1. Plasma Display

Fixed-pixel displays such as plasma TVs scale the video image of each incoming signal to the native resolution of the display panel. The most common native resolutions for plasma display panels are 854x480 (EDTV), 1,366x768 (HDTV ready) or 1,920x1,080 (HDTV). As a result picture quality varies depending on the performance of the video processor and the upscaling and downscaling algorithms used by each display manufacturer.

Plasma displays are bright (1,000 lux or higher for the module), have a wide color gamut, and can be produced in fairly large sizes-up to 3.8 m (150 inches) diagonally. They have a very low-luminance "dark-room" black level compared to the lighter grey of the unilluminated parts of an LCD screen. The display panel is only about 6 cm (2.5 inches) thick, while the total thickness, including electronics, is less than 10 cm (4 inches). Plasma displays use as much power per square meter as a CRT.

Power consumption varies greatly with picture content, with bright scenes drawing significantly more power than darker ones, as is also true of CRTs. Nominal power rating is typically 220 to 310 watts for a 127 cm display when set to cinema mode. Most screens are set to 'shop' mode by default, which draws at least twice the power (around 500-700 watts) of a 'home' setting of less extreme brightness. Panasonic has greatly reduced power consumption by using Neo-PDP screens in their 2009 series of Viera plasma HDTVs.

Panasonic claims that PDPs will consume only half the power of their previous series of plasma sets to achieve the same overall brightness for a given display size. The lifetime of the latest generation of plasma displays is estimated at 100,000 hours of actual display time, or 27 years at 10 hours per day. This is the estimated time over which maximum picture brightness degrades to half the original value.

Plasma displays have drawbacks other than power consumption. They are often criticized for reflecting more ambient light than LCD displays. The front screen is made from glass, which reflects more light than the material used to make an LCD screen, which results in glare from reflected objects in the viewing area. Companies such as Panasonic coat their newer plasma screens with an anti-glare filter material. Currently, plasma panels cannot be economically manufactured in screen sizes smaller than 32 inches. Although a few companies have been able to make plasma EDTVs this small, even fewer have made 32in plasma HDTVs. With the trend toward larger and larger displays, the 32in screen size is rapidly disappearing.

Though considered bulky and thick compared to their LCD counterparts, some sets such as Panasonic's 21 and Samsung's 8860 series are as slim as one inch thick making them comparable to LCDs in this respect.

Advantages of plasma display technology are that a large, very thin screen can be produced, and that the image is very bright and has a wide viewing angle. The viewing angle characteristics of plasma displays and flat-face CRTs are essentially the same, topping all LCD displays, which have a reduced viewing angle in at least one direction. Plasma TVs also do not exhibit an image blur common in many LCD TVs.

Contrast Ratio:
Contrast ratio is the difference between the brightest and darkest parts of an image, measured in discrete steps, at any given moment. Generally, the higher the contrast ratio, the more realistic the image is (though the "realism" of an image depends on many factors including color accuracy, luminance linearity, and spatial linearity.)
Contrast ratios for plasma displays are often advertised as high as 1,000,000:1. On the surface, this is a significant advantage of plasma over most other current display technologies, a notable exception being OLED.

Although there are no industry-wide guidelines for reporting contrast ratio, most manufacturers follow either the ANSI standard or perform a full-on-full-off test. The ANSI standard uses a checkered test pattern whereby the darkest blacks and the lightest whites are simultaneously measured, yielding the most accurate "real-world" ratings. In contrast, a full-on-full-off test measures the ratio using a pure black screen and a pure white screen, which gives higher values but does not represent a typical viewing scenario. Some displays, using many different technologies, have some "leakage" of light, through either optical or electronic means, from lit pixels to adjacent pixels so that dark pixels that are near bright ones appear less dark than they do during a full-off display.

Manufacturers can further artificially improve the reported contrast ratio by increasing the contrast and brightness settings to achieve the highest test values. However, a contrast ratio generated by this method is misleading, as content would be essentially unwatchable at such settings.

Plasma is often cited as having better (i.e. darker) black levels (and higher contrast ratios), although both plasma and LCD each have their own technological challenges. Each cell on a plasma display has to be precharged before it is due to be illuminated (otherwise the cell would not respond quickly enough) and this precharging means the cells cannot achieve a true black. Some manufacturers have worked hard to reduce the precharge and the associated background glow, to the point where black levels on modern plasmas are starting to rival CRT.

