chapter 21

Video

"Video killed the radio star
Video killed the radio star
In my mind and in my car
We can't rewind, we've gone too far."

—The Buggles, "Video Killed the Radio Star," *The Age of Plastic*

In this chapter, you will learn how to

- **Explain how video displays work**
- **Select the proper video card**
- **Install and configure video**
- **Troubleshoot basic video problems**

The term *video* encompasses a complex interaction among numerous parts of the PC, all designed to put a picture on the screen. The **monitor** or **video display** shows you what's going on with your programs and operating system. It's the primary output device for the PC. The video card or **display adapter** handles all of the communication between the CPU and the monitor (see Figure 21.1). The operating system needs to know how to handle communication between the CPU and the display adapter, which requires drivers specific for each card and proper setup within Windows. Finally, each application needs to be able to interact with the rest of the video system.

Let's look at monitors and display adapters individually. I'll bring them back together as a team later in the chapter so you can understand the many nuances that make video so challenging. Let's begin with the video display and then move to the display adapter.

• Figure 21.1 Typical monitor and video card

Video Displays

To understand displays, you need a good grasp of each component and how they work together to make a beautiful (or not so beautiful) picture on the screen. Different types of displays use different methods and technologies to accomplish this task. Video displays for PCs come in three varieties: CRT, LCD, and projectors. The first two you'll see on the desktop or laptop; the last you'll find in boardrooms and classrooms, splashing a picture onto a screen.

There's one other type of monitor used in computing devices, called OLED. Because you won't see this type of display on anything other than a smartphone or modern tablet, I've saved discussion of it for Chapter 27, which covers mobile devices.

Historical/Conceptual

CRT Monitors

Cathode ray tube (CRT) monitors were the original computer monitors—those heavy, boxy monitors that take up half your desk. Although for the most part they've been replaced by LCD technology on new systems, plenty of CRT monitors are still chugging away in the field. As the name implies, this type of display contains a large cathode ray tube, a type of airtight vacuum tube. One end of this tube is a slender cylinder that contains three electron guns. The other end of the tube, which is fatter and wider, is the display screen.

Before we begin in earnest, I want to give you a note of warning about the inside of a traditional monitor. I will discuss what can be repaired and what requires more specialized expertise. Make no mistake—the interior of a monitor might appear similar to the interior of a PC because of the printed circuit boards and related components, but the similarity ends there. No PC has voltages exceeding 15,000 to 30,000 V, but most monitors do. So let's get one thing perfectly clear: Opening up a monitor can kill you! Even when the power is disconnected, certain components retain a substantial voltage for an extended period of time. You can inadvertently short one of the components and fry yourself—to death. Given this risk, certain aspects of monitor repair lie outside the necessary skill set for a normal PC support person, and definitely outside the CompTIA A+ certification exam domains! I will

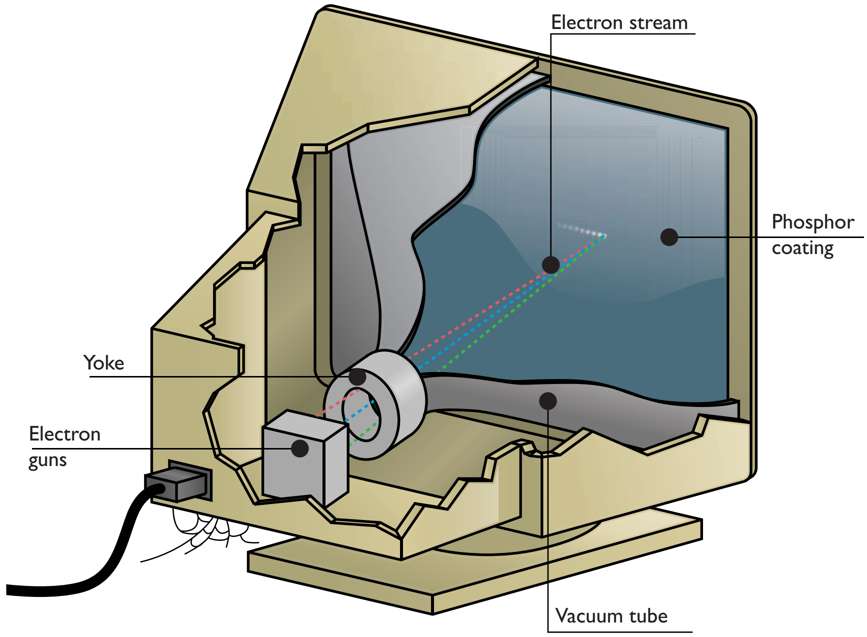


Figure 21.2 Electron stream in the CRT

The inside of a CRT has very high voltage components. These can kill you. Be careful!

show you how to address the problems you can fix safely and make sure you understand the ones you need to hand over to a monitor shop.

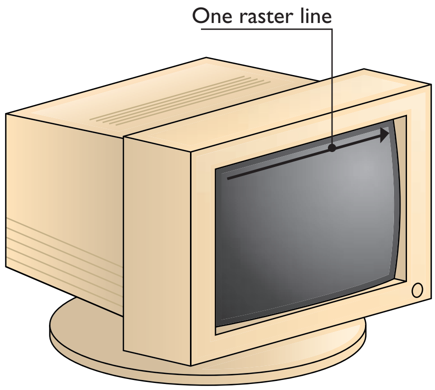
The inside of the display screen has a phosphor coating. When power is applied to one or more of the electron guns, a stream of electrons shoots towards the display end of the CRT (see Figure 21.2). Along the way, this stream is subjected to magnetic fields generated by a ring of electromagnets called a *yoke* that controls the electron beam's point of impact. When the phosphor coating is struck by the electron beam, it releases its energy as visible light.

When struck by a stream of electrons, a phosphor quickly releases a burst of energy. This happens far too quickly for the human eye and brain connection to register. Fortunately, the phosphors on the display screen have a quality called **persistence**, which means the phosphors continue to glow after being struck by the electron beam. Too much persistence and the image is smeary; too little and the image appears to flicker. The perfect combination of beam and persistence creates the illusion of a solid picture.

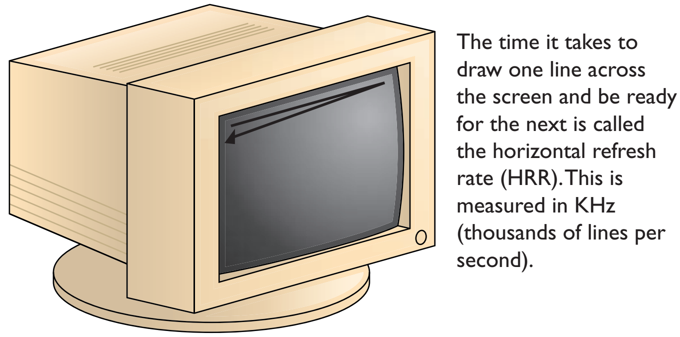
801

Refresh Rate

The monitor displays video data as the electron guns make a series of horizontal sweeps across the screen, energizing the appropriate areas of the phosphorous coating. The sweeps start at the upper-left corner of the monitor and move across and down to the lower-right corner. The screen is "painted" only in one direction; then the electron guns turn and retrace their path across the screen, to be ready for the next sweep. These sweeps are called **raster lines** (see Figure 21.3).

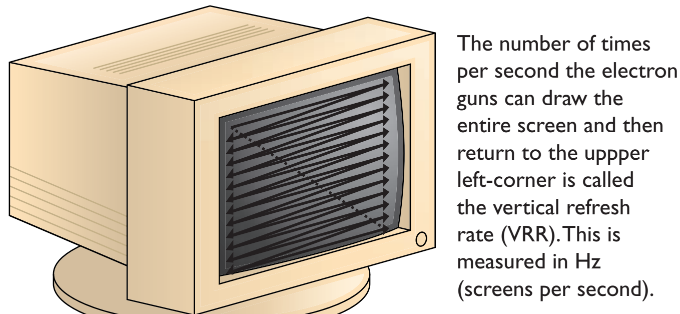


• **Figure 21.3** Electron guns sweep from left to right.



• **Figure 21.4** Horizontal refresh rate

The speed at which the electron beam moves across the screen is known as the **horizontal refresh rate (HRR)**, as shown in Figure 21.4. The monitor draws a number of lines across the screen, eventually covering the screen with glowing phosphors. The number of lines is not fixed, unlike television screens, which have a set number of lines. After the guns reach the lower-right corner of the screen, they turn off and point back to the upper-left corner. The amount of time it takes to draw the entire screen and get the electron guns back to the upper-left corner is called the **vertical refresh rate (VRR)**, shown in Figure 21.5.



• **Figure 21.5** Vertical refresh rate

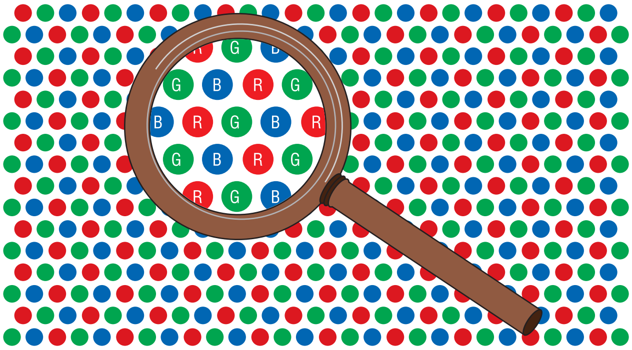
The monitor does not determine the HRR or VRR; the video card "pushes" the monitor at a certain VRR and then the monitor sets the corresponding HRR. If the video card is set to push at too low a VRR, the monitor produces a noticeable flicker, causing eyestrain and headaches for users. Pushing the monitor at too high a VRR, however, causes a definite distortion of the screen image and will damage the circuitry of the monitor and eventually destroy it. The number one killer of monitors is improper VRR settings, and the number one reason your office is filled with crabby workers is that the VRR is set too low. All good PC support techs understand this and take substantial time tweaking the VRR to ensure that the video card pushes the monitor at the highest VRR without damaging the monitor—this is the Holy Grail of monitor support!

Try This!

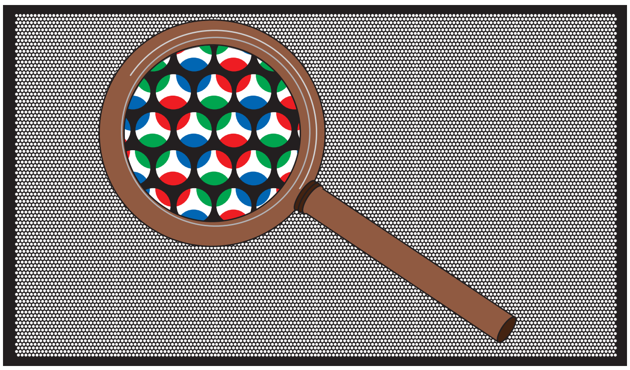
Discovering Your Refresh Rate

You should know the refresh rate for all CRTs you service. Setting up monitors incorrectly can cause havoc in the workplace, so Try This!

1. Most PCs have two places where you can discover the current refresh rate of the monitor. Many monitors offer a menu button for adjusting the display. Often it shows the refresh rate when you push it once.
2. If that doesn't work, go to the Control Panel and open the Display applet (Windows XP/7) or Personalization applet (Windows Vista). Select the Settings tab (XP), Display Settings option (Vista), or *Change display settings* link (7) and then click on Advanced or Advanced settings. Select the Monitor tab in the Monitor Properties dialog box.
3. Write down your refresh rate. How does it compare with that of your classmates?



• **Figure 21.6** A monitor is a grid of red, green, and blue phosphors.



• **Figure 21.7** Shadow mask

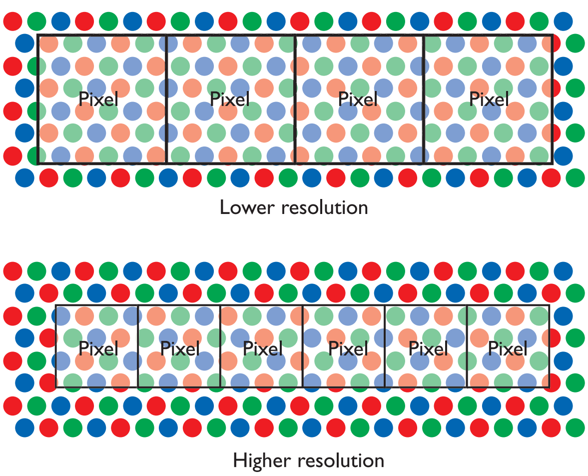
Phosphors and Shadow Mask

All CRT monitors contain dots of phosphorous or some other light-sensitive compound that glows *red*, *green*, or *blue* (RGB) when an electron gun sweeps over it. These **phosphors** are evenly distributed across the front of the monitor (see Figure 21.6).

A normal CRT has three electron guns: one for the red phosphors, one for the blue phosphors, and one for the green phosphors. It is important to understand that the electron guns do not fire colored light; they simply fire electrons at different intensities, which then make the phosphors glow. The higher the intensity of the electron stream, the brighter the color produced by the glowing phosphor.

Directly behind the phosphors in a CRT is the **shadow mask**, a screen that allows only the proper electron gun to light the proper phosphors (see Figure 21.7). This prevents, for example, the red electron beam from "bleeding over" and lighting neighboring blue and green dots.

The electron guns sweep across the phosphors as a group, turning rapidly on and off as they move across the screen. When the group reaches the end of the screen, it moves to the next line. It is crucial to understand that turning the guns on and off, combined with moving the guns to new lines, creates a mosaic that is the image you see on the screen. The number of times the guns turn on and off, combined with the number of lines drawn on the screen, determines the number of mosaic pieces used to create the image. These individual pieces are called **pixels**, from the term *picture elements*. You can't hold a pixel in your hand; it's just the area of phosphors lit at one instant when the group of guns is turned on. The size of pixels can change, depending on the number of times the group of guns is turned on and off and the number of lines drawn.



• **Figure 21.8** Resolution versus pixel size

Resolution

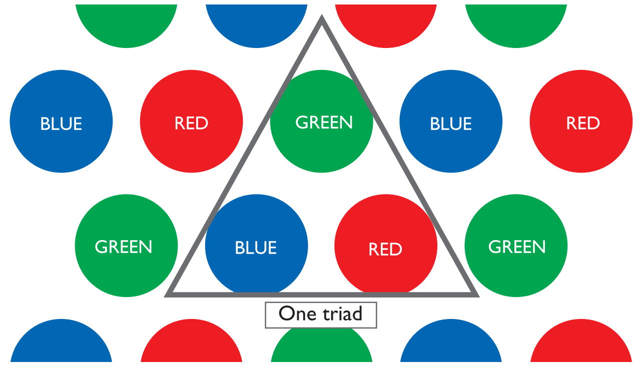
Monitor **resolution** is always shown as the number of horizontal pixels times the number of vertical pixels. A resolution of 640 × 480, therefore, indicates a horizontal resolution of 640 pixels and a vertical resolution of 480 pixels. If you multiply the values together, you can see how many pixels are on each screen: 640 × 480 = 307,200 pixels per screen. An example of resolution affecting the pixel size is shown in Figure 21.8.

Some common resolutions are 640 × 480, 800 × 600, 1024 × 768, 1280 × 960, 1280 × 1024, and 1600 × 1200. Notice that most of these resolutions match a 4:3 ratio. This is called the **aspect ratio**. Many monitors are shaped like television screens, with a 4:3 aspect ratio, so most resolutions are designed to match—or at least be close to—that shape. Other monitors, generically called *wide-screen monitors*, have a 16:9 or 16:10 ratio. Two of the common resolutions you'll see with these monitors are 1366 × 768 and 1920 × 1080.

The last important issue is to determine the maximum possible resolution for a monitor. In other words, how small can one pixel be? Well, the answer lies in the phosphors. A pixel must be made up of at least one red, one green, and one blue phosphor to make any color, so the smallest theoretical pixel would consist of one group of red, green, and blue phosphors: a **triad** (see Figure 21.9). Various limitations in screens, controlling electronics, and electron gun technology make the maximum resolution much bigger than one triad.

See the "Modes" section later in this chapter for the names of each resolution.

Great! Now that you have the basics of CRT monitors, let's turn to LCD monitors. Although the technology differs dramatically between the monitor types, most of the terms used for CRTs also apply to LCD functions.



• Figure 21.9 One triad

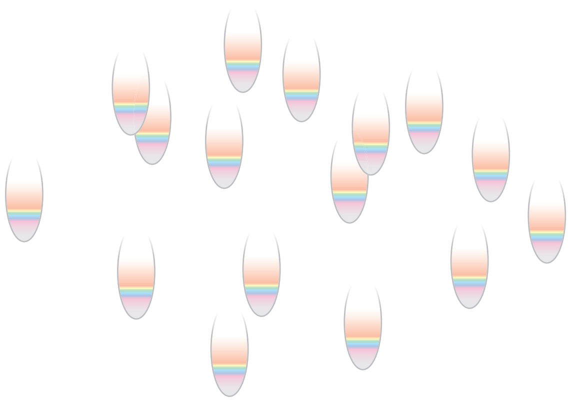
LCD Monitors

Liquid crystal displays (LCDs) are the most common type of display technology for PCs. LCD monitors have many advantages over CRTs. They are thinner and lighter, use much less power, are virtually flicker free, and don't emit potentially harmful radiation. LCDs still have resolution, refresh rates, and bandwidth, but LCDs also come with their own family of abbreviations, jargon, and terms you need to understand so you can install, maintain, and support LCDs.

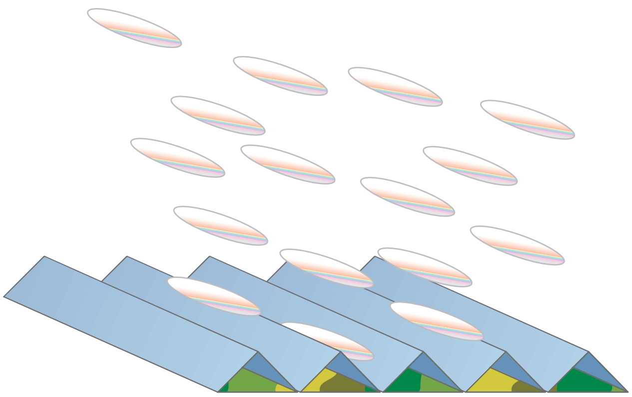
How LCDs Work

The secret to understanding the most common type of LCD panels is to understand the concept of the polarity of light. Anyone who played with a prism in sixth grade or has looked at a rainbow knows that light travels in waves (no quantum mechanics here, please!), and the wavelength of the light determines the color. What you might not appreciate is the fact that light waves emanate from a light source in three dimensions. It's impossible to draw a clear diagram of three-dimensional waves, so instead, let's use an analogy. To visualize this, think of light emanating from a flashlight. Now think of the light emanating from that flashlight as though someone was shaking a jump rope. This is not a rhythmic shaking, back and forth or up and down; it's more as if a person went crazy and was shaking the jump rope all over the place—up, down, left, right—constantly changing the speed.

That's how light really acts. Well, I guess we could take the analogy one step further by saying the person has an infinite number of arms, each holding a jump rope shooting out in every direction to show the three-dimensionality of light waves, but (a) I can't draw that and (b) one jump rope will suffice to explain the typical LCD panels. The varying speeds create wavelengths, from very short to very long. When light comes into your eyes at many different wavelengths, you see white light. If the light came in only one wavelength, you would see only that color. Light flowing through a polarized filter (like sunglasses) is like putting a picket fence between you and the people shaking the ropes. You see all of the wavelengths, but only the waves of similar orientation. You would still see all of the colors, just fewer of them because you only see the waves of the same orientation, making the image darker. That's why many sunglasses use polarizing filters.



• **Figure 21.10** Waves of similar orientation



• **Figure 21.11** Liquid crystal molecules tend to line up together.

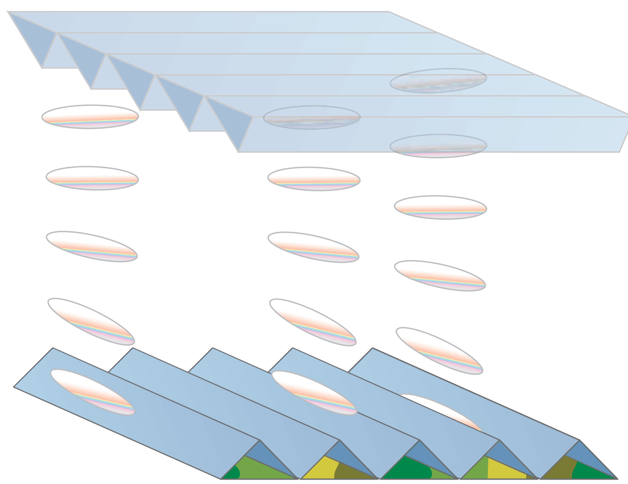
Now, what would happen if you added another picket fence but put the slats in a horizontal direction? This would effectively cancel out all of the waves. This is what happens when two polarizing filters are combined at a 90-degree angle—no light passes through.

Now, what would happen if you added a third fence between the two fences with the slats at a 45-degree angle? Well, it would sort of "twist" some of the shakes in the rope so that the waves could then get through. The same thing is true with the polarizing filters. The third filter twists some of the light so that it gets through. If you're really feeling scientific, go to any educational supply store and pick up three polarizing filters for about (US)$3 each and try it. It works.

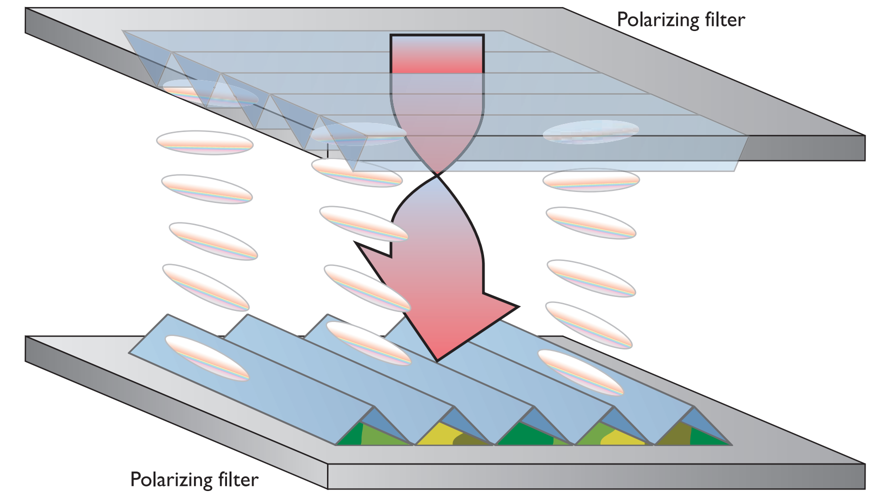
Liquid crystals take advantage of the property of polarization. Liquid crystals are composed of a specially formulated liquid full of long, thin crystals that always want to orient themselves in the same direction, as shown in Figure 21.10. This substance acts exactly like a liquid polarized filter. If you poured a thin film of this stuff between two sheets of glass, you'd get a darn good pair of sunglasses.

