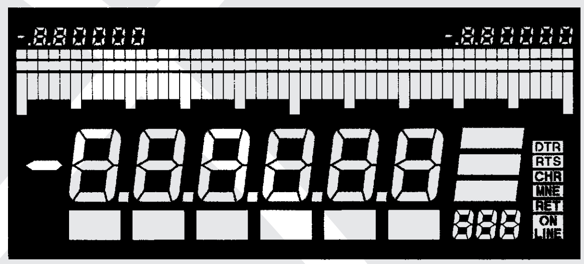
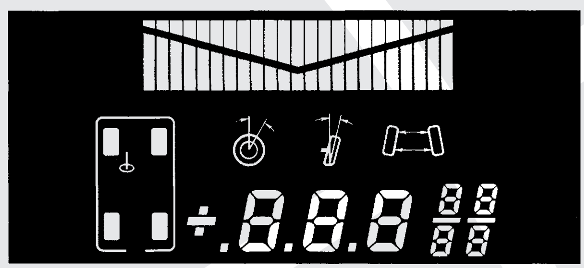
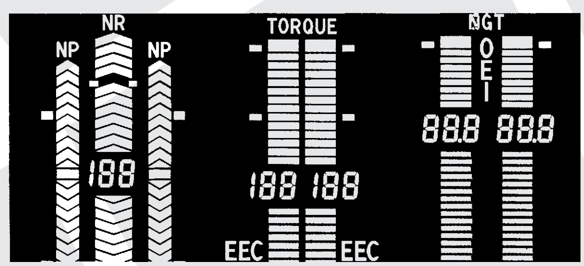
Liquid Crystal Displays: A Primer







Crystaloid®
LIQUID CRYSTAL DISPLAYS

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Crystaloid Electronics has been a leading manufacturer and supplier of liquid crystal displays since 1976. The Hudson, Ohio facility provides twisted nematic and dichroic displays for commercial and avionic applications.

Chapter 1

Basic Theory of Twisted Nematic LCDs

Liquid Crystal Displays (LCDs) control the reflection and transmission of light so as to create patterns of numbers, letters, symbols, icons, etc. Unlike Light-Emitting Diodes (LEDs), liquid crystal displays do not emit light.

The heart of the LCD is a specially formulated liquid crystal fluid whose molecules form distinct planes between two plates of glass. On any given plane, the cigar-shaped LC molecules align themselves so they are all pointing in the same direction, with their major axes aligned in parallel (see Diagram 1).

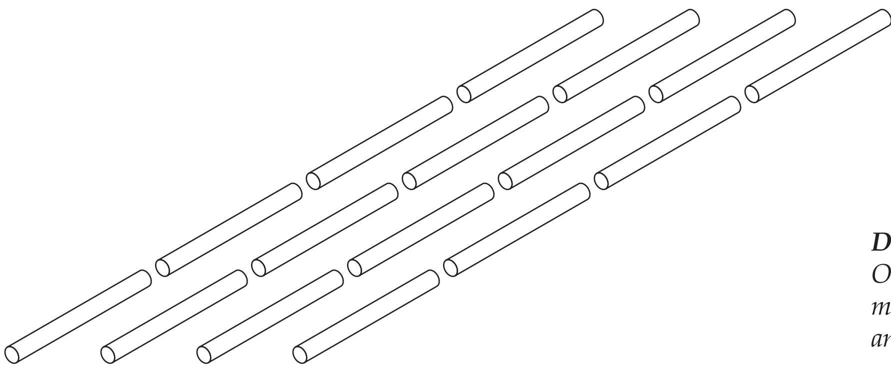


Diagram 1.
One plane of LC molecules. All molecules are parallel to one another.

The glass plates are specially coated such that the alignment of the molecules in the two outermost planes of fluid are at a 90° angle from each other. Each plane of LC molecules aligns itself so that it has a slightly different (molecular) orientation from the plane above and below it, forming a spiral or "twist" (see Diagram 2). This twists the polarization of the light as it passes through the display.

