Chapter 10

Video Display Hardware and Specifications

Your monitor provides the link between you and your computer. Although you can get rid of your printer, disk drives, and expansion cards, you cannot sacrifice the monitor. Without it, you would be operating blind; you couldn't see the results of your calculations or the mistyped words on-screen.

The first microcomputers were small boxes that lacked displays. Instead, users waited for the final output to be printed. When the monitor was added, the computer became more attractive to a wider audience. This trend continues today with graphical user interfaces such as Microsoft Windows.

The video subsystem of a PC consists of two main components:

- Monitor (or *video display*)
- Video adapter (also called the *video card, video adapter*, or *graphics card*)

This chapter explores the range of available IBM-compatible video adapters and the displays that work with them.

Monitors

The monitor is, of course, the display located on top of, near, or inside your computer. Like any computer device, a monitor requires a source of input. The signals that run from your monitor come from video circuitry inside your computer. Some computers, such as the IBM PS/2 computers, contain this circuitry on the motherboard. Most systems, though, use a separate circuit board that is plugged into an expansion slot. The expansion cards that produce video signals are called video cards, video adapters, or graphics cards.

Display Technologies

A monitor may use one of several display technologies. By far the most popular is *cathode-ray tube* (CRT) technology, the same technology used in television sets. CRTs consist of a vacuum tube enclosed in glass. One end of the tube contains an electron gun; the other end contains a screen with a phosphorous coating.

When heated, the electron gun emits a stream of high-speed electrons that are attracted to the other end of the tube. On the way, a focus control and deflection coil steer the beam to a specific point on the phosphorous screen. When struck by the beam, the phosphor glows. This light is what you see when you watch TV or your computer screen.

The phosphor chemical has a quality called *persistence*, which indicates how long this glow will remain on-screen. You should have a good match between persistence and scanning frequency so that the image has less flicker (if the persistence is too low) and no ghosts (if the persistence is too high).

The electron beam moves very quickly, sweeping the screen from left to right in lines from top to bottom, in a pattern called a *raster*. The *horizontal scan rate* refers to the speed at which the electron beam moves across the screen.

During its sweep, the beam strikes the phosphor wherever an image should appear on-screen. The beam also varies by intensity in order to produce different levels of brightness. Because the glow fades almost immediately, the electron beam must continue to sweep the screen to maintain an image—a practice called *redrawing* or *refreshing* the screen.

Most displays have a *refresh rate* (also called a vertical scan rate) of about 70 hertz (Hz), meaning that the screen is refreshed 70 times a second. Low refresh rates cause the screen to flicker, contributing to eyestrain. The higher the refresh rate, the better for your eyes.

It is important that the scan rates expected by your monitor match those produced by your video card. If you have mismatched rates, you won't be able to see an image and may actually damage your monitor.

Some monitors have a fixed refresh rate. Other monitors may support a range of frequencies; this support provides built-in compatibility with future video standards (described in "Video Cards" later in this chapter). A monitor that supports many video standards is called a *multiple-frequency monitor*. One example is the NEC MultiSync 4FGe, which supports all popular video standards. Different vendors call their multiple-frequency monitors by different names, including multisync, multifrequency, multiscan, autosynchronous, and autotracking.

Phosphor-based screens come in two styles: curved and flat. The typical display screen is curved, meaning that it bulges outward from the middle of the screen. This design is consistent with the vast majority of CRT designs (the same as the tube in your television set).

The traditional screen is curved both vertically and horizontally. Some models use the Trinitron design, which is curved only horizontally and is flat vertically. Many people prefer this flatter screen because it results in less glare and a higher-quality, more accurate image. The disadvantage is that the technology required to produce flat-screen displays is more expensive, resulting in higher prices for the monitors.

Alternative display designs are available. Borrowing technology from laptop manufacturers, some companies provide LCD (liquid-crystal diode) displays. LCD displays have low-glare flat screens and low power requirements (5 watts versus nearly 100 for an ordinary monitor). The color quality of an active-matrix LCD panel exceeds that of most CRT displays. At this point, however, LCD screens usually are limited to VGA resolution and are very expensive; even a 10-inch screen costs thousands of dollars. There are three LCD choices: passive-matrix monochrome, passive-matrix color, and active-matrix color.

In an LCD, a polarizing filter creates two separate light waves. In a color LCD there is an additional filter that has three cells per each pixel—one each for displaying red, green, and blue.

The light wave then passes through a liquid-crystal cell, with each color segment having its own cell. The liquid crystals are rod-shaped molecules that flow like a liquid. They let light pass straight through, but an electrical charge alters their orientation, as well as the orientation of light passing through them. Though monochrome LCDs do not have color filters, they can have multiple cells per pixel for controlling shades of gray.

In a passive-matrix LCD, each cell is controlled by electrical charges transmitted by transistors according to row and column positions on the screen's edge. As the cell reacts to the pulsing charge, it twists the light wave, with stronger charges twisting the light wave more. Supertwist refers to the orientation of the liquid crystals, comparing on-mode to off-mode—the greater the twist, the higher the contrast.

Charges in passive-matrix LCDs are pulsed, so the displays lack the brilliance of active-matrix, which provides a constant charge to each cell. To increase the brilliance, some vendors have turned to a new technique called double-scan LCD, which splits passive-matrix screens into a top half and a bottom half, cutting the time between each pulse.

In an active-matrix LCD, each cell has its own transistor to charge it and twist the light wave. This provides a brighter image than passive-matrix displays, since the cell can maintain a constant, rather than momentary, charge. However, active-matrix technology uses more energy than passive-matrix. With a dedicated transistor for every cell, active-matrix displays are more difficult and expensive to produce.

In both active- and passive-matrix LCDs, the second polarizing filter controls how much light passes through each cell. Cells twist the wavelength of light to closely match the filter's allowable wavelength. The more light that passes through the filter at each cell, the brighter the pixel.

Monochrome LCDs achieve gray scales (up to 64) by varying the brightness of a cell or dithering cells in an on-and-off pattern. Color LCDs, on the other hand, dither the three color cells and control their brilliance to achieve different colors on the screen. Double-scan passive-matrix LCDs have recently gained in popularity because they approach the quality of active-matrix displays but do not cost much more to produce than other passive-matrix displays.

Many active-matrix LCDs, which are produced by such firms as Sharp Electronics Corp. and NEC Corp., do not pass quality-assurance tests in the factory because of failed transistors, resulting in low factory yields and higher prices.

In the past, several hot cathode ray tubes were needed to light an LCD screen, but portable computer manufacturers now use a single tube the size of a cigarette. Light emitted from a tube gets spread evenly across an entire display using fiber-optic technology.

Thanks to supertwist and triple-supertwist LCDs, today's screens let you clearly see the screen from more angles with better contrast and lighting. To improve readability, especially in dim light, some laptops include *backlighting* or *edgelighting* (also called *sidelighting*). Backlit screens provide light from a panel behind the LCD. Edgelit screens get their light from the small fluorescent tubes mounted along the sides of the screen. Some laptops exclude such lighting systems to lengthen battery life.

The best color displays are active-matrix or thin-film transistor (TFT) panels, in which each pixel is controlled by three transistors (for red, green, and blue). Active-matrix-screen refreshes and redraws are immediate and accurate, with much less ghosting and blurring than in passive-matrix LCDs (which control pixels via rows and columns of transistors along the edges of the screen). Active-matrix displays are also much brighter and can easily be read at an angle.

An alternative to LCD screens is gas-plasma technology, typically known for its black and orange screens in some of the older Toshiba notebook computers. Some companies are incorporating gas-plasma technology for desktop screens and possibly color HDTV (high-definition television) flat-panel screens.

Monochrome versus Color

During the early years of the IBM PC and compatibles, owners had only two video choices: color using a CGA display adapter and monochrome using an MDA display adapter. Since then, many adapter and display options have hit the market.

Monochrome monitors produce images of one color. The most popular is amber, followed by white and green. The color of the monitor is determined by the color of the phosphors on the CRT screen. Some monochrome monitors with white phosphors can support many shades of gray.

Monochrome monitors cost less than color models—typically about one-third to one-fourth the price of color models. A monochrome monitor is ideal for character-based applications: word processing, spreadsheet analysis, database management, and computer programming. Such monitors, however, may not work as well with Windows software as the more-expensive color monitors do. In addition, large monochrome monitors designed for specialized applications, such as desktop publishing and CAD/CAM, cost hundreds of dollars more than standard color monitors.

Color monitors use more sophisticated technology than monochrome monitors, which accounts for their higher prices. Whereas a monochrome picture tube contains one electron gun, a color tube contains three guns arranged in a triangular shape referred to as a *delta configuration*. Instead of amber, white, or green phosphors, the monitor screen contains phosphor *triads*, which consist of one red phosphor, one green phosphor, and one blue phosphor arranged in the same pattern as the electron guns. These three primary colors can be mixed to produce all other colors.

Although color monitors cost more than monochrome monitors, they are more versatile, enabling you to take advantage of color software for purposes such as presentations.

The Right Size

Monitors come in difference sizes, ranging from inexpensive (albeit rare) 12-inch monochrome monitors to 42-inch color monitors. The larger the monitor, the higher the price tag. The most common monitor sizes are 14, 15, 17, and 21 inches. These diagonal measurements, unfortunately, represent not the actual screen that will be displayed but the size of the tube. As a result, comparing one company's 15-inch monitor to another's may be unfair unless you actually measure the active screen area. One company's 15-inch monitor may display a 13.8-inch image, whereas another company's 14-inch monitor may present a 13.5-inch image.

Larger monitors are handy for applications (such as desktop publishing) in which the smallest details must be clearly visible. With a larger monitor, you can see an entire 8 1/2-by-11-inch page in a 100-percent view—in other words, what you see on-screen virtually matches the page that will be printed. This feature is called *WYSIWYG* (what you see is what you get). If you can see the entire page at its actual size, you can save yourself the trouble of printing several drafts before you get it right.

