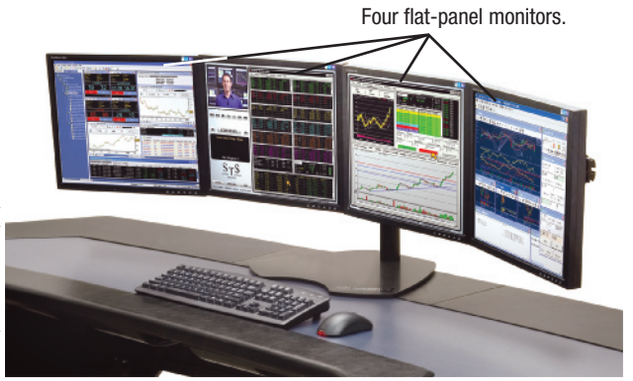


Courtesy CineMassive Displays

FIGURE 4-26
Flat-panel displays. The smaller footprint of a flat-panel display makes it possible to use multiple monitors together with a single computer to increase productivity.

While CRT monitors are still in use, most computers today (as well as most television sets, mobile phones, and other consumer devices containing a display screen) use the thinner and lighter **flat-panel displays**. As discussed in more detail shortly, flat-panel displays form images by manipulating electronically charged chemicals or gases sandwiched between thin panes of glass or other transparent material. Flat-panel displays take up less desk space, which makes it possible to use multiple monitors working together to increase the amount of data the user can view at one time (see Figure 4-26), increasing productivity without filling up an entire desk. Flat-panel displays also consume less power than CRTs and most use digital signals to display images (instead of the analog signals used with CRT monitors), which allows for sharper images. To use multiple monitors, you must have the necessary hardware to support it, such as a monitor port on a notebook computer or an appropriate video adapter, as discussed shortly. One disadvantage to a flat-panel display is that the images displayed on a flat-panel display sometimes cannot be seen clearly when viewed from certain angles.

Size and Aspect Ratio

Display device size is measured diagonally from corner to corner, in a manner similar to the way TV screens are measured. Most desktop computer monitors today are between 17 inches and 30 inches (though larger screens—up to 60 inches and more—are becoming increasingly common); notebook displays are usually between 14 inches and 17 inches; netbooks typically have 10-inch displays, and mobile tablet displays are typically between 7 inches and 10 inches. To better view DVDs and other multimedia content, many monitors today are *widescreen displays*, which conform to the *16:9 aspect ratio* of widescreen televisions, instead of the conventional *4:3 aspect ratio*.

FIGURE 4-27
Screen resolution. A higher screen resolution (measured in pixels) displays more content than a lower screen resolution, but everything is displayed smaller.

Screen Resolution

Regardless of the technology used, the screen of a display device is divided into a fine grid of tiny pixels, as previously discussed. The number of pixels used on a display screen determines the *screen resolution*, which affects the amount of information that can be displayed on the screen at one time. When a higher resolution is selected, such as 1,600 pixels horizontally by 900 pixels vertically for a widescreen computer monitor (written as 1,600 × 900 and read as *1600 by 900*), more information can fit on the screen, but everything will be displayed smaller than with a lower resolution, such as 1,280 × 768 (see Figure 4-27). The screen resolution on many computers today can be changed by users to match their preferences and the software being used. On Windows computers, display options are changed using the Control Panel. When multiple monitors are

1,280 × 768

1,600 × 900

Gjermund Alsos/Shutterstock.com

>**Flat-panel display.** A slim type of display device that uses electronically charged chemicals or gases instead of an electron gun to display images.

used, typically the screen resolution of each display can be set independently of the others. Very high-resolution monitors are available for special applications, such as viewing digital X-rays.

TIP

A growing trend is developing high-resolution, high-contrast displays with a wide viewing angle for mobile tablets and other mobile devices. For instance, Samsung is developing a new 10.1-inch panel that has a maximum screen resolution of 2560 x 1600 pixels; it is expected to ship by 2012.

Video Adapters, Interfaces, and Ports

The *video card* installed inside a computer or the integrated graphics component built directly into the motherboard or the CPU of the computer houses the *graphics processing unit* (*GPU*)—the chip devoted to rendering images on a display device. The video card or the integrated graphics component determines the graphics capabilities of the computer, including the screen resolutions available, the number of bits used to store color information about each pixel (called the *bit depth*), the total number of colors that can be used to display images, the number of monitors that can be connected to the computer via that video card or component, and the types of connectors that can be used to connect a monitor to the computer. Video cards typically contain a fan and other cooling components to cool the card. Most video cards also contain memory chips (typically called *video RAM* or *VRAM*) to support graphics display, although some do not and are designed to use a portion of the computer's regular RAM as video RAM instead. To support higher resolutions, higher bit depths, and a greater number of colors, a sufficient amount of video RAM is required. Most video cards today contain between 256 MB and 2 GB of video RAM. A typical video card is shown in Figure 4-28.

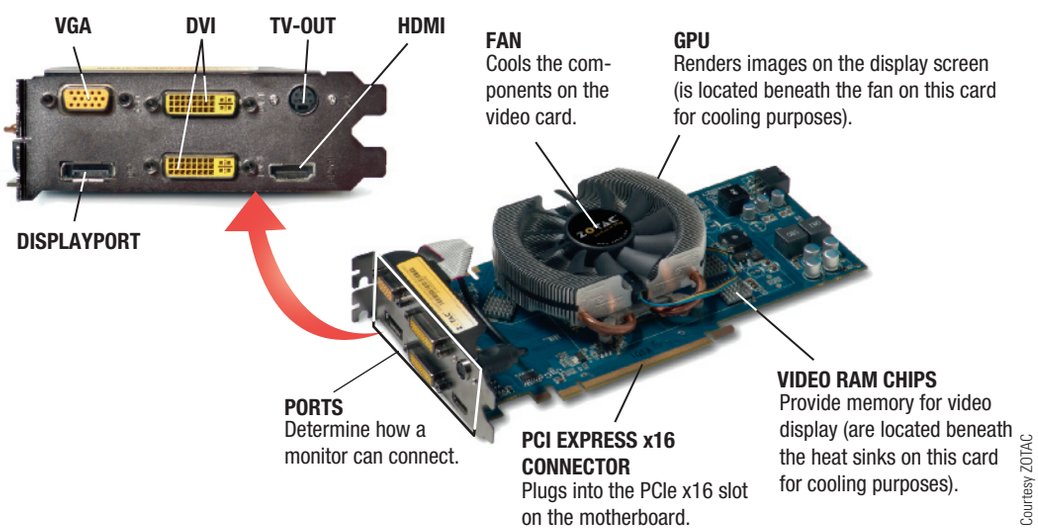


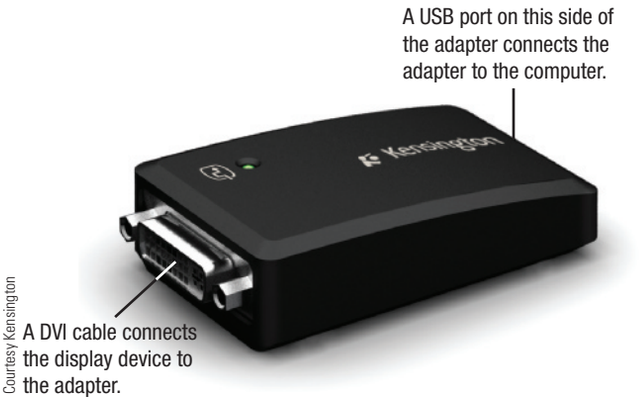
FIGURE 4-28
Video cards. Provide a connection to a monitor, as well as determine video capabilities.

