CHAPTER 19

Video

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 19-1). 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.

Figure 19-1 Typical monitor and video card

Let's look at monitors and video cards 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 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.

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 Although for the most part they've been replaced by LCD technology on new systems, plenty of CRT monitors are still chugging away in the field.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.

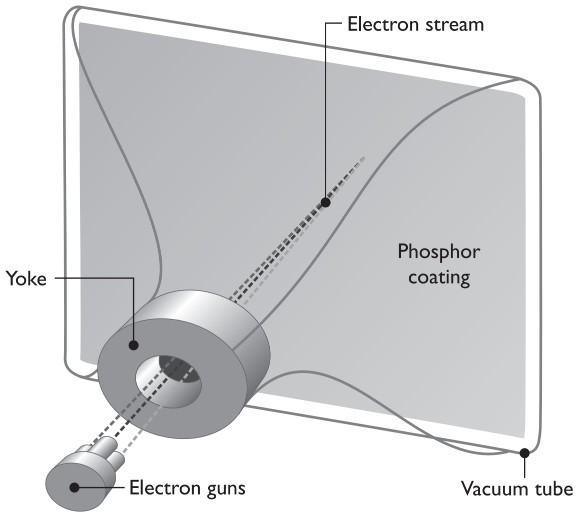
Before we begin in earnest, I want to give you a note of warning about the inside of a traditional monitor. I will discuss what can be repaired and what requires more specialized expertise. Make no mistake—the interior of a monitor might appear similar to the interior of a PC because of the printed circuit 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 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.

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

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 19-2). 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.

Figure 19-2 Electron stream in the CRT



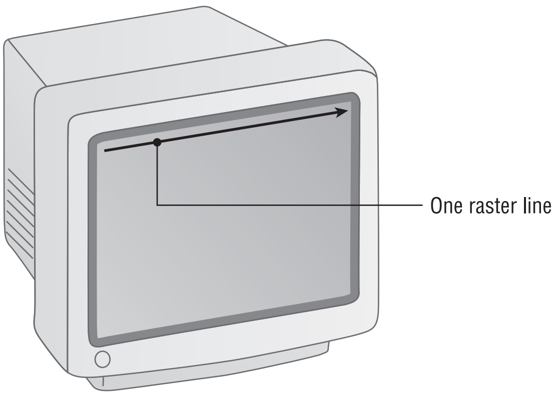
Fortunately, the phosphors on the display screen have a quality called *persistence*, which means the phosphors continue to glow after being struck by the electron beam. Too much persistence and the image is smeary; too little and the image appears to flicker. The perfect combination of beam and persistence creates the illusion of a solid picture.

Essentials

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 19-3).

Figure 19-3 Electron guns sweep from left to right.



The speed at which the electron beam moves across the screen is known as the *horizontal refresh rate* (*HRR*), as shown in Figure 19-4. 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 19-5.

Figure 19-4 Horizontal refresh rate

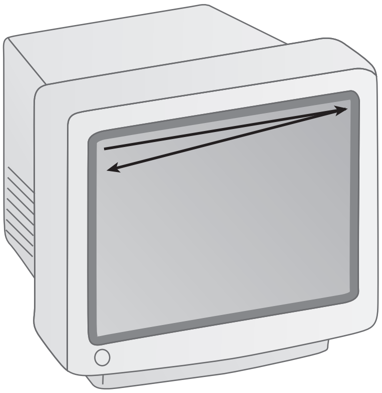
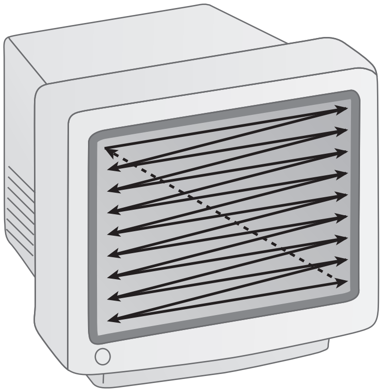


Figure 19-5 Vertical refresh rate



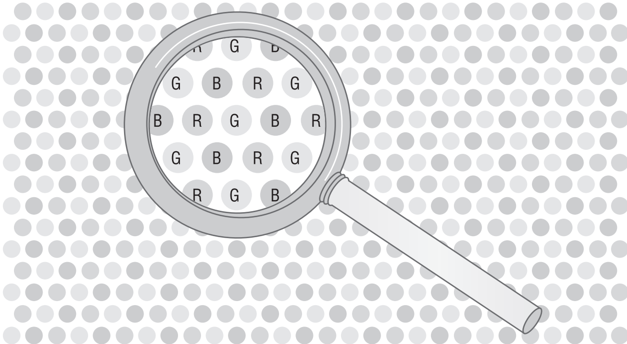
The monitor does not determine the HRR or VRR; the video card "pushes" the monitor at a certain VRR and then the monitor sets the corresponding HRR. If the video card is set to push at too low a VRR, the monitor produces a noticeable flicker, causing eyestrain and headaches for users. Pushing the monitor 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!

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 19-6).

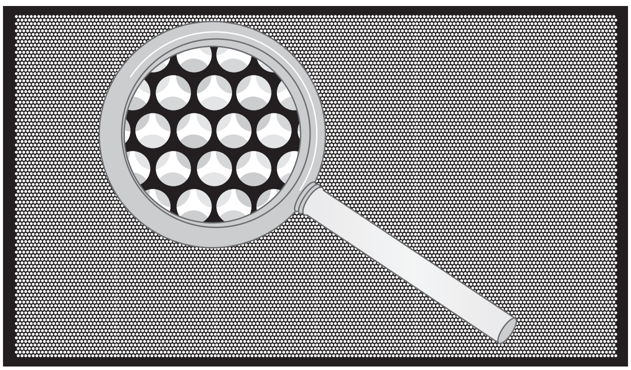
Figure 19-6 A monitor is a grid of red, green, and blue phosphors.



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 19-7). This prevents, for example, the red electron beam from "bleeding over" and lighting neighboring blue and green dots.

Figure 19-7 Shadow mask



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.

NOTE Not all CRT monitors use dots. The Sony Trinitron line of CRT monitors uses bars of red, green, and blue instead of dots. The holes in the shadow mask have a rectangular shape. Many people feel this makes the monitor's image much crisper and clearer. Somebody must agree with them because the Trinitron enjoys tremendous popularity. Even though the phosphors and shadow mask have a different shape, everything you learn here applies to Trinitrons also.

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 19-8.

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

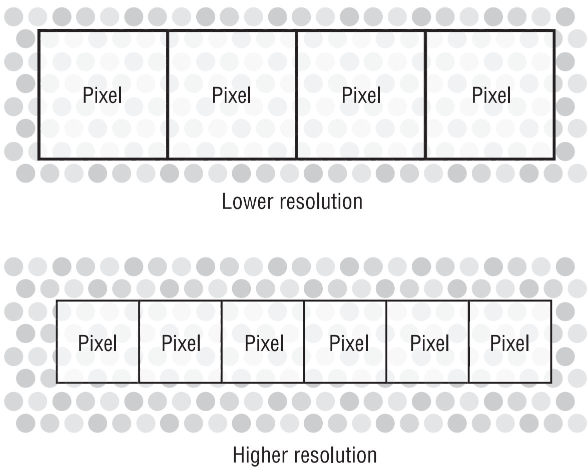


Figure 19-8 Resolution versus pixel size

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 × 1200.

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

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 19-9). Various limitations in screens, controlling electronics, and electron gun technology make the maximum resolution much bigger than one triad.

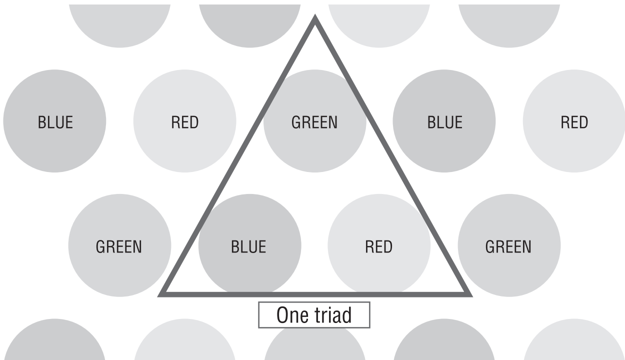


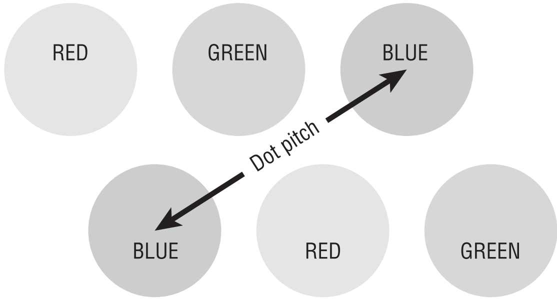
Figure 19-9
One triad

Dot Pitch

The resolution of a monitor is defined by the maximum amount of detail the monitor can render. The dot pitch of the monitor ultimately limits this resolution. The *dot pitch* defines the diagonal distance between phosphorous dots of the same color, and is measured in *millimeters* (*mm*). Because a lower dot pitch means more dots on the screen, it usually produces a sharper, more defined image (see Figure 19-10). Dot pitch works in tandem with the maximum number of lines the monitor can support to determine the greatest working resolution of the monitor. It might be possible to place an image at 1600 × 1200 on a 15-inch monitor with a dot pitch of 0.31 mm, but it would not be very readable.

The dot pitch can range from as high as 0.39 mm to as low as 0.18 mm. For most Windows-based applications on a 17-inch monitor, many people find that 0.28 mm is the maximum usable dot pitch that still produces a clear picture.

Figure 19-10 Measuring dot pitch



Bandwidth

Bandwidth defines the maximum number of times the electron gun can be turned on and off per second. Bandwidth is measured in *megahertz* (*MHz*). In essence, bandwidth tells us how fast the monitor can put an image on the screen. A typical value for a better-quality 17-inch color monitor would be around 150 MHz, which means that the electron beam can be turned on and off 150 million times per second. The value for a monitor's bandwidth determines the maximum VRR the video card should push the monitor for any given resolution. It reads as follows:

maximum VRR = bandwidth ÷ pixels per page

For example, what is the maximum VRR that a 17-inch monitor with a bandwidth of 100 MHz and a resolution of 1024 × 768 can support? The answer is

maximum VRR = 100,000,000 ÷ (1024 × 768) = 127 Hz

That's a pretty good monitor, as most video cards do not push beyond 120 Hz! At a resolution of 1200 × 1024, the vertical refresh would be

100,000,000 ÷ (1200 × 1024) = 81 Hz

So, we would make sure to set the video card's VRR to 80 Hz or less. If you had a monitor with a bandwidth of only 75 MHz, the maximum VRR at a 1200 × 1024 resolution would be only 61 Hz.

Most monitor makers know that people aren't going to take the time to do these calculations. Instead, they do the calculations for you and create tables of refresh rates at certain resolutions to show what a monitor can do.

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.

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 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 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.

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 teacher's 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 19-11. 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 19-12).

Figure 19-11 Waves of similar orientation

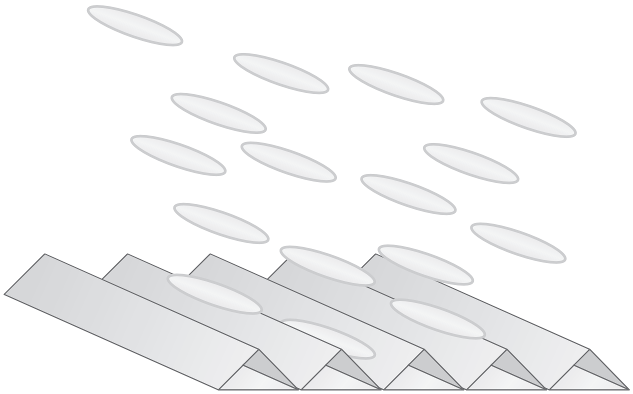


Figure 19-12 Liquid crystal molecules tend to line up together.

