CHAPTER 5

Supporting Processors and Upgrading Memory

In this chapter, you will learn:

- About the characteristics and purposes of Intel and AMD processors used for personal computers
- How to install and upgrade a processor
- About the different kinds of physical memory and how they work
- How to upgrade memory

In the last chapter, you learned about motherboards. In this chapter, you'll learn about the two most important components on the motherboard, which are the processor and memory. You'll learn how a processor works, about the many different types and brands of processors, and how to match a processor to the motherboard.

Memory technologies have evolved over the years. When you support an assortment of desktop and notebook computers, you'll be amazed at all the different variations of memory modules used in newer computers and older computers still in use. A simple problem of replacing a bad memory module can become a complex research project if you don't have a good grasp of current and past memory technologies.

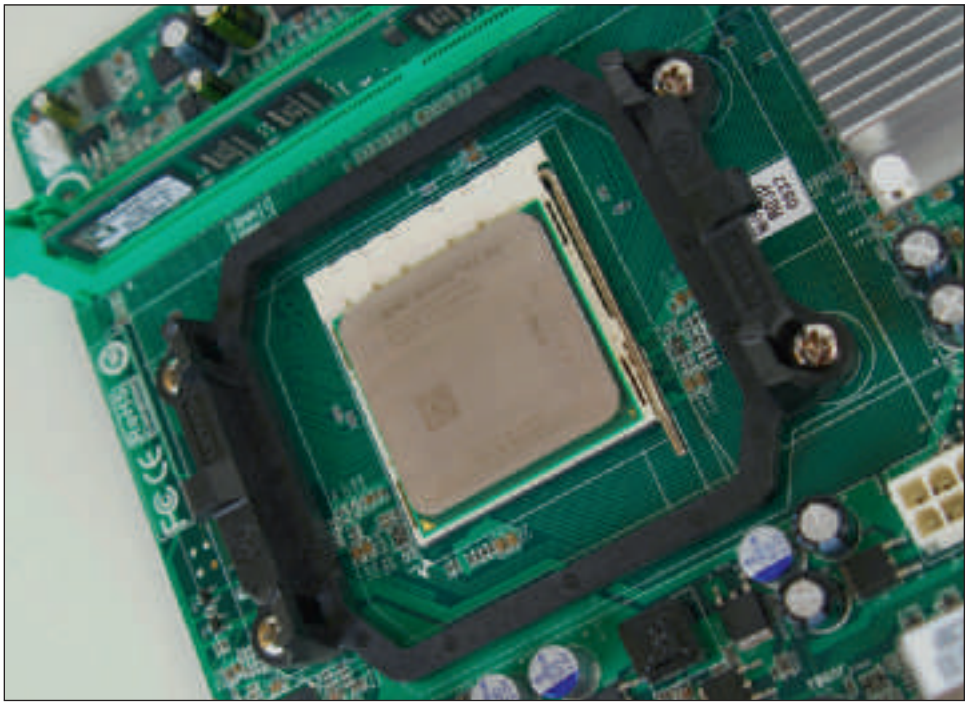
The processor and memory modules are considered field replaceable units (FRU), so you'll learn how to install and upgrade a processor and memory modules. Upgrading the processor or adding more memory to a system can sometimes greatly improve performance. How to troubleshoot problems with the processor or memory is covered in Chapter 13, *Troubleshooting Hardware Problems*.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

TYPES AND CHARACTERISTICS OF PROCESSORS

A+ 220-801 1.6

The processor installed on a motherboard is the primary component that determines the computing power of the system (see Figure 5-1). Recall that the two major manufacturers of processors are Intel (*www.intel.com*) and AMD (*www.amd.com*).



© Cengage Learning 2014

Figure 5-1 An AMD Athlon 64 X2 installed in socket AM2+ with cooler not yet installed

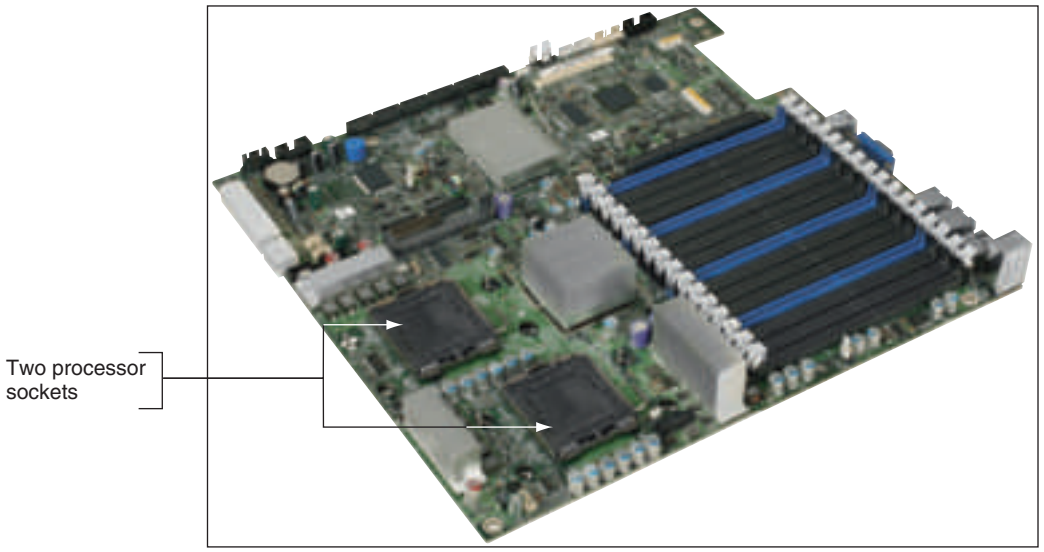
In this chapter, you learn a lot of details about processors. As you do, try to keep these nine features of processors at the forefront. These features affect performance and compatibility with motherboards:

- ***Feature 1: Clock speed the processor supports.*** Current Intel and AMD processors work with system buses that run at 1.8 GHz up to more than 3.4 GHz. Recall from Chapter 4 that the smaller the processor multiplier, the faster the system bus runs in comparison to the processor speed.
- ***Feature 2: Processor speed.*** Processor core frequency is measured in gigahertz, such as 3.3 GHz.
- ***Feature 3: Socket and chipset the processor can use.*** Recall from Chapter 4 that important Intel sockets for desktop systems are the PGA988, LGA2011, LGA1155, LGA1156, LGA1366, and LGA775. AMD's important desktop sockets are AM3+, AM3, AM2+, AM2, FM1, F, and 940 sockets.
- ***Feature 4: Processor architecture (32 bits or 64 bits).*** All desktop and laptop processors sold today from either Intel or AMD are hybrid processors, which can process 64 bits or 32 bits at a time, but older processors handled only 32 bits. A hybrid processor can use a 32-bit operating system or a 64-bit OS. Most editions of Windows 7 come in either type.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

- ***Feature 5: Multiprocessing abilities.*** The ability of a system to do more than one thing at a time is accomplished by several means:
  - ***Multiprocessing.*** Two processing units (called arithmetic logic units or ALUs) installed within a single processor (called **multiprocessing** and first used by Pentium processors). The Pentium was the first processor that could execute two instructions at the same time.
  - ***Dual processors.*** A server motherboard might have two processor sockets, called **dual processors** or a **multiprocessor platform** (see Figure 5-2). A processor (for example, the Xeon processor for servers) must support this feature.



Courtesy of Intel Corporation

Figure 5-2 This motherboard for a server has two processor sockets, which allow for a multiprocessor platform

  - ***Multi-core processing.*** Multiple processors can be installed in the same processor housing (called **multi-core processing**). A processor package might contain up to eight cores (dual-core, triple-core, quad-core, and so forth).
  - ***Multithreading.*** Each processor or core processes two threads at the same time. When Windows hands off a task to the CPU it is called a **thread** and might involve several instructions. To handle two threads, the processor requires extra registers, or holding areas, within the processor housing that it uses to switch between threads. In effect, you have two logical processors for each physical processor or core. Intel calls this technology **Hyper-Threading** and AMD calls it **HyperTransport**. The feature must be enabled in BIOS setup.
- ***Feature 6: Memory cache, which is the amount of memory included within the processor package.*** Today's processors all have some memory on the processor chip (called a die). Memory on the processor die is called **Level 1 cache (L1 cache)**. Memory in the processor package, but not on the processor die, is called **Level 2 cache (L2 cache)**. Some processors use a third cache farther from the processor core, but still in the processor package, which is called **Level 3 cache (L3 cache)**. Memory used in a memory cache

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

is **static RAM** or **SRAM** (pronounced "S-Ram"). Memory used on the motherboard loses data rapidly and must be refreshed often. It is, therefore, called volatile memory or **dynamic RAM** or **DRAM** (pronounced "D-Ram"). SRAM is faster than DRAM because it doesn't need refreshing; it can hold its data as long as power is available.

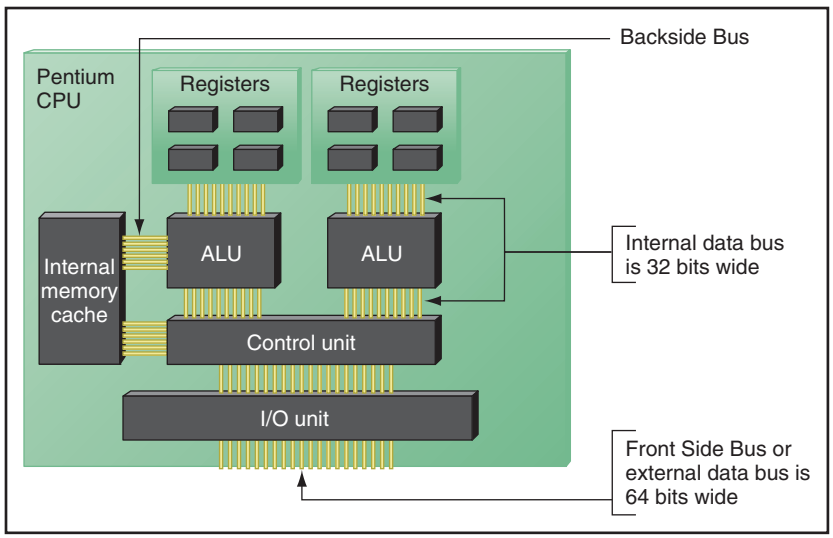
- ***Feature 7: The memory features on the motherboard that the processor can support.*** Current types of DRAM memory modules used on a motherboard include DDR, DDR2, or DDR3. Besides the type of memory, a processor can support certain amounts of memory, memory speeds, and number of memory channels (single, dual, triple, or quad channels). All these characteristics of memory are discussed later in the chapter.
- ***Feature 8: Support for virtualization.*** Recall from Chapter 4 that a computer can use software to create and manage multiple virtual machines that contain virtual devices. Most processors sold today support virtualization, and the feature must be enabled in BIOS setup.
- ***Feature 9: Integrated graphics.*** A processor might include an integrated GPU. A **graphics processing unit (GPU)** is a processor that manipulates graphic data to form the images on a monitor screen. The GPU might be on a video card, on the motherboard, or embedded in the CPU package. When inside the CPU package, it is called integrated graphics. Many AMD processors and all the Intel second generation (Sandy Bridge) and third generation (Ivy Bridge) processors have integrated graphics.

A+ Exam Tip The A+ 220-801 exam expects you to be familiar with the characteristics of processors. Know the purposes and characteristics of Hyper-threading, core processing, types of cache, virtualization, integrated GPU, and 32-bit versus 64-bit processing.

Let's now turn our attention to a discussion of how a processor works, including several of the processor features just listed. Then you'll learn about the families of Intel and AMD processors.

HOW A PROCESSOR WORKS

Although processors continue to evolve, they all have some common elements. These elements are diagrammed in Figure 5-3 for the Pentium processor. The Pentium made several major advances in processor technologies when it was first introduced. Because of its historical significance and the foundation it created for today's processors, it's a great place to start when learning how a processor works.



© Cengage Learning 2014

Figure 5-3 Since the Pentium processor was first released in 1993, the standard has been for a processor to have two arithmetic logic units so that it can process two instructions at once

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

A processor contains these basic components diagrammed in Figure 5-3 for the Pentium processor:

- An input/output (I/O) unit manages data and instructions entering and leaving the processor.
- A control unit manages all activities inside the processor itself.
- One or more arithmetic logic units (ALUs) do all logical comparisons and calculations inside the processor. All desktop and laptop processors sold today contain two ALUs in each processor core within the processor package.
- Registers, which are small holding areas on the processor chip, work much like RAM does outside the processor to hold counters, data, instructions, and addresses that the ALU is currently processing.
- Internal memory caches (L1, L2, and possibly L3) hold data and instructions waiting to be processed by the ALU.
- Buses inside the processor connect components within the processor housing. These buses run at a much higher frequency than the Front Side Bus (FSB) that connects the processor to the chipset and memory on the motherboard.

The speed at which the processor operates internally is called the **processor frequency**. For example, if the processor operates at 3.2 GHz internally but the Front Side Bus is operating at 800 MHz, the processor operates at four times the FSB speed. This factor is called the **multiplier**. As you learned in Chapter 4, you can view the actual processor frequency and the clock speed using the BIOS setup screens. You can also change the multiplier or the clock speed in order to overclock or throttle the processor.

In Figure 5-3, you can see the internal data bus for the Pentium was only 32 bits wide. More important, however, than the width of the internal bus is the fact that each ALU and register in the early Pentiums could process only 32 bits at a time. All desktop and laptop processors sold today from either Intel or AMD contain ALUs and registers that can process 32 bits or 64 bits at a time. To know which type of operating system to install, you need to be aware of three categories of processors currently used on desktop and laptop computers:

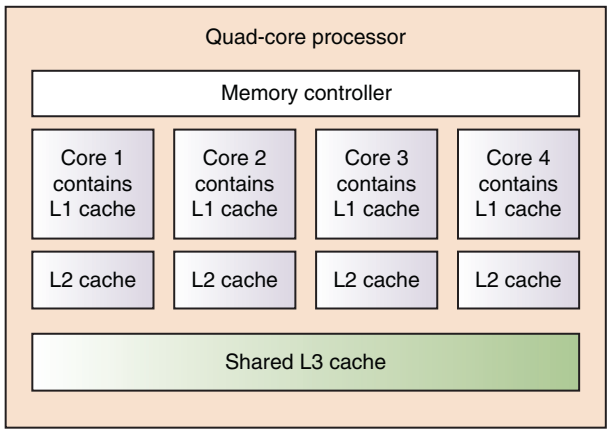
- ***32-bit processors.*** These older processors are known as **x86 processors** because Intel used the number 86 in the model number of these processors. If you are ever called on to install Windows on one of these old Pentium computers, you must use a 32-bit version of Windows. These processors can handle only 32-bit instructions from the OS.
- ***Processors that can process 32 bits or 64 bits.*** These hybrid processors are known as **x86-64 bit processors**. AMD was the first to produce one (the Athlon 64) and called the technology AMD64. Intel followed with a version of its Pentium 4 processors and called the technology Extended Memory 64 Technology (EM64T). Because of their hybrid nature, these processors can handle a 32-bit OS or a 64-bit OS. All desktop or laptop processors made after 2007 are of this type.
- ***64-bit processors.*** Intel makes several 64-bit processors for workstations or servers that use fully implemented 64-bit processing, including the Itanium and Xeon processors. Intel calls the technology IA64, but they are also called x64 processors. They require a 64-bit operating system and can handle 32-bit applications only by simulating 32-bit processing.

Notes To know which type of operating system is installed (32-bit or 64-bit) and other information about the Windows installation, recall from Chapter 4 that you can use the System window. To open the System window, click **Start**, right-click **Computer**, and select **Properties**.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

Each core in a processor has its own cache and can also share a cache. Figure 5-4 shows how quad-core processing can work if the processor uses an L3 cache and an internal memory controller. Each core within a processor has its own independent internal L1 and L2 caches. The L1 cache is on the die and the L2 cache is off the die. In addition, all the cores might share an L3 cache within the processor package. Recall from Chapter 4 that prior to the memory controller being in the processor package, it was part of the North Bridge chipset. Putting the controller inside the processor package resulted in a significant increase in system performance.



© Cengage Learning 2014

Figure 5-4 Quad-core processing with L1, L2, and L3 cache and the memory controller within the processor housing

INTEL PROCESSORS

Intel's current families of processors for the desktop include the Core, Atom, Celeron, and Pentium families of processors. In addition, Intel groups its processors into Third Generation, Second Generation, and Previous Generation processors. Each generation improves on how the processor and chipset are integrated in the system. Processors in each family are listed in Table 5-1. Some significant retired processors are also listed. Later in the chapter, I'll explain the memory technologies mentioned in the table.

Processor	Speed	Description
Third Generation (Ivy Bridge) Processors		
Core i7	Up to 3.9 GHz	8 MB cache, quad core 1333/1600 MHz DDR3 memory Dual channel memory
Core i5	Up to 3.8 GHz	6 MB cache, quad core 1333/1600 MHz DDR3 memory Dual channel memory

© Cengage Learning 2014

Table 5-1 Current Intel processors (continues)

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

Processor	Speed	Description
Second Generation (Sandy Bridge) Processors		
Core i7 Extreme	Up to 3.9 GHz	15 MB cache, six cores 1066/1333/1600 MHz DDR3 memory Quad channel memory
Core i7	Up to 3.9 GHz	8 to 12 MB cache, four or six cores 1066/1333/1600 MHz DDR3 memory Dual or quad channel memory
Core i5	Up to 3.8 GHz	3 to 6 MB cache, dual or quad core 1066/1333 MHz DDR3 memory Dual channel memory
Core i3	Up to 3.4 GHz	3 MB cache, dual core 1066/1333 MHz DDR3 memory Dual channel memory
Pentium	Up to 3.0 GHz	3 MB cache 1066/1333 MHz DDR3 memory Dual channel memory
Previous Generation Processors		
Core i7 Extreme	Up to 3.4 GHz	8 or 12 MB cache 1066 MHz DDR3 memory Triple channel memory
Core i7	Up to 3.3 GHz	8 or 12 MB cache, four or six cores 800/1066/1333 MHz DDR3 memory Dual or triple channel memory
Core i5	Up to 3.3 GHz	4 or 8 MB cache, dual or quad core 1066/1333 MHz DDR3 memory Dual channel memory
Core i3	Up to 3.3 GHz	Dual core, 4 MB cache 1066/1333 MHz DDR3 memory Dual channel memory
Atom	Up to 2.1 GHz	Up to 1 MB cache, some dual core 800/1066 MHz DDR3 memory 667/800 MHz DDR2 memory Single channel memory
Celeron, Celeron Desktop, Celeron D	1.6 to 3.6 GHz 533/667/800 MHz FSB	128 KB to 1 MB cache
Core 2 Extreme, Core 2 Quad, Core 2 Duo	Up to 3.2 GHz 533 to 1600 MHz FSB	2 to 12 MB cache Dual or quad core
Pentium Extreme, Pentium, Pentium 4, Pentium D	Up to 3.7 GHz	Up to 4 MB cache, some dual core

© Cengage Learning 2014

Table 5-1 Current Intel processors (continued)

An Intel Sandy Bridge Core i5 processor is shown in Figure 5-5. You can purchase a processor with or without the cooler. When it's purchased with a cooler, it's called a boxed processor. The cooler is also shown in the photo. If you purchase the cooler separately, make sure it fits the socket you are using.

