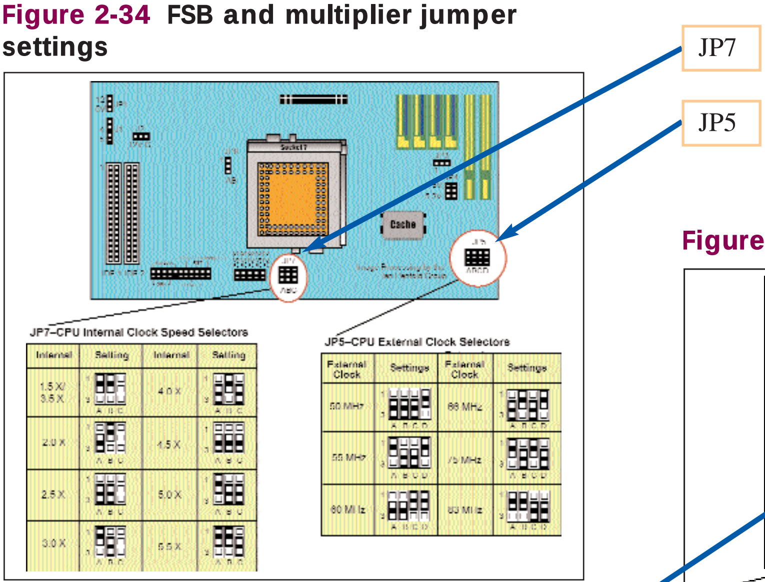


Figure 2-35 Classic Pentium voltage settings

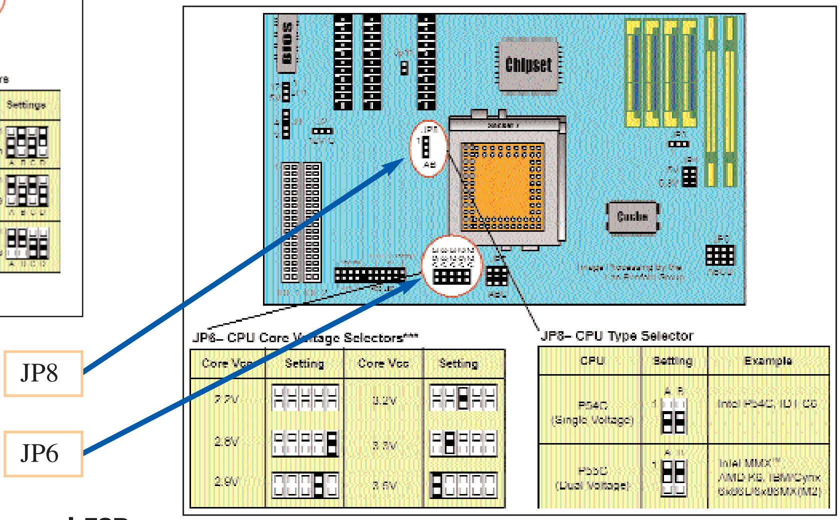
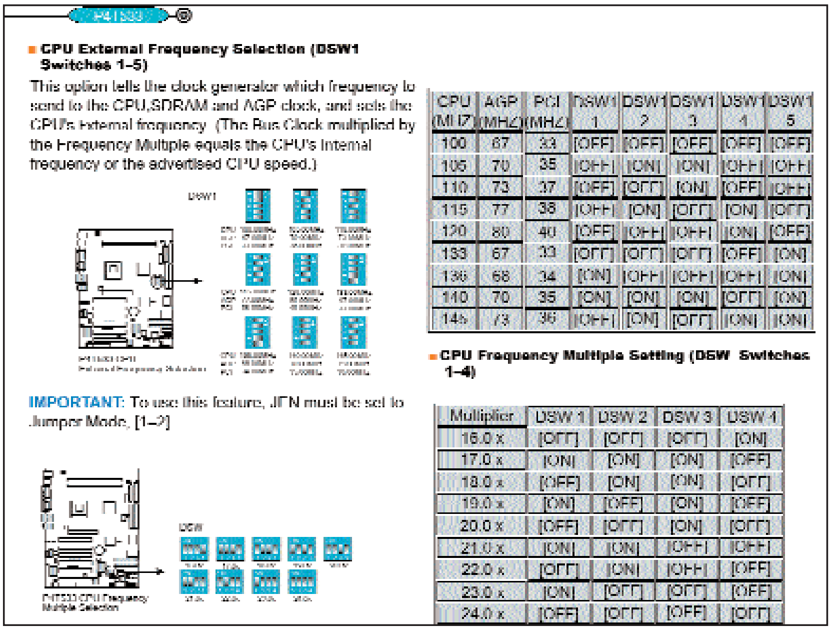


Figure 2-36 AMD Socket 478 motherboard FSB and multiplier settings



CPU External Frequency Selection (DSW1 Switches 1–5)

This option tells the clock generator which frequency to send to the CPU,SDRAM and AGP clock, and sets the CPU's External frequency. (The Bus Clock multiplied by the Frequency Multiple equals the CPU's Internal frequency or the advertised CPU speed.)

CPU (MHZ)	AGP (MHZ)	PCI (MHZ)	DSW1 1	DSW1 2	DSW1 3	DSW1 4	DSW1 5
100	67	33	[OFF]	[OFF]	[OFF]	[OFF]	[OFF]
105	70	35	[OFF]	[ON]	[ON]	[OFF]	[OFF]
110	73	37	[OFF]	[OFF]	[ON]	[OFF]	[OFF]
115	77	38	[OFF]	[ON]	[OFF]	[ON]	[OFF]
120	80	40	[OFF]	[OFF]	[OFF]	[ON]	[OFF]
133	67	33	[OFF]	[OFF]	[OFF]	[OFF]	[ON]
136	68	34	[ON]	[OFF]	[OFF]	[OFF]	[ON]
140	70	35	[ON]	[ON]	[ON]	[OFF]	[ON]
145	73	36	[OFF]	[ON]	[OFF]	[ON]	[ON]

IMPORTANT: To use this feature, JEN must be set to Jumper Mode, [1–2]

CPU Frequency Multiple Setting (DSW Switches 1–4)

Multiplier	DSW 1	DSW 2	DSW 3	DSW 4
16.0 x	[OFF]	[OFF]	[OFF]	[ON]
17.0 x	[ON]	[ON]	[ON]	[OFF]
18.0 x	[OFF]	[ON]	[ON]	[OFF]
19.0 x	[ON]	[OFF]	[ON]	[OFF]
20.0 x	[OFF]	[OFF]	[ON]	[OFF]
21.0 x	[ON]	[ON]	[OFF]	[OFF]
22.0 x	[OFF]	[ON]	[OFF]	[OFF]
23.0 x	[ON]	[OFF]	[OFF]	[OFF]
24.0 x	[OFF]	[OFF]	[OFF]	[OFF]

skill 13 Understanding CPU Cooling Systems (Fans, Heat Sinks, and Liquid Cooling)

A+ Hardware objective

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

overview

In general, the higher the clock speed of the CPU, the hotter it runs, and the more cooling is required to prevent overheating and performance failure. In the earliest PCs, air vents in the case combined with the fan attached to the power supply provided a sufficient cooling system. But since the Intel 80486 CPU, additional cooling systems have been necessary in the form of **heat sinks** and/or fans mounted on the CPU itself **(Figure 2-37)**. **Liquid cooling systems**, consisting of a pump and water block which acts as a heat sink, are being used in some new high-performance PCs **(Figure 2-38)**. These components draw heat away from the processor to prevent erratic performance and/or CPU failure.

