

Chapter 1

Core Hardware Components

THE FOLLOWING COMPTIA IT FUNDAMENTALS+ (ITF+) FC0-U61 EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

✓ **1.3 Illustrate the basics of computing and processing**

- Input
- Processing
- Output
- Storage

✓ **1.5 Compare and contrast common units of measure**

- Storage unit
  - Bit
  - Byte
  - KB
  - MB
  - GB
  - TB
  - PB
- Processing speed
  - MHz
  - GHz

✓ **2.3 Explain the purpose of common internal computing components**

- Motherboard/system board
- Firmware/BIOS

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- RAM
- CPU
  - ARM
    - Mobile phone
    - Tablet
  - 32-bit
    - Laptop
    - Workstation
    - Server
  - 64-bit
    - Laptop
    - Workstation
    - Server
- GPU
- Storage
  - Hard drive
  - SSD
- Cooling
- NIC
  - Wired vs. wireless
  - Onboard vs. add-on card

✓ 2.5 Compare and contrast storage types

- Volatile vs. non-volatile
- Local storage types
  - RAM
  - Hard drive
    - Solid state vs. spinning disk
  - Optical
  - Flash drive



What better way to kick off a book on IT Fundamentals+ (ITF+) than to talk about the most fundamental components of all—core hardware? When you really break it down to the basics, computers are simply collections of specialized hardware devices that work together (with software) to provide you with the functionality you want. For most users, the desired functionality is to take input, somehow process it, produce output (video or printed), and store data. Sometimes the hardware is in your hands, and at other times it's halfway around the world—but it's always necessary. Even soft and fluffy-sounding terms such as "the cloud" (which I will introduce in Chapter 5, "Software Applications") rely on much of the same hardware that sits snugly within your tablet or smartphone case.

To begin your journey of understanding fundamental IT concepts, I will discuss components that are commonly included inside the case. Some are absolutely critical, while others just provide features that are nice to have, such as sound or a network connection. In this way, I'll start from the inside out so that you understand what makes computers work the way they do.

Introducing Internal Components

In this section, I will talk about the components that are generally inside the computer case. Some of them are exclusively found inside the case, such as the motherboard and the processor, whereas others can be internal or external. For example, internal hard drives (for storage) are standard in desktop and laptop computers, but you can also buy external hard drives for expanded storage. Network cards are another great example. Today, the circuitry is generally built into the computer, but you can easily find external ones as well. Regardless of the location of your hard drive or network card, it still provides the same functionality.

Most home computer components are modular. That is, they can be removed and replaced by another piece of hardware that does the same thing, provided that it's compatible and that it fits. For example, if the hard drive in your laptop fails, it can be removed and replaced by another hard drive. This isn't always the case, of course, and the general rule is that the smaller the device, the less modular it is. This is because to achieve the smaller size, manufacturers need to integrate more functionality into the same component. It's usually quicker and just as cost-effective to replace a device such as a smartphone rather than repair it if a part fails. If a component is modular and can be replaced, you will sometimes hear it referred to as a *field replaceable unit (FRU)*.

Since I'm talking about components that are inside the case, it would be unfortunate to ignore the case itself. Cases are usually a combination of metal and plastic and serve these two primary functions:

- Keeping all the components securely in place
- Protecting the components from harm

Protecting the components is the key. Water and other liquids are obviously bad for electronic devices, and direct exposure to sunlight and dust can cause parts to overheat and fail. The case guards against all these things. Moreover, in some cases (pun intended), it can make your device easily mobile.



Throughout this section, I will specifically talk about PC (desktop and laptop) hardware. Many of the principles here apply to smaller devices such as tablets and smartphones as well.

Exploring Motherboards, Processors, and Memory

These three components—motherboards, processors, and memory—are the holy trinity of computers. Pretty much every personal computing device made today requires all three of these parts. So, without further ado, let's dive in.

Motherboards

The *motherboard* is the most important component in the computer because it connects all the other components. Functionally, it acts much like the nervous system of the computer. You will also hear it called the *system board* or the *mainboard*. With this introduction, you might think that this piece of hardware is complex—and you'd be right! Manufacturers and hardware resellers don't make it easy to understand what you're dealing with either. Here's the description of a motherboard for sale on an Internet hardware site:

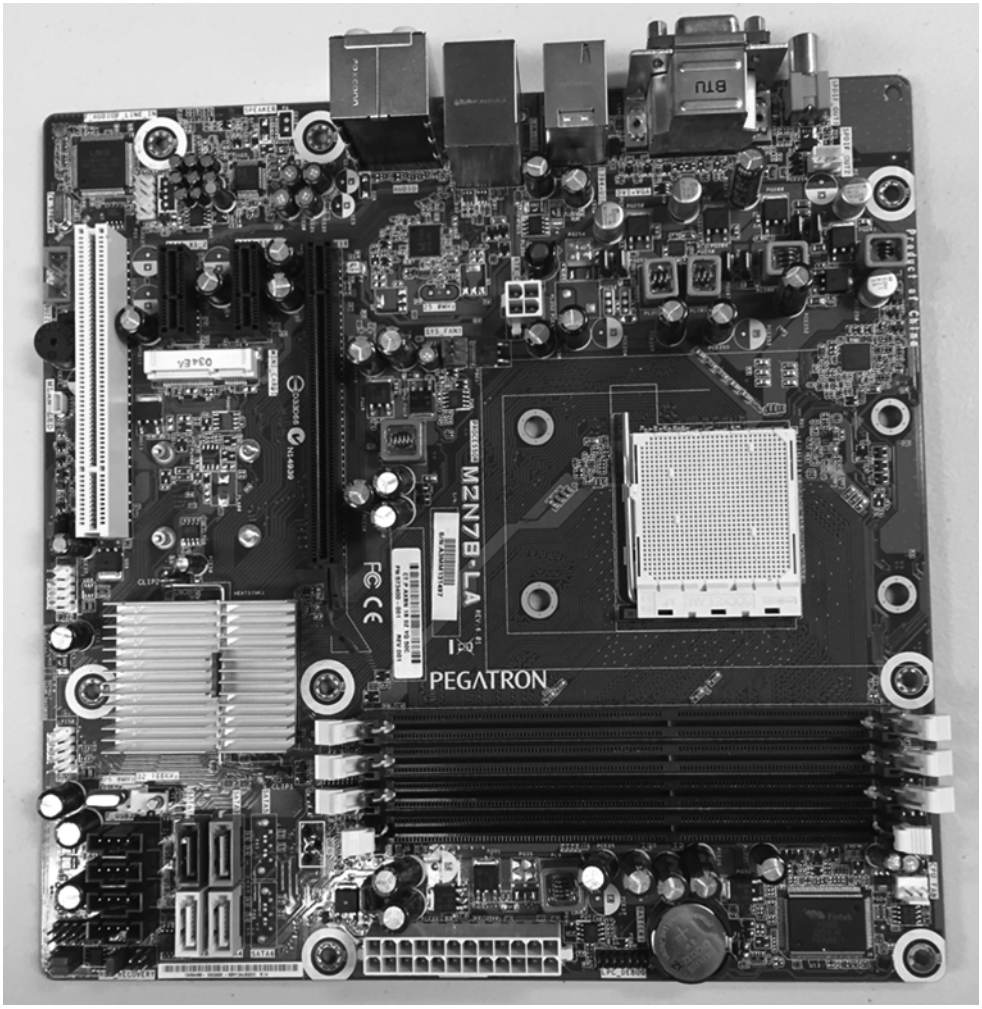
> Asus X99-PRO/USB 3.1 Intel X99 Chipset Core i7 Socket R3 (LGA2011) ATX Motherboard, DDR4, PCI-E 3.0 x16, SATA/M.2 Socket 3, GBLAN, Wi-Fi/Bluetooth, USB

What does that all mean? Is it even human language? Don't worry. By the end of this section on motherboards, you will understand what it all means.

The first thing to know about motherboards is that they are a *printed circuit board (PCB)*, that is, a conductive series of pathways laminated to a nonconductive substrate that lines the bottom of the computer. Most of the time they are green, but you will also see brown, blue, red, and black ones. If you look at the bottom of a motherboard, you will see

all the conductive pathways. Some of the most popular brands right now are ASUS, GIGABYTE, and MicroStar (MSI). Figure 1.1 shows a typical motherboard.

FIGURE 1.1 A motherboard



All other components are attached to this circuit board. Some are physically attached directly to the board and aren't intended to be removed, such as the underlying circuitry, the central processing unit (CPU) socket, random access memory (RAM) slots, expansion slots, and a variety of other chips. Components such as the CPU and the RAM get physically attached to the motherboard. Other devices, such as hard drives and power supplies, are attached via their own connectors.



Manufacturers can also integrate components such as the CPU, video card, network card, and others directly onto the motherboard as opposed to having slots into which they are inserted. As a rule of thumb, the smaller the motherboard, the more likely it is to have integrated components.

Let's start breaking down the features and components typically associated with motherboards. The following list might look long, but breaking each one down separately will help you to understand the importance of each one. Here are the topics coming up shortly:

- Form factors
- Chipsets
- Processor sockets
- Memory slots
- Expansion slots
- Disk controllers
- Power connectors
- BIOS/firmware
- CMOS and CMOS battery
- Back-panel connectors
- Front-panel connectors

In the following sections, you will learn about some of the most common components of a motherboard and what they do. I'll show you what each component looks like so that you can identify it on almost any motherboard you run across.

Form Factors

Motherboards are classified by their design, which is called a *form factor*. There are dozens of form factors in existence. Because motherboards mount to the system case, it's important to know what types of motherboards your case supports before replacing one. Desktop computer cases often support multiple sizes of motherboards, but laptops are another story. With laptops, you almost always need to replace an old motherboard with the same version.

The most common form factors used today are Advanced Technology Extended (ATX), micro ATX, and ITX.



ITX is not one specific form factor but a collection of small form factor (SFF) boards.

The form factors differ in size and configuration of the components on the motherboard. In addition, they may have different power requirements. Micro ATX and ITX are specifically designed to be paired with low-wattage power supplies to reduce the amount of heat produced by the computer. Because these two are smaller, they also offer fewer options for adding expansion cards versus the ATX design.



Here's a quick history lesson. The XT form factor was developed by IBM in 1983, and it is generally considered the first industry-standard PC form factor. In 1985, IBM released the Baby-AT, which because of its smaller size quickly became the most popular form factor in the market. The Baby-AT was king until 1996 when Intel released the ATX standard. As of this writing, the ATX and micro ATX (which is similar in configuration to ATX, only smaller) are still the most popular computer form factors.

Table 1.1 provides the dimensions of common form factors.

TABLE 1.1 Motherboard form factors

Form Factor	Release Year	Size
Baby-AT	1985	8.5 × 10–13 in (216 × 254–330 mm)
ATX	1996	12 × 9.6 in (305 × 244 mm)
Micro ATX	1996	9.6 × 9.66 in (244 × 244 mm)
Mini-ITX	2001	6.7 × 6.7 in (170 × 170 mm)
Nano-ITX	2003	4.7 × 4.7 in (120 × 120 mm)
Pico-ITX	2007	3.9 × 2.8 in (100 × 72 mm)
Mobile-ITX	2007	2.95 × 1.77 in (75 × 45 mm)
Neo-ITX	2012	6.7 × 3.35 in (170 × 85 mm)

In view of how quickly computer technology evolves, it is amazing that the form factors remain popular for as long as they do. The advent of smaller devices such as tablets and smartphones has driven the most recent form factor design changes.

Chipsets

The motherboard's *chipset* is a collection of chips or circuits that perform interface and peripheral functions for the processor. Said differently, this collection of chips provides interfaces for memory, expansion cards, and onboard peripherals, and it generally dictates how a motherboard will communicate with the installed peripherals.

Chipsets are usually given a name and model number by the original manufacturer, for example, Intel's X99. What features make the X99 so great? I will be honest; I have no idea. There are so many chipsets out there that it's impossible to know the features of every one. But, if you need to know, having the manufacturer and model can help you look up the features of that particular chipset, such as the type of RAM supported, the type and brand of onboard video, and so on.



The best place to look for motherboard specifications is on the manufacturer's website. For example, `https://www.asus.com/us/Motherboards/PRIME-Z370-A/specifications/` tells you everything that you need to know about the ASUS PRIME Z370-A motherboard.

The functions of chipsets can be divided into two major groups: Northbridge and Southbridge. It's unlikely that you'll be tested on these on the IT Fundamentals+ (ITF+) exam, but I want to introduce them just in case you hear the terms. Plus, I think it helps better explain exactly what the chipset does.

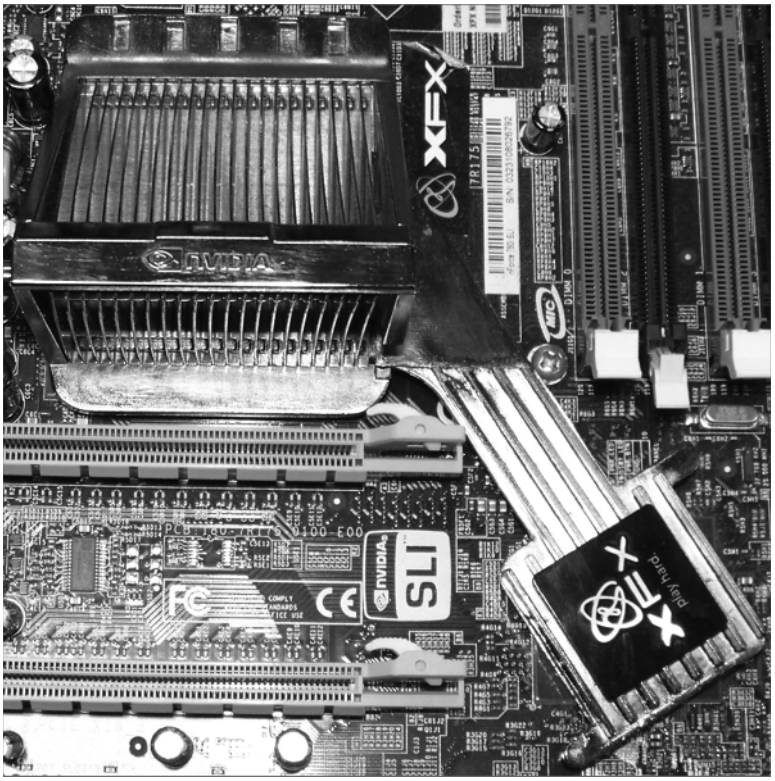
Northbridge The Northbridge subset of a motherboard's chipset performs one important function: management of high-speed peripheral communications. The Northbridge is responsible primarily for communications with integrated video and processor-to-memory communications.

The communications between the CPU and memory occur over what is known as the *front-side bus (FSB)*, which is just a set of signal pathways connecting the CPU and main memory. The *back-side bus (BSB)*, if present, is a set of signal pathways between the CPU and any external cache memory.

Southbridge The Southbridge subset of the chipset is responsible for providing support to the onboard slower peripherals (PS/2, parallel ports, serial ports, Serial and Parallel ATA, and so on) and managing their communications with the rest of the computer and the resources given to them. If you're thinking about any component other than the CPU, memory and cache, or integrated video, the Southbridge is in charge.

Figure 1.2 shows the chipset of a motherboard, with the heat sink of the Northbridge, at the top left, connected to the heat-spreading cover of the Southbridge, at the bottom right.

FIGURE 1.2 Northbridge and Southbridge



Real World Scenario

Who's Driving the Bus?