Monitors come in both portrait and landscape styles. The screen of a *portrait* (full-page) monitor is taller than it is wide, enabling you to view an entire page of a document. Portrait monitors differ from standard monitors in that they stretch image height to about 66 lines, enabling you to see the equivalent of a full printed page on one screen. A *landscape* (dual-page) monitor is the opposite of a portrait monitor, suitable for viewing two pages side by side at the same time.

Although most general-purpose monitors are landscape, monitors with this orientation are larger and wider—and usually more expensive—than portrait models. When you consider a portrait monitor, you should make sure that it supports your software. Some monitors require special video drivers to work with certain software packages.

Monitor Resolution

Resolution is the amount of detail that a monitor can render. This quantity is expressed in the number of horizontal and vertical picture elements, or *pixels*, contained in the screen. The greater the number of pixels, the more detailed the images. The resolution required depends on the application. Character-based applications (such as word processing) require little resolution, whereas graphics-intensive applications (such as desktop publishing and Windows software) require a great deal.

In a monochrome monitor, the picture element is a screen phosphor, but in a color monitor, the picture element is a phosphor triad. This difference raises another consideration called dot pitch, which applies only to color monitors. *Dot pitch* is the distance, in millimeters, between phosphor triads. Screens with a small dot pitch contain less distance between the phosphor triads; as a result, the picture elements are closer together, producing a sharper picture. Conversely, screens with a large dot pitch tend to produce less clear images.

Most monitors have a dot pitch between 0.25 and 0.52 millimeters. To avoid grainy images, look for a dot pitch of 0.28 millimeters or smaller for 12- and 14-inch monitors, or 0.31mm or smaller for 16-inch and larger monitors. Be wary of monitors with 0.39mm or greater dot pitches; for fine text and graphics, there is a lack of clarity.

Interlaced versus Noninterlaced

Monitors may support interlaced or noninterlaced resolution. In *noninterlaced* (conventional) mode, the electron beam sweeps the screen in lines from top to bottom, one line after the other, completing the screen in one pass. In *interlaced* mode, the electron beam also sweeps the screen from top to bottom, but it does so in two passes, sweeping the odd lines first and the even lines second; each pass takes half the time of a full pass in noninterlaced mode. Therefore, both modes refresh the entire screen in the same amount of time. This technique redraws the screen faster and provides more stable images.

Monitors that use interlacing can use lower refresh rates, lessening their cost. The drawback is that interlacing depends on the ability of the eye to combine two nearly identical lines, separated by a gap, into one solid line. If you are looking for high-quality video, however, you want to get a video adapter and monitor that support high-resolution, noninterlaced displays.

Energy and Safety

A monitor can save energy. Many PC manufacturers are trying to meet the Environmental Protection Agency's Energy Star requirements. Any PC-and-monitor combination that consumes less than 70 watts (35 watts apiece) can use the Energy Star logo. Some research shows that such "green" PCs can save each user about $70 per year in electricity costs.

Monitors, being one of the most power-hungry computer components, can contribute to those savings. Perhaps the best-known energy-saving standard for monitors is VESA's Display Power-Management Signaling (DPMS) spec, which defines the signals that a computer sends to a monitor to indicate idle times. The computer or video card decides when to send these signals.

If you buy a DPMS monitor, such as one of NEC's recent MultiSync models, you can take advantage of energy savings without remodeling your entire system. If you don't have a DPMS-compatible video adapter, some cards, such as ATI's (based on that company's mach32 chipset), can be upgraded to DPMS with a software utility typically available at no cost. Similarly, ViewSonic's energy-saving monitors include software that works with almost any graphics card to supply DPMS signals.

Another trend in green monitor design is to minimize the user's exposure to potentially harmful electromagnetic fields. Several medical studies indicate that these electromagnetic emissions may cause health problems, such as miscarriages, birth defects, and cancer. The risk may be low, but if you spend a third of your day (or more) in front of a computer monitor, that risk is increased.

The concern is that VLF (very-low-frequency) and ELF (extremely low-frequency) emissions somehow affect your body. These two emissions come in two forms: electric and magnetic. Some research indicates that ELF magnetic emissions are more threatening than VLF emissions, because they interact with the natural electric activity of body cells. Monitors aren't the only culprits; significant ELF emissions also come from electric blankets and power lines.

Note

ELF and VLF are not considered to be radiation; they actually are radio frequencies below those used for broadcasting.

These two frequencies are covered by the new Swedish monitor-emission standard called SWEDAC, named after the Swedish regulatory agency. In many European countries, government agencies and businesses buy only low-emission monitors. The degree to which emissions are reduced varies from monitor to monitor. The Swedish government's MPR I standard, which dates back to 1987, is the least restrictive. MPR II, established in 1990, is significantly stronger (adding maximums for ELF as well as VLF emissions) and is the level that you're most likely to find in low-emission monitors today.

A more stringent 1992 standard called TCO further tightens the MPR II requirements; in addition, it's a more broad-based environmental standard that includes power-saving requirements as well as emission limits. Nanao is one of the few manufacturers currently offering monitors that meet the TCO standard.

A low-emission monitor costs about $20 to $100 more than a similar regular-emission monitors. When you shop for a low-emission monitor, don't just ask for a low-emission monitor; also find out whether the monitor limits specific types of emission. Use as your guideline the two electromagnetic-emission standards described in this section.

If you decide not to buy a low-emission monitor, you can take other steps to protect yourself. The most important is to stay at arm's length (about 28 inches) from the front of your monitor. When you move a couple of feet away, ELF magnetic emission levels usually drop to those of a typical office with fluorescent lights. Also, monitor emissions are weakest at the front of a monitor, so stay at least three feet from the sides and backs of nearby monitors and five feet from any copiers—very strong sources of ELF.

Electromagnetic emissions should not be your only concern; you also should be concerned about screen glare. In fact, some antiglare screens not only reduce eyestrain, but also cut ELF and VLF electric (but not magnetic) emissions.

Monitor Buying Criteria

A monitor may account for as much as 50 percent of the price of a computer system. What should you look for when you shop for a monitor?

The trick is to pick a monitor that works with your selected video card. You can save money by purchasing a single-standard (fixed-frequency) monitor and a matching video card; for example, you can order a VGA monitor and a VGA video card. For greatest flexibility, get a multisync monitor that accommodates a range of standards, including those that are not yet standardized.

With multisync monitors, you must match the range of horizontal and vertical frequencies the monitor accepts with those generated by your video card. The wider the range of signals, the more expensive—and more versatile—the monitor. Your video card's vertical and horizontal frequencies must fall within the ranges supported by your monitor. The *vertical frequency* (or refresh/frame rate) determines how stable your image will be. The higher the vertical frequency, the better. Typical vertical frequencies range from 50 to 90 Hz. The *horizontal frequency* (or line rate) ranges between 31.5 kHz and 59 kHz.

To keep the horizontal frequency low, some video cards use interlacing signals, alternately displaying half the lines of the total image. On some monitors, interlacing can produce a pronounced flicker. For this reason, your monitor should synchronize to twice the vertical frequency of the video card. For example, the IBM XGA video standard uses a frame rate of 43.5 Hz. To match those signals, a monitor must accept a vertical frequency of 87 Hz and a horizontal frequency of 35.5 kHz.

When you shop for a VGA monitor, make sure that the monitor supports a horizontal frequency of at least 31.5 kHz—the minimum that a VGA card needs to paint a 640-by-480 screen. The VESA super-VGA (800-by-600) standard requires a 72 Hz vertical frequency and a horizontal frequency of at least 48 kHz. The sharper 1,024-by-768 image requires a vertical frequency of 60 Hz and a horizontal frequency of 58 kHz. If the vertical frequency increases to 72 Hz, the horizontal frequency must be 58 kHz. If flicker-prone interlacing is used, a 1,024-by-768 video card needs a monitor with a 43.5 Hz vertical frequency and a 35.5 kHz horizontal frequency.

Most of the analog monitors produced today are, to one extent or another, multisync. Because literally hundreds of manufacturers produce thousands of monitor models, it is impractical to discuss the technical aspects of each monitor model in detail. Suffice it to say that before investing in a monitor, you should check the technical specifications to make sure that the monitor meets your needs. If you are looking for a place to start, check out *PC Magazine*, which periodically features reviews of monitors. If you can't wait for a *PC Magazine* review, investigate monitors made by any of the following vendors:

- IBM
- Mitsubishi
- NEC
- Sony

Each of these manufacturers creates monitors that set the standards by which other monitors can be judged. Although you typically pay a bit more for these manufacturers' monitors, you never will be disappointed with their quality or with the service that you receive from them.

Many inexpensive monitors are curved because it's easier to send an electron beam across them. Flat-screen monitors, which are a bit more expensive, look better to most people. As a general rule, the less curvature a monitor has, the less glare it will reflect.

Consider the size of your desk before you think about a monitor 16 inches or larger. A 16-inch monitor typically is at least a foot and a half deep, and a 20-inch monitor takes up 2 square feet. (Typical 14-inch monitors are 16 to 18 inches deep.)

You also should check the dot pitch of the monitor. Smaller pitch values indicate sharper images. The original IBM PC color monitor had a dot pitch of 0.43mm, which is considered to be poor by almost any standard. The state-of-the-art displays marketed today have a dot pitch of 0.28mm or less. You can save money by picking a smaller monitor or one with a higher dot pitch. The tradeoff, of course, is clarity. Don't be too discerning; choosing a monitor with a 0.31mm dot pitch over one with a 0.28mm dot pitch may save you a good deal of money.