Some modern CPU/motherboard combinations also include automatic temperature sensors that shut down the computer when the CPU is too hot. However, automatic shutdown features are not always reliable; so a good cooling system is an essential feature for reliable PC performance. CPU cooling systems draw heat away in three ways, through **conduction**, **convection**, and **radiation**.

- A heat sink cools the CPU primarily through conduction—physical contact that transfers the heat from one solid surface to another. Most heat sinks are made of aluminum, a good heat conductor. Some heat sinks are composed of copper, which is an even more efficient heat conductor than aluminum. The metal fins on a heat sink increase the surface area exposed to cooler air and increase the efficiency of heat transfer. Heat is then transferred from the metal of the heat sink to surrounding air by convection.
- CPU fans use convection—the transfer of heat energy from a solid to a fluid medium, such as air or water. CPU cooling systems often include both a heat sink and a fan. After the heat is drawn from the processor to the heat sink, the fan forces large volumes of air over the heat sink's surface to further cool the system. The faster and bigger the fan, the better the air flow and the more convection that will take place. The principle factors used to rate the performance of a CPU fan are the amount of airflow it generates (measured in cubic feet per minute or CFM), and the noise produced by its operation (measured in decibels or dB).
- Liquid cooling systems **(Figure 2-38)** make use of the fact that when equal volumes of water and air pass over a hot metal surface, the rate of heat transfer from metal to water is about 100 times greater than the transfer rate from metal to air. In most liquid cooling systems, a pump forces cold water over heat-exchanging material called a waterblock. Inside the waterblock, the water absorbs heat energy from the processor, cooling it down. The hot water flows away from the CPU through a tube, passing through a heat sink that serves as a radiator. The heat sink transfers the heat energy to the ambient air outside of the case and the pump cycles the cooled water back to the waterblock. One benefit of liquid cooling is reduction of noise inside the computer. Heat sink/fan combinations generate a fair amount of noise because the fan must operate at high rotational speeds to force air to flow over the CPU.
- Electromagnetic radiation, the third process by which heat can be dissipated, plays only a small part in CPU cooling systems. Just as the sun's energy warms the surface of Earth, a hot CPU emits electromagnetic radiation that travels outward. This radiant energy will be reflected from a light-colored surface or absorbed by a dark colored one. Compared to the quantities of heat carried away by conduction and convection, heat transfer in a PC through radiation is relatively insignificant.

tip

If your PC's motherboard is a newer model equipped with temperature sensors, the CPU temperature can be monitored through software such as Intel's Active Monitor, supplied with systems that use Intel motherboards, or Motherboard Monitor, which is a freeware utility that works with most Pentium 4 and newer AMD Athlon motherboards.

more

Conduction is generally a more efficient cooling process than convection. The surfaces of a CPU and a heat sink or fan are generally uneven. If thin columns of air accumulate between the two surfaces, less heat conduction takes place. To seal the contact between the CPU and the heat sink (or fan), a good CPU cooling system will use a special thermal paste between the two surfaces to increase the efficiency of heat transfer.

Figure 2-37 CPU fans and heat sinks

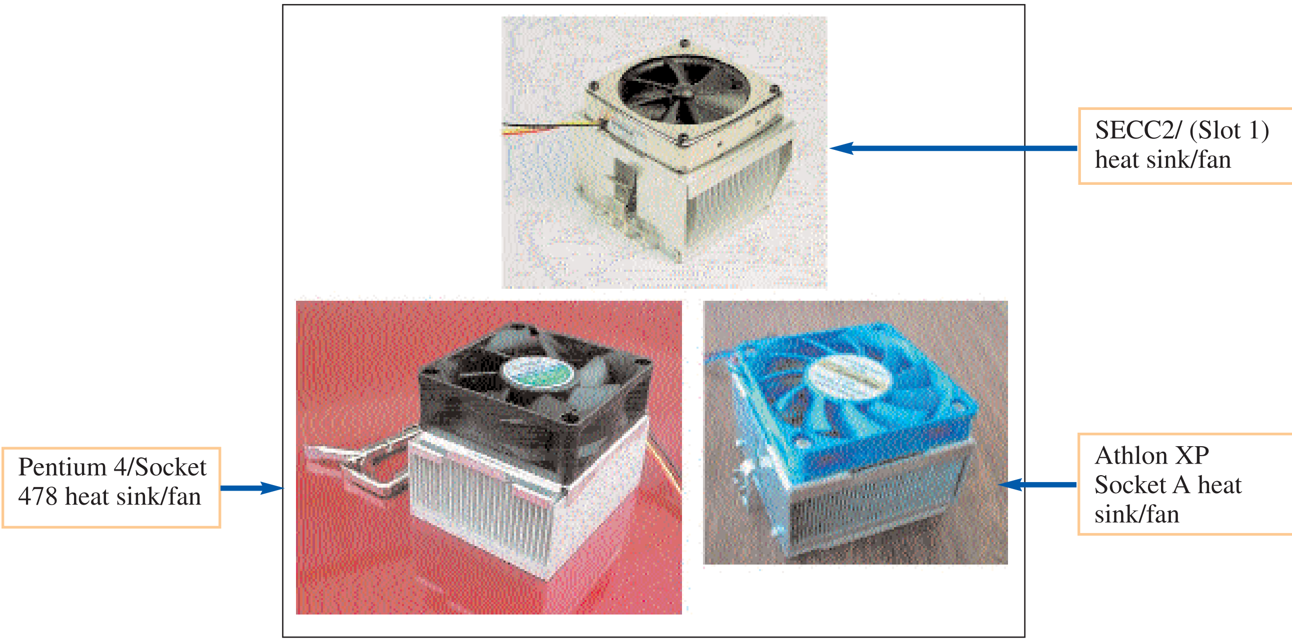
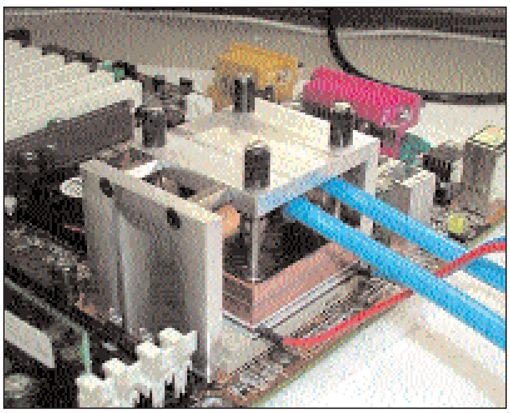


Figure 2-38 Liquid cooling system



skill 14

Installing a CPU and Heat Sink/Fan on a Motherboard with Slot Architecture

A+ Hardware objective

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

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.

overview

The first step of installing a new CPU on a motherboard (or replacing an existing CPU) is to read the motherboard's documentation to see if the CPU is supported. If the documentation doesn't discuss support for a newer CPUs, check the vendor's Web site to learn if the new CPU is supported by the manufacturer and if the manufacturer provides an updated Flash BIOS for the motherboard.

If the motherboard supports the CPU, you must then confirm that the new CPU has an appropriate cooling system. Intel's processors are sold in two different ways: a retail boxed kit that usually includes a heat sink/fan cooling system or an OEM (original equipment manufacturer) package intended for system vendors without including a cooling system. AMD Athlon CPUs are also often sold bare (without heat sinks) by OEM dealers.

Before you purchase a CPU cooling system, make sure you read the specifications to make sure it supports the CPU model you intend to install. In some cases, you may be able to transfer the heat sink or fan from an old CPU, but you may find that the heat sink assembly is glued to the processor. If you are adding a third-party heat sink or fan, make sure that you also have a tube of thermal paste compound or a thermal pad to seal its connection with the CPU surface.