The three most common types of interfaces used to connect a monitor to a computer are *VGA* (*Video Graphics Array*), *DVI* (*Digital Visual Interface*), and *HDMI* (*High-Definition Multimedia Interface*). VGA uses a 15-pin D-shaped connector and it is commonly used with CRT monitors and many flat-panel monitors to transfer analog images to the monitor. DVI uses a more rectangular connector and it is frequently used with flat-panel displays to allow the monitor to receive clearer, more reliable digital signals than is possible with a VGA interface. HDMI uses a smaller connector and can be used with display devices that support high-definition content. A newer type of connector is *DisplayPort*, which is designed to eventually replace VGA and DVI ports on computers, video cards, and monitors. In fact, Apple already includes a smaller version—referred to as a *Mini DisplayPort*—on its newest MacBooks. The ports used with each of these possible connections are illustrated in Figure 4-28.

A video card or integrated video component in a desktop computer will have at least one port exposed through the system unit case to connect a monitor. Notebook computers and other computers with a built-in display typically contain a monitor port to connect a second monitor to the computer. A relatively new option for connecting additional monitors to a computer is using the computer's USB port. *USB monitors* (monitors designed to connect via a USB port) can be added to a computer even if that computer does not have a video card that supports multiple monitors. Conventional monitors can also connect to a computer via a USB port if a *USB display adapter* (such as the one shown

ONLINE VIDEO

Go to the Chapter 4 page of the **UC14 CourseMate** to watch the "Connecting and Using Three DisplayLink USB Monitors" video clip.



Courtesy Kensington

FIGURE 4-29
A USB display adapter.

in Figure 4-29) or a peripheral device (such as a docking station) that includes USB display capabilities is used. A USB connection allows multiple monitors to be connected easily to a device. For instance, many USB monitors are designed to be *daisy-chained* together so they all connect via a single USB port, and multiple USB display adapters (such as the one shown in Figure 4-29) can typically be used to connect multiple conventional monitors to a single computer using multiple USB ports or a USB hub.

Wired vs. Wireless Displays

Most computer monitors today are *wired displays*; that is, monitors that are physically connected to the system unit via a cable. Some display devices—such as digital photo frames, e-book readers, and some computer monitors and television sets, however—are designed to be wireless. *Wireless displays* connect to a computer using a wireless networking connection such as *Wi-Fi*, *Bluetooth*, or a special wireless standard designed for transmitting multimedia (as discussed in more detail in Chapter 7); typically display content from a computer located within range of the monitor; and may support touch or pen input for when the display is used away from the computer.

2D vs. 3D Displays

While conventional displays are *two-dimensional* (*2D*) devices, recent improvements in flat-panel display technology and graphics processing have led to several emerging *three-dimensional* (*3D*) *output devices*, including *3D display screens* for computers. While traditional 3D displays (and most 3D televisions today) require special 3D glasses, the newest 3D computer display products use filters, prisms, multiple lenses, and other technologies built into the display screen to create the 3D effect and, as a result, do not require 3D glasses. Some 3D displays resemble conventional monitors; others are shaped differently, such as the dome-shaped *Perspecta* 3D display that is used primarily for medical imaging. 3D consumer products are increasingly available as well, such as the Nintendo 3DS handheld gaming device.

TIP

Researchers at Intel Labs predict that much of the Internet will use realistic-looking 3D applications by 2020.

Courtesy Lumus Ltd.

FIGURE 4-30
Wearable displays.

Wearable Displays

While most displays are designed to be looked at from at least several inches away, some displays are designed to be wearable. A *wearable display* (such as the eyeglasses-based display shown in Figure 4-30) projects the image from a mobile device (usually a mobile phone or portable digital media player) to a display screen built into the glasses. Typically, the technology allows the user to see the image as if it is on a distant large screen display, and many wearable displays overlay the projected image on top of what the user is seeing in real time in order to provide *situational awareness* while the display is being used. While wearable displays have entertainment applications, there are also wearable displays designed for soldiers and other mobile workers.

Touch and Gesture Capabilities

As discussed earlier in this chapter, it is increasingly common for monitors and display screens to support touch input. Touch screen displays are commonly used with personal computers, as well as with consumer kiosks, portable gaming devices, mobile phones, portable digital media players, and other consumer devices. Gesture input is widely used with these products as well. According to Francis MacDougall, Co-Founder and Chief Technology Officer of GestureTek, that company is working with major

telecom companies and electronics manufacturers to enable gesture control for their set-top boxes, consoles, and other consumer electronics devices.

Flat-Panel Display Technologies

The most common flat-panel technologies include *liquid crystal display* (*LCD*), various types of *light emitting diode* (*LED*), and *gas plasma*. One emerging flat-panel technology is *interferometric modulator display* (*IMOD*). These display technologies are discussed next. Another technology used by some flat-panel displays (including e-book readers, some digital signage systems, and the display on some wristwatches and USB flash drives) is *e-paper* technology, discussed in the Inside the Industry box.

ONLINE VIDEO

Go to the Chapter 4 page of the **UC14 CourseMate** to watch the "How E-Ink Works" video clip.

Liquid Crystal Displays (LCDs)

A **liquid crystal display (LCD)** uses charged liquid crystals located between two sheets of clear material (usually glass or plastic) to light up the appropriate pixels to form the image on the screen. Several layers of liquid crystals are used, and, in their normal state, the liquid crystals are aligned so that light passes through the display. When an electrical charge is applied to the liquid crystals (via an electrode grid layer contained within the LCD panel), the liquid crystals change their orientation or "twist" so that light cannot pass through the display, and the liquid crystals at the charged intersections of the electrode grid appear dark. Color LCD displays use a color filter that consists of a pattern of red, green, and blue *subpixels* for each pixel. The voltage used controls the orientation (twisting) of the liquid crystals and the amount of light that gets through, affecting the color and shade of that pixel—the three different colors blend to make the pixel the appropriate color.

LCD displays can be viewed only with reflective light, unless light is built into the display. Consequently, LCD panels used with computer monitors typically include a light inside the panel, usually at the rear of the display—a technique referred to as *backlighting*. While fluorescent lamps are used to backlight conventional LCD screens, today's screens are increasingly using *LED* backlighting instead for increased energy efficiency. An emerging option is backlighting LCDs using *quantum dot technology*, a nanotechnology development that enables LCDs to display about 50% more color than conventional LCDs. LCDs are currently the most common type of flat-panel technology used for small- to medium-sized computer monitors (the monitors shown in Figure 4-26 are LCD monitors). However, it is expected that, someday, LCD monitors may be completely replaced by newer technologies, such as the *LED technologies* discussed next.

Light Emitting Diode (LED) and Organic Light Emitting Diode (OLED) Displays

LED (*light emitting diode*) *technology* is another flat-panel technology commonly used with consumer products, such as alarm clocks, Christmas lights, car headlights, and more. As already mentioned, LEDs are also used to backlight LCD panels, although another form of LED—*OLED*—may eventually replace LCD technology entirely.

Organic light emitting diode (OLED) displays use layers of organic material, which emit a visible light when electric current is applied. Because they emit a visible light, OLED displays do not use backlighting. This characteristic makes OLEDs more energy efficient than conventional LCDs and LED-backlit LCDs and lengthens the battery life of portable devices using OLED displays. Other advantages of OLEDs are that they are thinner than LCDs, they have a wider viewing angle than LCDs and so displayed content is visible from virtually all directions, and their images are brighter and sharper than LCDs. OLED displays are incorporated into many digital cameras, mobile phones, portable digital media

>**Liquid crystal display (LCD).** A type of flat-panel display that uses charged liquid crystals to display images. >**Organic light emitting diode (OLED) display.** A type of flat-panel display that uses emissive organic material to display brighter and sharper images.