What resolution do you want for your display? Generally, the higher the resolution, the larger the display you will want. If you are operating at 640-by-480 resolution, for example, you should find a 14-inch monitor to be comfortable. At 1,024-by-768, you probably will find that the display of a 14-inch monitor is too small and therefore will prefer to use a larger one (such as a 17-inch monitor).

Get a monitor with positioning and image controls that are easy to reach. Look for more than just basic contrast and brightness controls; some monitors also enable you to adjust the width and height of your screen images. A tilt-swivel stand should be included with your monitor, enabling you to move the monitor to the best angle for your use.

A monitor is such an important part of your computer that it's not enough just to know its technical specifications. Knowing a monitor has a 0.28mm dot pitch doesn't necessarily tell you that it is ideal for you. It's best to "kick the tires" of your new monitor at a showroom or (with a liberal return policy) in the privacy of your office. To test your monitor:

- *Draw a circle with a graphics program.* If the result is an oval, not a circle, this monitor won't serve you well with graphics or design software.
- *Type some words in 8- or 10-point type* (1 point = 1/72 inch). If the words are fuzzy, or if the black characters are fringed with color, select another monitor.
- *Turn the brightness up and down* while examining the corner of the screen's image. If the image blooms or swells, it's likely to lose focus at high brightness levels.
- *Load Microsoft Windows to check for uniform focus.* Are the corner icons as sharp as the rest of the screen? Are the lines in the title bar curved or wavy? Monitors

usually are sharply focused at the center, but seriously blurred corners indicate a poor design. Bowed lines may be the result of a poor graphics card, so don't dismiss a monitor that shows those lines without using another card to double-check the effect. A good monitor will be calibrated so that rays of red, green, and blue light hit their targets (individual phosphor dots) precisely. If they don't, you have bad *convergence*. This is apparent when edges of lines appear to illuminate with a specific color. If you have good *convergence* then the colors will be crisp, clear, and true, provided there is not a predominant tint in the phosphor.

Video Cards

A video card provides signals that operate your monitor. With the PS/2 systems introduced in 1987, IBM developed new video standards that have overtaken the older display standards in popularity and support.

Most video cards follow one of several industry standards:

- MDA (Monochrome Display Adapter)
- CGA (Color Graphics Adapter)
- EGA (Enhanced Graphics Adapter)
- VGA (Video Graphics Adapter)
- SVGA (Super-VGA)
- XGA (eXtended Graphics Array)

These adapters and video standards are supported by virtually every program that runs on IBM or compatible equipment. Other systems are developing into de facto standards as well. For example, super-VGA (SVGA) offers different resolutions from different vendors, but 1,024-by-768 resolution is becoming a standard resolution for doing detailed work.

Most microcomputer monitors support at least one video standard, enabling you to operate them with video cards and software that are compatible with that standard. For example, a monitor that supports VGA may operate with VGA video cards and VGA software.

Although many types of display systems are considered to be standards, not all systems are considered to be viable standards for today's hardware and software. For example, the CGA standard works but is unacceptable for running the graphics-intensive programs on which many users rely. In fact, Microsoft Windows 3.1 does not work with any PC that has less-than-EGA resolution. The next several sections discuss the display adapters that are viewed as being obsolete in today's market.

Monochrome Display Adapter (MDA) and Display. The simplest (and first available) display type is the IBM Monochrome Display Adapter (MDA). (Actually, the MDA card doubles as a video and printer card.) The MDA video card can display text only at a resolution of 720 horizontal by 350 vertical pixels (720 by 350).

A character-only system, the display has no inherent graphics capabilities. The display originally was a top-selling option because it is fairly cost-effective. As a bonus, the MDA provides a printer interface, conserving an expansion slot.

The display is known for clarity and high resolution, making it ideal for business use—especially for businesses that use DOS-based word processing or spreadsheet programs.

Figure 10.1 shows the Monochrome Display Adapter pinouts.

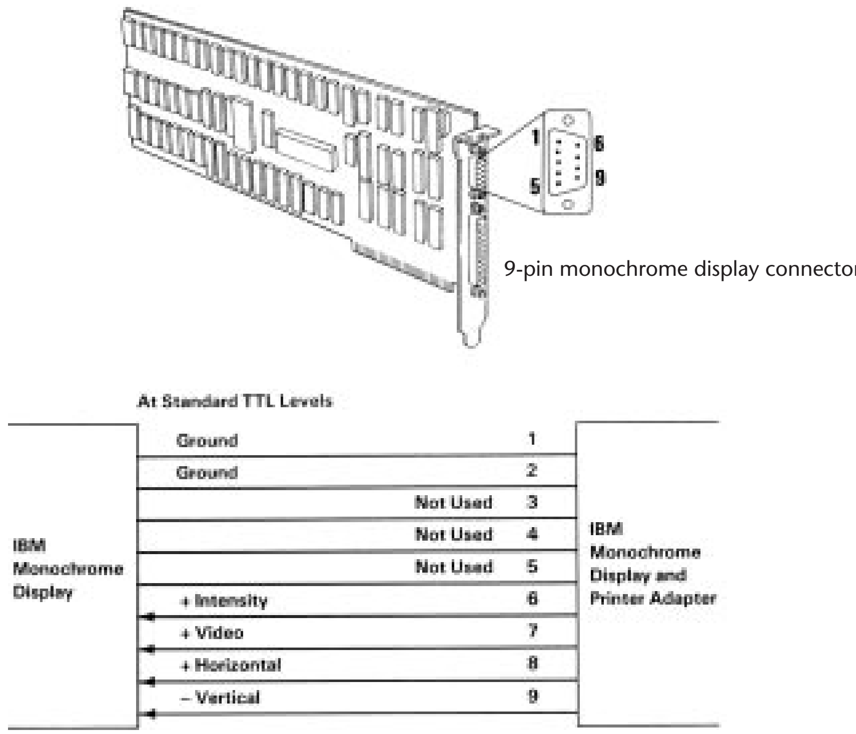


Fig. 10.1
Monochrome Display Adapter pinouts.

Because the monochrome display is a character-only display, you cannot use it with software that requires graphics. Originally, that drawback only kept the user from playing games on a monochrome display, but today, even the most serious business software uses graphics and color to great advantage. With the 9-by-14 dot character box (*matrix*), the IBM monochrome monitor displays attractive characters.

Table 10.1 summarizes the features of the MDA's single mode of operation.

Later, a company named Hercules released a video card called the Hercules Graphics Card (HGC). This card displays sharper text and can handle graphics, such as bar charts.

Table 10.1 IBM Monochrome Display Adapter (MDA) Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
MDA					
(08/12/81)	720 × 350	4	Text	07h	80 × 25

Colors refer to different display attributes such as regular, highlight, reverse video, and underlined.

Color Graphics Adapter (CGA) and Display. For many years, the Color Graphics Adapter (CGA) was the most common display adapter, although its capabilities now leave much to be desired. This adapter has two basic modes of operation: alphanumeric (A/N) or all points addressable (APA). In A/N mode, the card operates in 40-column by 25-line mode or 80-column by 25-line mode with 16 colors. In APA and A/N modes, the character set is formed with a resolution of
8-by-8 pixels. In APA mode, two resolutions are available: medium-resolution color mode (320 by 200), with four colors available from a palette of 16; and two-color high-resolution mode (640 by 200).

Figures 10.2 and 10.3 show the pinouts for the Color Graphics Adapter.

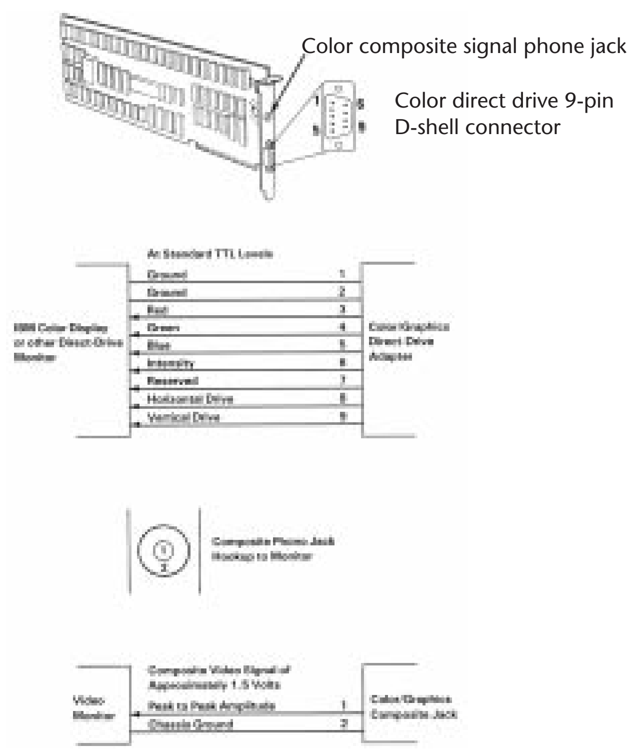


Fig. 10.2
CGA display connector specifications.

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
9 × 14	50	18.432	Std

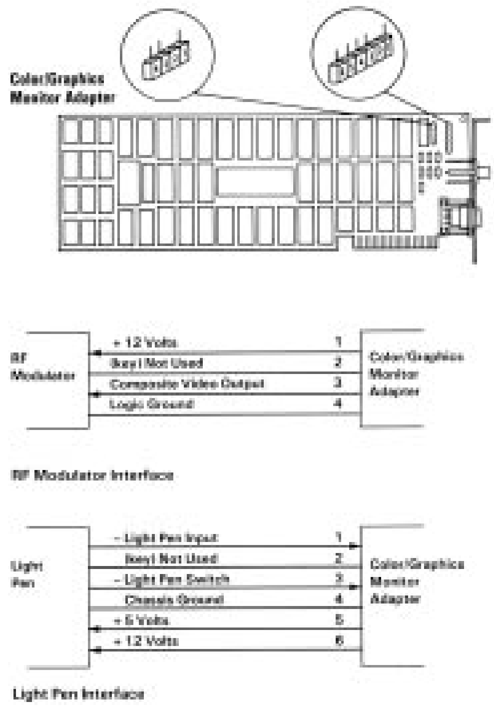


Fig. 10.3
CGA RF modulator and light-pen connector specifications.