When talking about the Northbridge, I mentioned a bus (specifically a front-side bus), so now is a good time to talk about what a bus does and to give you some historical context. You'll probably hear the term come up often when talking about computer hardware, such as in discussions about the system bus, expansion bus, parallel bus, and serial bus.

A *bus* is a common collection of signal pathways over which related devices communicate within the computer system. It refers specifically to a data path or the way that the computer communicates over that path.

Take serial and parallel buses, for example. A serial bus communicates one bit of data at a time, whereas a parallel bus communicates in several parallel channels (eight, for example) at once. Based on this explanation, you might think that parallel is faster than serial. After all, eight lanes should move more data than one lane, right? Sometimes, but not always. It depends on how fast you can get each lane to move.

Serial was developed before parallel, because at its core it's an easier technology to implement. In the late 1980s, parallel became much more popular for printers because it was a lot faster. The only downside to parallel was that the different streams of data needed to be carefully synchronized. This slowed down transmissions so that they weren't exactly eight times faster than the comparable serial connections.

By 1996, manufacturers had advanced the speed of serial technology enough so that it was faster than parallel, and the world saw the introduction of Universal Serial Bus (USB). It was faster than parallel, and it had a lot of additional features, such as the ability to hot plug devices (that is, plug and unplug them without needing to shut the system down). Today, many of the fastest peripheral-connection technologies in use, such as USB, FireWire, and Serial ATA (SATA), are all serial.

Thus, while parallel was king for a day, you can now get faster transmissions via serial technology.

Processor Sockets

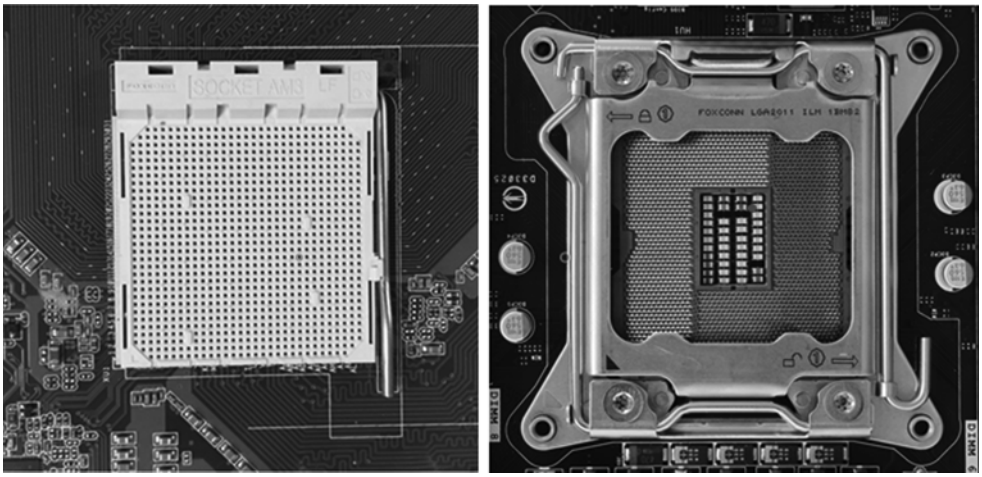
The *central processing unit (CPU)* is the "brain" of any computer. There are many different types of processors for computers, and the processor you have must fit into the socket on the motherboard. Typically, in today's computers, the processor is the easiest component to identify on the motherboard. It is usually the component that has either a large fan and/or a *heat sink* (usually both) attached to it.

CPU sockets are almost as varied as the processors they hold. Sockets are basically flat and have several columns and rows of holes or pins arranged in a square, as shown in Figure 1.3. You'll hear terms like pin grid array (PGA) or land grid array (LGA) to describe the socket type. In Figure 1.3, the left socket is PGA, and the right one is an LGA 2011. PGA sockets have holes, and the processors have pins that fit into the holes. LGA sockets have contacts (often pins) built in to them, which connect with contacts on the CPU. Both sockets have locking mechanisms to hold the processor in place. PGA uses a simple lever, while LGA has a more complex locking harness (which is closed in Figure 1.3). You might also see ball grid array (BGA) sockets, which use small balls as their contact points.



At the beginning of this section, I gave you a description of a motherboard for sale. LGA 2011 is the socket shown in the example.

FIGURE 1.3 CPU sockets



Intel Socket 2011 by smial (talk). Licensed under FAL via Wikimedia Commons (http://commons.wikimedia.org/wiki/File:Socket_2011_IMGP3918.jpg#/media/File:Socket_2011_IMGP3918.jpg).

Memory Slots

Random access memory (RAM) slots are for the modules that hold memory chips. RAM is the primary memory used to store currently used data and instructions for the CPU. Many and varied types of memory are available for PCs today. Examples include DDR2, DDR3, and DDR4. Memory for desktops comes on circuit boards called *dual inline memory modules (DIMMs)* and for laptops on *small outline DIMMs (SODIMMs)*. (I will talk about what these acronyms mean in the "Memory" section later in this chapter.)

Memory slots are easy to identify on a motherboard. First, they are long and slender and generally close to the CPU socket. Classic DIMM slots were usually black and, like all memory slots, were placed very close together. (Today manufacturers make memory slots of various colors.) Metal pins in the bottom make contact with the metallic pins on each memory module. Small metal or plastic tabs on each side of the slot keep the memory module securely in its slot. Figure 1.4 shows some memory slots on a desktop motherboard.

Laptops are space constrained, so they use the smaller form factor SODIMM chips. SODIMM slots are configured so that the chips lie nearly parallel to the motherboard, as shown in Figure 1.5.

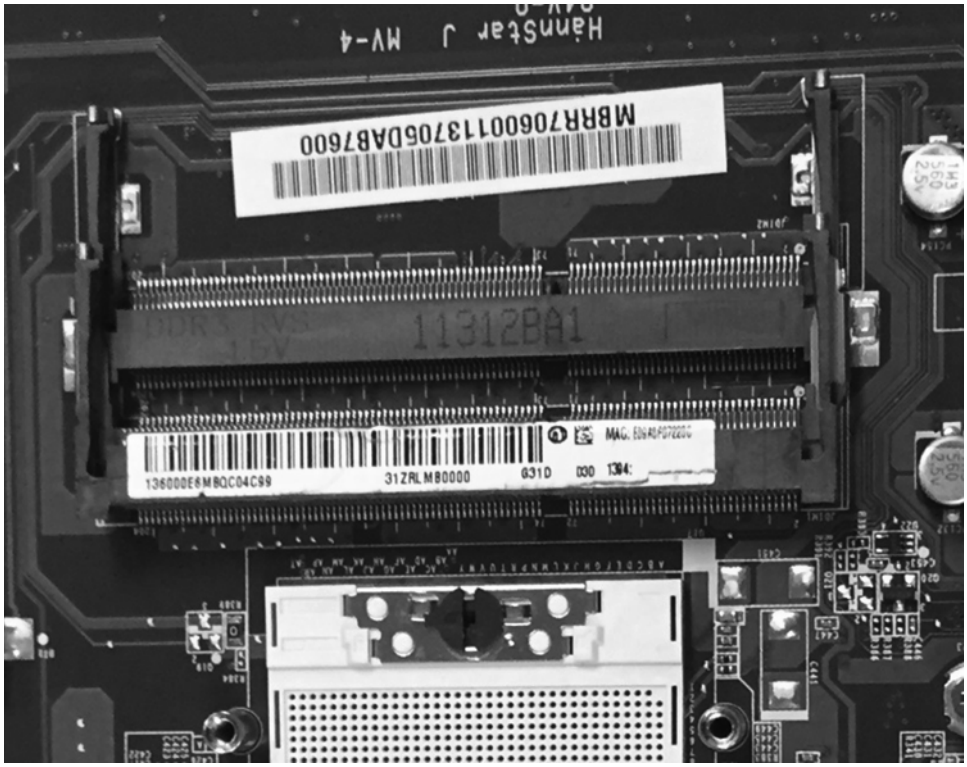
Motherboard designers can also speed up the system by adding *cache memory* between the CPU and RAM. Cache is a fast form of memory, and it improves system performance by predicting what the CPU will ask for next and prefetching this information before being asked. I will talk about cache more in the "Processors" section later in this chapter.

If there is cache on your motherboard, it is not likely to be a removable component. Therefore, it does not have a slot or connector like RAM does.

FIGURE 1.4 DIMM slots



FIGURE 1.5 SODIMM slots



Expansion Slots

The most visible parts of any motherboard are the *expansion slots*. These are small plastic slots, usually from 1 to 6 inches long and approximately ½ inch wide. As their name suggests, these slots are used to install various devices in the computer to expand its capabilities. Some expansion devices that might be installed in these slots include video, network, sound, and disk interface cards.

If you look at the motherboard in your computer, you will more than likely see one of these main types of expansion slots used in computers today:

- PCI
- AGP
- PCIe

Each type differs in appearance and function. In the following sections, I will cover how to identify visually the different expansion slots on the motherboard.

PCI Expansion Slots

Some of the most common expansion slots for many years were the 32-bit *Peripheral Component Interconnect (PCI)* slots. They are easily recognizable because they are only around 3 inches long and classically white, although modern boards take liberties with the color. Although popularity has shifted from PCI to PCIe, the PCI slot's service to the industry cannot be ignored; it has been an incredibly prolific architecture for many years.

PCI expansion buses operate at 33 MHz or 66 MHz over a 32-bit (4-byte) channel, resulting in data rates of 133 megabytes per second (MBps) and 266 MBps, respectively, with 133 MBps being the most common. PCI is a shared-bus topology, which means that mixing 33 MHz and 66 MHz adapters in a 66 MHz system will slow all adapters to 33 MHz.



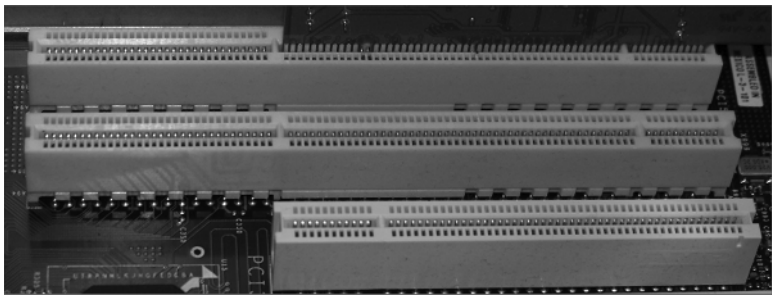
Real World Scenario

Understanding Data Rates

It can be a bit confusing trying to understand how bus speeds relate to data rates, but it doesn't have to be so. The quick way to figure it out is to take the bus speed (how fast it is) and multiply it by the channel width (how much it can push through in bytes) to get the data rate. Now, you might be thinking, "Wait. 33 times 4 is 132, and 66 times 4 is 264. That's different than 133 MBps or 266 MBps." You're absolutely correct. In a creative use of marketing math, some rounding was applied. You'll see this a lot in the computer industry; many specs will end in 33 or 66, even if the real math doesn't quite work out that way.

PCI slots and adapters are manufactured in 3.3V and 5V versions. Universal adapters are keyed to fit in slots based on either of the two voltages. The notch in the card edge of the common 5V slots and adapters is oriented toward the front of the motherboard, and the notch in the 3.3V adapters is oriented toward the rear. Figure 1.6 shows several PCI expansion slots. Note the 5V 32-bit slot in the foreground and the 3.3V 64-bit slots. Also notice that a universal 32-bit card, which has notches in both positions, is inserted into and operates fine in the 64-bit 3.3V slot in the background.

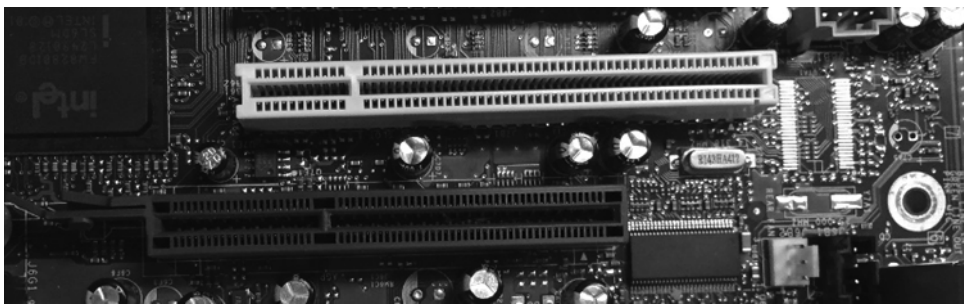
FIGURE 1.6 PCI expansion slots



AGP Expansion Slots

Accelerated Graphics Port (AGP) slots are known mostly for legacy video card use and have been supplanted in new installations by PCI Express slots and their adapters. AGP slots were designed to be a direct connection between the video circuitry and the PC's memory. They are also easily recognizable because they are usually brown and located right next to the PCI slots on the motherboard. AGP slots are slightly shorter than PCI slots and are pushed back from the rear of the motherboard in comparison with the position of the PCI slots. Figure 1.7 shows an example of an older AGP slot, along with a white PCI slot for comparison. Notice the difference in length between the two.

FIGURE 1.7 An AGP slot compared to a PCI slot



AGP performance is based on the original specification, known as AGP 1x. It uses a 32-bit (4-byte) channel and a 66 MHz clock, resulting in a data rate of 266 MBps. AGP 2x,

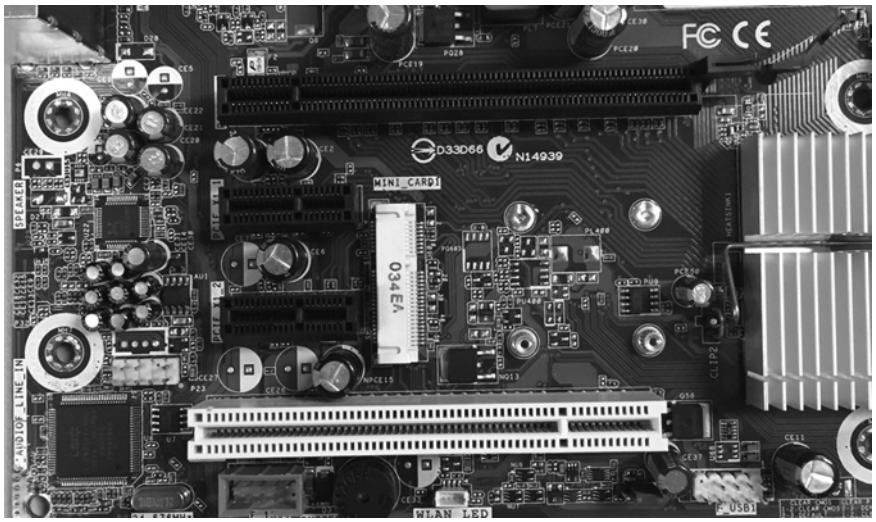
4x, and 8x specifications multiply the 66 MHz clock they receive to increase throughput linearly. For instance, AGP 8x uses the 66 MHz clock to produce an effective clock frequency of 533 MHz, resulting in throughput of 2133 MBps over the 4-byte channel. Note that this maximum throughput is only a fraction of the throughput of PCIe x16, which is covered in the following section.

PCIe Expansion Slots

Today's most common expansion slot architecture on motherboards is *PCI Express (PCIe)*. It was designed to be a replacement for AGP and PCI. PCIe has the advantage of being faster than AGP while maintaining the flexibility of PCI. PCIe has no plug compatibility with either AGP or PCI. As a result, some modern PCIe motherboards still have a regular PCI slot for backward compatibility, but AGP slots are rarely included.

