Display Devices Fact Sheet  
So, let's start with pixels and lumens. Now pixels is a word that’s made up out of picture elements, and it represents a basic programmable unit of color on a display device or a computer image. In the modern display device, the pixel is a 24-bit block that is composed of one-byte units of red, blue, and green—RGB. All the colors of the spectrum are composed by combining various intensities, byte values, of the color components. The pixels are combined, and the image is formed. The more pixels that are present, the sharper the resolution. Now, resolution is a method of establishing how many pixels wide and tall an image is, which has an effect on the sharpness of the image. Pixels are logical in nature, which means that their size is not a set standard. In most cases, you the user, can’t determine the resolution of the display.

Lumens are one measurement of light output, or brightness. The more lumens that are present, the more light that is output. Some display devices are rated for more lumens than others, which can have an impact on where they are deployed. For instance, a display device that doesn't have a very high lumen count will not perform very well in a situation where there is bright ambient lighting.

Now, let's move onto analog versus digital displays. So, let's begin with analog type displays. An image is created digitally inside the PC and delivered to the graphics device, the graphics card, or the onboard PC graphics. The graphics device converts the image from its native digital format into a modulated electrical current format that’s analog—that is then delivered to the display. The display uses that analog format to represent the image on the screen. Analog screens tend to be slower in processing images on the screen. Now, many digital displays can receive an analog signal, which they then convert back into a digital format.

A digital image is created and delivered to the graphics device. The graphics device transmits the image to the display device in its native digital format. The display device receives the digital image and represents it on the screen. It is the newer standard and tends to be faster than analog.

CRT, the cathode ray tube. Now, this is an older standard. A CRT monitor uses a combination of a vacuum tube, an electron gun, and a fluorescent screen. It is analog in nature. The electron gun excites the individual pixels on the fluorescent screen, which then light up and present the image. Each line on the screen needs to be refreshed, because the screen doesn't hold the electrical charge. The rate at which this is done is called the refresh rate. Too low of a refresh rate will cause the screen to flicker and cause eye fatigue. Now, CRT monitors tend to have very good color representation, and it’s easy to adjust the resolution and get a good sharp image.