To remove an existing CPU, make sure that the system is powered down. Disconnect the power cable from the back of the PC and make sure that you are wearing an antistatic wrist strap. The system documentation should tell you whether the motherboard automatically configures the system bus (front side bus) frequency and clock multiplier or whether this must be done manually. If the motherboard requires manual configuration through jumpers or dipswitches, make sure that you have configured them properly before physically removing/installing the CPU.

tip

Detailed, step by step instructions on attaching the heat sink assembly to an Intel Slot 1 CPU are available at http://www.intel.com/design/pentiumii/packtech/24445401.pdf.

caution

In removing a new CPU from its shipping bag or container, hold the chip by the edges—refrain from touching any of the pins.

how to

To install a new CPU on a motherboard that uses slot architecture.

1. Unfold the two arms of the universal retention mechanism (URM) that surrounds the slot **(Figure 2-39)**. If you are installing a new motherboard, you may need to install the retention mechanism around the CPU slot. See the documentation that comes with the motherboard for instructions. If you are replacing the CPU, slide the old CPU out of its slot on the motherboard. If there are latches on the arms of the URM, release them before attempting to lift the CPU. On some motherboards, the plastic runners at each end of the CPU may have clips that must be pulled back or depressed **(Figure 2-39)**. If the old CPU has a fan, detach the cable from the motherboard and make note of where the new fan will plug in.
2. Make sure that the proper heat sink/fan is attached to the SECC or SEPP package of the new CPU. In most cases, the heat sink will have two metal braces that clamp over opposite sides of the CPU cartridge. To attach a passive heat sink, you may need to obtain special tools available for this purpose **(Figure 2-40)**.
3. Insert the CPU cartridge, with attached heat sink/fan into the supporting arms on either side of the CPU slot. The slot will have a small orientation ridge in the center to prevent you from putting it in the wrong way. Push down until the contacts fit snugly and make sure the cartridge locks into position. **(Figure 2-41)**.
4. If the cooling system has a fan, connect the fan cable to the appropriate fan power connector on the motherboard.
5. If the motherboard requires manual configuration of the front side bus speed and clock multiplier through CMOS settings, boot into your computer's setup program and make any appropriate changes before attempting a normal boot into the operating system.

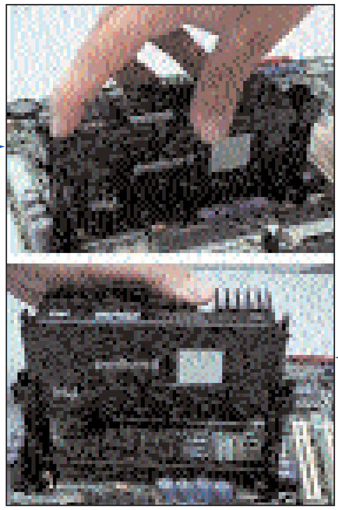


Figure 2-39 Removing a Slot 1 SECC cartridge

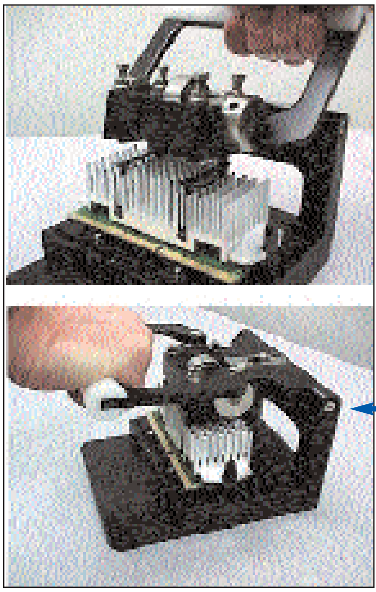


Figure 2-40 Installing a Slot 1 SECC cartridge

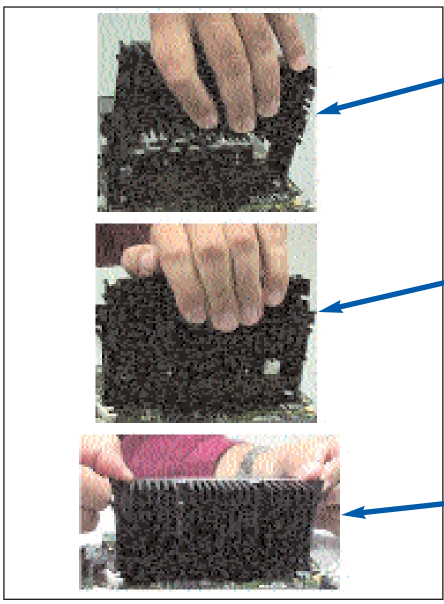


Figure 2-41 Attaching a passive heat sink to an SECC cartridge

skill 15

Installing a CPU and Heat Sink/Fan on a Motherboard with Socket Architecture

A+ Hardware objective

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

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.

overview

tip

Detailed instructions on removing and attaching the heat sink assembly on an Intel Pentium 4 CPU are available at http://support.intel.com/support/processors/pentium4/sb/CS-007989.htm#Heatsink.

To install a new CPU on a motherboard that uses socket architecture, you must first remove the old CPU. Determine whether the old CPU can be removed simply by raising the ZIF release lever on the socket and lifting. On older processors, you may need to remove the fan or heat sink assembly before lifting the CPU from its socket. CPU fans on older models can often be pulled off easily by toggling release levers on opposite sides of the socket (**Figure 2-42**).

With a Socket 478 Intel Pentium 4 CPU, the CPU socket is surrounded by a processor retention mechanism with four push pins (**Figure 2-43**). To release the heat sink/fan assembly, you must raise the clip levers on opposite sides of the retention mechanism (**Figure 2-44**). The retention mechanism's clip frame latches can be unhooked with a small flathead screwdriver. Once the frame latches are unhooked, lift the heat sink/fan assembly slowly to remove it from the processor. After the heat sink assembly has been removed, raise the processor socket handle to release the CPU pins and lift the CPU from the socket.

how to

Install a new CPU on a motherboard that uses socket architecture.

1. Inspect your new CPU and determine whether it includes an appropriate heat sink/fan cooling system. If you need to install a heat sink/fan assembly, you may want to practice clipping it over the socket on the motherboard without the CPU, until you get a sense of how it will snap into place. If you are attaching a third-party heat sink and fan to the CPU as separate components, you may want to apply a thin coating of thermal paste to the surface of the CPU chip before pressing the heat sink down on it. Likewise, apply thermal paste to the top surface of the heat sink before attaching a CPU fan to it.
2. Locate pin 1 on your new or replacement CPU. On older CPU models, pin 1 may be indicated by a white dot on the chip in the corner that contains pin 1; or the corner may be notched (**Figure 2-45**). An Intel Pentium 4 CPU with an FC-PGA2 package has a gold arrow pointing to pin 1 on the bottom side of the chip; additionally, the chip fits into the socket only one way—with pin 1 in the corner with the lever pivot for the socket (**Figure 2-46**).
3. Gently place the CPU over the socket, taking care to align the pins so that they fit smoothly into corresponding pinholes; then drop it into place. If the CPU does not immediately fit flush into the socket, you can slide it gently to the right or left until it drops into place. Once the CPU is in place, lower the socket lever to lock the pins into position.
4. On newer model CPUs, you may need to attach the heat sink/fan assembly after the CPU has been placed in the socket. If the installation instructions recommend it, apply a thin layer of thermal paste to the top of the CPU. Then, align the heat sink squarely on top of the CPU and press down. On many heat sink models, you will find a pair of clips on either side that fit over tabs protruding from the socket. Some heat sinks wrap around the CPU, with the thermal paste acting as the only binding attachment. If the fan was bundled