There are seven different speeds supported by PCIe, designated ×1 (pronounced "by 1"), ×2, ×4, ×8, ×12, ×16, and ×32, with ×1, ×4, and ×16 being the most common. A slot that supports a particular speed will be of a specific physical size because faster cards require more wires and therefore are longer. As a result, a ×8 slot is longer than a ×1 slot but shorter than a ×16 slot. Every PCIe slot has a 22-pin portion in common toward the rear of the motherboard, as shown in Figure 1.8, in which the rear of the motherboard is to the left. These 22 pins comprise mostly voltage and ground leads. Figure 1.8 shows, from top to bottom, a ×16 slot, two ×1 slots, and a legacy PCI slot.

FIGURE 1.8 PCIe expansion slots



Compared to its predecessors, PCIe is fast. Even at the older PCIe 2.0 standard, a PCIe ×1 card will run at 500 MBps, which is comparable to the best that PCI can offer (533 MBps). The current PCIe standard is PCIe 4.0, and with it a ×16 card can operate at a screaming 31.5 GBps. PCIe 4.0 slots are backward compatible with older PCIe cards.



PCIe 4.0 was released in October 2017, seven years after PCI 3.0. It provides double the throughput to support virtual reality and augmented reality applications. The next generation PCIe 5.0 is tentatively slated for a mid-2019 release. It should double the throughput of PCIe 4.0.

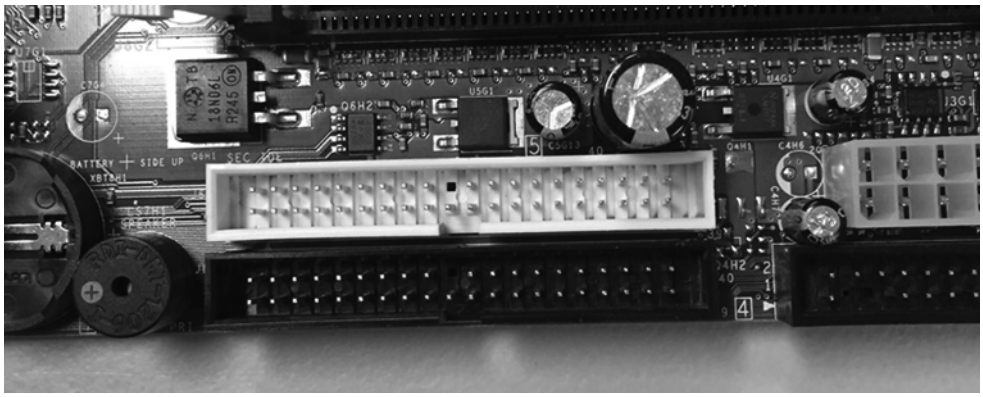
Its high data rate makes PCIe the current choice of gaming aficionados. The only downside with PCIe (and with later AGP slots) is that any movement of these high-performance devices can result in temporary failure or poor performance. Consequently, both PCIe and AGP slots have a latch and tab that secure the adapters in place.

Disk Controllers

One of the endearing features of computers is that they store data and allow it to be retrieved later. (It's true that they sometimes mysteriously lose our data too, but that's another story.) The long-term storage device is called a *hard drive*, and it plugs into the motherboard.

There are a few different hard drive standard connectors. The older one that you will run into is called *Integrated Drive Electronics (IDE)* or *Parallel ATA (PATA)*. The newer and much faster one is called *Serial ATA (SATA)*. Figure 1.9 shows the two IDE connectors (the black and white ones are the same). Figure 1.10 shows four SATA connectors. Notice how they are conveniently labeled for you on the motherboard!

FIGURE 1.9 IDE hard drive connectors



Power Connectors

Computers are obviously electronic devices, and electronics, of course, require power. In addition to the other sockets and slots on the motherboard, a special connector (the 24-pin block connector shown in Figure 1.11) allows the motherboard to be connected to the power supply to receive power. This connector is where the ATX power adapter plugs in. Older AT-style motherboards used a 20-pin connector, and other devices such as hard drives and optical drives use smaller connectors that we will talk about later.

FIGURE 1.10 SATA hard drive connectors

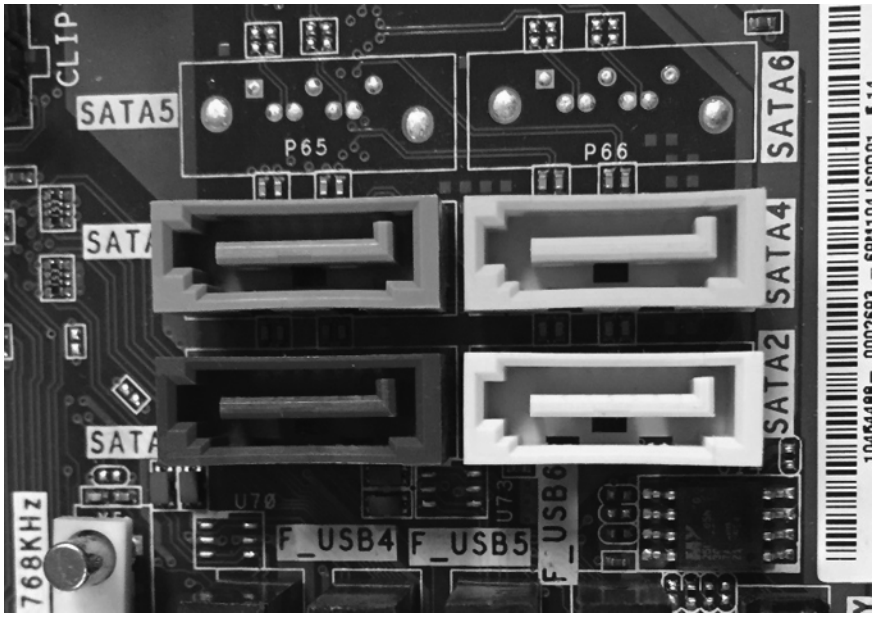
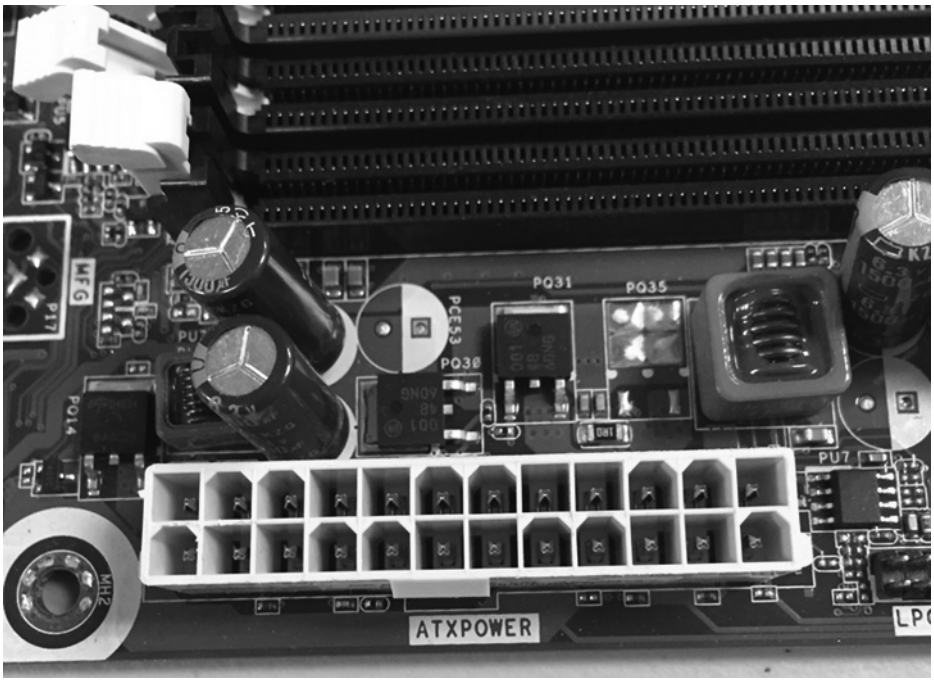


FIGURE 1.11 A 24-pin ATX power connector



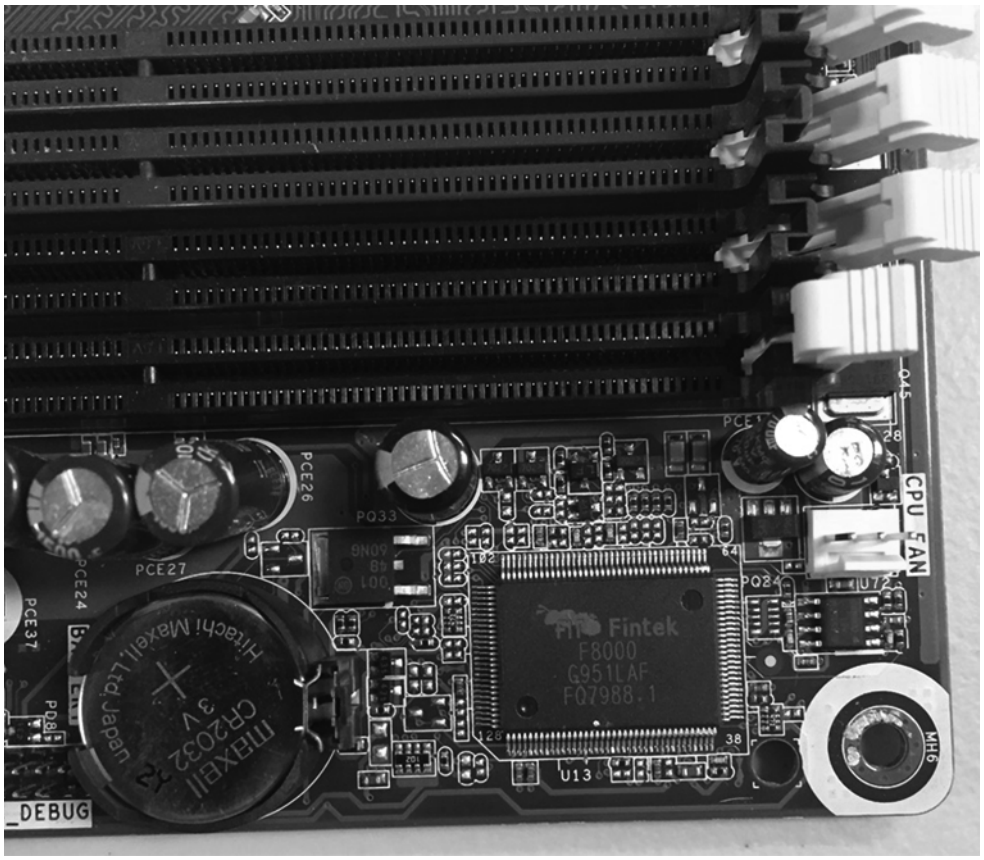
BIOS/Firmware

Firmware is the name given to any software that is encoded in hardware, usually a read-only memory (ROM) chip, and can be run without extra instructions from the operating system. Most computers and large printers use firmware in some sense. The best example of firmware is a computer's *Basic Input/Output System (BIOS)* routine, which is burned into a flash memory chip located on the motherboard. Also, some expansion cards, such as video cards, use their own firmware utilities for setting up peripherals.

Aside from the processor, the most important chip on the motherboard is the BIOS chip. This special memory chip contains the BIOS system software that boots the system and initiates the memory and hard drive to allow the operating system to start.

The BIOS chip is easily identified. If you have a brand-name computer, this chip might have the name of the manufacturer on it and usually the word *BIOS*. For clones, the chip usually has a sticker or printing on it from one of the major BIOS manufacturers (AMI, Phoenix/Award, Winbond, and so on). Figure 1.12 gives you an idea of what a BIOS chip might look like. This one is made by Fintek.

FIGURE 1.12 A BIOS chip on a motherboard

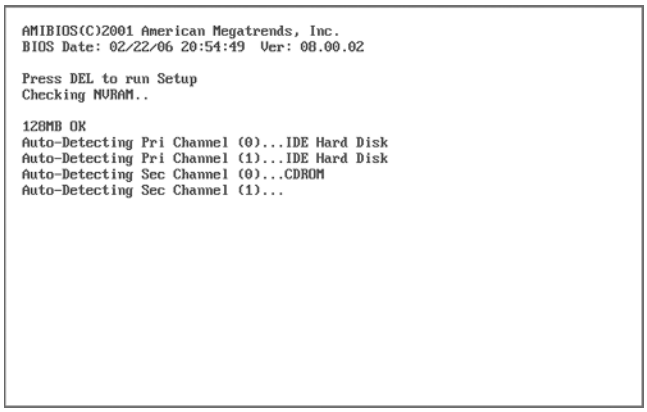


When you power on your computer, the BIOS initializes and runs a system-checking routine called the *power-on self-test (POST)*. The POST routine does the following things:

- Verifies the integrity of the BIOS itself
- Verifies and confirms the size of primary memory
- Analyzes and catalogs other forms of hardware, such as buses and boot devices
- Offers the user a key sequence to enter the configuration screen
- Hands over control to the boot device (usually a hard drive) highest in the configured boot order to load the operating system

If all its tests complete successfully, the POST process finishes. If there is an error, it can produce a beep code or displayed code that indicates there is an issue. Each BIOS publisher has its own series of codes that can be generated. Figure 1.13 shows a simplified POST display during the initial boot sequence of a computer.

FIGURE 1.13 An example of a BIOS boot screen



As mentioned, the POST routine offers the user a chance to enter the BIOS and change the configuration settings. This is usually done by pressing a key during the boot process, such as F2 or F12, or in the case of Figure 1.13, the Delete key. The computer will prompt you, but usually the prompt goes by quickly. If you get a screen showing that the operating system has started, you're too late.

Inside the BIOS, you can make system configuration selections (such as changing the system time or selecting a preferred boot device) and save the results. Also, many BIOSs offer diagnostic routines that you can use to have the BIOS analyze the state and quality of the same components it inspects during bootup but at a much deeper level.

Flashing the BIOS

When you upgrade your system's hardware, the system BIOS typically recognizes it upon bootup. If you upgraded your hard drive, processor, or memory and it's not recognized, though, you might need to update your system BIOS. This is done through a process called *flashing the BIOS*.

To flash the BIOS, you will need to download the most current version from the manufacturer of your computer (or motherboard, if you built your own system) and follow the instructions.

CMOS and CMOS Battery

Your PC has to keep certain settings when it's turned off and its power cord is unplugged, such as the date and time, hard drive configuration, memory and CPU settings, boot sequence, and power management features.

These settings are kept in a special memory chip called the *complementary metal oxide semiconductor (CMOS)*. CMOS (pronounced *see-moss*) is actually a manufacturing technology for integrated circuits, but since the first commonly used chip made from CMOS technology was a BIOS memory chip, the terms have become somewhat interchangeable. To be technically correct, though, the name of the chip is the CMOS, and the BIOS settings are stored on the chip.

The CMOS chip must have power constantly or it will lose its information (just like RAM does when your computer is powered off). To prevent CMOS from losing its rather important information, motherboard manufacturers include a small battery called the *CMOS battery* to power the CMOS memory. Most CMOS batteries look like watch batteries or small cylindrical batteries. If you look back at Figure 1.12, you will see the CMOS battery next to the BIOS.

If your system does not retain its configuration information after it's been powered off, it's possible that the CMOS battery has failed. Replacing it is similar to replacing a watch battery.

