Understanding Today's LCD Screen Technology

How-it-works: LCD screens explained

Liquid crystal display (LCD) is a device that utilizes the electro-optical characteristics of a liquid crystal to convert an electrical stimulus into a visual signal. It helps bring to life your imagination and ideas and display them on a screen.

The four basic principles that create this 'magical' experience are:

- Light can be polarized.
- The orientation of liquid crystals can be changed by electric current.
- Liquid crystals can manipulate (transmit or block) polarized light.
- There are transparent substances that can conduct electricity.

The fact that the molecular arrangement of the liquid crystal can be manipulated by the external electric field is what makes LCD's tick. Liquid crystals (LCs) are matter in a state, which has properties of both conventional liquids and solid crystals. The liquid crystal may flow like a liquid, but its molecules may be oriented in a crystal-like way.

Although Liquid Crystal forms the core of the display panel, there are other optical and electro-circuit components that play important roles in the display performance.

Want to learn more about the various liquid crystal modes? Read this white paper on various LCD modes.

What goes on inside your LCD screen?

Let us ride on a beam of light as it passes through the various components of an LCD screen:

1. As the screen is powered-up, backlight LED emits the white light.
2. Light goes into the light guide plate (LGP), reflects internally, and is distributed evenly over the upper surface of the panel.
3. Diffuser sheet further disperses the light, so no hot-spots are observed outside of the LGP.
4. DBEF recycles the scattered light and prism sheet ensures that the light is focused and directed towards the viewer.
5. Bottom polarizer allows light of the vertical wavelength to pass through while blocking other orientations.
6. Vertically polarized light then passes through the liquid crystal layer.
7. The liquid crystals are then manipulated by applying appropriate voltage through the TFT and common electrode. Liquid crystals can block the white light to a variable degree. The filter in front of each subpixel only allows through a range of wavelengths appropriate to its color. To control the brightness of each subpixel, the liquid crystal cell is energized or de-energized to

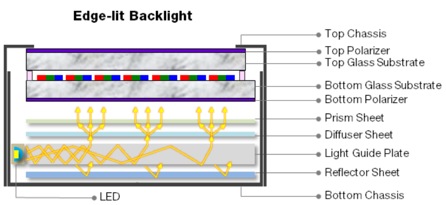
block or transmit light.

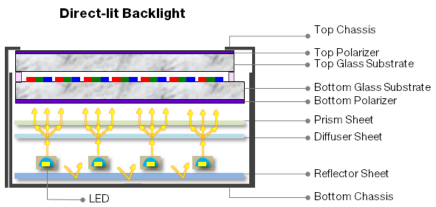
8. The light passes through the liquid crystals and the color filters to produce the primary red, green and blue colors.
9. The polarized light then is filtered by the top polarizer—only horizontally polarized light is transmitted.
10. Finally, the viewer can enjoy the vibrant color, high contrast and crisp image on the digital display.

LCD components deconstructed

- **Bottom Chassis**: Bottom chassis protects the LCD display components and acts as a foundation that houses the components together.
- **Backlight**: Liquid crystals do not generate light of their own, so another means of providing light is required to allow the screen to be viewed. The light source can either be an ambient light or an artificial light source located behind or to the side of the screen. An LCD is a transmissive display, thus it needs an external light source.

An LED-backlit LCD display is a flat panel display that uses LED backlighting. The use of LED backlighting allows for a thinner panel, lower power consumption, better heat dissipation, a brighter display, and better contrast levels. Light emitting diodes (LED) provide light for the display. The most common backlight arrangement these days is is either Edge LED (slimmer profile) or Direct LED (for high-brightness displays or narrow bezel video wall displays). The design of the backlight is important to ensure good color reproduction and a broad color gamut. Just because a backlight looks white, doesn't mean that it has a broad and even spectrum—it might have a very irregular "peaky" spectrum (and CCFL lights usually do).





- **Reflector Sheet:** A reflector sheet provides LCD backlight recycling. It is often called DBEF (dual brightness enhancement film). DBEF increases on-axis luminance and thus more light is available to be transmitted through the LCD. Typically, one BEF can increase brightness by 40%-60%. In some applications, two BEFs are used for enhanced brightness transmittance.