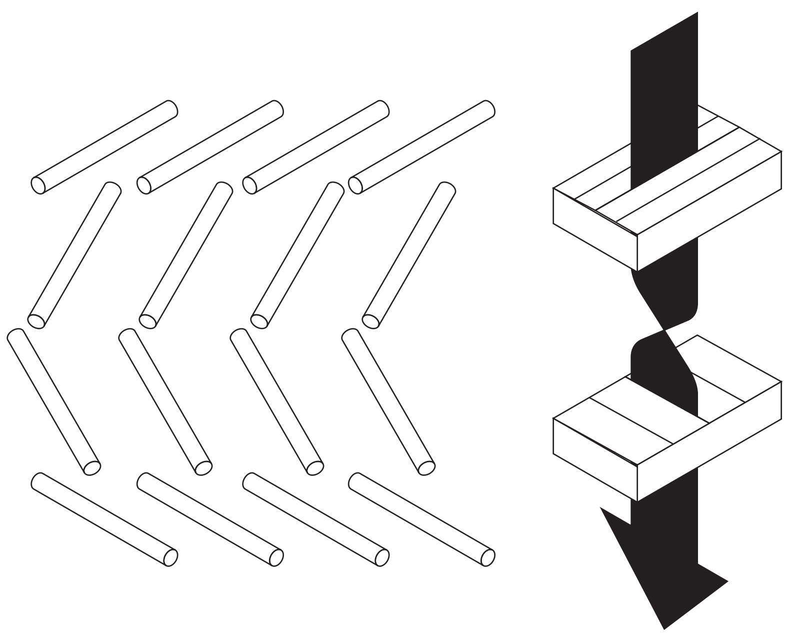


Diagram 2.
Several planes of LC molecules, arranged so that polarized light "twists" as it passes through them. If you could see the molecules when you looked through the display, their 90° twist would appear as a "helix."

Basic Theory of Twisted Nematic LCDs

When an electrical field is applied to the LC planes, the LC molecules re-align themselves so that they are parallel to the electrical field. This electrical process is known as **twisted nematic field-effect** or **TNFE**. In this alignment, polarized light is not twisted as it passes through the LC material (see Diagram 3A and 3B). If the front polarizer is oriented perpendicular to the rear polarizer, light will pass through the energized display but will be blocked by the rear polarizer. An LCD in this form is acting as a light shutter.

Displays with variable characters are created by selectively etching away the conductive surface that was originally deposited on the glass. Etched areas become the display's background; unetched areas become the display's characters.

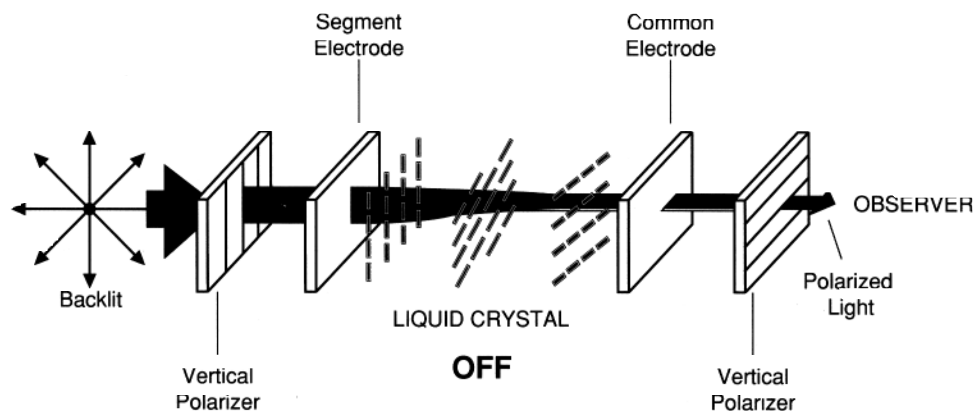


Diagram 3A.
The "off" state of a TN LCD—the LC molecules form a twist and therefore cause polarized light to twist as it passes through.