Back-Panel Connectors

If you've ever looked at the back of a computer, you know that there's a lot going on back there. There could be a dozen or so different types of connectors, including ones for power, video, audio, a keyboard and mouse, networking (such as Gigabit Ethernet), and other devices. Generally speaking, all of these connectors are connected to one of two things: the motherboard or an expansion card that's attached to the motherboard. I will talk about all of these in Chapter 2, "Peripherals and Connectors." For now, I offer you Figure 1.14, showing several connectors on the back panel.

FIGURE 1.14 Computer back panel



Front-Panel Connectors

Even though the front panel of the computer isn't as chaotic as the back panel, there's still a lot happening. The front of your computer might have one or more memory card readers or optical drives such as a DVD-ROM. It's kind of old-school to have these devices accessible from the front of your system. Years ago, you might have had 3½″ or even 5¼″ floppy drives on the front of your system too. (Google them!)

With the obsolescence of floppy drives, a lot more real estate opened up on the front of your computer. Computer manufacturers realized that accessibility was a big deal and started moving connectors that used to be found only on the backs of systems to the front. Now, your system will likely have most if not all of the following types of connectors on the front panel. All of them get connected to the motherboard in some fashion.

Power Button Having a *power button* in an easily accessible place seems kind of obvious, doesn't it? Well, they used to be on the back or side of computers too. Many times, your power button will also double as a power light, letting you know that the system is on.

Reset Button Reset buttons are hit-or-miss on computers today. The idea is that this button would reboot your computer from a cold startup without removing power from the components. The reset button is incredibly handy to have when a software application locks up your entire system. Because power is not completely lost, the reset button may not help if you had a memory issue.

Drive Activity Lights These little lights often look like circular platters (like a hard drive) or have a hard drive icon next to them. They let you know that your hard drive is working.

Audio Ports The front of most computers now has a port for headphones as well as a microphone. Long gone are the days where you had to put your computer in a certain spot on or under your desk, just so your short headphones cord could reach all the way to the back of the box.

Other Connectors Trying to get to the back of your computer to plug in a flash drive is about as convenient as ripping out the back seat of your car to get stuff out of the trunk. It might actually be faster just to remove your hard drive and give it to your friend so they can copy the files they need. (Okay, not really.) Fortunately, most new computers have one or more USB ports on the front of the box, in addition to FireWire, Thunderbolt, or external SATA (eSATA). Other systems will have memory card readers built into the front of the case as well. I will cover these different connectors in Chapter 2.



Real World Scenario

Motherboard, Revisited

At the beginning of this section, I gave you a description of a motherboard for sale.

> Asus X99-PRO/USB 3.1 Intel X99 Chipset Core i7 Socket R3 (LGA2011) ATX Motherboard, DDR4, PCI-E 3.0 x16, SATA/M.2 Socket 3, GBLAN, Wi-Fi/Bluetooth, USB

Now that you've learned about motherboards, let's translate the acronym string. Asus P99-PRO is the manufacturer and model of the motherboard, which supports Universal Serial Bus 3.1 (which I will talk about in Chapter 2). It has the Intel X99 chipset, supports the Intel Core i7 processor with an LGA 2011 CPU socket, and uses DDR4 RAM (which you will learn about in the "Memory" section later in this chapter). It has three PCIe ×16 slots, SATA/M.2 connectors, and supports gigabyte networking (GBLAN), Wi-Fi and Bluetooth, and USB.

Armed with this information, you can now compare motherboards to each other to determine which one has some of the features you are seeking!

Processors

The processor is the most important component on the motherboard. The role of the *central processing unit (CPU)* is to control and direct all the activities of the computer. Because of this role, the CPU often is called the brain of the computer. The analogy isn't perfect because the processor isn't capable of thinking independently. It just does what it's instructed to do, which is processing math. Still, the analogy of the processor as the computer's brain is close enough.

Processors are small silicon chips consisting of an array of *millions* of transistors. Intel and Advanced Micro Devices (AMD) are the two largest PC-compatible CPU manufacturers.



The terms *processor* and *CPU* are interchangeable.

CPUs are generally square, with contacts arranged in rows of pins. Older CPU sockets were in a configuration called a *pin grid array (PGA)*. The newer version uses a configuration called the *land grid array (LGA)*. LGA is sturdier than PGA because it has the pins in the socket versus on the processor, which results in less damage to processors from trying to insert them incorrectly into their sockets. Figure 1.15 shows an AMD processor.

FIGURE 1.15 AMD Athlon processor



As powerful as processors are, they don't look that impressive from the outside. Moreover, rarely will you see a processor without an accompanying heat-removal system. Your processor will have either a metal heat sink (it looks like rows of aluminum fins sticking up from it), a fan, or a combination of the two. Without a heat sink and/or fan, a modern processor would generate enough heat to destroy itself within a few seconds.

CPU Characteristics

The most important characteristic your processor can have is compatibility. Does it fit into your motherboard? Beyond this, there are literally dozens of different characteristics that CPUs have, such as hyperthreading and virtualization support. Most of those topics are beyond the scope of this book. Here, I'll focus on three key characteristics: architecture, speed, and cache.

Architecture

Three architecture-related terms with which you should be familiar are 32-bit, and 64-bit, and ARM. Processors that you find today will be labeled as 32-bit or 64-bit. What this refers to is the set of data lines between the CPU and the primary memory of the system; they can be 32- or 64-bits wide, among other widths. The wider the bus, the more data that can be processed per unit of time, and hence, the more work that can be performed. For true 64-bit CPUs, which have 64-bit internal registers and can run x64 versions of Microsoft operating systems, the external system data bus will always be 64-bits wide or some larger multiple thereof. You will find 32-bit and 64-bit processors designed for all types of computers, such as laptops, desktops, workstations, and servers. In today's world, though, using a 32-bit processor on a server would be a bit like entering a bicycle into a sports car race.

ARM (Advanced RISC Machines) refers to a type of processor that uses an architecture known as *reduced instruction set computing (RISC)*. That's in contrast to Intel's (and clones) x86 architecture, which employs *complex instruction set computing (CISC)*. Confused yet? Remember that processors do math. The differences between RISC and CISC is how the processors do the math and the instructions that the software needs to give them to do the math. Long story short, RISC processors may take more steps to do the same math problem than would a CISC processor. While that might sound inefficient and therefore slower, RISC processors have some advantages that compensate, eliminating most performance gaps. On the positive side, RISC processors can be made much smaller than their CISC cousins and produce less heat. The differences between RISC and CISC are way beyond the scope of the IT Fundamentals+ (ITF+) exam, but the context helps me explain these two key things that you *do* need know about ARM:

- ARM processors are made in both 32-bit and 64-bit versions, so you will find them in workstations and servers, albeit not very often.
- Because they can be made smaller and produce less heat, ARM processors are generally used in devices that are tablet-sized and smaller, like mobile phones. Roughly 90 percent of all small devices use ARM chips.

Another term that you will hear in terms of architecture is the number of cores a processor has. You might see something labeled dual-core, quad-core, or even 16-core. To keep making better and faster processors every year, manufacturers constantly have to find ways to increase the number of instructions a processor can handle per second. For the past several years, they've done it mostly by adding cores. Multicore means that the CPU is actually made up of several processors working in unison within the same package.

Speed

Hertz (Hz) are electrical cycles per second. Each time the internal clock of the processor completes a full cycle, a single Hz has passed. Back in 1981, IBM's first PC ran at 4.77 megahertz (MHz), which is 4.77 million cycles per second. Modern processors operate at billions (gigahertz, GHz) of cycles per second. For example, you might see a processor that runs at 3.5 GHz. Generally speaking, faster is better.

To save power during times when it's not busy, many CPUs can throttle down their speed to reduce the amount of energy used. CPU throttling is common in processors for

mobile devices, where heat generation and system-battery drain are key issues of full power usage.

Cache

I already mentioned cache when discussing motherboards, but many of today's processors also include their own built-in cache. Cache is a quick form of memory that greatly speeds up the performance of your computer.

You'll see three different cache designations. Level 1 cache (*L1 cache*) is the smallest and fastest, and it's on the processor die itself. In other words, it's an integrated part of the manufacturing pattern that's used to stamp the processor pathways into the silicon chip. You can't get any closer to the processor than that.

While the definition of L1 cache has not changed much over the years, the same is not true for other cache levels. L2 and L3 cache used to be on the motherboard but now have moved on the die in most processors as well. The biggest differences are the speed and whether they are shared. L2 cache is larger but a little slower than L1 cache. For processors with multiple cores, each core will generally have its own dedicated L1 and L2 caches. A few processors share a common L2 cache among the cores. L3 cache is larger and slower than L1 or L2, and it is usually shared among all processor cores.

The typical increasing order of capacity and distance from the processor die is L1 cache, L2 cache, L3 cache, and RAM. This is also the typical decreasing order of speed. The following list includes representative capacities of these memory types. The cache capacities are for each core of the original Intel Core i7 processor. The RAM capacity is simply a modern example.

- **L1 cache:** 64 KB (32 KB each for data and instructions)
- **L2 cache:** 256 KB
- **L3 cache:** 4 MB–12 MB
- **RAM:** 4 GB–64 GB

CPU Functionality

I've talked a lot about the features of processors, but what is it that they really do? (To quote the movie *Office Space*, perhaps the other components look at the processor and ask, "What would you say you *do* here?") The short answer is: "math."

Processors are made up of millions of transistors, which are electrical gates that let power through or not depending on their current state. They're the basis of binary processing, that is, processing based on things being in one of two states: on or off, 1 or 0.

At their most basic level, all that computers understand is 1s and 0s; it's the processor's job to do math on strings of 1s and 0s. The math that it performs is based on what's known as an *instruction set*—rules on how to do the math. It accepts numbers as input, performs calculations on them, and delivers other numbers as output. How many numbers the processor can accept at a time varies. Earlier, I mentioned 32-bit versus 64-bit architecture. Processors with 64-bit architecture can accept more data at once, and as you can imagine, that can make them much faster than their 32-bit cousins.

Binary numbering is a bit unfamiliar to most people, because we're more accustomed to using the decimal numbering system (0–9). Exercise 1.1 will get you more familiar with the binary numbering system.



I'll talk a lot more about binary, decimal, and hexadecimal in Chapter 6, "Software Development."

EXERCISE 1.1

Converting Between Decimal and Other Numbering Systems

1. In Windows 10, open the Calculator application.
2. Click the Calculator menu button, and choose Programmer to switch to Programmer view, as shown in Figure 1.16. Notice on the left that there is a mark next to the DEC option because that is what's selected. DEC is short for Decimal.

FIGURE 1.16 Calculator in Programmer view



3. Enter the number **267**.
4. Notice that the calculator shows you the hexadecimal (HEX), decimal (DEC), octal (OCT), and binary (BIN) conversions of the number. If you have an older version of Calculator, you will need to click the radio buttons next to these options to perform the conversion. The number in binary is 100001011.

5. Click BIN. Notice that all your number keys are now grayed out except 0 and 1.
6. Click HEX. Now you can also use all your number keys, as well as the letter keys A–F.
7. Click DEC again to return to decimal.
8. Experiment with other numbers. What would your birthdate look like in binary or hex? Close the calculator when you are finished.

Memory

Memory, generically speaking, is data storage that uses on/off states on a chip to record patterns of binary data. (Remember, computers deal only with 1s and 0s!) Inside a memory chip is a grid of on/off switches. An on value represents 1, and an off value represents 0.

Memory can be either static or dynamic. *Static memory* (aka nonvolatile memory) doesn't require power to maintain its contents. *Dynamic memory* (aka volatile memory) has to be constantly powered on to retain its contents.

Broadly speaking, all memory can be divided into one of two types: ROM and RAM. *Read-only memory (ROM)* chips store data permanently; you can't make changes to their content at all. (It takes a special ROM-writing machine to write one.) This type of memory is always static. The BIOS on your motherboard is stored on a ROM chip.



BIOS chips today are updatable through a process mentioned earlier called flashing the BIOS. BIOS chips are now stored on a newer, modified version of ROM called *electronically erasable programmable ROM (EEPROM),* which allows the ROM to be updated by using electronic pulses.

The programming on simple electronic devices that will never need to be user-updated, like the computer on an exercise treadmill that stores various fitness programs, will also be stored on ROM. The main advantage of ROM is its reliability. It can never be accidentally changed or deleted. The disadvantages of ROM are that it's slow compared to RAM and that you can't ever update it; you have to pull the chip out of the system and replace it. Because of these drawbacks, ROM isn't used as a PC's primary memory source; a PC has only a small amount of ROM.

Random access memory (RAM) can be written and rewritten on the device in which it's installed. It's called *random access* because the data is stored in whatever locations are available in it, and when reading data back from RAM, only the required data is read, not the entire contents.



You can never have too much RAM.

RAM can be either static or dynamic. Static RAM (SRAM), also called flash RAM, is the type you use when you store files on a USB flash drive. Static RAM is nonvolatile; you can disconnect a flash RAM device and carry it with you, and the next time you connect it to a computer, the data will still be there. Most of the memory on a PC's motherboard is dynamic RAM (DRAM), so when someone refers to a computer's memory or RAM, you can generally assume that they mean the DRAM on the motherboard. Dynamic RAM is volatile; when you turn off your computer, its content is gone.

The motherboard's RAM functions as a work area when the computer is on. The OS is loaded into it, as are any applications that you have open and any data associated with those applications. The more free RAM in the computer, the larger the available workspace, so the more applications and data files you'll be able to have open at once. If your system runs low on RAM, it can use slower virtual memory to compensate. Exercise 1.2 shows you how to configure your virtual memory.



Real World Scenario

Virtual Memory

Many OSs, including Microsoft Windows, use a tremendous amount of RAM as they operate. They sometimes do this to the point that even a well-equipped PC might not have enough RAM to do everything that a user wants. To prevent the user from being denied an activity because of a lack of available memory, these OSs employ virtual memory to take up the slack.

With virtual memory, a portion of the hard disk is set aside as a holding area for the contents of RAM. When there isn't enough space in RAM to hold the data that needs to be placed there, the OS's virtual memory management utility temporarily moves some of the least recently used data in RAM onto the hard disk, making room for the new incoming data. Then, if an application calls for the data that was moved out, the virtual memory manager moves something else out and swaps the needed data back in again.

Because of all this data swapping, the reserved area on the hard disk for virtual memory is sometimes called a *swap file* or a *page file*.

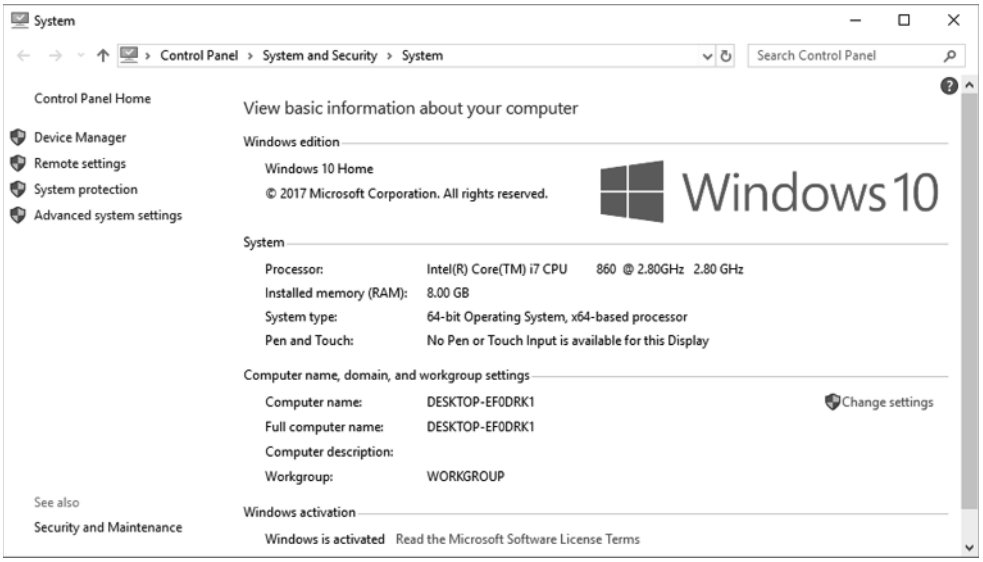
The main drawback of virtual memory is its speed, which is limited to the speed at which the hard drive can store and retrieve data. Compared to the speed of the processor and memory, the hard disk is very slow. Therefore, the less physical RAM available in a system and the more that system has to rely on virtual memory, the more slowly applications will run on that system. That's why adding more RAM to a system is often a worthwhile upgrade.