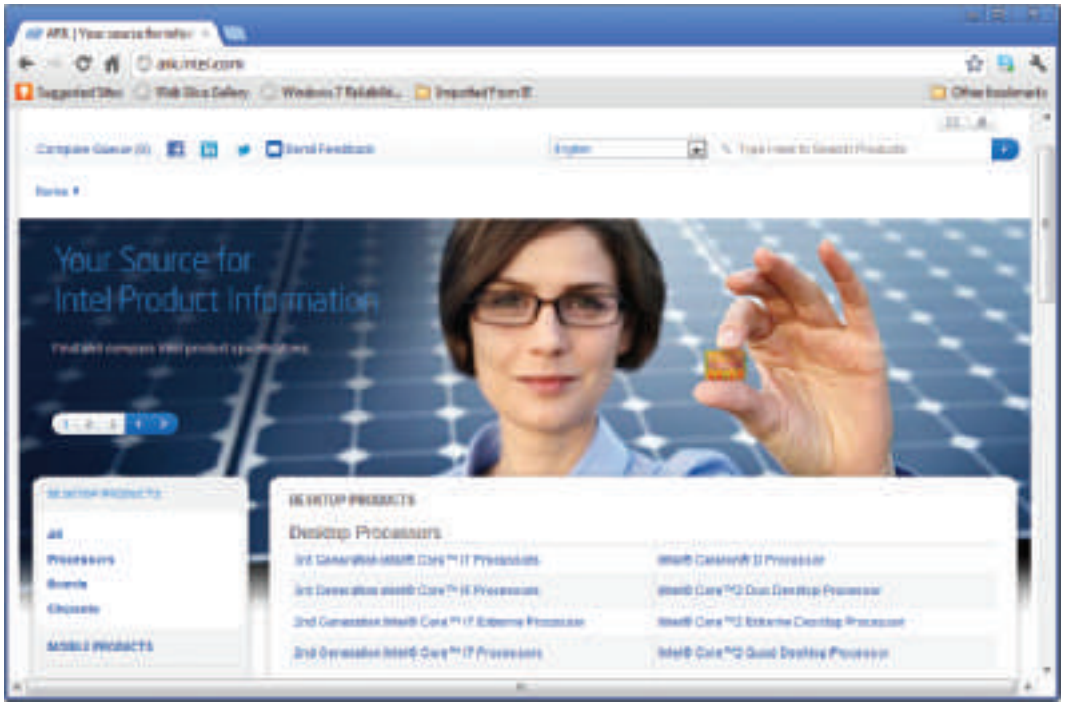
Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

© Cengage Learning 2014

Figure 5-5 The Intel Core i5 processor (processor number i5-2320) with boxed cooler

Each processor listed in Table 5-1 represents several processors that vary in performance and functionality. To help identify a processor, Intel uses a processor number. For example, two Core i7 processors are identified as i7-940 and i7-920. To find details about an Intel processor, search the Intel ARK database at *ark.intel.com* (see Figure 5-6).



Source: Intel

Figure 5-6 The Intel ARK database at *ark.intel.com* lists details about all Intel products

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

Some of the Intel mobile processors are packaged in the Centrino processor technology. Using the **Centrino** technology, the Intel processor, chipset, and wireless network adapter are all interconnected as a unit, which improves laptop performance. Several Intel mobile processors have been packaged as a Centrino processor. You also need to be aware of the Intel Atom processor, which is Intel's smallest processor and is used in low-cost PCs, laptops, and netbooks.

AMD PROCESSORS

Processors by Advanced Micro Devices, Inc. or AMD (*www.amd.com*) are popular in the game and hobbyist markets, and are generally less expensive than comparable Intel processors. Recall that AMD processors use different sockets than do Intel processors, so the motherboard must be designed for one manufacturer's processor or the other, but not both. Many motherboard manufacturers offer two comparable motherboards—one for an Intel processor and one for an AMD processor.

The current AMD processor families are the FX, Phenom, Athlon, and Sempron for desktops and the Athlon, Turion, V Series, Phenom, and Sempron for laptops. Table 5-2 lists the current AMD processors for desktops. Figure 5-7 shows an FX processor by AMD.

Processor	Core Speed	Description
FX Black Edition Family		
FX 4-Core Black Edition	Up to 3.6 GHz	Quad-core uses AM3+ socket
FX 6-Core Black Edition	Up to 3.3 GHz	Six-core uses AM3+ socket
FX 8-Core Black Edition	Up to 3.6 GHz	Eight-core uses AM3+ socket
Phenom Family		
Phenom II X6	Up to 3 GHz	Six core uses AM3 socket
Phenom II X6 Black	Up to 3.2 GHz	Six core uses AM3 socket
Phenom II X4	Up to 3.2 GHz	Quad-core uses AM3 socket
Phenom II X3	Up to 2.5 GHz	Triple-core uses AM3 socket
Phenom II X2	Up to 3.1 GHz	Dual-core uses AM3 socket
Phenom X4	Up to 2.6 GHz	Quad-core uses AM2+ socket
Phenom X3	Up to 2.4 GHz	Triple-core uses AM2+ socket
Athlon Family		
Athlon II X2	Up to 3 GHz	Dual-core uses AM3 socket
Athlon X2	Up to 2.3 GHz	Dual-core uses AM3 socket
Athlon	Up to 2.4 GHz	Single-core uses AM2 socket
Sempron Family		
Sempron	Up to 2.3 GHz	Single-core uses AM2 socket

© Cengage Learning 2014

Table 5-2 Current AMD processors

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

Courtesy of Advanced Micro Devices, Inc.

Figure 5-7 The AMD FX processor can have up to eight cores

In the next part of the chapter, you'll learn the detailed steps to select and install a processor in several of the popular Intel and AMD sockets used by a desktop computer.

SELECTING AND INSTALLING A PROCESSOR

A PC repair technician is sometimes called on to assemble a PC from parts, exchange a processor that is faulty, add a second processor to a dual-processor system, or upgrade an existing processor to improve performance. In each situation, it is necessary to know how to match a processor for the system in which it is installed. And then you need to know how to install the processor on the motherboard for each of the current Intel and AMD sockets used for desktop and laptop systems. In this part of the chapter, you'll learn about selecting and installing processors in desktops. In Chapter 19, you'll learn about selecting and installing processors in laptops.

SELECT A PROCESSOR TO MATCH SYSTEM NEEDS

When selecting a processor, the first requirement is to select one that the motherboard is designed to support. Among the processors the board supports, you need to select the best one that meets the general requirements of the system and the user's needs. To get the best performance, use the highest-performing processor the board supports. However, sometimes you need to sacrifice performance for cost.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

APPLYING CONCEPTS SELECT A PROCESSOR

Your friend, Alice, is working toward her A+ certification. She has decided the best way to get the experience she needs before she sits for the exam is to build a system from scratch. She has purchased an Asus motherboard and asked you for some help selecting the right processor. She tells you that the system will later be used for light business needs and she wants to install a processor that is moderate in price to fit her budget. She says she doesn't want to install the most expensive processor the motherboard can support, but neither does she want to sacrifice too much performance or power.

The documentation on the Asus web site (*support.asus.com*) for the ASUS P8Z68-V LX motherboard gives this information:

- The ATX board contains the Z68 chipset and socket LGA1155 and uses DDR3 memory.
- CPUs supported include a long list of Second Generation Core i3, Core i5, and Core i7 processors and Celeron and Pentium processors. Here are five processors found in this list:
  - Intel Core i7-2600, 3.4 GHz, 8 MB cache
  - Intel Core i5-3450, 3.1 GHz, 6 MB cache
  - Intel Core i3-2120, 3.3 GHz, 3 MB cache
  - Intel Celeron G540, 2.5 GHz, 2 MB cache
  - Intel Pentium G860, 3.0 GHz, 3 MB cache

Based on what Alice has told you, you decide to eliminate the most expensive processors (the Core i7) and the least-performing processors (the Celerons and Pentiums). That decision narrows your choices down to the Core i3 and Core i5. Before you select one of these processors, you need to check the list on the Asus site to make sure the specific Core i3 or Core i5 processor is in the list. Look for the exact processor number, for example, the Core i3-2120. Also double-check and make sure the processor uses the correct socket and is a Second Generation processor.

You will also need a cooler assembly. If your processor doesn't come boxed with a cooler, select a cooler that fits the processor socket and gets good reviews. You'll also need some thermal compound if it is not included with the cooler.

5

INSTALL A PROCESSOR

Now let's look at the details of installing a processor in an Intel LGA1155, LGA1366, LGA775, and AMD AM2+ sockets.

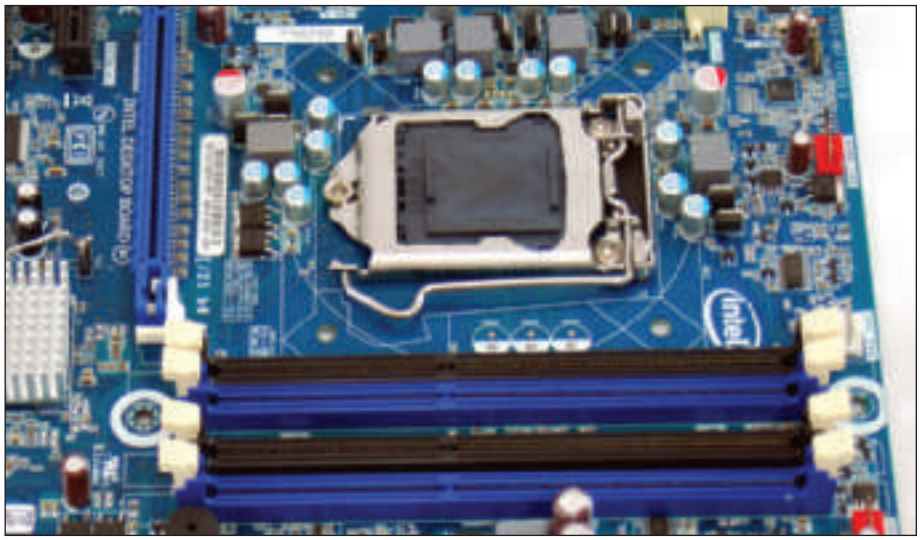
Video
Installing a Processor

INSTALLING AN INTEL PROCESSOR IN SOCKET LGA1155

We're installing the Intel Core i5-2320 processor in Socket LGA1155 shown in Figure 5-8. In the photo, the socket has its protective cover in place.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6



© Cengage Learning 2014

Figure 5-8 Intel socket LGA1155 with protective cover in place

A+ Exam Tip The A+ 220-801 exam expects you to know how to install a processor in these Intel processor sockets: LGA775, LGA1155, LGA1156, and LGA1366 sockets.

When building a new system, if the motherboard is not already installed in the case, follow the directions of the motherboard manufacturer to install the motherboard and then the processor or to install the processor and then the motherboard. The order of installation varies among manufacturers. When replacing a processor in an existing system, power down the system, unplug the power cord, press the power button to drain the system of power, and open the case. Follow these steps to install the processor and cooler using socket LGA1155:

1. Read all directions in the motherboard user guide and carefully follow them in order.
2. Use a ground bracelet or antistatic gloves to protect the processor, motherboard, and other components against ESD.
3. Open the socket by pushing down on the socket lever and gently pushing it away from the socket to lift the lever (see Figure 5-9).

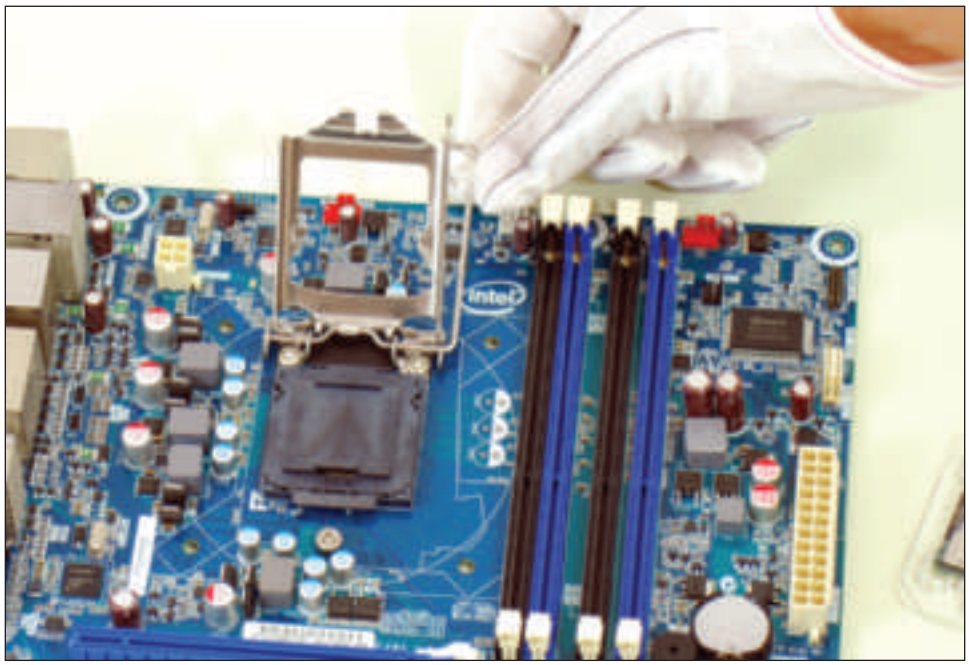
© Cengage Learning 2014

Figure 5-9 Release the lever from the socket

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

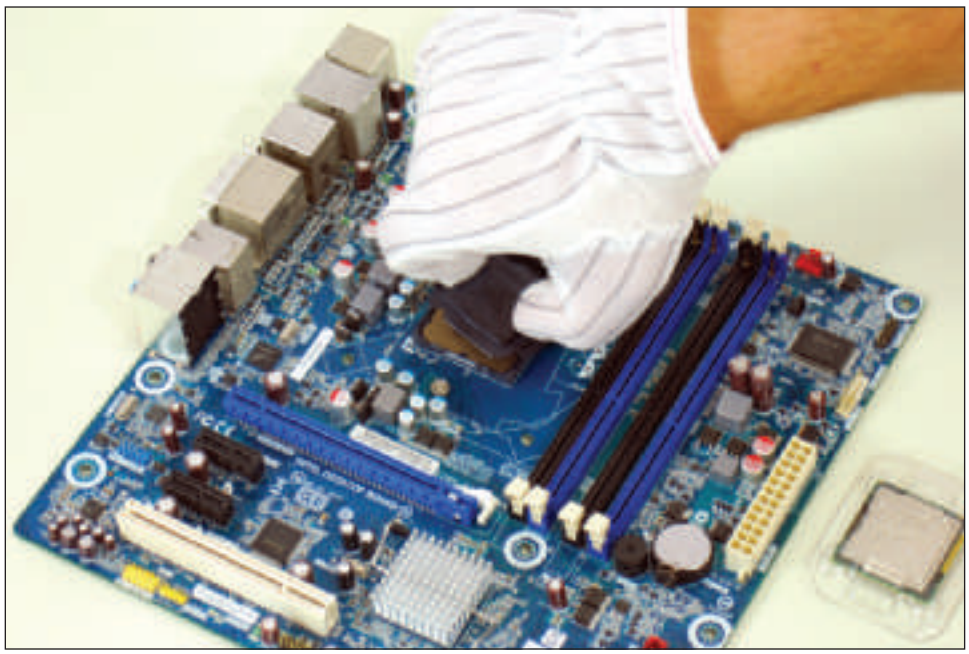
4. As you fully open the socket lever, the socket load plate opens, as shown in Figure 5-10.



© Cengage Learning 2014

Figure 5-10 Lift the socket load plate

5. Remove the socket protective cover (see Figure 5-11). Keep this cover in a safe place. If you ever remove the processor, put the cover back in the socket to protect the socket. While the socket is exposed, be *very careful* to not touch the pins in the socket.



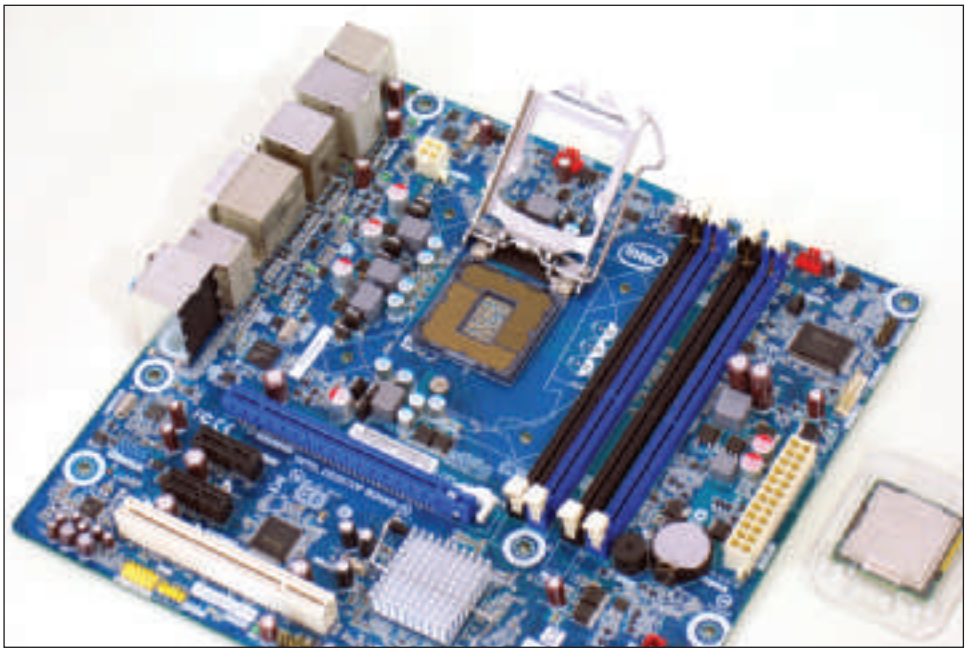
© Cengage Learning 2014

Figure 5-11 Remove the socket protective cover

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

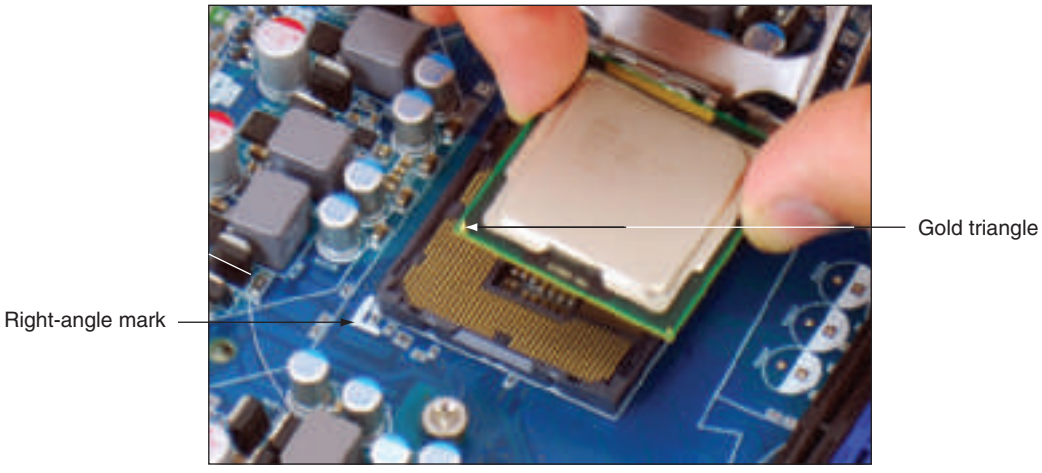
6. Remove the protective cover from the processor. You can see the processor in this clear plastic cover on the right side of Figure 5-12, which also shows the open socket. While the processor contacts are exposed, take extreme care to not touch the bottom of the processor. Hold it only at its edges. (It's best to use antistatic gloves as you work, but the gloves make it difficult to handle the processor.) Put the processor cover in a safe place and use it to protect the processor if you ever remove the processor from the socket.



© Cengage Learning 2014

Figure 5-12 Open socket LGA1155 and processor in a protective cover

7. Hold the processor with your index finger and thumb and orient the processor so that the gold triangle on the corner of the processor lines up with the right-angle mark embedded on the motherboard just outside a corner of the socket (see Figure 5-13). Gently lower the processor straight down into the socket. Don't allow the processor to tilt, slide, or shift as you put it in the socket. To protect the pads, it needs to go straight down into the socket.