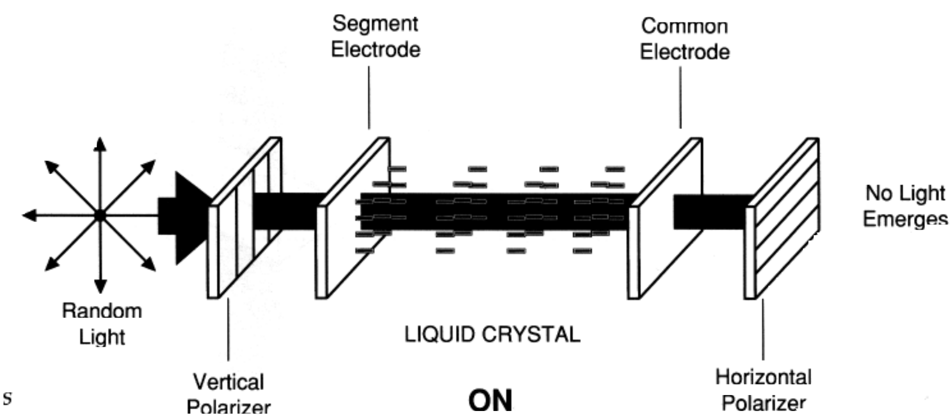


Diagram 3B.
The "on" state—the electrical field re-aligns the LC molecules so they do not twist the polarized light.

Basic Theory of Twisted Nematic LCDs

Each character is created from one or more **segments**. The segments can be individually addressed (i.e., their conductive surface energized) so as to create distinct electric fields. The passage of light then can be electrically controlled as needed to form characters. In non-active parts of the display, the molecular arrangement is always spiraled, forming a background. Energized segments form characters that contrast with the background.

Depending on polarizer orientation, an LCD can have positive or negative images. In a positive image display, the front and rear polarizers are perpendicular ("crossed polarized") to each other so that the unenergized segments and background area transmit the (twisted) light and the energized character segments inhibit the (untwisted) light, resulting in dark characters on a light background.

In a negative image display, the polarizers are "in phase," inhibiting the passage of (twisted) light so that unenergized segments and background are dark and the energized segments are clear.

A reflective LCD has a reflector behind the rear polarizer which will reflect ambient light through both the background area and the unenergized segments of a positive image display. In a negative image reflective display, ambient light is reflected only through the energized segments. Transmissive displays use the same principles but either the background or the segments are made brighter by using backlighting.

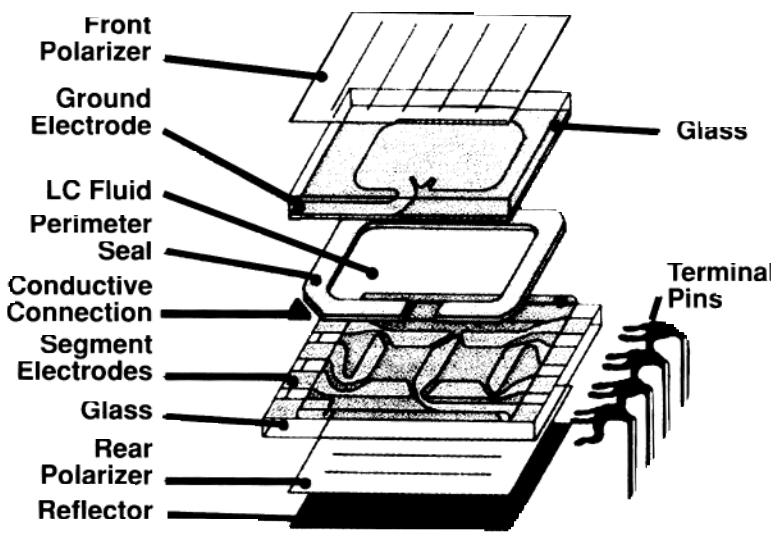


Diagram 4.
The basic components and construction of a (reflective) LCD.

LCD Display Viewing Modes

Viewing mode describes how a LCD handles light to create an image. To select the optimum viewing mode for your application, you need to consider the display's typical ambient lighting conditions (see selection chart below).

TABLE 1: 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	Poor	Unusable
Transflective Positive Image	Dark segments on gray 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 gray segments on a 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 a dark background	Cannot be read by reflection.	Poor (Backlit)	Good (Backlit)	Very Good (Backlit)	Excellent (Backlit)
Transmissive Positive Image	Dark segments on a 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)

Reflective Displays

Typically, LCDs employ the **reflective** viewing mode with dark images on a light background (i.e. a **positive image**).

With a segment turned OFF, ambient light takes the following path: It passes through the vertical front polarizer, through the transparent segment electrodes, through the LC molecules that twist it 90°, through the transparent common electrodes, through the horizontal polarizer, and finally onto a reflector that sends it back on same path (see diagram 5).

