How Computer Monitors Work

by Jeff Tyson

A computer display is a marvelous thing. An unassuming dark gray surface can suddenly transform into an artist's canvas, an engineer's gauges, a writer's page or your very own window to both the real world and a huge range of artificial worlds!

Because we use them daily, many of us have a lot of questions about our displays and may not even realize it. What does "aspect ratio" mean? What is dot pitch? How much power does a display use? What is the difference between CRT and LCD? What does "refresh rate" mean?

In this edition of **HowStuffWorks**, we will answer all of these questions and many more. By the end of the article, you will be able to understand your current display and also make better decisions when purchasing your next one.

The Basics

Often referred to as a **monitor** when packaged in a separate case, the display is the most-used output device on a computer. The display provides instant feedback by showing you text and graphic images as you work or play. Most desktop displays use a cathode ray tube (CRT), while portable computing devices such as laptops incorporate liquid crystal display (LCD), light-emitting diode (LED), gas plasma or other image projection technology. Because of their slimmer design and smaller energy consumption, monitors using LCD technologies are beginning to replace the venerable CRT on many desktops.

When purchasing a display, you have a number of decisions to make. These decisions affect how well your display will perform for you, how much it will cost and how much information you will be able to view with it. Your decisions include:

- **Display technology** - Currently, the choices are mainly between CRT and LCD technologies.
- **Cable technology** - VGA and DVI are the two most common.
- **Viewable area** (usually measured diagonally)
- **Aspect ratio** and **orientation** (landscape or portrait)
- **Maximum resolution**
- **Dot pitch**
- **Refresh rate**
- **Color depth**
- **Amount of power consumption**

In the following sections we will talk about each of these areas so that you can completely understand how your monitor works!

Display Technology

Displays have come a long way since the blinking green monitors in text-based computer systems of the 1970s. Just look at the advances made by IBM over the course of a decade:

- In 1981, IBM introduced the Color Graphics Adapter (CGA), which was capable of rendering four colors, and had a maximum resolution of 320 pixels horizontally by 200 pixels vertically.
- IBM introduced the Enhanced Graphics Adapter (EGA) display in 1984. EGA allowed up to 16 different colors and increased the resolution to 640x350 pixels, improving the

appearance of the display and making it easier to read text.

- In 1987, IBM introduced the Video Graphics Array (VGA) display system. Most computers today support the VGA standard and many VGA monitors are still in use.
- IBM introduced the Extended Graphics Array (XGA) display in 1990, offering 800x600 pixel resolution in true color (16.8 million colors) and 1,024x768 resolution in 65,536 colors.

Multi-scanning Monitors

If you have been around computers for more than a decade, then you probably remember when NEC announced the MultiSync monitor. Up to that point, most monitors only understood one frequency, which meant that the monitor operated at a single fixed resolution and refresh rate. You had to match your monitor with a graphics adapter that provided that exact signal or it wouldn't work.

The introduction of NEC MultiSync technology started a trend towards multi-scanning monitors. This technology allows a monitor to understand any frequency sent to it within a certain bandwidth. The benefit of a multi-scanning monitor is that you can change resolutions and refresh rates without having to purchase and install a new graphics adapter or monitor each time. Because of the obvious advantage of this approach, nearly every monitor you buy today is a multi-scanning monitor.

Most displays sold today support the Ultra Extended Graphics Array (UXGA) standard. **UXGA** can support a palette of up to 16.8 million colors and resolutions of up to 1600x1200 pixels, depending on the video memory of the graphics card in your computer. The maximum resolution normally depends on the number of colors displayed. For example, your card might require that you choose between 16.8 million colors at 800x600, or 65,536 colors at 1600x1200.

A typical UXGA adapter takes the digital data sent by application programs, stores it in video random access memory (VRAM) or some equivalent, and uses a digital-to-analog converter (DAC) to convert it to analog data for the display scanning mechanism. Once it is in analog form, the information is sent to the monitor through a VGA cable. See the diagram below:

1: Red out	**6**: Red return (ground)	**11**: Monitor ID 0 in
2: Green out	**7**: Green return (ground)	**12**: Monitor ID 1 in or data from display
3: Blue out	**8**: Blue return (ground)	**13**: Horizontal Sync out
4: Unused	**9**:	**14**: Vertical Sync

		5: Ground
10: Sync return (ground)	**15**: Monitor ID 3 in or data clock	

You can see that a VGA connector like this has three separate lines for the red, green and blue color signals, and two lines for horizontal and vertical sync signals. In a normal television, all of these signals are combined into a single **composite video signal**. The separation of the signals is one reason why a computer monitor can have so many more pixels than a TV set.