Imagine cutting extremely fine grooves on one side of one of those sheets of glass. When you place this liquid in contact with a finely grooved surface, the molecules naturally line up with the grooves in the surface (see Figure 21.11).

If you place another finely grooved surface, with the grooves at a 90-degree orientation to the other surface, opposite of the first one, the molecules in contact with that side will attempt to line up with it. The molecules in between, in trying to line up with both sides, will immediately line up in a nice twist (see Figure 21.12). If two perpendicular polarizing filters are then placed on either



• **Figure 21.12** Liquid crystal molecules twisting

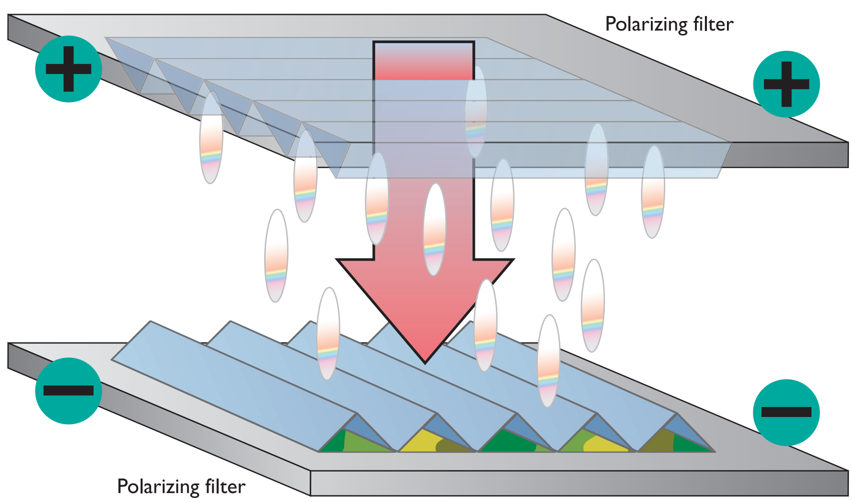


• **Figure 21.13** No charge, enabling light to pass

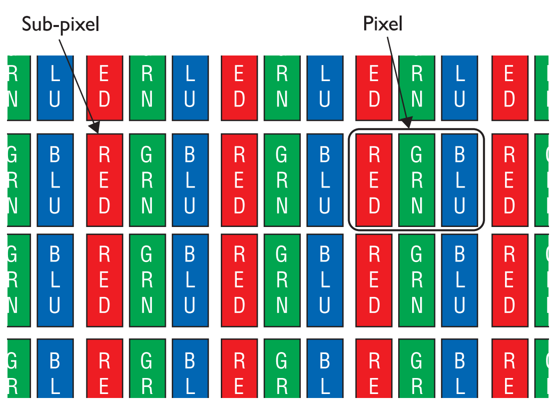
side of the liquid crystal, the liquid crystal will twist the light and enable it to pass (see Figure 21.13).

If you expose the liquid crystal to an electrical potential, however, the crystals will change their orientation to match the direction of the electrical field. The twist goes away and no light passes through (see Figure 21.14).

A color LCD screen is composed of a large number of tiny liquid crystal molecules (called **sub-pixels**) arranged in rows and columns between polarizing filters. A translucent sheet above the sub-pixels is colored red, green, or blue. Each tiny distinct group of three sub-pixels—one red, one green, and one blue—forms a physical pixel, as shown in Figure 21.15.



• **Figure 21.14** Electrical charge, no light is able to pass



• **Figure 21.15** LCD pixels

LCD pixels are very different from the pixels in a CRT. A CRT pixel's size changes depending on the resolution. The pixels in an LCD panel are fixed and cannot be changed. See the section "LCD Resolution" later in the chapter for the scoop.

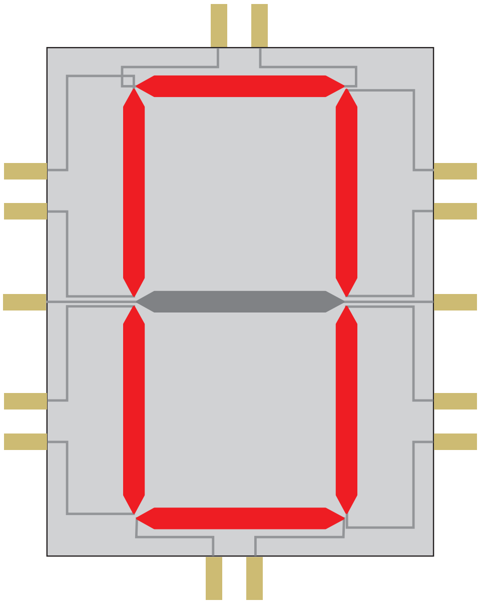


Figure 21.16 Single character for static LCD numeric display

> **Tech Tip**
>
> **TN and IPS**
>
> *The most common TFT displays use a technology called* twisted nematic (TN)*, which produces a decent display for a modest price. Most TN displays use only 6 bits for each color—red, green, and blue—and that 18-bit display will not reproduce the full 24-bit true color that video cards can send to it. This means the panel fudges a little bit when asked to do something it can't do, and this can produce noticeable problems with reproduction.*
>
> *Better TFT displays use a technology called* In-Plane Switching (IPS) *to create a wider viewing angle and far better color re-creation than TN panels can provide. Graphics professionals use IPS monitors, for example, because they can display what might print more faithfully than TN screens. Manufacturers use many types of IPS technology to find the right mix of price-to-performance.*

Once all of the pixels are laid out, how do you charge the right spots to make an image? Early LCDs didn't use rectangular pixels. Instead, images were composed of different-shaped elements, each electrically separate from the others. To create an image, each area was charged at the same time. Figure 21.16 shows the number zero, a display made possible by charging six areas to make an ellipse of sorts. This process, called *static charging*, is still quite popular in more basic numeric displays such as calculators.

The static method would not work in PCs due to its inherent inflexibility. Instead, early LCD screens used a matrix of wires (see Figure 21.17). The vertical wires, the Y wires, ran to every sub-pixel in the column. The horizontal wires, the X wires, ran along an entire row of sub-pixels. There had to be a charge on both the X wires and the Y wires to make enough voltage to light a single sub-pixel.

If you wanted color, you had to have three matrices. The three matrices intersected very close together. Above the intersections, the glass was covered with tiny red, green, and blue dots. Varying the amount of voltage on the wires made different levels of red, green, and blue, creating colors (see Figure 21.18).

We call this usage of LCD technology **passive matrix**. All LCD displays on PCs used only passive matrix for many years. Unfortunately, passive matrix is slow and tends to create a little overlap between individual pixels. This gives a slightly blurred effect to the image displayed. Manufacturers eventually came up with a speedier method of display, called **dual-scan passive matrix**, in which the screen refreshed two lines at a time.

Thin Film Transistor

Current LCD monitors use some form of **thin film transistor (TFT)** or **active matrix** technology (see Figure 21.19). Instead of using X and Y wires, one or more tiny transistors control each color dot, providing faster picture display, crisp definition, and much tighter color control than passive or dual-scan technologies could provide.

LCD Components

The typical LCD monitor is composed of three main components: the LCD panel, the backlight(s), and the inverters. The LCD panel creates the image,

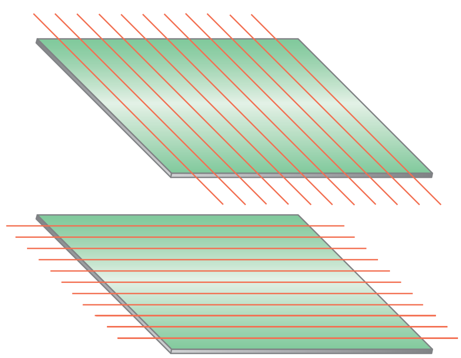


Figure 21.17 An LCD matrix of wires

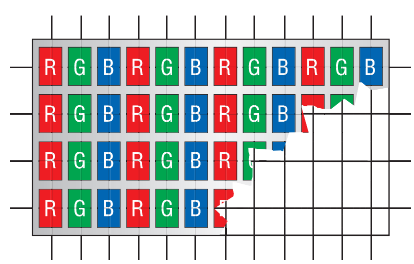
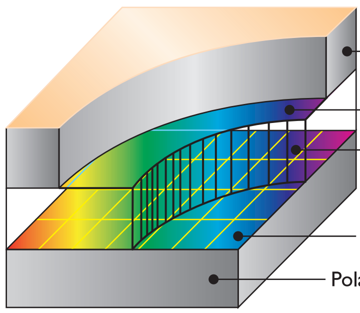
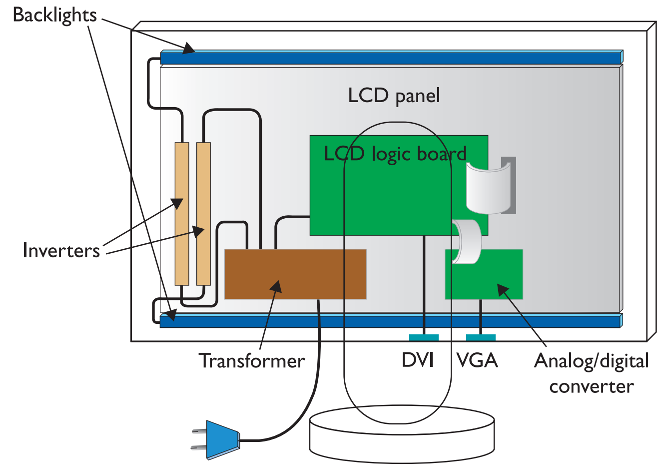


Figure 21.18 Passive matrix display



• **Figure 21.19** Active matrix display



• **Figure 21.20** LCD internals

the **backlights** illuminate the image so you can see it, and the **inverters** send power to the backlights. Figure 21.20 shows a typical layout for the internal components of an LCD monitor.

LCD Monitors with CCFL Backlights One of the great challenges to LCD power stems from the fact that the backlights need AC power while the electronics need DC power. Figure 21.20 shows one of the many ways that LCD monitor makers handle this issue. The AC power from your wall socket goes into an AC/DC transformer that changes the power to DC. The LCD panel uses this DC power.

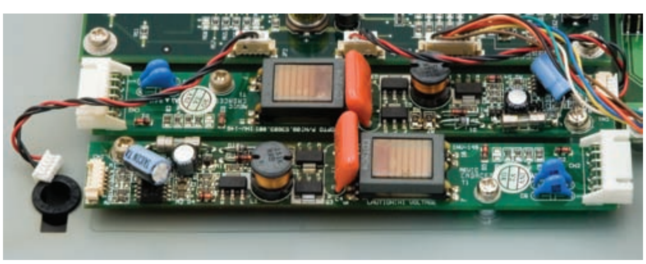
Note in Figure 21.20 that this monitor has two backlights: one at the top and one at the bottom. Most LCDs have two backlights, although some have only one. Most LCD backlights use **cold cathode fluorescent lamp (CCFL)** technology, popular for its low power use, even brightness, and long life. Figure 21.21 shows a CCFL from an LCD panel.

• **Figure 21.21** CCFL backlight

CCFLs need AC power to operate, but given that the transformer converts the incoming AC power to DC, each CCFL backlight needs a device called an inverter to convert the DC power back into AC. Figure 21.22 shows a typical inverter used in an LCD.

Looking once again at Figure 21.20, note the two input connectors, DVI and VGA. DVI is a digital signal, so it connects directly to the LCD's logic circuitry. The VGA goes to an analog-to-digital converter before reaching the LCD logic board.

Keep in mind that Figure 21.20 is a generic illustration. The actual location and interconnections of the components are as variable as the number of LCD panels available today!



• **Figure 21.22** Inverter

Try This!

Test the Viewing Angle of LCDs

Take a trip to your local computer store to look at LCD and LED displays. Don't be distracted looking at all of the latest graphics cards, sound cards, CPUs, motherboards, and RAM—well, actually, it's okay to look at those things. Just don't forget to look at monitors!

Stand about two feet in front of an LCD display. Look directly at the image on the screen and consider the image quality, screen brightness, and color. Take a small step to your right. Compare the image you see now to the image you saw previously. Continue taking small steps to the right until you are no longer able to discern the image on the display. You've reached the edge of the viewing angle for that LCD.

Do this test with a few different monitors. Do smaller LCDs, such as 17-inch displays, have smaller viewing angles? Do larger displays have better viewing angles? How different are the LCDs with CCFL backlights from the LED monitors? You might also want to test the vertical viewing angles of some monitors. Try to find a monitor that is on your eye level; then look at it from above and below—does it have a large viewing range vertically?

The CompTIA A+ 801 exam refers to LEDs as a display type, but such displays don't exist aside from marketing terms. LEDs manifest only as one form of backlighting for LCD monitors. Even so-called "LED monitors" and "LED televisions" are simply LCDs with LED backlights. The terms are merely marketing speak.

LED Monitors Manufacturers also use several types of **light-emitting diode (LED)** light for backlighting, either directly illuminating pixels from behind or flooding the panel from the edges of the bezel. The former produces outstanding contrast and color, but costs a lot more than the edge types. The edge types function similarly to a CCFL-style display, so they produce similar contrast and colors to the older technology. Manufacturers have rebranded LCD monitors that use LEDs for backlighting as **LED monitors**.

Using LEDs for backlighting reduces the thickness of the panels and reduces the overall electricity usage. LEDs don't need AC power, so there's no inverter to get involved in lighting the panel. Many smaller devices, such as smartphones and tablets, use LED backlights to save battery use. The better panels are also in high demand from graphics professionals.

Be sure you understand the features of CRT, LCD, LED, plasma, projector, and OLED display types.

LCD Resolution

All LCD monitors have a **native resolution**, such as 1680 × 1050, that enables them to display the sharpest picture possible. As mentioned earlier, the pixels are fixed. You simply cannot run an LCD monitor at a resolution higher than the native one. Worse, because LCDs have no equivalent to a shadow mask, they can't run at a *lower* than native resolution without severely degrading image quality. A CRT can simply use more dots and the filtering and smoothing of the shadow mask to make a picture at a lower resolution look as good and crisp as the same picture at a higher resolution, but an LCD cannot. The LCD has to use an edge-blurring technique called **anti-aliasing** to soften the jagged corners of the pixels when running at lower than native resolution, which simply does not look as good. The bottom line? Always set the LCD at native resolution!

Two LCD panels that have the same physical size may have different native resolutions.

Brightness

The strength of an LCD monitor's backlights determines the brightness of the monitor. The brightness is measured in **nits**. LCD panels vary from 100 nits on the low end to over 1000 nits or more on the high end. Average LCD panels are around 300 nits, which most monitor authorities consider excellent brightness.

Response Rate

An LCD panel's **response rate** is the amount of time it takes for all of the sub-pixels on the panel to go from pure black to pure white and back again. This is roughly the same concept as the CRT refresh rate, but with one important difference. Once the electron gun on a CRT lights a phosphor, that phosphor begins to fade until it is lit again. An individual LCD sub-pixel holds its intensity until the LCD circuitry changes that sub-pixel, making the problem of flicker nonexistent on LCDs.

Manufacturers measure LCD response rates in milliseconds, with lower being better. A typical lower-end or older LCD has a response rate of 20–25 ms. The screens look fine, but you'll get some ghosting if you try to watch a movie or play a fast-paced video game. In recent years, manufacturers have figured out how to overcome this issue, and you can find many LCD monitors with a response rate of 2–4 ms.

Refresh Rate

The refresh rate for an LCD monitor is described using numbers similar to those used to describe the refresh rate for a CRT monitor, such as 60 Hz, but the terms mean slightly different things between the two technologies. With CRTs, as you'll recall, the phosphors on the screen start to lose their glow and need to be hit again by the electron guns many times per second to achieve an unwavering or flicker-free image. Each dot on an active matrix LCD, in contrast, has its own transistor to light it up. There's no need to freshen up the dot; it's on or off. Regardless of the refresh rate for the LCD, therefore, there's never any flicker at all caused by refresh rate.

The refresh rate for an LCD monitor refers to how often a screen can change or update completely. Think of the refresh rate as a metronome or timer and you'll be closer to how it works in an LCD. For most computing issues, 60 Hz is fine and that's been the standard for the industry. Humans see things that change as infrequently as 24 times per second—the standard for motion pictures at the cinema, for example, and the best high-definition (HD) signal—as a full motion video. To be able to change almost three times faster is perfectly acceptable, even in higher-end applications such as fast-moving games.

Monitor manufacturers have released 120-Hz LCD monitors in a response to the convergence of LCDs, televisions, and computers to enable you to see HD movies or standard-definition (SD) content without any problems or visual artifacts on an LCD monitor. The easiest number that provides a whole-number division for both 24 frames per second and 30 frames per second was 120 Hz. The latter is the standard for SD content.

Tech Tip

Dealing with High-Resolution LCDs

The hard-wired nature of LCD resolution creates a problem for techs and consumers when dealing with bigger, better-quality monitors. A typical 17-inch LCD usually has 1280 × 1024 or higher resolution, for example, and the larger 20+-inch LCDs can go up to 1920 × 1080 or more. These high resolutions make the menus and fonts on a monitor super tiny, a problem for people with less-than-stellar vision. Many folks throw in the towel and run these high-end LCDs at lower resolution and just live with the lower-quality picture, but that's not the best way to resolve this problem.

Microsoft enables incredible customizing of the interface. You can change the font size, shape, and color. You can resize the icons, toolbars, and more. You can even change the number of dots per inch (DPI) for the full screen, making everything bigger or smaller!

For basic customizing, start at the Control Panel | Display applet | Appearance tab or Control Panel | Personalization applet. To change the DPI for the display, go to the Settings tab and click the Advanced button in Windows XP; in Windows Vista, just click the Adjust font size (DPI) *option in the Tasks list. In Windows 7, click Display and the select one of the preset font sizes or a custom size. Your clients will thank you!*

One nit equals one candela/m^2. One candela is roughly equal to the amount of light created by a candle.

A video card needs to be able to support Dual-Link DVI to run a 120-Hz monitor or television. See the discussion on DVI later in this chapter for details.

The CompTIA A+ 801 exam expects you to understand the refresh rate, resolution, and native resolution of a monitor.

Contrast Ratio

A big drawback of LCD monitors is that they don't have nearly the color saturation or richness of contrast of a good CRT monitor—although LCD technology continues to improve every year. A good contrast ratio—the difference between the darkest and lightest spots that the monitor can display—is 450:1, although a quick trip to a computer store will reveal LCDs with lower levels (250:1) and higher levels (1000:1).

LCD monitor manufacturers market a *dynamic contrast ratio* number for their monitors, which measures the difference between a full-on, all-white screen, and a full-off, or all-black screen. This yields a much higher number than the standard contrast ratio. My Samsung panels have a 1000:1 contrast ratio, for example, but a 20,000:1 dynamic contrast ratio. Sounds awesome, right? In general, the dynamic contrast ratio doesn't affect viewing on computer monitors. Focus on the standard contrast ratio when making decisions on LCD screens.

Projectors

Projectors are a third option for displaying your computer images, and the best choice when displaying to an audience or in a classroom. There are two ways to project an image on a screen: rearview and front-view. As the name would suggest, a **rearview projector** (see Figure 21.23) shoots an image onto a screen from the rear. Rearview projectors are always self-enclosed and are very popular for televisions, but are virtually unheard of in the PC world.

A **front-view projector** shoots the image out the front and counts on you to put a screen in front at the proper distance. Front-view projectors connected to PCs running Microsoft PowerPoint have been the cornerstone of every meeting almost everywhere for at least the past ten years (see Figure 21.24). This section deals exclusively with front-view projectors that connect to PCs.

Projector Technologies

Projectors that connect to PCs have been in existence for almost as long as PCs themselves. Given all that time, a number of technologies have been used in projectors. The first generation of projectors used CRTs. Each color used a separate CRT that projected the image onto a

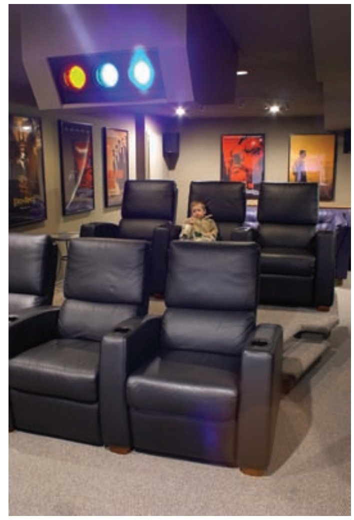
• **Figure 21.23** Rearview projector (photo courtesy of Samsung)

• **Figure 21.24** Front-view projector (photo courtesy of Dell Inc.)

screen (see Figure 21.25). CRT projectors create beautiful images but are expensive, large, and very heavy, and have for the most part been abandoned for more recent technologies.

Given that light shines through an LCD panel, LCD projectors are a natural fit for front projection. LCD projectors are light and very inexpensive compared to CRTs but lack the image quality. LCD projectors are so light that almost all portable projectors use LCD (see Figure 21.26).

All projectors share the same issues as their equivalent-technology monitors. LCD projectors have a specific native resolution, for example. In addition, you need to understand three concepts specific to projectors: lumens, throw, and lamps.



• Figure 21.25 CRT projector

Another type of technology that's seen in projectors but is outside the scope of the CompTIA A+ exams is called Digital Light Processing (DLP). Check out the "Beyond A+" section of this chapter for details.

Lumens

The brightness of a projector is measured in lumens. A **lumen** is the amount of light given off by a light source from a certain angle that is perceived by the human eye. The greater the lumen rating of a projector, the brighter the projector will be. The best lumen rating depends on the size of the room and the amount of light in the room. There's no single answer for "the right lumen rating" for a projector, but use this as a rough guide. If you use a projector in a small, darkened room, 1000 to 1500 lumens will work well. If you use a projector in a mid-sized room with typical lighting, you'll need at least 2000 lumens. Projectors for large rooms have ratings over 10,000 lumens and are very expensive.

Throw

A projector's **throw** is the size of the image at a certain distance from the screen. All projectors have a recommended minimum and maximum throw distance that you need to take into consideration. A typical throw would be expressed as follows. A projector with a 16:9 image aspect ratio needs to be 11 to 12 feet away from the projection surface to create a 100-inch diagonal screen. A *long throw lens* has about a 1:2 ratio of screen size to distance, so to display a 4-foot screen, you'd have to put the projector 8 feet away. Some *short throw lenses* drop that ratio down as low as 1:1!

Lamps

The bane of every projector is the lamp. Lamps work hard in your projector, as they must generate a tremendous amount of light. As a result, they generate quite a bit of heat, and all projectors come with a fan to keep the lamp from overheating. When you turn off a projector, the fan continues to run until the lamp is fully cooled. Lamps are also expensive, usually in

• Figure 21.26 LCD projector (photo courtesy of ViewSonic) the range of a few hundred dollars (U.S.), which comes as a nasty shock to someone who's not prepared for that price when the lamp dies!