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 19-13). If two perpendicular polarizing filters are then placed on either side of the liquid crystal, the liquid crystal will twist the light and enable it to pass (see Figure 19-14).

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 19-15).

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—form a physical pixel, as shown in Figure 19-16.

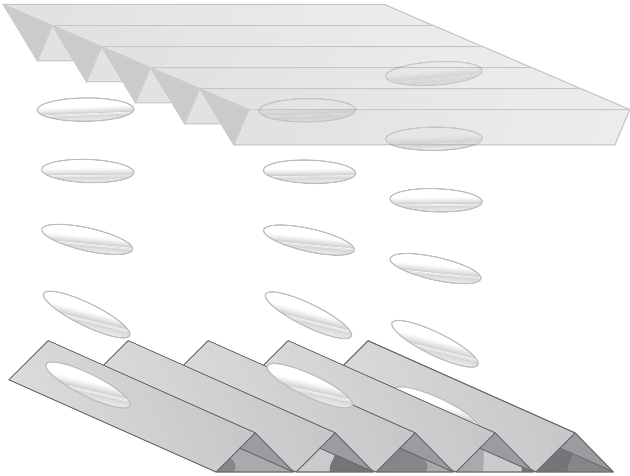


Figure 19-13 Liquid crystal molecules twisting

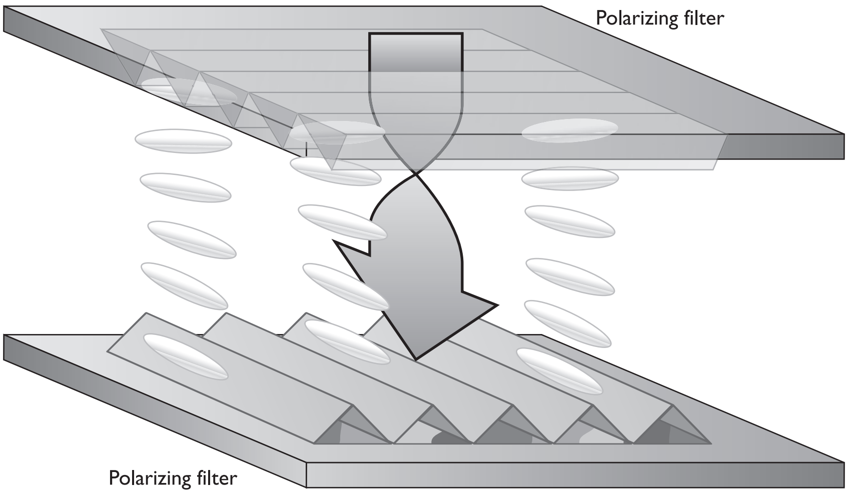


Figure 19-14 No charge, enabling light to pass

NOTE 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 called "LCD Resolution" later in the chapter for the scoop.

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

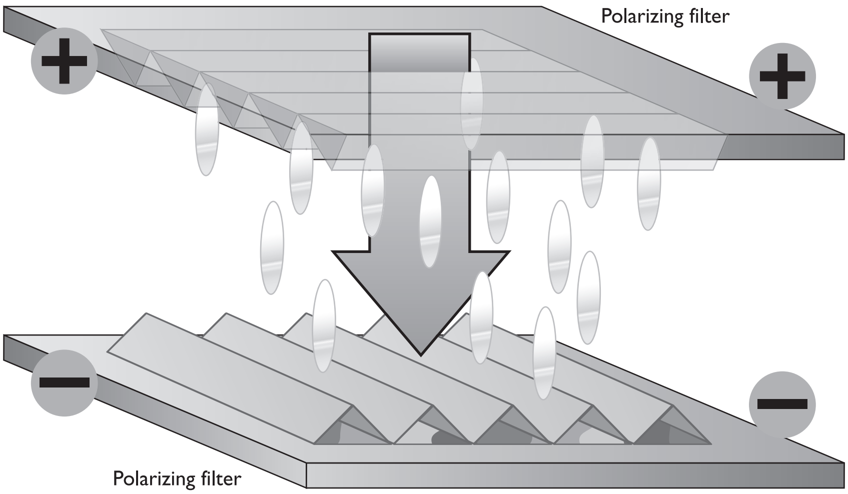
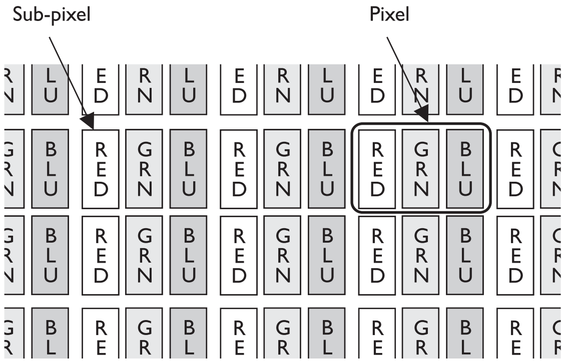


Figure 19-15 Electrical charge, no light is able to pass

Figure 19-16 LCD pixels



different-shaped elements, each electrically separate from the others. To create an image, each area was charged at the same time. Figure 19-17 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, LCD screens use a matrix of wires (see Figure 19-18). The vertical wires, the Y wires, run to every sub-pixel in the column. The horizontal wires, the X wires, run along an entire row of sub-pixels. There must be a charge on both the X and the Y wires to make enough voltage to light a single sub-pixel.

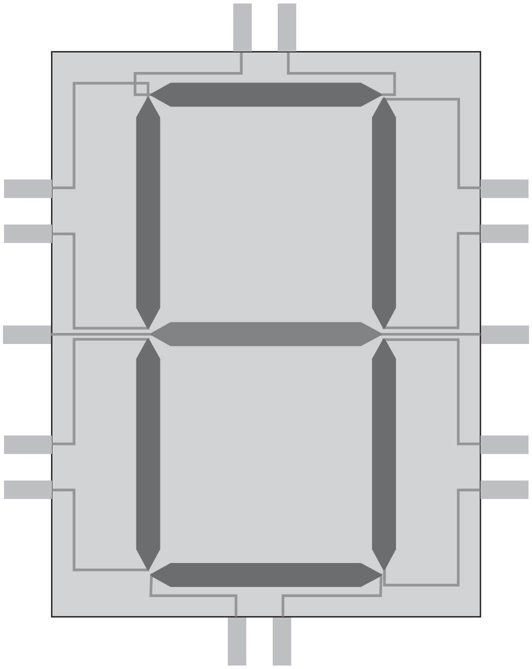


Figure 19-17 Single character for static LCD numeric display

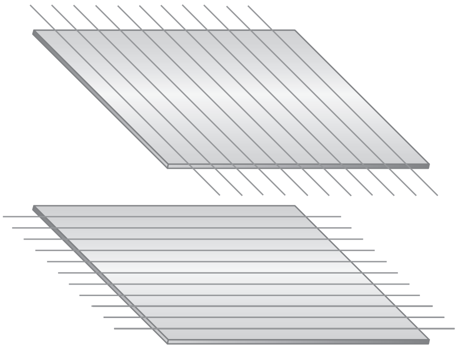


Figure 19-18 An LCD matrix of wires

If you want color, you have three matrices. The three matrices intersect very close together. Above the intersections, the glass is covered with tiny red, green, and blue dots. Varying the amount of voltage on the wires makes different levels of red, green, and blue, creating colors (see Figure 19-19).

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.

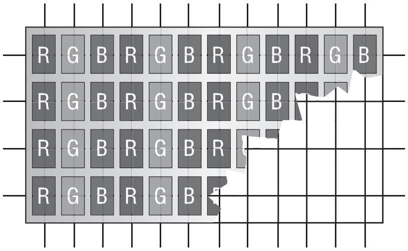


Figure 19-19 Passive matrix display

Although other LCD technologies have since appeared, dual-scan continues to show up on some lower-end LCD panels.

NOTE You'll also find passive matrix displays in smaller, handheld devices. See Chapter 21, "Portable Computing," for details about handheld computing devices.

Thin Film Transistor

A vast improvement over dual scan is called *thin film transistor* (*TFT*) or *active matrix* (Figure 19-20). 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. TFT is the LCD of choice today, even though it is much more expensive than passive matrix.

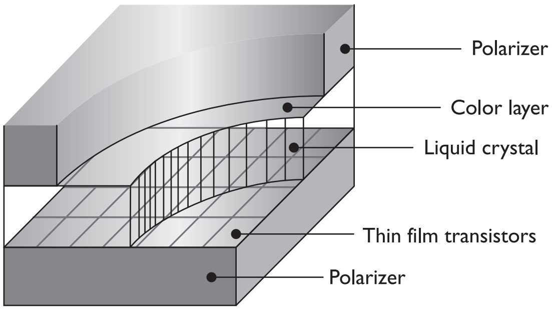


Figure 19-20 Active matrix display

LCD Components

The typical LCD projector is composed of three main components: the LCD panel, the backlight(s), and the inverters. The LCD panel creates the image, the backlights illuminate the image so you can see it, and the inverters send power to the backlights. Figure 19-21 shows a typical layout for the internal components of an LCD monitor.

One of the great challenges to LCD power stems from the fact that the backlights need AC power while the electronics need DC power. The figure shows one of the many

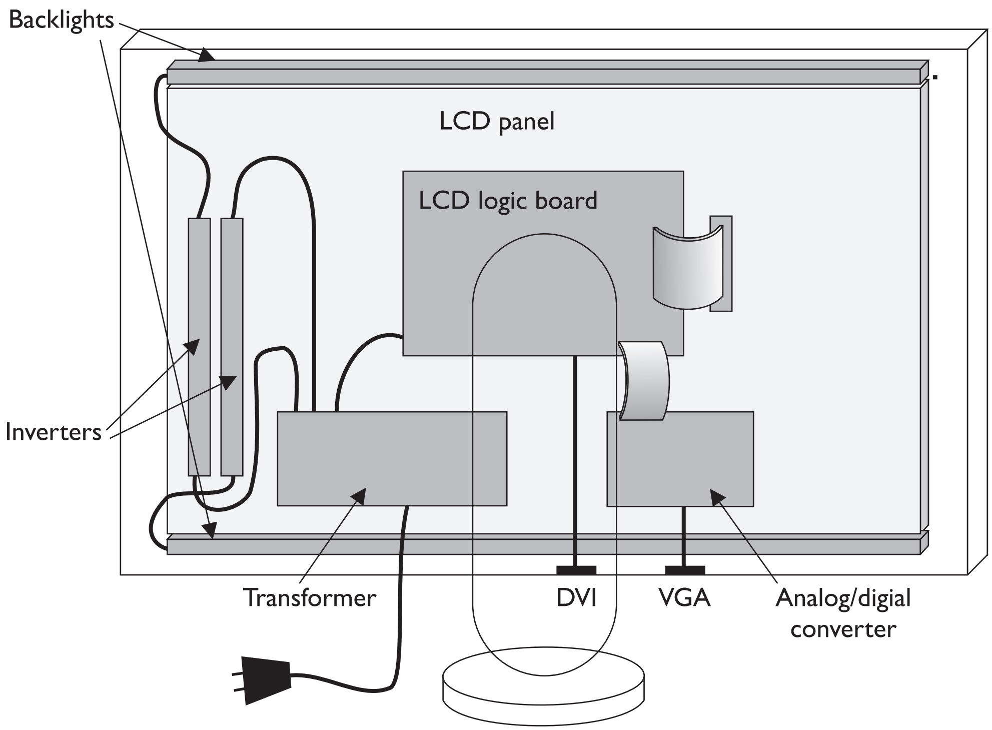


Figure 19-21 LCD internals

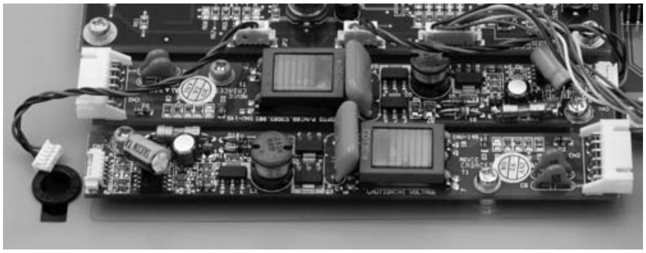
ways that LCD monitor makers handle this issue. The AC power from your wall socket goes into an AC/DC transformer that changes the power to DC. The LCD panel uses this DC power.