Since today's VGA adapters do not fully support the use of digital monitors, a new standard, Digital Video Interface (**DVI**) has been designed for this purpose. Because VGA technology requires that the signal be converted from digital to analog for transmission to the monitor, a certain amount of degradation occurs. DVI keeps data in digital form from the computer to the monitor, virtually eliminating signal loss. The DVI specification is based on Silicon Image's Transition Minimized Differential Signaling (TMDS) and provides a high-speed digital interface. TMDS takes the signal from the graphics adapter, determines the resolution and refresh rate that the monitor is using and spreads the signal out over the available bandwidth to optimize the data transfer from computer to monitor. DVI is technology-independent. Essentially, this means that DVI is going to perform properly with any display and graphics card that is DVI compliant. If you buy a DVI monitor, make sure that you have a video adapter card that can connect to it.

Viewable Area

Two measures describe the size of your display: the **aspect ratio** and the **screen size**. Most computer displays, like most televisions, have an aspect ratio of 4:3 right now. This means that the ratio of the width of the display screen to the height is 4 to 3. The other aspect ratio in common use is 16:9. Used in cinematic film, 16:9 was not adopted when the television was first developed, but has always been common in the manufacture of alternative display technologies such as LCD. With widescreen DVD movies steadily increasing in popularity, most TV manufacturers now offer 16:9 displays.

The display includes a projection surface, commonly referred to as the **screen**. Screen sizes are normally measured in inches from one corner to the corner diagonally across from it. This diagonal measuring system actually came about because the early television manufacturers wanted to make the screen size of their TVs sound more impressive. Because the listed size is measured from the inside beveled edges of the display casing, make sure you ask what the viewable screen size is. This will usually be somewhat less than the stated screen size.

Popular screen sizes are 15, 17, 19 and 21 inches. Notebook screen sizes are usually somewhat smaller, typically ranging from 12 to 15 inches. Obviously, the size of the display will directly affect resolution. The same pixel resolution will be sharper on a smaller monitor and fuzzier on a larger monitor because the same number of pixels is being spread out over a larger number of inches. An image on a 21-inch monitor with a 640x480 resolution will not appear nearly as sharp as it would on a 15-inch display at 640x480.

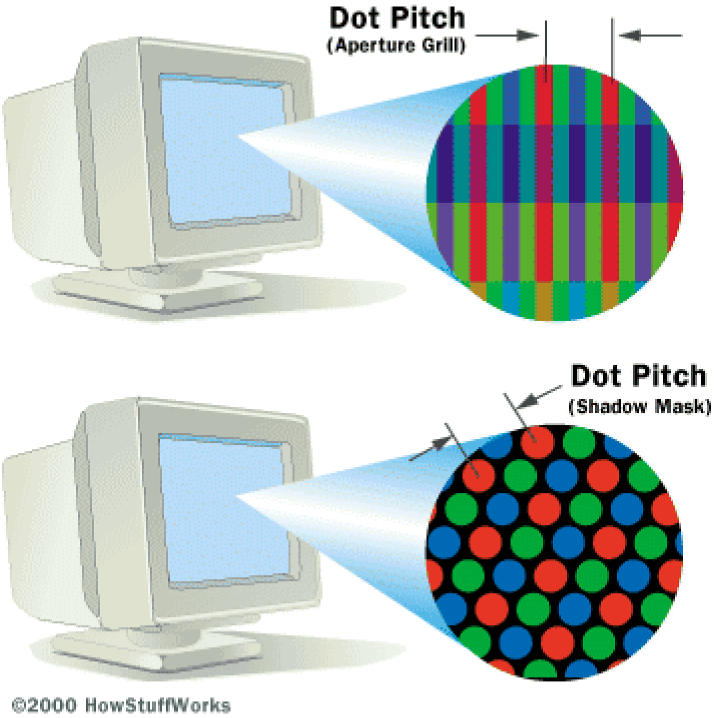
Maximum Resolution and Dot Pitch

Resolution refers to the number of individual dots of color, known as **pixels**, contained on a display. Resolution is typically expressed by identifying the number of pixels on the horizontal axis (rows) and the number on the vertical axis (columns), such as 640x480. The monitor's viewable area (discussed in the previous section), refresh rate and dot pitch all directly affect the maximum resolution a monitor can display.

Dot Pitch

Briefly, the dot pitch is the measure of how much space there is between a display's pixels. When considering dot pitch, remember that smaller is better. Packing the pixels closer together is fundamental to achieving higher resolutions.

A display normally can support resolutions that match the physical dot (pixel) size as well as several lesser resolutions. For example, a display with a physical grid of 1280 rows by 1024 columns can obviously support a maximum resolution of 1280x1024 pixels. It usually also supports lower resolutions such as 1024x768, 800x600, and 640x480.



