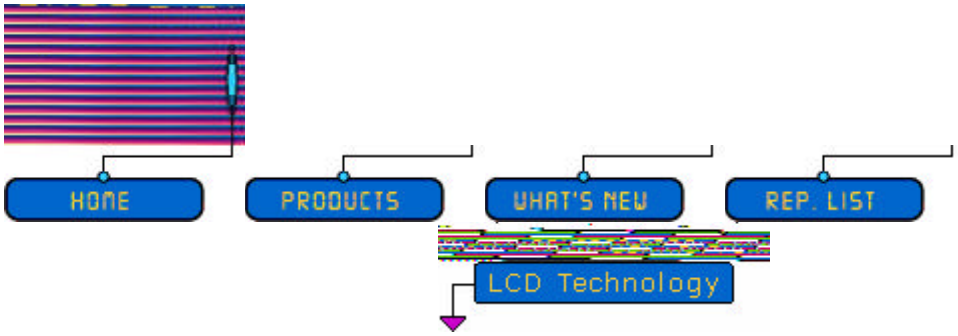


Basic Technology

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. 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 1).

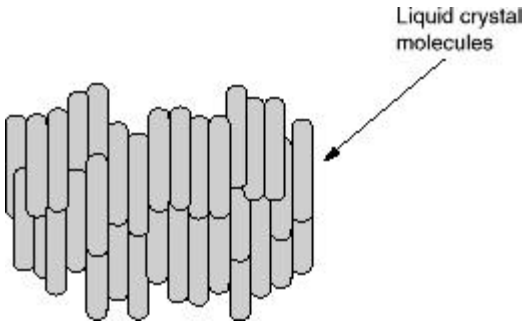


Figure 1 Structure of nematic liquid crystal

LCDs consist of two pieces of glass with electrodes printed on the inside. An alignment layer on each glass surface is used to twist the liquid crystal material in a helical or "twisted" pattern. Polarizers are used on the outside front and rear surfaces (see Figures 2 and 3).

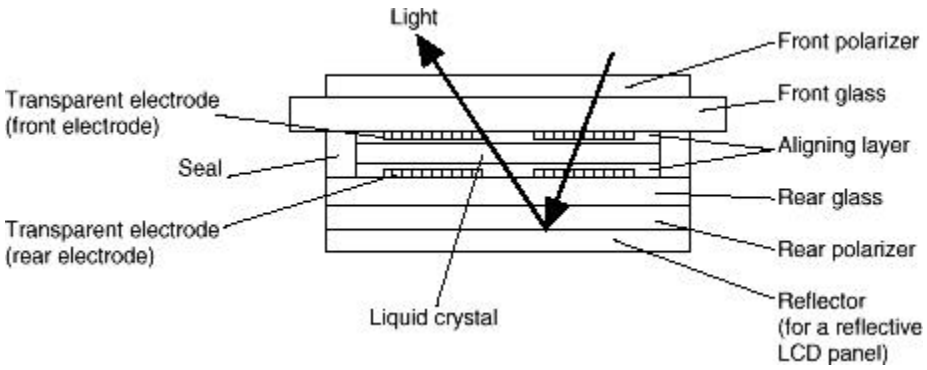


Figure 2 TN LCD panel

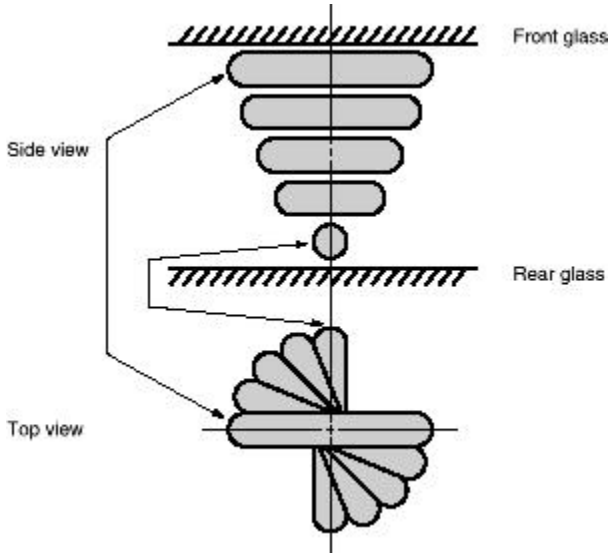
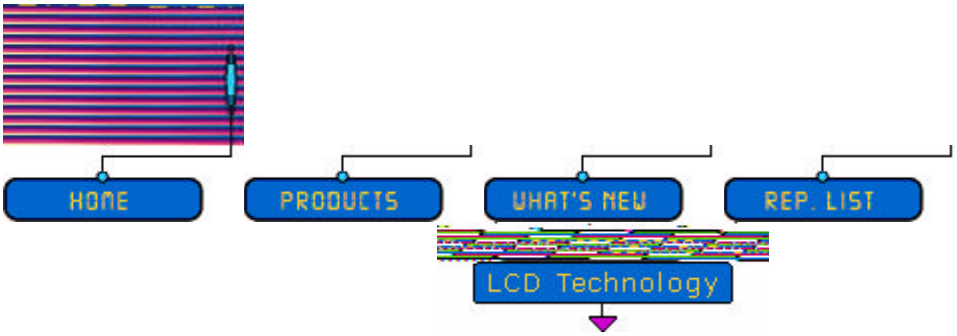