INSIDE THE INDUSTRY

E-Paper

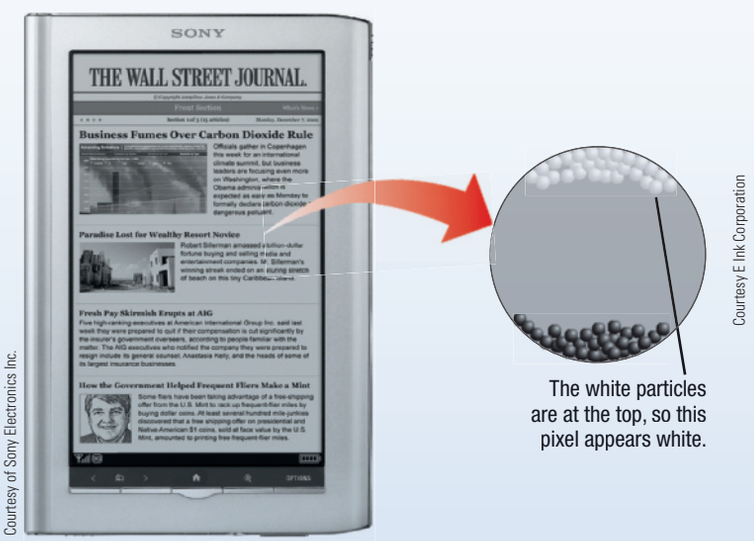
Electronic paper (*e-paper*) is a technology used with flat panel display devices that attempts to mimic the look of ordinary printed paper. The purpose of an *Electronic Paper Display* (*EPD*) is to give the user the experience of reading from paper, while providing them with the ability to update the information shown on the device electronically. EPDs display content in high-contrast, so they can be viewed in direct sunlight. They also require much less electricity than other types of displays, since they don't require a backlight and they don't require power to maintain the content shown on the display—they only require power to change the content. Because the content stored in an EPD can be erased when it is no longer needed and then replaced with new content, EPDs are more environmentally friendly than conventional paper documents. An additional benefit is portability; an *e-book reader* (such as the *Amazon Kindle* and the *Sony Reader* shown in the accompanying photograph), for instance, can hold over a thousand books stored in electronic format in a device about the size of a paperback novel. In fact, with an e-book reader, you could carry a small library in your backpack. New e-books are transferred to the e-book reader via a flash memory card or a wireless (typically Wi-Fi or 3G) download.

E-paper is also widely used for *e-signs*, which look like ordinary paper signs, but their text can be changed wirelessly. Their low power consumption means that e-signs can run off battery power for an extended period of time, even with moving data. Some e-signs don't even require a battery; instead, the wireless signal used to transmit data to the display is strong enough to update the sign content. Other retail applications currently on the market include e-paper shelf price tags that can communicate electronically with the store's database so the current price is always displayed, e-paper displays on wristwatches and USB flash drives, destination displays on trains, and e-paper newspapers that can be updated periodically during the day to reflect the latest news. Some e-book readers can also receive newspaper content (in addition to e-book content), check out and download electronic library books from the public library, and display Web pages.

E-paper technology used with fabric, plastic, metal, and other materials is in development and is expected to be used to enable keyboards to be printed on military uniform sleeves, light switches to be printed onto wallpaper, and radio circuitry and controls to be printed onto clothing and other everyday objects. It may also allow e-paper to be used on billboards, T-shirts, and even paint for easy redecorating, as well as regular-sized e-paper that can be inserted into a special computer printer to be printed electronically and then reused over and over. One improvement that has already occurred is the incorporation of touch and pen input with e-paper displays. For instance, both touch and pen input can be used in conjunction with the Sony Reader shown in the accompany photograph to flip the "pages" of the book and otherwise control the device, as well as to make notes on the pages or highlight passages of text.

So how does e-paper work? It is based on a display technology called *electrophoretic*, which was invented and is now manufactured and marketed by E Ink® Corporation. An electrophoretic display contains *electronic ink*—essentially charged ink that consists of millions of tiny beads or *microcapsules* about half the diameter of a human hair. These beads contain positively charged white particles and negatively charged black particles suspended in a clear fluid. When voltage is applied to the beads (through the circuitry contained within the display), either the white or the black particles rise to the top and the opposite colored particles are pulled to the bottom of the bead, depending on the polarity of the charge applied. Consequently, the beads in each pixel appears to be either white or black (see the accompanying illustration) and remain in that state until another transmission changes the pattern.

Next on the horizon? Colored e-ink displays that use a colored filter on top of the black and white microcapsules are beginning to be available, and faster screen responses so the devices can support video are in the works.



Courtesy of Sony Electronics Inc.

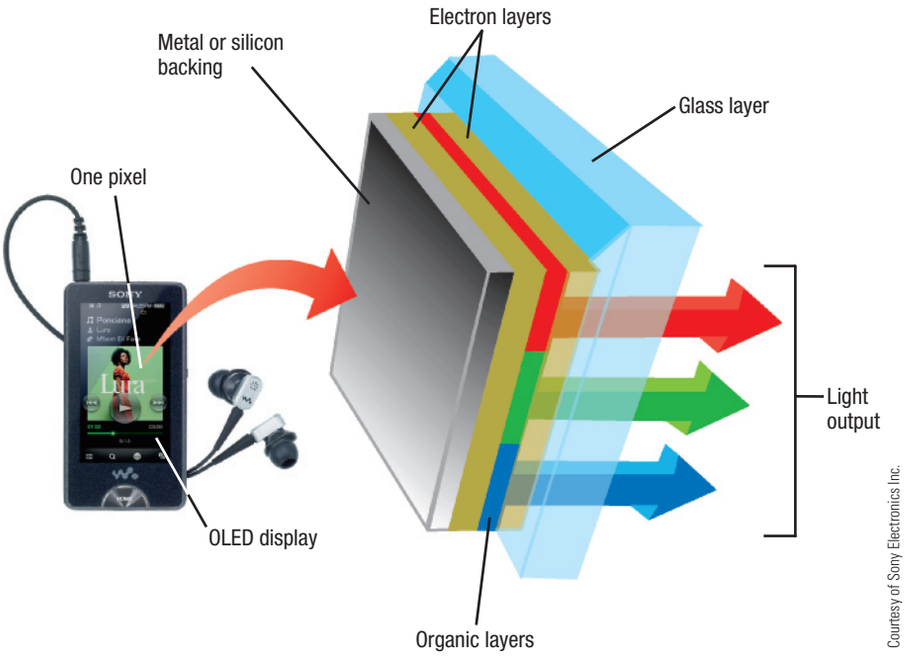
Courtesy E Ink Corporation

AN E-BOOK READER

AN E-INK MICROCAPSULE

players, and other consumer devices (see Figure 4-31). They are also beginning to appear in television and computer displays.

There are also a few special types of OLEDs that support applications not possible with CRT, LCD, or traditional LED technology. For instance, *flexible OLED* (*FOLED*) displays—a technology developed by Universal Display Corporation—are OLED displays built on flexible surfaces, such as plastic or metallic foil. Flexible displays using FOLED technology—such as displays for portable computers and mobile devices that can roll up when not in use (see Figure 4-32)—are being developed by several companies. Other possible uses for flexible screens include making lighter displays for computers and mobile devices, integrating displays on military uniform sleeves, and allowing retractable wall-mounted large screen displays.