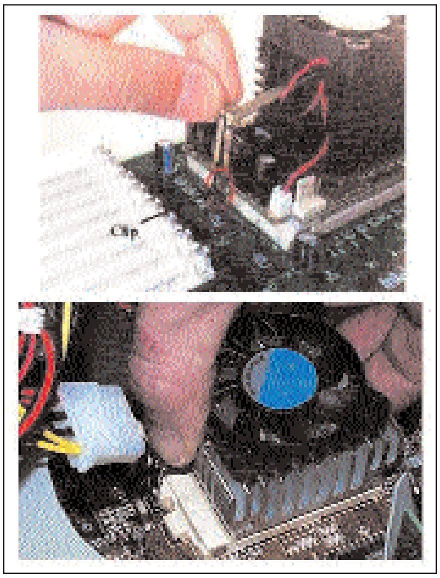


Figure 2-42 Removing an older, socketed CPU

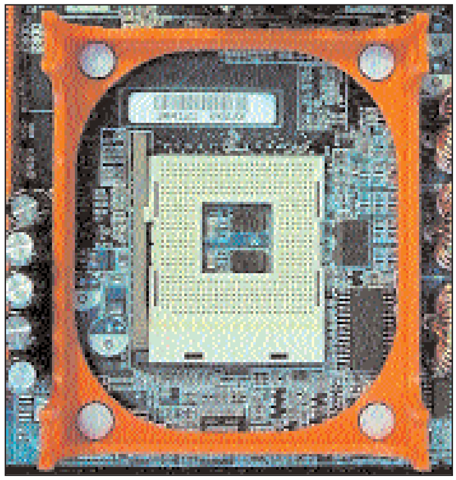


Figure 2-43 Socket 478 retention mechanism

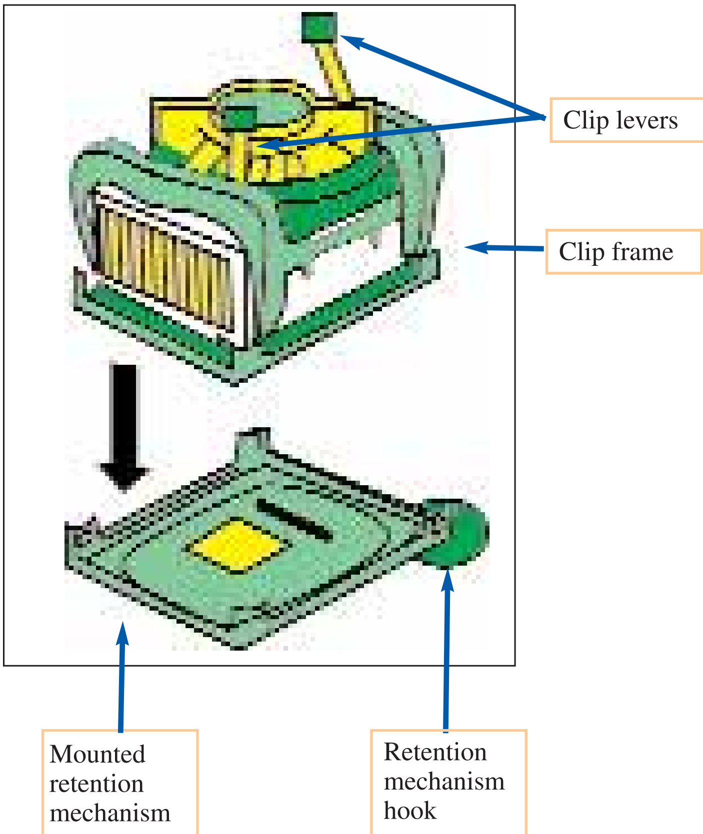


Figure 2-44 Removing Pentium 4 heat sink/fan assembly and retention mechanism

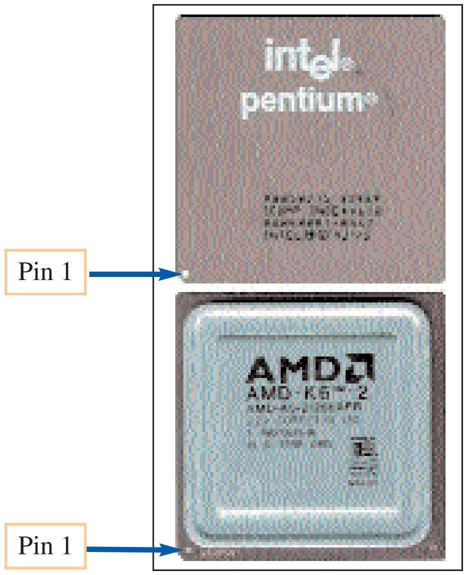


Figure 2-45 Finding pin 1 on older CPUs

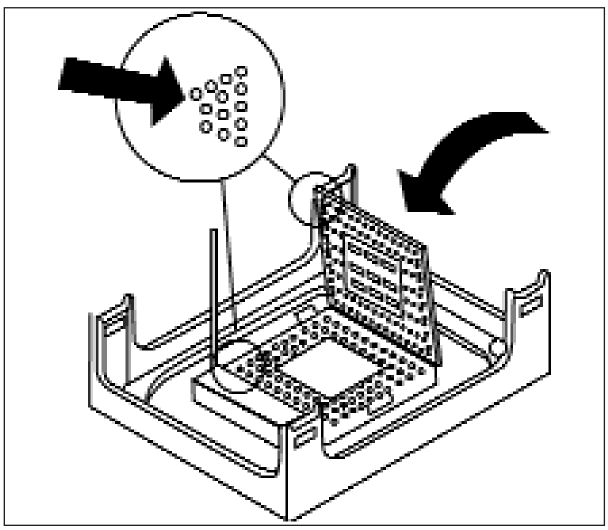


Figure 2-46 Aligning a P4 CPU in Socket 478

skill 15

Installing a CPU and Heat Sink/Fan on a Motherboard with Socket Architecture

A+ Hardware objective

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

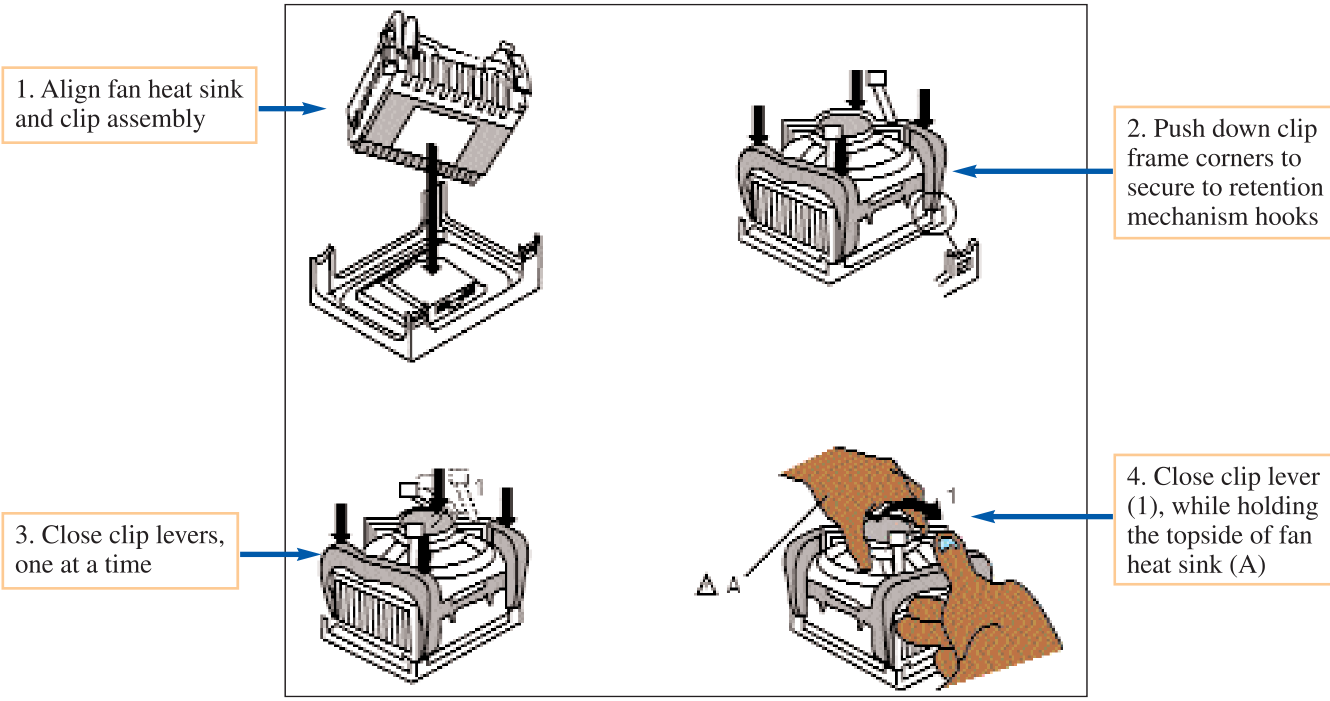
1.10 Determine the issues that must be considered when upgrading a PC. In a given scenario, determine when and how to upgrade system components.