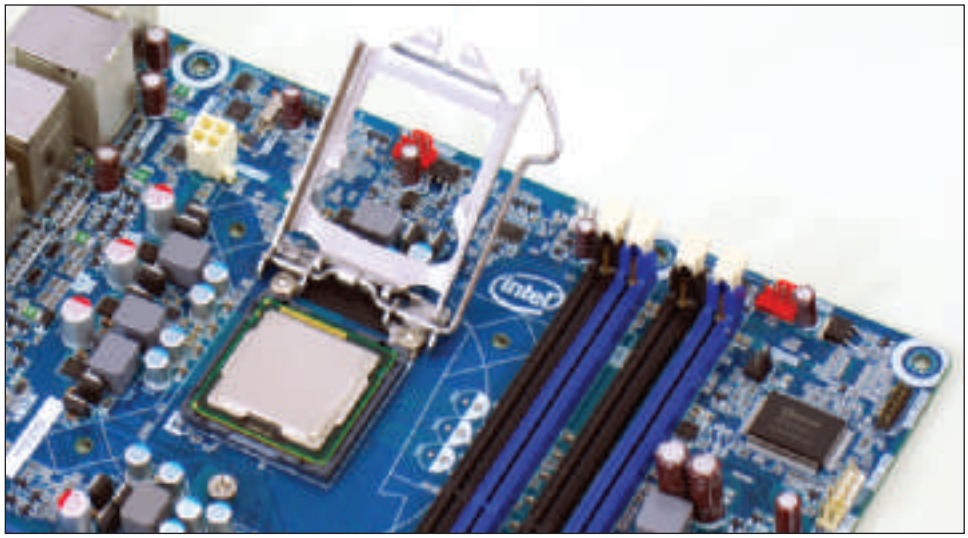
© Cengage Learning 2014

Figure 5-13 Align the processor in the socket using the gold triangle and the right-angle mark

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

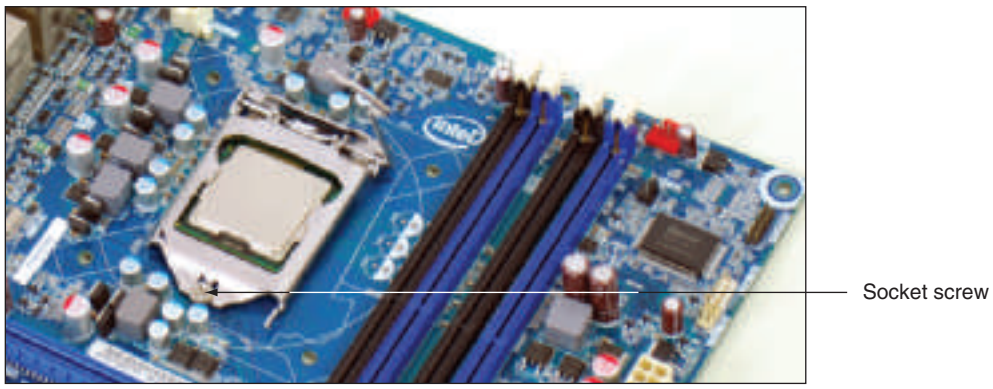
A+ 220-801 1.6

8. Check carefully to make sure the processor is aligned correctly in the socket. Closing the socket without the processor fully seated can destroy the socket. Figure 5-14 shows the processor fully seated in the socket. Close the socket load plate so that it catches under the screw head at the front of the socket (see Figure 5-15).



© Cengage Learning 2014

Figure 5-14 Processor in position ready to close the socket



© Cengage Learning 2014

Figure 5-15 The socket screw head secures the socket load plate

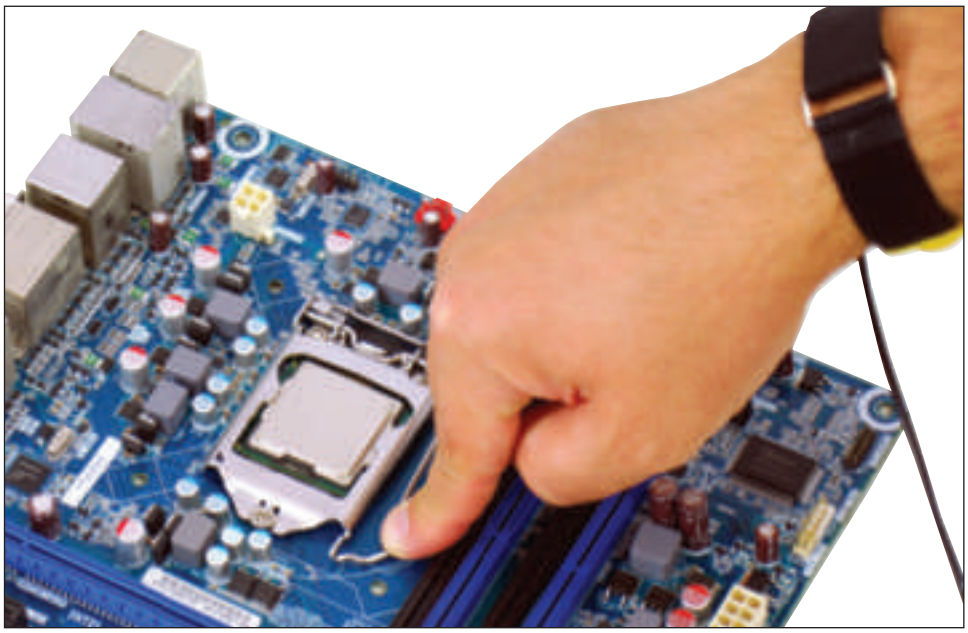
9. Push down on the lever and gently return it to its locked position (see Figure 5-16).

We are now ready to install the cooler. Before installing a cooler, read the directions carefully and make sure you understand them. Clips that hold the fan and heat sink to the processor frame or housing are sometimes difficult to install. The directions might give you important tips. Follow these general steps:

1. The motherboard has four holes to anchor the cooler. You can see them labeled in Figure 5-17. Examine the cooler posts that fit over these holes and the clips, screws, or wires that will hold the cooler firmly in place. Make sure you understand how this mechanism works.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

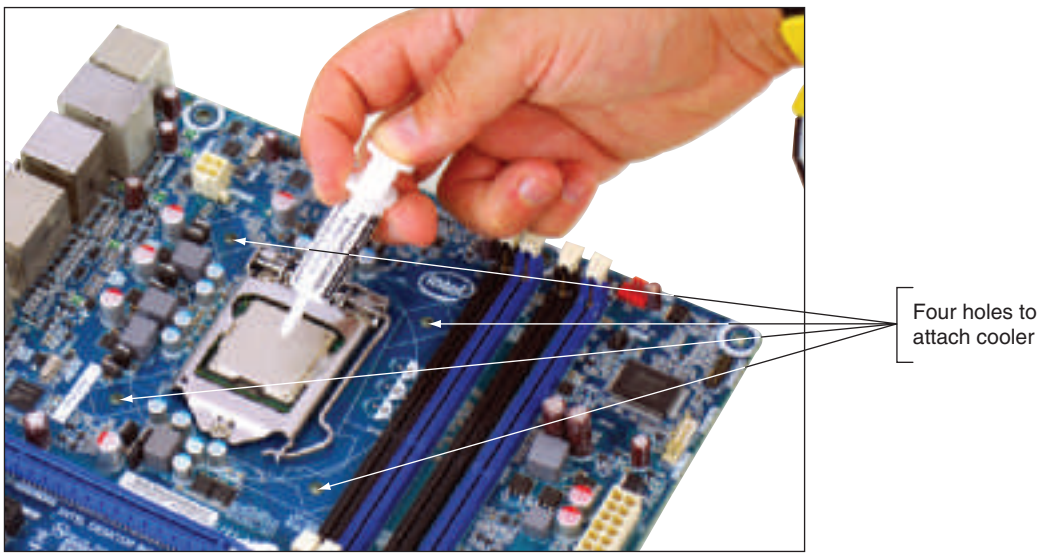
A+
220-801
1.6



© Cengage Learning 2014

Figure 5-16 Return the lever to its locked position

2. If the cooler has thermal compound preapplied, remove the plastic from the compound. If the cooler does not have thermal compound applied, put a small dot of compound (about the size of a small pea) in the center of the processor (see Figure 5-17). When the cooler is attached and the processor is running, the compound spreads over the surface. Don't use too much—just enough to later create a thin layer. If you use too much compound, it can slide off the housing and damage the processor or circuits on the motherboard. To get just the right amount, you can buy individual packets that each contain a single application of the thermal compound.



© Cengage Learning 2014

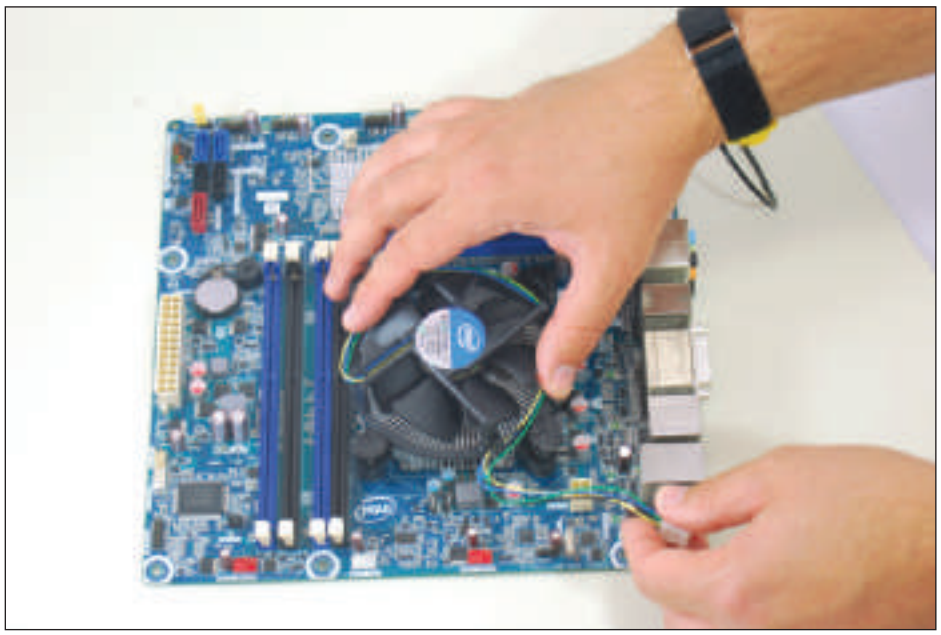
Figure 5-17 If the cooler does not have preapplied thermal compound, apply it on top of the processor

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.6

Notes When removing and reinstalling a processor, use a soft dry cloth to carefully remove all the old thermal compound from both the processor and the cooler. Don't try to reuse the compound.

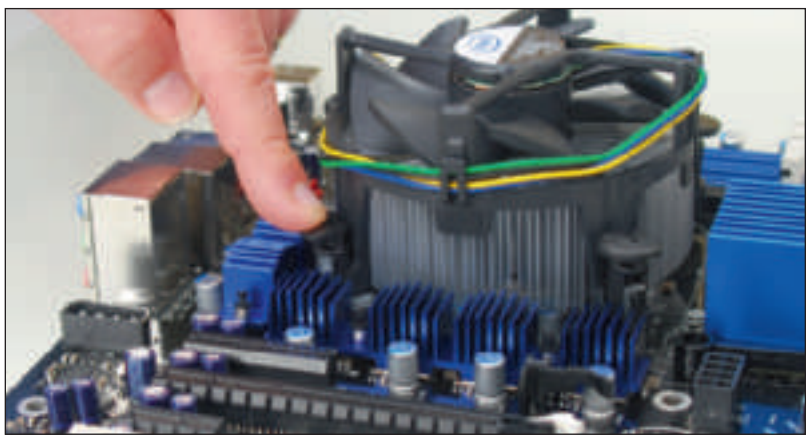
3. Verify the locking pins on the cooler are turned as far as they will go in a counterclockwise direction. (Make sure the pins don't protrude into the hollow plastic posts that go down into the motherboard holes.) Align the cooler over the processor so that all four posts fit into the four holes on the motherboard and the fan power cord can reach the fan header on the motherboard (see Figure 5-18).



© Cengage Learning 2014

Figure 5-18 Align the cooler over the four holes in the motherboard

4. Push down on each locking pin until you hear it pop into the hole (see Figure 5-19). To help keep the cooler balanced and in position, push down two opposite pins and then push the remaining two pins in place. Using a flathead screwdriver, turn the locking pin clockwise to secure it. (Later, if you need to remove the cooler, turn each locking pin counterclockwise to release it from the hole.)



© Cengage Learning 2014

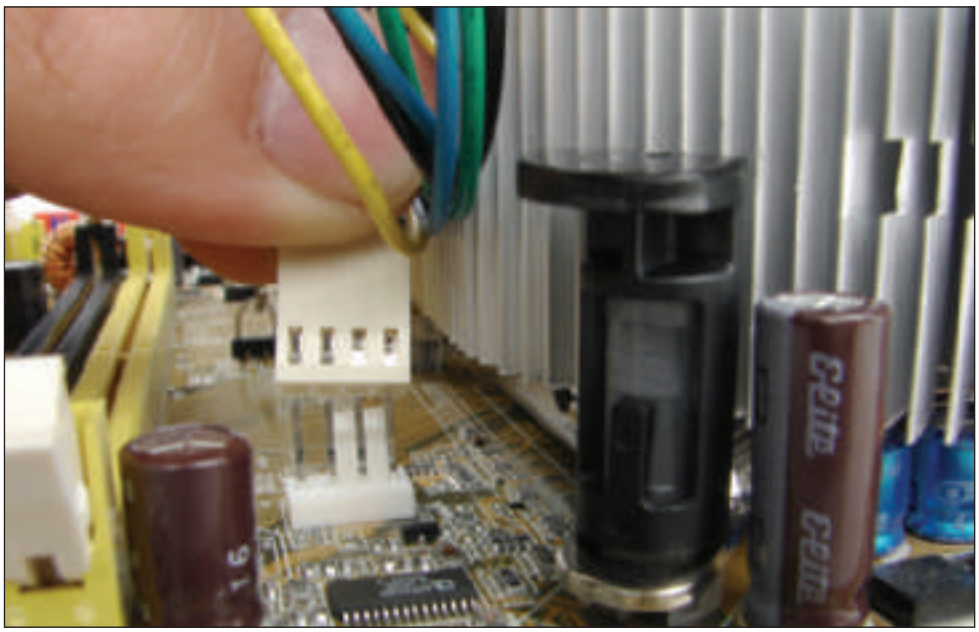
Figure 5-19 Push down on a locking pin to lock it into position

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

Notes If you later notice the CPU fan is running far too often, you might need to tighten the connection between the cooler and the processor.

5. Connect the power cord from the cooler fan to the motherboard power connector near the processor, as shown in Figure 5-20.



© Cengage Learning 2014

Figure 5-20 Connect the cooler fan power cord to the motherboard CPU fan header

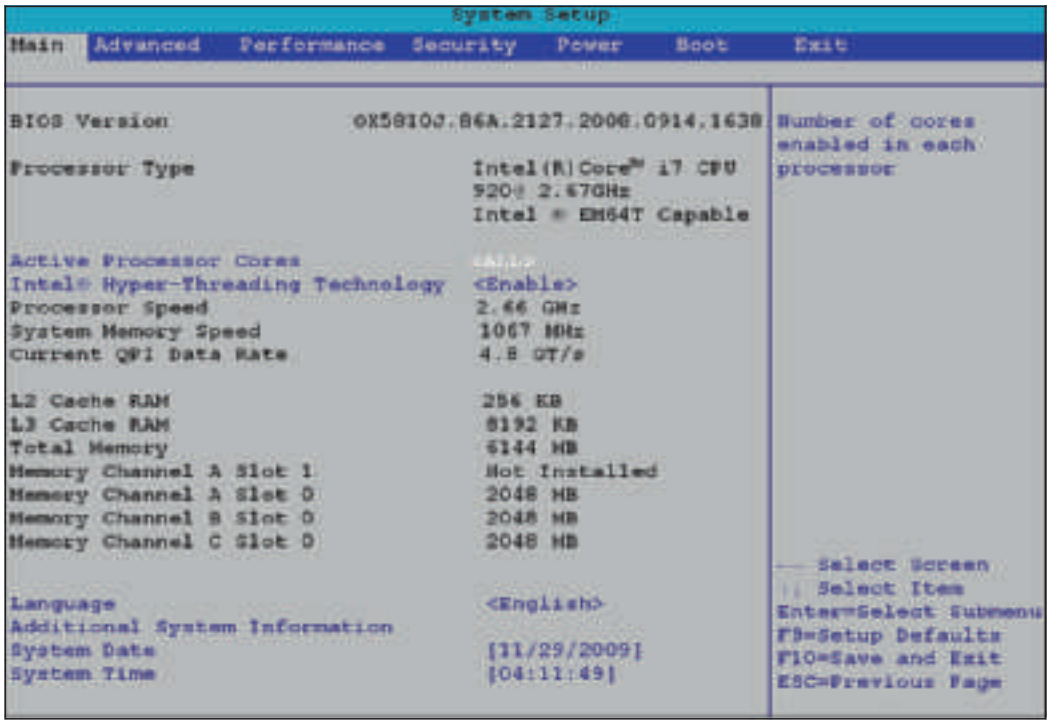
After the processor and cooler are installed and the motherboard is installed in the case, make sure cables and cords don't obstruct fans or airflow, especially airflow around the processor and video card. Use cable ties to tie cords and cables up and out of the way.

Make one last check to verify all power connectors are in place and other cords and cables connected to the motherboard are correctly done. You are now ready to plug back up the system, turn it on, and verify all is working. If the power comes on (you hear the fan spinning and see lights), but the system fails to work, most likely the processor is not seated solidly in the socket or some power cord has not yet been connected or is not solidly connected. Turn everything off, unplug the power cord, press the power button to drain power, open the case, and recheck your installation. If the system comes up and begins the boot process, but suddenly turns off before the boot is complete, most likely the processor is overheating because the cooler is not installed correctly. Turn everything off, unplug the power cord, press the power button to drain power, open the case, and verify the cooler is securely seated and connected.