Note in Figure 19-21 that this monitor has two backlights: one at the top and one at the bottom. Most LCDs have two backlights, although many only have one. All LCD backlights use cold cathode fluorescent lamp (CCFL) technology, popular for its low power use, even brightness, and long life. Figure 19-22 shows a CCFL from an LCD panel.

Figure 19-22 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 19-23 shows a typical inverter used in an LCD.

Figure 19-23
Inverter

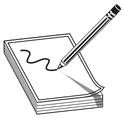


Looking once again at Figure 19-21, note the DVI and VGA inputs. DVI is a digital signal, so it connects directly to the LCD's logic circuitry. The VGA goes to an analog to digital converter before reaching the LCD logic board.

Keep in mind that Figure 19-21 is a generic illustration. The actual location and interconnections of the components are as variable as the number of LCD panels available today!

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!



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

The hard-wired nature of LCD resolution creates a problem for techs and consumers when dealing with bigger, better-quality monitors. A typical 15-inch LCD has a 1024 × 768 resolution, but a 17-inch usually has 1280 × 1024 or higher. 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.

With Windows XP (and to a lesser extent with the earlier versions of Windows), Microsoft allows 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. Your clients will thank you!

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.

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

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. Individual LCD sub-pixels hold their 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 6–8 ms.

Refresh Rate

The refresh rate for an LCD monitor uses numbers similar to that 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.

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.

NOTE 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.

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, 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 (Figure 19-24) shoots an image onto a screen from the rear. Rearview projectors are always self-enclosed and 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 (Figure 19-25). This section deals exclusively with front-view projectors that connect to PCs.

Figure 19-24 Rearview projector (*photo courtesy of Samsung*)

Figure 19-25 Front-view projector (*photo courtesy of Dell Inc.*)

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 screen (Figure 19-26). 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 (Figure 19-27).

Figure 19-26
CRT projector

Figure 19-27
LCD projector
(*photo courtesy of ViewSonic*)

NOTE 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.

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.

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 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!

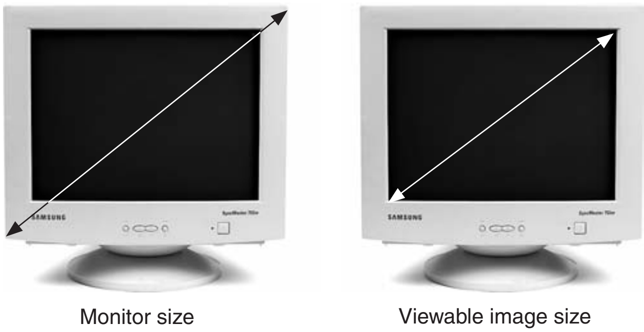
Common Features

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

Size

You need to take care when buying CRT monitors. 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*). You will commonly see a size difference of one-to-two inches between the two measurements (see Figure 19-28). A 17-inch CRT monitor, for example, might have a 15.5-inch VIS.

Figure 19-28 Viewable image size of a CRT

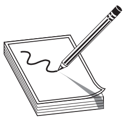


LCD monitors dispense with the two values and simply express the VIS value. You must consider this issue when comparing LCDs to CRTs. A 15-inch LCD monitor will have about the same viewing area as a 17-inch CRT.

Connections

CRT monitors for PCs all use the famous 15-pin, three-row, DB-type connector (see Figure 19-29) and a power plug. The DB connector is also called a *D-shell* or *D-subminiature* 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 19-29
A traditional CRT connector



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

Unlike the analog CRTs, LCD monitors need a digital signal. This creates somewhat of an issue. The video information stored on a video card's RAM is clearly digital. All VGA and better 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, RAMDAC takes the digital signal from the video card and turns it into an analog signal for the analog CRT (see Figure 19-30). The RAMDAC really defines the bandwidth that the video card outputs.

Well, RAMDACs certainly make sense for analog CRT monitors. However, if you want to plug your LCD monitor into a regular video card, you need circuitry on the LCD monitor to convert the signal from analog to digital (see Figure 19-31).

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.

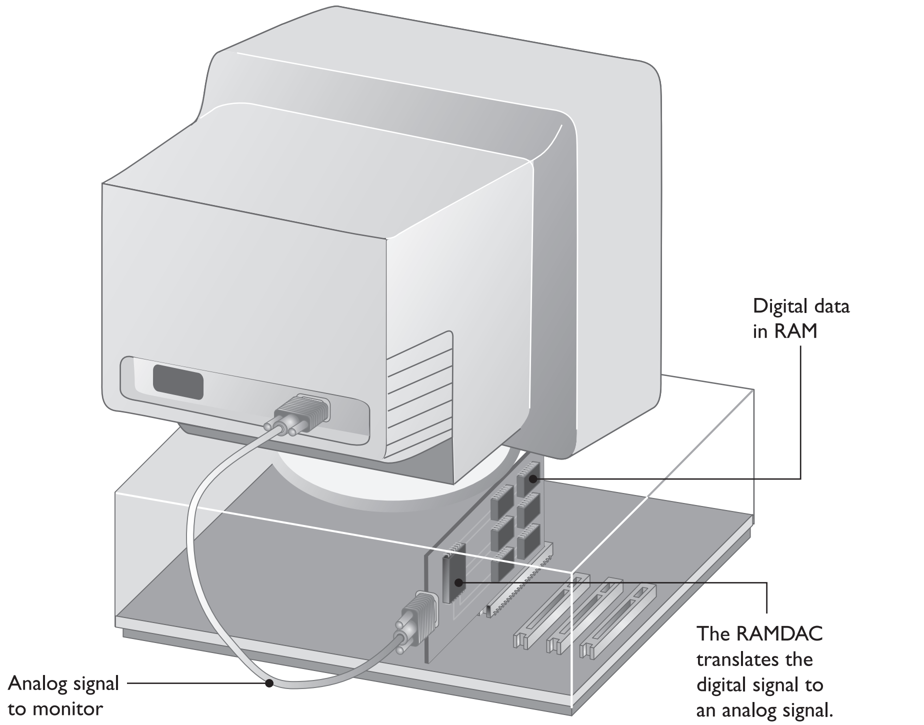


Figure 19-30 An analog signal sent to a CRT monitor

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.

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.

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 (Figure 19-32). With dual link, you can have displays up to a whopping 2048 × 1536 at 60 Hz!

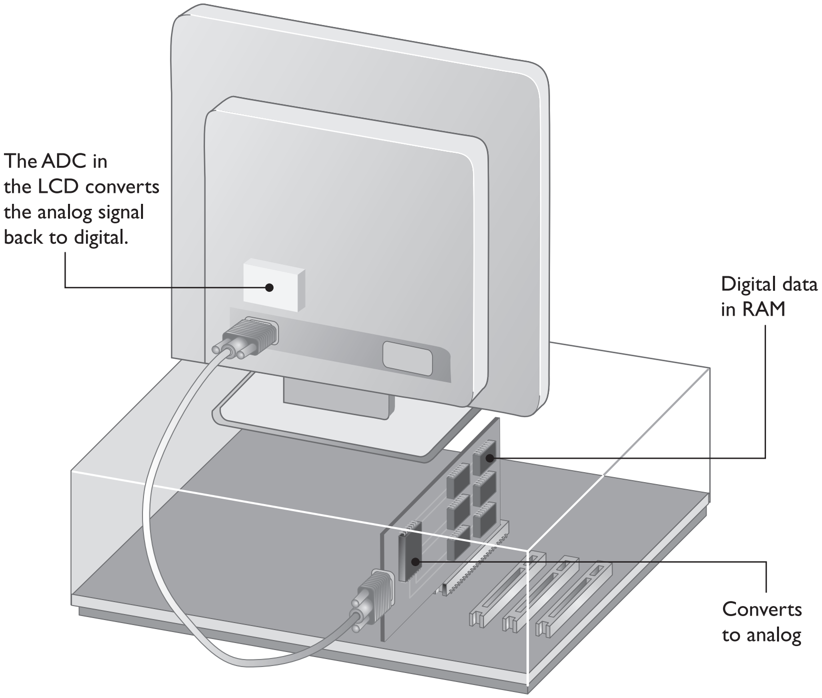


Figure 19-31 Converting analog back to digital on the LCD

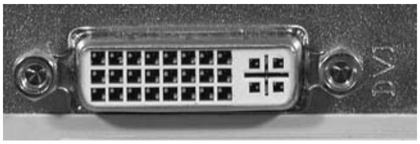


Figure 19-32 Dual-link DVI-I connector

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

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 the video card) like the one shown in Figure 19-33 and connect an analog monitor just fine.

Figure 19-33
DVI to VGA adapter

NOTE Video cards with two video connectors support dual monitors. See the "Dual Monitors" section later in this chapter.

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 guns 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 19-34).

Figure 19-34 Typical menu controls

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.

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!

Video Cards

The video card, or display adapter, handles the video chores within the PC, processing information from the CPU and sending it out to the monitor. The video card is composed of two major pieces: the video RAM and the video processor circuitry. The video RAM stores the video image. On the first video cards, this RAM was good old dynamic

RAM (DRAM), just like the RAM on the motherboard. Today's video cards often have better RAM than your system has! The video processing circuitry takes the information on the video RAM and shoots it out to the monitor. Although early video processing circuitry was little more than an intermediary between the CPU and the video RAM, modern video processors are more powerful than all but the latest CPUs! It's not at all uncommon to see video cards that need fans to cool their onboard processors (see Figure 19-35).

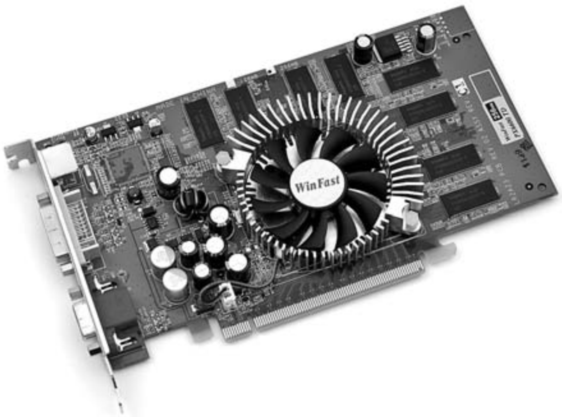


Figure 19-35 Video card with a cooling fan

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 eight 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 four 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 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 2000 or Windows XP computer in the Display Properties applet on the Settings tab (Figure 19-36). 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, almost every screen element can be semi-transparent (Figure 19-37).

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.

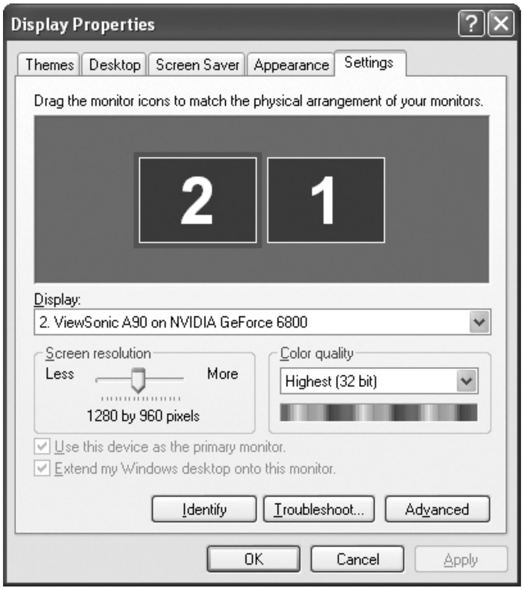


Figure 19-36 Adjusting color settings in Windows XP

Figure 19-37 Semi-transparency in Windows Vista

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.