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| Display Type | Description |
| LCD | Now, let's talk about the LCD display, the liquid crystal display. Now, this is a type of flat panel monitor that uses an arrangement of liquid crystals and a fluorescent backlight to place an image on the screen. The liquid crystals are sandwiched between layers of glass and make up the screen that you see. An electrical current is used to change the alignment of the crystals which then refract the fluorescent backlight, giving us the color image. The liquid crystals do not emit any light by themselves. The light we see is actually coming from the fluorescent backlight. Now, because of this, LCDs do not do very well in bright environments.  LCDs are a digital technology. LCDs do have a native resolution for the screen that is a pixel count that produces the best image. You can change the resolution, but you run the risk of distorting the image. With an LCD, the whole screen gets refreshed simultaneously, not line by line. LCDs are faster and consume less electricity than CRTs, but the color representation is not as good as the CRT.  LCDs (liquid-crystal displays) use liquid crystal technology to display visual information. LCDs are the most common type of display device and range in size from less than an inch to over 10 feet. Modern LCDs use LEDs (light-emitting diodes) to backlight the screen.   * Edge-Lit White LED (EL-WLED or WLED) displays use white LEDs along one edge (usually the top) of the LCD and a light diffuser to backlight the screen. EL-WLED LCDs are the least expensive, thinnest, and most widely used type of LCD. * Full-array WLED displays have an array of white LEDs behind the screen. Full-array WLED LCDs are able to dim specific regions of the screen, resulting in a much higher contrast ratio than LCDs that use EL-WLED technology. * RGB-LED displays have an array of special LEDs that are able to emit red, green, and blue light, resulting in superior color accuracy. RGB-LED displays are the most expensive type of backlighting technology.   Older LCD monitors, and some LCD HDTVs, use cold cathode fluorescent lamps (CCFLs) for backlighting. CCFLs are able to produce better colors than EL-WLED and full-array WLED technologies, but consume a lot more energy and require an internal inverter.  LCDs use one of the following panel technologies:   * TN (twisted nematic) panels are the most common technology used by LCDs. TN panels have very good response times (1–5 ms) and refresh rates (60–144 Hz), so are great for PC gaming.   + TN panels have imperfect color reproduction due to the fact that only 6-bits per color can be displayed. They mimic true 24-bit color using dithering and other techniques.   + TN panels have poor viewing angles and contrast ratios. * IPS (In-plane switching) panels have the best color reproduction quality and viewing angles among LCDs, making them well suited for graphic artists, designers, and photographers.   + IPS panels have relatively slow response times (5–16 ms) and refresh rates (60 Hz) and have a slight purple tint in blacks when viewed from a wide angle.   + High-end IPS LCDs are very expensive (over $1000). * Because of how they draw frames, LCDs suffer from motion blur (also called ghosting) when fast movements occur on the display. While motion blur can be reduced with higher refresh rates and lower response times, it can’t be eliminated entirely.   LCD screens are used in the following devices:   * HDTVs * Computer displays * Tablets * Smartphones * Mobile devices * Wearable technology   Display devices that are called LED monitors or LED TVs are simply LCDs that use LED backlighting. LED displays, that’s a light-emitting diode. LED displays operate exactly the same as LCD displays, except for one item. The LCD’s fluorescent backlight is replaced with an LED backlight. Other than that, they're exactly the same. |
| Plasma | Plasma is a flat panel display technology that uses fluorescent cells contained in the screen; there's millions of small cells that contain electrically charged ionized gases. When electrical current is applied to a plasma cell, the gas within the cell forms a plasma and emits a photon of light in different colors, which causes the image to appear on the screen. This technology does not require the use of a backlight. Plasma displays work okay in brighter ambient light levels. It is also a digital technology. The plasma display does have a native resolution. Now, it does require higher voltages than the LCD or LED monitor. It also tends to be more expensive than LCD and LED monitors, but it also produces much better color than those two. It actually produces color on par or better than the CRT.  Plasma displays have several advantages:   * Plasma displays usually display colors more accurately than LCD displays. * Because no backlighting is used, plasma displays have high contrast and can produce true black (displays that use backlighting can only display very dark grey). * Plasma displays have almost no motion blur due to the speed of the gas reaction and the way they draw frames. Because of this, most plasma displays do not specify response times.   Plasma displays have several disadvantages:   * Plasma displays consume two to three times as much power as LCDs. * They generate much more heat than other display types. * The gasses inside the cells are sensitive to air pressure fluctuations (e.g., from altitude changes). * Plasma displays also suffer from a problem known as image retention (IR). Static images that are displayed for a long time cause the phosphors to overheat, which creates a temporary shadow of the image that is visible even when the display is turned off. If the static image was displayed for too long, screen burn-in can occur and the shadow image will be permanent.   Plasma displays smaller than 32 inches are not sold because manufacturing them is not profitable. |
| OLED | OLED monitors, that's organic light-emitting diode monitors. This is an emerging display monitor technology, OLED is closer to LCD/LED technology than it is to plasma technology. Instead of liquid crystals, the screen is composed of diodes that are sandwiched between thin layers of glass. An electrical charge is used to light up the diodes, which then place the image on the screen. OLED displays are thinner, lighter, and consume less energy than any other type of display. Except for the cell phone market, organic light emitting diode display technology has not spread very far, because of the cost of creating the monitor. The yield for the displays is very low, so they are difficult to make, which drives up the cost. OLED displays are more efficient, offer a wider viewing angle, and provide faster response times (< 0.01 ms). However, they are costly to manufacture; OLEDs are the most expensive type of display device. In addition, the pixels in OLEDs (the organic compound) wears out faster than the pixels in LED or plasma displays.  OLEDs can be used in any device that uses a flat-panel display. And because of their size, OLEDs can even be used in textiles (e.g., clothing and upholstery).  Flexible materials can be used to create OLED screens, resulting in a bendable—sometimes even foldable—screen. These types of OLEDs are called FOLEDs (flexible OLEDs). |
| Projector | Projectors use a powerful light source (either an LED or laser diode) and a lens to project visual content onto a surface, which is typically a specialized screen. Visual output is achieved by controlling the flow of light. Now, projectors can either be analog or digital. The amount of lumens that the projector is rated for is important, as it will affect the amount of ambient light that can be present and still allow for the projected image to be seen easily.   * LCD projectors use a small, internal LCD screen to control light and create images. LCD projectors are inexpensive and can be very compact; some can fit inside a pocket.   + At larger projection sizes, LCD projectors suffer from what's called the "screen door" effect. This is when each RGB pixel of the display can be easily seen.   + LCD projectors also suffer from motion blur due to the way liquid crystal technology functions. * DLP projectors use a spinning color wheel to create RGB color and a DMD (digital micromirror device) to control light. The DMD is a small chip that contains millions of tiny mirrors that can redirect light extremely fast. DLP projectors are capable of very high-resolution output at even large projection sizes.   + DLP projectors are much more expensive than LCD projectors.   + DLP projectors are not as compact as LCD projectors and also use more energy and generate more heat.   Projectors are affected by environmental factors, such as physical obstructions, ambient light, and the surface being projected onto. As such, projectors are only practical in controlled environments (i.e., indoors). |

Display devices that use glass panels (e.g., plasma displays, OLED displays, and some LCDs) can suffer from a problem known as glare, where the shiny screen reflects light and reduces visibility. This is mostly a problem for mobile devices that are used outdoors (i.e., laptops, tablets, and smartphones). To reduce this effect, anti-glare filters—which are made of a special, non-reflective surface—can be placed over the screen of these devices.