Most of the monitors sold for the CGA are RGBs, not composite monitors. The color signal of a composite monitor contains a mixture of colors that must be decoded or separated. RGB monitors receive red, green, and blue separately, and combine the colors in different proportions to generate other colors. RGB monitors offer better resolution than composite monitors, and they do a much better job of displaying 80-column text.

One drawback of a CGA video card is that it produces flicker and snow. *Flicker* is the annoying tendency of the text to flash as you move the image up or down. *Snow* is the flurry of bright dots that can appear anywhere on the screen.

Most companies that sold CGA-type adapters have long since discontinued those products. When many VGA cards cost less than $100, recommending a CGA makes little sense.

Table 10.2 lists the specifications for all CGA modes of operation.

Table 10.2 IBM Color Graphics Adapter (CGA) Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
CGA					
(08/12/81)	320 × 200	16	Text	00/01h	40 × 25
	640 × 200	16	Text	02/03h	80 × 25
	160 × 200	16	APA	—	—
	320 × 200	4	APA	04/05h	40 × 25
	640 × 200	2	APA	06h	80 × 25

APA = All points addressable (graphics)
— = Not supported

Enhanced Graphics Adapter (EGA) and Display. The IBM Enhanced Graphics Adapter, discontinued when the PS/2 systems were introduced, consists of a graphics board, a graphics memory-expansion board, a graphics memory-module kit, and a high-resolution color monitor. The whole package originally cost about $1,800. The aftermarket gave IBM a great deal of competition in this area; you could put together a similar system from non-IBM vendors for much less money. One advantage of EGA, however, is that you can build your system in modular steps. Because the card works with any of the monitors IBM produced at the time, you can use it with the IBM Monochrome Display, the earlier IBM Color Display, or the IBM Enhanced Color Display.

With the EGA card, the IBM color monitor displays 16 colors in 320-by-200 or 640-by-200 mode and the IBM monochrome monitor shows a resolution of 640 by 350 with a 9-by-14 character box (text mode).

Figures 10.4 and 10.5 show the pinouts and P-2 connector of the Enhanced Graphics Display Adapter.

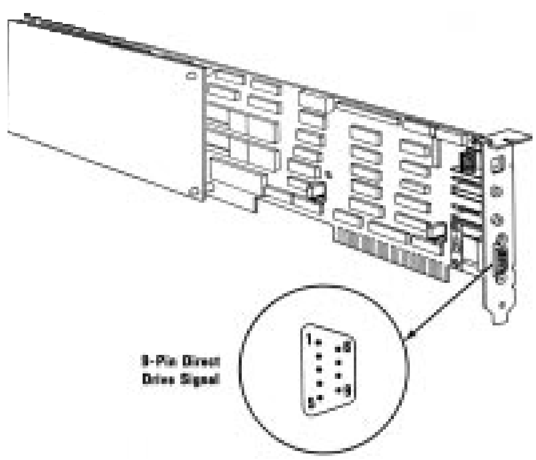
With the EGA card, the IBM Enhanced Color Display is capable of displaying 640-by-350 pixels in 16 colors from a palette of 64. The character box for text is 8 by 14, compared with 8 by 8 for the earlier CGA board and monitor. The 8-by-8 character box can be used, however, to display 43 lines of text. Through software, the character box can be manipulated up to the size of 8 by 32.

You can enlarge a RAM-resident, 256-member character set to 512 characters by using the IBM memory expansion card. A 1,024-character set is added with the IBM graphics memory-module kit. These character sets are loaded from programs.

All this memory fits in the unused space between the end of RAM user memory and the current display-adapter memory. The EGA has a maximum 128K of memory that maps into the RAM space just above the 640K boundary. If you install more than 640K, you probably will lose the extra memory after installing the EGA. The graphics memory-expansion card adds 64K to the standard 64K, for a total 128K. The IBM

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
8 × 8	60	15.75	Std
8 × 8	60	15.75	Std
—	60	15.75	Std
8 × 8	60	15.75	Std
8 × 8	60	15.75	Std

graphics memory-module kit adds another 128K, for a total 256K. This second 128K of memory is only on the card and does not consume any of the PC's memory space. (Because almost every aftermarket EGA card comes configured with the full 256K of memory, expansion options are not necessary.)



	Signal Name - Description	Pin	
Direct Drive Display	Ground	1	Enhanced Graphics Adapter
	Secondary Red	2	
	Primary Red	3	
	Primary Green	4	
	Primary Blue	5	
	Secondary Green/Intensity	6	
	Secondary Blue/Mono Video	7	
	Horizontal Retrace	8	
	Vertical Retrace	9	

Fig. 10.4
EGA display connector specifications.

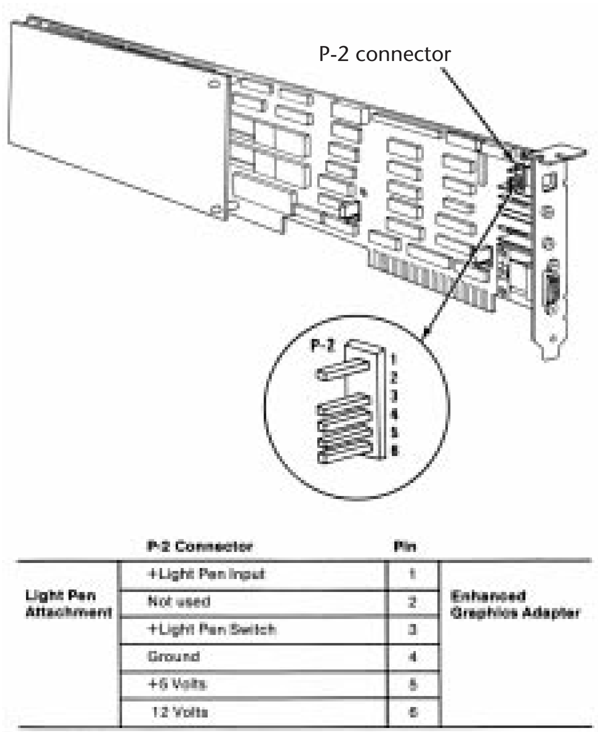


Fig. 10.5
EGA light-pen connector specifications.

The VGA system supersedes the EGA in many respects. The EGA has problems emulating the earlier CGA or MDA adapters, and some software that works with the earlier cards will not run on the EGA until the programs are modified.

Table 10.3 shows the modes supported by the EGA adapter.

Table 10.3 IBM Enhanced Graphics Adapter (EGA) Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
EGA					
(09/10/84)	320 × 350	16	Text	00/01h	40 × 25
	640 × 350	16	Text	02/03h	80 × 25
	720 × 350	4	Text	07h	80 × 25
	320 × 200	16	APA	0Dh	40 × 25
	640 × 200	16	APA	0Eh	80 × 25
	640 × 350	4	APA	0Fh	80 × 25
	640 × 350	16	APA	10h	80 × 25

APA = All points addressable (graphics)

Professional Color Display and Adapter. The Professional Graphics Display System is a video display product that IBM introduced in 1984. At $4,290, the system was too expensive to become a mainstream product.

The system consists of a Professional Graphics Monitor and a Professional Graphics Card Set. When fully expanded, this card set uses three slots in an XT or AT system—which is a high price to pay, but the features are impressive. The Professional Graphics Adapter (PGA) offers three-dimensional rotation and clipping as a built-in hardware function. The adapter can run 60 frames of animation per second because the PGA uses a built-in dedicated microcomputer.

The Professional Graphics card and monitor targeted engineering and scientific applications rather than financial or business applications. This system, which was discontinued when the PS/2 was introduced, has been replaced by the VGA and other higher resolution graphics standards for these newer systems.

Table 10.4 lists all supported PGA modes.

VGA Adapters and Displays

When IBM introduced the PS/2 systems on April 2, 1987, it also introduced the Video Graphics Array display. On that day, in fact, IBM also introduced the lower-resolution MultiColor Graphics Array (MCGA) and higher-resolution 8514 adapters. The MCGA and 8514 adapters did not become standards like the VGA, and both were discontinued.

Digital versus Analog Signals. Unlike earlier video standards, which are digital, the VGA is an analog system. Why are displays going from digital to analog when most other electronic systems are going digital? Compact disc players (digital) have replaced most turntables (analog), and newer VCRs and camcorders have digital picture storage for smooth slow-motion and freeze-frame capability. With a digital television set, you can watch several channels on a single screen by splitting the screen or placing a picture within another picture.

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
8 × 14	60	21.8	5td
8 × 14	60	21.8	Std
9 × 14	50	18.432	Std
8 × 8	60	15.75	Std
8 × 8	60	15.75	Std
8 × 14	50	18.432	Std
8 × 14	60	21.85	Std

Table 10.4 IBM Professional Graphics Adapter (PGA) Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
PGA					
(09/10/84)	320 × 200	16	Text	00/01	40 × 25
	640 × 200	16	Text	02/03	80 × 25
	320 × 200	4	APA	04/05	40 × 25
	640 × 200	2	APA	06	80 × 25
	640 × 480	256	APA	—	—

APA = All points addressable (graphics)
— = Not supported

Why, then, did IBM decide to change the video to analog? The answer is color.

Most personal-computer displays introduced before the PS/2 are digital. This type of display generates different colors by firing the red, green, and blue (RGB) electron beams in on-or-off mode. You can display up to eight colors (2 to the third power). In the IBM displays and adapters, another signal intensity doubles the number of color combinations from 8 to 16 by displaying each color at one of two intensity levels. This digital display is easy to manufacture and offers simplicity with consistent color combinations from system to system. The real drawback of the digital display system is the limited number of possible colors.