Plasma Displays

Plasma display panels (*PDP*) are a popular technology for displaying movies, competing directly with LCD screens for the flat-panel space. They offer a wider viewing angle and richer picture than the typical LCD and cost less. They weigh a lot more and consume much more electricity, though, compared to LCDs.

Unfortunately, plasma TVs have two issues that make them a bad choice for PC use. First is *burn-in*—the tendency for a screen to leave a "ghost" image even after the image is off the screen. Plasma TV makers have virtually eliminated burn-in, but even the latest plasma displays are subject to burn-in when used as PC displays.

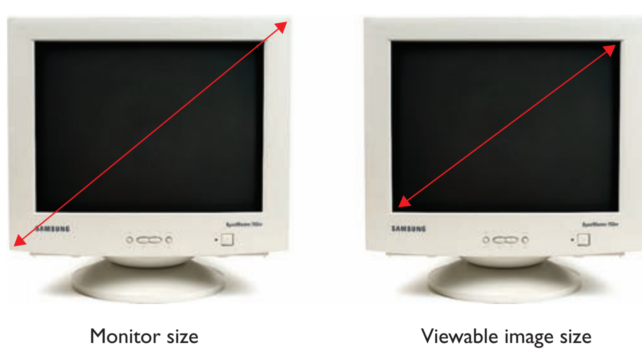
The second issue is *overscan*, a problem that can affect LCD-based TVs as well. Overscan is when the TV blows up the image, cropping off the edges of the picture. TVs do this for historical reasons, but the side effect is that when used with a PC, things like your taskbar get cut off. Some manufacturers have a setting to disable this feature, but not all do. Because media center PCs are becoming more common, CompTIA included the plasma display device in the 220-801 exam objectives. I would advise against using a plasma screen with a media center PC.

Common Features

CRT or LCD, all monitors share a number of characteristics that you need to know for purchase, installation, maintenance, and troubleshooting.

Size

CRT monitors come in a large number of sizes, all measured in inches (although most metric countries provide the metric equivalent value). All monitors provide two numbers: the monitor size and the actual size of the screen. The monitor size measures from two opposite diagonal corners. The actual screen is measured from one edge of the screen to the opposite diagonal side. This latter measurement is often referred to as the **viewable image size (VIS)**, as shown in Figure 21.27. You will commonly see a size



• **Figure 21.27** Viewable image size of a CRT difference of one to two inches between the two measurements. A 17-inch CRT monitor, for example, might have a 15.5-inch VIS.

LCD monitors dispense with the two values and simply express the VIS value. A 15-inch LCD monitor will have about the same viewing area as a 17-inch CRT.

You'll often hear the terms *flat-panel display*, *LCD panel*, or *LED monitor* to describe LCD monitors. I prefer the term *LCD monitor*, but you should be prepared to hear it a few different ways.

Connections

CRT monitors for PCs all use the famous 15-pin, three-row, DB-type connector (see Figure 21.28) and a power plug. The DB connector is also called a *D-shell* or *D-subminiature* connector or simply a *VGA connector*. Larger or multipurpose monitors may have a few other connectors, but as far as the CRT is concerned, these are the only two you need for video.

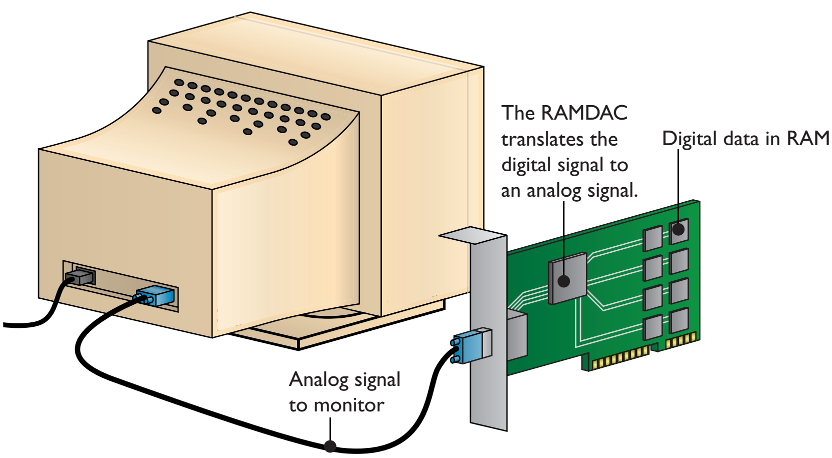
• Figure 21.28 A traditional CRT connector

Controlling a CRT requires an *analog signal* from the video card, meaning a signal that rises and falls in waves like a series of *S*s on their side. LCDs and computers, on the other hand, use digital signals, on or off, one or zero. There's no one-half signal in digital!

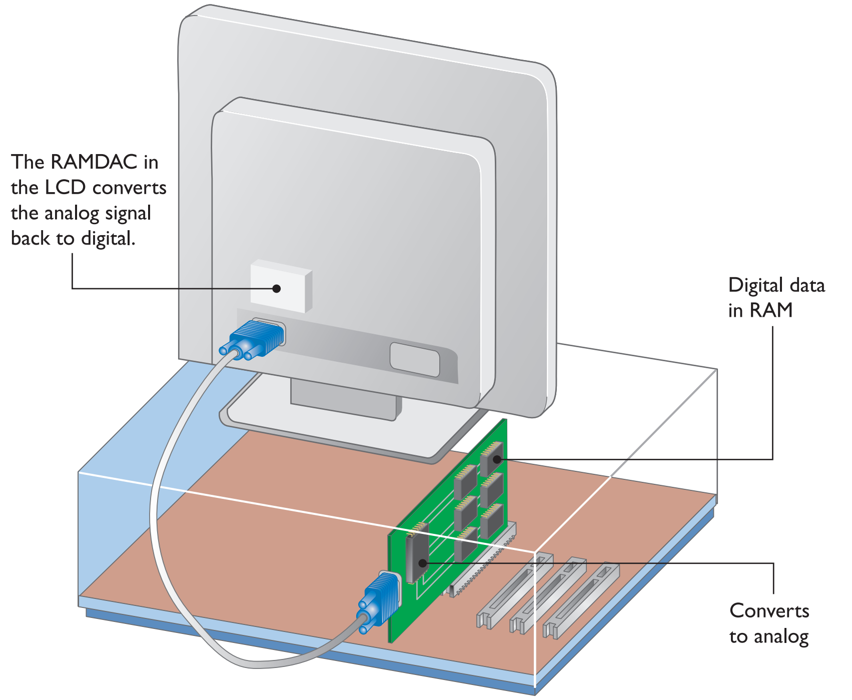
The video information stored on a video card's RAM is clearly digital. Video cards include a special chip (or function embedded into a chip that does several other jobs) called the **random access memory digital-to-analog converter (RAMDAC)**. As the name implies, the RAMDAC takes the digital signal from the video card and turns it into an analog signal for the analog CRT (see Figure 21.29).

Well, RAMDACs certainly make sense for analog CRT monitors. If you want to plug your LCD monitor into a regular video card, however, you need circuitry on the LCD monitor to convert the signal from analog to digital (see Figure 21.30).

Many LCD monitors use exactly this process. These are called *analog LCD monitors*. The monitor really isn't analog; it's digital, but it takes a standard VGA input. These monitors have one advantage: You may use any standard VGA video card. But these monitors require adjustment of the analog timing signal to the digital clock inside the monitor. This used to be a fairly painful process, but most analog LCD monitors now include intelligent circuitry to make this process either automatic or very easy.



• Figure 21.29 An analog signal sent to a CRT monitor



• **Figure 21.30** Converting analog back to digital on the LCD

Why convert the signal from digital to analog and then back to digital? Well, many monitor and video card people agree that it just doesn't make much sense. We now see quite a few digital LCD monitors and digital video cards. They use a completely different connector than the old 15-pin DB connector used on analog video cards and monitors. After a few false starts with connection standards, under names such as P&D and DFP, the digital LCD world, with a few holdouts, moved to the **digital visual interface (DVI)** standard. DVI is actually three different connectors that look very much alike: DVI-D is for digital, DVI-A is for analog (for backward compatibility if the monitor maker so desires), and the DVI-A/D or DVI-I (interchangeable) accepts either a DVI-D or DVI-A. DVI-D and DVI-A are keyed so that they will not connect.

• **Figure 21.31** Dual-link DVI-I connector

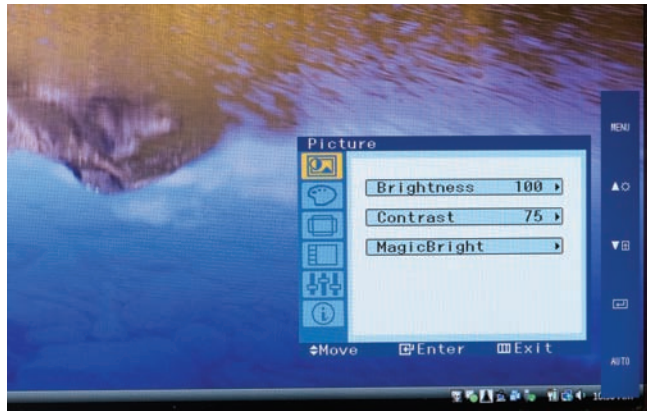
> You can plug a single-link DVI monitor into a dual-link DVI connector and it'll work just fine.

DVI-D and DVI-I connectors come in two varieties, single-link and dual-link. *Single-link DVI* has a maximum bandwidth of 165 MHz, which, translated into practical terms, limits the maximum resolution of a monitor to 1920 × 1080 at 60 Hz or 1280 × 1024 at 85 Hz. *Dual-link DVI* uses more pins to double throughput and thus grant higher resolutions (see Figure 21.31). With dual-link DVI, you can have displays up to a whopping 2048 × 1536 at 60 Hz!

Digital connectors are quickly replacing analog in the monitor world. Digital makes both the monitor and the video card cheaper, provides a clearer signal because no conversion is necessary, and makes installation easy. Many monitors and video cards these days only support digital signals, but there are still quite a few of each that provide both digital and analog connections.

The video card people have it easy. They either include both a VGA and a DVI-D connector or they use a DVI-I connector. The advantage to DVI-I is that you can add a cheap DVI-I-to-VGA adapter (one usually comes with

• **Figure 21.32** DVI-to-VGA adapter



• **Figure 21.33** Typical menu controls

the video card) like the one shown in Figure 21.32 and connect an analog monitor just fine.

Monitor makers have it tougher. Most LCD monitor makers have made the jump to DVI, but many include a VGA connector for those machines that still need it.

Unless you're buying a complete new system, you'll rarely buy a video card at the same time you buy a monitor. When you're buying a monitor or a video card, make sure that the new device will connect to the other!

Adjustments

Most adjustments to the monitor take place at installation, but for now, let's just make sure you know what they are and where they are located. Clearly, all monitors have an On/Off button or switch. Also, see if you can locate the Brightness and Contrast buttons. Beyond that, most monitors (at least the only ones you should buy) have an onboard menu system, enabling a number of adjustments. Every monitor maker provides a different way to access these menus, but they all provide two main functions: physical screen adjustment (bigger, smaller, move to the left, right, up, down, and others) and color adjustment. The color adjustment lets you adjust the red, green, and blue levels to give you the best color tones. All of these settings are a matter of personal taste. Make sure the person who will use the computer understands how to adjust these settings (see Figure 21.33).

Power Conservation

CRT and LCD monitors differ greatly in the amount of electricity they require. The bottom line is that CRTs use a lot and LCDs use a lot less. Here's the scoop.

Approximately half the power required to run a desktop PC is consumed by the CRT monitor. Monitors that meet the Video Electronics Standards Association (VESA) specification for **Display Power Management Signaling (DPMS)** can reduce monitor power consumption by roughly 75 percent. This is accomplished by reducing or eliminating the signals sent by the video card to the monitor during idle periods. By eliminating these pulses, the monitor essentially takes catnaps. The advantage over simply shutting the monitor off is in the time it takes to restore the display.

Tech Tip

Power Switch Versus DPMS

Turning off the monitor with the power switch is the most basic form of power management. The downside to this is the wear and tear on the cathode ray tube itself. The cathode ray tube is the most expensive component of a CRT monitor, and frequently turning the monitor on and off can damage the tube. When using a non-DPMS monitor or video card, it is best to turn the monitor on once during the day and then turn it off only when you are finished for the day. This on-off cycle must be balanced against the life of the CRT display phosphors. The typical monitor loses about half its original brightness after roughly 10,000 to 15,000 hours of display time. Leaving the monitor on all of the time brings a noticeable decrease in brightness in just over a year (8766 hours). The only way around this is enabling the DPMS features of the monitor or taking care to turn the monitor off.

A typical CRT monitor consumes approximately 120 watts. During a catnap or power-down mode, the energy consumption is reduced to below 25 watts, while enabling the screen to return to use in less than ten seconds. Full shutoff is accomplished by eliminating all clocking pulses to the monitor. Although this reduces power consumption to below 15 watts, it also requires anywhere from 15 to 30 seconds to restore a usable display.

A typical LCD monitor, in contrast, uses less than half the electricity that a CRT uses. A 19-inch, 4:3 aspect-ratio flat panel, for example, uses around 33 watts at peak usage and less than 2 watts in DPMS mode. Larger LCDs use more power at peak usage than smaller ones. A 21-inch wide-screen model, for example, might draw ~75 watts at peak but drop down to less than 2 watts in DPMS mode. Swapping out CRTs with LCDs is a great way to save on your electric bill!

Display Adapters

The display adapter, or video card, handles the video chores within the PC, processing information from the CPU and sending it out to the monitor. The display adapter is a complex set of devices. A graphics processor of some type processes data from the CPU and outputs commands to the display. Like any other processor, the graphics processor needs RAM. The graphics processor needs fast connectivity between it, the CPU, and system RAM. The display adapter must have a connection compatible with the monitor.

• Figure 21.34 Typical video card

Traditionally, and still quite commonly, the display adapter was an expansion card that plugged into the motherboard (see Figure 21.34). Although many new systems have the display adapter circuitry built into the motherboard, most techs still call it the video card, so we'll start there. This section looks at five aspects that define a video card: display modes, motherboard connection, graphics processor circuitry, video memory, and connections.

Modes

The trick to understanding video cards is to appreciate the beginnings and evolution of video. Video output to computers was around long before PCs were created. At the time PCs became popular, video was almost exclusively text-based, meaning that the only image the video card could place on the monitor was one of the 256 ASCII characters. These characters were made up of patterns of pixels that were stored in the system BIOS. When a program wanted to make a character, it talked to DOS or to the BIOS, which stored the image of that character in the video memory. The character then appeared on the screen.

The beauty of text video cards was that they were simple to use and cheap to make. The simplicity was based on the fact that only 256 characters existed, and no color choices were available—just monochrome text.

You could, however, choose to make the character bright, dim, normal, underlined, or blinking. Positioning the characters was easy, as space on the screen allowed for only 80 characters per row and 24 rows of characters.

Long ago, RAM was very expensive, so video card makers were interested in using the absolute least amount of RAM possible. Making a monochrome text video card was a great way to keep down RAM costs. Let's consider this for a minute. First, the video RAM is where the contents of the screen are located. You need enough video RAM to hold all of the necessary information for a completely full screen. Each ASCII character needs 8 bits (by definition), so a monitor with 80 characters/row and 24 rows will need

80 characters × 24 rows = 1920 characters = 15,360 bits or 1920 bytes

The video card would need less than 2000 bytes of memory, which isn't much, not even in 1981 when the PC first came out. Now, be warned that I'm glossing over a few things—where you store the information about underlines, blinking, and so on. The bottom line is that the tiny amount of necessary RAM kept monochrome text video cards cheap.

Very early on in the life of PCs, a new type of video, called a *graphics video card*, was invented. It was quite similar to a text card. The text card, however, was limited to the 256 ASCII characters, whereas a graphics video card enabled programs to turn any pixel on the screen on or off. It was still monochrome, but programs could access any individual pixel, enabling much more creative control of the screen. Of course, it took more video RAM. The first graphics cards ran at 320 × 200 pixels. One bit was needed for each pixel (on or off), so

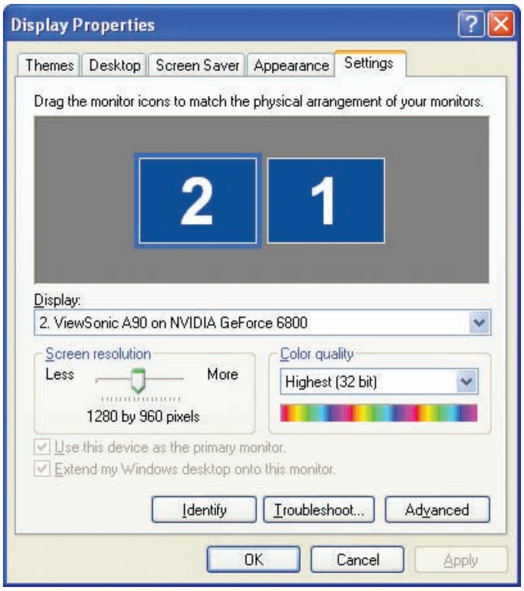
320 × 200 = 64,000 bits or 8000 bytes

That's a lot more RAM than was needed for text, but it was still a pretty low amount of RAM—even in the old days. As resolutions increased, however, the amount of video RAM needed to store this information also increased.

After monochrome video was invented, moving into color for both text and graphics video cards was a relatively easy step. The only question was how to store color information for each character (text cards) or pixel (graphics cards). This was easy—just set aside a few more bits for each pixel or character. So now the question becomes, "How many bits do you set aside?" Well, that depends on how many colors you want. Basically, the number of colors determines the number of bits. For example, if you want four colors, you need 2 bits (2 bits per pixel). Then, you could do something like this

00 = black	01 = cyan (blue)
10 = magenta (reddish pink)	11 = white

So if you set aside 2 bits, you could get 4 colors. If you want 16 colors, set aside 4 bits, which would make 16 different combinations. Nobody ever invented a text mode that used more than 16 colors, so let's start thinking in terms of only graphics mode and bits per pixels. To get 256 colors, each pixel would have to be represented with 8 bits. In PCs, the number of colors—called the **color depth**—is always a power of 2: 4, 16, 256, 64 K, and so on. Note that as more colors are added, more video RAM is needed to store



• **Figure 21.35** Adjusting color settings in Windows XP

the information. Here are the most common color depths and the number of bits necessary to store the color information per pixel:

2 colors = 1 bit (mono)

4 colors = 2 bits

16 colors = 4 bits

256 colors = 8 bits

64 K colors = 16 bits

16.7 million colors = 24 bits

Most technicians won't say, for example, "I set my video card to show over 16 million colors." Instead, they'll say, "I set my color depth to 24 bits." Talk in terms of bits, not colors. It is assumed that you know the number of colors for any color depth.

You can set the color depth for a Windows XP computer in the Display Properties dialog box on the Settings tab (see Figure 21.35). If you set up a typical Windows XP computer, you'll notice that Windows offers you 32-bit color quality, which might make you assume you're about to crank out more than 4 billion colors, but that's simply not the case. The 32-bit color setting offers 24-bit color plus an 8-bit alpha channel. An alpha channel controls the opacity of a particular color. By using an alpha channel, Windows can more effectively blend colors to create the effect of semi-transparent images. In Windows XP, you see this in the drop shadow under a menu; in Windows Vista and Windows 7, almost every screen element can be semi-transparent (see Figure 21.36).

• **Figure 21.36** Semi-transparency in Windows Vista

Your video card and monitor are capable of showing Windows in a fixed number of different resolutions and color depths. The choices depend on the resolutions and color depths the video card can push to the monitor and the amount of bandwidth your monitor can support. Any single combination of resolution and color depth you set for your system is called a **mode**. For standardization, VESA defines a certain number of resolutions, all derived from the granddaddy of video modes: VGA.

VGA

With the introduction of the PS/2, IBM introduced the **video graphics array (VGA)** standard. This standard offered 16 colors at a resolution of 640 × 480 pixels. VGA supported such an amazing variety of colors by using an analog video signal instead of a digital one, as was the case prior to the VGA standard. A digital signal is either all on or all off. By using an analog signal, the VGA standard can provide 64 distinct levels for the three colors (RGB)—that is, 64^3 or 262,144 possible colors—although only 16 or 256 can be seen at a time. For most purposes, 640 × 480 and 16 colors defines VGA mode. This is typically the display resolution and color depth referred to on many software packages as a minimum display requirement. Every video card made in the past 15 years can output as VGA, but VGA-only cards are now obsolete.

> To accommodate rotated LCD monitors in portrait view, the video resolution numbers might be reversed. Rather than 1280 × 1024, for example, you might see 1024 × 1280. The amount of RAM needed remains the same regardless.

Beyond VGA

The 1980s were a strange time for video. Until the very late 1980s, VGA was the highest mode defined by VESA, but demand grew for modes that went beyond VGA. This motivated VESA to introduce (over time) a number of new modes with names such as SVGA, XGA, and many others. Even today, new modes are being released! Table 21.1 shows the more common modes.

The video card must have sufficient RAM to support each combination of color depth and resolution. Many years ago this mattered, when video cards had scant megabytes of memory. A video card with only 2 MB of RAM, for example, could handle a high color (16-bit) display at 1024 × 768, but not the same resolution with true color (24-bit). Table 21.2 shows common modes and the minimum video memory needed. All modern video cards can handle true color at any resolution.

Table 21.1 Typical Display Modes

Video Mode	Resolution	Aspect Ratio	Typical Device
SVGA	800 × 600	4:3	Small monitors
HDTV 720p	1280 × 720	16:9	Lowest resolution that can be called HDTV
SXGA	1280 × 1024	5:4	Native resolution for many desktop LCD monitors
WXGA	1366 × 768	16:9	Widescreen laptops
WSXGA	1440 × 900	16:10	Widescreen laptops
SXGA+	1400 × 1050	4:3	Laptop monitors and high-end projectors
UXGA	1600 × 1200	4:3	Larger CRT monitors
HDTV 1080p	1920 × 1080	16:9	Full HDTV resolution
WUXGA	1920 × 1200	16:10	For 24"+ widescreen monitors
QWXGA	2048 × 1152	16:9	For smaller, fine monitors
WQXGA	2560 × 1600	16:10	For 27"+ widescreen monitors
WQUXGA	3840 × 2400	16:10	For smaller, fine monitors

Table 21.2 Common Modes and the Minimum Video Memory Required

Resolution	16-bit (High Color)	24-bit (True Color)
640 × 480	1 MB	1 MB
800 × 600	1 MB	2 MB
1024 × 768	2 MB	4 MB
1280 × 1024	4 MB	4 MB
1600 × 1200	4 MB	6 MB

Motherboard Connection

Techs will encounter four ways that display adapters connect to a motherboard. The oldest connector type, PCI, is used today only for an additional card to support extra monitors. Slightly newer but still quite old in computer terms is AGP. Every current discrete video card plugs into the PCIe slot on a motherboard. Finally, many motherboards have the display adapter built-in. I'll discuss integrated graphics after talking about graphics processors and memory types, at which point the topic will make more sense. For now, let's look at PCI, AGP, and PCIe.