how to

separately in the cooling system, apply a layer of thermal paste to the top of the heat sink. (The vendor may supply an adhesive thermal pad for this purpose.) Place the fan squarely on top of the heat sink and press down. The fan may also have a pair of clips that you can snap onto tabs protruding from the CPU socket.With a boxed Intel Pentium 4 CPU, the fan is pre-attached to the heat sink assembly and surrounded by the retention mechanism, which slides down into the four corner tabs on the retention socket. The entire assembly is lowered over the socketed CPU with the retention clip levers in an upward position. Once the assembly is in place, the clip levers are lowered in opposite directions **(Figure 2-47)**.

5. When the CPU and heat sink/fan assembly are in place, connect the fan's power cable to the proper connector/jumper on the motherboard.

Figure 2-47 **Installing a P4 heat sink assembly and retention mechanism**



skill 16 Working with Multiple Processors

A+ Hardware objective

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

overview

Symmetric Multiprocessing (SMP) is a PC system architecture that allows multiple CPUs on a single motherboard to run an operating system and its applications. SMP, developed by Intel, is the most common system for running a multiprocessor computer. The operating system and all applications can share common memory resources. Earlier, asymmetric multiprocessing systems attempted to divide system tasks, using one CPU to run the operating system and another for applications.

You might think that having two CPUs run an operating system would double the speed of a computer's performance, but it doesn't work that way in practice. The goal of using a multiprocessor system is to improve performance speed for applications, particularly database applications running on servers. The use of multiple CPUs on a single motherboard can produce improved system performance, but the improvement depends upon efficient programming of the operating system and SMP applications. If only one CPU at a time is actually doing useful work, then a multiprocessor system may produce no better performance than a single processor system. In addition to performance benefits, symmetric multiprocessing can provide reliability benefits. When a single CPU is forced beyond its capability, 100% utilization of its resources can prevent malfunctioning applications from terminating. Under SMP, if one CPU is overloaded, another CPU can issue instructions to close down a program that is not performing correctly. The requirements for running a multiprocessor system **(Figure 2-48)** are as follows:

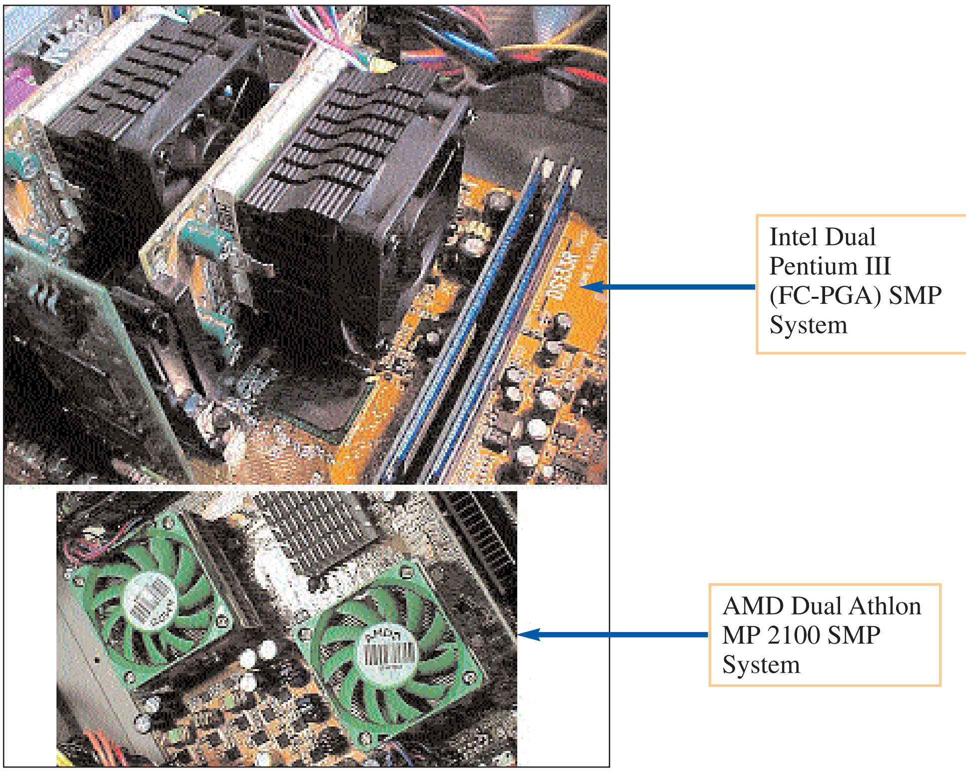
- **A motherboard that supports more than one CPU:** The motherboard must include more than one CPU slot or socket.
- **CPUs that support multiprocessing:** Not all PC CPUs from Intel, AMD, and other vendors can deliver multiprocessing support. Some members of individual CPU families support multiprocessing and others do not.
- **An operating system that supports multiprocessing:** Microsoft's Windows NT 4 Workstation, Windows 2000 Professional, and Windows XP Professional operating systems each support the use of two CPUs under Intel's SMP standard. The server versions of Windows NT4, Windows 2000, and Windows Server 2003 support the use of up to 32 CPUs on a single motherboard. Some versions of the Linux and Unix operating systems claim the ability to utilize 64 processors.

Intel's Dual Independent Bus (DIB) architecture, developed for the Pentium Pro processor, provides two independent buses. Two supported CPUs can access data on either bus simultaneously, rather than sequentially. The DIB architecture was extended for multiprocessing with subsequent Intel CPUs.

Intel's Slot-1 architecture, developed for Pentium II and Celeron processors, permits only two CPUs to cooperate on an SMP system. However, up to four socketed Pentium Pro CPUs can work together under an SMP operating system. The development of the Slot 2 CPU interface permitted SMP with up to eight Pentium III Xeon CPUs. Motherboards that support Pentium 4 Xeon and AMD Athlon CPUs may accommodate as many as 64 processors, although the current limit imposed by the Windows Server 2003 operating system is 32.

Glueless multiprocessing refers to a processor's ability to communicate with other processors without using special programming logic (or glue) to tie the CPUs together. With the addition of special logic chips on the motherboard, or custom software, it is possible to exceed the so-called glueless SMP limits of Intel and AMD CPUs, for instance, to run eight Pentium Pro CPUs on a single motherboard. If you see motherboard specifications that guarantee 4-way, 8-way, or 16-way glueless multiprocessing, this refers to the number of

Figure 2-48 **SMP dual CPU systems**



skill 16 Working with Multiple Processors (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

CPUs that can be used with standard SMP architecture and a supported operating systems **(Table 2-9)**.