In the PS/2 systems, IBM went to an analog display circuit. Analog displays work like the digital displays that use RGB electron beams to construct various colors, but each color in the analog display system can be displayed at varying levels of intensity—64 levels, in the case of the VGA. This versatility provides 262,144 possible colors (64^3). For realistic computer graphics, color often is more important than high resolution, because the human eye perceives a picture that has more colors as being more realistic. IBM moved graphics into analog form to enhance the color capabilities.

MultiColor Graphics Array (MCGA). The MultiColor Graphics Array (MCGA) is a graphics adapter that is integrated into the motherboard of the PS/2 Models 25 and 30. The MCGA supports all CGA modes when an IBM analog display is attached, but any previous IBM display is not compatible. In addition to providing existing CGA mode support, the MCGA includes four additional modes.

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
8 × 8	60	15.75	Std
8 × 8	60	15.75	Std
8 × 8	60	15.75	Std
8 × 8	60	15.75	Std
—	60	30.48	Std

The MCGA uses as many as 64 shades of gray in converting color modes for display on monochrome displays, so that users who prefer a monochrome display still can execute color-based applications.

Video Graphics Array (VGA). PS/2 systems contain the primary display adapter circuits on the motherboard. The circuits, called the Video Graphics Array, are implemented by a single custom VLSI chip designed and manufactured by IBM. To adapt this new graphics standard to the earlier systems, IBM introduced the PS/2 Display Adapter. Also called a VGA card, this adapter contains the complete VGA circuit on a full-length adapter board with an 8-bit interface. IBM has since discontinued its VGA card, but many third-party units are available.

The VGA BIOS (basic input/output system) is the control software residing in the system ROM for controlling VGA circuits. With the BIOS, software can initiate commands and functions without having to manipulate the VGA directly. Programs become somewhat hardware-independent and can call a consistent set of commands and functions built into the system's ROM-control software.

Future implementations of the VGA will be different in hardware but will respond to the same BIOS calls and functions. New features will be added as a superset of the existing functions. The VGA, therefore, will be compatible with the earlier graphics and text BIOS functions that were built into the PC systems from the beginning. The VGA can run almost any software that originally was written for the MDA, CGA, or EGA.

In a perfect world, software programmers would write to the BIOS interface rather than directly to the hardware and would promote software interchanges between different types of hardware. More frequently, however, programmers want the software to perform better, so they write the programs to control the hardware directly. As a result, these programmers achieve higher-performance applications that are dependent on the hardware for which they first were written.

Table 10.5 lists the MCGA display modes.

Table 10.5 IBM MultiColor Graphics Array (MCGA) Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
MCGA					
(04/02/87)	320 × 400	16	Text	00/01h	40 × 25
	640 × 400	16	Text	02/03h	80 × 25
	320 × 200	4	APA	04/05h	40 × 25
	640 × 200	2	APA	06h	80 × 25
	640 × 480	2	APA	11h	80 × 30
	320 × 200	256	APA	13h	40 × 25

APA = All points addressable (graphics)
DBL = Double scan

When bypassing the BIOS, a programmer must ensure that the hardware is 100-percent compatible with the standard so that software written to a standard piece of hardware runs on the system. Note that just because a manufacturer claims this register level of compatibility does not mean that the product is 100-percent compatible or that all software runs as it would on a true IBM VGA. Most manufacturers have "cloned" the VGA system at the register level, which means that even applications that write directly to the video registers will function correctly. Also, the VGA circuits themselves emulate the older adapters even to the register level and have an amazing level of compatibility with these earlier standards. This compatibility makes the VGA a truly universal standard.

Table 10.6 lists the VGA display modes.

Table 10.6 IBM Video Graphics Array (VGA) Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
VGA					
(04/02/87)	360 × 400	16	Text	00/01h	40 × 25
	720 × 400	16	Text	02/03h	80 × 25
	320 × 200	4	APA	04/05h	40 × 25
	640 × 200	2	APA	06h	80 × 25
	720 × 400	16	Text	07h	80 × 25
	320 × 200	16	APA	0Dh	40 × 25
	640 × 200	16	APA	0Eh	80 × 25

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
8 × 16	70	31.5	Std
8 × 16	70	31.5	Std
8 × 8	70	31.5	Dbl
8 × 8	70	31.5	Dbl
8 × 16	60	31.5	Std
8 × 8	70	31.5	Dbl

The VGA displays up to 256 colors on-screen, from a palette of 262,144 (256K) colors. Because the VGA outputs an analog signal, you must have a monitor that accepts an analog input.

VGA displays come not only in color but also in monochrome VGA models, using color summing. With color summing, 64 gray shades are displayed in lieu of colors; the translation is performed in the ROM BIOS. The summing routine is initiated if the BIOS detects the monochrome display when the system is booted. This routine uses a formula that takes the desired color and rewrites the formula to involve all three color guns, producing varying intensities of gray. The color that would be displayed, for example, is converted to 30-percent red plus 59-percent green plus 11-percent blue to achieve the desired gray. Users who prefer a monochrome display, therefore, can execute color-based applications.

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
9 × 16	70	31.5	Std
9 × 16	70	31.5	Std
8 × 8	70	31.5	Dbl
8 × 8	70	31.5	Dbl
9 × 16	70	31.5	Std
8 × 8	70	31.5	Dbl
8 × 8	70	31.5	Dbl

(continues)

Table 10.6 Continued

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
VGA					
	640 × 350	4	APA	0Fh	80 × 25
	640 × 350	16	APA	10h	80 × 25
	640 × 480	2	APA	11h	80 × 30
	640 × 480	16	APA	12h	80 × 30
	320 × 200	256	APA	13h	40 × 25

APA = All points addressable (graphics)
Dbl = Double scan

8514 Display Adapter. The PS/2 Display Adapter 8514/A offers higher resolution and more colors than the standard VGA. This adapter, designed to use the PS/2 Color Display 8514, plugs into a Micro Channel slot in any PS/2 model so equipped.

All operation modes of the built-in VGA continue to be available. An IBM Personal System/2 8514 memory-expansion kit is available for the IBM Display Adapter 8514/A. This kit provides increased color and grayscale support.

The IBM Display Adapter 8514/A has these advantages:

- Hardware assistance for advanced text, image, and graphics functions
- New high-content display modes
- Increased color and monochrome capability
- Support for the new family of IBM displays
- MDA, CGA, EGA, and VGA modes available
- 256/256K colors and 64/64 grayscales with memory-expansion kit

Table 10.7 IBM 8514 Specifications

Video Standard	Resolution	Number of Colors	Mode Type	BIOS Modes	Character Format
8514					
(04/02/87)	1024 × 768	256	APA	H-0h	85 × 38
	640 × 480	256	APA	H-1h	80 × 34
	1024 × 768	256	APA	H-3h	146 × 51

APA = All points addressable (graphics)
IL = Interlaced

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
8 × 14	70	31.5	Std
8 × 14	70	31.5	Std
8 × 16	60	31.5	Std
8 × 16	60	31.5	Std
8 × 8	70	31.5	Dbl

To take full advantage of this adapter, you should use the 8514 display, because it is matched to the capabilities of the adapter. Notice that IBM has discontinued the 8514/A adapter and specifies the XGA in its place. The 8514 display continues to be sold because it works well with the newer XGA.

Table 10.7 shows all 8514 modes.

Super-VGA (SVGA)

When IBM's XGA and 8514/A video cards were introduced, competing manufacturers chose not to clone these incremental improvements on VGA; instead, they began producing lower-cost adapters that offered even higher resolutions. These video cards fall into a category loosely known as *super-VGA* (SVGA).

SVGA provides capabilities that surpass those offered by the VGA adapter. Unlike display adapters discussed so far, super-VGA does not refer to a card that meets a particular specification but to a group of cards that have different capabilities.

For example, one card may offer two resolutions (800 by 600 and 1,024 by 768) that are greater than those achieved with a regular VGA, whereas another card may offer the same resolutions but also provide more color choices at each resolution. These cards have different capabilities; nonetheless, both of them are classified as super-VGA.

Character Box	Scan Frequency Vertical (Hz)	Horizontal (kHz)	Scan Mode
12 × 20	43.48	35.52	IL
8 × 14	60	31.5	Std
7 × 15	43.48	35.52	IL

Unlike the modes offered by IBM's CGA, EGA, and VGA standards, the new graphics modes are more or less proprietary. Because super-VGA cards are a category rather than a specification, the market at this level has been fractured. To take advantage of the enhanced capabilities of each card, you need special video-card drivers. To use an Orchid card with Microsoft Windows, for example, you need Orchid drivers. You cannot use an Orchid driver with a different SVGA card; you can use it only with Orchid models. This means that unlike VGA cards—which can have a single driver that works with all VGA cards, regardless of the vendor—each SVGA card must have a corresponding driver for each application you intend to use with it.

The SVGA cards look much like their VGA counterparts. They have the same connectors, including the feature adapter shown in figure 10.6.