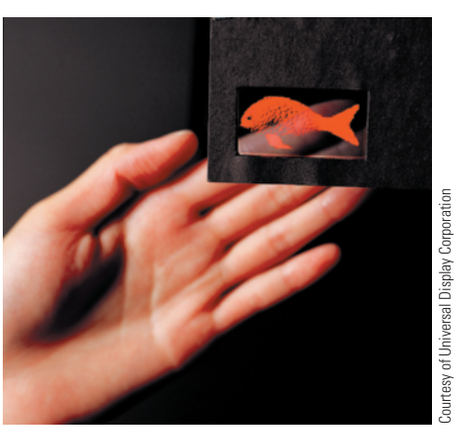


Courtesy of Sony Electronics Inc.

FIGURE 4-31
How OLED displays work. Each pixel on an OLED display emits light in the necessary color.

Another form of OLED developed by Universal Display Corporation is *transparent OLED* (*TOLED*). TOLED displays are transparent and can emit light toward the top and bottom of the display surface. The portion of the display that does not currently have an image displayed (and the entire display device when it is off) is nearly as transparent as glass, so the user can see through the screen (refer again to Figure 4-32). TOLED technology opens up the possibility of displays on home windows, car windshields, helmet face shields, and other transparent items. A third type of OLED developed by Universal Display Corporation is *Phosphorescent OLED* or *PHOLED*. The term *phosphorescence* refers to a process that results in much more conversion of electrical energy into light instead of heat; with phosphorescence, OLEDs can be up to four times more efficient than without it. Consequently, PHOLED technology is especially appropriate for use on mobile devices, consumer electronics, and other devices where power consumption is an important concern.

FOLEDS
Used to create flexible displays on plastic or another type of flexible material.



Courtesy of Universal Display Corporation

TOLEDS
Used to create transparent displays.

FIGURE 4-32
Special types of OLEDs.

Interferometric Modulator (IMOD) Displays

Another emerging flat-panel display technology is *interferometric modulator (IMOD) displays*. Designed initially for mobile phones and other portable devices, an IMOD display is essentially a complex mirror that uses external light—such as from the sun or artificial light inside a building—to display images. Because IMOD displays are utilizing light

Courtesy of QUALCOMM MEMS Technologies, Inc.

FIGURE 4-33
An IMOD display is bright and readable, even in direct sunlight.

instead of fighting it the way LCD displays do, images are bright and clear even in direct sunlight (see Figure 4-33). And, because backlighting isn't used, power consumption is much less than what is needed for LCD displays. In fact, similar to e-paper, devices using IMOD displays use no power unless the image changes so they can remain on at all times without draining the device battery. Beginning to be used with mobile devices, IMODs could eventually be used for outdoor television screens, large digital signs, and other outdoor display devices that normally consume a great deal of power.

Plasma Displays

Plasma displays use a layered technology like LCD and OLED and look similar to LCD displays, but they use a layer of gas between two plates of glass, instead of liquid crystals or organic material. A phosphor-coated screen (with red, green, and blue phosphors for each pixel) is used, and an electron grid layer and electronic charges are used to make the gas atoms light up the appropriate phosphors to create the image on the screen. While plasma technology has traditionally been used with the very large displays used by businesses, as well as many large screen televisions, it is slowly being replaced by LCDs.

Data and Multimedia Projectors

A **data projector** is used to display output from a computer to a wall or projection screen. Conventional data projectors are often found in classrooms, conference rooms, and similar locations and can be freestanding units or permanently mounted onto the ceiling. While most data projectors connect via cable to a computer, *wireless projectors* that use a Wi-Fi connection are available. Some projectors (such as the one shown in Figure 4-34) also include an *iPod dock* to connect an iPod in order to project videos stored on that device.

For projecting content to a small audience while on the go, small *pico projectors* are available. These pocket-sized projectors typically connect to a mobile phone, portable computer, or portable digital media player to enable the device to project an image (such as a document, presentation, or movie) onto a wall or other flat surface from up to 12 feet

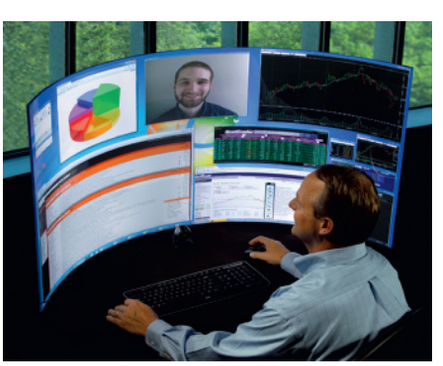
FIGURE 4-34
Data projectors.

Courtesy of ViewSonic Corporation

CONVENTIONAL DATA PROJECTORS
Frequently used for both business and classroom presentations.

Courtesy Microvision, Inc.

PICO PROJECTORS
Images from a mobile device (such as the mobile phone shown here) are projected onto any surface.



Courtesy of Scalable Display Technologies

TILED PROJECTORS
Project a single seamless image using multiple projectors.

>**Plasma display.** A type of flat-panel display that uses layers of gas to display images; most often used on large displays. >**Data projector.** A display device that projects all computer output to a wall or projection screen.

away (refer again to Figure 4-34). Pico projectors typically create a display up to 10 feet wide in order to easily share information stored on the device with others on the go without having to crowd around a tiny screen. They can also be built into mobile devices. Another type of data projector is designed to project actual 3D projections or *holograms*. For instance, holograms of individuals and objects can be projected onto a stage for a presentation and hologram display devices can be used in retail stores, exhibitions, and other locations to showcase products or other items in 3D. An emerging projector application is the use of multiple projectors to display content from a single source (such as a presentation or Windows desktop) onto a flat or curved screen that, unlike a display using multiple monitors, is seamless (see Figure 4-34). The primary market for these *tiled projectors* is expected to be schools, museums, meeting rooms, and other locations where large high-resolution displays are needed, as well as for videoconferencing and simulation/training applications.

HW

PRINTERS

Instead of the temporary, ever-changing soft copy output that a monitor produces, **printers** produce *hard copy*; that is, a permanent copy of the output on paper. Most desktop computers are connected to a printer; portable computers can use printers as well.

Printer Characteristics

Printers differ in a number of important respects, such as the technology used, size, print quality, speed, and type of connection used. Some general printer characteristics are discussed next, followed by a look at the most common types of printers.

Printing Technology

Printers produce images through either impact or nonimpact technologies. *Impact printers*, like old ribbon typewriters, have a print mechanism that actually strikes the paper to transfer ink to the paper. For example, a *dot-matrix printer* (see Figure 4-35) uses a *printhead* consisting of pins that strike an inked ribbon to transfer the ink to the paper—the appropriate pins are extended (and, consequently, strike the ribbon) as the printhead moves across the paper in order to form the appropriate words or images. Impact printers are used today primarily for producing multipart forms, such as invoices, packing slips, and credit card receipts.

Most printers today are *nonimpact printers*, meaning they form images without the print mechanism actually touching the paper. Nonimpact printers usually produce higher-quality images and are much quieter than impact printers are. The two most common types of printers today—*laser printers* and *ink-jet printers*—are both nonimpact printers. As discussed in more detail shortly, laser printers form images with *toner powder* (essentially ink powder) and ink-jet printers form images with liquid ink. Both impact and nonimpact printers form images with dots, in a manner similar to the way monitors display images with pixels. Because of this, printers are very versatile and can print text in virtually any size, as well as print photos and other graphical images. In addition to paper, both impact and nonimpact printers can print on transparencies, envelopes, mailing labels, and more.

Courtesy InfoPrint Solutions Company

FIGURE 4-35
Dot-matrix printers. Dot-matrix printers are impact printers; today they are typically high-speed printers used in manufacturing, shipping, or similar applications.

>**Printer.** An output device that produces output on paper.

Paul Broadbent/Shutterstock.com

FIGURE 4-36
Color printing. Color printers require multiple color cartridges or cartridges that contain multiple colors.