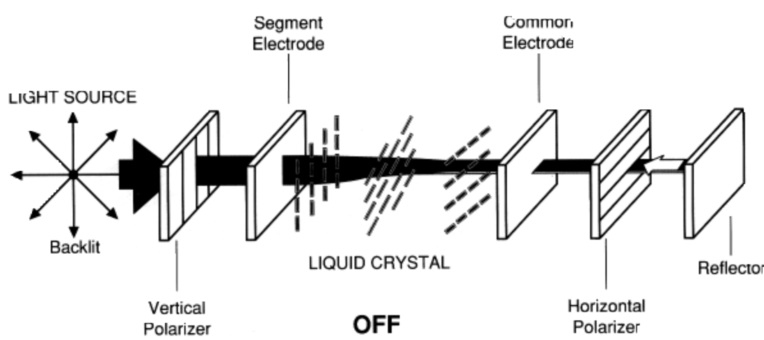


Diagram 5A.
A reflective display in the OFF state. Light passes through the horizontal polarizer and is reflected back.

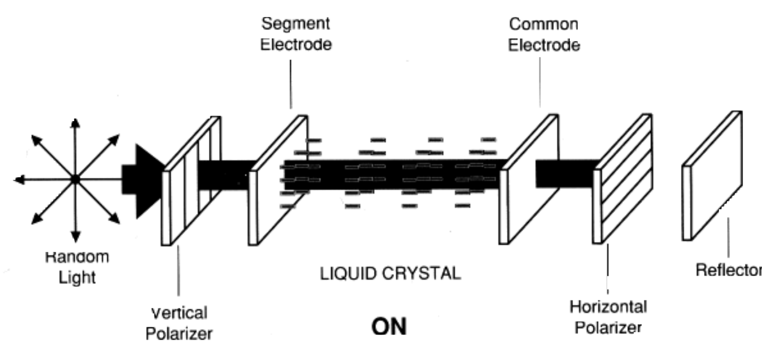


Diagram 5B.
In the ON state, the light is not in phase with the horizontal polarizer, so it does not pass through to the reflector.

A positive image display has front and back polarizers that are said to be "out-of-phase" with one another, or "crossed polarized" by 90°.

With a segment turned ON, the ambient light is not twisted by the LC molecules in that segment. So the light is out-of-phase when it reaches the bottom polarizer, which prevents it from passing through (to the reflector). Because the light is not reflected, a dark (positive) image is created for that particular segment—see Diagram 5B.

Reflective displays are very bright, with excellent contrast, and they can be seen from wide viewing angles. Reflective displays require sufficient ambient light; they are not backlit with auxiliary illumination. (Although unusual applications may lend themselves to frontlighting.) Reflective displays are frequently used in battery-operated devices.

Transmissive Displays

Transmissive LCDs do not reflect light. Instead, they create images by controlling light from an artificial source as the light passes through the back of the display to the viewer.

Transmissive (backlit) displays have front and back polarizers that are "in-phase" with one another. With a segment turned OFF, the polarized light is twisted 90° by the LC molecules and is therefore out-of-phase when it reaches the front polarizer. The front polarizer blocks the light, producing a dark segment.

With the segment turned ON, the light will not be twisted, so it will be in-phase with the front polarizer and will pass through it, producing a light image. So transmissive displays create light images on a dark background (i.e. a **negative image**).

Transmissive displays must be backlit to assure uniform illumination of the display's images (see "Auxiliary Lighting"). These displays are very good for subdued light or very low-light conditions. Transmissive LCDs do not perform well in direct sunlight because the backlighting cannot overcome strong sunlight.

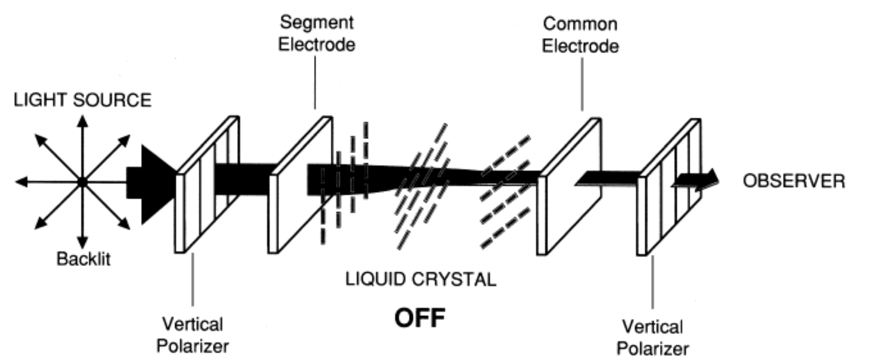


Diagram 6A. *In the OFF state, virtually no light passes through the transmissive display.*