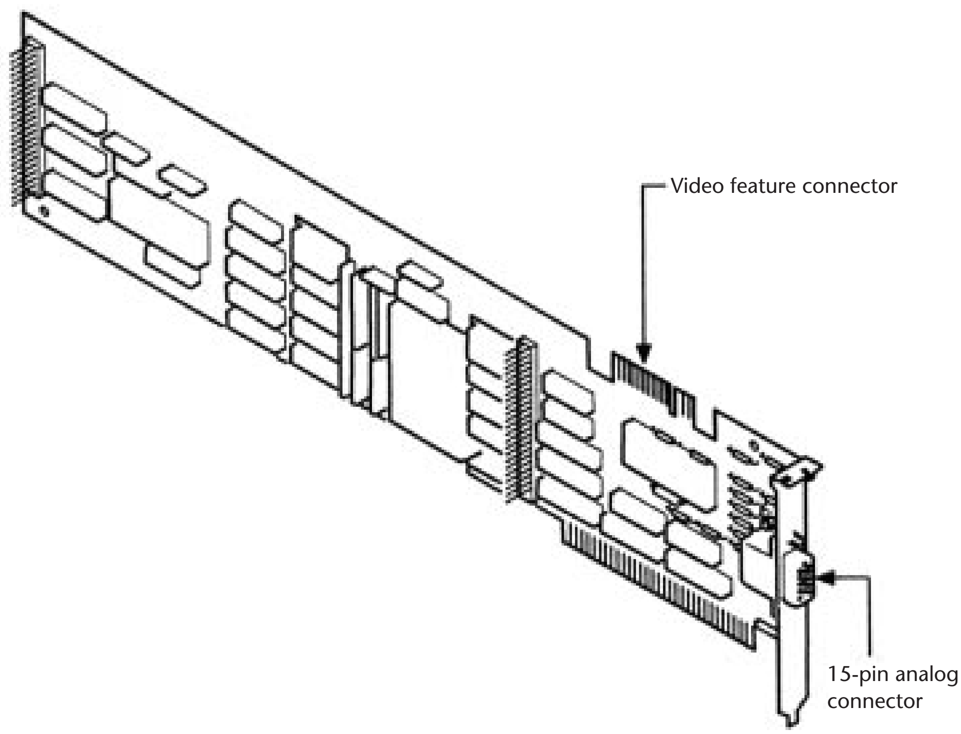


Fig. 10.6
The IBM PS/2 Display Adapter (VGA card).

Because the technical specifications from different SVGA vendors vary tremendously, it is impossible to provide a definitive technical overview in this book.

VESA SVGA Standards

In October 1989, the Video Electronics Standards Association (VESA), recognizing that programming for the many SVGA cards on the market is virtually impossible, proposed a standard for a uniform programmer's interface for SVGA cards. This association includes ATI Technologies, Genoa Systems, Orchid Technology, Renaissance GRX, STB Systems, Techmar, Headland Technology (formerly Video Seven), Western Digital Imaging/ Paradise Systems, and NEC.

The SVGA standard is called the VESA BIOS Extension. If a video card incorporates this standard, a program easily can determine the capabilities of the card and then access those capabilities. The benefit of the VESA BIOS Extension is that a programmer needs to worry about only one routine or driver to support SVGA. Different cards from different manufacturers are accessible through the common VESA interface.

This concept, when first proposed, met with limited acceptance. Several major SVGA manufacturers started supplying the VESA BIOS Extension as a separate memory-resident program that you could load when you booted your computer. Over the years, however, other vendors started supplying the VESA BIOS Extension as an integral part of their SVGA BIOS. Obviously, from a user's perspective, support for VESA in BIOS is a better solution. You don't need to worry about loading a driver or other memory-resident program whenever you want to use a program that expects the VESA extensions to be present.

Today, most SVGA cards support the VESA BIOS Extensions in one way or another. When you shop for an SVGA card, make sure that it supports the extensions in BIOS. Also, if you are interested in finding out more about programming for the VESA BIOS Extensions, check out the IBMPRO forum on CompuServe, or contact the Video Electronics Standards Association at (408)435-0333 for a copy of the VESA Programmer's Toolkit.

The current VESA super-VGA standard covers just about every video resolution and color-depth combination currently available, up to 1,280 by 1,024 with 16,777,216 (24-bit) colors. Even if a SVGA video adapter claims to be VESA-compatible, however, it still may not work with a particular driver, such as the 800-by-600, 256-color, super-VGA driver that comes with Microsoft Windows. In practice, however, manufacturers continue to provide their own driver software.

XGA and XGA-2

IBM announced the PS/2 XGA Display Adapter/A on October 30, 1990, and the XGA-2 in September 1992. Both adapters are high-performance, 32-bit bus-master adapters for Micro Channel-based systems. These video subsystems, evolved from the VGA, provide greater resolution, more colors, and much better performance.

Combine fast VGA, more colors, higher resolution, a graphics coprocessor, and bus mastering, and you have XGA. Being a bus-master adapter means that the XGA can take control of the system as though it were the motherboard. In essence, a bus master is an adapter with its own processor that can execute operations independent of the motherboard.

The XGA was introduced as the default graphics-display platform with the Model 90 XP 486 and the Model 95 XP 486. In the desktop Model 90, the XGA is on the motherboard; in the Model 95 (a tower unit), it is located on a separate add-in board. This board—the XGA Display Adapter/A—also is available for other 386- and 486-based Micro Channel systems. The XGA adapter can be installed in any MCA systems that have 80386, 80386SX, 80386SLC, 486SLC2, 486SLC3, or 80486 processors, including PS/2 Models 53, 55, 57, 65, 70, and 80.

The XGA comes standard with 512K of graphics memory, which can be upgraded to 1M with an optional video-memory expansion.

Following are some of the XGA adapter's features:

- 1,024 by 768 with 256 colors (16 colors with standard memory)
- 640 by 480 with 256 colors
- DOS XGA adapter interface provides 8514/A compatibility
- Integrates a 16-bit compatible VGA
- Optimized for windowing operating systems
- Includes device drivers for DOS, OS/2, and Windows

In addition to all VGA modes, the XGA adapter offers several new modes of operation, which are listed in table 10.8.

Table 10.8 XGA Unique Modes of Operation

Maximum Resolution	Maximum Colors	Required VRAM
1,024 × 768	256 colors	1M
1,024 × 768	16 colors	512K
640 × 480	65,536 colors	1M
1,024 × 768	64 gray shades	1M
1,024 × 768	16 gray shades	512K
640 × 480	64 gray shades	512K

The 65,536-color mode provides almost photographic output. The 16-bit pixel is laid out as 5 bits of red, 6 bits of green, and 5 bits of blue (5-6-5)—in other words, 32 shades of blue, 64 shades of green, and 32 shades of blue. (The eye notices more variations in green than in red or blue.) One major drawback of the current XGA implementation is the interlacing that occurs in the higher-resolution modes. With interlacing, you can use a less expensive monitor, but the display updates more slowly, resulting in a slight flicker.

The XGA-2 improves on the performance of the XGA in several ways. To begin with, the XGA-2 increases the number of colors supported at 1,024-by-768 resolution to 64K. In addition, because of the circuitry of the XGA-2, it can process data at twice the speed of the XGA. The XGA-2 also works in noninterlaced mode, so it produces less flicker than the XGA does.

Both the XGA and XGA-2 support all existing VGA and 8514/A video modes. A large number of popular applications have been developed to support the 8514/A high-resolution 1,024-by-768 mode. These applications are written to the 8514/A Adapter interface, which is a software interface between the application and the 8514/A hardware. The XGA's extended graphics function maintains compatibility at the same level. Because of the power of the XGA and XGA-2, current VGA or 8514/A applications run much faster.

Much of the speed of the XGA and XGA-2 also can be attributed to its video RAM (VRAM), a type of dual-ported RAM designed for graphics-display systems. This memory can be accessed by both the processor on the graphics adapter and the system CPU simultaneously, providing almost instant data transfer. The XGA VRAM is mapped into the system's address space. The VRAM normally is located in the top addresses of the 386's 4G address space. Because no other cards normally use this area, conflicts should be rare. The adapters also have an 8K ROM BIOS extension that must be mapped somewhere in segments C000 or D000. (The motherboard implementation of the XGA does not require its own ROM, because the motherboard BIOS contains all the necessary code.)

Table 10.9 summarizes the XGA modes.

Table 10.9 IBM Extended Graphics Array (XGA) Specifications

Video Standard	Number Resolution	Mode of Colors	BIOS Type	Character Modes	Character Format
XGA					
(10/30/90)	360 x 400	16	Text	00/01h	40 x 25
	720 × 400	16	Text	02/03h	80 × 25
	320 × 200	4	APA	04/05h	40 × 25
	640 × 200	2	APA	06h	80 × 25
	720 × 400	16	Text	07h	80 × 25
	320 × 200	16	APA	0Dh	40 × 25
	640× 200	16	APA	0Eh	80 × 25
	640 × 350	4	APA	0Fh	80 × 25
	640 × 350	16	APA	10h	80 × 25
	640 × 480	2	APA	11h	80 × 30
	640 × 480	16	APA	12h	80 × 30
	320 × 200	256	APA	13h	40 × 25
	1,056 × 400	16	Text	14h	132 × 25
	1,056 × 400	16	Text	14h	132 × 43
	1,056 × 400	16	Text	14h	132 × 56
	1,056 × 400	16	Text	14h	132 × 60
	1,024 × 768	256	APA	H-0h	85 × 38
	640 × 480	65,536	APA	H-1h	80 × 34
	1,024 × 768	256	APA	H-2h	128 × 54
	1,024 × 768	256	APA	H-3h	146 × 51

APA = All points addressable (graphics)
Dbl = Double scan
Il = Interlaced

Video Memory

A video card relies on memory in drawing your screen. Often, you can select how much memory you want on your video card—for example, 256K, 512K, 1M, or 2M. Finding 256K on a VGA card is rare, however; most cards come with at least 512K, if not 1M. The 512K and 1M of memory does not speed your video card; rather, it enables your monitor to display more colors and/or higher resolutions. For 256 colors drawn from a palette of 256,000, you need at least 512K of video memory. At 1,024 by 768 pixels, you need at least 1M.