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 19-1 shows the more common 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
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

Table 19-1 Typical Display 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 19-2 shows common modes and the minimum video memory needed. All modern video cards can handle true color at any resolution.

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

Table 19-2 Common modes and the minimum video memory required

EXAM TIP 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.

Motherboard Connection

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 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.

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:

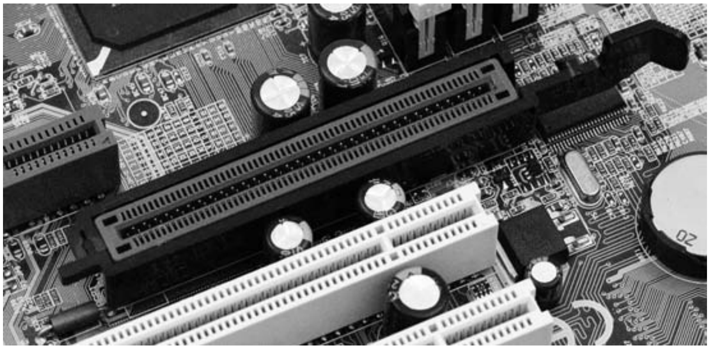
$$800 \times 600 \times 1 \text{ byte} \times 70 = 33.6 \text{ MBps}$$

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 many current systems.

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 19-38 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.

Figure 19-38
AGP



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.

First, AGP currently resides alone, on its own personal data bus, connected directly to the Northbridge (see Figure 19-39). This is important because more advanced versions of AGP outperform every bus on the system except the frontside bus!

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

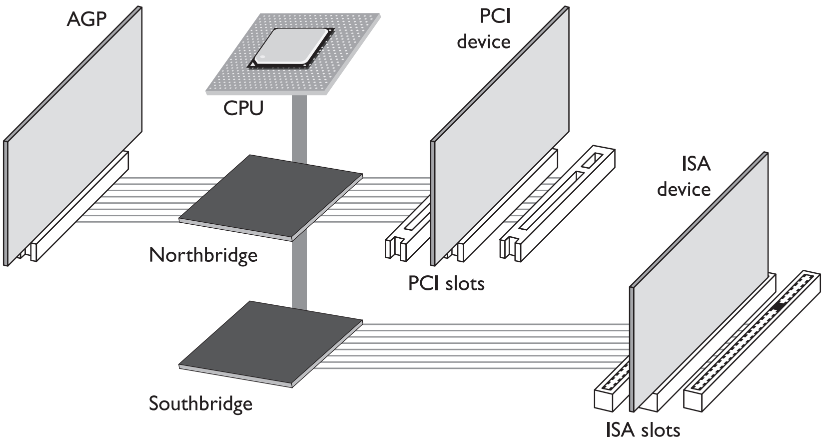


Figure 19-39 An AGP bus

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.

NOTE Intel couldn't quite bring itself to call AGP's system memory access…err…system memory access, so they use a couple of different terms. The video processor maps out a portion of system memory by using the *Graphics Address Remapping Table* (*GART*). The size of the remapped region is called the *AGP aperture*. A typical AGP aperture is 32 MB or 64 MB.

AGP has gone through three sets of specifications (AGP1.0, AGP2.0, and AGP3.0), 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.

Some motherboards support multiple types of AGP. Figure 19-40 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.

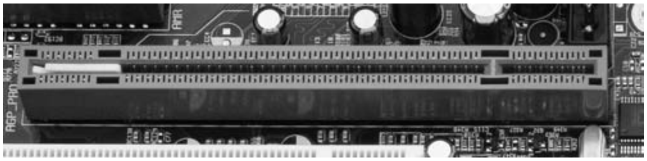


Figure 19-40
AGP 8× slot

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.

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 (Figure 19-41). PCIe replaced AGP as the primary video interface almost overnight.

Figure 19-41
PCIe video card connected in PCIe slot

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.

Video card discussion, at least among techs, almost always revolves around the graphics processor they use and the amount of RAM onboard. A typical video card might be called an ATI Radeon X1950 XTX 512 MB, so let's break that down. ATI is the manufacturer, Radeon X1950 XTX is the model of the card as well as the graphics processor, and 512 MB is the amount of video RAM.

Many companies make the hundreds of different video cards on the market, but only two companies produce the vast majority of graphics processors found on video cards: NVIDIA and ATI. NVIDIA and ATI make and sell graphics processors to third-party manufacturers who then design, build, and sell video cards under their own branding. ATI also makes and sells its own line of cards. Figure 19-42 shows an NVIDIA GeForce GTX 260 on a board made by EVGA.

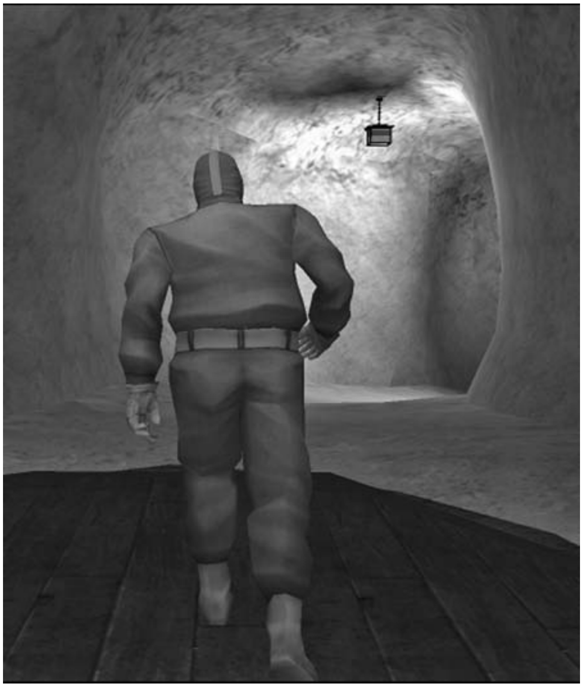
Figure 19-42
NVIDIA GeForce
GTX 260

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.

NVIDIA and ATI are extremely competitive, and both companies introduce multiple models of graphics processors (and therefore new models of cards) every year. However, unless you're using the Vista Aero glass desktop, all of these extra features you see in video cards are really only for the true driving force in video cards: 3-D gaming. Your PC is capable of providing you with hours of incredible entertainment via a huge number of popular games that immerse you in 3-D environments full of light, shadows, explosions, and other amazing effects that create a fun and beautiful gaming experience.

These 3-D games have special needs to do all this amazing stuff. One need is textures. A *texture* is a small picture that is tiled over and over again on walls, floors, and other surfaces to create the 3-D world. Take a look at the wall in Figure 19-43. It's made up of only three textures that are repeated over and over on the surface.

Figure 19-43
Wall of textures



Games also use hundreds of lighting effects such as transparency (water), shadows, reflection, and bump mapping—the process of laying multiple textures on the same spot to give a more textured (bumpy) look to the surface. These games are where the higher-quality graphics processors really shine. Learn more about 3-D issues in more depth in the "3-D Graphics" section later in the chapter.

Choosing a graphics processor is a challenge because the video industry is constantly coming out with new models. One of the best guides is price. The best (and newest) graphics cards usually cost around (US)$400–500. The cheapest cards cost around $50. I usually split the difference and go for a card priced around $180 to $200—such a card will have most of the features you want without breaking your bank account.

If you use your computer only for 2-D programs (most office applications such as word processors, e-mail, and Web browsers are 2-D), most of the features of the more advanced graphics cards will do you little good. If you're not a gamer, you can meet your needs with a cheap, low-end video card.

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, or even 256 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 (Figure 19-44).

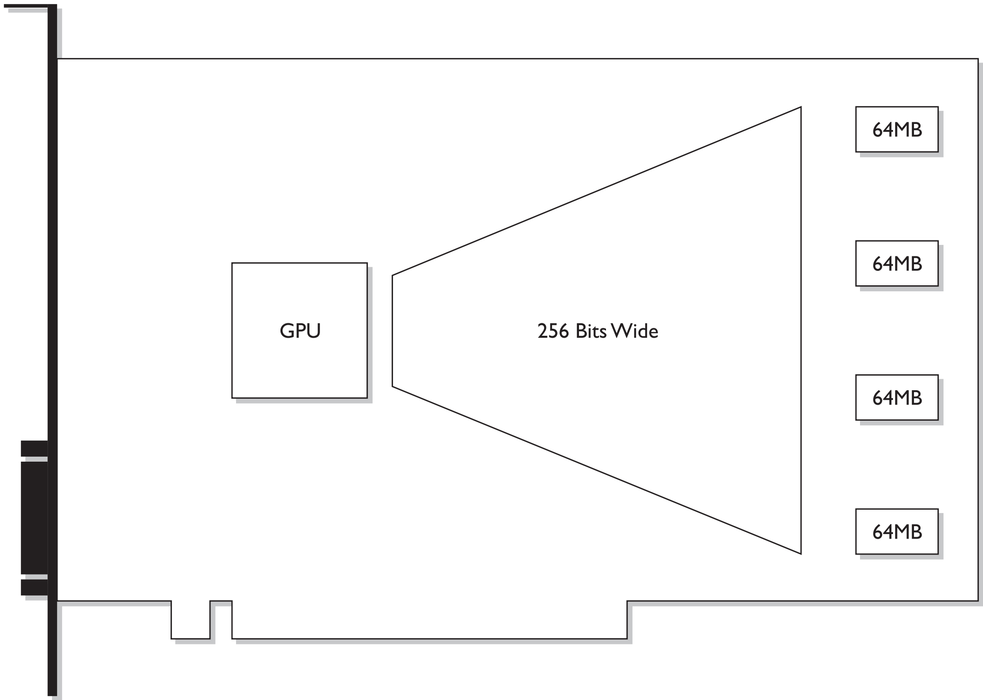


Figure 19-44 Wide path between video processor and video RAM

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 19-3 shows a list of common video memory technologies used yesterday and today—make sure you know these for the exams!

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

Table 19-3 Video RAM Technologies

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 or even 1 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.

Connections

Modern video cards offer connections to one or more PC monitors. Many also sport connectors for non-monitors, such as televisions. The video card in Figure 19-45 has three connectors: VGA, DVI-I, and S-video. Other connectors enable the video card to connect to composite, component, and even high-definition devices.

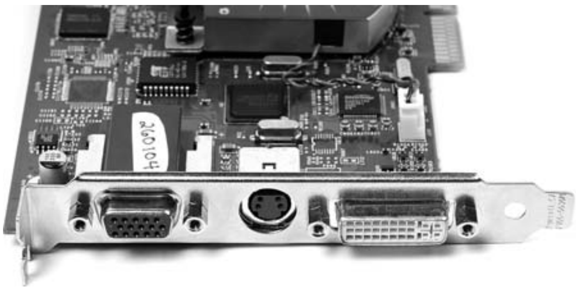


Figure 19-45 Video card connectors, VGA, S-video, and DVI-I

For Standard Monitors

You know about the standard monitor connectors, 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.

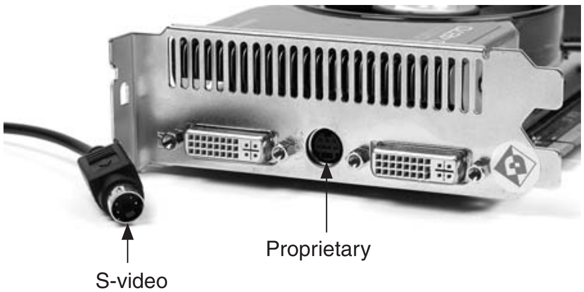
Apple Macintosh desktop models use a DisplayPort connection rather than VGA or DVI for connecting to a monitor. Dell offers support for DisplayPort as well at the time of this writing. Figure 19-46 shows a DisplayPort jack on a Dell portable.