After the system is up and running, you can check BIOS setup to verify that the system recognized the processor correctly. The setup screen for one processor is shown in Figure 5-21. Look for items on the screen that manage processor features, and make sure each is set correctly. For example, in Figure 5-21, items listed in blue can be changed. Verify the two blue items that apply to the processor; verify that all processor cores are active and Hyper-Threading Technology is enabled.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

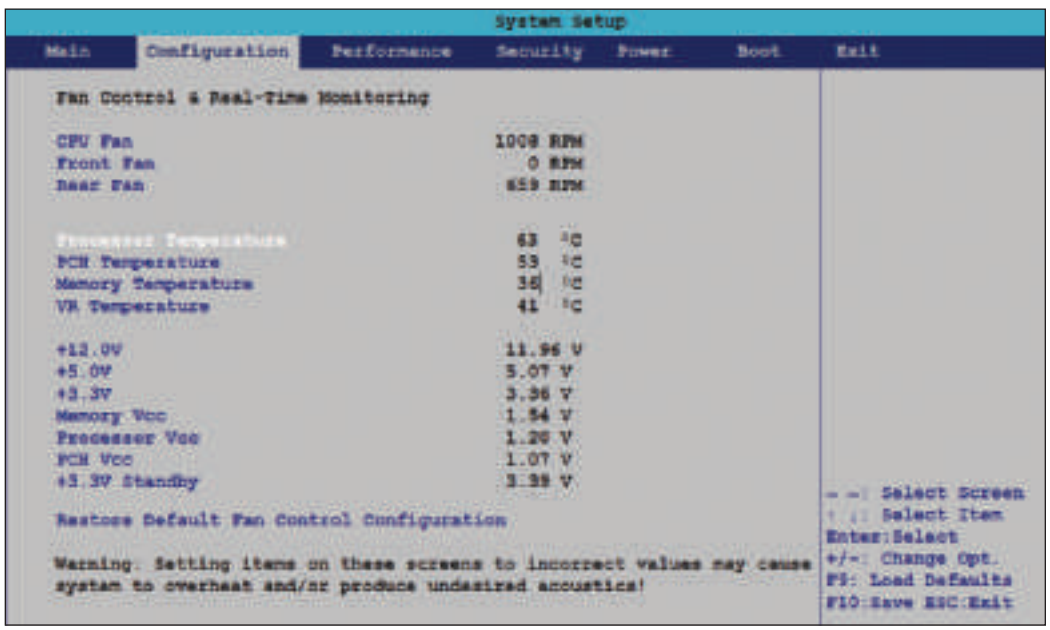
A+ 220-801 1.6



Source: Intel

Figure 5-21 Verify the CPU is recognized correctly by BIOS setup

Also check in BIOS setup the CPU and motherboard temperatures to verify the CPU is not overheating. For one BIOS setup in another system, this screen is under the Configuration menu, Fan Control & Real-Time Monitoring window, as shown in Figure 5-22.



Source: Intel

Figure 5-22 Verify the processor temperature is within an acceptable range

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

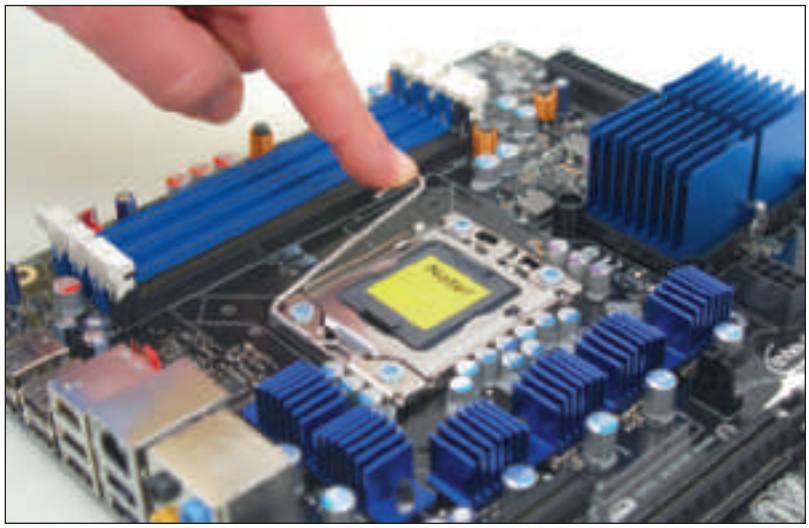
A+ 220-801 1.6

If you see the processor temperature rising and reaching 80 degrees, open the case cover and verify the processor fan is running. Perhaps a wire is in the way and preventing the fan from turning or the fan wire is not connected. Other troubleshooting tips for processors are covered in Chapter 13.

INSTALLING AN INTEL PROCESSOR IN SOCKET LGA1366

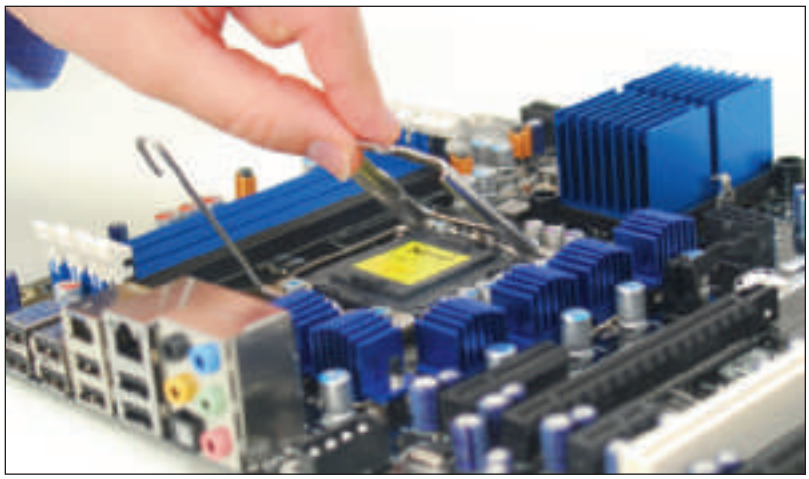
The installations of all processors and sockets in this part of the chapter are similar to that of installing a processor in Socket LGA1155, so we will not repeat many of those steps. Listed next are the differences when installing a processor in the LGA1366 socket. These socket pins are delicate, so work slowly and take care. Here is how to work with this socket:

1. To open the socket, press down on the socket lever and gently push it away from the socket to lift the lever (see Figure 5-23). You can then lift the socket load plate, as shown in Figure 5-24. Next, remove the socket protective cover.



© Cengage Learning 2014

Figure 5-23 Release the lever from the socket



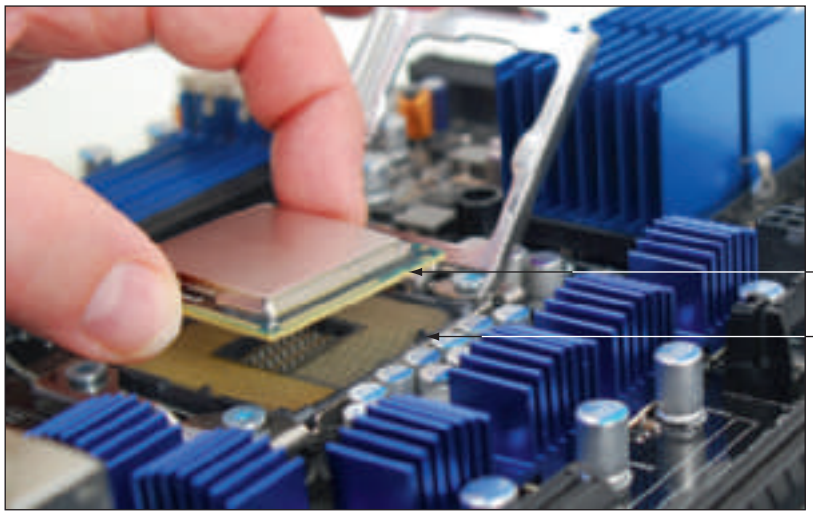
© Cengage Learning 2014

Figure 5-24 Lift the socket load plate

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

2. To install the processor, hold the processor with your index finger and thumb and orient the processor so that the notches on the two edges of the processor line up with the two posts on the socket. You can see the notch and post on the right side of the processor and socket in Figure 5-25. Gently lower the processor straight down into the socket. Don't allow the processor to tilt, slide, or shift as you put it in the socket. To protect the pins, it needs to go straight down into the socket.



© Cengage Learning 2014

Figure 5-25 Orient the processor over the socket so that the notches on each side of the processor match the posts on each side of the socket

3. You can now lower the socket load plate and return the lever to its locked position (see Figure 5-26).

© Cengage Learning 2014

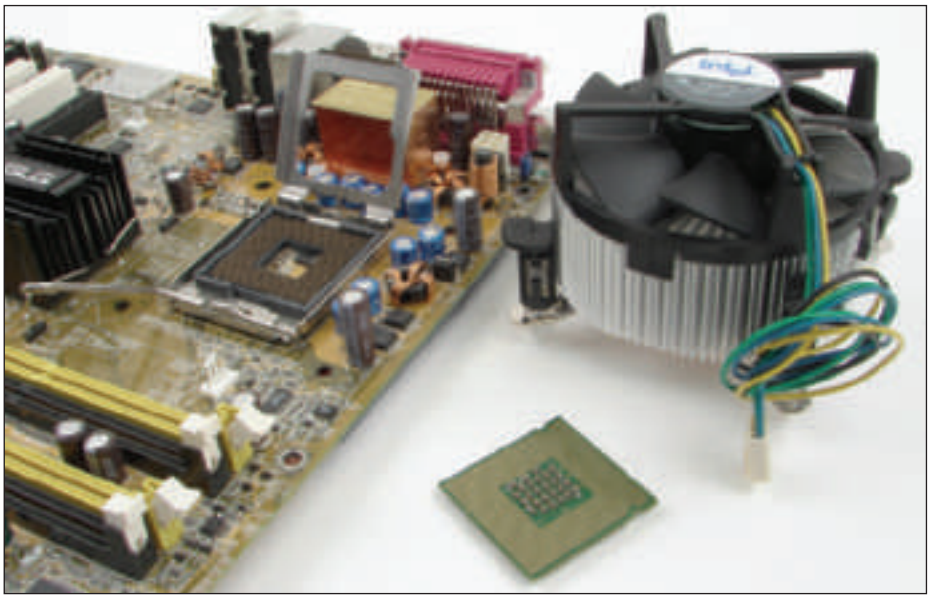
Figure 5-26 Return the lever to its locked position

INSTALLING AN INTEL PROCESSOR IN SOCKET LGA775

Socket LGA775 is shown in Figure 5-27 along with a Pentium processor and cooler. In the photo, the socket is open and the protective cover removed. The processor is lying upside down in front of the cooler.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.6

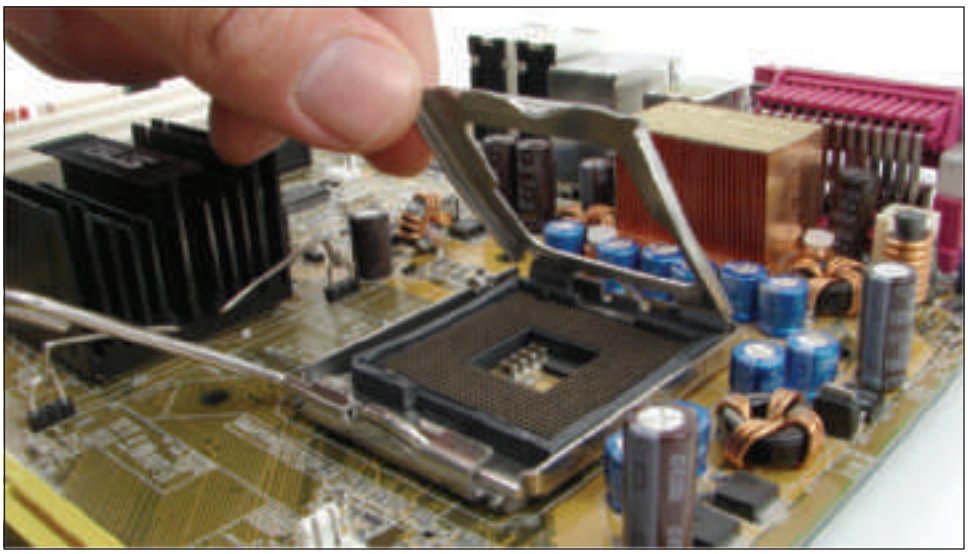


© Cengage Learning 2014

Figure 5-27 A Pentium, cooler, and open socket 775

When installing a processor in socket LGA775, do the following:

1. Push down on the lever and gently push it away from the socket to lift it. Lift the socket load plate (see Figure 5-28). Remove the socket protective cover.



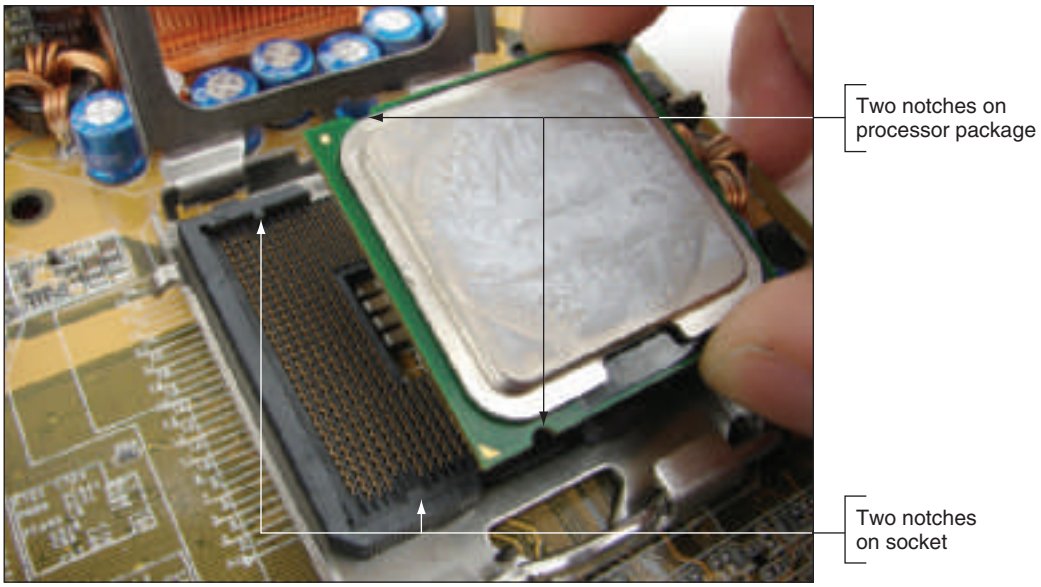
© Cengage Learning 2014

Figure 5-28 Lift the socket load plate

2. Orient the processor so that the notches on the two edges of the processor line up with the two notches on the socket (see Figure 5-29). Gently place the processor in the socket. Socket LGA775 doesn't have those delicate pins that Socket LGA1366 has, but you still need to be careful to not touch the top of the socket or the bottom of the processor as you work.
3. Close the socket cover. Push down on the lever and gently return it to its locked position.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.6



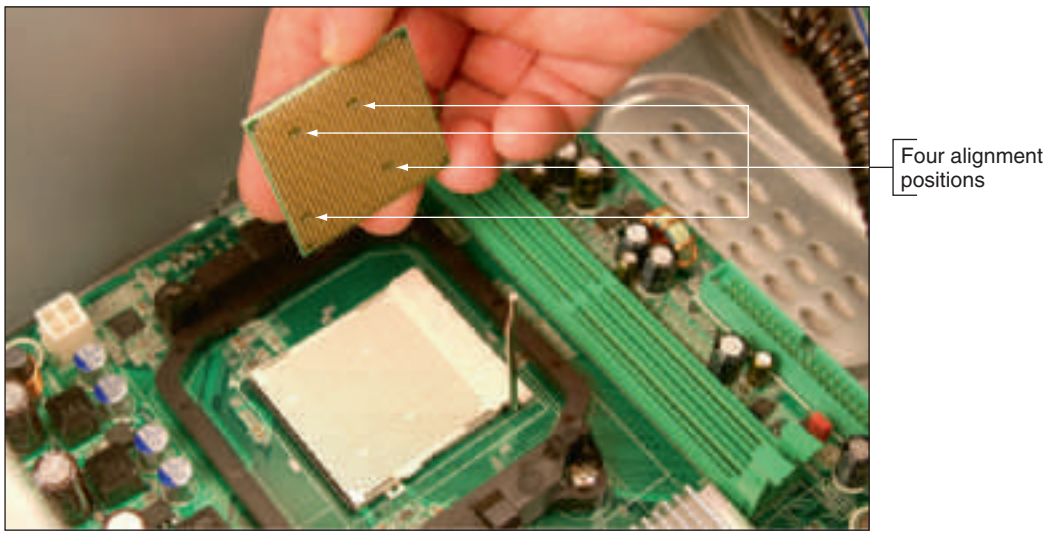
© Cengage Learning 2014

Figure 5-29 Place the processor in the socket, orienting the notches on two sides

INSTALLING AN AMD PROCESSOR IN SOCKET AM2+

When installing an AMD processor in AMD socket AM2, AM2+, or other AMD sockets, do the following:

1. Open the socket lever. If there's a protective cover over the socket, remove it.
2. Holding the processor very carefully so you don't touch the bottom, orient the four empty positions on the bottom with the four empty positions in the socket (see Figure 5-30). For some AMD sockets, a gold triangle on one corner of the processor matches up with a small triangle on a corner of the socket. Carefully lower the processor into the socket. Don't allow it to tilt or slide as it goes into the socket. The pins on the bottom of the processor are very delicate, so take care as you work.



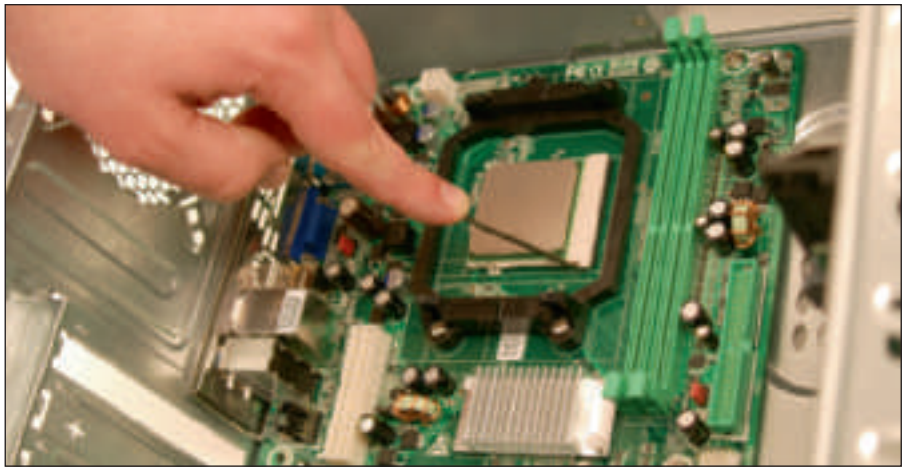
© Cengage Learning 2014

Figure 5-30 Orient the four alignment positions on the bottom of the processor with those in the socket

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

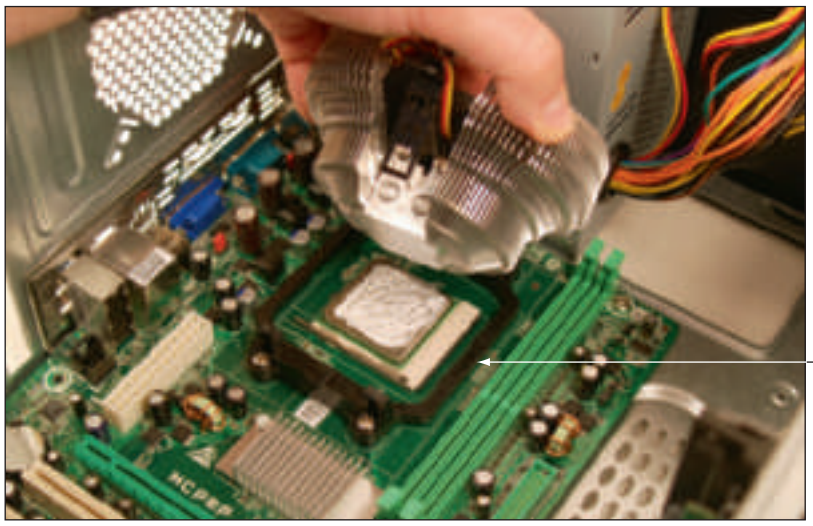
3. Check carefully to make sure the pins in the processor are sitting slightly into the holes. Make sure the pins are not offset from the holes. If you try to use the lever to put pressure on these pins and they are not aligned correctly, you can destroy the processor. You can actually feel the pins settle into place when you're lowering the processor into the socket correctly.
4. Press the lever down and gently into position (see Figure 5-31).



© Cengage Learning 2014

Figure 5-31 Lower the lever into place, which puts pressure on the processor

5. You are now ready to apply the thermal compound and install the cooler assembly. For one system, the black retention mechanism for the cooler is already installed on the motherboard (see Figure 5-32). Sit the cooler on top of the processor, aligning it inside the retention mechanism.