**Display Specifications fact sheet** The following table describes the various specifications used by display devices:

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| Specification | Description |
| Resolution | *Resolution* is the number of pixels on a display screen. Resolution is expressed in a *width × height* formula (e.g., 1920 × 1080). The numbers represent the number of pixels on that axis. A higher resolution means that more information can be shown on the screen at a time.  Resolutions are often described using a naming standard, although these standards encompass much more than just resolution size.   * **SVGA** 800 × 600 * **XGA** 1024 × 768 * **XGA+** 1152 × 864 * **WXGA** 1280 × 720 * **SXGA** 1280 × 1024 * **WSXGA+** 1680 × 1050 * **UXGA** 1600 × 1200 * **FHD** 1920 × 1080 * **WUXGA** 1920 × 1200 * **QHD** 2560 × 1440 * **4K UHD** 3840 × 2160   In addition, resolutions are sometimes referred to by their last number followed by the letter "p" (e.g., 720p, 1080p, or 2160p). The "p" stands for progressive scan, which means the display device draws each line on the screen in order. This naming convention is primarily used by HDTVs.  All flat-panel displays have a native resolution. The native resolution specifies both the number of physical pixels on the screen and the display's maximum resolution. The native resolution also specifies the resolution that should be used to achieve optimal image quality. |
| Aspect ratio | The aspect ratio is the proportion between the width and height of a resolution. Aspect ratios are used by both display devices and video content. The following are the three most commonly used aspect ratios:   * 4:3 is used primarily by analog TV broadcasts and older flat-panel and CRT displays. Common 4:3 resolutions include:   + 800 × 600 (SVGA)   + 1600 × 1200 (UXGA) * 16:9 is a widescreen aspect ratio used by HDTVs, computer displays, and most production films. Common 16:9 resolutions include:   + 1280 × 720 (WXGA)   + 1920 × 1080 (FHD)   + 3840 × 2160 (4K UHD) * 16:10 is a widescreen aspect ratio used exclusively by computer display devices. Common 16:10 resolutions include:   + 1680 × 1050 (WSXGA+)   + 1920 × 1200 (WUXGA) |
| Viewing angle | The viewing angle specifies the optimal viewing area of the display device. Viewing angles are rated in degrees and specify both a horizontal and vertical threshold (e.g., 178°(H)/178°(V)). |
| Response time | Response time is a measurement, in milliseconds (ms), of how long it takes for a single pixel to turn on and off (go from black, to white, and back to black). Most manufacturers specify a grey-to-grey transition time instead of black-to-black. A response time of less than 5 ms is recommended for fast-moving graphics, such as movies or games.  Response time is typically only used by displays that use LCD technology. Other display technologies have such fast response times (< 0.01 ms) that listing this specification is unnecessary. |
| Refresh rate | The refresh rate is the number of times the entire screen is redrawn per second.   * Refresh rates are measured in Hz. * Most monitors support multiple refresh rates. * Increasing the refresh rate reduces screen flicker. A desirable range of refresh rate is 60 Hz or higher. * Fast-moving graphics require a refresh rate of 120 Hz or higher. * The refresh rate must be supported by both the video card, the monitor, and the cable being used. * By default, Windows only shows supported refresh rates. |
| Brightness | Brightness (also called luminance) identifies the amount of light a display is able to produce. Brightness is measured in candelas per square meter (cd/m2), with a higher number indicating a brighter screen. A brighter screen istypically desired for mobile devices or for watching movies.  Projectors use a brightness specification known as ANSI lumens. This is a measurement of the amount of visible light a projector is able to display on a screen. |
| Contrast ratio | Contrast ratio refers to the difference in light intensity between the brightest white and the darkest black. An example contrast ratio is 1000:1. A higher initial number indicates a better quality picture.   * The *static* contrast ratio indicates the difference that can be displayed at the same time. * The *dynamic* contrast ratio indicates the difference that the monitor is capable of producing. |
| Color depth | The color depth is the number of different colors that can be displayed on the screen at a time. Color depth is expressed in bits (a higher bit count increases the number of colors that can be displayed). Common bit depths include:   * 8-bit (256 possible colors) * 16-bit, also called *high color* (65,536 possible colors) * 24-bit, also called *true color* (16.7 million possible colors) * 32-bit, also called *true color* (16.7 million possible colors and alpha channel) |