Figure 19-46
DisplayPort jack

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 player, or video camera. The earliest type of connector commonly found is the S-video connector. This provides decent-quality video output or, in some cases, input. More commonly now you see both 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 19-47 shows the similar round ports.

Figure 19-47
S-video and proprietary round connectors



A composite connector provides a video signal through a single cable, whereas a component adapter provides a split signal, red, green, and blue. Figure 19-48 shows the two connector dongles.

Figure 19-48 Composite and component connection options

The best connections for outputting to television are the High Definition Multimedia Interface (HDMI) connectors. Although a few devices offer HDMI output directly (such as the portable pictured in Figure 19-49), most video cards support HDMI through a special cable that connects to a dual-link DVI port. Figure 19-50 shows an example of such a cable.

Figure 19-49 HDMI port on Lenovo laptop

Figure 19-50 DVI to HDMI cable

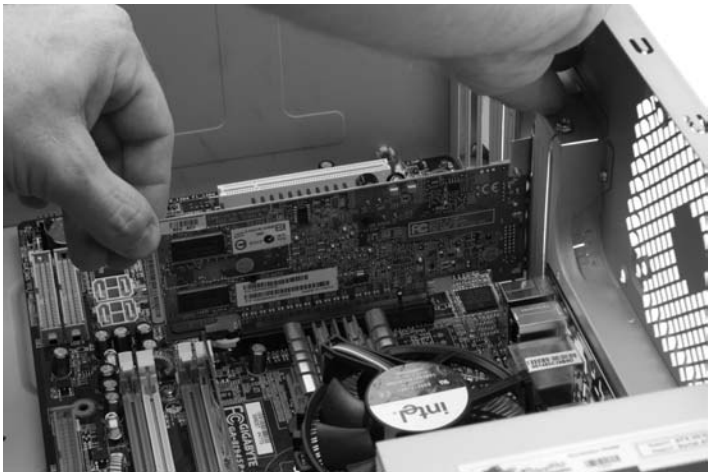
NOTE Some video cards with built-in television tuners that enable the PC to be a television as well as a computer have a standard coaxial jack for connecting a cable or antenna. See Chapter 20, "Multimedia," for the scoop on TV tuners.

Installing and Configuring Video

Once you've decided on the features and price for your new video card or 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 PCI card. Some high-end video cards simply won't fit in certain cases or block access to needed motherboard connectors such as the IDE 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 (Figure 19-51).

Figure 19-51 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 2000/XP) or Personalization applet (Windows Vista/7) 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 CD 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 CD. 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 applet. Like so many things about video, you can't fully understand one topic without understanding at least one other!

Using the Display/Personalization Applet

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 (Figure 19-52), has five tabs: Themes, Desktop, Screen Saver, Appearance, and Settings. Earlier versions of Windows have a subset of these tabs. 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.

Figure 19-52 Display Properties dialog box in Windows XP

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 (Figure 19-53). 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.

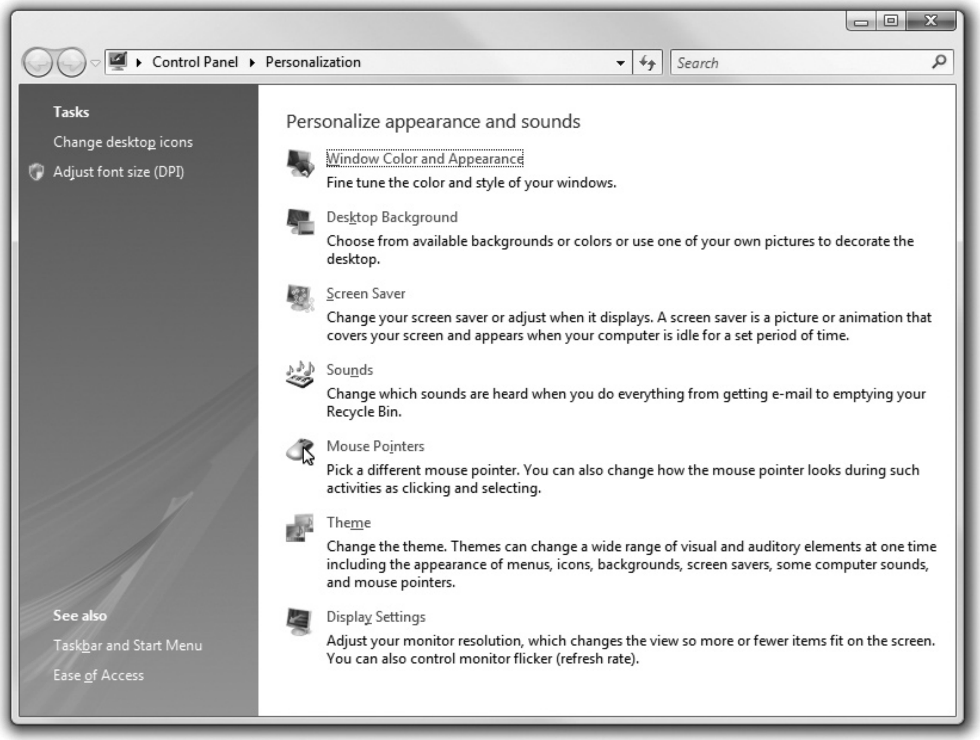


Figure 19-53 Personalization applet in Windows Vista

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

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/ Windows Color and Appearance. Windows themes are preset configurations of the look and feel of the entire Windows environment (Figure 19-54).

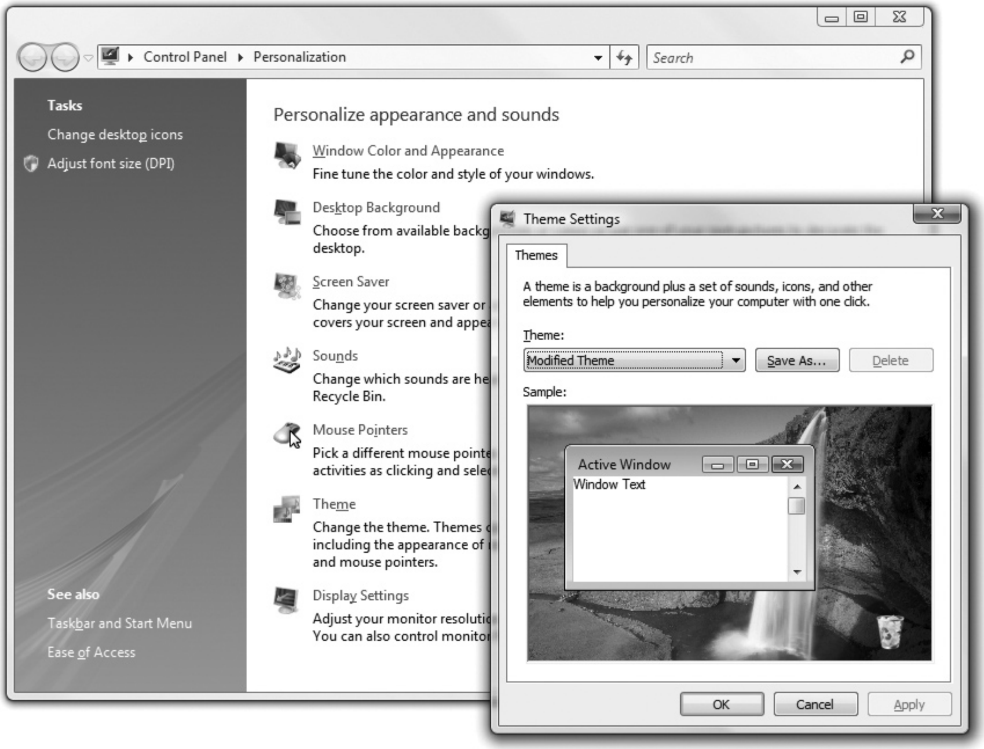


Figure 19-54 Theme option in the Personalization applet

The Desktop tab/option (Figure 19-55) 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 (Figure 19-56), and the Change desktop icons option on 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 2000/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 (Figure 19-57). Using this dialog box, you may adjust almost 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/7 is a little simpler on the surface, enabling you to change the color scheme, intensity, and transparency (Figure 19-58). You can unlock the full gamut of options, though, by clicking the *Open classic appearance properties for more color options* link.