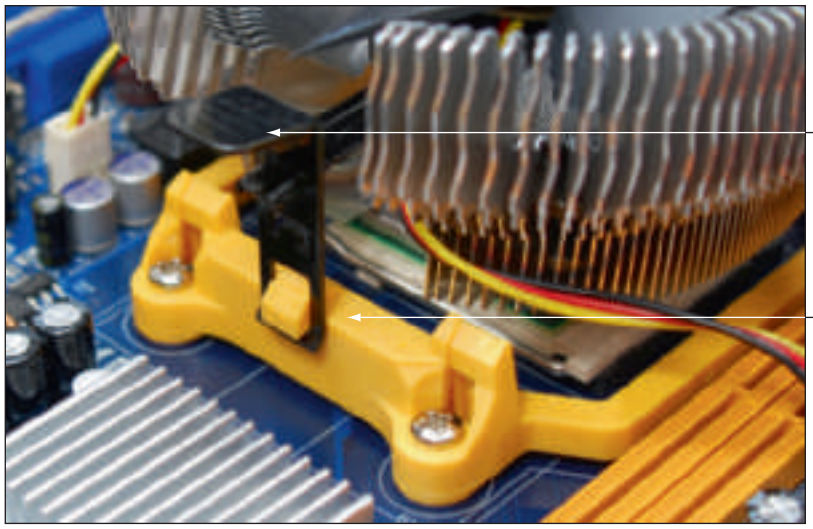
© Cengage Learning 2014

Figure 5-32 Align the cooler over the retention mechanism

6. Next, clip into place the clipping mechanism on one side of the cooler. Then push down firmly on the clip on the opposite side of the cooler assembly; the clip will snap into place. Figure 5-33 shows the clip on one side in place for a system that has a yellow retention mechanism and a black cooler clip. Later, if you need to remove the cooler, use a Phillips screwdriver to remove the screws holding the retention mechanism in place. Then remove the retention mechanism along with the entire cooler assembly.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.6



© Cengage Learning 2014

Figure 5-33 The clips on the cooler attach the cooler to the retention mechanism on the motherboard

7. Connect the power cord from the fan to the 4-pin fan header on the motherboard next to the CPU.

Notes How to troubleshoot problems with the processor, motherboard, and RAM is covered in Chapter 13.

Hands-on Project 5-1 Research a Processor Upgrade or Replacement

To identify your motherboard and find out the processor and processor socket a motherboard is currently using, you can use BIOS setup, Windows utilities, or third-party software such as Speccy at *www.periform.com/speccy*. To research processors a board can support, you can use the motherboard user guide, the web site of the motherboard manufacturer, and for Intel processors, the Intel site at *ark.intel.com*. Research the current processor and processor socket of your computer's motherboard and which processors your board can support, and answer the following questions:

1. What is the brand and model of your motherboard? What processor socket does it use? How did you find your information?
2. Identify the currently installed processor, including its brand, model, speed, and other important characteristics. How did you find your information?
3. List three or more processors the board supports according to the motherboard documentation or web site.
4. Search the web for three or more processors that would match this board. Save or print three web pages showing the details and prices of a high-performing, moderately performing, and low-performing processor the board supports.
5. If your current processor fails, which processor would you recommend for this system? Explain your recommendation.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.6

Now assume the Core i7 920 processor that you saw installed in the chapter in Figure 5-25 has gone bad. The motherboard in which it is installed is the Intel DX58SO desktop board. The owner of the motherboard has requested that you keep the replacement cost as low as possible. What processor would you recommend for the replacement? Save or print a web page showing the processor and its cost.

Hands-on Project 5-2 Insert and Remove a Processor

In this project, you remove and install a processor. As you work, be very careful to not bend pins on the processor or socket, and protect the processor and motherboard against ESD. Do the following:

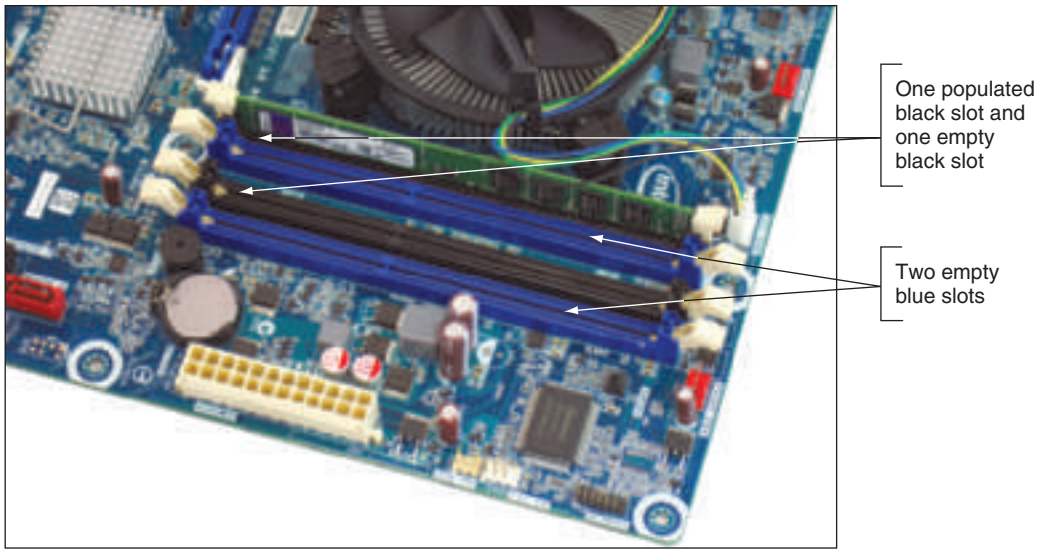
1. Verify the computer is working. Turn off the system, unplug it, press the power button, and open the computer case. Put on your ground bracelet. Remove the cooler assembly and processor.
2. To best protect the processor, if you have thermal compound available, remove all the compound from the processor and cooler and replace it with new compound.
3. You are now ready to reinstall the processor and cooler. But first have your instructor check the thermal compound.
4. Reinstall the processor and cooler. Power up the system and verify all is working.

Now let's turn our attention to the various memory technologies used in personal computers, and how to upgrade memory.

MEMORY TECHNOLOGIES

A+ 220-801 1.2, 1.3

Recall that random access memory (RAM) temporarily holds data and instructions as the CPU processes them and that the memory modules used on a motherboard are made of dynamic RAM or DRAM. DRAM loses its data rapidly, and the memory controller must refresh it several thousand times a second. RAM is stored on memory modules, which are installed in memory slots on the motherboard (see Figure 5-34).



© Cengage Learning 2014

Figure 5-34 RAM on motherboards today is stored in DIMMs

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

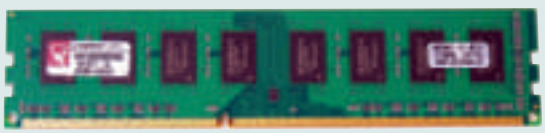
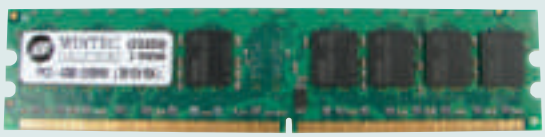
A+ 220-801 1.2, 1.3

A+ Exam Tip The A+ 220-801 exam expects you to know the purposes and characteristics of the following memory technologies: DRAM, SRAM, SDRAM, DDR, DDR2, DDR3, and Rambus.

Several variations of DRAM have evolved over the years. Here are the four major categories of memory modules:

- All new motherboards for desktops sold today use a type of memory module called a **DIMM (dual inline memory module)**.
- Laptops use a smaller version of a DIMM called a **SO-DIMM (small outline DIMM** and pronounced "sew-dim"). MicroDIMMs are used on subnotebook computers and are smaller than SO-DIMMs. You learn about SO-DIMMs in Chapter 19.
- An older type of module is a **RIMM**, which is designed by Rambus, Inc.
- Really old computers used **SIMMs (single inline memory module)**. You're unlikely to ever see these modules in working computers.

The major differences among these modules are the width of the data path that each type of module accommodates and the way data moves from the system bus to the module. DIMMs have seen several evolutions. Four versions of DIMMs, one RIMM, and two types of SIMMs are shown in Table 5-3. Notice the notches on the modules, which prevent the wrong type of module from being inserted into a memory slot on the motherboard.

Description of Module	Example
240-pin DDR3 DIMM is currently the fastest memory. It can support quad, triple, or dual channels or be installed as a single DIMM. It has an offset notch farther from the center than a DDR2 DIMM.	 © Cengage Learning 2014
240-pin DDR2 DIMM can support dual channels or be installed as a single DIMM. It has one notch near the center of the edge connector.	 © Cengage Learning 2014
184-pin DDR DIMM can support dual channels or be installed as a single DIMM. It has one offset notch.	 © Cengage Learning 2014
168-pin SDRAM DIMM has two notches on the module. The positions of these notches depend on the memory features the DIMM uses.	 © Cengage Learning 2014
RIMM has 184 pins and two notches near the center of the edge connector.	 © Cengage Learning 2014

© Cengage Learning 2014

Table 5-3 Types of memory modules (continues)

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

Description of Module	Example
72-pin SIMMs were installed in groups of two modules to each bank of memory.	 © Cengage Learning 2014
30-pin SIMMs were installed in groups of four modules to each bank of memory.	 © Cengage Learning 2014

© Cengage Learning 2014

Table 5-3 Types of memory modules (continued)

In this chapter, you'll see tons of different technologies used by RAM and so many can get a little overwhelming. You need to know about them because each motherboard you might support requires a specific type of RAM. Figure 5-35 is designed to help you keep all these technologies straight. You might find it a useful roadmap as you study each technology in the chapter. And who keeps up with all these technologies? JEDEC (*www.jedec.org*) is the organization responsible for standards used by solid state devices, including RAM technologies. The goal of each new RAM technology approved by JEDEC is to increase speed and performance without greatly increasing the cost.

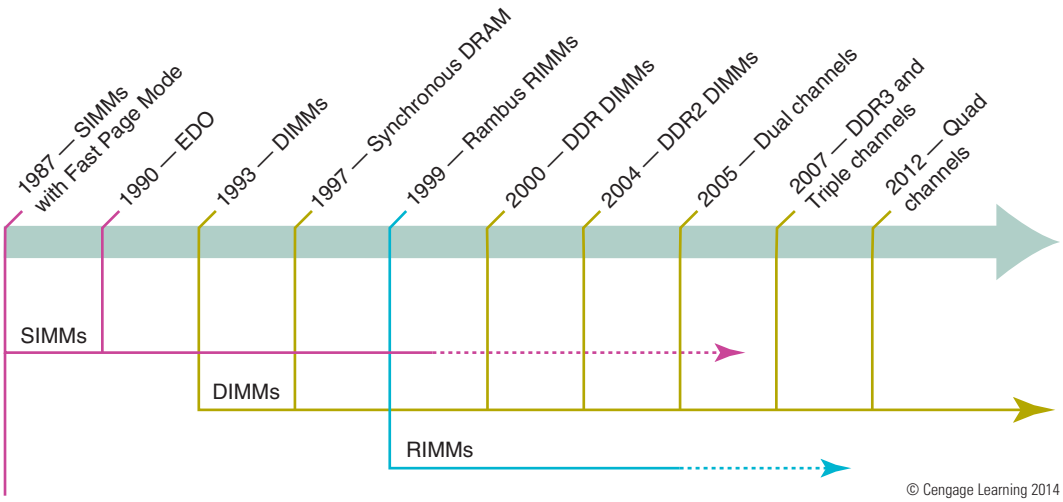


Figure 5-35 Timeline of memory technologies

Even though an older RAM technology is no longer used by new motherboards, RAM manufacturers continue to produce the older RAM because older motherboards require these replacement modules. In Figure 5-35, the dotted lines for SIMMs and RIMMs indicate these technologies are now obsolete. All new motherboards today use DIMMs. However, if you check some retail web sites, you can see that RIMMs can still be purchased.

Notes For an interesting discussion on how RAM works, complete with animation, see the web site by HowStuffWorks, Inc. at *www.howstuffworks.com/ram.htm*.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

We'll now look at each of the types of DIMM and RIMM modules and wrap up the chapter section with a quick summary of the technologies.

DIMM TECHNOLOGIES

DIMMs use a 64-bit data path. (Some early DIMMs had a 128-bit data path, but they're now obsolete.) A DIMM (dual inline memory module) gets its name because it has independent pins on opposite sides of the module.

Early DIMMs did not run in sync with the system clock because they were too slow to keep up. Their speeds are measured in nanoseconds (ns), which is how long it takes for the module to read or write data. The first DIMM to run synchronized with the system clock was **synchronous DRAM (SDRAM)**, which has two notches, and uses 168 pins. (Don't confuse SDRAM with SRAM. SRAM is static RAM used in processor memory caches, and SDRAM is dynamic RAM used on DIMMs.) Synchronized memory runs in step with the processor and system clock, and its speeds are measured just as processor and bus speeds are measured in MHz.

Double Data Rate SDRAM (**DDR SDRAM**, or **SDRAM II**, or simply **DDR**) is an improved version of SDRAM. DDR runs twice as fast as regular SDRAM, has one notch, and uses 184 pins. Instead of processing data for each beat of the system clock, as regular SDRAM does, it processes data when the beat rises and again when it falls, doubling the data rate of memory. If a motherboard runs at 200 MHz, DDR memory runs at 400 MHz. Two other improvements over DDR are DDR2 and DDR3. **DDR2** is faster and uses less power than DDR. **DDR3** is faster and uses less power than DDR2. Both DDR2 and DDR3 use 240 pins, although their notches are not in the same position. They are not compatible, and the different notch positions keep someone from installing a DDR2 or DDR3 DIMM in the wrong memory slot.

Factors that affect the capacity, features, and performance of DIMMs include the number of channels they use, how much RAM is on one DIMM, the speed, error-checking abilities, and buffering. All these factors are discussed next.

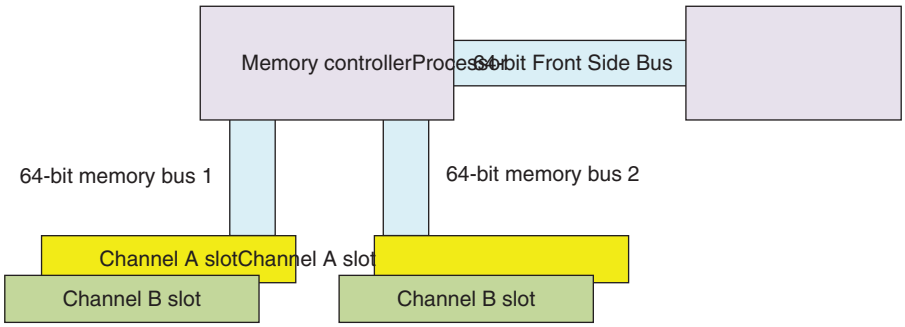
SINGLE, DUAL, TRIPLE, AND QUAD CHANNELS

When you look at a motherboard, you might notice the DIMM slots are different colors. This color coding is used to identify the channel each slot uses. Channels have to do with how many DIMM slots the memory controller can address at a time. Early DIMMs only used a **single channel**, which means the memory controller can access only one DIMM at a time. To improve overall memory performance, **dual channels** allow the memory controller to communicate with two DIMMs at the same time, effectively doubling the speed of memory access. A motherboard that supports **triple channels** can access three DIMMs at the same time. Sandy Bridge technology introduced **quad channels** where the processor can access four DIMMs at the same time. DDR, DDR2, and DDR3 DIMMs can use dual channels. DDR3 DIMMs can also use triple channels and quad channels. For dual, triple, or quad channels to work, the motherboard and the DIMM must support the technology.

Figure 5-36 shows how dual channeling works on a board with four DIMM slots. The board has two memory channels, Channel A and Channel B. With dual channeling, the two DIMMs installed in the two slots labeled Channel A can be addressed at the same time. If two more DIMMs are installed in the Channel B slots, they can be accessed at the same time.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

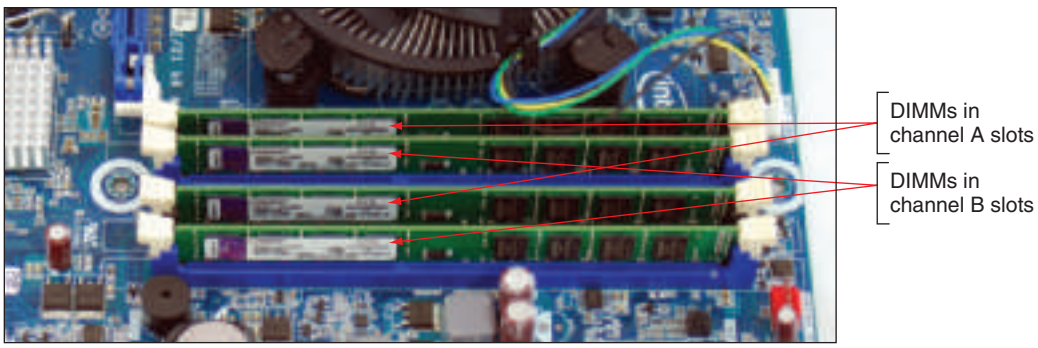
A+ 220-801 1.2, 1.3



© Cengage Learning 2014

Figure 5-36 Using dual channels, the memory controller can read from two DIMMs at the same time

When setting up dual channeling, know that the pair of DIMMs in a channel must be equally matched in size, speed, and features, and it is recommended they come from the same manufacturer. A motherboard using dual channels was shown in Figure 5-34. The two black DIMM slots make up the first channel, and the two blue slots make up the second channel. To use dual channeling, matching DIMMs must be installed in the black slots and another matching pair in the blue slots, as shown in Figure 5-37. Know that the second pair of DIMMs does not have to match the first pair of DIMMs because the first channel runs independently of the second channel. If the two DIMM slots of a channel are not populated with matching pairs of DIMMs, the motherboard will revert to single channeling.



© Cengage Learning 2014

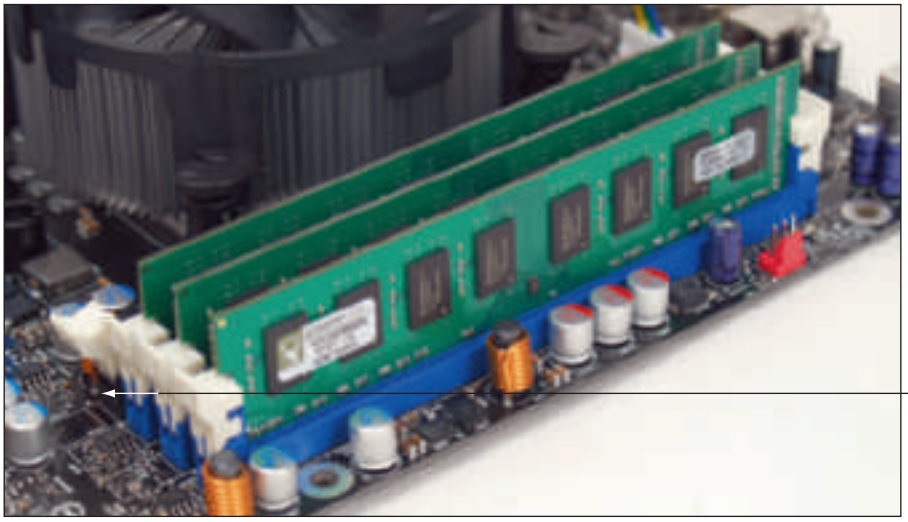
Figure 5-37 Matching pairs of DIMMs installed in four DIMM slots that support dual channeling

A+ Exam Tip The A+ 220-801 exam expects you to be able to distinguish between single-channel, dual-channel, and triple-channel memory installations.