Figure 3 Orientation of nematic liquid crystal molecules (twist angle:90)

When the LCD is 'off,' no voltage is applied to the electrodes, and light passes through the LCD. When it is 'on,' voltage is applied and the LC molecules align themselves in the direction of the electric field. This causes the LC to be out of phase with the light, creating a dark area on the LCD. By selectively applying voltage to the electrodes, a variety of patterns can be achieved.

Many advances in TN LCDs have been produced. Super twisted nematic (STN) LC material offers a higher twist angle (>=200° vs. 90°) that provides higher contrast and a better viewing angle. However, one negative feature is the birefringence effect, which shifts the background color to yellow-green and the character color to blue. This background color can be changed to a gray by using a special filter.

The most recent advance has been the introduction of film super twisted nematic (FSTN) displays. This adds a retardation film to the STN display that compensates for the color added by the birefringence effect. This allows a black and white display to be produced.



Backlighting

An LCD is basically a reflective part. It needs ambient light to reflect back to the eye. In uses where ambient light is low or nonexistent, a light source must be placed behind the LCD. This is known as backlighting (see Figure 4a). There are several technologies used:

Electroluminescent (EL)

EL backlights are very thin, lightweight and provide an even light. They are available in a variety of colors, with white being the most popular for use with LCDs. While their power consumption is fairly low, they require voltages of 80 to 100 VAC. This is supplied by an inverter that converts a 5, 12 or 24 VDC input to the AC output. ELs have a limited life of 3,000 to 5,000 hours to half brightness.

Light Emitting Diode (LED)

LED backlights offer a longer operating life - 50,000 hours minimum - and are brighter than ELs. They do consume more power than ELs. Being a solid state device, they operate directly off +5 VDC, so they do not require an inverter. However, a current limiting resistor is recommended for protection of the LEDs. LEDs are mounted in an array directly behind the display. LEDs come in a variety of colors, with yellow-green being the most common.

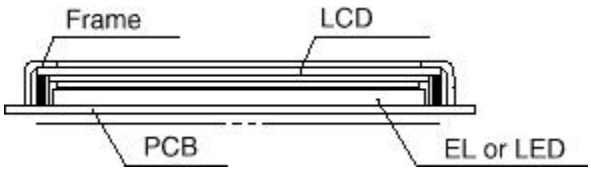
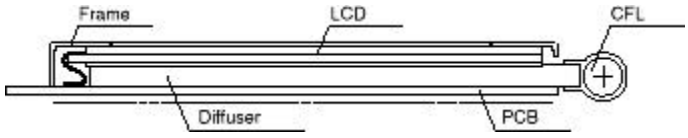


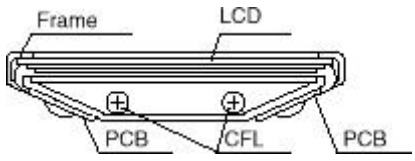
Figure 4a: EL and LED Backlight

Cold Cathode Fluorescent Lamp (CFL)

CFL backlight offers low power consumption and a very bright white light. Two technologies are used: direct and edge lighting. In both types a cold cathode fluorescent tube is the light source. A diffuser distributes the light evenly across the viewing area. Edge lighting offers a thinner package and less power. CFLs require an inverter to supply the 270 to 300 VAC used by the CFL tube. They are used primarily in graphic LCDs and have a longer life - 10,000 to 15,000 hours - than ELs do.