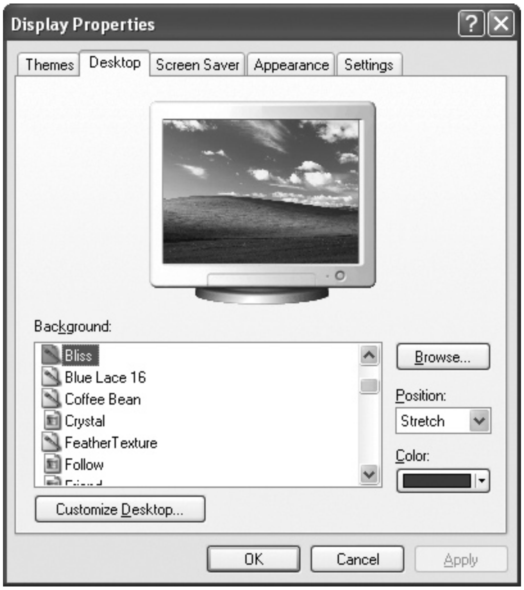


Figure 19-55 Desktop tab on Display Properties dialog box

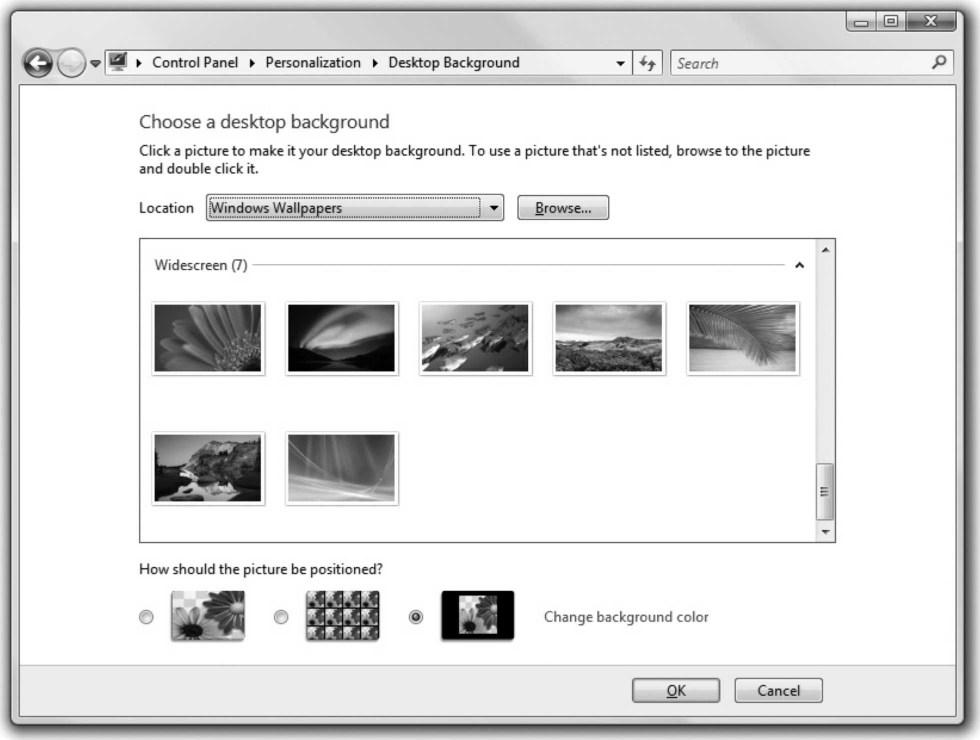


Figure 19-56 Desktop Background options in Windows Vista

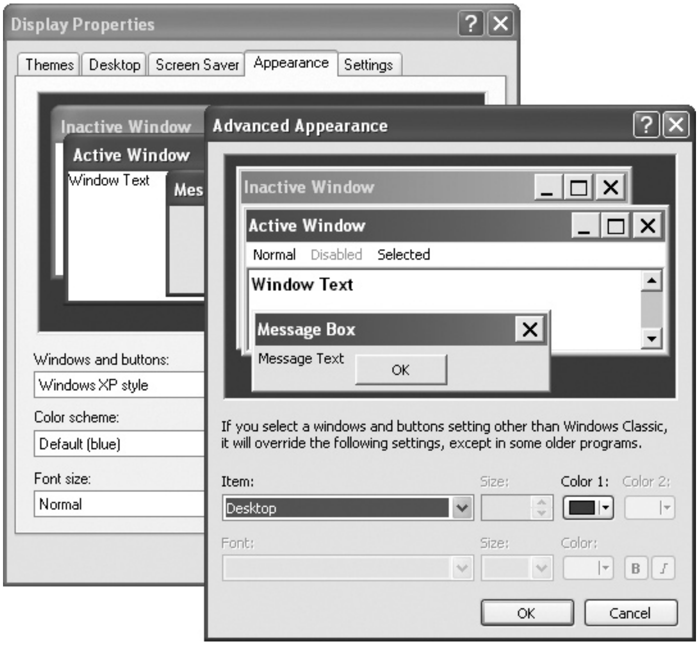


Figure 19-57 Advanced Appearance dialog box

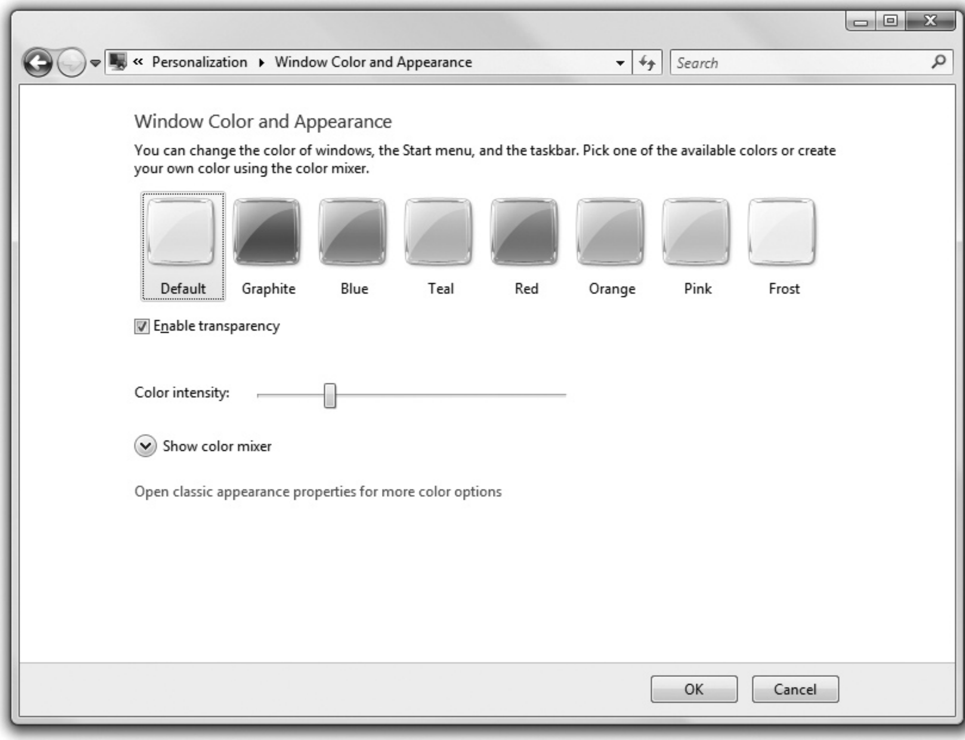


Figure 19-58 Window Color and Appearance option

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. 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 (Figure 19-59).

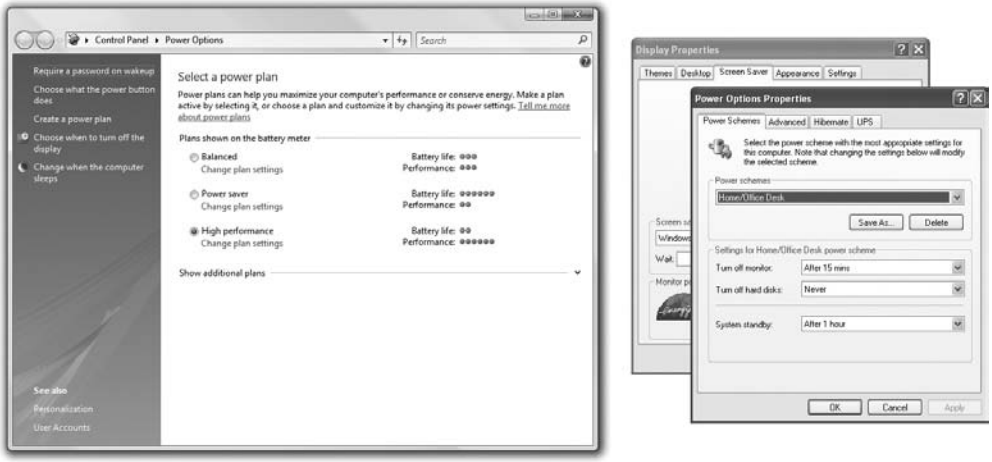


Figure 19-59 Power Options Properties dialog box

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 21, "Portable Computing."

Settings Tab/Display Settings Applet

The Settings tab or Display Settings applet (Figure 19-60) is the centralized location for configuring all of your video settings. 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 all of the resolutions to see which you like—just remember that LCD monitors look sharpest at their native resolution (usually the highest listed).

The color quality is the number of colors displayed on the screen. You can change the screen resolution with a simple slider, adjusting the color depth from 4-bit all of the way up to 32-bit color. Unless you have an older video card or a significant video speed issue, you'll probably set your system for 32-bit color and never touch this setting again.

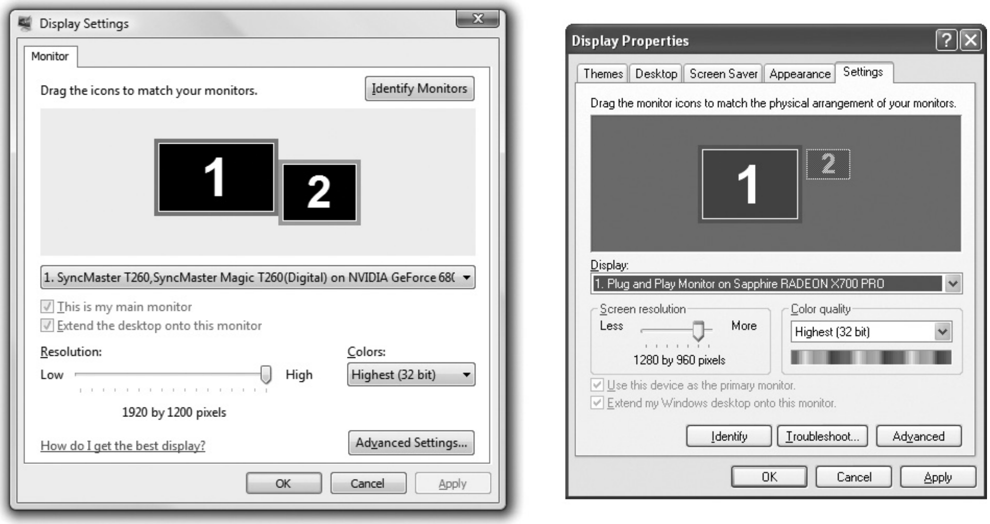


Figure 19-60 Settings tab

Another option you may see in the Settings tab is dual monitors. 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. Dual monitors are handy if you need lots of screen space but don't want to buy a really large, expensive monitor (Figure 19-61). Microsoft calls this feature *DualView*.

Figure 19-61 My editor hard at work with dual monitors

EXAM TIP Windows supports *DualView* technology, enabling you to use multiple monitors.

There are two ways to set up dual monitors: plug in two video cards or use a single video card that supports two monitors (a "dual-head" video card). Both methods are quite common and work well. Dual monitors are easy to configure: just plug in the monitors and Windows should detect them. Windows will show both monitors in the Settings tab, as shown in Figure 19-62. By default, the second monitor is not enabled. To use the second monitor, just select the *Extend the desktop onto this monitor* checkbox.

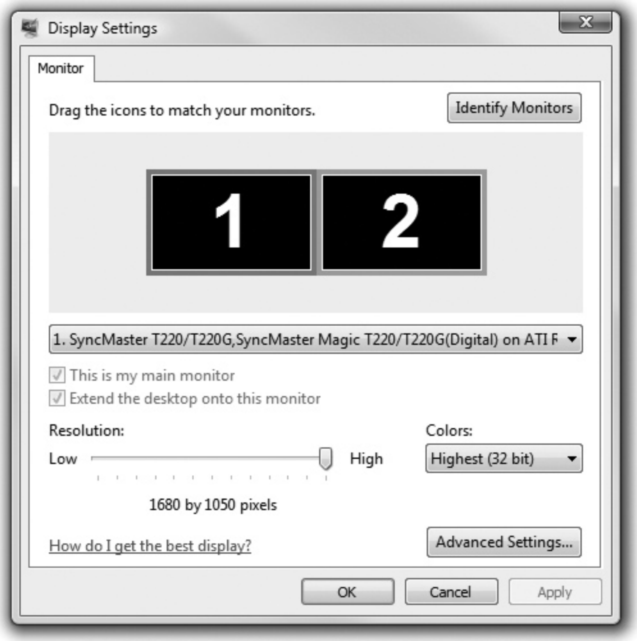


Figure 19-62 Enabling dual monitors

If you need to see more advanced settings, click on…that's right, the Advanced or Advanced Settings button (Figure 19-63). The title of this dialog box reflects the monitor and video card. As you can see in the screen shot, this particular monitor is a Samsung SyncMaster T220 running off of an ATI Radeon 3850 video card.

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.

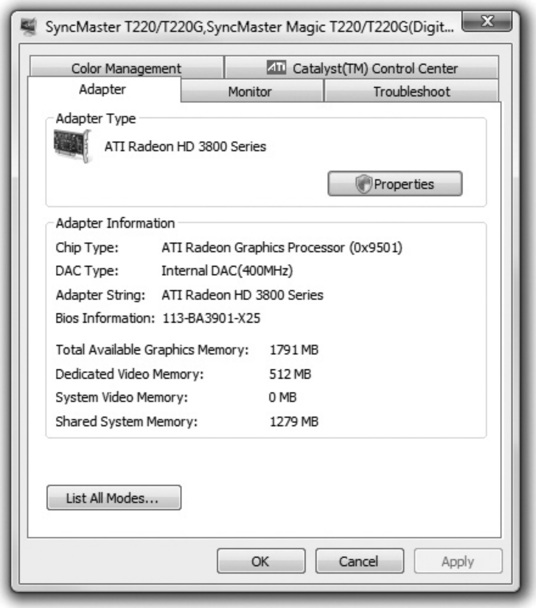


Figure 19-63 Advanced video settings

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 (Figure 19-64). 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.

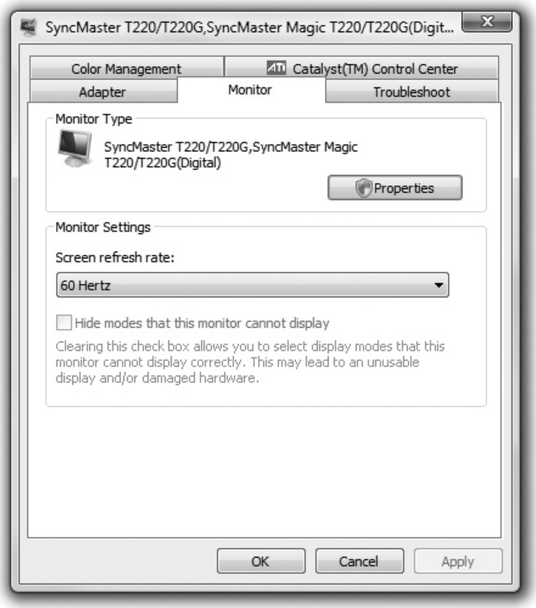


Figure 19-64 Monitor tab

NOTE All LCD monitors have a fixed refresh rate

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.