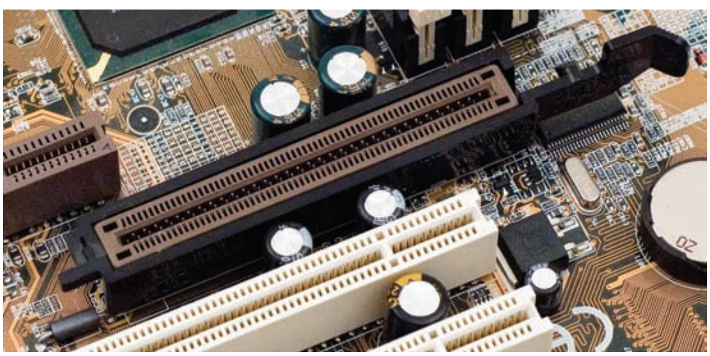
PCI

Using more color depth slows down video functions. Data moving from the video card to the display has to go through the video card's memory chips and the expansion bus, and this can happen only so quickly. The standard PCI slots used in almost all systems for many years are limited to 32-bit transfers at roughly 33 MHz, yielding a maximum bandwidth of 132 MBps. This sounds like a lot until you start using higher resolutions, high color depths, and higher refresh rates. (The refresh rates mattered because we only had CRTs when video cards used the PCI bus.)

For example, take a typical display at 800 × 600 with a fairly low refresh of 70 Hz. The 70 Hz means the display screen is being redrawn 70 times per second. If you use a low color depth of 256 colors, which is 8 bits ($2^8 = 256$), you can multiply all of the values together to see how much data per second has to be sent to the display:

800 × 600 × 1 byte × 70 = 33.6 MBps

If you use the same example at 16 million (24-bit) colors, the figure jumps to 100.8 MBps. You might say, "Well, if PCI runs at 132 MBps, it can handle that!" That statement would be true if the PCI bus had nothing else to do but tend to the video card, but almost every system has more than one PCI device, each requiring part of that throughput. The PCI bus simply cannot handle the needs of any current systems and is therefore used only for adding a second (or third) video card to a system to support an extra monitor.



• Figure 21.37 AGP

AGP

Intel answered the desire for video bandwidth even higher than PCI with the **Accelerated Graphics Port (AGP)**. AGP is a single, special port, similar to a PCI slot, that is dedicated to video. You will never see a motherboard with two AGP slots. Figure 21.37 shows an early-generation AGP. AGP is derived from the 66-MHz, 32-bit PCI 2.1 specification. AGP uses a function called *strobing* that increases the signals two, four, and eight times for each clock cycle.

Simply describing AGP as a faster PCI would seriously misrepresent the power of AGP. AGP has several technological advantages over PCI, including the bus, the internal operations, and the capability to handle 3-D texturing (discussed later in the chapter).

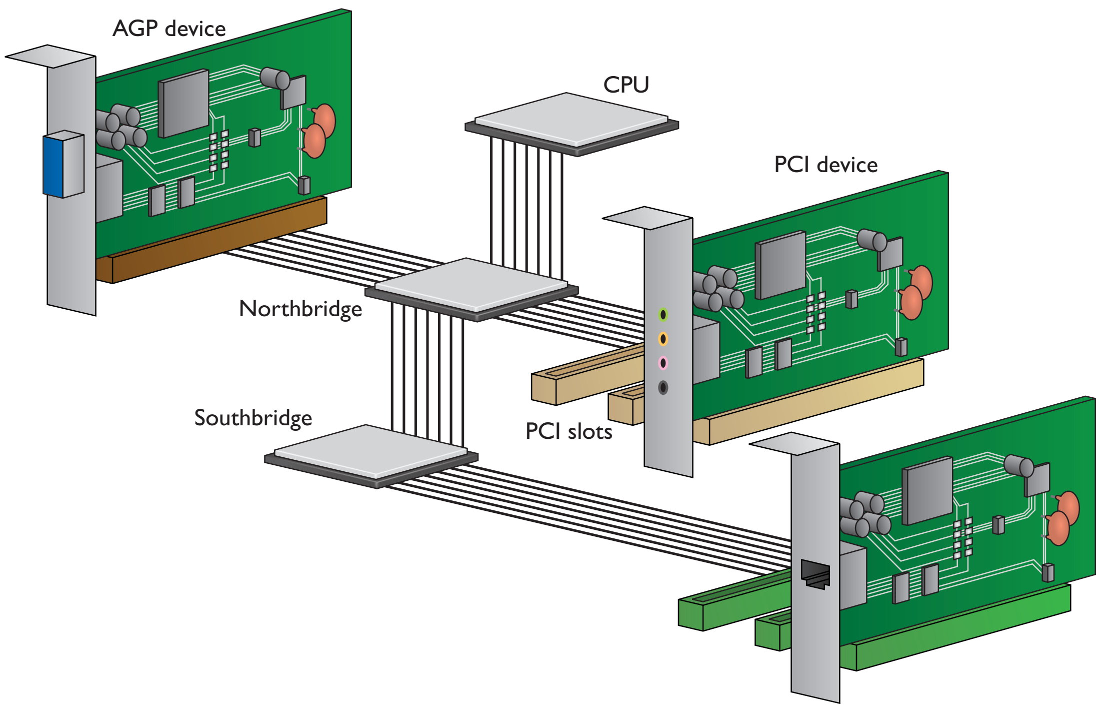
First, AGP currently resides alone, on its own personal data bus, connected directly to the Northbridge (see Figure 21.38). This is important because more advanced versions of AGP outperform every bus on the system except the frontside bus!

> **Cross Check**
>
> **Multiple Actions per Clock Cycle**
>
> You've run into devices in the PC that can handle multiple actions during a single clock cycle, right? Refer to Chapters 6 and 7 and cross-check your memory. Which CPUs can clock multiply? What advantages does that bring to the PC? Which types of RAM run faster than the system clock?

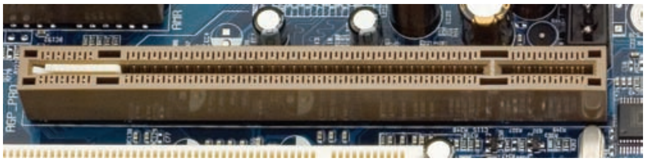
Second, AGP takes advantage of pipelining commands, similar to the way CPUs pipeline. Third, AGP has a feature called **sidebanding**—basically a second data bus that enables the video card to send more commands to the Northbridge while receiving other commands at the same time.

Video cards do all kinds of neat stuff with their RAM; for example, video cards store copies of individual windows so they can display the windows at different points on the screen very quickly. A demanding application can quickly max out the onboard RAM on a video card, so AGP provides a pathway so the AGP card can "steal" chunks of the regular system memory to store video information, especially textures. This is generically called a *system memory access* and is quite popular.

AGP has gone through three sets of specifications (AGP 1.0, AGP 2.0, and AGP 3.0), but the official names tend to be ignored. Most techs and consumers refer to the various cards by their strobe multiplier, such as AGP 1×, 2×, 4×, and 8×. The only problem with blurring the distinctions between the specifications comes from the fact that many new motherboards simply don't support the older AGP cards because the older cards require a different physical connection than the new ones.



• **Figure 21.38** An AGP bus

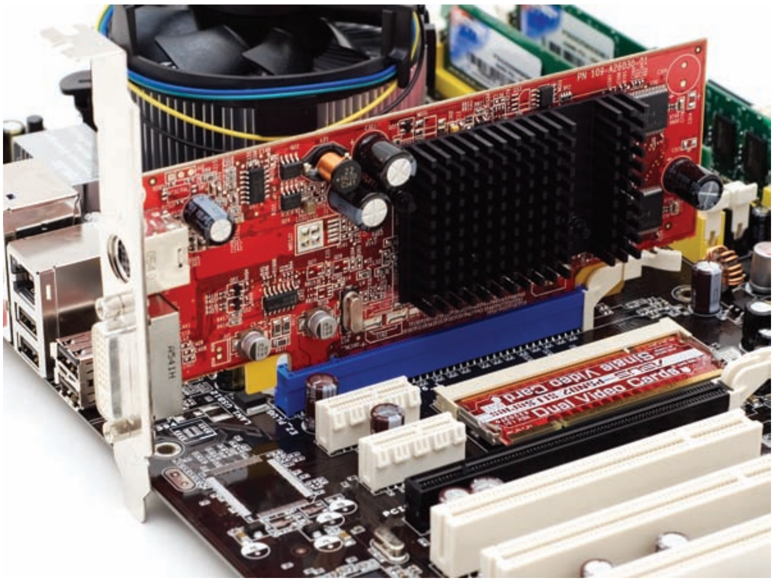


• **Figure 21.39** AGP 8× slot

Some motherboards support multiple types of AGP. Figure 21.39 shows an AGP slot that accommodates everything up to 8×, even the very rare AGP Pro cards. Note that the tab on the slot covers the extra pins required for AGP Pro.

Because many AGP cards will run on older AGP motherboards, you can get away with mixing AGP specifications. To get the best, most stable performance possible, you should use an AGP card that's fully supported by the motherboard.

The only significant downside to AGP lies in the close connection tolerances required by the cards themselves. It's very common to snap in a new AGP card and power up just to get a no-video-card beep or a system that doesn't boot. Always take the time to ensure that an AGP card is snapped down securely and screwed in before starting the system.



• **Figure 21.40** PCIe video card connected in PCIe slot

PCIe

AGP is a great way to get video information to and from video cards very quickly, but it has the downside of being a unique connector in a world where saving money is important. AGP, being based on PCI, also uses a parallel interface. When the **PCI Express (PCIe)** interface was developed to replace PCI, the PCIe designers worked hard to make sure it would also replace AGP. PCIe is a natural evolution for video because it is incredibly fast, using a serial communication method. Also, because PCIe is a true expansion bus designed to talk to the CPU and RAM, it also supports all of the little extras found in AGP, such as sidebanding and system memory access. All PCIe video cards use the PCIe ×16 connector (see Figure 21.40). PCIe replaced AGP as the primary video interface almost overnight.

> **Cross Check**
>
> **PCIe Versions**
>
> You first encountered PCIe way back in Chapter 9, so check your memory now. What's the significance of PCIe 1.0 versus 2.0? What kind of data transfers can PCIe 3.0 devices attain?

Graphics Processor

The graphics processor handles the heavy lifting of taking commands from the CPU and translating them into coordinates and color information that the monitor understands and displays. Most techs today refer to the device that processes video as a **graphics processing unit (GPU)**.

Video card discussion, at least among techs, almost always revolves around the graphics processor the video card uses and the amount of RAM onboard. A typical video card might be called an XFX Radeon HD7970 3-GB 384-bit GDDR5 PCI Express 3.0, so let's break that down. XFX is the manufacturer of the video card; Radeon HD7970 is the graphics processor; 3-GB 384-bit GDDR5 describes the dedicated video RAM and the connection between the video RAM and the graphics processor; and PCI Express 3.0 describes the motherboard expansion slot the card requires.

Many companies make the hundreds of different video cards on the market, but only three companies produce the vast majority of graphics processors found on video cards: NVIDIA, AMD, and Intel. NVIDIA and AMD make and sell graphics processors to third-party manufacturers who then design, build, and sell video cards under their own branding. Intel made its own line of cards, but now concentrates on graphics processors built into motherboards. Figure 21.41 shows an NVIDIA GeForce GTX 570 on a board made by EVGA.

Your choice of graphics processor is your single most important decision in buying a video card. Low-end graphics processors usually work fine for the run-of-the-mill user who wants to write letters or run a Web browser. High-end graphics processors are designed to support the beautiful 3-D games that are so popular today, and they provide excellent video playback for high-definition video. We'll look at 3-D issues a little later in this chapter, but we'll save HD video for Chapter 25.

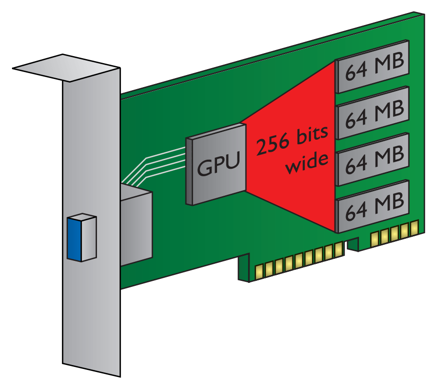
• **Figure 21.41** NVIDIA GeForce GTX 570

Video Memory

Video memory is crucial to the operation of a PC. It is probably the hardest-working set of electronics on the PC. Video RAM constantly updates to reflect every change that takes place on the screen. When you're working with heavy-duty applications (such as games), video memory can prove to be a serious bottleneck in three ways: data throughput speed, access speed, and simple capacity.

Manufacturers have overcome these bottlenecks by upping the width of the bus between the video RAM and video processor; using specialized, super-fast RAM; and adding more and more total RAM.

First, manufacturers reorganized the video display memory on cards from the typical 32-bit-wide structure to 64, 128, 256, and 384 bits wide. Because the system bus is limited to 32 or 64 bits, this would not be of much benefit if video display cards weren't really coprocessor boards. Most of the graphics rendering and processing is handled on the card by the video processor chip rather than by the CPU. The main system simply provides the input data to the processor on the video card. Because the memory bus on the video card is as much as eight times wider than the standard 32-bit pathway (256 bits), data can be manipulated and then sent to the monitor much more quickly (see Figure 21.42).



• **Figure 21.42** Wide path between video processor and video RAM

Specialized types of video RAM have been developed for graphics cards, and many offer substantial improvements in video speeds. The single most important feature that separates DRAM from video RAM is that video RAM can read and write data at the same time. Table 21.3 shows a list of common video memory technologies used yesterday and today—make sure you know these for the exams!

Table 21.3 Video RAM Technologies

Acronym	Name	Purpose
VRAM	Video RAM	The original graphics RAM
WRAM	Window RAM	Designed to replace VRAM; never caught on
SGRAM	Synchronous Graphics RAM	A version of SDRAM with features to speed up access for graphics
DDR SDRAM	Double Data Rate Synchronous DRAM	Used on budget graphics cards and very common on laptop video cards
DDR2 SDRAM	Double Data Rate version 2, Synchronous DRAM	Popular on video cards until GDDR3; lower voltage than DDR memory
GDDR3 SDRAM	Graphics Double Data Rate, version 3	Similar to DDR2 but runs at faster speeds; different cooling requirements
GDDR4 SDRAM	Graphics Double Data Rate, version 4	Upgrade of GDDR3; faster clock
GDDR5 SDRAM	Graphics Double Data Rate, version 5	Successor to GDDR4; double the input/output rate of GDDR4

Finally, many advanced 3-D video cards come with huge amounts of video RAM. It's very common to see cards with 64, 128, 256, or 512 MB of RAM, or even 1, 2, or 3 GB of RAM! Why so much? Even with PCI Express, accessing data in system RAM always takes a lot longer than accessing data stored in local RAM on the video card. The huge amount of video RAM enables game developers to optimize their games and store more essential data on the local video RAM.

Integrated GPUs

A lot of current motherboards have integrated GPUs or are ready for a CPU with an integrated GPU. The motherboard GPU can be a separate chip attached to the motherboard or can be built into the Northbridge chip. You might run into AMD Radeon chips or NVIDIA nForce chips powering the GPU. Intel has long integrated the Intel Graphics Media Accelerator (GMA) into its chipsets.

AMD, Intel, and NVIDIA make CPUs with integrated GPUs that vary a lot in graphical performance. Some of AMD's Fusion processors, for example, have a CPU/GPU combination that rivals any CPU/discrete graphics card combination, though only at a level seen in portable computers. They're good enough for casual gaming and even some medium-duty games. Intel's graphics support is geared to desktop performance, not gaming at all. NVIDIA's Tegra line is focused on gaming on mobile devices such as tablets and smartphones (see Chapter 27 for the details).

With an integrated GPU, the CPU circuitry is getting pretty crowded. A single AMD Fusion chip, for example, integrates two to four CPU cores, a memory controller that supports DDR3, cache memory, and a GPU that can handle advanced 3-D graphics. Wow! One of the best parts of all this integration is that the chip requires far less electricity than comparable discrete components. Many techs and companies call current integrated GPUs *accelerated processing units* (*APUs*), though that term can be applied to other chips that integrate multiple processing functions.

Connector Types and Associated Cables

You can find many different connectors on video cards, plus variations within those connector types. CompTIA also makes a distinction between the names of the ports on the cards and the cables associated with them, though most techs will refer to the connectors and cables by multiple names interchangeably. Here's the scoop.

Standard monitors connect through one of three connectors:

- DVI
- DB-15
- DisplayPort

Video cards offer other connector types for connecting to things like television sets, camcorders, and other multimedia devices, although these are mostly associated with older cards:

- RCA
- BNC
- Mini-DIN
- HDMI

The video card shown in Figure 21.43 has three connectors: DB-15, DVI-I, and S-video. Other connectors enable the video card to connect to composite, component, and even high-definition devices.

The CompTIA A+ competencies mention *RJ-45* as a video connector type and Ethernet as a video cable type. The only place you'll find both used in video is with SP Controls' *CatLinc* system. CatLinc uses adapters to connect your VGA, DVI, HDMI, and component devices to a CAT5 cable (commonly associated with Ethernet networks). CAT5 cables enable the video signal to be transmitted across greater distances more clearly at a lower cost.

For Standard Monitors

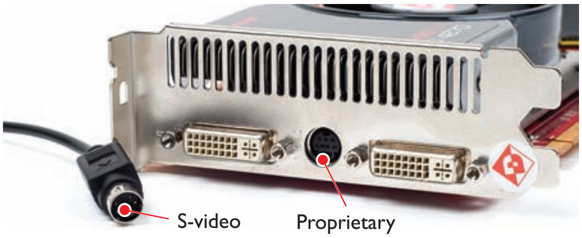
You know about the standard monitor connectors, the DB-15 that most people call VGA and DVI, from the monitor discussion earlier. About the only thing to add is that most DVI connections on video cards these days natively support analog signals. You can use a simple DVI-to-VGA adapter, for example, for connecting a VGA cable to a video card.

Apple Mac desktop models use a **DisplayPort** connection rather than VGA or DVI for connecting to a monitor. Dell offers support for DisplayPort as well at the time of this writing. Figure 21.44 shows a DisplayPort jack on a Dell portable.

• **Figure 21.43** Video card connectors: VGA, S-video, and DVI-I

The CompTIA A+ 801 exam might make a distinction between the VGA cable and the DB-15 connector into which it plugs.

• **Figure 21.44** DisplayPort jack



• **Figure 21.45** S-video and proprietary round connectors

• **Figure 21.46** Composite and component connection options

CompTIA has pulled out all the stops on adding extra acronyms to your plate with connector types. The 220-801 exam objectives refer to the mini-DIN used with S-video as a *Din-6* (yes, with the weird initial capping of Din rather than DIN to refer to the acronym). Most techs refer to the port as an *S-video port*, but CompTIA seems to reserve the S-video label only to the cable.

Some video cards with built-in TV tuners that enable the PC to be a TV as well as a computer have a standard coaxial jack for connecting a cable or antenna. See Chapter 25 for the scoop on TV tuners.

For Multimedia Devices

Video cards can have one or more standard connections plus non-standard connections for hooking the PC to a multimedia device, such as a television, DVD or Blu-ray Disc player, or video camera. The earliest type of connector commonly found is the mini-DIN for attaching an S-video cable. This provides decent-quality video output or, in some cases, input. You'll sometimes find a proprietary round connector that supports S-video and a proprietary dongle that adds support for video through either component connection or composite connections. Figure 21.45 shows the similar round ports.

A composite connector provides a video signal through a single cable that plugs into a standard RCA jack, whereas a component adapter provides a split signal: red, green, and blue (RGB). Figure 21.46 shows the two connector dongles. Note that all are RCA connectors.

The best connections for outputting to television are the **High Definition Multimedia Interface (HDMI)** connectors. Some devices offer HDMI output directly (such as the portable pictured in Figure 21.47), while other video cards support HDMI through a special cable that connects to a dual-link DVI port. Figure 21.48 shows an example of such a cable.

HDMI comes in three standard sizes, Standard, Mini, and Micro. (Plus there's the Type E connector used exclusively for automobile video systems—and don't we all need video while driving?) Standard HDMI is what you'll find on video cards and televisions and some portable devices. Most tablet devices out today use Mini HDMI (see Figure 21.49). See Chapter 27 for the discussion on tablets and other mobile devices.

• **Figure 21.47** HDMI port between two USB ports on Lenovo laptop

• **Figure 21.48** DVI-to-HDMI cable

• Figure 21.49 Mini HDMI port

Installing and Configuring Video

Once you've decided on the features and price for your new video card and monitor, you need to install them into your system. As long as you have the right connection to your video card, installing a monitor is straightforward. The challenge comes when installing the video card.

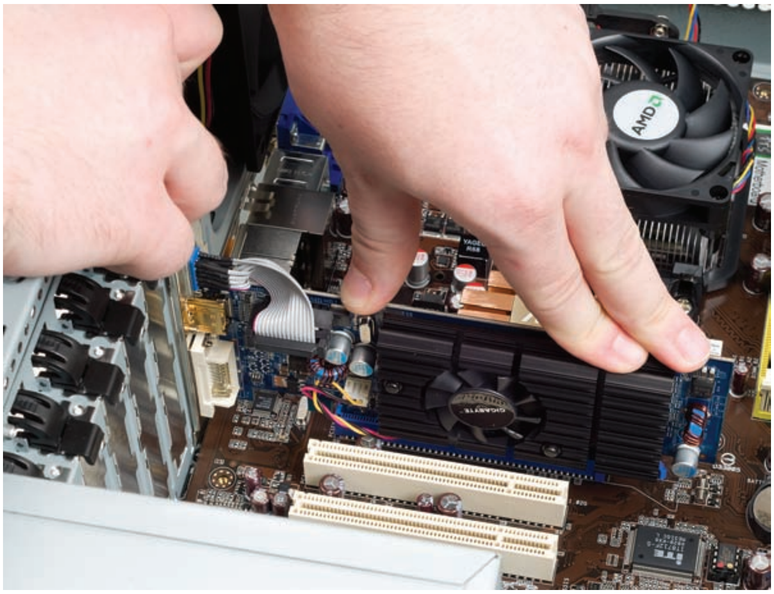
During the physical installation of a video card, watch out for two possible issues: long cards and proximity of the nearest expansion card. Some high-end video cards simply won't fit in certain cases or block access to needed motherboard connectors such as the SATA sockets. There's no clean fix for such a problem—you simply have to change at least one of the components (video card, motherboard, or case). Because high-end video cards run very hot, you don't want them sitting right next to another card; make sure the fan on the video card has plenty of ventilation space. A good practice is to leave the slot next to the video card empty to allow better airflow (see Figure 21.50). (Many high-end video cards come as double-wide cards with built-in air vents, so you don't have any choice but to take up double the space.)