Color vs. Black and White

Both *color printers* and *black-and-white printers* are available. Color printers work similarly to black-and-white printers, except that, instead of using just black ink, they also use cyan (blue), magenta (red), and yellow ink (see Figure 4-36). Color printers either apply all of the colors in one pass or go through the entire printing process multiple times, applying one color during each pass. Color printers are often used in homes (to print photographs, greeting cards, flyers, and more). Businesses may use black-and-white printers for output that does not need to be in color (since it is less expensive and faster to print in black and white) and color printers for output that needs to be in color (such as product brochures and other colorful marketing materials).

Personal vs. Network Printers

Printers today can be designated as *personal printers* (printers designed to be connected directly to a single computer) or *network printers* (printers designed to be connected directly to a home or an office network). Personal printers can be shared over a home network if the computer to which the printer is connected is powered up and the printer is designated as a shared device. However, network printers are designed to connect directly to a network (instead of to a single computer) so they can be used by anyone connected to the network via a wired or wireless connection. In addition, many network printers today are designed for high-volume office printing and often include other capabilities, such as to collate, staple, hole-punch, and print on both sides of the page (referred to as *duplex printing*). Networks are discussed in detail in Chapter 7.

TIP

To save money, consider buying *recharged* (refilled) toner cartridges when your laser printer cartridge runs out of toner powder. Recharged cartridges typically cost about one-third less than new cartridges and last at least as long.

Print Resolution

Most printing technologies today form images with dots of liquid ink or flecks of toner powder. The number of dots per inch (dpi)—called the *print resolution*—affects the quality of the printed output. Printers with a higher print resolution tend to produce sharper text and images than printers with a lower resolution tend to produce, although other factors (such as the technology and number of colors used) also affect the quality of a printout. Guidelines for acceptable print resolution are typically 300 dpi for general-purpose printouts, 600 dpi for higher-quality documents, 1,200 dpi for photographs, and 2,400 dpi for professional applications.

Print Speed

Print speed is typically measured in *pages per minute* (*ppm*). How long it takes a document to print depends on the actual printer being used, the selected print resolution, the amount of memory inside the printer, and the content being printed. For instance, pages containing photographs or other images typically take longer to print than pages containing only text, and full-color pages take longer to print than black-and-white pages. Common speeds for personal printers today range from about 20 to 35 ppm; network printers typically print from 30 to 65 ppm.

VIDEO PODCAST

Go to the Chapter 4 page of the **UC14 CourseMate** to download or listen to the "How To: Print from Your Cell Phone or iPad" video podcast.

Connection Options

Most personal printers today connect to a computer via a USB connection; many have the option of connecting via a wired or wireless networking connection as well. In addition, many personal printers can receive data to be printed via a flash memory card, a cable connected to a digital camera (such as for printers and cameras adhering to the *PictBridge standard*), or a *camera docking station* (a device connected to a printer into which a digital camera is placed so images stored in the camera can be printed). Most network printers are connected directly to a wired or wireless network.

Multifunction Capabilities

Some printers today offer more than just printing capabilities. These units—referred to as **multifunction devices (MFDs)** or *all-in-ones*—typically copy, scan, fax, and print documents (see Figure 4-37). MFDs can be based on ink-jet printer or laser printer technology, and they are available as both color and black-and-white devices. Although multifunction devices have traditionally been desktop units used in small offices and home offices, larger workgroup multifunction devices are now available that are designed for multiple users, either as stand-alone stations or as networked units.

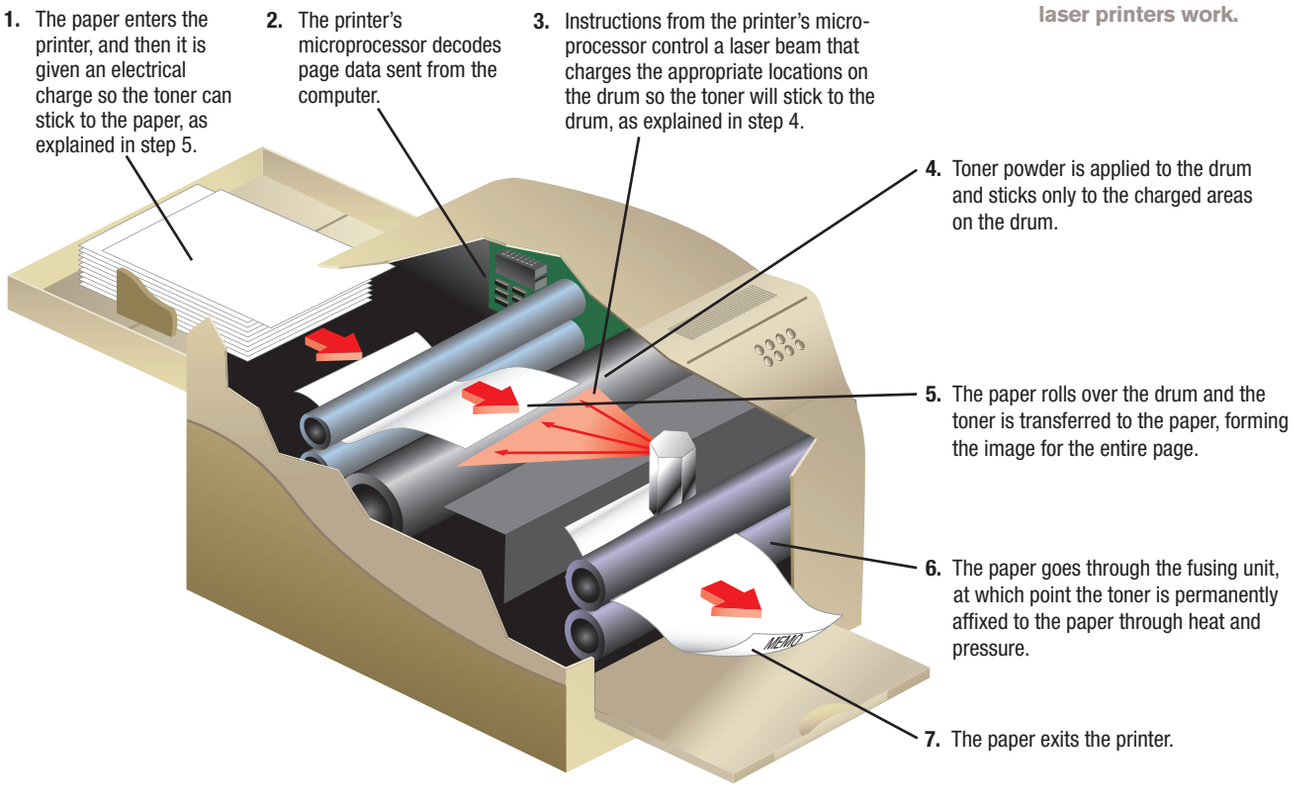
Courtesy Epson America

FIGURE 4-37
A multifunction device (MFD).

Laser Printers

Laser printers are the standard for business documents and come in both personal and network versions; they are also available as both color and black-and-white printers. To print a document, the laser printer first uses a laser beam to charge the appropriate locations on a drum to form the page's image, and then *toner powder* (powdered ink) is released from a *toner cartridge* and sticks to the drum. The toner is then transferred to a piece of paper when the paper is rolled over the drum, and a heating unit fuses the toner powder to the paper to permanently form the image (see Figure 4-38). Laser printers print one entire page at a time and are typically

FIGURE 4-38
How black-and-white laser printers work.