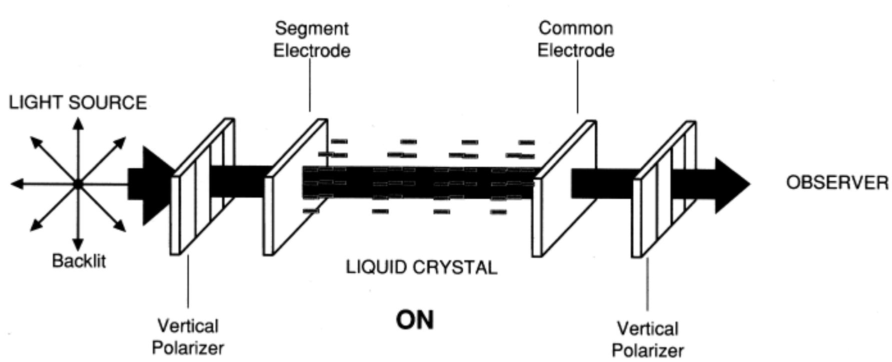


Diagram 6B. *In the ON state, light passes through the transmissive display, creating light images against a dark background.*

LCD Display Viewing Modes

Transflective Displays

Transflective displays use a white or silver translucent material which reflects some of the ambient light, but also transmits the back-lighting.

Because transflective displays both reflect and transmit light, they are useful for applications with widely-varying lighting conditions. For example, gas meter readers have transflective displays on their portable terminals—the LCDs can be read in bright, outdoor light and in poorly-lit basements. (For the same application, a reflective LCD would be easy to read in the sun, but difficult to read in the basement; a backlit, transmissive display would perform just the opposite.)

Transflective displays have a slightly lower contrast ratio when compared to reflective displays because they allow some light to pass through.

Auxiliary Backlighting

Whether a display needs back-lighting or not depends upon its ambient lighting conditions (see Table 1 above). Shown below are some common backlighting methods:

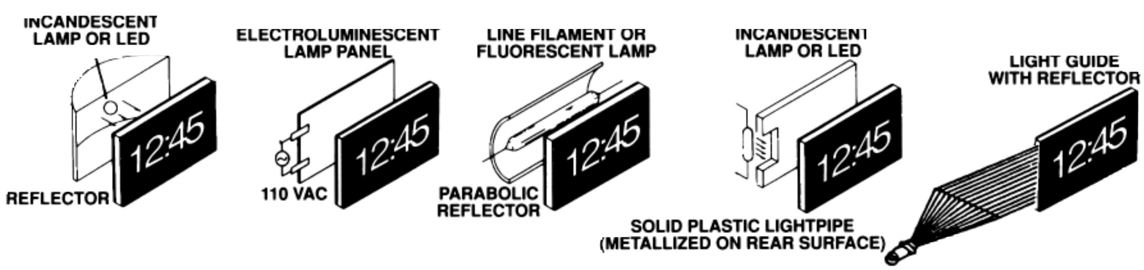


Diagram 7.

TABLE 2: A COMPARISON OF BACKLIGHTING METHODS

Feature	LED	Incandescent	Electroluminescent
Brightness	Medium	High	Low-Medium
Color	Limited	White	White
Size	Small	Small-Medium	Thin
Mounting	SMD/Radial	Radial/Axial	Axial
Voltage	5 Volts	1.5V–28V	45V–100V
Current @5V/sq. in.	10–30mA	20mA	1-10mA
Temperature	Warm	Hot	Cool
Cost/sq. in.	$0.10–$1.00	$0.10–$0.80	$0.50–$2.00
Emission	Directional	Spherical	Lambertian
Shock	Excellent	Fragile	Excellent
Life [HRS]	100,000	150–10,000	500–15,000

Application Environments

Operating & Storage Temperatures

Temperature ranges are a important consideration when specifying an LCD.