Try This!

Install a Video Card

You know how to install an expansion card from your reading in earlier chapters. Installing a video card is pretty much the same, so Try This!

1. Refer to Chapter 9 for the steps on installing a new card.
2. Plug the monitor cable into the video card port on the back of the PC and power up the system. If your PC seems dead after you install a video card, or if the screen is blank but you hear fans whirring and the internal speaker sounding off *long-short-short-short*, your video card likely did not get properly seated. Unplug the PC and try again.



• Figure 21.50 Installing a video card

Once you've properly installed the video card and connected it to the monitor, you've conquered half the territory for making the video process work properly. You're ready to tackle the drivers and tweak the operating system, so let's go!

Software

Configuring your video software is usually a two-step process. First you need to load drivers for the video card. Then you need to open the Control Panel and go to the Display applet (Windows XP/7) or Personalization applet (Windows Vista) to make your adjustments. Let's explore how to make the video card and monitor work in Windows.

Drivers

Just like any other piece of hardware, your video card needs a driver to function. Video card drivers install pretty much the same way as all of the other drivers we've discussed thus far: either the driver is already built into Windows or you must use the installation media that comes with the video card.

Video card makers are constantly updating their drivers. Odds are good that any video card more than a few months old has at least one driver update. If possible, check the manufacturer's Web site and use the driver located there if there is one. If the Web site doesn't offer a driver, it's usually best to use the installation media. Always avoid using the built-in Windows driver as it tends to be the most dated.

We'll explore driver issues in more detail after we discuss the Display and Personalization applets. Like so many things about video, you can't fully understand one topic without understanding at least one other!

• Figure 21.51 Display Properties dialog box in Windows XP

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Using the Display and Personalization Applets

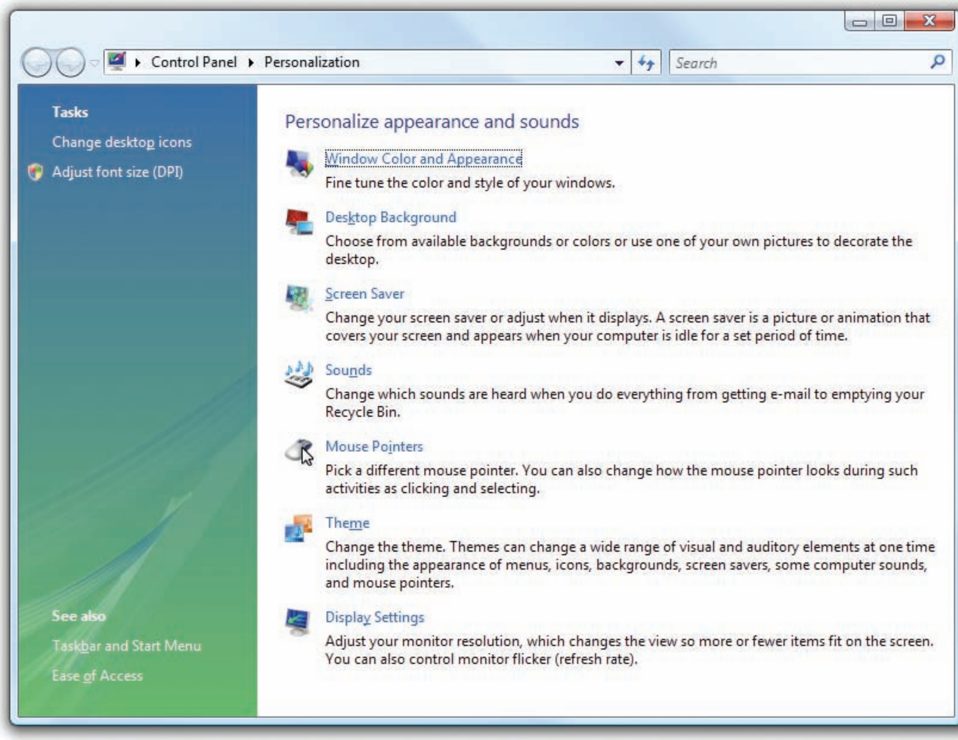
With the driver installed, you're ready to configure your display settings. The Display applet or Personalization applet on the Control Panel is your next stop. The **Display applet** and **Personalization applet** provide convenient, central locations for all of your display settings, including resolution, refresh rate, driver information, and color depth.

The default Display applet window in Windows XP, called the Display Properties dialog box (see Figure 21.51), has five tabs: Themes, Desktop, Screen Saver, Appearance, and Settings. The first four tabs have options you can choose to change the look and feel of Windows and set up a screensaver; the fifth tab is where you make adjustments that relate directly to your monitor and video card.

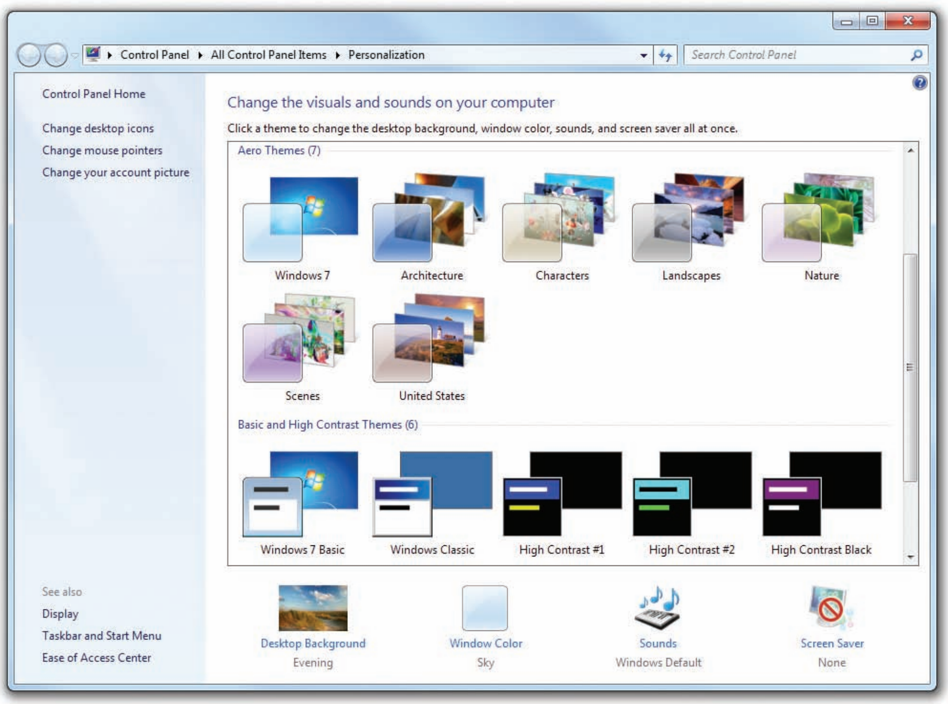
The Personalization applet in Windows Vista offers functions similar to the Display applet, but each function manifests as a clickable option rather than as a separate tab (see Figure 21.52). Four of the seven options mirror the look and feel options of earlier versions of Windows, such as Window Color and Appearance, Desktop Background, Screen Saver, and Theme. The last option, Display Settings, is where you make adjustments to your monitor and video card. Two options, Sounds and Mouse Pointers, don't concern us at all at this time.

With Windows 7, Microsoft created a more visually oriented Personalization applet (see Figure 21.53). Most users typically want to change only their background or theme rather than anything else, so those options are front and center. Other options are in the Tasks panel on the left or in the Display applet, which is different than Windows XP's display applet.

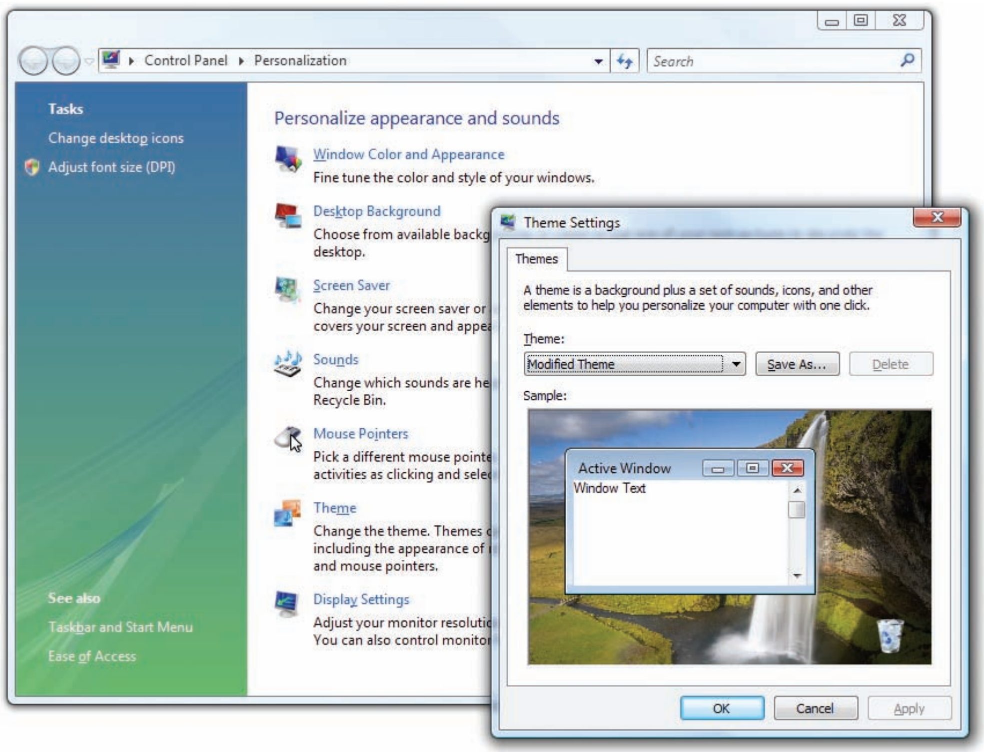
Whether discussing tabs or options, the functions on all three applets are pretty much the same, so let's do this in one discussion. I'll point out any serious differences among the versions.



• **Figure 21.52** Personalization applet in Windows Vista



• **Figure 21.53** Personalization applet in Windows 7



• Figure 21.54 Theme option in the Windows Vista Personalization applet

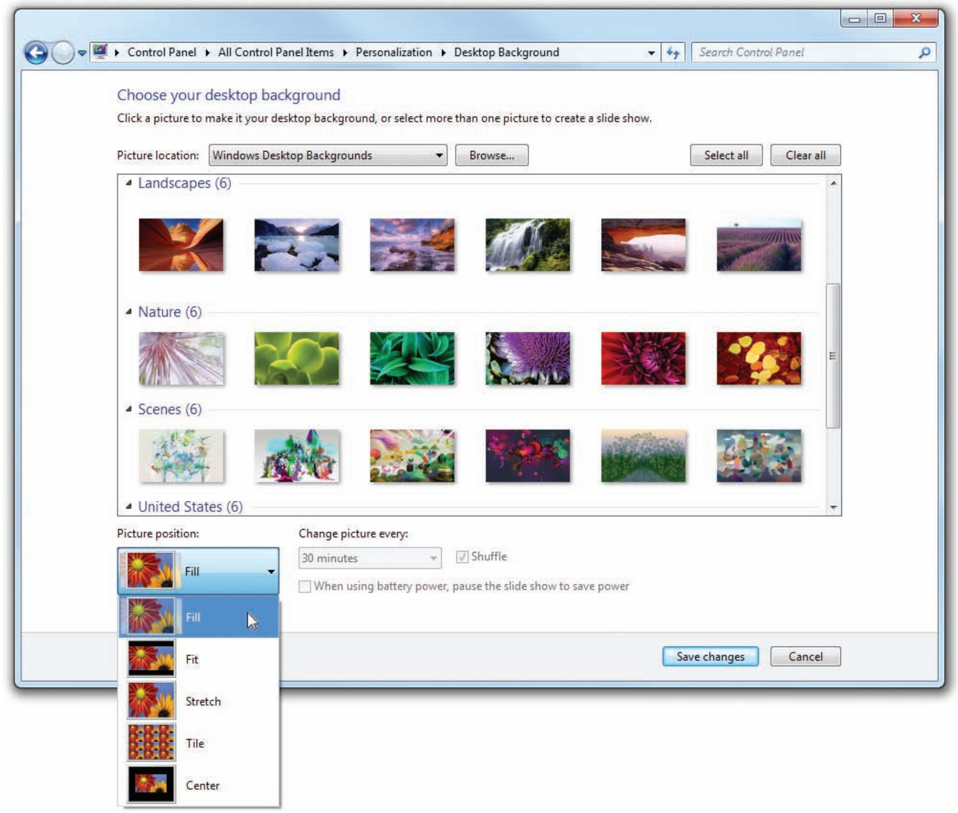
Making the Screen Pretty

Three tabs/options in the Display/Personalization applet have the job of adjusting the appearance of the screen: Themes/Theme, Desktop/Desktop Background, and Appearance/Window Color and Appearance. Windows 7 simplifies this process by making those adjustments available on the Personalization screen, as you saw in Figure 21.53. Windows themes are preset configurations of the look and feel of the entire Windows environment (see Figure 21.54).

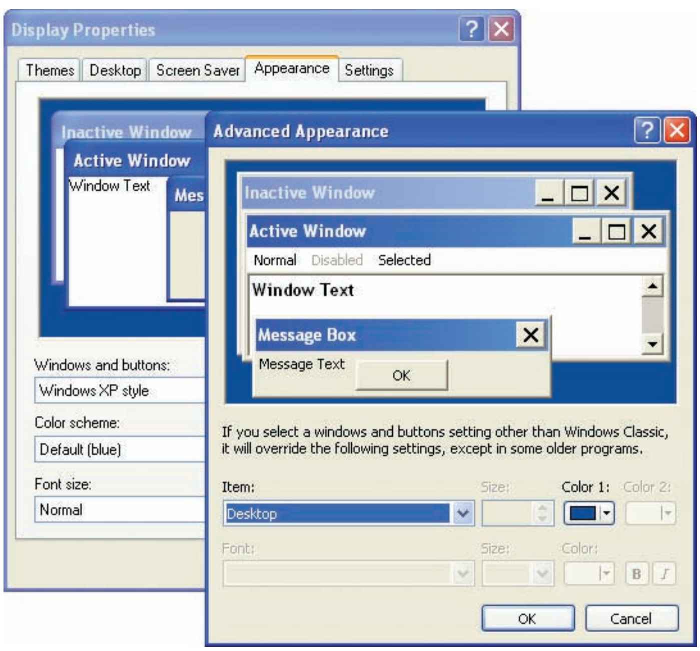
• Figure 21.55 Desktop tab on Display Properties dialog box

The Desktop tab in Windows XP (see Figure 21.55) or Desktop Background link in Windows Vista/7 defines the background color or image. In Windows XP, it also includes the handy Customize Desktop button that enables you to define the icons as well as any Web pages you want to appear on the desktop. Windows Vista/7 give you the option to position the image on the screen (see Figure 21.56), and the *Change desktop icons* option in the Tasks list in the Personalization applet enables you to choose which system icons (such as Computer, Recycle Bin, and Network) show up on your desktop, as well as which graphical icons they use.

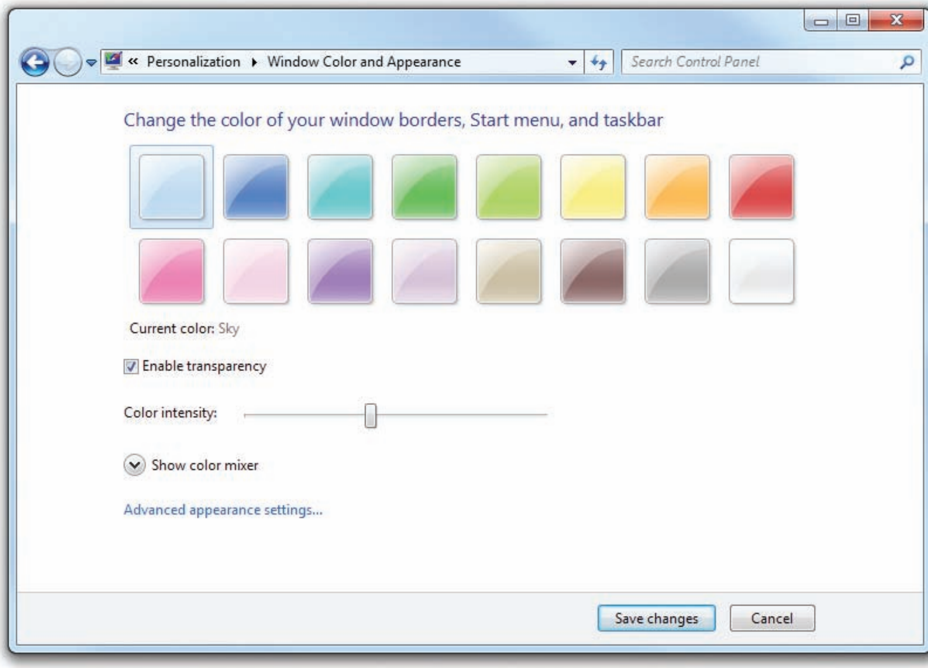
The last of the tabs for the look and feel of the desktop in Windows XP is the Appearance tab. Think of the Appearance tab as the way to fine-tune the theme to your liking. The main screen gives only a few options—the real power is when you click the Advanced button to open the Advanced Appearance dialog box (see Figure 21.57). Using this dialog box, you may adjust almost



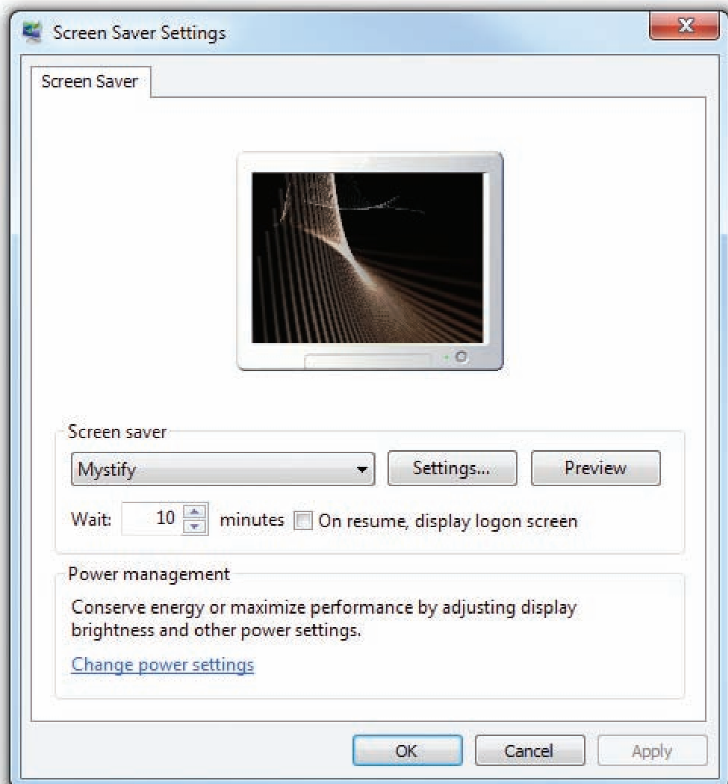
• **Figure 21.56** Desktop Background options in Windows 7



• **Figure 21.57** Advanced Appearance dialog box in Windows XP



• Figure 21.58 Window Color and Appearance options in Windows 7



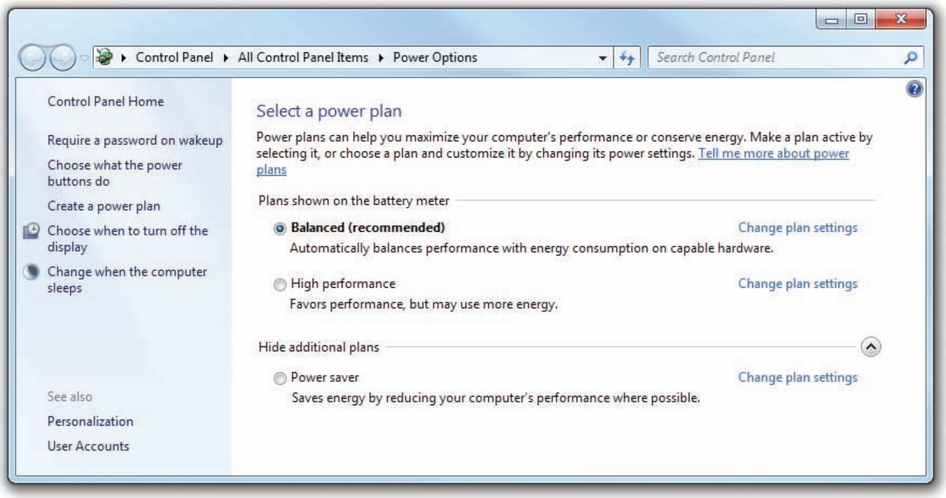
• Figure 21.59 Screen Saver Settings in Windows 7

everything about the desktop, including the types of fonts and colors of every part of a window.

The Window Color and Appearance option in Windows Vista is a little simpler on the surface, enabling you to change the color scheme, intensity, and transparency. Windows 7 shows similar controls following the Windows Color link (see Figure 21.58). You can unlock the full gamut of options, though, by clicking the *Open classic appearance properties for more color options* link in Windows Vista or *Advanced appearance settings* in Windows 7.

Screen Saver

At first glance, the Screen Saver tab/option seems to do nothing but set the Windows screensaver—no big deal, just about everyone has set a screensaver (see Figure 21.59). But another option on the Screen Saver tab gets you to one of the most important settings of your system: power management. Click on the Power button or *Change power settings* option to get to the Power Options Properties dialog box or Power Options applet (see Figure 21.60).