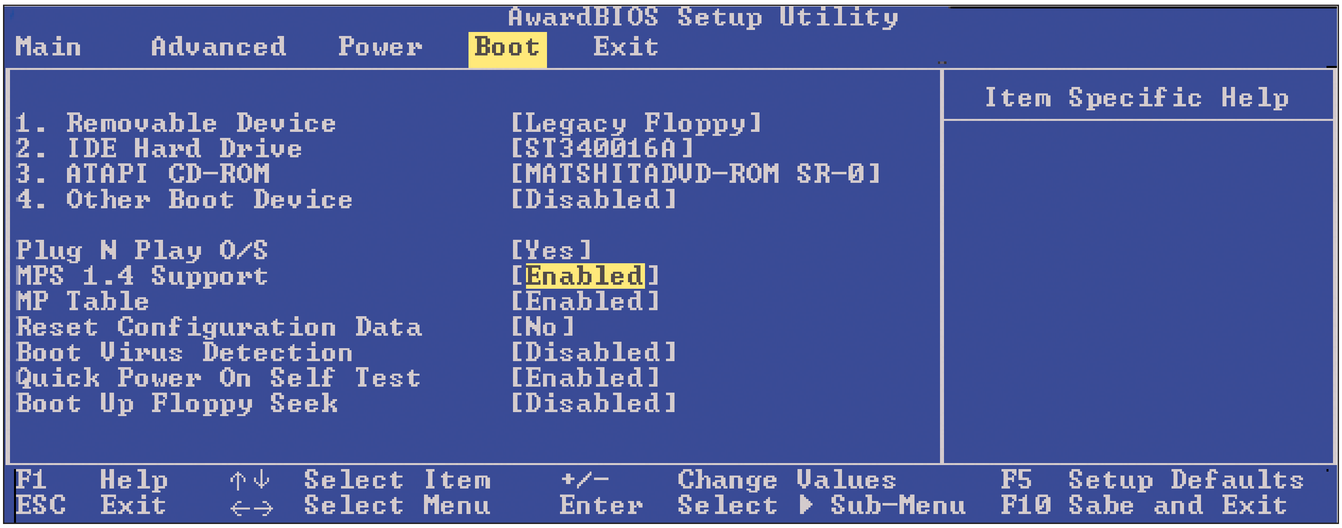
For a computer to use multiprocessor hardware effectively, it must run software written for an SMP system. SMP-compliant operating systems allow improved performance when a computer is used primarily as a file server. Ordinary Windows applications, written for a single processor environment, do not speed up appreciably on SMP systems. The kinds of programs that benefit most from an SMP environment are specially written, CPU-intensive applications, such as databases and multimedia-editing suites.

On some multiprocessor motherboards SMP support must be enabled through the CMOS setup program **(Figure 2-49)**. Other multiprocessor motherboards detect and configure multiple CPUs automatically.

Table 2-9 Intel and AMD CPUs that support Symmetric Multiprocessing

CPU	SMP Support
Intel Processors	
Pentium Pro	2 to 4-Way Glueless
Pentium II, III, Celeron (Slot 1)	2-Way Glueless
Pentium II, III Xeon (Socket 370)	2 to 8-Way Glueless
Pentium 4 Xeon (Socket 478)	2 to 32-Way Glueless
AMD Processors	
Athlon MP	2-Way Glueless
Opteron	2 to 8-Way Glueless

Figure 2-49 SMP BIOS settings



Summary

- The CPU (central processing unit) is a device in your computer that executes programmed hardware and software instructions through its embedded binary electrical circuits.
- The internal components of a CPU consist of an execution unit that receives and carries out hardware and program instructions, an arithmetic logic unit (ALU) that performs necessary numerical calculations, and a control unit that manages information flow between the CPU and RAM. Since the introduction of the Pentium CPU family, all CPUs contain at least two ALUs.
- CPUs designed for Intel-compatible PCs generally make use of the CISC (Complex Instruction Set Computing) instruction set. Intel's newest 64-bit Itanium CPUs use the new EPIC (Explicitly Parallel Instruction Computing) instruction set.
- The performance speed of internal CPU (and of external motherboard) electrical circuits is measured in millions (or billions) of clock cycles. One Hertz (Hz) is a unit of measure for a single clock cycle in one second of time. One megahertz (1 MHz) equals one million cycles.
- The front side bus frees the CPU from the necessity of communicating directly with slower motherboard components. It allows information to flow directly between the CPU and RAM in 64-bit chunks, at an increased system clock speed (frequency). The increased frequency is implemented with a special chip called a clock multiplier.
- The CPU installed in a computer may be identified by inspecting system startup screens, by examining the General tab of System Properties under Windows operating systems, by running third-party diagnostic software, or by visual inspection of the CPU on the motherboard. The key elements in CPU identification are the manufacturer, the model name or number, the speed, and the package that houses it.
- PC CPUs have increased in features and processing power through a series of development cycles. Intel, the original and largest manufacturer of PC CPUs, has been joined by several competitors, including AMD and Transmeta, in the current marketplace.
- The amount of data that flows through the CPU, RAM, and storage devices is measured in binary units called bytes, kilobytes, megabytes, and gigabytes. One kilobyte is equal to 2^{10} or 1,024 bytes. One megabyte is equal to 2^{10} or 1,024 kilobytes, one gigabyte is equal to 2^{10} or 1,024 megabytes, and so on.
- The internal bus width of a CPU is the amount of data that can flow through it (measured in bits) within one clock cycle. The internal bus width of PC CPUs, since the original Intel 8088, has increased from 16 bits to 32 bits, and most recently to 64 bits with the newest Intel Itanium and AMD Athlon-64 families.
- The address bus width of a CPU is the total amount of RAM on the motherboard that the CPU can address for data and instruction storage. Since the original Intel 8088, address bus width has increased from 20 bits (1024 kilobytes) to 32 bits (4 gigabytes), and most recently to 64 bits (64 exabytes) with the newest Intel Itanium and AMD Athlon 64 families.
- The external bus width of a CPU or other motherboard component (measured in bits) determines the amount of data that can be written to an external device within one clock cycle. Since the Pentium I, PC CPUs have had a 64-bit external bus width. Intel's new Itanium CPUs use a 128-bit external bus.
- CPUs run at separate internal and external frequencies (clock speeds) measured in megahertz (MHz) and gigahertz (GHz). The internal speed of a CPU is set by its design architecture. The external speed (or bus speed) the CPU uses to communicate with RAM and the rest of the motherboard is regulated by the system clock chip.
- A memory cache is a small quantity of RAM that runs at a faster speed than ordinary system RAM. Since the Pentium I, PC CPUs have all included a small onboard internal cache called a Level-1 (or L1) cache to improve their performance. Most CPUs also include a larger secondary Level 2 (or L2) cache. Some CPUs, including some Pentium 4 Xeon CPUs and the Intel Itanium family, make use of a third external Level 3 (or L3) cache.
- The CPU package is the component that houses or mounts the microprocessor chip. Packages for modern CPUs come in two basic formats: a pin grid array designed for a socket interface on the motherboard and a card containing a series of metal contacts, designed for a slot interface on the motherboard. Each CPU package has a unique identifying name that corresponds to the socket or slot type that will accept it.
- Intel's 242-contact, Slot 1 interface was designed for Pentium II and early Celeron CPUs. Intel's 330-contact, Slot 2 interface was an improvement, designed for Xeon processors. One significant difference between Slot 1 and Slot 2 is that Slot 2 allows the CPU to communicate with the L2 cache at the CPU's full clock speed. Slot 1 limits communication between the L2 cache and CPU to half the CPU's internal clock speed.
- The standard motherboard interface for more recent AMD Athlon CPUs is the 462-pin Socket A. More recent Pentium 4 CPUs use the 478-pin Socket 478. Intel's 64-bit Itanium and Itanium-2 CPUs use the new PAC418 (418-pin) and PAC611 (611-pin) sockets. AMD's 64-bit Athlon-64 and Opteron CPUs use Socket 754 and Socket 940, which are proprietary AMD interfaces.
- If a motherboard supports the use of more than one CPU model, it may be necessary to manually configure individual settings for front side bus speed, clock multi-

plier, and system voltage. On some motherboards, particularly older models, front side bus speed and CPU voltage settings must be adjusted manually through the use of jumpers and dipswitches. When configuring a motherboard to accept a new CPU, the Internal CPU frequency must be equal to the front side bus speed x the clock multiplier. Intel Pentium and AMD Athlon CPUs now use separate packages and interfaces that require separate motherboard designs.