Edge lighting type



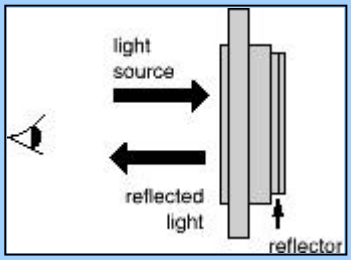
Backlight type

Viewing Modes

LCDs are offered in three basic light transmission modes: reflective, transflective and transmissive.

Reflective LCD

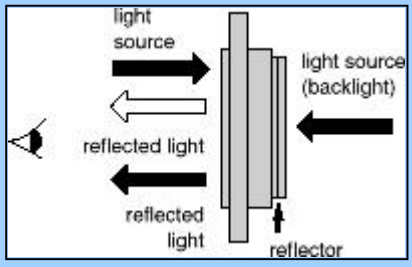
In the reflective mode, ambient light is used to illuminate the display. This is achieved by combining a reflector with the rear polarizer. It works best in an outdoor or well-lighted office environment.



Reflector bonded to the rear polarizer reflects the incoming ambient light. Low power consumption.

Transflective LCD

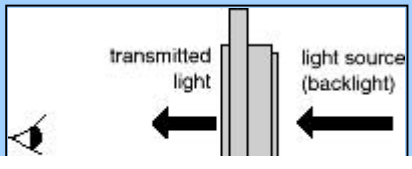
Transflective LCDs are a mixture of the reflective and transmissive types, with the rear polarizer having partial reflectivity. They are combined with a backlight for use in all types of lighting conditions. The backlight can be left off where there is sufficient outside lighting, conserving power. In darker environments, the backlight is turned on to provide a bright display. Transflective LCDs will not "wash out" when operated in direct sunlight.



Transflector bonded to the rear polarizer reflects light from front as well as enabling lights to pass through the back. Used with backlight off in bright light and with it on in low light to reduce power consumption.

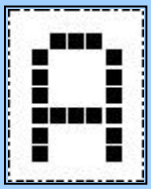
Transmissive LCD

Transmissive LCDs have a transparent rear polarizer and do not reflect ambient light. They require a backlight to be visible. They work best in low light conditions with the backlight on continuously.

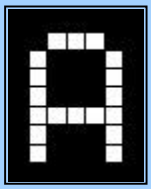


Without reflector or transflector bonded to the rear polarizer. Backlight required. Most common is transmissive negative image.

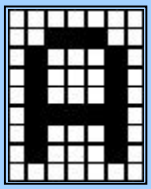
Positive/Negative



Positive Type



Negative Type



Negative Type (inverse image) (when data is inverted)

Another feature of the viewing mode is whether the LCD is a positive or negative image. The standard image is positive, which means a light background with a dark character or dot. This works best in reflective or transflective mode. A negative image is usually combined with a transmissive mode. This provides a dark background with a light character. A backlight must be used to provide good illumination. In most graphic applications, the transmissive negative mode is inverted. This combination provides a light background with dark characters.

LCD Viewing Modes

Viewing Mode	Display Description	Application Comments	Direct Sunlight	Office Light	Subdued Light	Very Low Light
Reflective Positive Image	Dark segments on light background	Not backlit. Provides best head-on contrast and environmental stability	Excellent	Very Good	Average	Poor
Transflective Positive Image	Dark segments on grey background	Can be viewed by reflected ambient light or with backlighting	Excellent (No backlight)	Good (No backlight)	Good (Backlit)	Very Good (Backlit)
Transflective Negative Image	Light grey segments on dark background	Needs high ambient light or backlighting. Frequently used with color and multicolor transflector	Good (No backlight)	Fair (No backlight)	Good (Backlit)	Very Good (Backlit)
Transmissive Negative Image	Backlit segments on dark background	Cannot be read by reflection	Poor (Backlit)	Good (Backlit)	Very Good (No backlight)	Excellent (Backlit)
Transmissive Positive Image	Dark segments on backlit background	Designed for very low light conditions, yet able to be read in bright ambient lights	Good (No backlight)	Good (Backlit)	Very Good (Backlit)	Excellent (Backlit)

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