EXERCISE 1.2

Assessing Your Computer's RAM and Virtual Memory

1. In Windows 10, click Start and type **this**, which will show the This PC desktop app. Right-click This PC and click Properties. (Alternatively, open Control Panel ➢ System And Security ➢ System.) You will get a screen similar to the one shown in Figure 1.17.

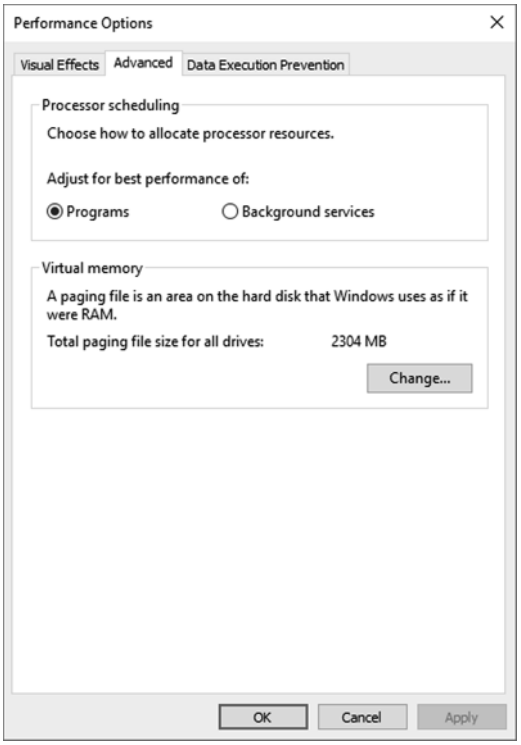
FIGURE 1.17 System information



2. In the System section of the page that appears, note the amount of installed memory (RAM). This is the total physical amount of RAM.
3. In the bar at the left, click Advanced System Settings. The System Properties dialog box opens.
4. On the Advanced tab, in the Performance section, click Settings. The Performance Options dialog box opens.
5. Click the Advanced tab and, in the Virtual Memory section, note the total paging file size for all drives, as shown in Figure 1.18. This is the amount of virtual memory set aside for the system's use.

EXERCISE 1.2 *(continued)*

FIGURE 1.18 Virtual memory



6. Click the Change button. The Virtual Memory dialog box opens.
7. Click Cancel to close the dialog box without making any changes. (It's usually best to continue to let this setting be automatically managed by the system.)
8. Click Cancel to close the Performance Options dialog box.
9. Click Cancel to close the System Properties dialog box.
10. Close the Control Panel window.

Memory Bus Speeds

The pathway that delivers data to and from the memory is called a *memory bus*. Memory has a bus width that determines how many columns are in each row of storage. All the bits

in a single row are read together as a single value, so the wider the memory bus width, the more data that can be read at once. For example, in memory with an 8-bit width, you might have a number like 01001100. In memory with a 32-bit width, you could have a number with up to 32 binary digits.

The memory bus also has a speed, which determines how quickly data will travel on its pathway. Memory on modern PCs is synchronized with the system bus, which in turn is controlled by the system timer on the motherboard. (Remember the Northbridge? It controls all of that.) The system timer determines the speed at which data enters the processor. Memory that operates at the same speed as the front-side bus is called *single data rate (SDR) synchronous dynamic random-access memory (SDRAM)*.

The original successor to SDR SDRAM was *double data rate (DDR) SDRAM*, also sometimes called DDR1. It makes higher transfer rates achievable by strictly controlling the timing of the electrical data and clock signals so that data can be double-pumped into the RAM. The term *double data rate* is a reference to DDR's capability of achieving nearly twice the bandwidth of SDR.

After DDR1 came DDR2 SDRAM, which enables greater throughput and requires lower power by running the internal clock at half the speed of the data bus in addition to double-pumping the bus. This effectively multiplies the DDR1-level performance by two so that there is a total of four data transfers per internal clock cycle.

DDR3 and DDR4 go even further, doubling the data rate from each previous version and using less power. DDR5, expected to be released in late 2018 or early 2019, will double the speed of DDR4.



Video cards with DDR5 RAM are already on the market. The 2019 release date is for system RAM.

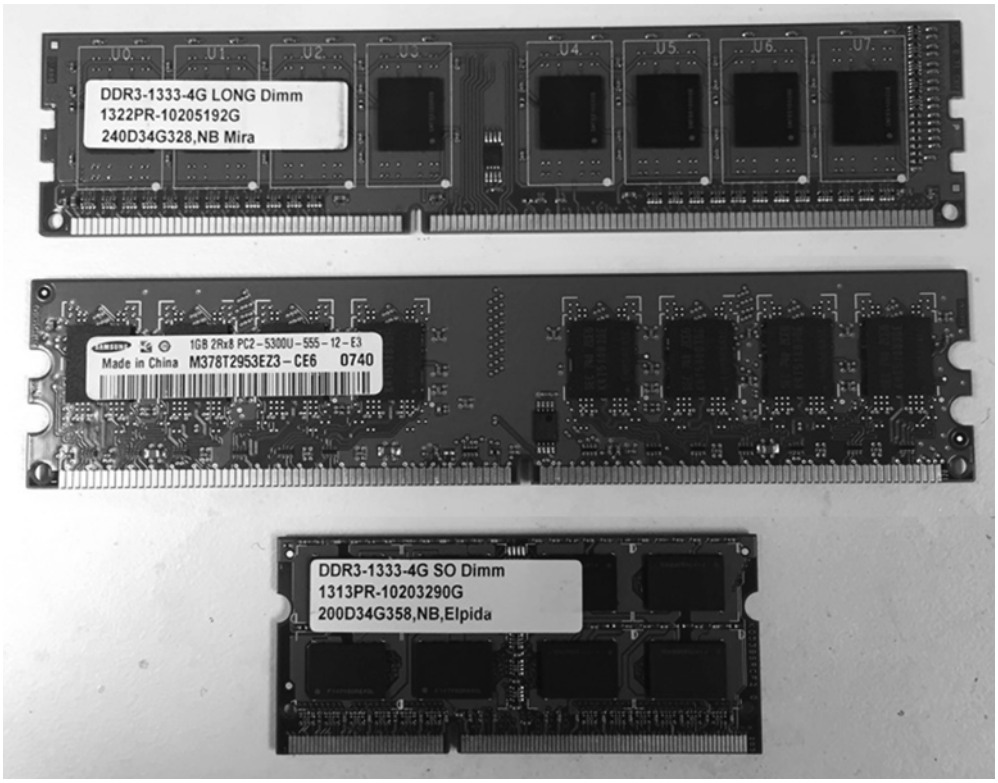
Generally speaking, most motherboards accept only one type of RAM: SDR, DDR, DDR2, DDR3, or DDR4. Even if the motherboard is physically compatible with other types, it's programmed to work with RAM at a certain speed.

Physical Characteristics of RAM

There have been various sizes and shapes of RAM modules in PCs over the years. For the most part, PCs today use memory chips arranged on a small circuit board; an example is the *dual inline memory module (DIMM)*. The *dual* in DIMM refers to the fact that the module uses pins on both sides of the circuit board. DIMMs differ in the number of conductors, or pins, that each particular physical form factor uses. Some common examples include 168-, 184-, 240-, and 288-pin configurations. In addition, laptop memory comes in smaller form factors known as a *small outline DIMM (SODIMM)*. (Some laptops also use a smaller version known as a MicroDIMM.) Figure 1.19 shows the form factors for some

popular memory modules. The top two are DDR3 and DDR2. Notice how they basically look the same but the keying notches are different. The bottom one is a SODIMM for a laptop.

FIGURE 1.19 Memory module form factors



Different types of DIMMs and SODIMMs may be similar or even identical in overall size and shape and may even have the same number of pins. For example, DDR2 and DDR3 DIMMs both have 240 pins. DDR4 has 288 pins, but it is the same length as DDR2 and DDR3. The good news is that each type of RAM has a uniquely placed notch in the edge that contains the pins. That notch makes the RAM fit only into a slot that has a correspondingly placed spacer, and it prevents people from installing the wrong type of memory. You could try, but the memory stick would likely break before you got it in there.

Exercise 1.3 helps you determine what type of RAM you have in your computer.

EXERCISE 1.3

Determining the Type of Installed RAM

1. Look in the documentation that came with your computer to see whether there is anything about the RAM specifications. In the documentation, locate the information about installing a RAM upgrade. This will tell you where to find the RAM on your system.
2. If you didn't find information in the documentation, you might need to look at the RAM itself. To do this, you will need to open the case. Before opening the case, be sure the computer is powered off!
3. Open the computer's case and locate the RAM. Identify whether it's DIMM or SODIMM. (Most laptops use SODIMM, and most desktop PCs use DIMM.) To avoid damaging it with static electricity, avoid touching it. If you need to touch it, touch the metal frame of the PC's case first.
4. Examine the numbers or codes, if any, on the DIMM or SODIMM, looking for model numbers, speeds, or any other pertinent information.
5. Look at the data you gathered online to see whether you can determine anything about the memory based on those numbers.
6. If you can't determine the RAM type by any of these methods, find the motherboard's brand and model number (look for this information printed on the motherboard itself). Then look up the motherboard online to see whether information about its RAM requirements is available.

Exploring Storage and Expansion Devices

Beyond the "big three" of the motherboard, processor, and RAM, there are several other important devices located inside your computer. Broadly speaking, they fall into one of two camps. They either provide long-term storage or expand your system's functionality by giving you features such as video, audio, or network access.

Over the following sections, I will introduce you to six different types of devices. The first two, hard drives and optical drives, give you the ability to store data on a long-term basis. The last four, video cards, soundcards, network cards, and modems, provide features that take your computer from being a really good paperweight to being a helpful and fun device to use.

Hard Drives

Computers would be a lot less useful to us if they weren't able to store our data long-term. This is where hard drives come in. Hard disk drive (HDD) systems (called hard disks or *hard*

drives for short) are used for permanent storage and quick access. They hold our data as well as files the system needs to operate smoothly. Drives differ in their capacity, their speed (access time), and the type of materials they are made from (metal or glass platters coated with a magnetic coating).

Hard disks typically reside inside the computer, where they are semipermanently mounted with no external access (although there are external and removable hard drives), and can hold more information than other forms of storage. Hard drives use a magnetic storage medium and are known as conventional drives to differentiate them from newer solid-state storage media.

Inside a conventional, spinning disk hard drive, you will find a sealed stack of metal platters, each with a read-write head on a retractable arm that reads data from and writes data to the platters by magnetizing bits of iron oxide particles on the platters in patterns of positive and negative polarity. As a hard disk operates, the platters rotate at a high speed, and the read/write heads hover just over the disk surfaces on a cushion of air generated by the spinning. Normally, you won't see the inside of a hard drive, so you can see one in Figure 1.20. Once you open the metal box in which it's encased, you ruin the drive. The platters are typically 3½″ in diameter for full-size hard disk drives (for desktop PCs) and 2½″ for smaller hard disk drives used in laptops.

FIGURE 1.20 Inside a hard drive



Photo credit: Eric Gaba. Wikimedia Commons user: Sting.



You might hear old-timers talk about floppy disks and floppy disk drives (FDDs). Floppy disks were square and held a thin, pliable disk of magnetic material. They were written to and read from magnetically, just like hard drives. You would insert them into an FDD, which performed the reading and writing functions on the disk.

The two most common sizes were 3½″ and 5¼″, and they held 1.44 MB and 1.2 MB, respectively. You won't need to know those numbers for the exam, but they give you a good perspective on how little data they could hold. The one advantage they had was that they were portable. Now we have USB flash drives, with capacities in the gigabytes (and no special read/write device required), which make floppy disks obsolete.

Hard Drive Characteristics

When evaluating hard drives, there are really two factors that determine their performance: size and speed.

Size is fairly self-evident. Hard drives with larger capacity store more data. There isn't anything too tricky about it. You can easily find hard drives with capacities from several hundred gigabytes up to 10 terabytes. Table 1.2 has some conversions that will likely come in handy.

TABLE 1.2 Bit and byte conversions

How Many	Equals	Example
1 bit	1 bit	A single 0 or 1
8 bits	1 byte	One text character
1,000 bytes	1 kilobyte (KB)	A 1,000-character plain-text file or a small icon
1,000 kilobytes	1 megabyte (MB)	A small photograph or one minute of music
1,000 megabytes	1 gigabyte (GB)	A full-length audio CD is about 800 MB; a two-hour DVD movie is about 4 GB.
1,000 gigabytes	1 terabyte (TB)	A large business database
1,000 terabytes	1 petabyte (PB)	Data from a large government institution, such as the U.S. Internal Revenue Service

TABLE 1.2 Bit and byte conversions *(continued)*

How Many	Equals	Example
1,000 petabytes	1 exabyte (EB)	It's rumored that YouTube stores just over 1 EB of data, but it's hard to confirm that claim.
1,000 exabytes	1 zettabyte (ZB)	In 2013, NPR and Forbes reported that the U.S. National Security Agency's new Utah data center could store up to 5 ZB of data. But it's the NSA, so of course there is no official confirmation of this.

The historical convention was always that the next level up equaled 1,024 of the previous level, such that 1 MB = 1,024 KB. Now, it's more or less accepted that we just round everything off to 1,000 to make it easier to do the math.

Most people assume that they don't need to think in terms of exabytes or zettabytes (not to mention yottabytes, which are 1,000 zettabytes), but with 6 TB hard drives being relatively common today, these larger measures are probably right around the corner.

Speed is the other thing you will want to look at when considering a hard drive. Hard drive access is much slower than RAM access, so hard drives can often be the bottleneck in system performance. Over the years, though, technology has evolved to improve hard drive access time. To speed up data access, manufacturers increase the speed at which the platters spin from one generation of drives to the next, with multiple speeds coexisting in the marketplace for an unpredictable period until demand dies down for one or more speeds.

The following spin rates, in revolutions per minute (rpm), have been used in the industry for the platters in conventional magnetic hard disk drives:

- 5400 rpm
- 7200 rpm
- 10,000 rpm
- 12,000 rpm
- 15,000 rpm

A higher rpm rating results in the ability to move data more quickly. The lower speeds can be better for laptops, where heat production and battery usage can be issues with the higher-speed drives.

Connecting a Hard Drive

There are two common hard drive standards in the marketplace today: Parallel ATA (PATA), also known as Integrated Drive Electronics (IDE), and Serial ATA (SATA). PATA/IDE has been around a lot longer (IDE came out in the late 1980s), and SATA is the newer and faster technology, launched in 2003.