- **Light Guide Plate (LGP):** LGP is an acrylic panel typically made from pure PMMA (poly methyl methacrylate) resin. PMMA is extremely transparent and highly weather resistant. The light guide is a sheet of plastic etched with a pattern of bumps that reflects light in a particular direction. LGP converts a line-shaped light source into a uniform plane-shaped light source. A matrix of lines is etched on the bottom of the LPG panel to direct the light out the front, which is called V-cutting. Light entering the light guide layer from the sides will exit through the front.
- **Diffuser Sheet:** A diffuser sheet is designed to break up and distribute light evenly to give the soft light. The diffuser sheet spreads the light evenly across the screen dimensions making a solid, evenly lit square and reduces LED hot-spots.
- **Prism Sheet:** A prism sheet is provided on the upper surface of the light guide plate of the liquid crystal display. The prism sheet has small, angled ridges on its front-facing surface that recycle off-axis light until it is emitted at the optimal viewing angle. The light waves either exit at the brightest angle to the viewer, or they are sent through the back lighting layers again until they exit correctly.
- **Bottom Polarizer:** Polarizer is made by stretching a plastic-like material to lengthen its fibers, then dipping the material in iodine to further lengthen and organize the material’s fibers into a grid of darkened parallel lines that are invisible to the human eye. This is like a filter that only allows light waves in a vertical orientation to pass through, and rest of the light waves are blocked off.
- **Bottom Glass Substrate (Backplane):** Special glass used as a starting substrate for the thin film transistor (TFT) manufacturing process. The liquid crystal is normally 'sandwiched' between two polarizing filters at 90 degrees to each other. Polarized light enters the back of the liquid crystal from the back-lit LED. When the nematic crystal is not energized, it 'twists' the polarized light by 90 degrees so that it passes through the second polarizing filter. When an electric field is applied to the liquid crystal, the light does not get twisted so gets blocked by the second polarizing filter.
- **Thin Film Transistor:** A transistor whose active, current-carrying layer is a thin film (usually a film of silicon—Si), in contrast to MOSFETs, which are made on silicon wafers and use the bulk-silicon as the active layer. In a flat-panel display, light must be able to pass through the substrate material to reach the viewer. Opaque silicon wafers obviously will not be suitable for these transmissive displays. Glass is the most commonly used starting substrate because it is highly transparent and is compatible with conventional semiconductor processing steps. Since glass is not a semiconductor like silicon, a thin film of silicon is deposited on top and the transistors are fabricated using this thin layer. TFT help manipulate the voltage at each subpixel to orchestrate the display image.

Samsung Display’s PID panels are Active Matrix TFTs. Active Matrix LCD display panels depend on the thin film transistors (TFT) to maintain the state of each pixel between scans while improving response times. TFTs are micro-switching transistors (and associated capacitors) that are arranged in a matrix on a glass substrate to control each picture element (or pixel). Switching on one of the TFTs will activate the associated pixel. The use of an active switching device embedded onto the display panel itself to control each picture element helps reduce the cross-talk between adjacent pixels while drastically improving the display response time. By carefully adjusting the amount of voltage applied in very small increments, it is possible to create a gray scale effect. Most of the today's LCD displays support a minimum of 256 levels of brightness per pixel, though high-end LCD panels used in LCD signage can support up to 1,024 different levels of brightness. This results in improved gray scale performance and therefore improved picture detail in those areas of the image that are primarily all dark or all bright.

- **Liquid Crystal:** Liquid crystals change orientation under an applied electric field and can thereby block or pass light. Liquid crystals are rod-shaped molecules that twist when an electric current is applied to them. Each crystal acts like a shutter, either allowing light to pass through or blocking the light. The pattern of transparent and dark crystals forms the image. The liquid crystals in an LCD display are in a naturally twisted form.
- **Common Electrode:** It is made from the transparent indium-tin-oxide (ITO) for applying the voltage to liquid crystal layer. Common electrode plays a critical role in maintaining the uniform pixel voltage across the whole LCD screen. In color screens, the ITO is now separated into three colors: red, green, and blue (RGB).
- **Color Filter (RGB):** Color filter creates colors for an image on LCD. The color filter is comprised of red, green, and blue pigment and is aligned with a particular subpixel within the cell. This filter is composed of the thin glass substrate and color resist. Three color resists (red, green, and blue) patterns are formed on the glass substrate. R, G, B patterns are called subpixels. An LCD that can show colors must have three subpixels with red, green and blue color filters to create each color pixel. Through the careful control and variation of the voltage applied, the intensity of each subpixel can range over 256 shades. Combining the subpixels produces a possible palette of 16.8 million colors (256 shades of red x 256 shades of green x 256 shades of blue with 8-bit color depth). These color displays take an enormous number of transistors (TFT’s). A typical laptop computer supports resolutions up to 1,920x1,080. If we multiply 1,920 columns by 1,080 rows by 3 subpixels, we get 6,220,800 transistors etched onto the backplane glass.
- **Top Glass Substrate:** Special glass used for the color filter manufacturing process.
- **Top Polarizer:** Light is horizontally polarized at the top polarizer. The function of the polarizer is to improve color and definition, making it possible to see the screens of LCDs. If polarizers were removed from LCDs, it would be impossible to recognize letters or graphics. When two polarizing films are placed one on the top of the other in parallel, the screen of the LCD will be at its brightest. However, when placed on the top of and perpendicular to each other, the screen will look as though it is black. Hence as described, the optical characteristics of LCDs, such as brightness and contrast, are greatly influenced by the properties of polarizing films.
- **Top Chassis or Frame:** Top chassis is located on the top and use an open frame.

Additional resources

Here are some resources to help you continue your journey to master LCD display knowledge:

- Get a lesson on the history of LCD here.
- A quick video on how an LCD screen works (2.34 min).
- A deeper session into the LCD workings by Nanolearning Channel (17.25 min).
- Learn more about the Thin Film Transistors (TFT) (10.41 min).
- Get a sneak peek into building an LCD display.
- Learn more about how we see color in this report on Color and Displays.