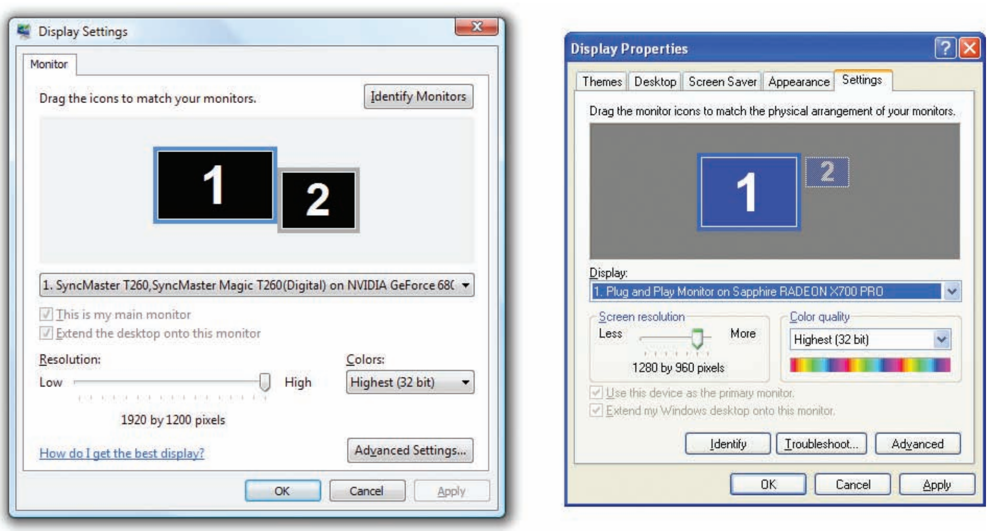


• **Figure 21.60** Power Options applet in Windows 7

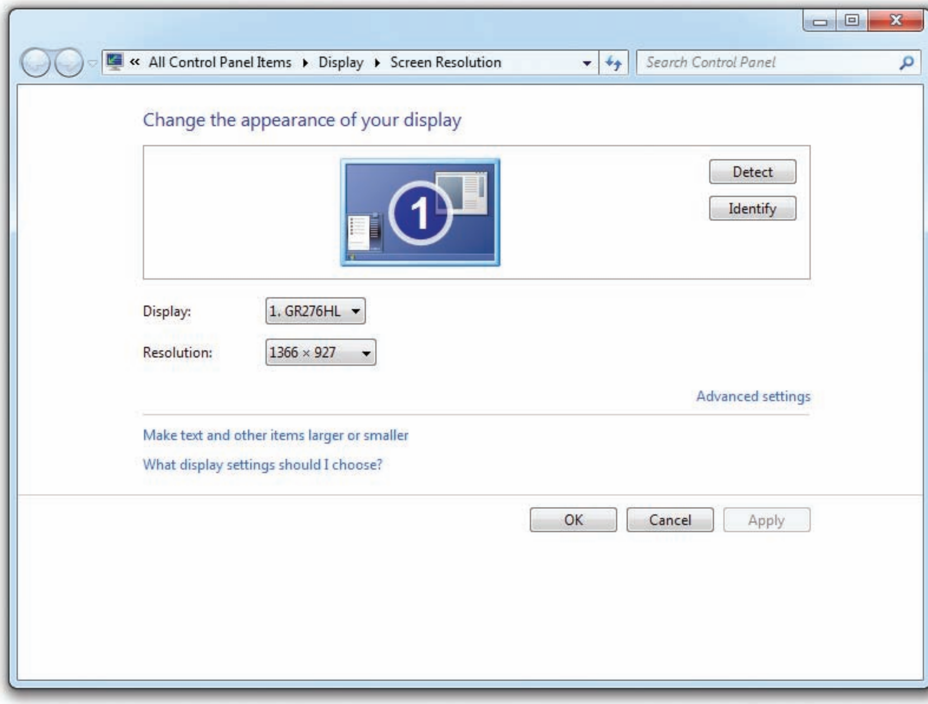
The tabs and options define all of the power management of the system. Power management is a fairly involved process, so we'll save the big discussion for where we need to save power the most: Chapter 26.

Settings Tab/Display Settings Applet/Display Applet

The Settings tab in Windows XP and the Display Settings applet in Windows Vista (see Figure 21.61) are the centralized location for configuring all of your video settings in Windows XP/Vista. From the main screen you can adjust both the resolution and the color depth. Windows only displays resolutions and color depths that your video card/monitor combination can accept and that are suitable for most situations. Everyone has a favorite resolution, and higher isn't always better. Especially for those with trouble seeing small screen elements, higher resolutions can present a difficulty—already small icons are *much* smaller at 1280 × 1024 than at 800 × 600. Try



• **Figure 21.61** Display Settings applet and Settings tab



• **Figure 21.62** Display applet in Windows 7

all of the resolutions to see which you like—just remember that LCD monitors look sharpest at their native resolution (usually the highest listed).

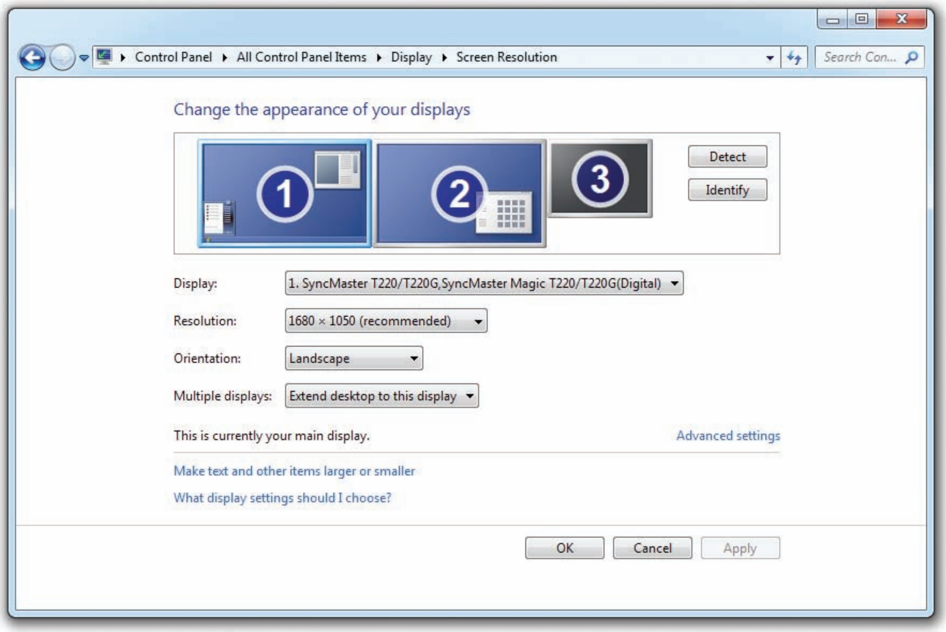
Clicking the Display link in the Tasks list of the Personalization applet in Windows 7 takes you to a simpler interface, again designed to give you quick access to only features you might commonly want to change. Changing the font size is centrally featured, but links in the top left of the task pane enable you to drill down to more advanced options, such as setting the color depth (see Figure 21.62).

Another option you may see in the Settings tab/Display Settings applet is multiple monitors. To see the same feature options in Windows 7, click the *Change display settings* link in the Display applet. Windows supports the use of two (or more) monitors. These monitors may work together like two halves of one large monitor, or the second monitor might simply show a duplicate of what's happening on the first monitor. Multiple monitors are handy if you need lots of screen space but don't want to buy a really large, expensive monitor (see Figure 21.63).

• **Figure 21.63** My editor hard at work with dual monitors

There are two ways to set up multiple monitors: plug in two or more video cards or use a single video card that supports multiple monitors. Both methods are quite common and work well. Multiple monitors are easy to configure: just plug in the monitors and Windows should detect them. Windows will show the monitors in the applet, as shown in Figure 21.64 for Windows 7. By default, the second monitor is not enabled. To use the second monitor, just select *Extend my Windows desktop onto this monitor* in Windows XP, *Extend the desktop onto this monitor* in Windows Vista, or use the Multiple displays dropdown box and select *Extend these displays* in Windows 7.

If you need to see more advanced settings, click on…that's right, the Advanced or Advanced Settings button in Windows XP/Vista, or on the Advanced settings link in the Screen Resolution dialog box in Windows 7. The title of the dialog



• **Figure 21.64** Enabling multiple monitors

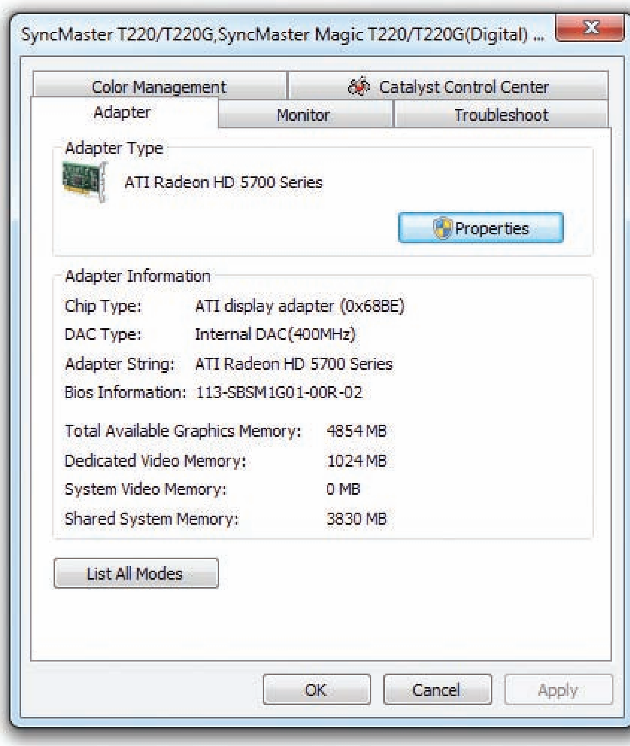
box that opens reflects the monitor and video card. As you can see in Figure 21.65, this particular computer uses a pair of Samsung SyncMaster T220 monitors running off of an ATI Radeon 5750 video card.

All LCD monitors have a fixed refresh rate.

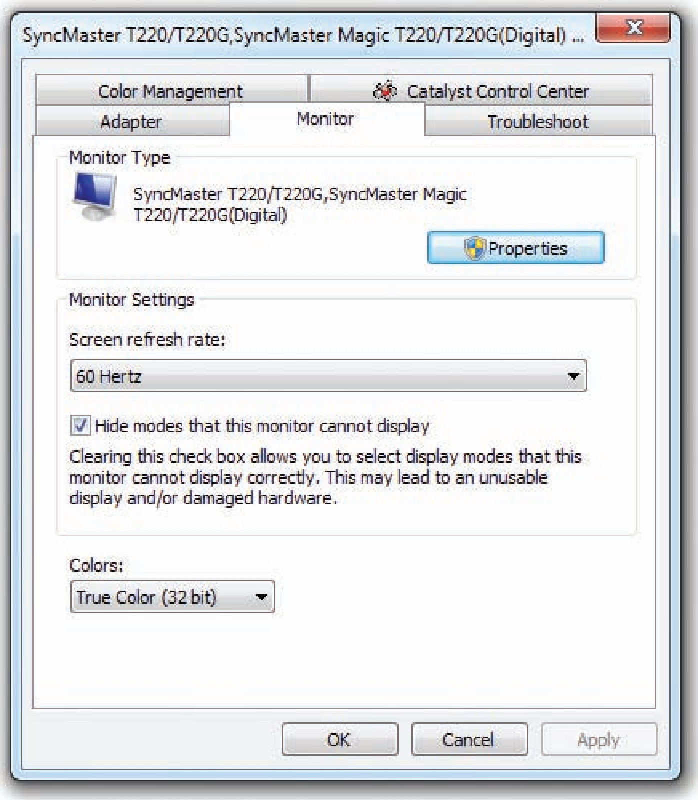
The two tabs you're most likely to use are the Adapter and Monitor tabs. The Adapter tab gives detailed information about the video card, including the amount of video memory, the graphics processor, and the BIOS information (yup, your video card has a BIOS, too!). You can also click on the List All Modes button to change the current mode of the video card, although any mode you may set here, you can also set in the sliders on the main screen.

If you're still using a CRT, you'll find the Monitor tab a handy place. This is where you can set the refresh rate (see Figure 21.66). Windows only shows refresh rates that the monitor says it can handle, but many monitors can take a faster—and therefore easier on the eyes—refresh rate. To see all of the modes the video card can support, uncheck the *Hide modes that this monitor cannot display* option.

If you try this, always increase the refresh rate in small increments. If the screen looks better, use it. If the screen seems distorted or disappears, wait a moment and Windows will reset to the original refresh rate. Be careful when using modes that Windows says the monitor cannot display. Pushing a CRT past its fastest refresh rate for more than a minute or two can damage it.



• **Figure 21.65** Advanced video settings, Adapter tab



• **Figure 21.66** Advanced video settings, Monitor tab

• **Figure 21.67** Third-party video tab

Most video cards add their own tab to the Advanced dialog box. In the case of the tab shown in Figure 21.67, you'd need to click on the Catalyst Control Center button to see more settings for the video card. What you see here varies by model of card and version of driver, but here's a list of some of the more interesting settings you might see.

Color Correction Sometimes the colors on your monitor are not close enough for your tastes to the actual color you're trying to create. In this case you use color correction to fine-tune the colors on the screen to get the look you want.

Rotation All monitors are by default wider than they are tall. This is called *landscape mode*. Some LCD monitors can be physically rotated to facilitate users who like to see their desktops taller than they are wide (*portrait mode*). Figure 21.68 shows the author's LCD monitor rotated in portrait mode. If you want to rotate your screen, you must tell the system you're rotating it.

Modes Most video cards add very advanced settings to enable you to finely tweak your monitor. These very dangerous settings have names such as "sync polarity" or "front porch" and are outside the scope of both CompTIA A+ certification and the needs of all but the most geeky techs. These settings are mostly used to display a non-standard resolution. Stay out of those settings!

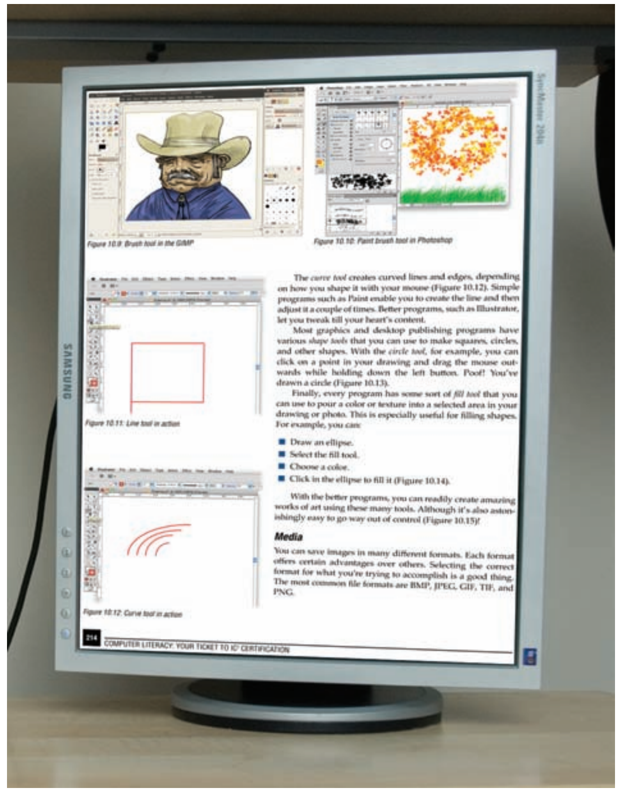
Working with Drivers

Now that you know the locations of the primary video tools within the operating system, it's time to learn about fine-tuning your video. You need to know how to work with video drivers from within the Display (Windows XP/7) and Personalization (Windows Vista) applets, including how to update them, roll back updates, and uninstall them.

Windows is very persnickety when it comes to video card drivers. You can crash Windows and force a reinstallation simply by installing a new video card and not uninstalling the old card's drivers. This doesn't happen every time but certainly can happen. As a basic rule, always uninstall the old card's drivers before you install drivers for a new card.

When you update the drivers for a card, you have a choice of uninstalling the outdated drivers and then installing new drivers—which makes the process the same as for installing a new card—or you can let Windows flex some digital muscle and install the new ones right over the older drivers.

To update your drivers, go to the Control Panel and double-click the Display applet (Windows XP and Windows 7) or click the Personalization applet and click Display Settings (Windows Vista). In the Display Properties dialog box in Windows XP, select the Settings tab and click the Advanced button. In Windows Vista's Display Settings dialog box, select the Monitor tab and click the Advanced Settings button. In the Display applet for Windows 7, click *Change display settings* in the Tasks list and then click the *Advanced settings* link. In the dialog box that appears (all versions), click the Adapter tab and then click the Properties button. In the Properties dialog box for your adapter (see Figure 21.69), select the Driver tab and then click the Update Driver button to run the Hardware Update wizard.



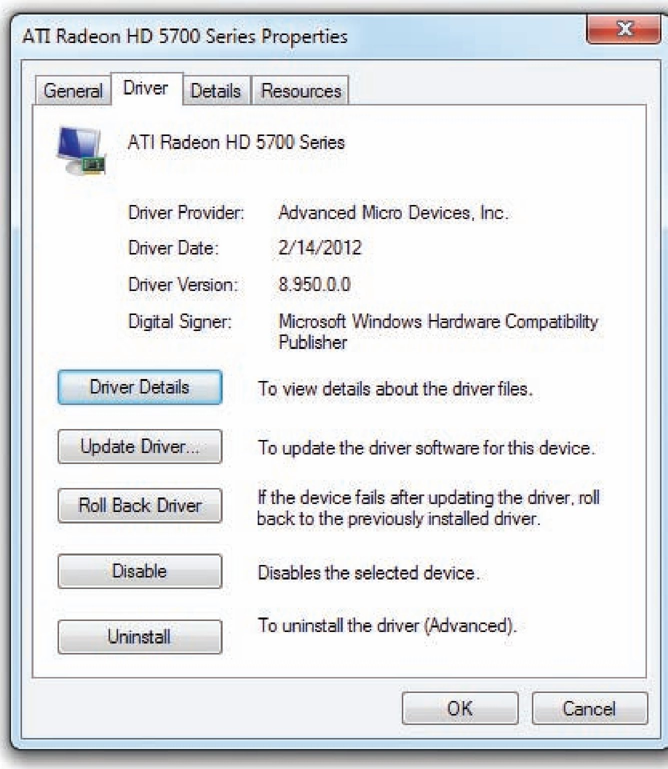
• **Figure 21.68** Portrait mode

3-D Graphics

No other area of the PC world reflects the amazing acceleration of technological improvements more than **3-D graphics**—in particular, 3-D gaming—which attempts to create images with the same depth and texture as objects seen in the real world. We are spectators to an amazing new world where software and hardware race to produce new levels of realism and complexity displayed on the computer screen. Powered by the wallets of tens of millions of PC gamers always demanding more and better, the video industry constantly introduces new video cards and new software titles that make today's games so incredibly realistic and fun. Although the gaming world certainly leads the PC industry in 3-D technologies, many other PC applications—such as *Computer Aided Design* (*CAD*) programs—quickly snatch up these technologies, making 3-D more useful in many ways other than just games. In this section, we'll add to the many bits and pieces of 3-D video encountered over previous chapters in the book and put together an understanding of the function and configuration of 3-D graphics.

Before the early 1990s, PCs did not mix well with 3-D graphics. Certainly, many 3-D applications existed, primarily 3-D design programs such as AutoCAD and Intergraph, but these applications would often run only on expensive, specialized hardware—not so great for casual users.

The big change took place in 1992 when a small company called id Software created a new game



• **Figure 21.69** Adapter Properties dialog box

• **Figure 21.70** *Wolfenstein 3D*

called *Wolfenstein 3D* (see Figure 21.70). They launched an entirely new genre of games, now called *first-person shooters* (*FPSs*), in which the player looks out into a 3-D world, interacting with walls, doors, and other items, and shoots whatever bad guys the game provides.

Wolfenstein 3D shook the PC gaming world to its foundations. That this innovative format came from an upstart little company made *Wolfenstein 3D* and id Software into overnight sensations. Even though their game was demanding on hardware, they gambled that enough people could run it to make it a success. The gamble paid off for John Carmack and John Romero, the creators of id Software, making them the fathers of 3-D gaming.

Early 3-D games used fixed 3-D images called **sprites** to create the 3-D world. A sprite is nothing more than a bitmapped graphic such as a BMP file. These early first-person shooters would calculate the position of an object from the player's perspective and place a sprite to represent the object. Any single object had only a fixed number of sprites—if you walked around an object, you noticed an obvious jerk as the game replaced the current sprite with a new one to represent the new position. Figure 21.71 shows different sprites for the same bad guy in *Wolfenstein 3D*. Sprites weren't pretty, but they worked without seriously taxing the 486s and early Pentiums of the time.

• **Figure 21.71** Each figure had a limited number of sprites.

The second generation of 3-D games began to replace sprites with true 3-D objects, which are drastically more complex than sprites. A true 3-D object is composed of a group of points called **vertices**. Each vertex has a defined X, Y, and Z position in a 3-D world. Figure 21.72 shows the vertices for a video game character in a 3-D world.

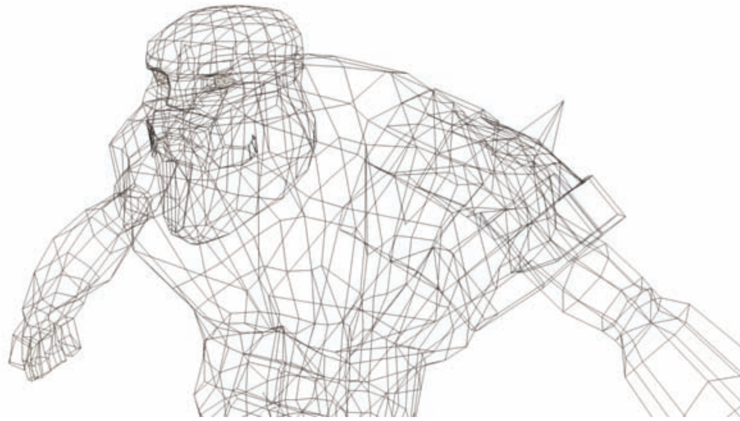
The computer must track all of the vertices of all of the objects in the 3-D world, including the ones you cannot currently see. Keep in mind that objects may be motionless in the 3-D world (a wall, for example), may have animation (such as a door opening and closing), or may be moving (like bad monsters trying to spray you with evil alien goo). This calculation process is called *transformation* and, as you might imagine, is extremely taxing to most CPUs. Intel's SIMD and AMD's 3DNow! processor extensions were expressly designed to perform transformations.

Once the CPU has determined the positions of all vertices, the system begins to fill in the 3-D object. The process begins by drawing lines (the 3-D term is *edges*) between vertices to build the 3-D object into many triangles. Why triangles? Well, mainly by consensus of game developers. Any shape works, but triangles make the most sense from a mathematical standpoint. I could go into more depth here, but that would require talking about trigonometry, and I'm gambling you'd rather not read that detailed a description! All 3-D games use triangles to connect vertices. The 3-D process then groups triangles into various shapes called **polygons**. Figure 21.73 shows the same model as Figure 21.72, now displaying all of the connected vertices to create a large number of polygons.

Originally, the CPU handled these calculations to create triangles, but now special 3-D video cards do the job, greatly speeding up the process.

The last step in second-generation games was texturing. Every 3-D game stores a number of image files called **textures**. The program wraps textures around an object to give it a surface. Textures work well to provide dramatic detail without using a lot of triangles. A single object may take one texture or many textures, applied to single triangles or groups of triangles (polygons). Figure 21.74 shows the finished warrior.

True 3-D objects, more often referred to as *rendered*, immediately created the need for massively powerful video cards and much wider data buses. Intel's primary motivation for creating AGP was to provide a big enough pipe for massive data pumping between the video card and the CPU. Intel gave AGP the ability to read system RAM to support textures. If it weren't for 3-D games, AGP (and probably even PCIe) would almost certainly not exist.