Regardless of the standard, hard drives need two connections to function properly: power and the data cable. The power comes from the power supply, and the data cables connect to the motherboard. Figure 1.21 shows the back of two standard 3½″ desktop hard drives. The top one is PATA/IDE, and the bottom one is SATA.

FIGURE 1.21 PATA/IDE and SATA hard drives

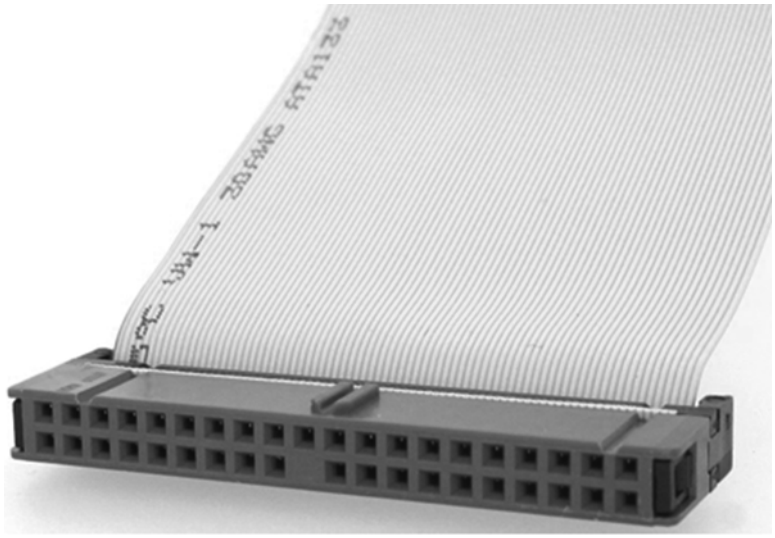


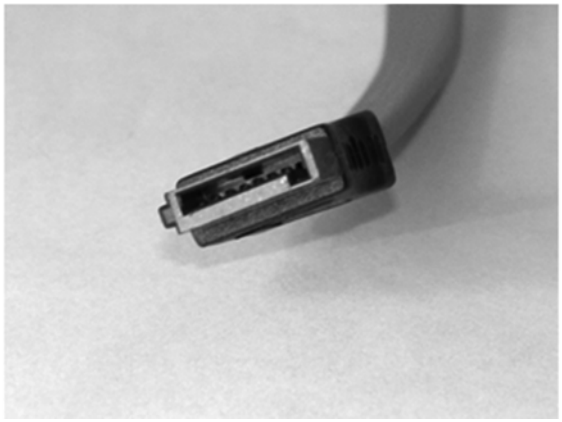
Figure 1.22 shows the ends of the data cables. Again, the top one is PATA, and the bottom one is SATA. The connectors where the data cables plug into the motherboard were shown in Figure 1.9 and Figure 1.10.



There's a third connector type, called Small Computer System Interface (SCSI), that you might hear about. It uses a ribbon cable similar to IDE but wider. It was once popular for high-end systems, but the speed and lower cost of SATA has made SCSI fade in popularity. Few motherboards had SCSI controllers built onto them. If you wanted a SCSI hard drive, you needed to add an internal expansion board with a SCSI controller on it.

FIGURE 1.22 PATA and SATA data cables







Real World Scenario

Connecting Multiple PATA Devices

Hard drives are important, and for many years the most common hard drive standard was PATA (at the time called IDE). Most motherboards came with two connectors; today, motherboards will have one, if they support PATA at all. When CD-ROM drives came out, they too used the same 40-pin connector as hard drives. If you had only two devices, this wasn't a problem. But what if you wanted two hard drives *and* a CD-ROM?

The 40-pin PATA ribbon cable has three connectors on it. One goes to the motherboard, and the other two—one in the middle of the cable and one at the other end—go to drives. If you have only one PATA drive, you use the connector at the far end of the cable, and the extra connector in the middle of the cable goes unused.

If you need to connect two devices to one cable, then you also need to tell the computer which device has priority over the other. Otherwise, they fight like spoiled children and neither one will work. To do that, you need to configure each drive as either the master (MA) or the slave (SL) on that cable. Master and slave configuration is performed via jumpers on the back of the hard drive. If you look at Figure 1.21, the jumper block is the 10-pin block between the PATA data connector and the power block. The right two pins have a jumper placed over them, configuring the drive.

Some PATA cables will assign mastery or slavery to a drive based on the connector into which it's plugged. (That's called Cable Select [CS], with the master at the end and the slave in the middle.) To make this work, you must set the jumpers on each of the drives to the CS setting. Fortunately, they are usually set to CS by default. The top of the hard drive might have a sticker showing you the jumper settings (the one in Figure 1.21 does), or you can check the manufacturer's documentation.

When a newly installed PATA drive doesn't work, it could be because the jumpers aren't set correctly.

Solid-State Drives

Unlike conventional hard drives, a *solid-state drive (SSD)* has no moving parts but uses the same solid-state memory technology found in the other forms of flash memory. You can think of them as bigger versions of the flash drives that are so common.

When used as a replacement for traditional HDDs, SSDs are expected to behave in a similar fashion, mainly by retaining contents even when the system is powered off. Connecting an SSD is just like connecting a regular HDD: they have the same PATA/SATA and power connectors. Most manufacturers also make them in the same physical dimensions as traditional hard drives.

As you might expect, SSDs have several advantages over their mechanical counterparts. These include the following:

- Faster start-up and read times
- Less power consumption and heat produced
- Silent operation
- Generally more reliable because of a lack of moving parts
- Less susceptible to damage from physical shock and heat production
- Higher data density per square centimeter

Disadvantages of SSDs are as follows:

- The technology to build an SSD is more expensive per byte.
- All solid-state memory is limited to a finite number of write (including erase) operations. Lack of longevity could be an issue.

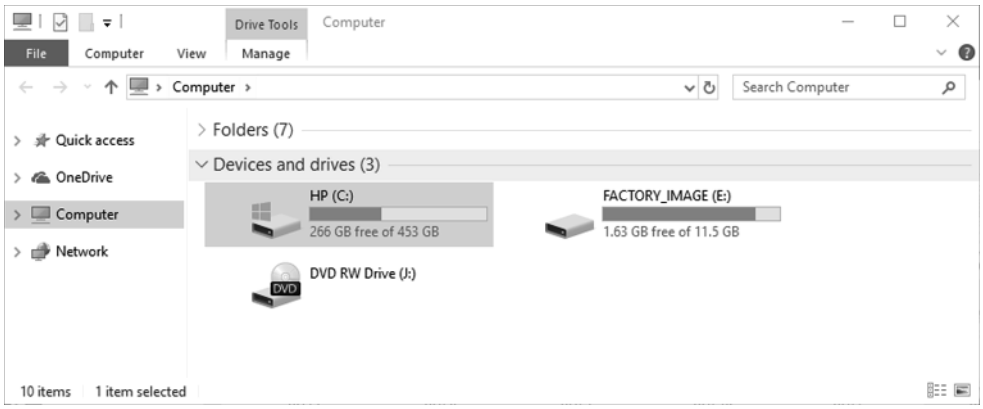
To summarize, SSDs are faster and produce less heat but are generally more expensive than conventional hard drives. Exercise 1.4 shows how to view information about your hard drive in Windows 10.

EXERCISE 1.4

Examining Hard Drives in Windows

1. In Windows 10, click Start and type **`this`**, which will show the This PC desktop app. Click it to open This PC. A list of the drives on your PC appears, like the one shown in Figure 1.23.

FIGURE 1.23 Installed disk drives



2. Examine the primary hard disk (C:). You can see a bar that shows you how much storage space it has as well as how much space is free. Figure 1.23 shows an example.
3. Right-click the primary hard disk (C:), and click Properties. A Properties dialog box opens for that drive, as shown in Figure 1.24.
4. Examine the information about the file system, used space, free space, and capacity. If free space is low (under about 10 percent), your computer could run slower than it should.
5. Click the Hardware tab. Information appears about all of the disk drives, including any connected USB storage devices and your DVD/CD drive if you have one. Here you can see the brand name and model number of each drive, like in Figure 1.25.

FIGURE 1.24 Hard disk properties

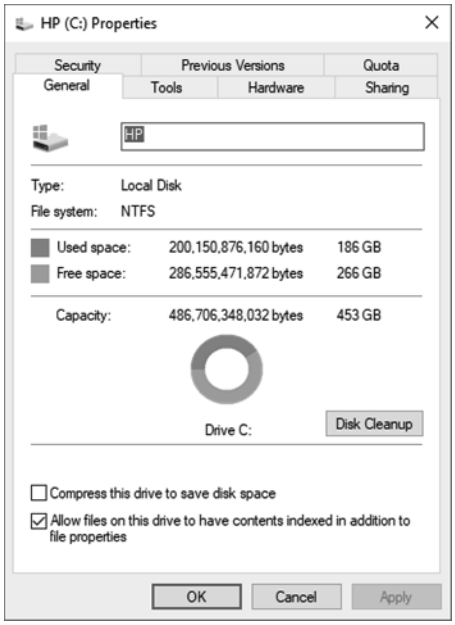
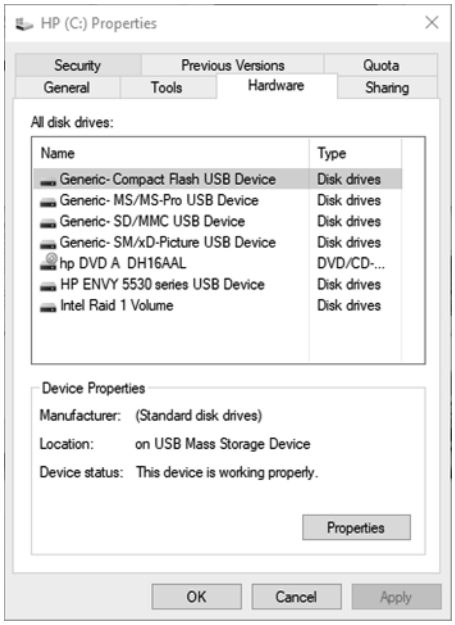


FIGURE 1.25 Disk drives



6. Click Cancel to close the dialog box, and close the Computer window.

Optical Drives

Most computers today have an optical storage drive capable of reading the latest Blu-ray Disc (BD), a digital versatile disc or digital video disc (DVD), or the legacy compact disc (CD) that you have lying around. Each type of optical drive can also be expected to support the technology that came before it. Optical storage devices began replacing floppy drives in the late 1990s. Even though these discs have greater data capacity and increased performance over floppies, they are not intended to replace hard drives.

The CDs, DVDs, and BDs used for data storage are virtually the same as those used for permanent recorded audio and video. The way data, audio, and video information is written to consumer-recordable versions makes them virtually indistinguishable from professionally manufactured discs.

Each of these media types requires an optical drive capable of reading them. Those devices are designated with a *-ROM* ending, for example, *CD-ROM*, *DVD-ROM*, or *BD-ROM*. If the drive is capable of writing to these discs (called a *burner*), it will have a different ending, such as *-R* (recordable) or *-RW* (rewritable). To confuse matters further, there are two standards of DVD burners: DVD-RW and DVD+RW. Today's DVD readers can generally handle both formats, but older devices might not be able to do so. Burnable BD drives are designated BD-R or BD-RE (for re-recordable). Figure 1.26 shows a DVD-ROM. It's really hard to tell optical drives apart from each other, unless you see the logo that's on it.

FIGURE 1.26 A DVD-ROM



Each of the formats I have mentioned so far has different capacities. Table 1.3 lists the most common. Before getting to Table 1.3, though, I need to define a few more acronyms. Discs can be single sided (SS) or double-sided (DS), meaning that information is written

to one or both faces of the disc. In addition, DVDs and BDs can have multiple layers on the same side, otherwise known as *dual-layer* (DL). The ability to create dual layers nearly doubles the capacity of one side of the disc. Boldfaced capacities in the table are the commonly accepted values for their respective formats.

TABLE 1.3 Optical discs and their capacities

Disc Format	Capacity
CD SS (includes recordable versions)	650 MB, **700 MB**, 800 MB, 900 MB
DVD-R/RW SS, SL	4.71 GB (**4.7 GB**)
DVD+R/RW SS, SL	4.70 GB (**4.7 GB**)
DVD-R, DVD+R DS, SL	**9.4 GB**
DVD-R SS, DL	8.54 GB (**8.5 GB**)
DVD+R SS, DL	8.55 GB (**8.5 GB**)
DVD+R DS, DL	17.1 GB
BD-R/RE SS, SL	25 GB
BD-R/RE SS, DL	50 GB
BD-R/RE DS, DL	100 GB

SS: single-sided; DS: double-sided; SL: single-layer; DL: dual-layer



A double-sided, single-layer DVD will give you more storage space than a single-sided, dual-layer DVD. This is because there is a bit of inefficiency when writing a second layer on one side, so the second layer doesn't quite give you double the storage space versus just one layer.

Now you know why Blu-ray movies are so much better than those on DVD. Even the simplest BD can store nearly 50 percent more data than the most advanced DVD!

Video Cards

A video adapter (more commonly called a *graphics adapter* or even more commonly a *video card*) is the expansion card you put into a computer to allow the computer to display output

on some kind of monitor. A video card is responsible for converting the data sent to it by the CPU into the pixels, addresses, and other items required for display.

Sometimes, video cards can include dedicated chips to perform some of these functions, thus accelerating the speed of display. This type of chip is called a *graphics processing unit (GPU)*. Some of the common GPUs are AMD Radeon and NVIDIA GeForce. Most video cards also have their own onboard RAM. This is a good thing, and just like the RAM on your motherboard, the more the better. Figure 1.27 shows a video card.

FIGURE 1.27 A video card



Most video cards sold today use the PCIe interface, but you might still see some older AGP cards out there. They both work the same way, except that AGP is very slow compared to PCIe.

Video cards can have one or more external plugins for monitors or other display devices. You can see that the card shown in Figure 1.27 has three plugins—one S-video port and two DVI ports. These will be covered in more detail in Chapter 2. Also notice that this card has a rather large fan attached to it. This is because the card has its own processor and memory and generates a lot of heat. Secondary cooling is necessary to keep this card from melting down.

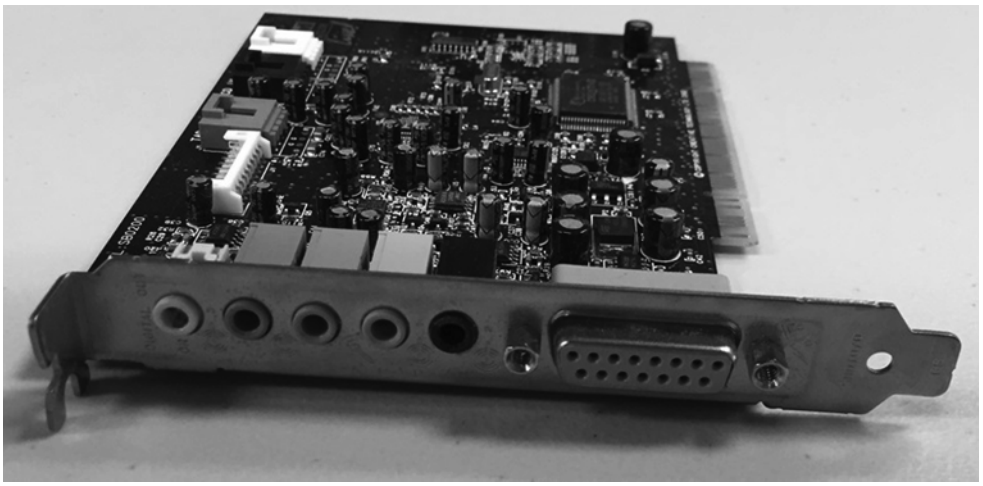


To save space and money, some systems (primarily laptops) will have the GPU built into the CPU or otherwise located on the motherboard. These systems will also split the system RAM between video and other system functions. (Usually, in these cases, the amount of RAM dedicated to video can be configured in the BIOS or in Windows.) There's nothing wrong with this type of configuration, other than it's slower than having separate components. If you are a gamer or otherwise have high video processing needs, you will want a separate video card with as much RAM on it as you can get.