All LC materials have a very well-defined **isotropic** or operating temperature limit, above which the LC molecules will assume a random orientation. Isotropic conditions cause positive image displays to become completely dark, while negative image displays become transparent. The isotropic temperature is formally known as the nematic-to-isotropic transition temperature, or N→I transition.

LCDs can recover from short exposures to isotropic temperatures, although temperatures above 110°C will begin to deteriorate the display's internal coatings.

The low end of the LC temperature range is not as clearly defined as the high end. At low temperatures, display response time increases as molecular movement slows down due to increased LC fluid viscosity (see "Response Time").

At very low temperatures, the LC material approaches a solid or crystalline state. This is known as the theoretical crystalline-to-nematic transition temperature, or C→N transition. However, LC material "supercools," so it takes temperatures below the C→N limit to actually cause the material to turn crystalline. (Usually, exposures below –60°C). As a result, LCDs frequently operate at temperatures below their C→N transition temperature.

Low temperature effects are usually reversible. For example, LCDs immersed in liquid nitrogen have returned to normal operation after a brief warm-up period.

In addition, LC materials have a low temperature coefficient. Over broad temperature ranges, temperature compensation may be required. This coefficient is particularly important for multiplexed displays because of their lower effective drive voltage. For additional information, see the "LCD Drivers" chapter and Table 4.

Crystaloid offers numerous LC materials, providing a wide range of operating and storage temperature (see Appendix).

Heaters

Displays with integral heaters can overcome the effects of temperatures as low as –55°C. Heaters require a temperature-compensated power source. Heaters are used to achieve a O°C response time at low temperatures. (For additional information about response times, see "Display Appearance").

Increasing the power of the heater will decrease the warm-up time. Heaters usually require between 2 and 3 watts for every square inch of the back surface of the display.

Application Environments

Ambient Lighting

As already discussed, the application's ambient lighting conditions are very important. See Table 1, page 4, as well as the section on Auxiliary Lighting.

Environmental Stress

There are several options Crystaloid can offer for harsh environment conditions, such as those listed in Military Standards. For example, there are "high stability" coatings for protection from high temperatures and high humidity. "Barrier" coatings can help prevent contamination by conductive substances that could cause electrical shorts within the display. Thin film heaters can be used in low temperature applications. Careful selection of connectors can also help a LCD overcome difficult environments.

Be certain to fully describe your LCD's environmental requirements with your Crystaloid Applications Engineer.

Chapter 4

Display Appearance

Viewing Angle

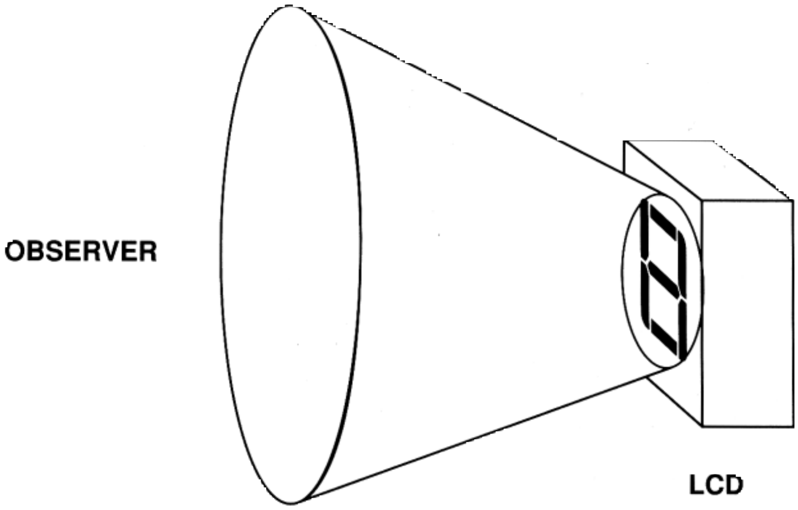


Diagram 8.
A Viewing Cone represents the area within which a person can read a display.

The LCD specifier needs to consider how the display will be viewed: Will the viewer be sitting or standing? At what angle to the display? How wide does the viewing angle need to be?

Crystaloid will ask the end-user about the viewer's "quadrant:" Will the viewer be looking down (from 12 o'clock) or up (from 6 o'clock)? This helps determine the viewing angles needed for a particular application. Critical viewing requirements can be illustrated with iso-contrast plots, which demonstrate contrast at varying viewing angles.