**Screen Burn-In**

With phosphor-based electronic displays (including cathode ray and plasma displays), the prolonged display of a menu bar or other static (fixed in place and unchanging) graphical elements over time can create a permanent ghost-like image of these objects since phosphor compounds which emit the light lose their luminosity with use. As a result, when certain areas of the display are used more frequently than others, over time the lower luminosity areas become visible to the naked eye and the result is called burn-in. While a ghost image is the most noticeable effect, a more common result is that the image quality will continuously and gradually decline as luminosity variations develop over time, resulting in a "muddy" looking picture image. Most plasma display producers state a 100,000 hours time before brightness halves, theoretically allowing for over ten years of normal viewing before the display dims significantly.

Plasma displays also exhibit another image retention issue which is sometimes confused with screen burn-in damage. In this mode, when a group of pixels are run at high brightness (when displaying white, for example) for an extended period of time, a charge build-up in the pixel structure occurs and a ghost image can be seen. However, unlike burn-in, this charge build-up is transient and self-corrects after the image condition that caused the effect has been removed and a long enough period of time has passed (with the display either off or on).

Plasma manufacturers have over time managed to devise ways of eliminating the past problems of image retention with solutions involving gray pillarboxes, pixel orbiters and image washing routines.

The xenon and neon gas in a plasma television is contained in hundreds of thousands of tiny cells positioned between two plates of glass. Long electrodes are
also sandwiched between the glass plates, on both sides of the cells. The address electrodes sit behind the cells, along the rear glass plate. The transparent display electrodes, which are surrounded by an insulating dielectric material and covered by a magnesium oxide protective layer, are mounted above the cell, along the front glass plate. Both sets of electrodes extend across the entire screen. The display electrodes are arranged in horizontal rows along the screen and the address electrodes are arranged in vertical columns. As you can see in the diagram below, the vertical and horizontal electrodes form a basic grid.

To ionize the gas in a particular cell, the plasma display's computer charges the electrodes that intersect at that cell. It does this thousands of times in a small fraction of a second, charging each cell in turn. When the intersecting electrodes are charged (with a voltage difference between them), an electric current flows through the gas in the cell. As we saw in the last section, the current creates a rapid flow of charged particles, which stimulates the gas atoms to release ultraviolet photons. The released ultraviolet photons interact with phosphor material coated on the inside wall of the cell. Phosphors are substances that give off light when they are exposed to other light. When an ultraviolet photon hits a phosphor atom in the cell, one of the phosphor's electrons jumps to a higher energy level and the atom heats up. When the electron falls back to its normal level, it releases energy in the form of a visible light photon. The phosphors in a plasma display give off colored light when they are excited. Every pixel is made up of three separate subpixel cells, each with different colored
phosphors. One subpixel has a red light phosphor, one subpixel has a green light phosphor and one subpixel has a blue light phosphor. These colors blend together to create the overall color of the pixel. By varying the pulses of current flowing through the different cells, the control system can increase or decrease the intensity of each subpixel color to create hundreds of different combinations of red, green and blue. In this way, the control system can produce colors across the entire spectrum. The main advantage of plasma display technology is that you can produce a very wide screen using extremely thin materials. And because each pixel is lit individually, the image is very bright and looks good from almost every angle. The image quality isn't quite up to the standards of the best cathode ray tube sets, but it certainly meets most people's expectations. The biggest drawback of this technology has been the price. However, falling prices and advances in technology mean that the plasma display may soon edge out the old CRT sets.

**Advantages:**
- Slim Profile
- Can be wall mounted
- Lighter and less bulky than rear-projection televisions
- Achieves better and more accurate color reproduction than LCDs (68 billion $2^{36}$ versus 16.7 million $2^{24}$).
- Produces deep, true blacks allowing for superior contrast ratios (up to 1:2,000,000)
- Far wider viewing angles than those of LCD (up to 178")'
- images do not suffer from degradation at high angles unlike LCDs
- Virtually nonexistent motion blur, thanks in large part to very high refresh rates and a faster response time, contributes to the superior performance of plasma displays when displaying video and film content, for example sports, action movies, etc., that contains significant amounts of rapid motion

**Disadvantages:**
- Susceptible to "large area flicker"
- Generally do not come in smaller sizes than 32 inches
- Susceptible to reflection glare in bright rooms
- Heavier than LCD due to the requirement of a glass screen to hold the gases
- Use more electricity, on average, than an LCD
- Do not work as well at high altitudes due to pressure differential between the gases inside the screen and the air pressure at altitude. It may cause a buzzing noise. Manufacturers rate their screens to indicate the altitude parameters.

- For those who wish to listen to AM radio, or are Amateur Radio operators (Hams) or Shortwave Listeners (SWL), the Radio Frequency Interference (RFI) from these devices can be irritating or disabling.