© Cengage Learning

>**Multifunction device (MFD).** A device that offers multiple functions (such as printing, scanning, and faxing) in a single unit. >**Laser printer.** An output device that uses toner powder and technology similar to that of a photocopier to produce images on paper.

faster and have better quality output than *ink-jet printers*, discussed next. Common print resolutions for laser printers are between 600 and 2,400 dpi; speeds for personal laser printers range from about 15 to 35 ppm. Black-and-white laser printers start at about $100; color laser printers start at about $300.

Ink-Jet Printers

Ink-jet printers form images by spraying tiny drops of liquid ink from one or more *ink cartridges* onto the page, one printed line at a time (see Figure 4-39). Some printers print with one single-sized ink droplet; others print using different-sized ink droplets and using multiple nozzles or varying electrical charges for more precise printing. The printhead for an ink-jet printer typically travels back and forth across the page, which is one reason why ink-jet printers are slower than laser printers. However, an emerging type of ink-jet printer uses a printhead that is the full width of the paper, which allows the printhead to remain stationary while the paper feeds past it. These printers are very fast, printing up to 60 ppm for letter-sized paper.

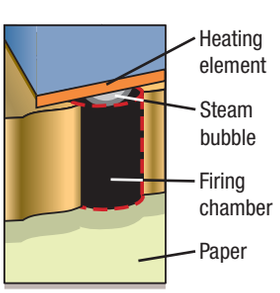
Because they are relatively inexpensive, have good-quality output, and can print in color, ink-jet printers are usually the printer of choice for home use. With the use of special photo paper, ink-jet printers can also print photograph-quality digital photos. Starting at less than $50 for a simple home printer, ink-jet printers are affordable, although the cost of the replaceable ink cartridges can add up, especially if you do a lot of color printing.

FIGURE 4-39
How ink-jet printers work.

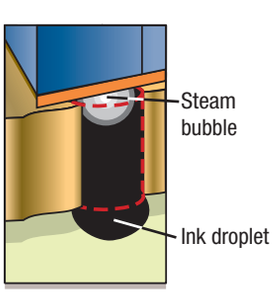
Each ink cartridge is made up of multiple tiny ink-filled firing chambers; to print images, the appropriate color ink is ejected through the appropriate firing chamber.

Courtesy Epson America

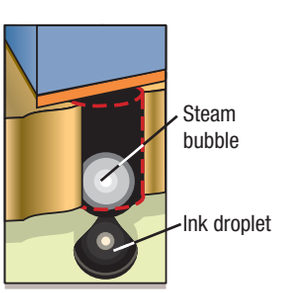
INK-JET PRINTER



1. A heating element makes the ink boil, which causes a steam bubble to form.



2. As the steam bubble expands, it pushes ink through the firing chamber.



3. The ink droplet is ejected onto the paper and the steam bubble collapses, pulling more ink into the firing chamber.

>**Ink-jet printer.** An output device that sprays droplets of ink to produce images on paper.

In addition to being used in computer printers, ink-jet technology is being applied to a number of other applications. For instance, ink-jet technology may eventually be used for dispensing liquid metals, aromas, computer chips and other circuitry, and even "printing" human tissue and other organic materials for medical purposes.

Special-Purpose Printers

Although both laser and ink-jet printers can typically print on a variety of media—including sheets of labels, envelopes, transparencies, photo paper, and even fabric, in addition to various sizes of paper—some printers are designed for a particular purpose. Some of the most common *special-purpose printers* are discussed next and illustrated in Figure 4-40.

Photo Printers

Photo printers are color printers designed to print photographs. Although many photo printers are connected to a computer to print photos stored on the hard drive, most photo printers also can print photos directly from a digital camera or a storage medium (such as a flash memory card) without transferring the photos to a computer first. Often, photo printers have a

FIGURE 4-40
Special-purpose printers.

PHOTO PRINTERS
Used to print digital photographs in a variety of sizes.

BARCODE PRINTERS
Used to print barcoded labels. Some printers can also program RFID tags when they are embedded inside the barcoded labels.

PORTABLE PRINTERS
Used to print items (such as shelf labels shown here) while on the go.

INTEGRATED PRINTERS
This printer uses no ink and is integrated into the digital camera to print digital photographs.

WIDE-FORMAT PRINTERS
Used for printouts that are too big for a standard-sized printer.

3D PRINTERS
Used to print items (such as plastic parts or models) in 3D.

>**Photo printer.** An output device designed for printing digital photographs.

TIP

In addition to printing your digital photos, many retail and Internet photo services can print digital photos on shirts, mugs, playing cards, calendars, mouse pads—even valid U.S. postage stamps.

preview screen to allow for minor editing and cropping before printing, but it is usually more efficient to do extensive editing on a computer. Some photo printers can print a variety of photo paper sizes; others—sometimes called *snapshot printers*—print only on standard 4 by 6-inch photo paper. In addition to photo printers designed for home use (like the one shown in Figure 4-40), there are also professional photo printers used by businesses and photo processing companies. Although home photo printers offer the convenience of printing digital photos at home and whenever the need arises, the cost per photo is typically higher than using a photo printing service at a retail store or an Internet photo printing service.

Barcode, Label, and Postage Printers

Barcode printers enable businesses and other organizations to print custom barcodes on price tags, shipping labels, and other documents for identification or pricing purposes. Most barcode printers can print labels in a variety of barcode standards; some can also encode RFID tags embedded in labels. For other types of labels, such as for envelopes, packages, and file folders, regular *label printers* may come in handy. Some special-purpose label printers referred to as *postage printers* can print *electronic postage* (also called *e-stamps*). E-stamps are valid postage stamps that can be printed once a postage allotment has been purchased via the Internet or from an e-stamp vendor; postage values are deducted from your allotment as you print the e-stamps. Some e-stamp services also allow stamps to be printed directly onto shipping labels and envelopes using laser or ink-jet printers.

Portable and Integrated Printers

Portable printers are small, lightweight printers that can be used on the go, usually with a notebook computer or mobile device, and they connect via either a wired or wireless connection. Portable printers that can print on regular-sized (8.5 by 11-inch) paper are used by businesspeople while traveling; portable receipt, label, and barcode printers are used in some service professions (see Figure 4-40). Printers can also be integrated into other devices. For instance, the digital camera shown in Figure 4-40 contains an *integrated printer* that is based on a new technology developed by *ZINK* (for "zero ink") *Imaging*. This printer uses no ink; instead, it uses special paper that is coated with special color dye crystals. Before printing, the embedded dye crystals are clear, so *ZINK Paper* looks like regular white photo paper. The ZINK printer uses heat to activate and colorize these dye crystals when a photo is printed, creating a full-color image. In addition to being integrated into a variety of consumer electronics devices, including digital cameras and digital picture frames, stand-alone printers that use ZINK Paper are also available.

Wide-Format Ink-Jet Printers

To print charts, drawings, maps, blueprints, posters, signs, advertising banners, and other large documents in one piece, a larger printer (such as the one shown in Figure 4-40) is needed. Today, most large format printers (sometimes called *plotters*) are *wide-format ink-jet printers*, which are designed to print documents from around 24 inches to 60 inches in width. Although typically used to print on paper, some wide-format ink-jet printers can print directly on fabric and other types of materials.

3D Printers

When 3D output is required, such as to print a 3D model of a new building or prototype of a new product, **3D printers** (see Figure 4-40) can be used. Instead of printing on paper,

>**Barcode printer.** An output device that prints barcoded documents. >**Portable printer.** A small, lightweight printer designed to be used while on the go. >**3D printer.** An output device designed to print three-dimensional objects, such as product prototypes.

these printers typically form output in layers using molten plastic during a series of passes to build a 3D version of the desired output—a process called *fused deposition modeling* (*FDM*®). Some printers can produce multicolor output; others print in only one color and need to be painted by hand if color output is desired.