Viewing angle is also a function of cell spacing. Most "standard" LCDs are produced to the Second Minima, with cell spacing of 6 to 8 microns. First Minima LCDs have cell spacing of 3 to 4 microns. A very wide viewing angle of 165° is possible with 4 micron cell spacing. Reduced spacing also speeds up response time.

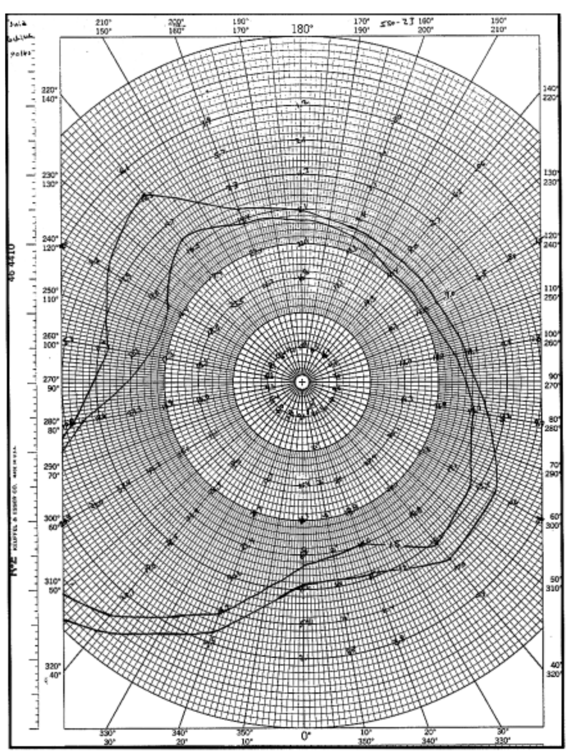


Diagram 9.
Typical isocontrast plot of an LCD. The plot is an objective measurement of image contrast at various viewing angles.

Display Appearance

Image Contrast

Contrast is primarily a function of the ambient lighting conditions and the appropriate selection of positive or negative images. A Crystaloid Applications Engineer will help you achieve the highest possible contrast for your LCD's ambient lighting conditions.

Contrast is influenced by several factors. The higher the rms voltage, the greater the contrast. Polarizer efficiency contributes to higher contrast, as does the specific type of LC fluid.

Segment Notation

The sections of the LCD that act as shutters—turning ON and OFF to form the display's images—are known as segments.

The segments are created by transparent indium tin oxide (ITO) electrodes that are patterned on the LCD glass. Numbers from 0 to 9, as well as some letters, can be formed using a 7-segment digit. A 16-segment digit can form all the numbers and all the letters, as well as some symbols.

Because dot matrix displays have many more segments, their alphanumeric symbols become less angular and more natural. Dot matrix displays can also create small graphic designs.

The number of segments desired in a display will influence how it is driven (see "LCD Drivers," page 14).

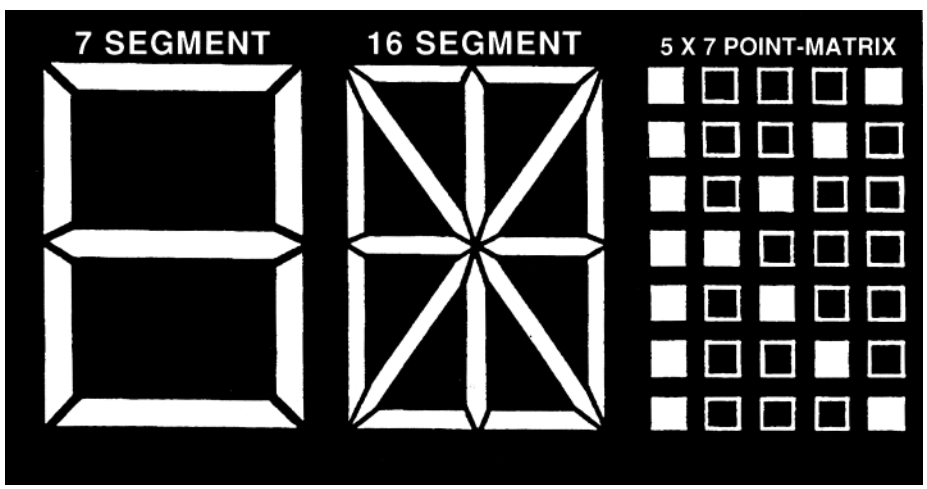


Diagram 10.
7-Segment Display
16-Segment Display
5 × 7 Point Matrix Display

Display Appearance

Function Indication Displays

In addition to alphanumeric symbols, LCDs can present small pictures or icons. For example, the display below indicates correction procedures for a photocopier. These images do not vary—they only turn ON or OFF—so they are known as "dedicated" images.