A 24-bit (or true-color) video card can display photographic images by using 16.7 million colors. If you spend a lot of time working with graphics, you may want to invest in a

Scan Frequency Vertical Box	Horizontal (Hz)	Scan (kHz)	Mode
9 x 16	70	31.5	Std
9 × 16	70	31.5	Std
8 × 8	70	31.5	Dbl
8 × 8	70	31.5	Dbl
9 × 1	70	31.5	Std
8 × 8	70	31.5	Dbl
8 × 8	70	31.5	Dbl
8 × 14	70	31.5	Std
8 × 14	70	31.5	Std
8 × 16	60	31.5	Std
8 × 16	60	31.5	Std
8 × 8	70	31.5	Dbl
8 × 16	70	31.5	Std
8 × 9	70	31.5	Std
8 × 8	70	31.5	Std
8 × 6	70	31.5	Std
12 × 20	43.48	35.52	Il
8 × 14	60	31.5	Std
8 × 14	43.48	35.52	Il
7 × 15	43.48	35.52	Il

24-bit video card. In 1992, true-color cards cost as much as a decent PC. Today, you can buy one for well under $1,000.

Improving Video Speed

Many efforts have been made recently to improve the speed of video adapters, due to the complexity and sheer data of the high-resolution displays used by today's software. The improvements in video speed are occurring along three fronts:

- Processor
- RAM
- Bus

The combination of these three is reducing the video bottleneck caused by the demands of graphical user interface software, such as Microsoft Windows.

The Video Processor. Three types of processors, or chipsets, can be used in creating a video card. The chipset used is, for the most part, independent of which video specification (VGA, SVGA, or XGA) the adapter follows.

The oldest technology used in creating a video adapter is known as *frame-buffer technology*. In this scheme, the video card is responsible for displaying individual frames of an image. Each frame is maintained by the video card, but the computing necessary to create the frame comes from the CPU of your computer. This arrangement places a heavy burden on the CPU, which could be busy doing other program-related computing.

At the other end of the spectrum is a chip technology known as *coprocessing*. In this scheme, the video card includes its own processor, which performs all video-related computations. This arrangement frees the main CPU to perform other tasks. Short of integrating video functions directly into the CPU, this chipset provides the fastest overall system throughput.

Between these two arrangements is a middle ground: a fixed-function accelerator chip. In this scheme, used in many of the graphics accelerator boards on the market today, the circuitry on the video card does many of the more time-consuming video tasks (such as drawing lines, circles, and other objects), but the main CPU still directs the card by passing graphics-primitive commands from applications, such as an instruction to draw a rectangle of a given size and color.

The Video RAM. Historically, most video adapters have used regular dynamic RAM (DRAM) to store video images. This type of RAM, although inexpensive, is rather slow. The slowness can be attributed to the need to constantly refresh the information contained within the RAM, as well as to the fact that DRAM cannot be read at the same time it is being written.

Newer video cards, however, use specialized video RAM (VRAM). This type of memory is optimized for video use, achieving faster throughput because it can be read from and written to at the same time. Such an arrangement can lead to impressive speed improvements, but it also costs more than DRAM.

The Bus. Earlier in this chapter, you learned that certain video cards are designed for certain buses. For example, the VGA was designed to be used with an MCA bus, and the XGA and XGA-2 still are intended for use with the MCA. The bus system that you are using in your computer (ISA, EISA, or MCA) affects the speed at which your system processes video information. The ISA offers a 16-bit data path at speeds of 8.33 MHz. The EISA or MCA buses can process 32 bits of data at a time, but they also run at speeds up to 10 MHz. (Don't confuse the bus speed with the CPU speed. Even though the CPU currently runs at speeds up to 100 MHz, the bus still can handle only a limited degree of speed.)

One improvement on this frontier is the VESA local bus (VL-Bus) standard. The VL-Bus standard typically is an addition to an existing bus technology. For example, you may have an ISA system that also contains a VL-Bus slot. Even if it is used in an ISA system, the VL-Bus processes 32 bits of data at a time and does so at the full-rated speed of the CPU: up to 40 MHz. Thus, you can achieve blinding speed by using a well-implemented VL-Bus in your system.

In July 1992, Intel Corporation introduced Peripheral Component Interconnect (PCI) as a blueprint for directly connecting microprocessors and support circuitry; it then extended the design to a full expansion bus with Release 2 in 1993. Popularly termed a mezzanine bus, PCI 2 combines the speed of a local bus with microprocessor independence. PCI video cards, like VL-Bus video cards, can increase video performance dramatically. PCI video cards, by their design, are meant to be *plug-and-play*, meaning that they require little configuration.

VL-Bus and PCI have some important differences, as table 10.10 shows.

Table 10.10 Local Bus Specifications

Feature	VL-Bus	PCI
Theoretical maximum throughput	132Mps	132Mps
Actual throughput in burst mode (on a 33 MHz 486)	107Mps	76Mps
Slots	3 (typical)	3 (typical)
Plug-and-play support	No	Yes
Cost	Inexpensive	Moderate, trailing off over time
Ideal use	Desktop 486s	High-end desktops and servers

The Fastest Speed Possible. Fortunately, you can choose the best of each area—chipset, RAM, and bus—to achieve the fastest speed possible. The faster you want your card to perform, the more money you will need to spend; it is not unusual to find high-performance video cards that cost close to $1,000. This price does not include the cost of a new motherboard, if you want to implement VL-Bus.

The trick to choosing a video subsystem is making an early decision. As you research specifications for your entire system, you should pay attention to the video and make sure that it performs the way you want it to. The best speeds can be achieved by a VL-Bus card that uses a coprocessor and VRAM, running in a system at higher CPU speeds (40 MHz or greater). At this writing, you can get the best performance from a card that uses the Weitek Power9000 chipset (make sure that you get an implementation that uses the VL-Bus or PCI bus with VRAM).

Video Card Buying Criteria

One trend is to display higher-resolution images on larger and larger monitors. The growth of multimedia also has encouraged users to invest in 24-bit video cards for photographic-quality images. Both of these trends mean that you may want your video card to produce its 17 million hues at high resolution—at least 1,024-by-768 pixels.

Better cards can produce high color (or 65,000 hues) at even finer resolutions of 1,280 by 1,024 and 256 colors at very high resolutions of 1,600 by 1,280. To avoid bothersome flickering images, make sure that your card supports at least 72 Hz vertical refresh rates at all resolutions (76 Hz is even better). To accomplish such tasks, you'll require at least 2M of video RAM (VRAM), although 4M is preferable.

True-color cards now appear in both VL-Bus and PCI versions. If you have an older system, plenty of ISA and MCA 24-bit cards still are available.

Whichever card you buy, make sure that it also has on-board VGA support so that you don't need an extra VGA card. Drivers for your particular operating system should be included, as should a utility for switching resolutions. Look for extras that better cards now include: auto-installation and mode-switching utilities. A Microsoft Windows utility should be provided to ease switching resolutions and colors.

If you are shopping for a video card to provide super-VGA resolutions, you need special software drivers for each of your software programs to take advantage of this resolution; otherwise, your video card will act as a typical VGA card. For example, if you use the desktop publishing program Ventura Publisher Gold (GEM version), you need a software driver for your SVGA video card to display more of the page on-screen.

When you shop for a higher-resolution video card, ensure that it has drivers that support the software packages you own; otherwise, your software will operate in the typical VGA mode. Don't expect many drivers to be available. Drivers usually are provided for only a few of the following programs: AutoCAD, Autoshade, CADKEY, Framework, GEM Desktop, Lotus 1-2-3, Microsoft Windows, Microsoft Word, P-CAD, Symphony, Ventura Publisher, VersaCAD, WordPerfect, WordStar, OS/2 Presentation Manager, and Quattro Pro.

Video Cards for Multimedia

Multimedia is the result of several different media working together. Video is just one, albeit important, element to be considered. Topics we have not yet discussed include animation, full-motion video (playback and capture), still-images, and graphics processing. Still images and video provide dazzling slides, while animation and full-motion video breathe life into any presentation.

A computer can mathematically animate sequences between *keyframes*. A *keyframe* identifies specific points. A bouncing ball, for example, can have three *keyframes*: up; down; up. Using these frames as a reference point, the computer will create all the images in-between. This creates a smooth bouncing ball.

More people are realizing the benefits of 3D animation. Prices are dropping and technology, once available only to high-end workstations, is now available on PCs. One example is the 64-bit graphics accelerator offered by Matrox Graphics. What makes this graphics accelerator card unique is the on-board 3D rendering engine. This allows smooth, photo realistic 3D images to be performed on a PC level at speeds exceeding low-end workstations.

Video Output Devices. When video technology was first introduced it was based upon television. There is a difference between the signals a television uses versus the signals used by a computer. In the U.S., color TV standards were established in 1953 by the *National Television System Committee (NTSC)*. Some countries, like Japan, followed this standard; other countries in Europe developed more sophisticated standards (Phase Alternate Line, PAL; SEquential Couleur Avec Memoire, SECAM). Table 10.11 shows the differences between these TV standards.

Table 10.11 Television versus Computer Monitors

Standard	Yr. Est.	Country	Lines	Rate
Television				
NTSC	1953 (color) 1941 (b&w)	U.S., Japan	525	60 Hz
PAL	1941	Europe*	625	50 Hz
SECAM	1962	France	625	25 Hz
Computer				
VGA			640 × 480**	72 Hz

* *England, Holland, West Germany*

** *VGA is based upon more lines and uses pixels (480) versus lines; "gen-locking" is used to lock pixels into lines and synchronize computers with TV standards.*

A video-output (or VGA-to-NTSC) adapter lets you show computer screens on a TV set or record them onto videotape for easy distribution. These products fall into two categories: those with genlocking (which lets the board synchronize signals from multiple video sources or video with PC graphics) and those without. Genlocking provides the signal stability needed to obtain adequate results when recording to tape, but is not necessary for simply using a video display.