Display devices use a variety of connection interfaces to transfer visual information. The following table describes the specifications of the most common cable and interface types:

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| Interface | Description |
| VGA https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_vga.png | * Provides an analog video signal * Uses a DB-15 connector * Maximum supported resolution of 2048 × 1536 @ 85 Hz |
| DVI-A (Analog) https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_dvi-a.png | * Provides an analog video signal * Used by older HDTVs (rarely used by computers) * Cables typically have a DVI-A connector on one end and a VGA connector on the other * Maximum supported resolution of 1920 × 1200 @ 60 Hz |
| DVI-D (Digital) https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_dvi-d-sl.png Single Link https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_dvi-d-dl.png Dual Link | * Provides a digital video signal only * Single Link interface:   + Transmission bandwidth of 4.59 Gbps   + Maximum supported resolution of 1920 × 1080 @ 60 Hz * Dual Link interface:   + Supports longer cable lengths than single link DVI-D   + Found on most video cards and flat-panel displays   + Transmission bandwidth of 9.9 Gbps   + Maximum support resolution of 2048 × 1536 @ 60 Hz |
| DVI-I (Integrated) https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_dvi-i-sl.png Single Link https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_dvi-i-dl.png Dual Link | * Provides either an analog or digital signal * Contains all pins found on both DVI-A and DVI-D connectors * Works with older analog devices without the need for an expensive digital-to-analog converter box * Compatible with all DVI connection types * Single Link interface:   + Maximum supported resolution of 1920 × 1080 @ 60 Hz * Dual Link interface:   + Maximum support resolution of 2048 × 1536 @ 60 Hz   Some video cards use a special interface called a DMS-59. This interface provides two separate DVI-I signals from a single port, allowing two monitors to be connected. |
| HDMI https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_hdmi.png | * Provides both a digital video and digital audio signal * Used by HDTVs and computers * The miniHDMI interface is used by laptops, SFF computers, and digital video cameras * Used by HDTVs and computers * HDMI version 1.3:   + Transmission bandwidth of 10 Gbps   + Maximum support resolution of 2560 × 1600 @ 60 Hz * HDMI version 1.4:   + Transmission bandwidth of 10 Gbps   + Maximum support resolution of 3840 × 2160 @ 30 Hz * HDMI version 2.0:   + Supports 21:9 aspect ratio   + Transmission bandwidth of 18 Gbps   + Maximum support resolution of 3840 × 2160 @ 60 Hz   Adapters that convert HDMI to another connection type (e.g., DVI-to-HDMI or HDMI-to-VGA) only provide a video signal; the HDMI audio signal is lost. |
| DisplayPort https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_displayport.png | * Provides both a digital video and digital audio signal * Used by laptop screens as a way to interface with the internal video card * Operates at a lower voltage than DVI and HDMI * Compatible with DVI and HDMI interfaces by using simple cable adapters * Used by HDTVs and computers * DisplayPort 1.2:   + Transmission bandwidth of 21 Gbps   + Maximum support resolution of 3840 × 2400 @ 60 Hz * DisplayPort 1.3:   + Transmission bandwidth of 32 Gbps   + Maximum support resolution of 5120 × 2880 @ 60 Hz   Unlike HDMI, DisplayPort is royalty free (manufacturers do not have to pay a fee to use the interface). Because of this, DisplayPort has the potential to replace HDMI. |
| Composite https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_composite.png | * Provides analog, video-only TV output (audio signals must be supplied separately) * Uses yellow RCA connectors * Combines three qualities of video into a single signal:   + Y channel for brightness/luminance   + U and V channels for color information * Used to connect older analog devices (standard TVs, VCRs, or video cameras) to a video card |
| Component https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_component-rca.png RCA https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_component-minidin-7.png 7-pin mini-din | * Provides analog, video-only TV output (audio signals must be supplied separately) * Supports 480i or 576i resolutions (standard definition resolutions) * Sends a video signal using three separate channels:   + R (red)   + G (green)   + B (blue) * Video cards using a component connection use a 7-pin mini-din connection * HDTVs use three RCA connectors for the separate channels   HDTVs use three RCA connectors for the three separate component channels. |
| Coaxial (F-type) https://cdn.testout.com/pcpro2016-en-us/en-us/resources/text/disp_spec/disp_spec_coaxial-f-type.png | * Provides a multi-channel analog audio and video signal * Can provide multiple data streams on a single cable * Used by video cards and TVs with built-in tuners   Do not confuse video in, which can be supplied by composite, s-video, or HDTV connectors, with TV-tuner capabilities. The built-in tuner means that the card or monitor itself has the ability to accept multi-channel input and change the display by changing the channel. Without a built-in tuner, video input is limited to a single channel, and changing TV channels must be done at the source device before inputting into the video card. |