For a triple-channel installation, three DIMM slots must be populated with three matching DDR3 DIMMs (see Figure 5-38). The three DIMMs are installed in the three blue slots on the board. This motherboard has a fourth black DIMM slot. You can barely see this black slot behind the three filled slots in the photo. If the fourth slot is used, then triple channeling is disabled, which can slow down performance. If a matching pair of DIMMs is installed in the first two slots and another matching pair of DIMMs is installed in the third and fourth slots, then the memory controller will use dual channels. Dual channels are not as fast as triple channels, but certainly better than single channels.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

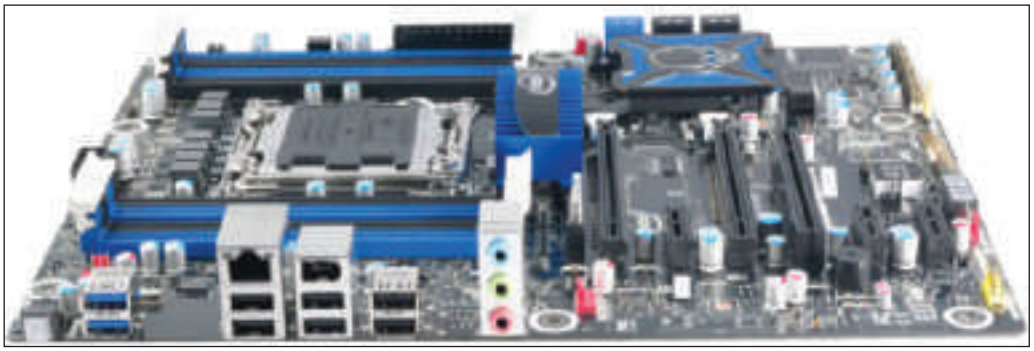
A+
220-801
1.2, 1.3



© Cengage Learning 2014

Figure 5-38 Three identical DDR3 DIMMs installed in a triple-channel configuration

The latest memory technology is quad channeling that was introduced with Intel Sandy Bridge chipsets and processors. Figure 5-39 shows an Intel motherboard that has the LGA2011 socket and eight memory slots. The processor can access four slots at the same time. The four black slots can be addressed by the processor on one memory channel and the four blue slots on another channel. Recall from Chapter 4 that Second Generation Sandy Bridge processors contain the memory controller within the processor package rather than on the chipset. To get the highest performance, memory slots are placed on either side of the processor in order to shorten the length of the memory bus. Because of the high performance of processors that use the LGA2011 socket, Intel recommends that systems using this socket use liquid cooling methods.



Courtesy of Intel Corporation

Figure 5-39 The Intel Desktop Board DX79TO has eight memory slots and supports two quad channels

DIMM SPEEDS

DIMM speeds are measured either in MHz (such as 1333 MHz or 800 MHz) or PC rating (such as PC6400). A PC rating is a measure of the total bandwidth of data moving between the module and the CPU. To understand PC ratings, let's take an example of a DDR DIMM module that runs at 800 MHz. The module has a 64-bit (8-byte) data path. Therefore, the transfer rate is 8 bytes multiplied by 800 MHz, which yields 6400 MB/second. This value equates to the PC rating of PC6400 for a DDR DIMM. A DDR2 PC rating is usually labeled PC2, and a DDR3 PC rating is labeled PC3. In Figure 5-40, this memory ad shows both the MHz and PC rating.

Some current PC ratings for DDR3 memory are PC3-16000 (2000 MHz), PC3-14400 (1800 MHz), PC3-12800 (1600 MHz), and PC3-10600 (1333 MHz). A couple of current

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

Source: tigerdirect.com

Figure 5-40 Memory speed is expressed in MHz and PC rating

PC ratings for DDR2 memory are PC2-6400 (800 MHz) and PC2-5400 (667 MHz). DDR memory might be rated at PC6400 (800 MHz), PC4000 (500 MHz), PC3200 (400 MHz), or PC2700 (333 MHz). An older 168-pin SDRAM DIMM might run at PC100 or PC133.

SINGLE-SIDED AND DOUBLE-SIDED DIMMS

A DIMM can have memory chips installed on one side of the module (called **single-sided**) or both sides of the module (called **double-sided**). Most desktop and laptop processors address memory 64 bits at a time. A **memory bank** is the memory a processor addresses at one time and is 64 bits wide, and a DIMM slot provides a 64-bit data path. However, some double-sided DIMMs provide more than one bank, which means the chips on the DIMM are grouped so that the memory controller addresses one group and then addresses another. These DIMMs are said to be **dual ranked**, and don't perform as well as DIMMs where all the memory is addressed at one time. Notice in the memory ad in Figure 5-41 that the second item listed shows Dual Ranked as a feature.

Source: crucial.com

Figure 5-41 Memory ad lists dual ranked DDR3 memory

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

ERROR CHECKING AND PARITY

Because DIMMs intended to be used in servers must be extremely reliable, error-checking technology called **ECC (error-correcting code)** is sometimes used. Some SDRAM, DDR, DDR2, and DDR3 memory modules support ECC. A DIMM normally has an even number of chips on the module, but a DIMM that supports ECC has an odd number of chips on the module. The odd extra chip is the ECC chip. ECC compares bits written to the module to what is later read from the module, and it can detect and correct an error in a single bit of the byte. If there are errors in two bits of a byte, ECC can detect the error but cannot correct it. The data path width for DIMMs is normally 64 bits, but with ECC, the data path is 72 bits. The extra 8 bits are used for error checking. ECC memory costs more than non-ECC memory, but it is more reliable. For ECC to work, the motherboard and all installed modules must support it. Also, it's important to know that you cannot install a mix of ECC and non-ECC memory on the motherboard because such a mixture causes the system to not work.

As with most other memory technologies discussed in this chapter, when buying memory to add to a motherboard, match the type of memory to the type the board supports. To see if your motherboard supports ECC memory, look for the ability to enable or disable the feature in BIOS setup, or check the motherboard documentation. Figure 5-42 shows one ad for DIMMs. The first three items are non-ECC, and the last item is ECC memory. Also notice the first two items offer DIMMs in a kit of 4 DIMMs or 2 DIMMs.

Source: kingston.com

Figure 5-42 Memory ad for DDR3 and DDR2 memory

Refer back to the memory ad shown in Figure 5-41. The first item is non-ECC memory and has ×64 in the ad. The second item is ECC memory and has ×72 in the ad. The 64 or 72 is the width of the data path for non-ECC or ECC memory.

Older SIMMs used an error-checking technology called **parity**. Using parity checking, a ninth bit is stored with every 8 bits in a byte. If memory is using odd parity, it makes the ninth or parity bit either a 1 or a 0, to make the number of ones in the nine bits odd. If it uses even parity, it makes the parity bit a 1 or a 0 to make the number of ones in the 9 bits even.

A+ Exam Tip The A+ 220-801 exam expects you to know that parity memory uses 9 bits (8 bits for data and 1 bit for parity). You also need to be familiar with ECC and non-ECC memory technologies.

Later, when the byte is read back, the memory controller checks the odd or even state. If the number of bits is not an odd number for odd parity or an even number for even parity,

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

a **parity error** occurs. A parity error always causes the system to halt. On the screen, you see the error message "Parity Error 1" or "Parity Error 2" or a similar error message about parity. Parity Error 1 is a parity error on the motherboard; Parity Error 2 is a parity error on an expansion card.

Figure 5-43 shows a SIMM for sale. It's pricy because this old technology is hardly ever used. Notice the module is non-parity memory. In the ad, the SIMM is called EDO memory. EDO (extended data out) is a technology used by SIMMs.

Source: crucial.com

Figure 5-43 A SIMM appears in a memory ad as EDO memory

Notes RAM chips that have become undependable and cannot hold data reliably can cause errors. Sometimes this happens when chips overheat or power falters.

BUFFERED AND REGISTERED DIMMS

Buffers and registers hold data and amplify a signal just before the data is written to the module. (Using buffers is an older technology than using registers.) Some DIMMs use buffers, some use registers, and some use neither. If a DIMM doesn't support registers or buffers, it's referred to as an unbuffered DIMM. Looking at the ad in Figure 5-44, you can see a kit of DDR3 unbuffered DIMMs and kits of registered DIMMs.

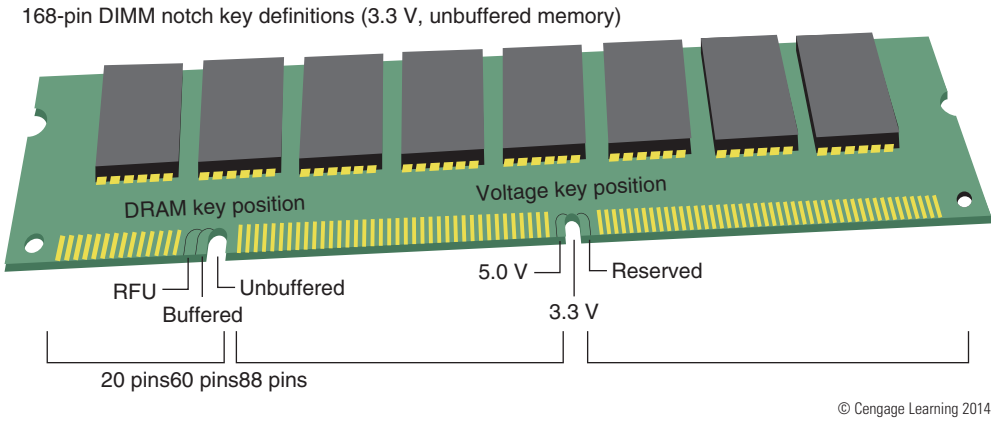
Source: crucial.com

Figure 5-44 Kits of unbuffered or registered DIMMs

Notches on SDRAM DIMMs are positioned to identify the technologies that the module supports. In Figure 5-45, the position of the notch on the left identifies the module as registered (RFU), buffered, or unbuffered memory. The notch on the right identifies the voltage used by the module. The position of each notch not only helps identify the type of module but also prevents the wrong kind of module from being used on a motherboard.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3



© Cengage Learning 2014

Figure 5-45 The positions of two notches on an SDRAM DIMM identify the type of DIMM and the voltage requirement and also prevent the wrong type from being installed on the motherboard

CAS LATENCY AND RAS LATENCY

Two other memory features are **CAS Latency** (CAS stands for "column access strobe") and **RAS Latency** (RAS stands for "row access strobe"), which are two ways of measuring access timing. Both features refer to the number of clock cycles it takes to write or read a column or row of data off a memory module. CAS Latency is used more than RAS Latency. Lower values are better than higher ones. For example, CL8 is a little faster than CL9.

Notes In memory ads, CAS Latency is sometimes written as CL, and RAS Latency might be written as RL.

Ads for memory modules sometimes give the CAS Latency value within a series of timing numbers, such as 5-5-5-15. The first value is CAS Latency, which means the module is CL5. The second value is RAS Latency. Looking back at Figure 5-44 you can see two DDR3 DIMM kits are rated at CL9 and one is rated at CL7.

Notes When selecting memory, use the memory type that the motherboard manufacturer recommends.

RIMM TECHNOLOGIES

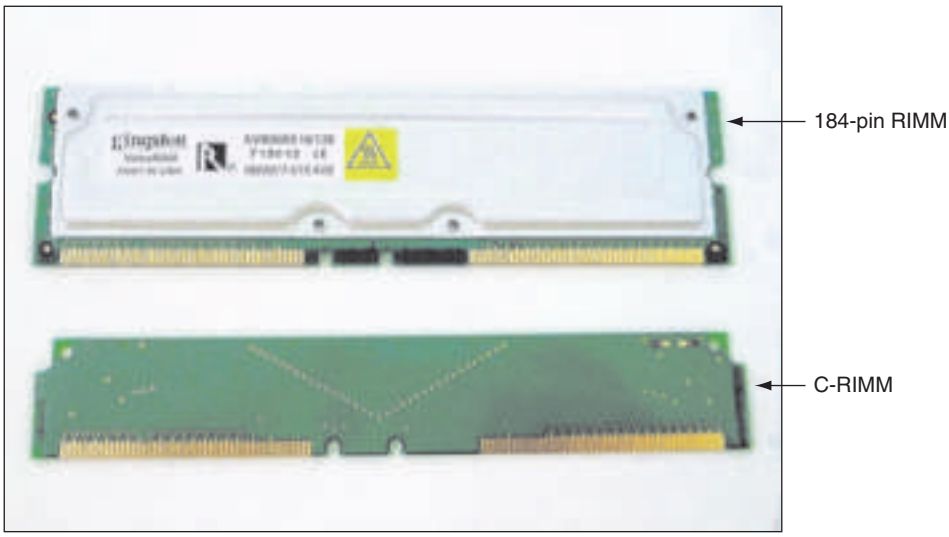
Direct Rambus DRAM (sometimes called **RDRAM** or **Direct RDRAM** or simply **Rambus**) is named after Rambus, Inc., the company that developed it. A Rambus memory module is called a RIMM. RIMMs are expensive and are now slower than current DIMMs. No new motherboards are built to use RIMMs, but you might be called on to support an old motherboard that uses them.

RIMMs that use a 16-bit data bus have two notches and 184 pins (see Figure 5-46). RIMMs that use a 32-bit data bus have a single notch and 232 pins. The 232-pin RIMMs can support dual channels. RIMMs can be ECC or non-ECC and vary in size and speed. Size can vary from 64 MB to 512 MB, and speed ratings are 800 MHz or 1066 MHz.

With RIMMs, each memory slot on the motherboard must be filled to maintain continuity throughout all slots. If a slot does not hold a RIMM, it must hold a placeholder module called a **C-RIMM (Continuity RIMM)** to ensure continuity throughout all slots. The C-RIMM contains no memory chips. A C-RIMM is shown in Figure 5-46.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3



© Cengage Learning 2014

Figure 5-46 A RIMM or C-RIMM must be installed in every RIMM slot on the motherboard

MEMORY TECHNOLOGIES AND MEMORY PERFORMANCE

So now let's summarize the different memory technologies and consider how they affect overall memory performance. Factors to consider when looking at the overall performance of memory are listed below:

- ***The total RAM installed.*** The more memory there is, the faster the system. Generally use as much memory in a system as the motherboard and the OS can support and you can afford.
- ***The memory technology used.*** DDR3 is faster than DDR2. DDR2 is faster than DDR, and DDR is faster than SDRAM. When required by the motherboard, buffered or registered memory can improve performance. For all these technologies, use what the board supports.
- ***The speed of memory in MHz or PC rating.*** Use the fastest memory the motherboard supports. If you install modules of different speeds in the same system, the system will run at the slowest speed or might become unstable. Know that most computer ads give speeds in MHz or PC rating, but some ads give both values.
- ***ECC or non-ECC.*** Non-ECC is faster and less expensive but might not be as reliable. Use what the board supports.
- ***CL or RL rating.*** The lower the better. Use what the board supports, although most boards don't specify a particular CL rating. The CL rating might be expressed as a series of timing numbers.
- ***Single, dual, triple, or quad channeling.*** DIMMs that differ in capacity or speed can function on a motherboard in single channels as long as you use DIMMs that the board supports and match ECC ratings. However, to improve performance, use dual, triple, or quad channeling if the board supports the feature. To use dual, triple, or quad channeling, install matching DIMMs from the same manufacturer in each group of channel slots. These matching modules are sometimes sold as memory kits.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

When selecting memory, you need to know one more fact about memory technologies. On a motherboard, the connectors inside the memory slots are made of tin or gold, as are the edge connectors on the memory modules. It used to be that all memory sockets were made of tin, but now most are made of gold. You should match tin leads to tin connectors and gold leads to gold connectors to prevent a chemical reaction between the two metals, which can cause corrosion. Corrosion can create intermittent memory errors and even make the PC unable to boot.

HOW TO UPGRADE MEMORY

To upgrade memory means to add more RAM to a computer. Adding more RAM might solve a problem with slow performance, applications refusing to load, or an unstable system. When Windows does not have adequate memory to perform an operation, it gives an "Insufficient memory" error or it slows down to a painful crawl.

When first purchased, many computers have empty slots on the motherboard, allowing you to add DIMMs to increase the amount of RAM. Sometimes a memory module goes bad and must be replaced.

When you add more memory to your computer, you need answers to these questions:

- How much RAM do I need and how much is currently installed?
- How many and what kind of memory modules are currently installed on my motherboard?
- How many and what kind of modules can I fit on my motherboard?
- How do I select and purchase the right modules for my upgrade?
- How do I physically install the new modules?

All these questions are answered in the following sections.

HOW MUCH MEMORY DO I NEED AND HOW MUCH IS CURRENTLY INSTALLED?

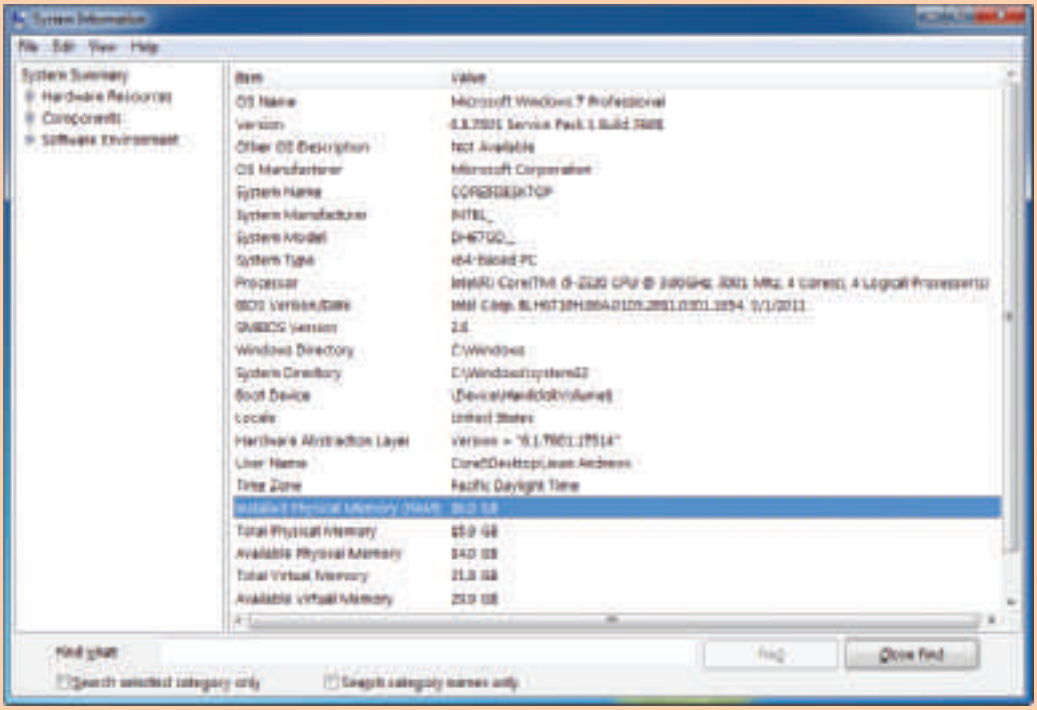
With the demands today's software places on memory, the answer is probably, "All you can get." Windows 7 needs at least 2 GB, but more is better. The limit for a 32-bit OS is 4 GB installed RAM. A 64-bit Windows installation can handle more. For example, a 64-bit installation of Windows 7 Home Premium can use up to 16 GB of RAM.