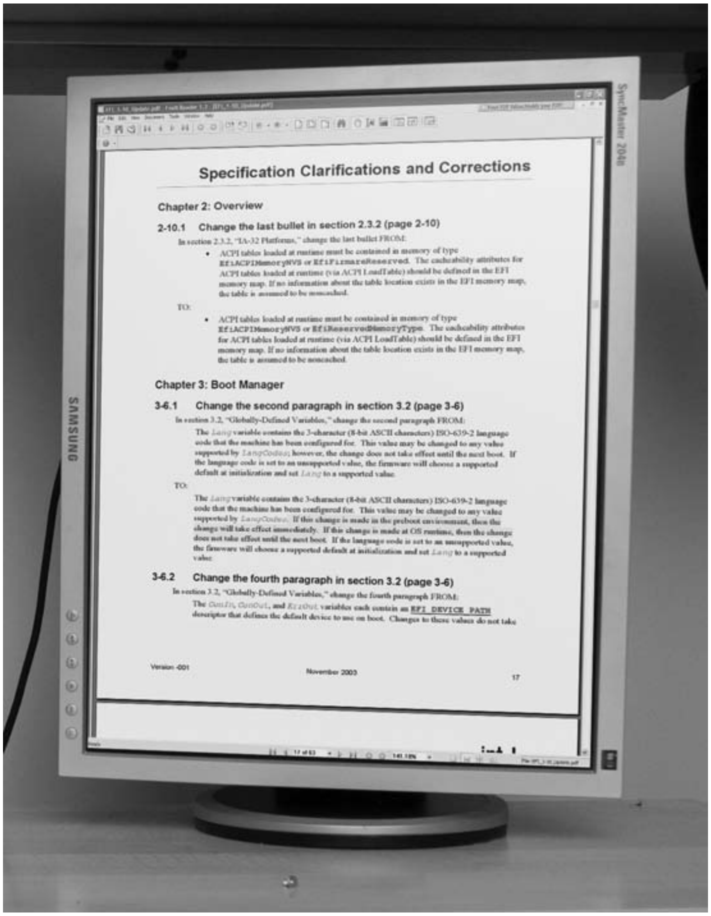
Most video cards add their own tab to the Advanced dialog box, such as the one shown in Figure 19-65. This tab adjusts all of the specialized settings for that video card. What you see here varies by model of card and version of driver, but here's a list of some of the more interesting settings you might see.

Figure 19-65 Third-party video tab

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 19-66 shows the author's LCD monitors rotated in portrait mode. If you want to rotate your screen, you must tell the system you're rotating it.

Figure 19-66
Portrait mode



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/Personalization applet, 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 or Personalization applet. In the Display Properties/Display Settings dialog box, select the Settings tab/Monitor tab and click the Advanced or Advanced Settings button. In the Advanced button dialog box, click the Adapter tab and then click the Properties button. In the Properties dialog box for your adapter (Figure 19-67), select the Driver tab and then click the Update Driver button to run the Hardware Update wizard.

Figure 19-67 Adapter Properties dialog box

Practical Application

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—that 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 called Wolfenstein 3D (see Figure 19-68). 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.

Figure 19-68 Wolfenstein 3D

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 19-69 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 19-69 Each figure had a limited number of sprites.

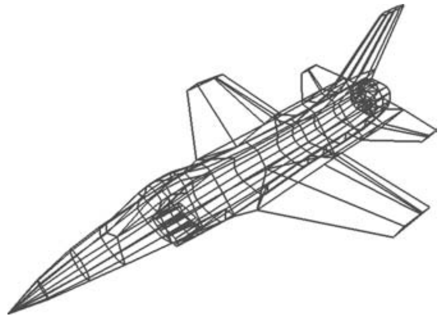
The second generation of 3-D began to replace sprites with true 3-D objects, which are drastically more complex than sprites. A true 3-D object is composed of a group of points called *vertices*. Each vertex has a defined X, Y, and Z position in a 3-D world. Figure 19-70 shows the vertices for an airplane in a 3-D world.

Figure 19-70 Vertices for a 3-D airplane

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 19-71 shows the same model as Figure 19-70, now displaying all of the connected vertices to create a large number of polygons.

Figure 19-71 Connected vertices forming polygons on a 3-D airplane



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 19-72 shows the finished airplane.

Figure 19-72 3-D airplane with textures added

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.

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 re-creates 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 *graphics processing units* (*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 using 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. In Windows 2000/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 (see Figure 19-73).

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

The System tab gives the version of DirectX. The system pictured in Figure 19-73 runs DirectX 10. You may then test the separate DirectX functions by running through the other tabs and running the tests.

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

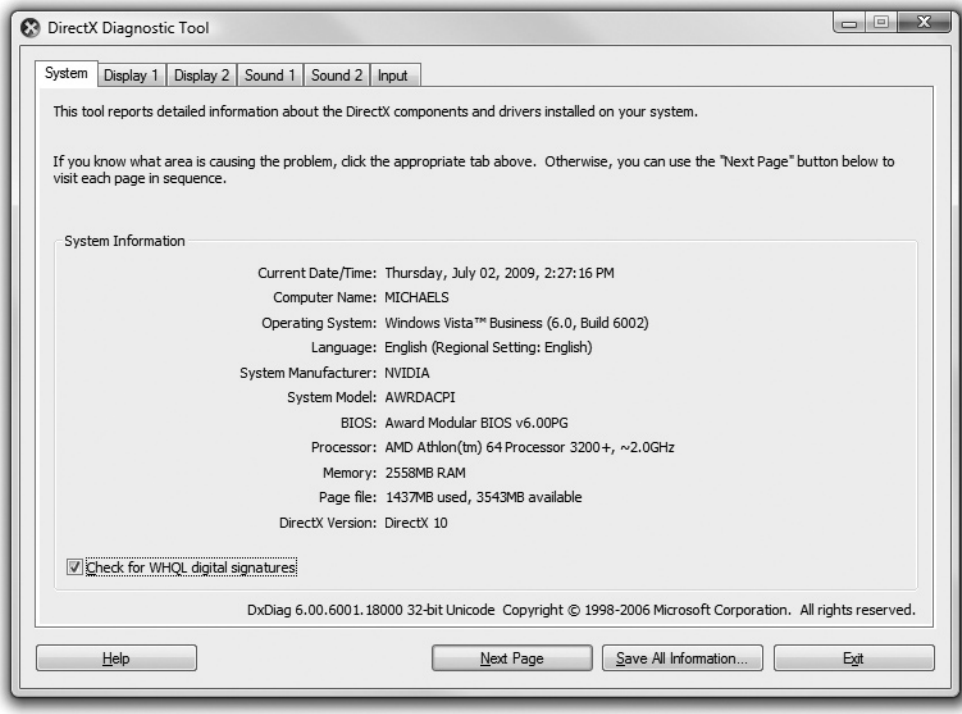


Figure 19-73 The DirectX Diagnostic Tool

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.

- www.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. 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. 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, 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 (Figure 19-74).

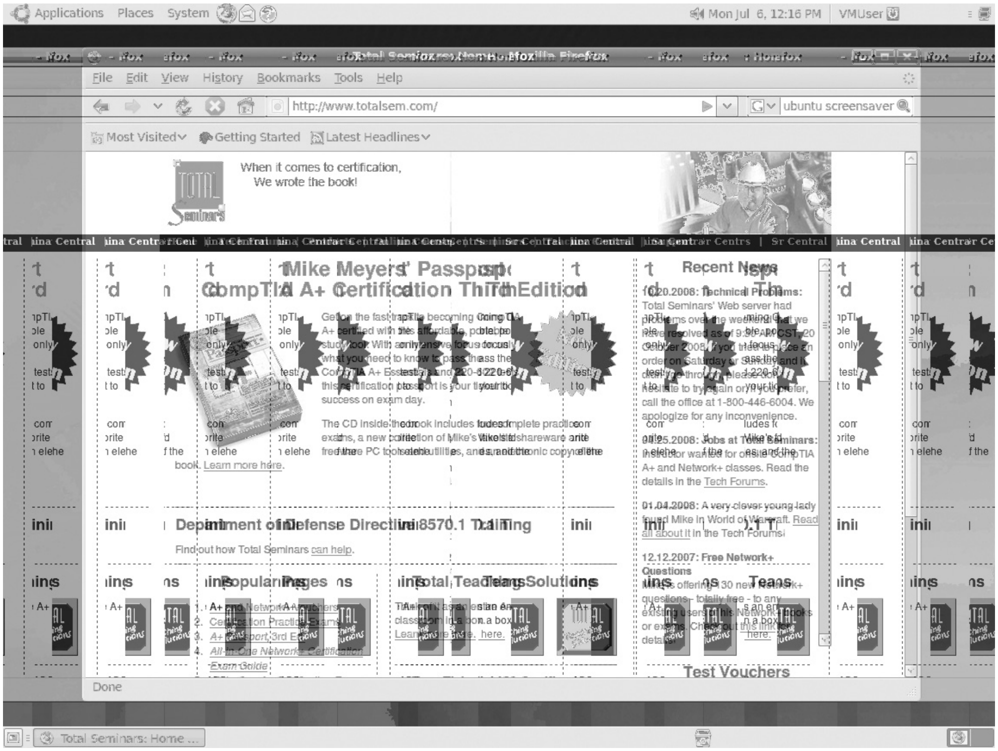


Figure 19-74 Serious video problem

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!

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. Go into your Display Properties and reset them to a setting that works! 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" (Figure 19-75), you need to set your resolution back to something that works for your video card/monitor combination!

Figure 19-75 Pushing a monitor too hard

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 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 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. Whenever a user calls me with a fuzzy monitor problem, I always have them degauss first.

Troubleshooting CRTs

As shipped, most monitors do not produce an image out to the limits of the screen, because of poor convergence at the outer display edges. *Convergence* defines how closely the three colors can meet at a single point on the display. At the point of convergence, the three colors combine to form a single white dot. With misconvergence, a noticeable halo of one or more colors appears around the outside of the white point. The farther away the colors are from the center of the screen, the more likely the chance for misconvergence. Low-end monitors are especially susceptible to this problem. Even though adjusting the convergence of a monitor is not difficult, it does require getting inside the monitor case and having a copy of the schematic, which shows the location of the variable resistors. For this reason, it is a good idea to leave this adjustment to a trained specialist.

I don't like opening a CRT monitor. I avoid doing this for two reasons: (1) I know very little about electronic circuits, and (2) I once almost electrocuted myself. At any rate, the CompTIA A+ exams expect you to have a passing understanding of adjustments you might need to perform inside a monitor. Before we go any further, let me remind you about a little issue with CRT monitors (see Figure 19-76).

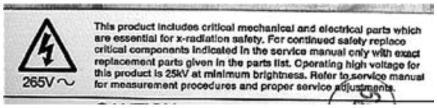


Figure 19-76 Hey! That's 25,000 volts! *Be careful!*

The CRT monitor contains a wire called a *high-voltage anode*, covered with a suction cup. If you lift that suction cup, you will almost certainly be seriously electrocuted. The anode wire leads to the flyback transformer and produces up to 25,000 volts. Don't worry about what they do; just worry about what they can do to *you*! That charge is stored in a capacitor, which holds that charge even if the monitor is turned off. It will hold the charge even if the monitor is unplugged. That capacitor (depending on the system) can hold a charge for days, weeks, months, or even years. Knowing this, you should learn how to discharge a CRT.