**2. LCD Display**

Liquid crystal displays (LCDs) are a passive display technology. This means they do not emit light; instead, they use the ambient light in the environment. By manipulating this light, they display images using very little power. This has made LCDs the preferred technology whenever low power consumption and compact size are critical. Liquid crystal (LC) is an organic substance that has both a liquid form and a crystal
molecular structure. In this liquid, the rod-shaped molecules are normally in a parallel array, and an electric field can be used to control the molecules. Most LCDs today use a type of liquid crystal called Twisted Nematic (TN). See figure below to see a visual of the molecule alignment.

A Liquid Crystal Display (LCD) consists of two substrates that form a "flat bottle" that contains the liquid crystal mixture. The inside surfaces of the bottle or cell are coated with a polymer that is buffed to align the molecules of liquid crystal. The liquid crystal molecules align on the surfaces in the direction of the buffing. For Twisted Nematic devices, the two surfaces are buffed orthogonal to one another, forming a 90 degree twist from one surface to the other, see figure below.

This helical structure has the ability to control light. A polarizer is applied to the front and an analyzer/reflecter is applied to the back of the cell. When randomly polarized light passes through the front polarizer it becomes linearly polarized. It then passes through the front glass and is rotated by the liquid crystal molecules and passes through the rear glass. If the analyzer is rotated 90 degrees to the polarizer, the light will pass through the analyzer and be reflected back through the cell. The observer will see the background of the display, which in this case is the silver gray of the reflector.

The LCD glass has transparent electrical conductors plated onto each side of the glass in contact with the liquid crystal fluid and they are used as electrodes. These electrodes are made of Indium-Tin Oxide (ITO). When an appropriate drive signal is applied to the cell electrodes, an electric field is set up across the cell. The liquid crystal molecules will rotate in the direction of the electric field. The incoming linearly polarized light passes through the cell unaffected and is absorbed by the rear analyzer. The observer sees a black character on a silver gray background, see figure 2. When the electric field is turned off, the molecules relax back to their 90 degree twist structure. This is referred to as a positive image, reflective viewing mode. Carrying this basic technology further, an LCD having multiple selectable electrodes and selectively applying voltage to the electrodes, a variety of patterns can be achieved.
3. LED Displays

An organic light emitting diode (OLED), also light emitting polymer (LEP) and organic electro luminescence (OEL), is a light-emitting diode (LED) whose emissive electroluminescent layer is composed of a film of organic compounds. The layer usually contains a polymer substance that allows suitable organic compounds to be deposited. They are deposited in rows and columns onto a flat carrier by a simple "printing" process. The resulting matrix of pixels can emit light of different colors. Such systems can be used in television screens, computer monitors, small, portable system screens such as cell phones and PDAs, watches, advertising, information and indication. OLEDs can also be used in light sources for general space illumination, and large-area light-emitting elements. OLEDs typically emit less light per area than inorganic solid-state based LEDs which are usually designed for use as point-light sources.

In the context of displays, OLEDs have a significant advantage over traditional liquid crystal displays (LCDs). OLEDs do not require a backlight to function. Thus, they can display deep black levels, draw far less power, and can be much thinner and lighter than an LCD panel. OLED displays also naturally achieve much higher contrast ratio than LCD screens using cold cathode fluorescent lamp (CCFL) backlights.

A typical OLED is composed of an emissive layer, a conductive layer, a substrate, and anode and cathode terminals. The layers are made of organic molecules that conduct electricity. The layers have conductivity levels ranging from insulators to conductors, so OLEDs are considered organic semiconductors.

The first, most basic OLEDs consisted of a single organic layer, for example the first lightemitting polymer device synthesised by Burroughs et al. involved a single layer of poly(p-phenylene vinylene). Multilayer OLEDs can have more than two layers to improve device efficiency. As well as conductive properties, layers may be chosen to aid charge injection at electrodes by providing a more gradual electronic profile, or block a charge from reaching the opposite electrode and being wasted.
A voltage is applied across the OLED such that the anode is positive with respect to the cathode. This causes a current of electrons to flow through the device from cathode to anode. Thus, the cathode gives electrons to the emissive layer and the anode withdraws electrons from the conductive layer; in other words, the anode gives electron holes to the conductive layer.

Soon, the emissive layer becomes negatively charged, while the conductive layer becomes rich in positively charged holes. Electrostatic forces bring the electrons and the holes towards each other and they recombine. This happens closer to the emissive layer, because in organic semiconductors holes are more mobile than electrons. The recombination causes a drop in the energy levels of electrons, accompanied by an emission of radiation whose frequency is in the visible region. That is why this layer is called emissive.