APPLYING CONCEPTS — **HOW MUCH MEMORY IS CURRENTLY INSTALLED?**

In Windows, you can use the System Information window to report the amount of physical memory installed. Click **Start**, type **Msinfo32**, and press **Enter**. The System Information window shown in Figure 5-47 reports the amount of installed physical memory. Notice on the window that 16 GB is installed, but only 14 GB is available to Windows. The other 2 GB is used by BIOS and most of that is used for video memory.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

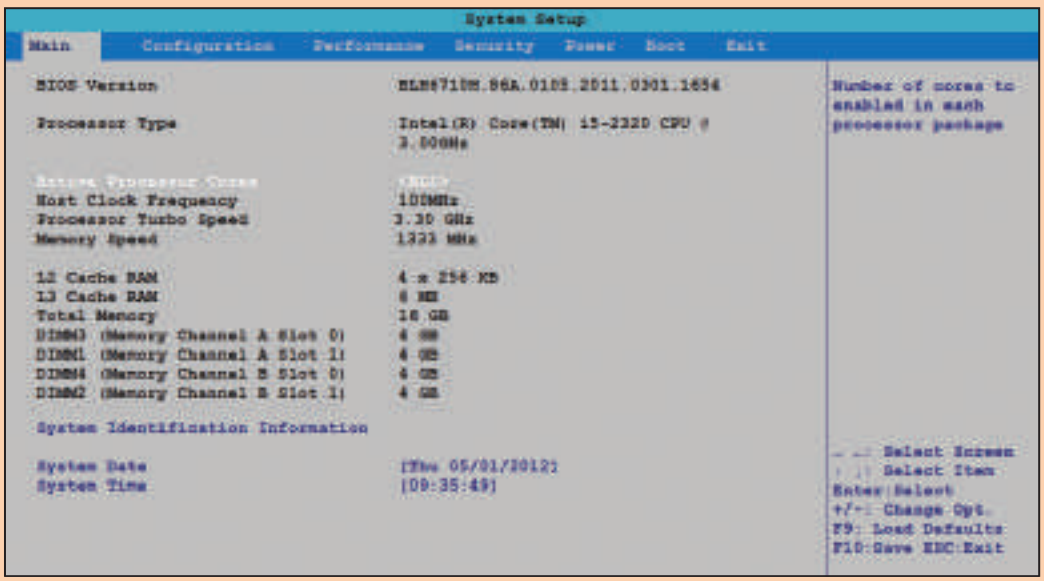
A+ 220-801 1.2, 1.3



Source: Microsoft Windows 7

Figure 5-47 The System Information window reports installed physical memory

The BIOS setup screen shows more information about installed memory than does Windows. Reboot the computer and access BIOS setup (you learned how to do that in Chapter 4.) The BIOS setup main menu for one system is shown in Figure 5-48. This screen shows the number of memory slots and how much RAM is installed in each slot. Notice the system has two memory channels of two slots each. You can, therefore, conclude this system is using dual channels.



Source: Intel

Figure 5-48 BIOS setup reports memory configuration and amount

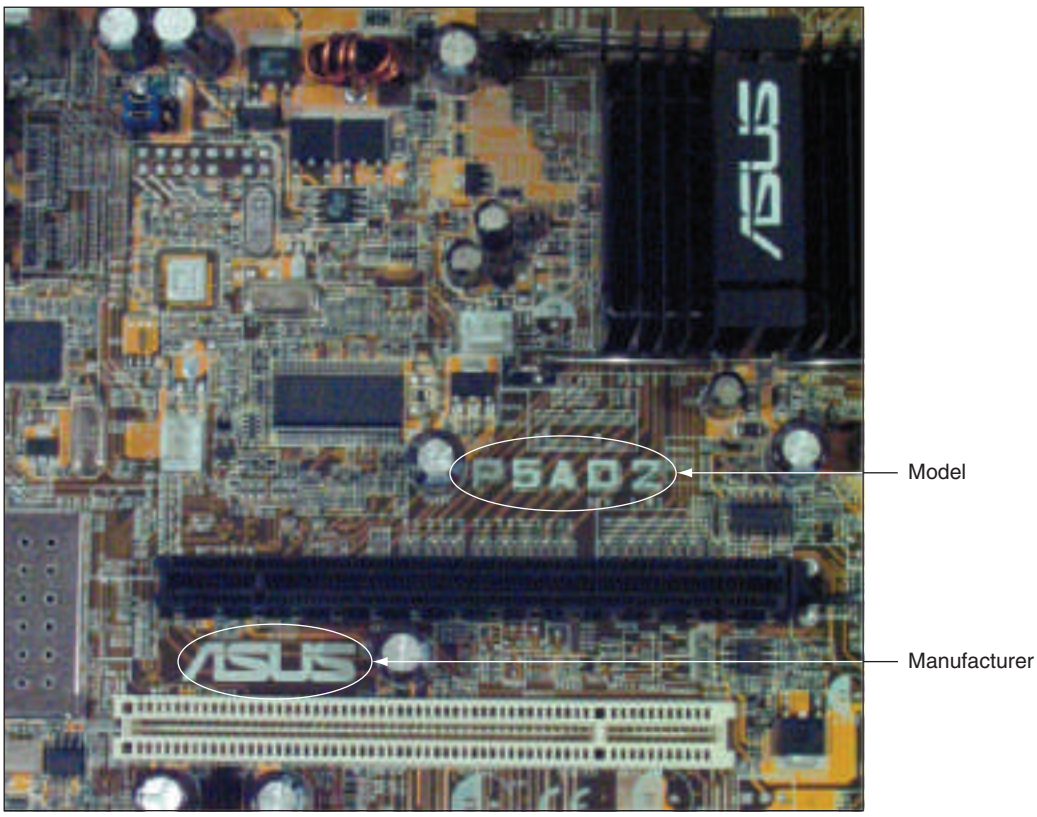
Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3

HOW MANY AND WHAT KIND OF MEMORY MODULES ARE CURRENTLY INSTALLED?

The next step to upgrading memory is to determine what type of memory modules the motherboard is currently using. If the board already has memory installed, you want to do your best to match the new modules with whatever is already installed. To learn what type of memory modules are already installed, do the following:

- Open the case and look at the memory slots. How many slots do you have? How many are filled? Remove each module from its slot and look on it for imprinted type, size, and speed. For example, a module might say "PC2-4200/512MB." The PC2 tells you the memory is DDR2, the 4200 is the PC rating and tells you the speed, and the 512 MB is the size. This is not enough information to know exactly what modules to purchase, but it's a start.
- Examine the module for the physical size and position of the notches. Compare the notch positions to those in Table 5-3 and Figure 5-45.
- Read your motherboard documentation. If the documentation is not clear (and some is not) or you don't have the documentation, look on the motherboard for the imprinted manufacturer and model (see Figure 5-49). With this information, you can search a good memory web site such as Kingston (*www.kingston.com*) or Crucial (*www.crucial.com*), which can tell you what type of modules this board supports.



© Cengage Learning 2014

Figure 5-49 Look for the manufacturer and model of a motherboard imprinted somewhere on the board

- Look in the documentation to see if the board supports dual channel, triple channel, or quad channels. If it does, most likely the memory slots on the board will be color-coded in pairs (for dual channels) or groups of three slots (for triple channels) or four

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

slots (for quad channels). If the board supports multiple channels and modules are already installed, verify that matching DIMMs are installed in each channel.

- If you still have not identified the module type, you can take the motherboard and the old memory modules to a good computer parts store and they should be able to match it for you.

Hands-on Project 5-3 Use an Online Memory Scanner

A great shortcut to research a memory upgrade is an online memory scanner. Go to *www.crucial.com/systemscanner* by Crucial. Download and run the Crucial System Scanner, which scans your system and reports what type of memory is installed and can be installed. Using the Crucial report, answer these questions:

1. Which motherboard do you have installed? How much memory is installed? How many memory slots does the board have? How many are populated?
2. What is the maximum memory the board supports? What type of memory does the board support? What would be the total cost of the memory upgrade if you were to max out the total memory on the board?

HOW MANY AND WHAT KIND OF MODULES CAN FIT ON MY MOTHERBOARD?

Now that you know what memory modules are already installed, you're ready to decide how much and what kind of modules you can add to the board. Keep in mind that if all memory slots are full, sometimes you can take out small-capacity modules and replace them with larger-capacity modules, but you can only use the type, size, and speed of modules that the board can support. Also, if you must discard existing modules, the price of the upgrade increases.

To know how much memory your motherboard can physically hold, read the documentation that comes with the board. Next, let's look at what to consider when deciding how many and what kind of DIMMs or RIMMs to add to a system.

DIMM MODULES

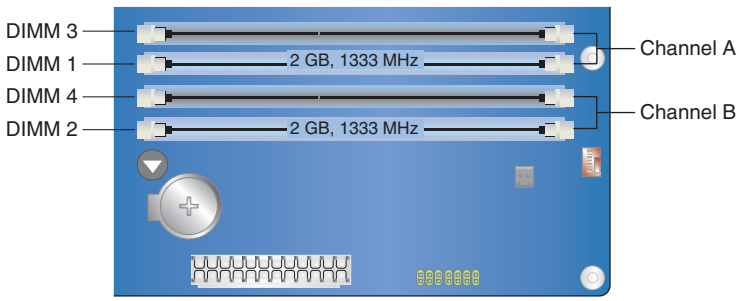
You can always install DIMMs as single modules, but you might not get the best performance by doing so. For best performance, install matching DIMMs in all the slots (two, three, or four slots) on one channel. Now let's look at a few examples. The examples are ordered from a recent motherboard to an older motherboard. As you study these examples, notice that the older the board, the more complicated the configuration can be and the harder it is to understand the documentation. Is life with computers getting simpler or what?

Motherboard Using DDR3 Dual-Channel DIMMs

The Intel Desktop Board DH67GD shown earlier in Figure 5-12 has four memory slots that use dual channeling. These slots are numbered in the user guide, as shown in Figure 5-50. The slots can hold Dual Channel DDR3 1333 MHz and 1066 MHz non-ECC, 1.35 V modules for up to 32 GB of RAM on this board. To use four DIMMs and dual channeling, install matching DIMMs in the two blue slots and matching DIMMs in the two black slots.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3



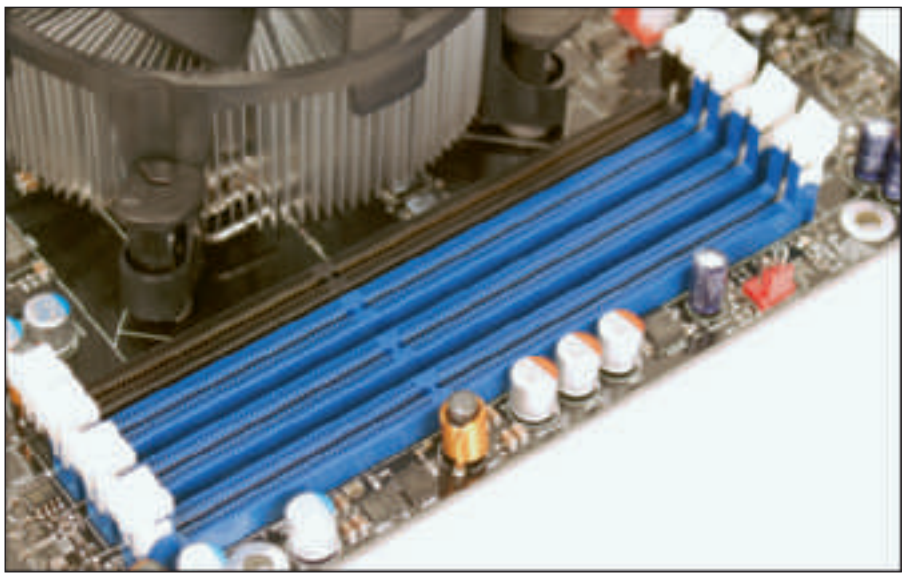
© Cengage Learning 2014

Figure 5-50 Documentation shows four DIMM slots that use dual channels

The mobo user guide says it is possible to use only three DIMMs and dual channeling if you install matching DIMMs in the two blue slots and install a third DIMM in a black slot. This third DIMM must be equal in speed and total size of the DIMMs in the blue slots. For example, you can install two 4 GB DIMMs in the two blue slots and one 8 GB DIMM in a black slot for a total of 16 GB RAM. If you install only a single DIMM on this board, it must go in the first blue slot, which is the blue slot closest to the processor.

Motherboard Using DDR3 Triple-Channel DIMMs

The Intel motherboard shown earlier in Figure 5-38 has four DDR3 memory slots that can be configured for single, dual, or triple channeling. The four empty slots are shown in Figure 5-51. If triple channeling is used, three matching DIMMs are used in the three blue slots. If the fourth slot is populated, the board reverts to single channeling. For dual channeling, install two matching DIMMs in the two blue slots farthest from the processor and leave the other two slots empty. If only one DIMM is installed, it goes in the blue slot in the farthest position from the processor.



© Cengage Learning 2014

Figure 5-51 Four DDR3 slots on a motherboard

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

The motherboard documentation says that these types of DIMMs can be used:

- The DIMM voltage rating no higher than 1.6 V
- Non-ECC DDR3 memory
- Serial Presence Detect (SPD) memory only
- Gold-plated contacts (some modules use tin-plated contacts)
- 1333 MHz, 1066 MHz, or 800 MHz (best to match the system bus speed)
- Unbuffered, nonregistered single- or double-sided DIMMs
- Up to 16 GB total installed RAM

The third item in the list needs an explanation. Serial Presence Detect (SPD) is a DIMM technology that declares to system BIOS at startup the module's size, speed, voltage, and data path width. If the DIMM does not support SPD, the system might not boot or boot with errors. Today's memory always supports SPD.

Motherboard Using DDR DIMMs with Dual Channeling

Let's look at another example of a DIMM installation. The Pentium motherboard allows you to use three different speeds of DDR DIMMs in one to four sockets on the board. The board supports dual channeling and has two blue slots for one channel and two black slots for the other channel. For dual channeling to work, matching DIMMs must be installed in the two blue sockets. If two DIMMs are installed in the two black sockets, they must match each other.

This board supports up to 4 GB of unbuffered, 184-pin, non-ECC memory running at PC3200, PC2700, or PC2100. The documentation says the system bus can run at 800 MHz, 533 MHz, or 400 MHz, depending on the speed of the processor installed. Therefore, the speed of the processor determines the system bus speed, which determines the speed of memory modules.

Figure 5-52 outlines the possible configurations of these DIMM modules, showing that you can install one, two, or four DIMMs and which sockets should hold these DIMMs. To take advantage of dual channeling on this motherboard, you must populate the sockets according to Figure 5-52, so that identical DIMM pairs are working together in DIMM_A1 and DIMM_B1 sockets (the blue sockets), and another pair can work together in DIMM_A2 and DIMM_B2 sockets (the black sockets).

	Sockets			
Mode	**DIMM_A1**	**DIMM_A2**	**DIMM_B1**	**DIMM_B2**
Single channel(1)———	Populated			
(2)—Populated—				—
(3)——Populated—				
(4)———Populated				
Dual channel*(1)—Populated—	Populated			
(2)—Populated—Populated				
(3)	PopulatedPopulatedPopulatedPopulated			

*Use only identical DDR DIMM pairs

© Cengage Learning 2014

Figure 5-52 Motherboard documentation shows that one, two, or four DIMMs can be installed

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3

The board has two installed DDR DIMMs. The label on one of these DIMMs is shown in Figure 5-53. The important items on this label are the size (256 MB), the speed (400 MHz or 3200 PC rating), and the CAS Latency (CL3). With this information and knowledge about what the board can support, we are now ready to select and buy the memory for the upgrade. For example, if you decide to upgrade the system to 1 GB of memory, you would buy two DDR, 400 MHz, CL3 DIMMs that support dual channeling. For best results, you need to also match the manufacturer and buy Elixir memory.

© Cengage Learning 2014

Figure 5-53 Use the label on this DIMM to identify its features

Pentium Motherboard Using SDRAM DIMMs

Our last DIMM example uses older SDRAM DIMMs. The Pentium motherboard uses 168-pin single-sided DIMM modules, and the documentation says to use unbuffered, 3.3 V, ECC, PC100 DIMM SDRAM modules. The PC100 means that the modules should be rated to work with a motherboard that runs at 100 MHz. You can choose to use ECC modules. If you choose not to, BIOS setup should show the feature disabled. Three DIMM slots are on the board, which the motherboard documentation calls sockets. Each socket holds one bank of memory. Figure 5-54 shows the possible combinations of DIMMs that can be installed in these sockets.

DIMM Location	168-Pin DIMM		Total Memory
Socket 1 (Rows 0 & 1)	SDRAM 8, 16, 32, 64, 128, 256 MB	×1	
Socket 2 (Rows 2 & 3)	SDRAM 8, 16, 32, 64, 128, 256 MB	×1	
Socket 3 (Rows 4 & 5)	SDRAM 8, 16, 32, 64, 128, 256 MB	×1	
	Total System Memory (Max 768 MB)	=	

© Cengage Learning 2014

Figure 5-54 This table is part of the motherboard documentation and is used to show possible DIMM sizes and calculate total memory on the motherboard

RIMM MODULES

Systems using RIMMs are no longer made, but you might be called on to support one. Because RIMMs are obsolete, they are really expensive. Most likely you can purchase a comparable motherboard and processor that use DIMMs for less money than you can buy the RIMMs for one of these old systems. However, if you ever find yourself needing to

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

replace or upgrade memory using RIMMs, if possible, match the new RIMMs with one already installed on the board. Be sure to follow guidelines given in the motherboard documentation for the capacity and speeds supported.

For example, suppose you see installed a RIMM like the one shown in Figure 5-55. The important information for us is "800X16/128." The value 128 is the size of the RIMM, 128 MB. The value 800 is the speed, 800 MHz. The value X16 tells us this RIMM is a non-ECC RIMM. (If it had been ECC compliant, the value would have been X18.) That's enough information to go find a RIMM for sale that matches this one.

© Cengage Learning 2014

Figure 5-55 Use the label on this RIMM to identify its features

Recall that all RIMM slots must be filled with either RIMMs or C-RIMMs. When you upgrade, you replace one or more C-RIMMs with RIMMs.

As you can see, the motherboard documentation is essential when selecting memory. If you can't find the motherboard manual, look on the motherboard manufacturer's web site.

HOW DO I SELECT AND PURCHASE THE RIGHT MEMORY MODULES?

You're now ready to make the purchase. As you select your memory, you might find it difficult to find an exact match to DIMMs or RIMMs already installed on the board. If necessary, here are some compromises you cannot or can make:

- Mixing unbuffered memory with buffered or registered memory won't work.
- When matching memory, for best results, also match the module manufacturer. But in a pinch, you can try using memory from two different manufacturers.
- If you mix memory speeds, know that all modules will perform at the slowest speed.

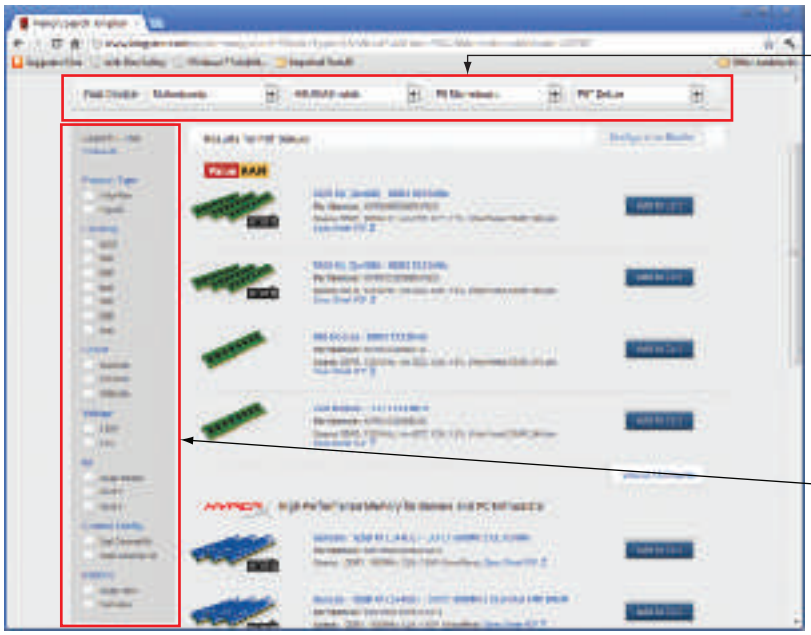
Now let's look at how to use a web site or other computer ad to search for the right memory.