• **Figure 21.72** Vertices for a video game warrior

• **Figure 21.73** Connected vertices forming polygons on a 3-D character

• **Figure 21.74** Video game warrior with textures added

3-D Video Cards

No CPU of the mid-1990s could ever hope to handle the massive processes required to render 3-D worlds. Keep in mind that to create realistic movement, the 3-D world must refresh at least 24 times per second. That means that this entire process, from transformation to texturing, must repeat once every 1/24th of a second! Furthermore, although the game recreates each screen, it must also keep score, track the positions of all of the objects in the game, provide some type of intelligence to the bad guys, and so on. Something had to happen to take the workload off the CPU. The answer came from video cards.

Video cards were developed with smart onboard GPUs. The GPU helped the CPU by taking over some, and eventually all, of the 3-D rendering duties. These video cards not only have GPUs but also have massive amounts of RAM to store textures.

But a problem exists with this setup: How do we talk to these cards? This is done by means of a device driver, of course, but wouldn't it be great if we could create standard commands to speed up the process? The best thing to do would be to create a standardized set of instructions that any 3-D program could send to a video card to do all of the basic work, such as "make a cone" or "lay texture 237 on the cone you just made."

The video card instructions standards manifested themselves into a series of **application programming interfaces (APIs)**. In essence, an API is a library of commands that people who make 3-D games must use in their programs. The program currently using the video card sends API commands directly to the device driver. Device drivers must know how to understand the API commands. If you were to picture the graphics system of your computer as a layer cake, the top layer would be the program making a call to the video card driver that then directs the graphics hardware.

Several APIs have been developed over the years, with two clear winners among all of them: OpenGL and DirectX. The **OpenGL** standard was developed for UNIX systems but has since been *ported*, or made compatible with, a wide variety of computer systems, including Windows and Apple computers. As the demand for 3-D video became increasingly strong, Microsoft decided to throw its hat into the 3-D graphics ring with its own API, called DirectX. We look at DirectX in depth in the next section.

Although they might accomplish the same task (for instance, translating instructions and passing them on to the video driver), every API handles things just a little bit differently. In some 3-D games, the OpenGL standard might produce more precise images with less CPU overhead than the DirectX standard. In general, however, you won't notice a large difference between the images produced by OpenGL and DirectX.

DirectX and Video Cards

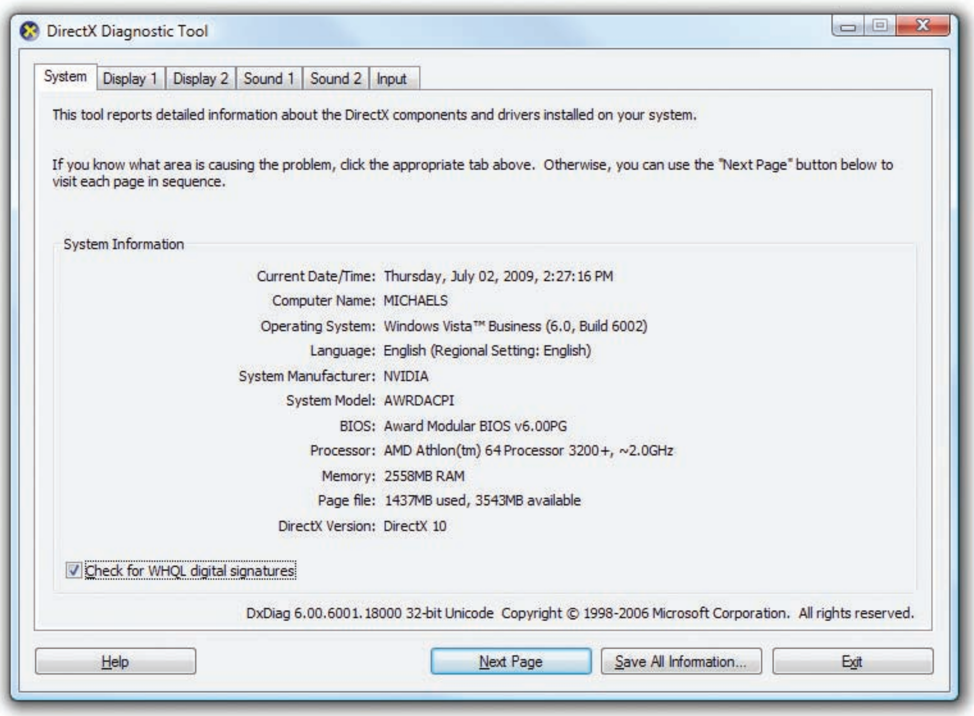
In the old days, many applications communicated directly with much of the PC hardware and, as a result, could crash your computer if not written well enough. Microsoft tried to fix this problem by placing all hardware under the control of Windows, but programmers balked because Windows added too much work for the video process and slowed down everything. For the most demanding programs, such as games, only direct access of hardware would work.

This need to "get around Windows" motivated Microsoft to unveil a new set of protocols called **DirectX**. Programmers use DirectX to take control of certain pieces of hardware and to talk directly to that hardware; it provides the speed necessary to play the advanced games so popular today. The primary impetus for DirectX was to build a series of products to enable Windows to run 3-D games. That's not to say that you couldn't run 3-D games in Windows *before* DirectX; rather, it's just that Microsoft wasn't involved in the API rat race at the time and wanted to be. Microsoft's goal in developing DirectX was to create a 100-percent stable environment, with direct hardware access, for running 3-D applications and games within Windows.

DirectX is not only for video; it also supports sound, network connections, input devices, and other parts of your PC. Each of these subsets of DirectX has a name, such as DirectDraw, Direct3D, or DirectSound.

- **DirectDraw** Supports direct access to the hardware for 2-D graphics
- **Direct3D** Supports direct access to the hardware for 3-D graphics—the most important part of DirectX
- **DirectInput** Supports direct access to the hardware for joysticks and other game controllers
- **DirectSound** Supports direct access to the hardware for waveforms
- **DirectMusic** Supports direct access to the hardware for MIDI devices
- **DirectPlay** Supports direct access to network devices for multiplayer games
- **DirectShow** Supports direct access to video and presentation devices

Microsoft constantly adds to and tweaks this list. As almost all games need DirectX and all video cards have drivers to support DirectX, you need to verify that DirectX is installed and working properly on your system. To do this, use the **DirectX Diagnostic Tool (dxdiag)**, as shown in Figure 21.75).



• **Figure 21.75** The DirectX Diagnostic Tool

The CompTIA A+ 802 exam refers to the DirectX Diagnostic Tool only by its Run command, *dxdiag*.

In Windows XP, you can find it in the System Information program. After you open System Information (it usually lives in the Accessories | System Tools area of the Start menu), click the Tools menu and select DirectX Diagnostic Tool.

For Windows Vista/7, go to Start and type **dxdiag** in the Search bar. Press ENTER to run the program.

The System tab gives the version of DirectX. The system pictured in Figure 21.75 runs DirectX 10.

Cross Check

Keeping DirectX Updated

I always have the latest version of DirectX installed on my system. In my experience, each new version adds functionality and increases stability—both items are extremely important to me. Most versions of Windows have a tool for updating important system files, so flip back to Chapter 17 and run through the steps for updating. What tool should you use to update?

So, what does DirectX do for video cards? Back in the bad old days before DirectX became popular with the game makers, many GPU makers created their own chip-specific APIs. 3dfx had Glide, for example, and S3 had ViRGE. This made buying 3-D games a mess. There would often be multiple versions of the same game for each card. Even worse, many games never used 3-D acceleration because it was just too much work to support all of the different cards.

That all changed when Microsoft beefed up DirectX and got more GPU makers to support it. That in turn enabled the game companies to write games by using DirectX and have them run on any card out there. The bottom line: When Microsoft comes out with a new version of DirectX, all of the GPU companies hurry to support it or they will be left behind.

Trying to decide what video card to buy gives me the shakes—too many options! One good way to narrow down your buying decision is to see what GPU is hot at the moment. I make a point to check out these Web sites whenever I'm getting ready to buy, so I can see what everyone says is the best.

- http://arstechnica.com
- www.hardocp.com
- www.tomshardware.com
- www.sharkyextreme.com

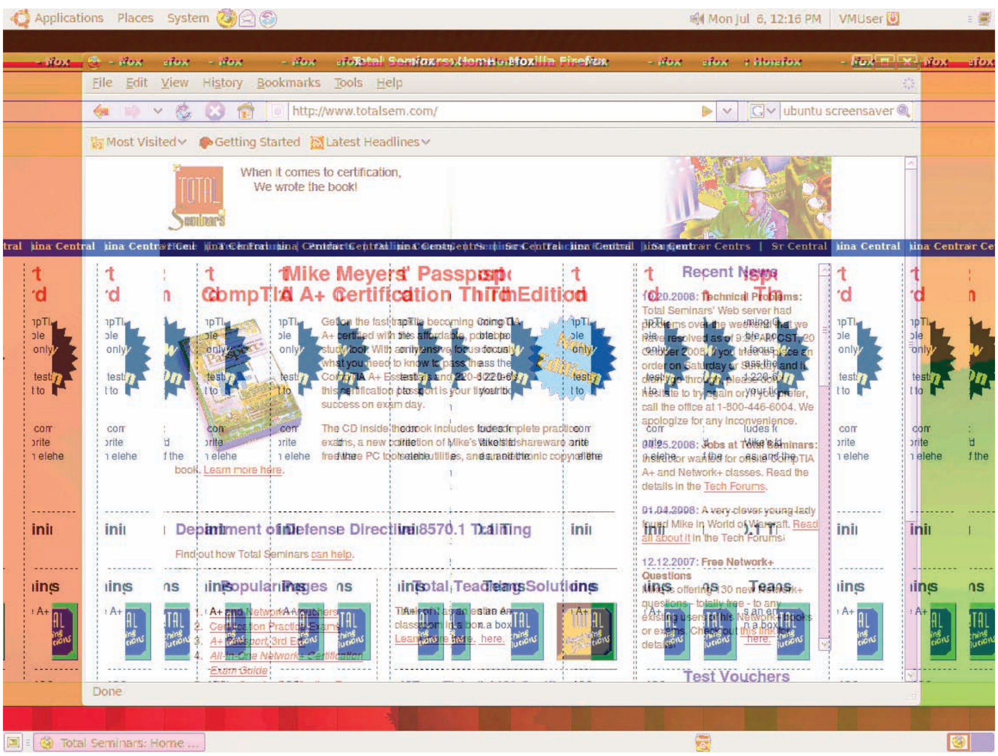
Troubleshooting Video

People tend to notice when their monitors stop showing the Windows desktop, making video problems a big issue for technicians. Users might temporarily ignore a bad sound card or other device, but will holler like crazy when the screen doesn't look the way they expect. To fix video problems quickly, the best place to start is to divide your video problems into two groups: video cards/drivers and monitors.

Troubleshooting Video Cards/Drivers

Video cards rarely go bad, so the vast majority of video card/driver problems are bad or incompatible drivers or incorrect settings. Always make sure you have the correct driver installed. If you're using an incompatible driver, Windows defaults to good old 640 × 480, 16-color VGA mode or you might get a Blue Screen of Death (BSoD) as soon as Windows starts to load. A driver that is suddenly corrupted usually doesn't show the problem until the next reboot. If you reboot a system with a corrupted driver, Windows will do one of the following: go into VGA mode, blank the monitor, lock up, or display a garbled screen with weird color patterns or a very distorted image. Whatever the output, reboot into Safe mode and roll back or delete the driver. Keep in mind that more advanced video cards tend to show their drivers as installed programs under Add or Remove Programs in Windows XP or Programs and Features in Windows Vista/7, so always check there first before you try deleting a driver by using Device Manager. Download the latest driver and reinstall.

Video cards are pretty durable but they have two components that do go bad: the fan and the RAM. Lucky for you, if either of these goes out, it tends to show the same error—bizarre screen outputs followed shortly by a screen lockup. Usually Windows keeps running; you may see your mouse pointer moving around and windows refreshing, but the screen turns into a huge mess (see Figure 21.76).



• **Figure 21.76** Serious video problem

Bad drivers sometimes also make this error, so always first try going into Safe mode to see if the problem suddenly clears up. If it does, you do not have a problem with the video card!

Excessive heat inside the case, even with the video card fan running at full blast, can create some interesting effects. The computer could simply shut down due to overheating. You'll recognize this possible cause because the computer will come back up in a minute or two, but then shut down again as you use it hard and it heats up again. Sometimes the screen will get bizarre artifacts or start distorting. Check your case fans and make sure nothing is too close to the video card. You might need to blow out (outdoors!) the dust from filters, vents, and fans.

The last and probably most common problem is nothing more than improperly configured video settings. Identifying the problem is just common sense—if your monitor is showing everything sideways, someone messed with your rotation settings; if your gorgeous wallpaper of a mountain pass looks like an ugly four-color cartoon, someone lowered the color depth. You'll need to reset the color depth to a more appropriate setting. In Windows XP, open the Display Properties. In Windows Vista, go to Personalization | Display Settings. In Windows 7, go to Display | Change display settings | Advanced settings, then open the Monitor tab.

The one serious configuration issue is pushing the resolution too high. If you adjust your resolution and then your monitor displays an error message such as "Input Signal Out of Range," just wait. Windows will automatically put your settings back after a few seconds if you don't click on anything.

Troubleshooting Monitors

Because of the inherent dangers of the high-frequency and high-voltage power required by monitors, and because proper adjustment requires specialized training, this section concentrates on giving a support person the information necessary to decide whether a trouble call is warranted. Virtually no monitor manufacturers make schematics of their monitors available to the public, because of liability issues regarding possible electrocution. To simplify troubleshooting, look at the process as three separate parts: common monitor problems, external adjustments, and internal adjustments.

Common Monitor Problems

Although I'm not super comfortable diving into the guts of a monitor, you can fix a substantial percentage of monitor problems yourself. The following list describes the most common monitor problems and tells you what to do—even when that means sending it to someone else.

- Almost all CRT and LCD monitors have replaceable controls. If the Brightness knob or Menu button stops working or seems loose, check with the manufacturer for replacement controls. They usually come as a complete package.
- For problems with ghosting, streaking, and/or fuzzy vertical edges, check the cable connections and the cable itself. These problems rarely apply to monitors; more commonly, they point to the video card.

- If one color is missing, check cables for breaks or bent pins. Check the front controls for that color. If the color adjustment is already maxed out, the monitor will require internal service.
- As monitors age, they lose brightness. If the brightness control is turned all of the way up and the picture seems dim, the monitor will require internal adjustment. This is a good argument for power-management functions. Use the power switch or the power-management options in Windows to turn off the monitor after a certain amount of time.

Common Problems Specific to CRTs

The complexity of CRTs compared to LCDs requires us to look at a number of monitor problems unique to CRTs. Most of these problems require opening the monitor, so be careful! When in doubt, take it to a repair shop.

- Most out-of-focus monitors can be fixed. Focus adjustments are usually on the inside, somewhere close to the flyback transformer. This is the transformer that provides power to the high-voltage anode.
- Hissing or sparking sounds are often indicative of an insulation rupture on the flyback transformer. This sound is usually accompanied by the smell of ozone. If your monitor has these symptoms, it definitely needs a qualified technician. Having replaced a flyback transformer once myself, I can say it is not worth the hassle and potential loss of life and limb.
- Big color blotches or discoloration on the display are an easy and cheap repair. Find the Degauss button and use it. If your monitor doesn't have a Degauss button, you can purchase a special tool called a degaussing coil at any electronics store.
- Bird-like chirping sounds occurring at regular intervals usually indicate a problem with the monitor power supply.
- Suppose you got a good deal on a used 19-inch monitor, but the display is kind of dark, even though you have the brightness turned up all the way. This dim image points to a dying CRT. So, how about replacing the CRT? Forget it. Even if the monitor was free, it just isn't worth it; a replacement tube runs into the hundreds of dollars. Nobody ever sold a monitor because it was too bright and too sharp. Save your money and buy a new monitor.
- If the monitor displays only a single horizontal or vertical line, the problem is probably between the main circuit board and the yoke, or a blown yoke coil. This definitely requires a service call.
- A single white dot on an otherwise black screen means the high-voltage flyback transformer is most likely shot. Take it into the repair shop.

External Adjustments

Monitor adjustments range from the simplest—brightness and contrast—to the more sophisticated—pincushioning and trapezoidal adjustments. The external controls provide users with the opportunity to fine-tune the monitor's image. Many monitors have controls for changing the tint and saturation of color, although plenty of monitors put those controls inside the monitor. Better monitors enable you to square up the visible portion of the screen with the monitor housing.

Finally, most monitors have the ability to **degauss** themselves with the push of a button. Over time, the shadow mask picks up a weak magnetic charge that interferes with the focus of the electron beams. This magnetic field makes the image look slightly fuzzy and streaked. Most monitors have a special built-in circuit called a *degaussing coil* to eliminate this magnetic buildup. When the degaussing circuit is used, an alternating current is sent through a coil of wire surrounding the CRT, and this current generates an alternating magnetic field that demagnetizes the shadow mask. You activate the degaussing coil by using the Degauss button or menu selection on the monitor. Degaussing usually makes a rather nasty thunk sound and the screen goes crazy for a moment—don't worry, that's normal.

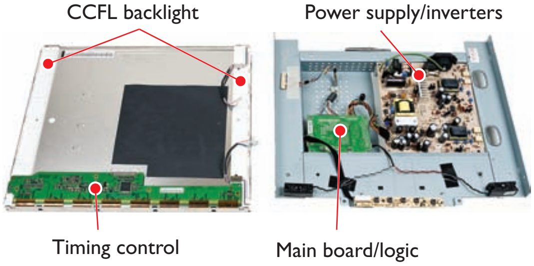
Internal CRT adjustments should be left to the professional monitor techs.

Troubleshooting LCDs

With the proliferation of LCD panels in the computing world, PC techs need to have some understanding of what to do when they break. Some of the components you can fix, including replacing some of the internal components. I tend to use monitor repair shops for most LCD issues, but let's take a look.

An LCD monitor may have bad pixels. A bad pixel is any single pixel that does not react the way it should. A pixel that never lights up is a *dead pixel*, a pixel that is stuck on pure white is a lit pixel, and a pixel on a certain color is a stuck pixel. You cannot repair bad pixels; the panel must be replaced. All LCD panel makers allow a certain number of bad pixels, even on a brand-new LCD monitor! You need to check the warranty for your monitor and see how many they allow before you may return the monitor.

- If your LCD monitor cracks, it is not repairable and must be replaced.
- A flickering image with an LCD usually points to either a very inexpensive panel with too much light bleed from the backlight or a dying CCFL backlight. LEDs don't flicker, so you won't see this issue with those types of LCDs. Replace the backlight if necessary.
- A dim image, especially on only the top or bottom half of the screen, points to a dead or dying backlight in a multibacklight system. Replace as necessary.
- If the LCD goes dark but you can still barely see the image under bright lights, you lost either the backlight or the inverter. In many cases, especially with super-thin panels, you'll replace the entire panel and backlight as a unit. On the other hand, an inverter can be on a separate circuit board that you can replace, such as the one pictured in Figure 21.77.
- If your LCD makes a distinct hissing noise, an inverter is about to fail. Again, you can replace the inverter if need be.



• **Figure 21.77** LCD components labeled

Be careful if you open an LCD to work on the inside. The inverter can bite you in several ways. First, it's powered by a high-voltage electrical circuit that can give you a nasty shock. Worse, the inverter will retain a charge for a few minutes after you unplug it, so unplug and wait for a bit. Second, inverters get very hot and present a very real danger of burning you at a touch. Again, wait for a while after you unplug it to try to replace it. Finally, if you shock an inverter, you might irreparably damage it. So use proper ESD-avoidance techniques.

Bottom line on fixing LCD monitors? You can find companies that sell replacement parts for LCDs, but repairing an LCD is difficult, and there are folks who will do it for you faster and cheaper than you can. Search for a specialty LCD repair company. Hundreds of these companies exist all over the world.

Cleaning Monitors

Cleaning monitors is easy. Always use antistatic monitor wipes or at least a general antistatic cloth. Some LCD monitors may require special cleaning equipment. Never use window cleaners that contain ammonia or any liquid because getting liquid into the monitor may create a shocking experience! Many commercial cleaning solutions will also melt older LCD screens, which is never a good thing.

Safety Concerns

Aside from avoiding the inside of a CRT, the biggest safety issues involve moving and recycling monitors. Always practice good cable management, especially if you have the back of the monitor area exposed to traffic. One accidental hook of a monitor cable could cause it to come crashing to the floor. They don't do too well with impact.

CRTs are heavy, even the small ones, and the ones likely still in use are probably the graphics workstation 20+-inch units. Use proper lifting techniques (use your legs, not your back) and be careful when you place the monitor on lighter-weight shelves or stands. Monitor stands all have weight limitations.

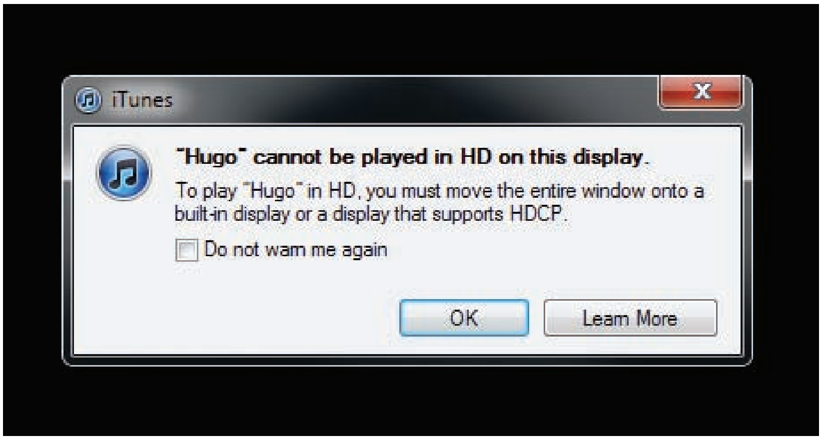
CompTIA is not much interested in mounting LCD monitors to wall mounts, but all of the wall mounts have fairly strict weight limitations as well. Don't hang that lovely new 24-inch panel on a mount designed to handle the weight of a 17-inch unit!

Finally, you should always take a monitor—CRT or LED—to a proper recycling center. They have toxic chemicals such as lead and mercury and should never be placed in a landfill.

Troubleshooting Playback

One of the odd "video" issues techs run into today is when a Blu-ray Disc or downloaded HD movie won't play and the user gets the error message that his or her display won't play that media. Figure 21.78 shows the dreaded message from iTunes that says you can't play the movie you just rented.

Note the fine print under the generic comment: ". . . display that supports HDCP." The HDCP part is the key here.