AUDIO OUTPUT

Audio output includes voice, music, and other audible sounds. **Computer speakers**, the most common type of audio output device, connect to a computer and provide audio output for computer games, music, video clips and TV shows, Web conferencing, and other applications. Computer speaker systems resemble their stereo system counterparts and are available in a wide range of prices. Some speaker systems (such as the one shown in Figure 4-41) consist of only a pair of speakers. Others include additional speakers and a subwoofer to create better sound (such as surround sound) for multimedia content. Instead of being stand-alone units, the speakers for some desktop computers are built directly into, or permanently attached to, the monitor. Portable computers and mobile devices typically have speakers integrated into the device; mobile devices can also be connected to a stereo system or other consumer device (such as the treadmill shown in Figure 4-41) that contains an *iPod/MP3 dock* and integrated speakers designed to be used to play music stored on a portable digital media player. In addition, many cars can connect a portable digital media player or other mobile device to the car's stereo system. Typically, mobile devices are connected to a speaker system via the device's headphone jack, dock connection, or USB port. There are also wireless speakers available to play audio obtained from a home entertainment system or to deliver (via a home network) music from your digital music library or the Internet.

Headphones can be used instead of speakers when you don't want the audio output to disturb others (such as in a school computer lab or public library). **Headsets** (see Figure 4-41) are headphones with a built-in microphone and are often used when dictating to a computer and when making telephone calls or participating in Web conferences using a computer; wireless headsets are commonly used in conjunction with mobile phones. Even smaller than headphones are the *earphones* and *earbuds* often used with portable digital media players, handheld gaming devices, and other mobile devices.

FIGURE 4-41
Audio output devices.


Courtesy of Altec Lansing

COMPUTER SPEAKERS
Used to output sound from a computer.


Courtesy NordicTrack

IPOD/MP3 DOCK
Used to output sound from a portable digital media player.


AXL/Shutterstock.com

HEADSETS
Used when both voice input and audio output are required.

>**Computer speakers.** Output devices connected to computers that provide audio output. >**Headphones.** A personal audio output device used by an individual so only he or she can hear the sound; headphones with a built-in microphone are typically referred to as **headsets**.

SUMMARY

KEYBOARDS

Chapter Objective 1: Explain the purpose of a computer keyboard and the types of keyboards widely used today.

Most people use a **keyboard** to input data into a personal computer. Keyboards typically include the standard alphanumeric keys, plus other keys for special purposes. Many mobile phones and other mobile devices include a keyboard today—if not, a *portable keyboard* can often be used. *Wireless keyboards* are also available.

POINTING AND TOUCH DEVICES

Chapter Objective 2: List several different pointing devices and describe their functions.

Pointing devices are hardware devices that move an on-screen *mouse pointer* or similar indicator. The most widely used pointing device is the **mouse**. Another common pointing device is the **stylus**, which is used with pen-based computers, many mobile devices, and *digital writing systems* to input handwritten data and to select options; with **handwriting recognition** technology, the input can be converted to typed text. Use of *digital forms* in conjunction with handwriting recognition is a growing trend. **Touch screens** are monitors that are touched with the finger to select commands or provide input. Touch screens are commonly used in consumer kiosks, as well as with personal computers, mobile phones, mobile devices, and other consumer devices. Other pointing devices include **graphics tablets**, gaming devices, and **touch pads**.

SCANNERS, READERS, AND DIGITAL CAMERAS

Chapter Objective 3: Describe the purposes of scanners and readers and list some types of scanners and readers in use today.

There are many different input devices that can be used to convert data that already exists (such as *source documents*) to digital form or to initially capture data in digital form. A **scanner** allows users to input data that exists in physical form, such as photographs, drawings, and printed documents, into a computer. Most scanners are **flatbed scanners** or **portable scanners**. *Receipt*, *3D*, and *business card scanners* are also available. When used with **optical character recognition** (**OCR**) software, the computer can recognize scanned text characters as editable text; if not, the scanned page is input as a single image.

Barcode readers read **barcodes**, such as the *UPC codes* used to identify products in many retail stores. **Radio frequency identification** (**RFID**) is a technology used to store and transmit data located in **RFID tags**, which contain tiny chips and antennas and which are attached to items. RFID tags are read by **RFID readers** and are most often used in conjunction with shipping containers and other large assets. RFID technology can also be used to track individuals, assets, and other items, as well as be used for electronic payment systems.

Optical mark readers (*OMRs*) read specific types of marks on certain forms, such as on testing forms and voter ballots. *OCR readers* read characters, such as the specially printed *optical characters* used on bills and other *turnaround documents*. *Magnetic ink character recognition* (*MICR*) is used by the banking industry to rapidly sort, process, and route checks to the proper banks. **Biometric readers** read *biometric* characteristics (such as a fingerprint, hand geometry, or a face) in order to identify individuals.

Chapter Objective 4: Explain what digital cameras are and how they are used today.

Digital cameras work much like conventional film cameras, but they record digital images on a digital storage medium (such as a flash memory card, digital tape cartridge, built-in hard drive, or DVD disc), instead of on conventional film or videotape. The images are immediately available without processing and can be transferred to a computer for manipulation or printing, or sent directly to some printers for printing. *Digital still cameras* take still photos; *digital video cameras* are either *digital camcorders* or *PC cam/Webcam* digital video cameras that are used in conjunction with personal computers.

AUDIO INPUT

Chapter Objective 5: Understand the devices that can be used for audio input.

Speech recognition systems, which enable computer systems to recognize spoken words, are one means of *audio input*. Speech recognition can be used for data input, as well as for controlling a computer or other device (such as a mobile phone, car navigation system, or surgical robot). *Music input systems* are used to input music, such as original music compositions, into a computer. Music can also be input via a CD, DVD, or Web download.

DISPLAY DEVICES

HW

Chapter Objective 6: Describe the characteristics of a display device and explain some of the technologies used to display images.

Display devices (also called **monitors** and **display screens**) are the most common type of output device for a computer; they are also incorporated into a wide variety of other electronic devices. Display devices are available in a wide variety of sizes and are generally either **CRT monitors** or **flat-panel displays**. Flat-panel displays are most often **liquid crystal displays** (**LCDs**) or **plasma displays**, but these technologies are expected to be replaced by **organic light emitting diode** (**OLED**) **displays** and other new display technologies, such as *interferometric modulator* (*IMOD*) displays. Special types of OLEDs (such as *flexible*, *transparent*, and *Phosphorescent OLEDs*) are emerging for special applications. Regardless of the technology used, the screen of a display device is divided into a fine grid of small areas or dots called **pixels**. Monitors can be *color* or *monochrome*, *wired* or *wireless*, and are available in a wide variety of sizes. Some monitors support 3D images, and some include touch screen capabilities. The *video card* or integrated graphics component being used determines many of the graphics capabilities of the computer. **Data projectors** connect to a computer and project any output sent to the computer's monitor through the projector onto a wall or projection screen. Some projectors are integrated into mobile devices; others project *holograms*.

PRINTERS

Chapter Objective 7: List several types of printers and explain their functions.

Printers produce *hard copy* output through either *impact* or *nonimpact* printing technology. Most printers today form images as matrices of dots, although with many technologies, the dots are too small to be visible. Printer quality is usually measured in *dots per inch* (*dpi*); speed is typically measured in *pages per minute* (*ppm*). Both *personal* and *network printers* are available and there are a number of options for connecting a printer to a network, computer, or other device. Some printers print in color and others print in just black and white. **Multifunction devices** (**MFDs**) incorporate the functions of multiple devices—typically a printer, scanner, and fax machine—into a single unit.