- Intel and AMD standardized sockets include a feature called ZIF (zero insertion force) that makes use of a side lever to loosen and tighten the socket connection to the CPU pins. A pin grid array CPU most always be inserted so that pin 1 on the CPU matches the hole for pin 1 on the CPU socket.
- All modern, high-performance CPUs require cooling systems. A heat sink cools the CPU primarily through conduction. A CPU fan cools the CPU through convection. Many CPUs are designed to accept heat sinks and fans working in combination. The principle factors used to rate the performance of a CPU fan are the amount of airflow it generates (measured in cubic feet per minute), and the noise produced by its operation (measured in decibels). Liquid cooling systems, used less frequently, pass water or another liquid through a tube to a waterblock, which draws heat away from the CPU. The heated liquid then passes through a radiator system to be cooled and recycled back to the waterblock.
- When installing a new CPU, first read the documentation supplied by the vendor and verify that the model is supported by your motherboard. Make sure that an appropriate cooling system is available, and set any necessary motherboard jumper or dipswitch settings before installing the CPU. Always use an antistatic wrist strap when removing components from or adding components to the motherboard. Avoid touching CPU pins or contacts and hold the chip by the edges. Align the CPU properly with the socket or slot interface on the motherboard before dropping or pushing the package into place.
- Symmetric Multiprocessing (SMP) is a PC system architecture that allows multiple CPUs on a single motherboard to run an operating system and its applications. Successful deployment of an SMP computer requires a motherboard that supports more than one CPU, a set of two or more CPUs that support multiprocessing, and an operating system that supports multiprocessing.

Key Terms

advanced transfer cache (ATC)
arithmetic logic unit (ALU)
back side bus
chipset
Complex Instruction Set Computing (CISC)
clock cycle
clock doubling
clock multiplier
clock speed
conduction
control unit
convection
CPU package
CPU slot
CPU socket
dipswitch
discrete L2 cache
dual-voltage CPU
execution unit
execution trace cache
external cache (L2 cache)
Explicitly Parallel Instruction Computing (EPIC)
Flip Chip Pin Grid Array (FC-PGA)
floating point unit (FPU)
front side bus
glueless multiprocessing
heat sink
Hertz (Hz)
instruction pipelining
instruction set
internal cache (L1 cache)
Itanium
jumper
kilobyte (KB)
L2 (Level 2) cache
L3 (Level 3) cache
liquid cooling system
low insertion force (LIF)
memory address space
memory cache
Moore's Law
NetBurst
North Bridge
Opteron
Pin Array Cartridge (PAC)
Pin Grid Array (PGA)
Plastic Pin Grid Array (PPGA)
primary cache
processor die
processor speed
program counter
Reduced Instruction Set Computing (RISC)
radiation
registers
Single Edge Processor Package (SEPP)
Single Edge Contact Cartridge (SECC)
single-voltage CPU
slocket
South Bridge
Staggered Pin Grid Array (SPGA)
Symmetric Multiprocessing (SMP)
system bus
system clock
voltage regulator module (VRM)
write-through cache
write-back cache
zero insertion force (ZIF)

Test Yourself

1. Currently, who is the largest manufacturer of processor chips for personal computers?
a. Microsoft
b. Motorola
c. AMD
d. Intel

2. A CPU based on the CISC instruction set will perform faster than one based on the RISC instruction set, because CISC chips are streamlined to contain fewer built-in functions. (True or False?)

3. The performance speed of the CPU is measured in units called ____________.
a. Bits
b. Kilobytes
c. Words
d. Hertz

4. The speed at which the CPU operates internally is called the ____________.
a. System bus speed
b. Processor speed
c. Cache frequency
d. Both B and C

5. On modern computers, the ____________ connects the CPU or the front side bus to system RAM, allowing communication with faster motherboard components, such as the video display without involving the rest of the motherboard.
a. Back side bus
b. North Bridge
c. PCI bus
d. South Bridge

6. What purpose does the address bus on the motherboard serve?
a. The address bus permits the CPU to access internal data registers.
b. The address bus allows the CPU to communicate with PCI peripherals installed on the motherboard.
c. The address bus provides a data path for the CPU to communicate with RAM on the motherboard.
d. The address bus is a data path between the motherboard's memory controller chip and system RAM.

7. A CPU with a 24-bit address bus can recognize a maximum of ____________ megabytes of RAM?
a. 1
b. 16
c. 1024
d. 4096

8. What is the size (width) of the external data bus for Pentium I, II, III, and 4 CPUs?
a. 16 bits
b. 20 bits
c. 32 bits
d. 64 bits

9. Which of the following technologies is designed specifically to improve the multimedia performance of a CPU? (Select the best choice.)
a. Instruction pipelining
b. MMX
c. L2 cache
d. FPU

10. Of the following components, which is always located on the CPU die and accelerates instruction processing? (Select the best choice.)
a. The L1 cache
b. The L2 cache
c. The heat sink
d. The cooling fan

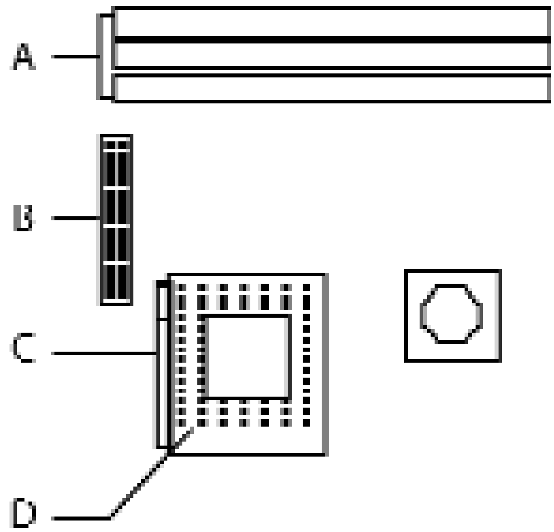
11. Which of the following technologies was introduced in Intel's Pentium III processor family? (Select the best choice.)
a. Instruction pipelining
b. Multimedia Extensions
c. Streaming SIMD Extensions
d. Hyper threading

12. A secondary cache located on the same die as the processor is called a(n) ____________.
a. Advanced Transfer Cache (ATC)
b. Discrete L2 cache
c. Execution Trace Cache
d. L3 cache

13. Which processor was the first microprocessor to use the Single Edge Contact Cartridge design?
a. Pentium MMX
b. Pentium II
c. Celeron
d. K6

14. What type of memory is included on the processor housing for a Single Edge Connector Pentium II processor?
a. Level 1 cache
b. Level 2 cache
c. Level 3 cache
d. Advanced transfer cache

15. Which letter in the figure below points to the zero insertion force release lever for the CPU socket?



16. Which of the following is a true statement about hyper threading?
a. It increases the number of clock cycles per second the CPU can execute.
b. It increases the number of instructions in the CPU.
c. It allows two physical processors to act as one processor.
d. It allows one physical processor to act as two logical processors.