The device does not work when the anode is put at a negative potential with respect to the cathode. In this condition, holes move to the anode and electrons to the cathode, so they are moving away from each other and do not recombine.

Indium tin oxide is commonly used as the anode material. It is transparent to visible light and has a high work function which promotes injection of holes into the polymer layer. Metals such as aluminium and calcium are often used for the cathode as they have low work functions which promote injection of electrons into the polymer layer.

Just like passive-matrix LCD versus active-matrix LCD, OLEDs can be categorized into passive-matrix and active-matrix displays. Active-matrix OLEDs (AMOLED) require a thin-film transistor backplane to switch the individual pixel on or off, and can make higher resolution and larger size displays possible.

**Phosphorescent materials**

Phosphorescent OLED (PHOLED) uses the principle of electrophosphorescence to convert electrical energy in an OLED into light in a highly efficient manner.

**Structure**

Bottom emission uses a transparent or semi-transparent bottom electrode to get the light through a transparent substrate. Top emission uses a transparent or semitransparent top electrode to get the light through the counter substrate.

Transparent organic light-emitting device (TOLED) uses a proprietary transparent contact to create displays that can be made to be top-only emitting, bottom-only emitting, or both top and bottom emitting (transparent). TOLEDs can greatly improve contrast, making it much easier to view displays in bright sunlight. This technology is
used in Head-up displays.
Stacked OLED (SOLED) uses a pixel architecture that stacks the red, green, and blue subpixels on top of one another instead of next to one another, leading to substantial increase in gamut and colour depth, and greatly reducing pixel gap. Currently, all display technologies have the RGB (and RGBW) pixels mapped next to each other.

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In contrast to a conventional OLED, in which the anode is placed on the substrate, an Inverted OLED (IOLED) uses a bottom cathode that can be connected to the drain end of an n-channel TFT especially for the low cost amorphous silicon TFT backplane useful in the manufacturing of AMOLED displays.

Advantages
The radically different manufacturing process of OLEDs lends itself to many advantages over flat-panel displays made with LCD technology. Since OLEDs can be printed onto any suitable substrate using an inkjet printer or even screen printing technologies, they can theoretically have a significantly lower cost than LCDs or plasma displays. Printing OLEDs onto flexible substrates opens the door to new applications such as roll-up displays and displays embedded in fabrics or clothing. OLEDs enable a greater range of colors, gamut, brightness, contrast (both dynamic range and static) and viewing angle than LCDs because OLED pixels directly emit light. OLED pixel colours appear correct and unshifted, even as the viewing angle approaches 90 degrees from normal. LCDs use a backlight and cannot show true black, while an off OLED element produces no light and consumes no power. Energy is also wasted in LCDs because they require polarizers that filter out about half of the light emitted by the backlight. Additionally, colour filters in most colour LCDs filter out two-thirds of the light! technology to separate backlight colours by diffraction has not been widely adopted.

OLEDs also have a faster response time than standard LCD screens. Whereas the fastest LCD displays currently have a 2ms response time, an OLED can have less than 0.01ms response time.

Disadvantages
Lifespan
The biggest technical problem for OLEDs is the limited lifetime of the organic materials. In particular, blue OLEDs historically have had a lifetime of around 14,000 hours (five years at 8 hours a day) when used for flat-panel displays, which is lower than the typical lifetime of LCD, LED or PDP technology—each currently rated for about 60,000 hours, depending on manufacturer and model. However, some manufacturers of OLED displays claim to have come up with a way to solve this problem with a new technology to increase the lifespan of OLED displays, pushing their expected life past that of LCD displays. A metal membrane helps deliver light from polymers in the substrate throughout the glass surface more efficiently than current OLEDs. The result is the same picture quality with half the brightness and a doubling of the screen's expected life.

In 2007, experimental OLEDs were created which can sustain 400 cd/m’ of luminance for over 198,000 hours for green OLEDs and 62,000 hours for blue OLEDs.
Colour balance issues

Additionally, as the OLED material used to produce blue light degrades more rapidly than other materials that produce other colors, blue light output will decrease relative to the other colors of light. This differential color output change will change the color balance of the display and is much more noticeable than a decrease in overall luminance. This can be partially avoided by adjusting colour balance but this may require advanced control circuits and interaction with the user, which is unacceptable for some uses. The intrusion of water into displays can damage or destroy the organic materials. Therefore, improved sealing processes are important for practical manufacturing and may limit the longevity of more flexible displays.