Discharging a CRT There are 75,000 opinions on how to discharge a CRT properly. Although my procedure may not follow the steps outlined in someone's official handbook on electrical code, I know this works. Read the rules, and then look at Figure 19-77.

Figure 19-77 Discharging a CRT

1. Make sure everything is unplugged.
2. If possible, let the monitor sit for a couple of hours. Most good monitors discharge themselves in two to three hours, and many new monitors discharge in just a few moments.
3. Get a heavy, well-insulated, flat-head screwdriver.
4. Get a heavy-gauge wire with alligator clips on each end.
5. Do not let yourself be grounded in any way. Wear rubber-soled shoes, and no rings or watches.

6. Wear safety goggles to protect yourself in the very rare case that the CRT implodes.
7. Remove the monitor's case. Remember where the screw went in.
8. Attach one alligator clip to an unpainted part of the metal frame of the monitor.
9. Clip the other clip to the metal shaft of the screwdriver.
10. Slide the screwdriver blade under the suction cup. Make triple-sure that neither you nor the screwdriver is in any incidental contact with anything metal.
11. Slide the blade under until you hear a loud pop—you'll also see a nice blue flash.
12. If anyone is in the building, they will hear the pop and come running. Tell them everything's okay.
13. Wait about 15 minutes and repeat.

The main controls that require you to remove the monitor case to make adjustments include those for convergence, gain for each of the color guns, and sometimes the focus control. A technician with either informal or formal training in component-level repair can usually figure out which controls do what. In some cases, you can also readily spot and repair bad solder connections inside the monitor case, and thus fix a dead or dying CRT. Still, balance the cost of repairing the monitor against the cost of death or serious injury—is it worth it? Finally, before making adjustments to the display image, especially with the internal controls, give the monitor at least 15 to 30 minutes of warm-up time. This is necessary both for the components on the printed circuit boards and for the CRT itself.

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.
- If the LCD goes dark but you can still barely see the image under bright lights, you lost either the lamp or the inverter. In many cases, especially with super-thin panels, you'll replace the entire panel and lamp 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 19-78.
- If your LCD makes a distinct hissing noise, an inverter is about to fail. Again, you can replace the inverter if need be.

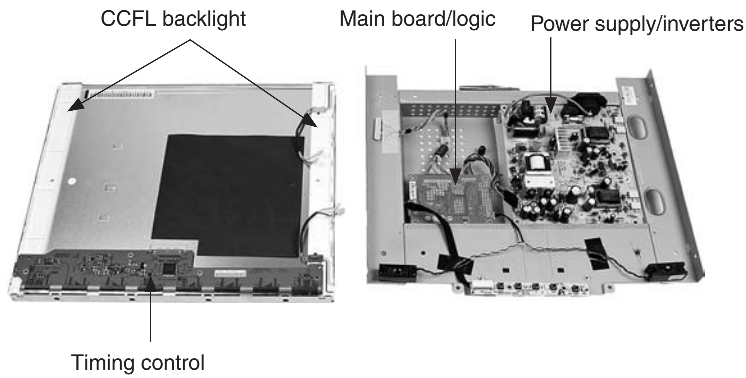


Figure 19-78 LCD components labeled

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. 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.

Beyond A+

Video and CMOS

I'm always impressed by the number of video options provided in CMOS, especially in some of the more advanced CMOS options. I'm equally impressed by the amount of disinformation provided on these settings. In this section, I'll touch on some of the most common CMOS settings that deal with video. You may notice that no power-management video options have been included.

Video

Every standard CMOS setup shows an option for video support. The default setting is invariably EGA/VGA. Many years ago, this setting told the BIOS what type of card was installed on the system, enabling it to know how to talk to that card. Today, this setting has no meaning. No matter what you put there, the system will ignore it and boot normally.

Init Display First

This CMOS setting usually resides in an advanced options or BIOS options screen. In multi-monitor systems, Init Display First enables you to decide between PCIe and PCI as to which monitor initializes at boot. This also determines the initial primary monitor for Windows.

Assign IRQ for VGA

Many video cards do not need an *interrupt request* (*IRQ*). This option gives you the ability to choose whether your video card gets an IRQ. In general, lower-end cards that do not provide input to the system do not need an IRQ. Most advanced cards will need one; try it both ways. If you need it, your system will freeze up without an IRQ assigned. If you don't need it, you get an extra IRQ.

VGA Palette Snoop

True-VGA devices only show 16 out of a possible 262,000 colors at a time. The 16 current colors are called the *palette*. VGA Palette Snoop opens a video card's palette to other devices that may need to read or temporarily change the palette. I am unaware of any device made today that still needs this option.

Video Shadowing Enabled

As mentioned in previous chapters, this setting enables you to shadow the Video ROM. In most cases, this option is ignored as today's video cards perform their own automatic shadowing. A few cards require this setting to be off, so I generally leave it off now, after years of leaving it on.

Other Display Technologies

A few other screen technologies exist, but not so much for computer monitors. Plasma and DLP screens grace many a household's media room as the primary television display.

Plasma

Plasma display panels (*PDP*) are a very popular technology for displaying movies. Unfortunately, plasma TVs have two issues that make them a bad choice for PC use. First, they have strange native resolutions (such as 1366 × 768) that are hard to get your video card to accept. Second is *burn-in*—the tendency for a screen to "ghost" an 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 with PC displays.

DLP

Digital Light Processing (*DLP*) displays use a chip covered in microscopically small mirrors (Figure 19-79).

Figure 19-79 DLP chip (*photo courtesy of Texas Instruments*)

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 19-80 for a diagram of how the mirrors would appear in a microscopic close-up of the chip.

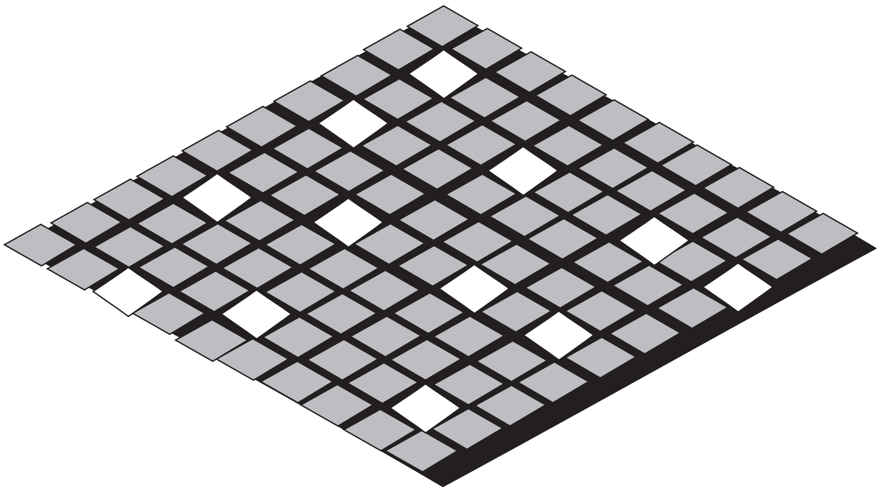


Figure 19-80 Microscopic close-up of DLP showing tiny mirrors—note that some are tilted.

Figure 19-81 shows a diagram of a typical DLP system. 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.

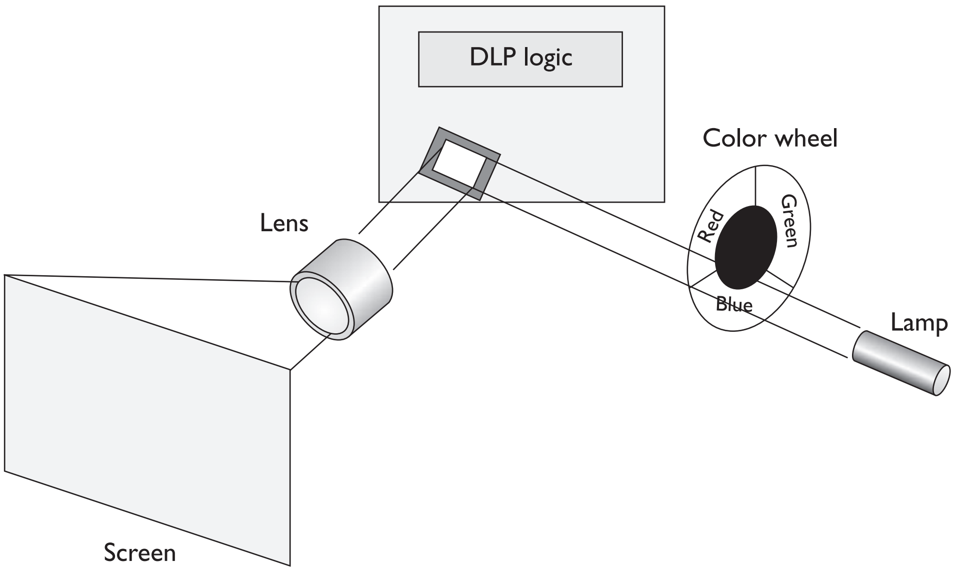


Figure 19-81 DLP in action

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 as projectors. DLP projectors are much more expensive than LCD projectors, but many customers feel the extra expense is worth the image quality.

Chapter Review Questions

1. What do we call the time it takes to draw the entire screen and get the electron guns back to the upper-left corner?
   - A. Horizontal refresh rate
   - B. Horizontal redraw rate
   - C. Vertical refresh rate
   - D. Vertical redraw rate
2. What does the dot pitch signify about a CRT monitor?
   - A. The resolution, such as 1024 × 768
   - B. The sharpness of the picture, such as 0.31 or 0.18
   - C. The maximum refresh rate, such as 100 Hz
   - D. The minimum refresh rate, such as 60 Hz

3. On an LCD monitor, what is the technology that uses a matrix of wires under colored glass?
    - A. Active matrix
    - B. Passive matrix
    - C. Active TFT
    - D. Passive TFT
4. What provides the illumination for LCD monitors?
    - A. Backlights
    - B. Inverter
    - C. Lamp
    - D. LCD panel
5. Which statement best describes the difference, if any, between CRT and LCD resolution?
    - A. The CRT has a single native resolution; LCDs have no native resolution.
    - B. The CRT has three native resolutions; LCDs have no native resolution.
    - C. The CRT has no native resolution; LCDs have three native resolutions.
    - D. The CRT has no native resolution; LCDs have a single native resolution.
6. Which typically uses more wattage?
    - A. CRT
    - B. DVI
    - C. LCD
    - D. VGA
7. What is WSXGA+ resolution?
    - A. 1024×768
    - B. 1280×1024
    - C. 1680×1050
    - D. 1920×1080
8. What is the processor on a video card called?
    - A. CPU
    - B. GPU
    - C. GDDR
    - D. MPU

9. What Microsoft API supports 3-D graphics?
   A. Active Desktop
   B. DirectX
   C. Glide
   D. OpenGL
10. How would you adjust your screen settings in Windows Vista?
    A. Go to Start | Run and type DISPLAY to open the Display applet.
    B. Go to Start | Control Panel and double-click the Personalization applet icon.
    C. Go to Start | Control Panel and double-click the Display applet icon.
    D. Go to Start | All Programs and select the Display applet icon.

Answers

1. **C.** 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.
2. **B.** The dot pitch, measured in millimeters, tells you how fine the screen will be.
3. **B.** Passive matrix technology uses a matrix of wires under colored glass.
4. **A.** The backlights provide the illumination for the LCD panel.
5. **D.** The CRT has no native resolution; LCDs have a single native resolution.
6. **A.** CRTs use a lot more wattage than LCDs.
7. **C.** WSXGA+ resolution is 1680×1050.
8. **B.** You'll typically see video card processors referred to as GPUs.
9. **B.** Microsoft makes the DirectX API to support 3-D programs.
10. **B.** The Personalization applet in Control Panel enables you to change video settings in Windows Vista.