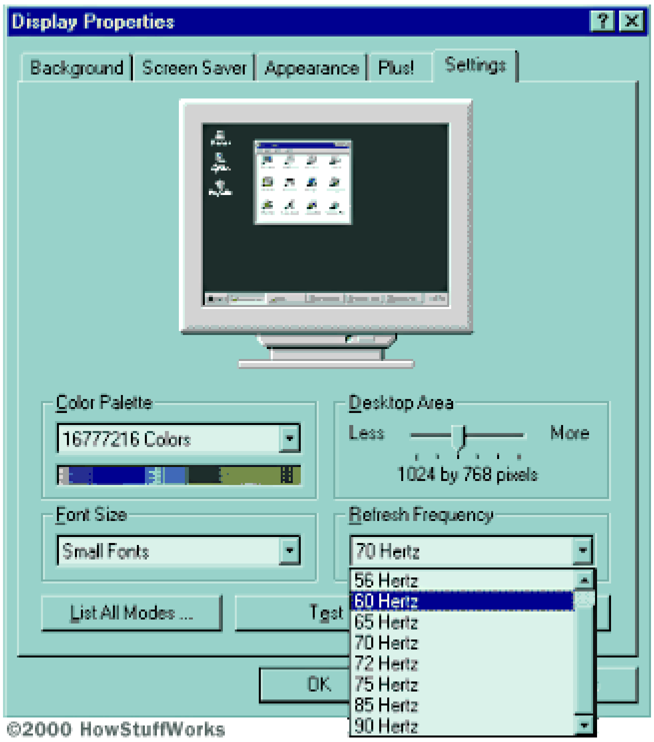
See [What does .28 dot pitch mean?](#) for details on dot pitch.

Refresh Rate and Color Depth

Refresh Rate

In monitors based on CRT technology, the **refresh rate** is the number of times that the image on the display is drawn each second. If your CRT monitor has a refresh rate of 72 Hertz (Hz), then it cycles through all the pixels from top to bottom 72 times a second. Refresh rates are very important because they control flicker, and you want the refresh rate as high as possible. Too few cycles per second and you will notice a flickering, which can lead to headaches and eye strain.

Televisions have a lower refresh rate than most computer monitors. To help adjust for the lower rate, they use a method called **interlacing**. This means that the electron gun in the television's CRT will scan through all the odd rows from top to bottom, then start again with the even rows. The phosphors hold the light long enough that your eyes are tricked into thinking that all the lines are being drawn together.



Because your monitor's refresh rate depends on the number of rows it has to scan, it limits the maximum possible resolution. A lot of monitors support multiple refresh rates, usually dependent on the resolution you have chosen. Keep in mind that there is a tradeoff between flicker and resolution, and then pick what works best for you.

Color Depth

The combination of the display modes supported by your graphics adapter and the color capability of your monitor determine how many colors can be displayed. For example, a display that can operate in SuperVGA (SVGA) mode can display up to 16,777,216 (usually rounded to 16.8 million) colors because it can process a 24-bit-long description of a pixel. The number of bits used to describe a pixel is known as its **bit depth**.

With a 24-bit bit depth, 8 bits are dedicated to each of the three additive primary colors -- red, green and blue. This bit depth is also called **true color** because it can produce the 10,000,000 colors discernible to the human eye, while a 16-bit display is only capable of producing 65,536 colors. Displays jumped from 16-bit color to 24-bit color because working in 8-bit increments makes things a whole lot easier for developers and programmers.

Simply put, color bit depth refers to the number of bits used to describe the color of a single pixel. The bit depth determines the number of colors that can be displayed at one time. Take a look at the following chart to see the number of colors different bit depths can produce:

Bit-Depth	Number of Colors
1	2 (monochrome)
2	4 (CGA)
4	16 (EGA)
8	256

	(VGA)
16	65,536 (High Color, XGA)
24	16,777,216 (True Color, SVGA)
32	16,777,216 (True Color + Alpha Channel)

You will notice that the last entry in the chart is for 32 bits. This is a special graphics mode used by digital video, animation and video games to achieve certain effects. Essentially, 24 bits are used for color and the other 8 bits are used as a separate layer for representing levels of translucency in an object or image.

Nearly every monitor sold today can handle 24-bit color using a standard VGA connector, as discussed previously.

Power Consumption

Power consumption varies greatly with different technologies. CRTs are somewhat power-hungry, at about 110 watts for a typical display, especially when compared to LCDs, which average between 30 and 40 watts.

In a typical home computer setup with a CRT-based display, the monitor accounts for over 80 percent of the electricity used! Because most users don't interact with the computer much of the time it is on, the U.S. government initiated the Energy Star program in 1992. Energy Star-compliant equipment monitors user activity and suspends non-critical processes, such as maintaining a visual display, until you move the mouse or tap the keyboard. According to the EPA, if you use a computer system that is Energy Star compliant, it could save you approximately $400 a year on your electric bill! Similarly, because of the difference in power usage, an LCD monitor might cost more upfront but end up saving you money in the long run.

CRT technology is still the most prevalent system in desktop displays. Because standard CRT technology requires a certain distance between the beam projection device and the screen, monitors employing this type of display technology tend to be very bulky. Other technologies make it possible to have much thinner displays, commonly known as flat-panel displays.

Photo courtesy Sony
Sony flat-panel display

Liquid crystal display (LCD) technology works by blocking light rather than creating it, while light-emitting diode (LED) and gas plasma work by lighting up display screen positions based on the voltages at different grid intersections. LCDs require far less energy than LED and gas plasma technologies and are currently the primary technology for notebook and other mobile computers. As flat-panel displays continue to grow in screen size and improve in resolution and affordability, they will gradually replace CRT-based displays.