• **Figure 21.78** HDCP erro

You'll recall from Chapter 13 the High-bandwidth Digital Content Protection (HDCP) standard that Intel created to help movie makers ensure copyright protection and stop pirates from stealing copyright-protected content. It's not just the monitor that must support HDCP; every part of the connection between the video card and the monitor must support it. The monitor that captured the screenshot in Figure 21.78 most assuredly is HDCP compliant, as is the video card. The error appeared because the monitor connects to the video card through a VGA cable.

Only HDMI, DVI, and DisplayPort cables support HDCP. VGA does not, which is one of the major differences among the standards. Note also that HDCP can bite you when using converters too, like Mini HDMI to Standard HDMI, so always check that as well.

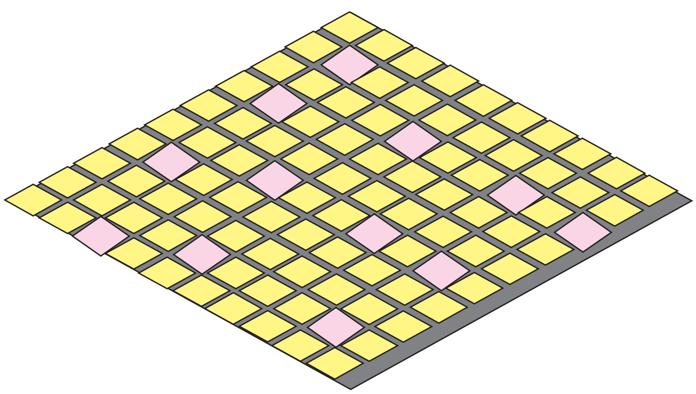
• **Figure 21.79** DLP chip (photo courtesy of Texas Instruments)

Beyond A+

DLP

Digital Light Processing (*DLP*) displays use a chip covered in microscopically small mirrors (see Figure 21.79).

These individual mirrors move thousands of times per second toward and away from a light source. The more times per second they move toward a light source, the whiter the image; the fewer times they move, the grayer the image. See Figure 21.80 for a diagram of how the mirrors would appear in a microscopic close-up of the chip. The lamp projects through a color wheel onto the DLP chip. The DLP chip creates the image by moving the tiny mirrors, which in turn reflect onto the screen.



• **Figure 21.80** Microscopic close-up of DLP showing tiny mirrors—note that some are tilted.

DLP was very popular for a time in home theater systems, as it makes an amazingly rich image. DLP has had very little impact on PC monitors, but has had great success in projectors. DLP projectors are much more expensive than LCD projectors, but many customers feel the extra expense is worth the image quality.

Chapter 21 Review

Chapter Summary

After reading this chapter and completing the exercises, you should understand the following about video.

Explain how video displays work

- The term *video* encompasses a complex interaction among numerous parts of the PC, all designed to put a picture on the screen. The monitor is the primary output device for the PC and shows you what's going on with your programs and operating system. The video card or display adapter handles all of the communication between the CPU and the monitor. Video displays come in three varieties: CRT, LCD, and projectors.
- CRT monitors have a tube that contains three electron guns at the slender end and a display screen coated with phosphor at the wide end. The speed of the electron beam across the screen is the horizontal refresh rate (HRR), more commonly referred to as the refresh rate. The vertical refresh rate (VRR) is the time it takes to draw the entire screen and return the electron guns to the upper-left corner.
- Monitors do not determine the HRR or VRR. The video card "pushes" the monitor at a certain VRR that, in turn, determines the HRR. Setting the VRR too low results in screen flicker, which causes headaches and eyestrain. Setting the VRR too high results in image distortion and damage to the monitor's circuitry.
- A monitor is a grid of red, green, and blue light-sensitive dots called phosphors. Normal CRT monitors have three electron guns that fire electrons of different intensities (not colors) at the colored phosphors. A shadow mask prevents electron bleed-over so electrons from any of the three guns hit only their own colored phosphors. The area of phosphors lit at one instant is a pixel and must consist of at least one red, one green, and one blue phosphor; therefore, the smallest pixel, a triad, would consist of three phosphors.
- Resolution is the number of horizontal pixels times the number of vertical pixels. A resolution of 640 × 480 means 640 pixels across and 480 pixels down, for a total of 307,200 pixels total. Many monitors have a resolution that matches a 4:3 aspect ratio. Widescreen monitors have an aspect ratio of 16:9 or 16:10.
- Liquid crystal displays are the most common type of display for PCs. They offer many advantages over CRTs. An LCD monitor is thinner, lighter, uses less power, is virtually flicker-free, and does not emit potentially harmful radiation.
- An LCD screen is composed of tiny liquid crystal molecules called sub-pixels. Although you may find dual-scan passive matrix on some low-end LCD panels, most of today's LCD panels use active matrix or thin film transistor (TFT) technology.
- The typical LCD monitor is composed of the LCD panel, backlights, and inverters. Most backlights require AC power and the electronics require DC. The AC/DC transformer changes the AC wall current into DC that the LCD panel can use. Most LCD backlights use cold cathode fluorescent lamp (CCFL) technology. CCFLs require AC power, so inverters convert the DC back to AC. Newer and better LCDs use LED backlights. These use DC, so they require no inverter. Manufacturers refer to these types of displays as LED monitors.
- LCD monitors, unlike CRTs, have a native resolution and a fixed pixel size. LCDs cannot run at a resolution higher than their native resolution, and running a lower resolution results in degraded image quality. Anti-aliasing softens the edges of jagged pixel corners when running at lower resolutions, but as the image quality degrades, you should use the native resolution.
- LCD monitor brightness is determined by its backlights and is measured in nits. An average LCD measures around 300 nits, with higher numbers being brighter and better.
- The time it takes for sub-pixels to go from pure black to pure white and back again is the LCD's response rate. Response rate is measured in milliseconds, with lower numbers being faster and better. An excellent LCD monitor has a response rate somewhere between 2 and 4 ms.

- LCD monitors lack the color saturation and contrast of a CRT, making CRT the choice for graphics artists. Look for an LCD monitor with a contrast ratio of 450:1 or higher.
- Projectors come in two main varieties: rearview and front-view. Rearview projectors shoot an image onto the screen from the back and are almost always self-enclosed. They are a popular choice for televisions, but not for PCs. Front-view projectors shoot an image from the front and are widely used during computer presentations.
- LCD projectors, like LCD monitors, have a native resolution and are lightweight, but lack the image quality of a CRT. Projector brightness is measured in *lumens*. Larger numbers are brighter and better, with 1500 lumens being sufficient for a small, dark room. The size of the projected image at a certain distance from the screen is the projector's *throw*. LCD projectors come with internal fans that cool the lamp. Lamps are costly to replace and are considered consumable (meaning you can expect to replace them periodically).
- Measured from two opposite diagonal corners, size for CRT monitors is not usually the same as the viewable image size. A 17-inch CRT monitor might have only a 15.5-inch VIS. Because LCD monitors report only VIS, a 15-inch LCD monitor may have approximately the same viewing area as a 17-inch CRT.
- CRT monitors require two connectors: a 15-pin, three-row, DB-type connector and a power plug. Video cards use a RAMDAC, which takes the digital signal from the video card and turns it into an analog signal for the CRT. LCD monitors require a digital signal. Analog LCD monitors reverse the effects of the RAMDAC so you can plug your LCD monitor into the 15-pin VGA connector on the video card.
- The DVI standard allows the digital signal from the PC to be used by the LCD monitor without any digital-to-analog-and-back-to-digital conversion. The DVI standard includes DVI-D, DVI-A, and DVI-I. Both DVI-D and DVI-I come in single-link and dual-link varieties, with dual-link offering significantly higher resolutions.
- Monitors have adjustment controls for brightness, contrast, image size and position, and color adjustment. These controls are usually accessed via an onboard menu system rather than with hardware knobs or dials.
- A CRT monitor accounts for about half of the power consumption of a desktop PC. Monitors using the VESA standard for Display Power Management Signaling (DPMS) can cut monitor power consumption by about 75 percent. An LCD monitor uses less than half the electricity a CRT uses.

Select the proper video card

- The display adapter, or video card, handles the video chores within the PC, processing information from the CPU and sending it out to the monitor. The display adapter is a complex set of devices. The video card has two major pieces: the video RAM and the video processing circuitry. The video RAM stores the video image, and the processing circuitry is similar to that of your computer's CPU.
- The combination of a specific resolution and color depth is referred to as a mode. The VGA mode is defined by a resolution of 640 × 480 and 4-bit color depth (16 colors). Modern video cards and monitors are capable of supporting many modes.
- Using more color depth slows down video functions. PCI slots maxed out at a bandwidth of 132 MBps. The Accelerated Graphics Port (AGP) is better suited for video than PCI because it resides alone on its own bus, pipelines commands, and supports sidebanding and system memory access.
- AGP has undergone several specification upgrades, and the cards are normally referred to by their strobe multiplier. Although you can mix some AGP specifications, it is best to use an AGP card that is fully supported by your motherboard. Make sure AGP cards are properly and fully inserted in the AGP port, as they require a close connection between card and port.
- PCI Express video cards currently dominate the market for all recent systems. Like AGP, PCI Express supports sidebanding and system memory access, but it uses a faster serial communication method than that of the parallel communication method used by AGP.
- Video cards are identified by their manufacturer, model number, graphics processor, amount of video RAM, and the slot to which they connect. Although a number of companies produce video cards, the three major manufacturers of graphics processors are NVIDIA, AMD, and Intel. The most important decision when buying a video card

is the graphics processor, especially if you play 3-D games.

- To overcome the bottlenecks of data throughput speed, access speed, and capacity of video RAM, manufacturers use specialized fast RAM and more and more total RAM. Video memory technologies include VRAM, WRAM, SGRAM, DDR SDRAM, DDR2 SDRAM, GDDR3 SDRAM, GDDR4 SDRAM, and GDDR5 SDRAM.
- A lot of current motherboards have integrated GPUs or are ready for a CPU with an integrated GPU. The motherboard GPU can be a separate chip attached to the motherboard or can be built into the Northbridge chip. You might run into AMD Radeon chips or NVIDIA nForce chips powering the GPU. Intel has long integrated the Intel Graphics Media Accelerator (GMA) into its chipsets.
- You can find many different types of connector types on video cards, plus variations within those types. CompTIA also makes a distinction between the names of the ports on the cards and the cables associated with them, though most techs will refer to the connectors and cables by multiple names interchangeably.
- Common connectors and cables include VGA (DB-15), DVI, DisplayPort, and HDMI. Other less-common connectors and cables include BNC (used with coaxial cable), Din-6 (used with S-video), and RCA (used with component and composite cables).

Install and configure video

- During the physical install of a video card, be conscious of long cards and proximity to other PCI cards. Long cards simply don't fit in some cases, and close proximity to other expansion cards can cause overheating.
- Video card drivers install pretty much the same as all other drivers: either the driver is already built into Windows or you must use the installation media that comes with the video card.
- As a basic rule, always uninstall an old video card's drivers before you install drivers for a new card.
- The Display applet (Windows XP) or Personalization applet (Windows Vista) provides a convenient, central location for adjusting all of your display settings, including resolution, refresh rate, driver information, and color depth. Windows 7 splits its display controls across both the Display applet and the Personalization applet.
- In Windows XP's Display applet, the Screen Saver tab provides access to the power-management settings. In Windows Vista and Windows 7, this is an option in the Personalization applet.
- The Settings tab in Windows XP's Display applet provides access for configuring all of your video settings, such as resolution, color depth, and dual monitor configuration. The Settings tab also provides an Advanced button for access to the Monitor tab. The Monitor tab enables you to set the refresh rate for your CRT monitor. Most video cards add their own tabs to the Advanced section. In Windows Vista, all of these controls are contained within the Personalization | Display Settings option. In Windows 7, these controls are found within the Display | Change display settings option.
- You can configure dual monitors by using a video card with two monitor connectors or by using two video cards. Either way, once both monitors are connected, you can enable the second monitor in Windows XP from the Display applet's Settings tab, in Windows Vista from the Personalization | Display Settings option, and in Windows 7 from the Display | Change display settings option.
- Early 3-D games used sprites to create a 3-D world. Later games replaced sprites with true 3-D objects composed of vertices. Bitmap textures are used to tile a section of the screen to provide a surface in the 3-D world.
- Video cards use a series of APIs to translate instructions for the video device driver. If you were to picture the graphics system of your computer as a layer cake, the top layer would be the program making a call to the graphics hardware. The next layer is the API. The device driver comes next, and way down at the base of the cake is the actual graphics hardware: RAM, graphics processor, and RAMDAC. OpenGL and DirectX are the most popular APIs.
- DirectX includes several subsets, including DirectDraw, Direct3D, DirectInput, DirectSound, DirectMusic, DirectPlay, and DirectShow. You can verify your DirectX installation via the DirectX Diagnostics Tool, which is found in Windows XP under the Tools menu of the System Information utility and in Windows Vista/7 by typing **dxdiag** in the Start | Search bar.

Troubleshoot basic video problems

- Video problems may be divided into two categories: video cards/drivers and monitors.
- If your screen is black or garbled, or Windows freezes after you install a video card driver, reboot into Safe mode and roll back or delete the driver. Check Add or Remove Programs in Windows XP and Programs and Features in Windows Vista/7 first, as many video card drivers show up there. If Safe mode doesn't fix the problem, you may have a bad video card that needs to be replaced.
- All monitors have replaceable hardware controls (knobs and buttons). Check with the manufacturer for replacement parts. Ghosting, streaking, or fuzzy images may mean a bad or improperly connected video cable, or the video card may be the cause.
- Because monitors have high-voltage power that can harm or kill you, always leave it to the trained professional to work inside the monitor. Many CRT monitors have a button to degauss themselves. When the shadow mask picks up a weak magnetic charge, it interferes with the focus of the electron beams, making the monitor appear fuzzy or streaked. A built-in circuit called a degaussing coil generates an alternating magnetic field that eliminates the magnetic buildup on the shadow mask.
- Clean CRT monitors with an antistatic monitor wipe. Never use window cleaners or other liquids. LCD monitors need special cleaning equipment or a soft, damp cloth.
- Common monitor problems are often related to cable breaks or bent pins. Monitors also lose brightness over time, especially if you are not using the power-management functions.
- For best performance, keep the screen clean, use power management, don't block the ventilation slots, and don't leave the monitor on all of the time, even with a screensaver. If the monitor is dead, use proper disposal methods.
- A cracked LCD monitor must be replaced. If the LCD screen goes dark, starts to hiss, or develops bad pixels, it is best to either replace the monitor or find a company specializing in LCD repair.

Key Terms

3-D graphics *(803)*
Accelerated Graphics Port (AGP) *(786)*
active matrix *(772)*
anti-aliasing *(774)*
application programming interface (API) *(806)*
aspect ratio *(768)*
backlight *(773)*
cathode ray tube (CRT) *(765)*
cold cathode fluorescent lamp (CCFL) *(773)*
color depth *(783)*
degauss *(812)*
digital visual interface (DVI) *(780)*
DirectX *(806)*
DirectX Diagnostic Tool (dxdiag) *(807)*
display adapter *(764)*
Display applet *(794)*
DisplayPort *(791)*
Display Power-Management Signaling (DPMS) *(781)*
dual-scan passive matrix *(772)*
front-view projector *(776)*
graphics processing unit (GPU) *(788)*
High Definition Multimedia Interface (HDMI) *(792)*
horizontal refresh rate (HRR) *(767)*
inverter *(773)*
light-emitting diode (LED) *(774)*
liquid crystal display (LCD) *(769)*
lumen *(777)*
mode *(785)*
monitor *(764)*
native resolution *(774)*
nit *(775)*
OpenGL *(806)*
passive matrix *(772)*
PCI Express (PCIe) *(788)*
persistence *(766)*
Personalization applet *(794)*
phosphors *(768)*
pixel *(768)*
polygons *(805)*
projector *(776)*
random access memory digital-to-analog converter (RAMDAC) *(779)*
raster line *(766)*
rearview projector *(776)*

resolution *(768)*
response rate *(775)*
shadow mask *(768)*
sidebanding *(787)*
sprite *(804)*
sub-pixel *(771)*
texture *(805)*
thin film transistor (TFT) *(772)*
throw *(777)*
triad *(769)*
vertical refresh rate (VRR) *(767)*
vertices *(804)*
video display *(764)*
video graphics array (VGA) *(785)*
viewable image size (VIS) *(778)*

Key Term Quiz

Use the Key Terms list to complete the sentences that follow. Not all terms will be used.

1. To provide the optimal display for an LCD monitor, always set it to its ________________.
2. On a CRT screen, a(n) ________________ consists of one red, one green, and one blue phosphor; in theory, the smallest pixel a monitor can display.
3. DirectX is a(n) ________________, a program that translates instructions for the video device driver.
4. Using an aspect ratio of 4:3, the ________________ refers to the number of horizontal pixels times the number of vertical pixels.
5. The ________________ bus, designed specifically for video cards, connects directly to the Northbridge, but has for the most part been phased out in favor of the ________________ bus.
6. If your monitor displays big color blotches, it indicates that you should ________________ the monitor to eliminate the magnetic buildup on the shadow mask.
7. The number of sweeps or raster lines that the electron guns make across the screen is called the ________________ while the time it takes to draw the entire screen is called the ________________.
8. Apple Macs primarily use the ______________________ display connector type.
9. A(n) ________________ handles the video processing chores in modern systems.
10. The size of the projected image at a specific distance from the screen is defined as the projector's ________________.

Multiple-Choice Quiz

1. If one of the colors is missing on the monitor and you cannot fix the problem by adjusting the front controls, you should then check for ________________.
   - **A.** A refresh rate that is set higher than that recommended by the manufacturer
   - **B.** A corrupted video driver
   - **C.** A broken cable or bent pins
   - **D.** Misconvergence
2. Which of the following resolutions will produce the best quality picture on the monitor (assuming the monitor is capable of displaying the resolutions well)?
   - **A.** 640 × 480
   - **B.** 800 × 600
   - **C.** 1024 × 768
   - **D.** 1280 × 1024

3. Which of the following problems would make it impossible to repair an LCD monitor?
   - **A.** A blown yoke coil
   - **B.** A broken LCD panel
   - **C.** A bad flyback transformer
   - **D.** Misconvergence
4. CRT monitors attach to the video card by using a(n) __________________ connector.
   - **A.** 9-pin, 2-row, DB
   - **B.** 36-pin Centronics
   - **C.** 15-pin, 3-row, DB
   - **D.** 25-pin, 2-row, DB
5. Which of the following statements best describes the electron guns in a CRT monitor?
   - **A.** A single gun shoots electrons at the phosphors on the screen.
   - **B.** Three electron guns, one each for red, green, and blue phosphors, paint the screen.
   - **C.** The electron guns stay on all of the time to shoot electrons that produce the solid image on the screen.
   - **D.** One electron gun shoots red phosphors, another shoots green phosphors, and the third shoots blue phosphors at the screen.
6. If the monitor displays only a single horizontal or vertical line, the problem is likely to be caused by a __________________.
   - **A.** Bad flyback transformer
   - **B.** Blown yoke coil
   - **C.** Bad monitor power supply
   - **D.** Bad electron gun
7. What advantages do LCD monitors offer over CRT monitors?
   - **A.** Better color and more contrast
   - **B.** Energy efficiency and no emission of potentially harmful radiation
   - **C.** Electron guns fire CMYK instead of RGB
   - **D.** Both A and B
8. Which projector produces the brightest image?
   - **A.** One with the longest throw lens
   - **B.** One with the largest lamp
   - **C.** One with the largest degaussing coil
   - **D.** One with the highest lumen rating
9. Which statement best describes pixels?
   - **A.** Pixels consist of exactly one red, one green, and one blue phosphor.
   - **B.** Pixels on a CRT are always the same size.
   - **C.** Higher resolutions result in more pixels per row.
   - **D.** LCDs don't use pixels.
10. A user wishes to display millions of colors. What is the minimum color depth the user must set in the adapter settings?
    - **A.** 4-bit
    - **B.** 8-bit
    - **C.** 16-bit
    - **D.** 24-bit
11. What is the most popular API used by 3-D game developers?
    - **A.** DirectX
    - **B.** OpenGL
    - **C.** DigitalDirector
    - **D.** RAMDAC
12. A Windows XP user calls in complaining that her monitor is too small. Upon further questioning, you find out that it's not the monitor that's small, but the font and icon size that are too small! What would you do to help the user fix the problem?
    - **A.** In the Control Panel, open the Display applet. Select the Settings tab and increase the screen resolution.
    - **B.** In the Control Panel, open the Display applet. Select the Settings tab and decrease the screen resolution.
    - **C.** In the Control Panel, open the Monitor applet. Select the Settings tab and increase the screen resolution.
    - **D.** In the Control Panel, open the Monitor applet. Select the Settings tab and decrease the screen resolution.
13. Which two technologies are used for backlights in LCD monitors?
    - **A.** CCFL and LED
    - **B.** CCFL and LCD
    - **C.** CCFL and AC
    - **D.** HDMI and DisplayPort

14. What tool enables you to test 3-D video in a modern PC?

    A. DirectX
    B. dxdiag
    C. OpenGL
    D. NVIDIA

15. Which Control Panel applet in Windows 7 enables you to change settings involving how the monitor shows text and the Windows theme that determines the colors of boxes and other visual items?

    A. Display
    B. Personalization
    C. System
    D. Visualization

Essay Quiz

1. Your company is getting ready to replace their computers and monitors. You would like to see all of the new PCs come with LCD monitors. Write a memo to your boss that talks about the advantages of LCD monitors over CRT monitors, but also discusses some of the variations among LCD technologies that she should take into consideration.
2. The editor of your company's newsletter has asked you to prepare a short article for next month's edition that explains how to care for monitors to extend their lifespan. Explain at least four things that the average user can do.
3. Dave and Shannon disagree about whether the monitor should stay on all of the time or not. Dave says it's okay to leave the monitor on as long as you have a screensaver. Shannon disagrees, saying the monitor will become dim and burn out sooner if you leave it on. Dave thinks that leaving it on actually extends its life because turning the monitor on and off is bad for it. They've called you to save their monitor and their marriage. What will you tell them?
4. You've been tasked to write a guide for new users of Windows 7, specifically how to tailor their screens to suit their eyes and sensibilities. Write a short essay discussing the appropriate Control Panel applets and the various things they can do.
5. Your company just hired two new technicians. You've been tapped to teach them what they can and cannot do to troubleshoot and repair an LCD monitor. What will you tell them?

Lab Projects

• Lab Project 21.1

If you just received a $500 bonus and decided to buy a new video system for your computer, what would you select? Go to the local computer store or to Web sites such as www.newegg.com and pick out the best combination of monitor and video card that you can buy with your bonus. Now imagine that you also received a $200 birthday gift and have decided to purchase an even better graphics card and monitor. Which ones will you select now that you have $700 to spend?

• Lab Project 21.2

Monitors are not the only output device for the computer. Research one of the following devices and prepare a short essay for the class about how the device works and its features, cost, and connections.

- Rearview projectors
- Plasma monitors
- Touch screens