USING A WEB SITE TO RESEARCH YOUR PURCHASE

When purchasing memory from a web site such as Crucial Technology's site (*www.crucial.com*) or Kingston Technology's site (*www.kingston.com*), look for a search utility that will match memory modules to your motherboard (see Figure 5-56). These utilities are easy to

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3



Source: kingston.com

Figure 5-56 The Kingston web site DIMM recommendations for a particular motherboard

use and help you confirm you have made the right decisions about type, size, and speed to buy. They can also help if motherboard documentation is inadequate, and you're not exactly sure what memory to buy.

Let's look at one example on the Crucial site where we are looking to install memory in the Intel DH67GD motherboard discussed earlier in the chapter. The search results are shown in Figure 5-57. Modules faster than the board supports are listed. They will work on the board, running at a slower speed, but it's not necessary to spend the money for speed you won't use. The best buy is the second item listed; these DIMMs are rated at 1333 MHz, which is the maximum speed the board supports.

Source: crucial.com

Figure 5-57 Selecting memory off the Crucial web site

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3

Hands-on Project 5-4 Plan and Price a Memory Upgrade

Using the information you gained about your computer in Hands-on Project 5-3, research the web to determine the total cost of the memory upgrade in order to max out the total memory on your computer. You can keep the cost down by using the modules you already have, but don't forget to match the speed of the modules already installed. Print two web pages from two sites other than the Crucial site that show the modules you would purchase. How much will the upgrade cost?

HOW DO I INSTALL THE NEW MODULES?

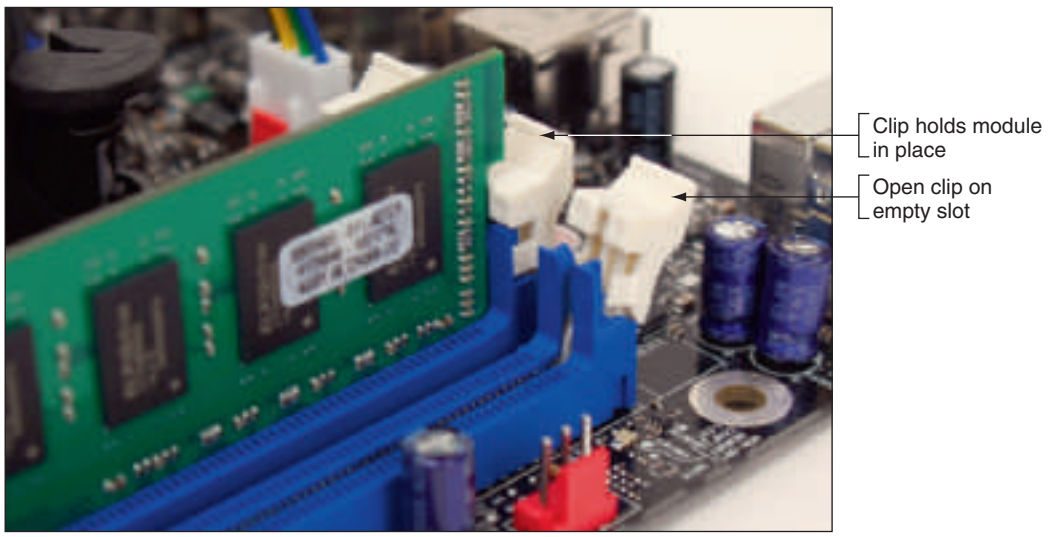
When installing RAM modules, be careful to protect the chips against static electricity, as you learned to do in Chapter 1. Follow these precautions:

- Always use a ground bracelet as you work.
- Turn off the power, unplug the power cord, press the power button, and remove the case cover.
- Handle memory modules with care.
- Don't touch the edge connectors on the memory module or on the memory slot.
- Don't stack cards or modules because you can loosen a chip.
- Usually modules pop into place easily and are secured by spring catches on both ends. Make sure that you look for the notches on one side or in the middle of the module that orient the module in the slot.

Let's now look at the details of installing a DIMM and a RIMM.

INSTALLING DIMMS

For DIMM modules, small clips latch into place on each side of the slot to hold the module in the slot, as shown in Figure 5-58. To install a DIMM, first pull the supporting arms on the sides of the slot outward. Look on the DIMM edge connector for the notches, which help you orient the DIMM correctly over the slot, and insert the DIMM straight down into the slot. When the DIMM is fully inserted, the supporting clips should pop back into place. Figure 5-59 shows a DIMM being inserted into a slot on a motherboard. Apply pressure on both ends of the DIMM at the same time.

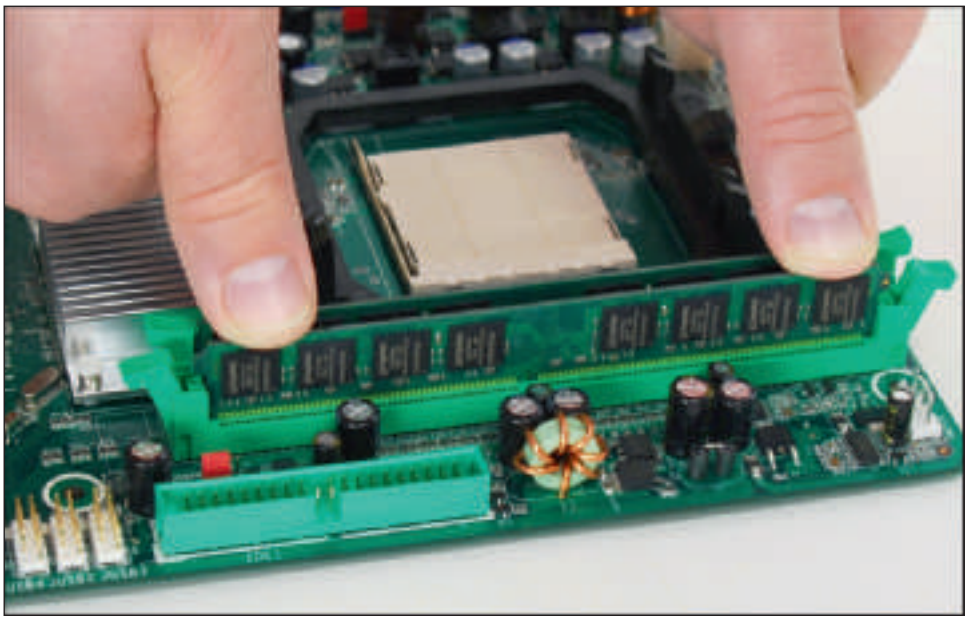


© Cengage Learning 2014

Figure 5-58 Clips on each side of a slot hold a DIMM in place

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+
220-801
1.2, 1.3



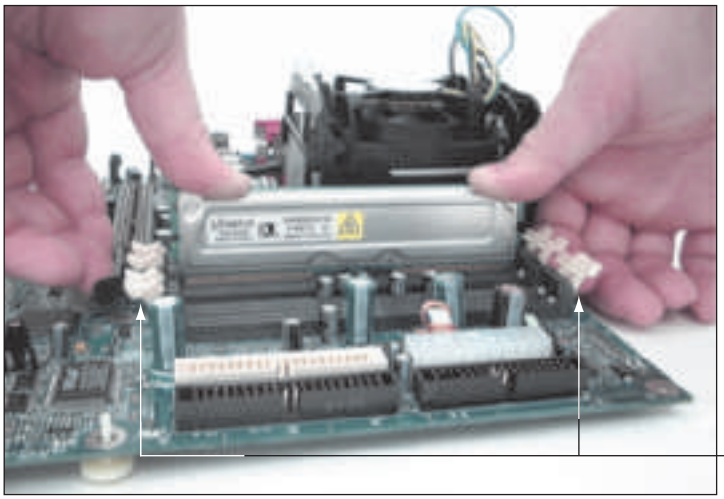
© Cengage Learning 2014

Figure 5-59 Insert the DIMM into the slot by pressing down until the support clips lock into position

Most often, placing memory on the motherboard is all that is necessary for installation. When the computer powers up, it counts the memory present without any further instruction and senses the features that the modules support, such as ECC or buffering. For some really old computers, you must tell BIOS setup the amount of memory present. Read the motherboard documentation to determine what yours requires. If the new memory is not recognized, power down the system and reseat the module. Most likely it's not installed solidly in the slot.

INSTALLING RIMMs

For RIMM modules, install the RIMMs beginning with bank 0, followed by bank 1. (To know which slot is bank 0, see the motherboard documentation.) If a C-RIMM is already in the slot, remove the C-RIMM by pulling the supporting clips on the sides of the socket outward and pulling straight up on the C-RIMM. When installing the RIMM, notches on the edge of the RIMM module will help you orient it correctly in the socket. Insert the module straight down in the socket (see Figure 5-60). When it is fully inserted, the supporting clips should pop back into place.



© Cengage Learning 2014

Figure 5-60 Install RIMM modules in banks beginning with bank 0

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

A+ 220-801 1.2, 1.3

Hands-on Project 5-5 Examine BIOS Settings

On your home or lab computer, use BIOS setup to answer these questions:

1. Which processor is installed? What is the processor frequency?
2. What are the BIOS settings that apply to the processor and how is the processor configured?
3. What information does BIOS report about total memory installed and how each memory slot is populated? Does the board support dual, triple, or quad channelling? How do you know?

Hands-on Project 5-6 Upgrade Memory

To practice installing additional memory in a computer in a classroom environment, remove the DIMMs or RIMMs from one computer and place them in another computer. Boot the second computer and check that it counts the additional memory. When finished, return the borrowed modules to the original computer.

>> CHAPTER SUMMARY

Types and Characteristics of Processors

- The most important component on the motherboard is the processor, or central processing unit. The two major manufacturers of processors are Intel and AMD.
- Processors are rated by the speed of the system bus the processor can support, the processor speed, the socket and chipset the processor can use, processor architecture (32-bit or 64-bit), multi-core rating, how much internal memory cache the processor has, amount and type of RAM the processor can support, and the computing technologies the processor can use.
- A processor's memory cache inside the processor housing can be an L1 cache (contained on the processor die), L2 cache (off the die), and L3 cache (farther from the core than L2 cache).
- The core of a processor has two arithmetic logic units (ALUs). Multi-core processors have two, three, or more cores (called dual core, triple core, quad core, and so forth). Each core can process two threads at once if the feature is enabled in BIOS setup.
- The current families of Intel processors for desktops include the Core, Atom, Celeron, and Pentium families of processors. Several different processors are within each family.
- The current AMD desktop processor families are the FX, Phenom, Athlon, and Sempron. Several processors exist within each family.

Selecting and Installing a Processor

- Select a processor that the motherboard supports. A board is likely to support several processors that vary in performance and price.
- When installing a processor, always follow the directions given in the motherboard user guide and be careful to protect the board and processor against ESD. Current Intel sockets

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

LGA1155, LGA1366, and LGA775 use a socket lever and socket load plate. When opening these sockets, lift the socket lever and then the socket load plate, install the processor, and then close the socket. Many AMD sockets have a socket lever, but not a socket load plate.

Memory Technologies

- DRAM is stored on four kinds of modules: DIMM, SO-DIMM, RIMM, and SIMM modules.
- Types of DIMMs are DDR3 and DDR2 DIMMs that have 240 pins, DDR DIMMs with 184 pins, and SDRAM DIMMs with 168 pins. A RIMM has 184 or 232 pins, and RIMMs are outdated technologies.
- DIMMs can be single-sided or double-sided. Some double-sided DIMMs provide more than one memory bank and are called dual ranked or quad ranked. A memory bank has a 64-bit data path and is accessed by the processor independently of other banks.
- DIMMs can work together in dual channels, triple channels, and quad channels so that the memory controller can access more than one DIMM at a time to improve performance. In a channel, all DIMMs must match in size, speed, and features. DDR3 DIMMs can use dual, triple, or quad channeling, but DDR and DDR2 DIMMs can only use dual channels.
- DIMM and RIMM speeds are measured in MHz (for example, 1333 MHz) or PC rating (for example, PC3-10600).
- The memory controller can check memory for errors and possibly correct those errors using ECC (error-correcting code). Using parity, an older technology, the controller could only recognize an error had occurred, but not correct it.
- Buffers and registers are used to hold data and amplify a data signal. A DIMM is rated as a buffered, registered, or unbuffered DIMM.
- CAS Latency (CL) and RAS Latency (RL) measure access time to memory. The lower values are faster than the higher values.
- RIMMs require that every RIMM slot be populated. If a RIMM is not installed in the slot, install a placeholder module called a C-RIMM.

How to Upgrade Memory

- When upgrading memory, use the type, size, and speed the motherboard supports and match new modules to those already installed. Features to match include DDR3, DDR2, DDR, size in MB or GB, speed (MHz or PC rating), buffered, registered, unbuffered, single-sided, double-sided, CL rating, tin or gold connectors, support for dual, triple, or quad channeling, ECC, and non-ECC. Using memory made by the same manufacturer is recommended.

>> KEY TERMS

For explanations of key terms, see the Glossary near the end of the book.

CAS Latency
Centrino
C-RIMM (Continuity RIMM)
DDR
DDR2
DDR3
DIMM (dual inline memory module)
Direct Rambus DRAM
Direct RDRAM
Double Data Rate SDRAM (DDR SDRAM)
double-sided
dual channels
dual processors
dual ranked
dynamic RAM (DRAM)
ECC (error-correcting code)
graphics processing unit (GPU)
Hyper-Threading
HyperTransport
Level 1 cache (L1 cache)
Level 2 cache (L2 cache)
Level 3 cache (L3 cache)
memory bank
multi-core processing
multiplier

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

multiprocessing
multiprocessor platform
parity
parity error
processor frequency
quad channels
Rambus
RAS Latency
RDRAM
RIMM
SDRAM II
SIMM (single inline memory module)
single channel
single-sided
SO-DIMM (small outline DIMM)
static RAM (SRAM)
synchronous DRAM (SDRAM)
thread
triple channels
x86 processors
x86-64 bit processor

>> REVIEWING THE BASICS

1. Who are the two major manufacturers of processors?
2. What is the name of the memory cache that is on the same die as the processor?
3. What is the name of the memory cache that is closest to the processor die but is not housed on the die?
4. What is the name of the Intel technology that allows a processor to handle two threads at the same time?
5. How many threads can a quad-core processor handle at once?
6. Which Intel processor socket uses a screw head to hold down the socket load plate?
7. Which is faster, SRAM or DRAM? Why?
8. How many pins are on a DDR3 DIMM? DDR2 DIMM?
9. How many pins are on a DDR DIMM? SDRAM DIMM?
10. How many notches does a DDR3 DIMM have?
11. What was the first type of DIMM that ran synchronized with the system clock?
12. What major improvement did DDR make over regular SDRAM?
13. Which DIMM performs better, a double-sided dual-ranked DIMM or a double-sided single-ranked DIMM?
14. What prevents a DDR DIMM from being installed in a DDR2 DIMM slot on a motherboard?
15. Which module, a DDR3 or DDR2 DIMM, uses lower voltage?
16. In a memory ad for DIMMs, you notice 64Meg ×72 for one DIMM and 64Meg ×64 for another DIMM. What does the 72 tell you about the first DIMM?
17. A DIMM that contains memory chips in two memory banks on the module is said to be _____.
18. What type of DIMM supports triple channeling?
19. If two bits of a byte are in error when the byte is read from ECC memory, can ECC detect the error? Can it fix the error?
20. How many notches are on an SDRAM DIMM?
21. Looking at an SDRAM DIMM, how can you know for certain the voltage needed by the module?

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

22. A DIMM memory ad displays 5-5-5-15. What is the CAS Latency value of this DIMM?
23. What is the most amount of RAM that can be used by a 32-bit installation of Windows 7 Professional?
24. A motherboard uses dual channeling, but you have four DIMMs available that differ in size. The motherboard supports all four sizes. Can you install these DIMMs on the board? Will dual channeling be enabled?
25. You need to upgrade memory on a motherboard that uses RIMMs. You notice one RIMM and one C-RIMM module are already installed on the board. Which module should you replace?
26. What two types of memory can be used on a 100-MHz motherboard?
27. Which is faster, CL3 memory or CL5 memory?
28. You are looking to purchase two DIMMs running at 400 MHz. You find DIMMs advertised at PC4000 and PC3200. Which do you purchase?
29. You need to find out how much RAM is installed in a system. What command do you enter in the Search box to launch the System Information utility?
30. Although ECC memory costs more than non-ECC memory, why would you choose to use it? Which type of computer typically requires ECC memory?

>> THINKING CRITICALLY

1. You need to upgrade memory in a system but you don't have the motherboard documentation available. You open the case and notice that the board has four DIMM slots; three slots are colored yellow and one slot is black. What type of DIMM does the board likely use? How can you be sure?
2. If your motherboard supports DIMM memory, will RIMM memory still work on the board?
3. If your motherboard supports ECC SDRAM memory, can you substitute non-ECC SDRAM memory? If your motherboard supports buffered SDRAM memory, can you substitute unbuffered SDRAM modules?
4. You have just upgraded memory on a computer from 1 GB to 2 GB by adding one DIMM. When you first turn on the PC, the memory count shows only 1 GB. Select which of the following is most likely the source of the problem. What can you do to fix it?
   a. Windows is giving an error because it likely became corrupted while the PC was disassembled.
   b. The new DIMM you installed is faulty.
   c. The new DIMM is not properly seated.
   d. The DIMM is installed in the wrong slot.
5. Your motherboard supports dual channeling and you currently have two slots used in Channel A on the board; each module holds 1 GB. You want to install an additional 1 GB of RAM. Will your system run faster if you install two 512 MB DIMMs or one 1 GB DIMM? Explain your answer.

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.

>> REAL PROBLEMS, REAL SOLUTIONS

REAL PROBLEM 5-1: Understanding Dual-Processor Motherboards

Print the web page of a picture of a motherboard that supports dual processors. Use one of these web sites to find the picture:

- ASUS at *www.asus.com*
- Intel at *www.intel.com*

Answer these questions about the motherboard:

1. What is the manufacturer and model number of the motherboard?
2. What type of memory and how much memory does the board support?
3. What operating systems does the board support?
4. What processors does the board support?

REAL PROBLEM 5-2: Troubleshooting Memory

Follow the rules outlined in Chapter 1 to protect the PC against ESD as you work. Remove the memory module in the first memory slot on a motherboard, and boot the PC. Did you get an error? Why or why not?

REAL PROBLEM 5-3: Memory Research Game

In a group of four players with Internet access and a fifth person who is the scorekeeper, play the Memory Research Game. The scorekeeper asks a question and then gives players one minute to find the best answer. Five points are awarded to the player who has the best answer at the end of each one-minute play. The scorekeeper can use these questions or make up his or her own. If you use these questions, mix up the order:

1. What is the fastest DDR3 DIMM sold today?
2. What is the lowest price for a 232-pin non-ECC Rambus RIMM?
3. What is the largest size DDR2 DIMM sold today?
4. What is the largest size fully buffered ECC 240-pin DDR2 DIMM sold today?
5. What is the lowest price for an 8 GB 240-pin ECC DDR3 DIMM?

Copyright 2012 Cengage Learning. All Rights Reserved. May not be copied, scanned, or duplicated, in whole or in part. Due to electronic rights, some third party content may be suppressed from the eBook and/or eChapter(s). Editorial review has deemed that any suppressed content does not materially affect the overall learning experience. Cengage Learning reserves the right to remove additional content at any time if subsequent rights restrictions require it.