VGA-to-NTSC converters come as both internal boards—such as Magni Systems' VGA Producer Pro—or external boxes that you can port along with your laptop-based presentation—such as VideoLogic's Mediator LC. These latter devices do not replace your VGA adapter, but instead connect to your video adapter via an external cable that works with any type of VGA card. In addition to VGA input and output ports, a video-output board has a video output interface for S-Video and composite video.

VGA-to-TV converters support the standard NTSC television format and may also support the European PAL format. The resolution shown on a TV set or recorded on videotape is often limited to straight VGA at 640-by-480 pixels. Such boards may contain an "anti-flicker" circuit to help stabilize the picture, which often suffers from a case of the jitters in VGA-to-TV products.

Still-Image Video Capture Cards. Like a Polaroid camera, you can capture individual screen images for later editing and playback. One device, the Presenter Video Capture unit, plugs into a PC's parallel port. The unit captures still images from NTSC video sources like camcorders or VCRs. Although image quality is limited by the input signal, the results are still good enough for presentations and desktop publishing applications.

The Presenter Video Capture works with 8-, 16-, and 24-bit VGA cards, and accepts video input from VHS, Super VHS, and Hi-8 devices. The test unit performed well with a variety of cards, VCRs, and cameras. As you might expect, though, Super VHS and Hi-8 video sources give better results, as do Super VGA modes with more than 256 colors.

The Presenter Video Capture is easy to set up—one cable connects it to your PC and another to your video source. No memory-resident drivers are necessary, but you'll need to run a bundled Windows utility to capture and store images. The software displays incoming video at about one frame per second; when you see an image that you like, clicking the Capture button freezes it on the screen for saving as a BMP or DIB file. You have a choice of 16.7 million colors, 256 colors, or 256 gray levels.

You may want to invest in image-processing applications that offer features like image editing, file conversion, screen capture, and graphics file management.

Desktop Video (DTV) Boards. You can also capture NTSC (TV) signals to your computer system for display or editing. When capturing video, think in terms of digital versus analog, The biggest convenience of analog TV signals is efficiency; it's a compact way to transmit video information through a low-bandwidth pipeline. The disadvantage is that while you can control how the video is displayed, you can't edit it.

Actually capturing and recording video from external sources and saving the files onto your PC requires special technology. What is needed is a video capture board, which is also referred to as a video digitizer, or video grabber.

One of the most common uses for analog video is with interactive CBT programs in which your application sends start, stop, and search commands to a laserdisk player that plays disks you've mastered. The software controls the player via an interface that also converts the laserdisk's NTSC signal into a VGA-compatible signal for display on your computer's monitor. These types of applications require NTSC-to-VGA conversion hardware that ranges from adapters such as the VideoBlaster, ProMovie Spectrum, and VideoSpigot for Windows to Super VideoWindows, DVA-4000, or Matrox's Illuminator family.

While a computer can display up to 16 million colors, the NTSC standard only allows for approximately 32,000 colors. Affordable video is the Achilles' heel of multimedia. The images are often jerky or less than full-screen. Why? Full-motion video, such as you see on TV requires 30 images or frames per second (fps).

The typical computer screen was designed to display mainly static images. The storing and retrieving of these images requires managing huge files. Consider this: a single, full-screen color image requires almost 2M of disk space; a one-second video would require 45M. Also, any video transmission you may want to capture for use on your PC must be converted from an analog NTSC signal to a digital signal your computer can use. On top of that, the video signal must be moved inside your computer at 10 times the speed of the conventional ISA bus structure. You not only need a superior video card and monitor, but also an excellent expansion bus, such as VL-Bus or PCI.

Considering the fact that full-motion video can consume massive quantities of disk space (0.5 seconds = 15Meg), it becomes apparent that compression is needed. Compression and decompression (codec) applies to both video and audio. Not only does a compressed file take up less space, it also performs better; there is simply less data to process. When you're ready to replay the video/audio, you simply decompress the file during playback.

There are two types of codecs: 1) hardware dependent codecs; and, 2) software (hardware independent) codecs. Hardware codecs are typically better, however they do require additional hardware. Software codes don't require hardware for compression or playback, but they typically don't deliver the same quality or compression ratio. Two of the major codec algorithms are:

- *JPEG (Joint Photographic Experts Group)*. Originally developed for still images, it was discovered that JPEG could be compressed and decompressed at rates acceptable for nearly full-motion video (30 fps). JPEG still uses a series of still-images, which is easier for editing. Typically *lossy* (but can be *lossless*), JPEG eliminates redundant data for each individual image (*intraframe*). Compression efficiency is approximately 30:1 (20:1–40:1).
- *MPEG (Motion Pictures Expert Group)*. Since MPEG can compress up to 200:1 at high-quality levels it results in better, faster videos that require less space. MPEG is an interframe compressor. Since MPEG stores only incremental changes it is not used during editing phases.

If you will be capturing, compressing, and playing video then you will need Microsoft Video for Windows (VFW). Codecs are provided along with VFW:

- *Cinepak (also referred to Compact Video Coded (CVC))*. Although Cinepak can take longer to compress it can produce better quality and higher compression than Indeo.
- *Indeo*. Can outperform Cinepak and is capable of real-time compression (Intel Smart Video board required for real-time compression).
- *Microsoft Video 1*. Developed by MediaVision (MotiVE). Renamed to MS Video 1. A DCT based post-processor; file is compressed after capture.

To play or record video on your multimedia PC (MPC), you'll need some extra hardware and software:

- Video system software, such as Apple's QuickTime for Windows or Microsoft's Video for Windows.

- A compression/digitization video card that allows you to digitize and play large video files.
- An NTSC-to-VGA adapter that combines TV signals with computer video signals for output to a VCR. Video can come from a variety of sources: TV; VCR; video camera; or, a laser disc player. When an animation file is recorded it can be saved in a variety of different formats:
    - AVI: Audio Video Interleave
    - FLI: 320-by-200 pixel animation file
    - FLC: an animation file of any size

These files can then be incorporated into a multimedia presentation using authoring software like Icon Author from AIMTECH, or you can include the animated files as OLE! objects to be used with MS-Word, Excel, Access, or other OLE! compliant applications.

When you're connecting video devices it is recommended you use the S-Video (S-VHS) connector whenever available. This cable provides the best signal since separate signals are used for color (chroma) and brightness (luma). Otherwise, you will have to use *composite video* which mixes *luma* and *chroma*. This results in a lower quality signal. The better your signal the better your video quality will be.

You can get devices that just display NTSC signals on your computer. Soon, you won't know if you are using a computer screen or a television. Digital video, in screen-filling, full-motion color, has arrived on desktop platforms with titles, playback boards and encoding equipment. Sigma Designs' $449 ReelMagic is a MPEG playback controller. It is a complete motion-video decoder board for PCs that can display 32,000 colors and achieves a resolution of 1,024 by 768. ReelMagic can play (but not record) MPEG video and VideoCD ("White Book") movies, with CD-quality audio. Using OLE, Windows applications can call MPEG movies from within documents and business presentations. Soon, MPEG movie clip libraries will be the next form of clip art on CD-ROM.

Adapter and Display Troubleshooting

Solving most graphics adapter and monitor problems is fairly simple, although costly, because replacing the adapter or display is the usual procedure. A defective or dysfunctional adapter or display usually is replaced as a single unit, rather than repaired. Most of today's cards cost more to service than to replace, and the documentation required to service the adapters or displays properly is not always available. You cannot get schematic diagrams, parts lists, wiring diagrams, and so on for most of the adapters or monitors. Many adapters now are constructed with surface-mount technology that requires a substantial investment in a rework station before you can remove and replace these components by hand. You cannot use a $25 pencil-type soldering iron on these boards!

Servicing monitors is slightly different. Although a display often is replaced as a whole unit, many displays are too expensive to simply replace. Your best bet is to contact the company from which you purchased the display. If, for example, your NEC Multisync display goes out, a swap with another monitor can confirm that the display is the problem. After you narrow the problem to the display, call NEC for the location of the nearest factory repair depot. Third-party service companies can repair most displays; their prices often are much lower than "factory" service.

You usually cannot repair a display yourself. First, opening the case of a color display exposes you to as much as 35,000 volts of electricity, and if you don't follow recommended safety precautions, you easily can electrocute yourself. Second, the required documentation is not always available. Without schematic diagrams, board layouts, parts lists, or other documentation, even an experienced service technician may not be able to properly diagnose and repair the display.

Caution

You should not attempt to repair a display yourself. Touching the wrong item can be fatal. The display circuits sometimes hold extremely high voltages for hours, days, or even weeks after the power is shut off. A qualified service person should discharge the tube and power capacitors before proceeding.

For most displays, you are limited to making simple adjustments. For color displays, the adjustments can be quite formidable if you lack experience. Even factory service technicians often lack proper documentation and service information for newer models; they usually exchange your unit for another and repair the defective one later. Never buy a display for which no local factory repair depot is available.

If you have a problem with a display or adapter, it pays to call the manufacturer; the manufacturer may know about the problem and make repairs available, as occurred with the IBM 8513 display. Large numbers of the IBM 8513 color displays were manufactured with components whose values change over time and may exhibit text or graphics out of focus. This problem haunted the author's IBM 8513. Opening the monitor and adjusting the focus helped for a while, but the display became fuzzy again. The author discovered that IBM replaces these displays at no cost when focusing is a problem. If you have a fuzzy 8513 display, you should contact IBM to see whether your display qualifies for a free replacement.

You can call IBM at (800) IBM-SERV or contact an IBM-authorized dealer for assistance. This particular problem is covered under Engineering Change Announcement (ECA) 017.

Summary

This chapter discussed and examined the video portion of the original PC and its descendants. Monitor technologies and buying criteria were discussed. Video cards and standards were discussed, including techniques used to provide more graphics speed. Lastly, multimedia-related video cards were discussed, including NTSC-to-VGA, still-image capture, and video-in-window adapters and techniques.