17. The ____________ is Intel's first 64-bit microprocessor designed to run Microsoft operating systems. (Fill in the correct answer.)

18. Which of the following components can you connect to a ZIF socket? (Select the best choice.)
a. Intel 80286
b. Intel SEPP Celeron
c. Intel Pentium I MMX
d. Intel SECC Pentium II

19. You have been asked to choose a computer with a CPU suitable for work with 3-D graphics. Which of the following is the most powerful CPU (which should be selected for use with processor-intensive graphic design software)?
a. AMD Athlon MP
b. Intel Celeron
c. Intel Pentium II
d. AMD K6

20. Which of the following processors support an off-chip L2 cache, located on the motherboard? (Select all that apply.)
a. Intel Pentium MMX
b. Intel Pentium Pro
c. AMD K6
d. Intel Itanium
e. AMD Athlon Classic

21. Which of the following processors includes Intel's SSE2 feature?
a. Pentium 4
b. Duron
c. Pentium II
d. Celeron
e. There is no such processor feature

22. You are installing a 550 MHz CPU on a motherboard with a 100 MHz front side bus speed. What clock multiplier setting should you use? (Select the best choice.)
a. 3
b. 4
c. 5
d. 5.5

23. You are upgrading the CPU on an older computer that has an Intel Pentium I 120 MHz CPU. You intend to replace the CPU with an Intel Pentium I MMX CPU designed to run at an internal frequency of 166 MHz. Reviewing the jumper settings on the system board, you determine that the bus speed is set to 60 MHz, the clock multiplier is 2.0. The motherboard supports dual CPU voltage settings with both internal and external CPU voltages currently set to 3.3 volts. What changes should you make in the motherboard's configuration before upgrading the CPU? (Choose as many appropriate answers as apply.)
a. Change the jumpers so that the bus speed is set to 33 MHz.
b. Change the jumpers so that the internal and external CPU voltage is set to 5 V.
c. Change the jumpers so that the bus speed set to 66 MHz.
d. Change the jumpers so that the clock multiplier is set to 2.5.
e. Change the jumpers so that the core voltage is set to 2.8V.

24. Which of the following CPUs can be used with a SuperSocket 7 motherboard? (Select three choices.)
a. Intel 486SX
b. AMD K6
c. Intel Pentium MMX
d. Intel Celeron
e. Cyrix 6x86
f. Intel Pentium II

25. Which of the following CPUs can be installed on a motherboard with a Slot A processor interface? (Select the best choice.)
a. Intel Pentium II
b. AMD K6-2
c. AMD Athlon
d. Cyrix 686

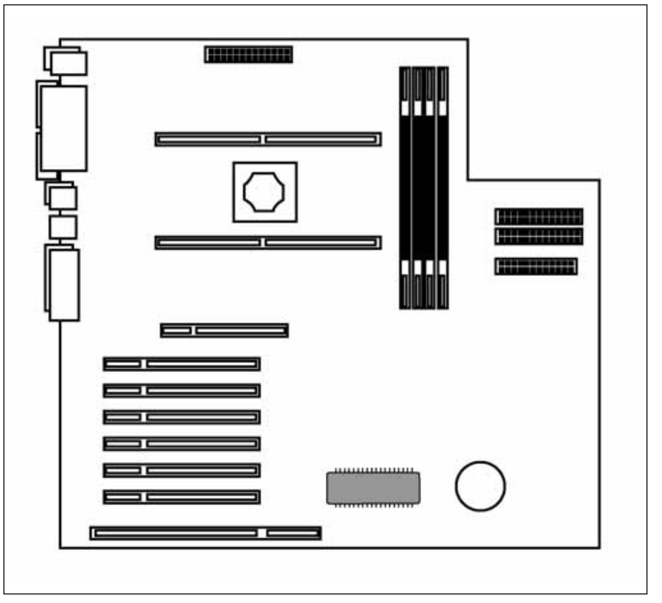
26. Which of the following motherboard interfaces is used to connect an Intel Pentium III Xeon processor to the system board? (Select the best choice.)
a. Slot 1
b. Slot 2
c. Socket 370
d. Socket 7

27. Heat is drawn away from a CPU by which of the following methods? (Select all that apply.)
a. Conduction
b. Convection
c. Convention
d. Induction
e. Radiation

28. Which of the following are parts included in a liquid cooling system for a PC motherboard? (Select all that apply.)
a. CPU fan
b. Pump
c. Fins
d. Waterblock
e. Radiator
f. Voltage regulator

29. With Pentium III Xeon processors, a system can theoretically use up to how many CPUs for SMP multiprocessing?
a. One
b. Two
c. Four
d. Eight

30. How many CPUs can be installed on the motherboard shown below? (Select the best choice.)
a. 1
b. 2
c. 3
d. 4



Projects: On Your Own

1. Comparing CPU Specifications: There are so many different models and speeds for CPUs manufactured by the current market leaders (Intel and AMD) that it's difficult to keep track of them all. As an IT technician you may be required to order computer systems and determine which CPU is most appropriate or cost-effective for your computing needs.
   a. Investigate the Web sites of major system vendors, such as Dell (www.dell.com) and Gateway (www.gateway.com). Check the price of the most inexpensive low-end system offered by each vendor and identify the CPU used in that model. If the vendor offers a system customization option, you can click on it to compare the price of a the same computer with different installed microprocessors.
   b. Now, start over, and check the price of a mid-price system and a high-end system, identifying the CPUs used in each.
   c. Compare the type of the default CPU offered in the low-end systems with the type of CPU offered in the high-end systems.
   d. Perform another Internet search to find benchmark statistics on the performance of the CPU models used in the low-end and high-end computer systems. You may also be able to look up the price of each CPU when it is sold separately. How do the differences in performance that you find relate to the differences in price for the CPUs?
2. Identify the type of socket or slot into which the CPU is inserted on your computer and the type of package in which the CPU is housed.
   a. Remove your computer's case.
   b. Locate the CPU on the motherboard and very carefully remove it.
   c. Examine the CPU package and compare it to the types covered in Skill 10.
   d. Examine the socket or slot that the CPU was in and compare it to the types covered in Skill 11.
3. Compare CPU cooling systems:Perform an online search to determine the prices for different CPU cooling systems (heat sinks, CPU fans, and liquid cooling systems).
   a. Prepare a table that lists the cheapest and most expensive systems for Pentium 4 and Athlon CPUs.
   b. Identify the most common physical materials used in heat sinks and see if you can determine which materials make the heat sink more expensive.
   c. Compare the specifications for several CPU fans that are sold as part of a heat sink/fan assembly. Prepare a table that lists the minimum and maximum noise levels and airflow ratios and see if you can find a relationship.

Problem Solving Scenarios

1. You run a contract IT support business. One of your clients reports that she has recently performed a motherboard upgrade and installed a 2.4 gigahertz (GHz) CPU in a server computer. The BIOS setup program for the computer reports a 2.0 GHz processor at startup. Write down a series of troubleshooting steps that you might perform to try to resolve the problem. (Hint: You will want to identify the motherboard used in the system, verify whether it supports the current CPU, and determine how certain performance settings are configured. You may also want to obtain benchmarking software that verifies the CPU's performance statistics under a Windows operating system.)
2. You are chief of IT for a company that has just purchased a new set of Socket 478 motherboards and a separate set of retail, boxed Intel Pentium 4 CPUs. You need to write a procedure that tells your IT support technicians how to install the Pentium CPUs on the motherboards, which will later be mounted in CPU cases. Write down a series of steps that describes how to unpack the Pentium 4 CPU and heat sink/fan assembly and install it on the motherboard.