Sound Cards

Just as there are devices to convert computer signals into printouts and video information, there are devices to convert those signals into sound. These devices are known as *sound cards* (or audio cards). Although sound cards started out as pluggable adapters, this functionality is one of the most common integrated technologies found on motherboards today. A sound card typically has small, round, 1/8″ (3.5 mm) jacks on the back of it for connecting microphones, headphones, and speakers, as well as other sound equipment. Many sound cards used to have a DA15 game port, which could be used either for joysticks or for MIDI controllers (used with external keyboards, and so forth). Figure 1.28 shows an example of a legacy sound card with a DA15 game port.

FIGURE 1.28 A legacy sound card



The most popular sound card standard in the market is the Sound Blaster, which is made by Creative Technology.

Network Cards

It seems like every computer participates on a network these days, whether it's at the office or at home. A *network interface card (NIC)* is an expansion card that connects a computer to a network so that it can communicate with other computers on that network. It translates the data from the parallel data stream used inside the computer into the serial data stream that makes up the frames used on the network. It has a connector for the type of expansion bus on the motherboard (PCIe, PCI, and so on) as well as a connector for the type of network (wired connectors such as fiber or RJ-45, or an antenna for wireless). Figure 1.29 shows a wireless network card designed for a desktop PC.

FIGURE 1.29 A wireless desktop NIC

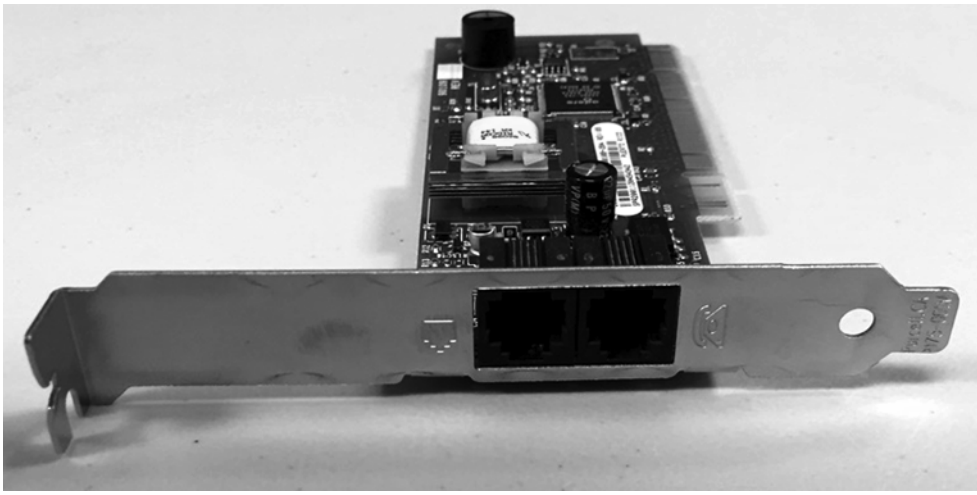


A large number of computers today have the NIC circuitry integrated into their motherboards. A computer with an integrated NIC wouldn't need to have a NIC add-on card installed unless it was faster or if you were using the second NIC for load balancing, security, or fault tolerance.

Modems

Any computer that connects to the Internet using an analog dial-up connection needs a modem, or *mo*dulator/*dem*odulator. A *modem* is a device that converts digital signals from a computer into analog signals that can be transmitted over phone lines and back again. These expansion card devices are easy to identify because they have phone connectors on the plate. Usually, as you can see in Figure 1.30, there are two RJ-11 ports: one for connection to the telephone line and the other for connection to a telephone. This is primarily so that a phone can gain access to the same wall jack to which the computer connects without swapping their cords. Keep in mind, though, that you won't be able to use the phone while the computer is connected to the Internet.

FIGURE 1.30 A modem



Before high-speed Internet became popular, a modem was the device people used to get on the Internet. Of course, this meant that the phone line was in use and no one could call your home phone. This was back in the days when people still had land phone lines and when mobile phones were a rare luxury. (I feel like my grandpa talking about the "olden days" when I say these things!) Modems are rarely used today.

Exploring Power and Cooling

Without electricity, there wouldn't be any computers. With too much electricity, you'll fry everything inside the box. The goal is to find a happy medium and provide consistent power to your computer.

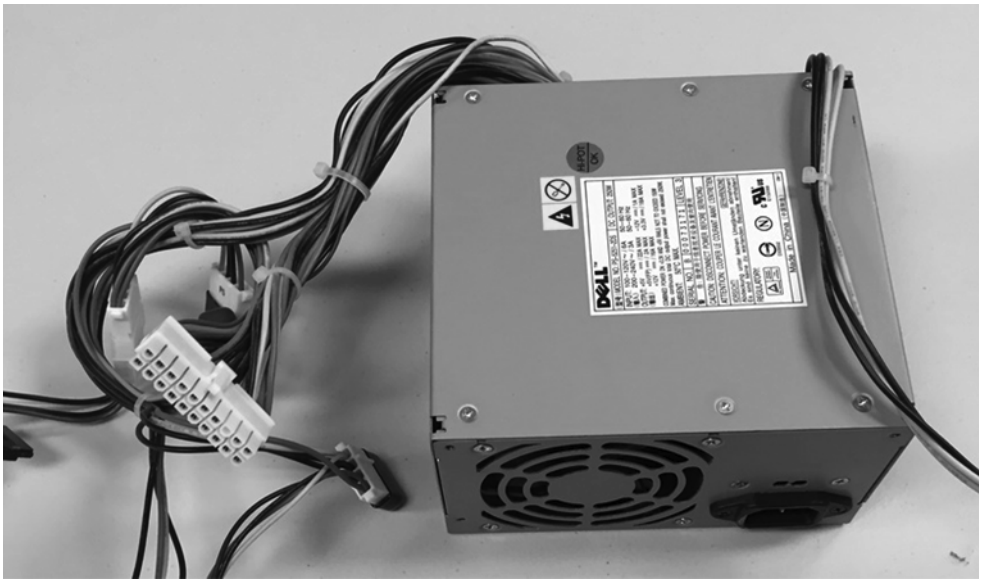
Electronics components produce heat. The amount of heat depends on a variety of things, such as the number of transistors it has, the size of the piece, and the ventilation provided. Having components overheat is the most surefire way of having them fail, except perhaps for dousing them with water.

In the next two sections, you'll learn about providing your computer components with the right amount of power and then cooling them off so that they last as long as possible.

Power Supplies

The device in the computer that provides power is appropriately named the *power supply* (see Figure 1.31), sometimes called a *power supply unit (PSU)*. That nondescript silver box with the tangle of cords coming from it converts 110V or 220VAC current into the DC voltages that a computer needs to operate. These are +3.3VDC, +5VDC, and –5VDC (on older systems) and +12VDC and –12VDC on newer ones. The jacket on the leads carrying each type of voltage has a different industry-standard color coding for faster recognition. Black ground leads offer the reference that gives the voltage leads their respective magnitudes. The +3.3VDC voltage was first offered on ATX motherboards.

FIGURE 1.31 A desktop power supply





The abbreviation *VDC* stands for *volts DC*. *DC* is short for *direct current*. Unlike alternating current (AC), DC does not alter the direction in which the electrons flow. AC for standard power distribution does so 50 or 60 times per second (50 Hz or 60 Hz, respectively).



Power supplies contain transformers and capacitors that can discharge *lethal* amounts of current even when disconnected from the wall outlet for long periods. They are not meant to be serviced, especially by untrained personnel. *Do not* attempt to open them or do any work on them. Simply replace and recycle them when they go bad.

Power supplies are rated in watts. A *watt* is a unit of power. The higher the number, the more power your computer can draw from the power supply. Think of this rating as the capacity of the device to supply power. Most computers require power supplies in the 250-watt to 500-watt range. Higher-wattage power supplies might be required for more advanced systems that employ power-hungry graphics technologies or multiple disk drives, for instance. It is important to consider the draw that the various components and subcomponents of your computer place on the power supply before choosing one or its replacement.

Power supplies have an input plug for the power cord (shown on the left in Figure 1.32), a connector to power the motherboard, and then other connectors to power peripherals such as hard drives and optical drives. Each has a different appearance and way of connecting to the device. Newer systems have a variety of similar, replacement, and additional connectors, such as dedicated power connectors for SATA and PCIe, additional power connectors for the motherboard, and even modular connections for these leads back to the power supply instead of a permanent wiring harness. Figure 1.33 shows the ATX power connector that goes to the motherboard. Notice that it's keyed so that it can't be put in the wrong way. Figure 1.34 shows three different types of peripheral power connectors: a four-pin Molex connector for PATA hard drives and optical drives, a six-pin PCIe (called a PEG connector), and a SATA connector.

FIGURE 1.32 Power supply in the case

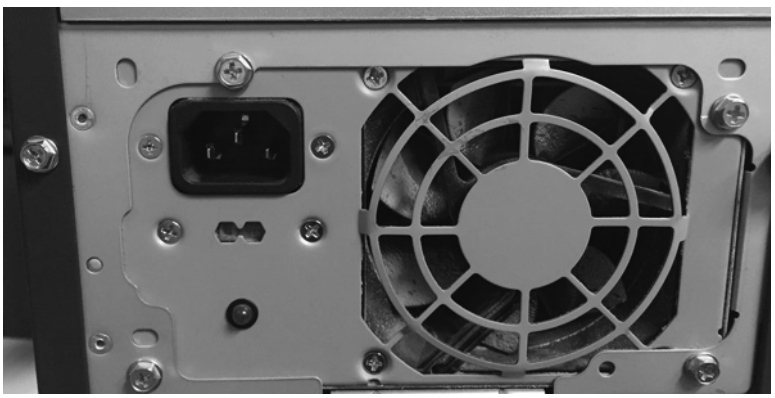


FIGURE 1.33 A 20-pin ATX power connector

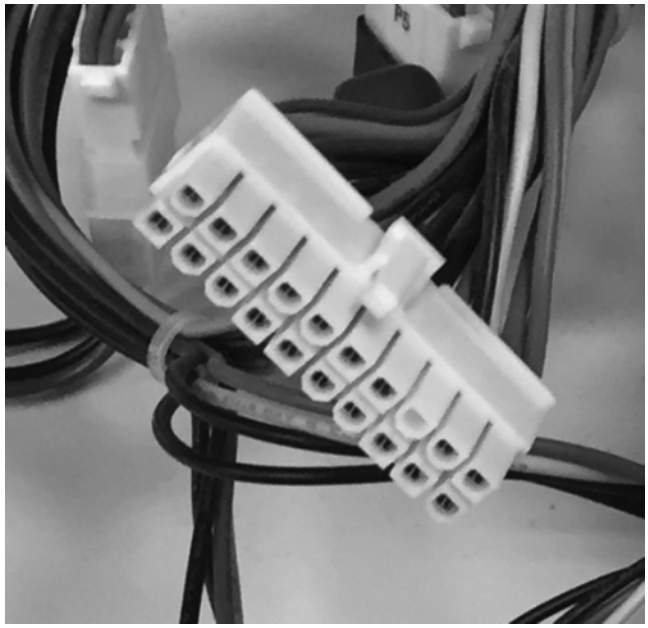
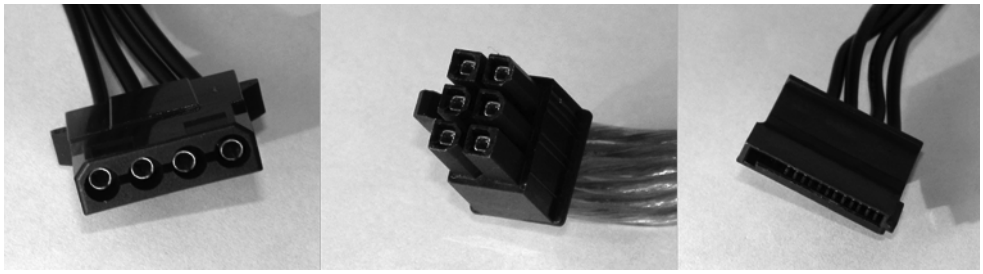


FIGURE 1.34 Peripheral power connectors



Most power supplies have a recessed, two-position slider switch, often a red one, on the rear that is exposed through the case. You can see it in Figure 1.32. Selections read 110 and 220, 115 and 230, or 120 and 240. This dual-voltage selector switch is used to adjust for the voltage level used in the country where the computer is in service. For example, in the United States, the power grid supplies anywhere from 110VAC to 120VAC. However, in Europe, for instance, the voltage supplied is double, ranging from 220VAC to 240VAC.

Although the voltage is the same as what is used in the United States to power high-voltage appliances, such as electric ranges and clothes driers, the amperage is much lower.

The point is the switch is not there to match the type of outlet used in the same country. If the wrong voltage is chosen in the United States, the power supply expects more voltage than it receives and might not power up at all. If the wrong voltage is selected in Europe, however, the power supply receives more voltage than its setting. The result could be disastrous for the entire computer. Sparks could also ignite a fire that could destroy nearby property and endanger lives. Always check the switch before powering up a new or recently relocated computer. In the United States and other countries that use the same voltage, check the setting of this switch if the computer fails to power up.

Laptop computers don't have big, bulky power supplies like the one shown in Figure 1.31, but instead they use smaller AC adapters. They function the same way, converting AC current into DC power for the laptop's components. AC adapters are also rated in watts and selected for use with a specific voltage the same as power supplies. One difference is that AC adapters are also rated in terms of DC volts out to the laptop or other device, such as certain brands and models of printers. Figure 1.35 shows a laptop AC adapter. You can see the circular connector on the laptop for the adapter.

FIGURE 1.35 Laptop power supply



Because both power supplies and AC adapters go bad on occasion, you should replace them both and not attempt to repair them yourself. When replacing an AC adapter, be sure to match the size, shape, and polarity of the tip with the adapter you are replacing. However, because the output DC voltage is specified for the AC adapter, be sure to replace it with one of equal output voltage, an issue not seen when replacing desktop power supplies that have standard outputs. Additionally, and as with power supplies, you can replace an AC adapter with a model that supplies more watts to the component because the component uses only what it needs.

Cooling Systems

The downside of providing power to electronic components is that they produce heat. The excess heat must be dissipated, or it will shorten the life of the components. In some cases (as with the CPU), the component will produce so much heat that it can destroy itself in a matter of seconds if there is not some way to remove this extra heat. All computer systems today come with some cooling systems to reduce and remove heat. Here I'll discuss two broad categories of cooling systems: case cooling and CPU cooling.

Case Cooling

The most common method used to cool computers is air cooling. With air cooling, the movement of air removes the heat from the component. Sometimes, large blocks of metal called *heat sinks* are attached to a heat-producing component to dissipate the heat more rapidly.

When you turn on a computer, you will often hear lots of whirring. Contrary to popular opinion, the majority of the noise isn't coming from the hard disk (unless it's about to go bad). Most of this noise is coming from the various fans inside the computer. Fans provide airflow within the computer.