The most common printers are **laser printers** (which use *toner powder*) and **ink-jet printers** (which use liquid ink). Special-purpose printers include **photo printers**, **barcode printers**, **portable printers**, *wide-format ink-jet printers*, and **3D printers**. Some printers are integrated into other devices, such as digital cameras.

AUDIO OUTPUT

Chapter Objective 8: Identify the hardware devices typically used for audio output.

Computer speakers, which output music or spoken voice, are the most common *audio output* device. **Headphones** or **headsets** can be used to prevent the sound from disturbing other people; speakers are also integrated into some consumer devices (such as treadmills) to play music stored on portable digital media players.

REVIEW ACTIVITIES

KEY TERM MATCHING

a. digital camera

b. ink-jet printer

c. laser printer

d. mouse

e. OLED display

f. optical character recognition (OCR)

g. RFID tag

h. scanner

i. stylus

j. touch screen

Instructions: Match each key term on the left with the definition on the right that best describes it.

1. _____ A common pointing device that the user slides along a flat surface to move a pointer around the screen and clicks its buttons to make selections.

2. _____ A device containing a tiny chip and a radio antenna that is attached to an object so it can be identified using radio frequency identification technology.

3. _____ A display device that is touched with the finger to issue commands or otherwise provide input to the connected device.

4. _____ An input device that reads printed text and graphics and transfers them to a computer in digital form.

5. _____ An input device that is used to write electronically on the display screen.

6. _____ An input device that takes pictures and records them as digital images.

7. _____ An output device that uses toner powder and technology similar to that of a photocopier to produce images on paper.

8. _____ A type of flat-panel display that uses emissive organic material to display brighter and sharper images.

9. _____ An output device that sprays droplets of ink to produce images on paper.

10. _____ The ability of a scanning device to recognize scanned text characters and convert them to electronic form as text, not images.

SELF-QUIZ

Instructions: Circle **T** if the statement is true, **F** if the statement is false, or write the best answer in the space provided. **Answers for the self-quiz are located in the References and Resources Guide at the end of the book.**

1. **T** **F** A keyboard is an example of a pointing device.

2. **T** **F** Most digital still cameras store photos on flash memory media.

3. **T** **F** UPC is a type of barcode.

4. **T** **F** Consumer kiosks located in retail stores commonly use touch screens for input.

5. **T** **F** An ink-jet printer normally produces a better image than a laser printer.

6. With _____ software, pen-based computers can convert handwritten text into editable, typed text.

7. A(n) _____ can be used to convert flat printed documents, such as a drawing or photograph, into digital form.

8. The smallest colorable area in an electronic image (such as a scanned document, digital photograph, or image displayed on a display screen) is called a(n) _____.

9. Portable computers and mobile devices virtually always use _____ displays, while some desktop computers may use the larger, more bulky _____ monitors.

10. Match each input device to its input application, and write the corresponding number in the blank to the left of the input application.

a. _____ Pen-based computing	**1.** Keyboard
b. _____ Consumer kiosk	**2.** Stylus
c. _____ Text-based data entry	**3.** RFID tag
d. _____ Secure facility access	**4.** Biometric reader
e. _____ Tracking goods	**5.** Touch screen

EXERCISES

1. For the following list of computer input and output devices, write the appropriate abbreviation (I or O) in the space provided to indicate whether each device is used for input (I) or output (O).

a. _____ Biometric reader	**f.** _____ Digital camera
b. _____ Graphics tablet	**g.** _____ Data projector
c. _____ Speaker	**h.** _____ Microphone
d. _____ Photo printer	**i.** _____ OLED monitor
e. _____ Flat-panel display	**j.** _____ Gaming controller

2. Write the number of the type of printer that best matches each of the printing applications in the blank to the left of each printing application.

a. _____ To print inexpensive color printouts for a wide variety of documents.

b. _____ To print all output for an entire office.

c. _____ To print receipts for jet-ski rentals at the beach.

d. _____ To print high-quality black-and-white business letters and reports at home.

1. Personal laser printer

2. Network laser printer

3. Ink-jet printer

4. Portable printer

3. List three advantages of RFID technology over barcode technology.

4. Would an OLED display or an LCD display use more battery power? Explain why.

5. List one personal or business application that you believe is more appropriate for a dot-matrix printer, instead of another type of printer, and explain why.

DISCUSSION QUESTIONS

1. While gaming and texting are both popular pastimes, it is possible to become injured by performing these activities. For instance, some Wii users have developed tennis elbow and other ailments from some Wii Sports games and heavy texters have developed problems with their thumbs. Think of the devices you use regularly. Have you ever become sore or injured from their use? If so, was it the design of the input device being used, overuse, or both? What responsibilities do hardware manufacturers have in respect to creating safe input devices? If a user becomes injured due to overuse of a device, whose fault it is? Should input devices come with warning labels?

2. The choice of an appropriate input device for a product is often based on both the type of device being used and the target market for that device. For instance, a device targeted to college students and one targeted to older individuals may use different input methods. Suppose that you are developing a device to be used primarily for Internet access that will be marketed to senior citizens. What type of hardware would you select as the primary input device? Why? What are the advantages and disadvantages of your selected input device? How could the disadvantages be minimized?

PROJECTS

HOT TOPICS

1. **Biometrics and Personal Privacy** Biometric input devices, such as fingerprint readers and iris scanners, are increasingly being used for security purposes, such as to clock in and out of work, or to obtain access to locked facilities, a computer, or a computer network. Other uses of biometric technology are more voluntary, such as expedited airport-screening programs used by some frequent travelers and the fingerprint payment systems used at some retail stores. While viewed as a time-saving tool by some, other individuals may object to their biometric characteristics being stored in a database for this purpose. Is convenience worth compromising some personal privacy? What about national security? Would you be willing to sign up for a voluntary program, such as an airport-screening system or a fingerprint payment system, that relies on biometric data? Would you work at a job that required you to use a biometric input device on a regular basis? Do you think a national ID card containing hard-to-forge biometric data could help prevent terrorist attacks, such as the September 11, 2001 attacks? If so, do you think most Americans would support its use?

   For this project, research the use of biometric input devices today and form an opinion about their use and any potential impact their use may have on personal privacy. At the conclusion of your research, prepare a one-page summary of your findings and opinions and submit it to your instructor.

SHORT ANSWER/ RESEARCH

2. **Printer Shopping** Printers today have many more features than a few years ago. These features may include improved quality, more memory, photo printing capabilities, digital camera connectivity, built-in flash memory card readers, wireless connectivity, and faster speed.

   For this project, suppose you are in the market for a new personal printer. Make a list of the most important features needed to meet your needs, and then research printers to identify the best printer for your needs. Be sure to consider both the price of the printer and the price of consumables (such as paper and ink/toner) in your evaluation process. At the conclusion of your research, prepare a one-page summary of your findings and best options and submit it to your instructor.

HANDS ON

3. **Keyboarding Speed Test** Although voice and other alternative means of input are emerging, most data input today is still performed via the keyboard. Proper keyboarding technique can help increase speed and accuracy. Online keyboarding tests can help to evaluate your keyboarding ability.

   For this project, find a site (such as **Typingtest.com**) that offers a free online typing test and test your keyboarding speed and accuracy. At the conclusion of the test, rate your keyboarding ability and determine whether a keyboarding course or tutor program, or just keyboarding practice, will help you improve if your score is not at least 20 correct words per minute (cwpm). Take the test one more time to see if your speed improves now that you are familiar with how the test works. If your speed is fast, but accuracy is low, take the test once more, concentrating on accuracy. If you still test less than 20 cwpm, locate a free typing tutor program or Web site and evaluate it to see if it would help you to increase your speed and accuracy. At the conclusion of this task, prepare a short summary of your experience, including the typing test site used and your best score.