Most desktop PCs have a combination of these fans:

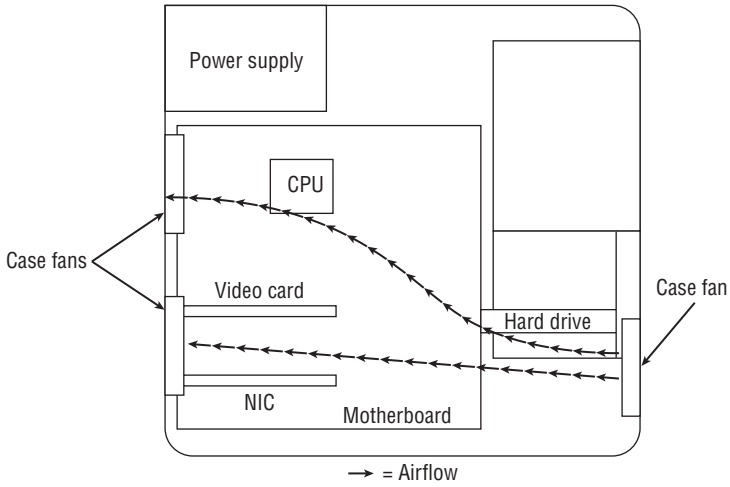
Front Intake Fan This fan is used to bring fresh, cool air into the computer for cooling purposes.

Rear Exhaust Fan This fan is used to take hot air out of the case.

Power Supply Exhaust Fan This fan is usually found at the back of the power supply and is used to cool the power supply. In addition, this fan draws air from inside the case into vents in the power supply. This pulls hot air through the power supply so that it can be blown out of the case. The front intake fan assists with this airflow. The rear exhaust fan supplements the power supply fan to achieve the same result outside the power supply.

In addition, you can buy supplemental cooling devices for almost any component inside your computer. For example, you can get cooling systems specifically for hard drives, RAM, chipsets, and video cards. Ideally, the airflow inside a computer should resemble what is shown in Figure 1.36.

FIGURE 1.36 System unit airflow



Note that you must pay attention to the orientation of the power supply's airflow. If the power supply fan is an exhaust fan, as assumed in this discussion, the front and rear fans will match their earlier descriptions: front, intake; rear, exhaust. If you run across a power supply that has an intake fan, the orientation of the supplemental chassis fans should be reversed as well. The rear chassis fan (or fans) should always be installed in the same orientation as the power supply fan runs to avoid creating a small airflow circuit that circumvents the cross flow of air through the case. The front chassis fan and the rear fans should always be installed in the reverse orientation to prevent them from fighting against each other and reducing the internal airflow.

CPU Cooling

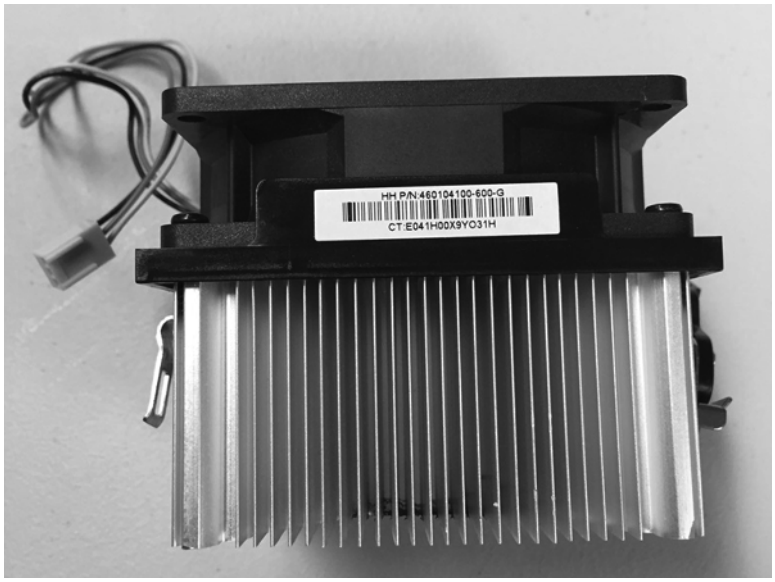
Without a doubt, the greatest challenge in computer cooling is keeping the CPU's temperature in check. It is the component that generates the most heat in a computer; if left unchecked, it will fry itself in a matter of seconds. That's why most motherboards have an internal CPU heat sensor and a CPU fan sensor. If no cooling fan is active, these devices will shut down the computer before damage occurs.

There are a few different types of CPU cooling methods, but the two most common can be grouped into two categories: air cooling and liquid cooling.

Air Cooling

The parts inside most computers are cooled by air moving through the case. The CPU is no exception. However, because of the large amount of heat produced, the CPU must have (proportionately) the largest surface area exposed to the moving air in the case. Therefore, the heat sinks on the CPU are the largest of any inside the computer. Figure 1.37 shows a CPU heat sink.

FIGURE 1.37 CPU heat sink



The metal fins on the heat sink in Figure 1.37 attach to the processor, and the fan on top helps dissipate the heat. You will find a variety of different types of processor heat sinks on the market, but most of them involve both the metal heat spreaders and a fan.



Don't touch a CPU heat sink until your computer has been turned off for at least several minutes!

The CPU fan often blows air down through the body of the heat sink to force the heat into the ambient internal air, where it can join the airflow circuit for removal from the case. However, in some cases, you might find that the heat sink extends up farther, using radiator-type fins, and the fan is placed at a right angle and to the side of the heat sink. This design moves the heat away from the heat sink immediately instead of pushing the air down through the heat sink. CPU fans can be purchased that have an adjustable rheostat to allow you to dial in as little airflow as you need, aiding in noise reduction but potentially leading to accidental overheating.

Liquid Cooling

Liquid cooling is the second most popular way to cool processors, but it's not often found in the PC market. Liquid cooling uses a special water block to conduct heat away from the processor (as well as from the chipset). Water is circulated through this block to a radiator, where it is cooled.

The theory is that you could achieve better cooling performance through the use of liquid cooling. For the most part, this is true. However, with traditional cooling methods (which use air and water), the lowest temperature you can achieve is room temperature. Plus, with liquid cooling, the pump is submerged in the coolant (generally speaking), so as it works, it produces heat, which adds to the overall liquid temperature.

The main benefit to liquid cooling is that it's quiet. There is only one fan needed: the fan on the radiator to cool the water. Thus, a liquid-cooled system can run extremely quietly.

Liquid cooling, while more efficient than air cooling and much quieter, has its drawbacks. Most liquid-cooling systems are more expensive than supplemental fan sets and require less-familiar components, such as a reservoir, pump, water block (or blocks), hose, and radiator.

The relative complexity of installing liquid-cooling systems, coupled with the perceived danger of liquids in close proximity to electronics, leads most computer owners to consider liquid cooling a novelty or a liability. The primary market for liquid cooling is high-performance systems and servers.

Summary

In this chapter, you began your survey of fundamental IT concepts with a tour inside the case of a computer. Considering that computers are collections of hardware, with software that lets you interact with that hardware, it makes sense to know what all the components inside that metal and plastic box do.

First, you looked at motherboards, CPUs, and memory. The motherboard is the most important component in the system because it connects everything and provides pathways for communication. If the motherboard fails, your computer will not work. Processors are analogous to the brain of the computer, but what they really do is math and logic operations. They do it very quickly, and they generate a ton of heat. Much like the motherboard, if the processor fails, you don't have a computer. Memory is critical too. It's a temporary storage area for data; that data is lost when your system is turned off. Generally speaking, the more memory your system has, the better.

Second, you looked at storage and expansion devices. Hard drives give you the permanent storage you need to make computers useful. They can be either conventional hard drives or newer solid-state drives. You can also store data on optical discs such as CD-ROMs, DVD-ROMs, or BD-ROMs. Expansion devices add functionality to your computers. Video cards let you see pictures on your screens, sound cards give you music, network cards are pretty much necessary to communicate with other computers, and modems, well, modems used to be important for getting on the Internet but are now nearly extinct.

Finally, I talked about power supplies and system cooling. Computers are electronics, so of course they need power. Power supplies take AC power from wall outlets and convert it into DC power that the computer components need. The use of all this electricity generates

heat, and too much heat can cause your components to fail. Most systems have built-in heat-mitigation systems such as fans and heat sinks. CPUs generate the most heat and therefore have the most pressing need to be adequately cooled.

Exam Essentials

Illustrate the basics of computing and processing. At a fundamental level, most users want computers to do four things: take input, provide processing on the input, produce output, and provide long-term storage.

Understand the purpose of motherboards, CPUs, and RAM. Motherboards connect all the components together and provide electrical pathways for data. CPUs perform mathematical and logic operations on data, and RAM is used as a temporary storage area for data that the processor and applications need.

Know the difference between conventional hard drives and solid-state drives. First, they both do the same thing, which is to provide long-term, nonvolatile data storage. Conventional hard disk drives have spinning platters and read/write heads, whereas SSDs use flash memory. SSDs are faster but generally more expensive than their conventional HDD counterparts.

Understand how to compare common data units of measure. A bit is either a 0 or a 1. Eight bits are one byte. Further, 1,000 bytes equal 1 kilobyte; 1,000 kilobytes equal 1 megabyte; 1,000 megabytes equal 1 gigabyte; 1,000 gigabytes equal 1 terabyte; and 1,000 terabytes equal 1 petabyte.

Know the features of optical discs. Optical discs store data but are not designed to replace hard drives. BD-ROMs store more data than DVD-ROMs, which store more than CD-ROMs.

Understand what different expansion devices do. Video cards produce images for display devices such as monitors. Audio (sound) cards produce sound. Network cards and modems are for communication. Network cards communicate via network cable or wirelessly, whereas modems use conventional telephone lines.

Understand the importance of system cooling. Computers generate heat. Processors in particular generate a lot of heat. They need to be cooled off to survive. Case fans are generally good enough for computers. CPUs require more active cooling methods, such as a combination of a heat sink and a fan or advanced systems such as liquid cooling.

Chapter 1 Written Lab

You can find the answers to the written labs in Appendix A.

In this lab, you are being given the task of buying a new computer for a relative. You've been given a strict budget. Based on that budget, you found three systems at the same price. Your relative will use the computer for browsing the Internet, paying bills, and occasionally playing some games. They also take a lot of family photos and videos and like to edit them on their computer. See Table 1.4 for the specifications of each of the three systems you found.

TABLE 1.4 Shopping comparison

Specification	System J	System L	System S
Processor	3.5 GHz AMD Ryzen 3	3.2 GHz Intel Core i5	2.5 GHz Intel Core i5
Cache memory	8 MB	6 MB	6 MB
System memory (RAM)	12 GB DDR4	8 GB DDR4	8 GB DDR4
RAM expandable to	Non-expandable	32 GB	32 GB
Hard drive type	SATA 7200 RPM	SATA SSD	SATA SSD
Hard drive size	1 TB	256 GB	256 GB
Optical drive	DVD±RW/CD-RW	DVD±RW/CD-RW	None
Graphics	AMD Radeon RX560	Intel integrated	Intel integrated
Video memory	2 GB dedicated	Shared	Shared
Sound card	7.1-channel integrated	5.1-channel integrated	7.1 channel integrated
Network card	Wireless AC, GBLAN	GBLAN	Wireless AC, GBLAN
Expansion slots	1 PCIe x1, 1 PCIe x16	2 PCIe x16	None
USB ports	8 USB 2.0	4 USB 2.0 4 USB 3.1	6 USB 3.1
Other ports	HDMI, VGA, DVI, DisplayPort	VGA, DVI	DVI, DisplayPort × 2

TABLE 1.4 Shopping comparison *(continued)*

Specification	System J	System L	System S
Media card reader	Yes	No	Yes
Operating system	Windows 10	Windows 7 Professional	Windows 10
Other			Small form factor

1. Based on the system specifications, which one would you recommend and why?
2. What specifications made you not choose the others?
3. If you were looking for a computer for someone who played a lot of online action games, would you change your recommendation? Why?
4. Which computer has the best expansion capabilities?

Review Questions

You can find the answers in Appendix B.

1. Which components in your computer store data? (Choose three.)
   - **A.** RAM
   - **B.** SSD
   - **C.** PCI
   - **D.** PSU
   - **E.** BD-ROM

2. What type of expansion card allows your computer to talk to other computers without wires?
   - **A.** Modem
   - **B.** NIC
   - **C.** PSU
   - **D.** PCIe

3. Which type of expansion slot provides the fastest data transfer speeds?
   - **A.** PCI
   - **B.** PCIe x1
   - **C.** PCIe x16
   - **D.** PCIe x64

4. Which of the following optical discs will store the most data?
   - **A.** CD-ROM
   - **B.** DVD-ROM DL
   - **C.** DVD-ROM DS
   - **D.** BD-ROM

5. What is the name of the component that controls communication between the processor and memory?
   - **A.** Motherboard
   - **B.** Chipset
   - **C.** CPU
   - **D.** Expansion bus

6. Your friend Joe wants to add another hard drive to his computer. What should he check to make sure that his system will support it?
   - **A.** PSU
   - **B.** Expansion slots
   - **C.** CPU
   - **D.** RAM

7. Which of the following devices is most likely to have a joystick port on it?
   - **A.** Video card
   - **B.** Sound card
   - **C.** Network card
   - **D.** Modem

8. You want to upgrade your computer to give it a faster boot time and more space for your files. What should you purchase?
   - **A.** RAM
   - **B.** HDD
   - **C.** SSD
   - **D.** CPU

9. If your computer runs low on RAM, what will it use instead?
   - **A.** Cache
   - **B.** SSD
   - **C.** Optical drive
   - **D.** Virtual memory

10. Which of the following are hard drive connector types? (Choose two.)
    - **A.** PATA
    - **B.** SATA
    - **C.** PCIe
    - **D.** AGP

11. When you turn on your computer, it tells you that it does not have the time and date set and asks you to enter setup. What likely needs to be replaced?
    - **A.** CMOS battery
    - **B.** BIOS chip
    - **C.** CPU
    - **D.** Time controller

12. A user named Monika wants to upgrade the memory in her laptop. What type of memory will she need?

A. DIMM

B. SODIMM

C. DDR3

D. DDR4

13. Which device is connected to the motherboard with a 24-pin block connector?

A. HDD

B. SSD

C. RAM

D. PSU

14. Which of the following is faster than RAM?

A. Cache

B. HDD

C. SSD

D. BD-ROM

E. None of the above

15. Which of the following processor types is most likely to be found in a smartphone?

A. 32-bit

B. GPU

C. Intel

D. ARM

16. You just installed more memory in your computer, but it's not recognized. Your friend suggests that you upgrade your BIOS. What's the best way to do this?

A. Order a new BIOS chip from the motherboard manufacturer.

B. Order a new BIOS chip from the memory manufacturer.

C. Flash the BIOS.

D. You can't upgrade a BIOS.

17. Which component inside a computer produces the most heat?

A. PSU

B. CPU

C. GPU

D. RAM

18. Which of the following uses a 240-pin connector?

- **A.** SODIMM
- **B.** DIMM
- **C.** SATA
- **D.** PATA

19. Your boss wants you to justify your suggestion to purchase solid-state hard drives. What are advantages of solid-state drives? (Choose three.)

- **A.** Faster than HDDs
- **B.** Generate less heat than HDDs
- **C.** Quieter than HDDs
- **D.** Cheaper than HDDs

20. Which of the following are communications devices for computers? (Choose two.)

- **A.** NIC
- **B.** Modem
- **C.** PCIe
- **D.** Sound card