LCDs can also display bar graphs, circular graphs, pie charts, and numerous other graphic representations of function, speed, pressure, direction, etc. Any of these graphic representations can be placed alongside alphanumeric images. LCDs can even be made to look like analog displays.

Diagram 11.
A function indication LCD for a photocopier.

Response Time

LCDs typically have a response time of 50ms at 20°C, with advanced models as fast as 10ms. A standard LCD can track a 10Hz signal if required; the unaided human eye can hardly comprehend data at that rate.

Color Images & Backgrounds

There are numerous methods to achieve color in LCDs, as shown in Table 3.

TABLE 3: COLOR OPTIONS

Color Techniques	Reflective	Transmissive	Transflective
Multicolor Front Polarizer	✔	N/A	✔
Standard Single-Color Front Polarizer Red, Blue, Neutral, Gray, Green	✔	N/A	✔
Color Ink (silk-screen) Process (Infinite Color Selection)	N/A	✔	✔
Custom Color Rear Filter	N/A	✔	✔
Custom Overlays & Silk-screen (Front)	✔	✔	✔

Chapter 5

LCD Connection Options

When selecting a connection method, the LCD specifier needs to consider the cost of assembly, the cost of the connecting method, and the application's typical environment.

Dual-In-Line Pins

Dual-In-Line (DIL) pins have been used almost since LCDs became available and are useful for very harsh environments. DIL pins allow rapid, self-aligning connection of the LCD. The pins are either soldered to the Printed Circuit Board (PCB) or inserted into plug-in strip sockets. Their highly-conductive, corrosion-free contacts offer rigid support, even under shock and vibration.

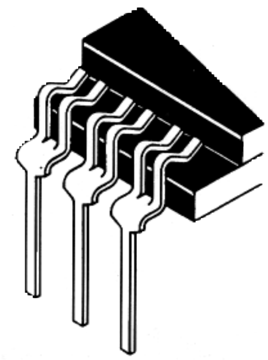


Diagram 12.
DIL pin connector

Elastomeric Connectors

Elastomeric connections offer fast assembly/disassembly, no soldering, non-abrasive contact pads, and self-alignment. These connections are frequently used on small instruments, where space is restricted. Although they are resistant to shock and vibration, elastomeric connections should not be used in extremely harsh environments without special attention being paid to the sealing techniques.

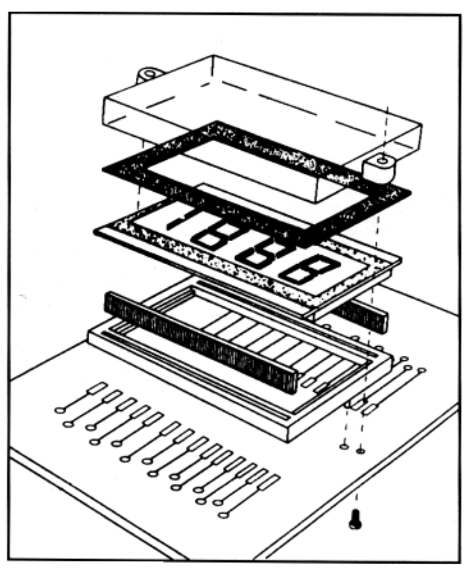


Diagram 13.
Elastomeric connector

LCD Connection Options

Flex Connectors

Both the LCD and the PCB are attached to a flexible connector using a process of heat and pressure (heat seal) and anisotropic connective film (ACF). These connectors are used in more rugged applications, where movements could cause pin connectors to break. Flex connectors are also frequently used on very large LCDs or applications requiring remote mounting of the driver boards. This method of connection is becoming increasingly popular as designers find more applications for flexible connectors.

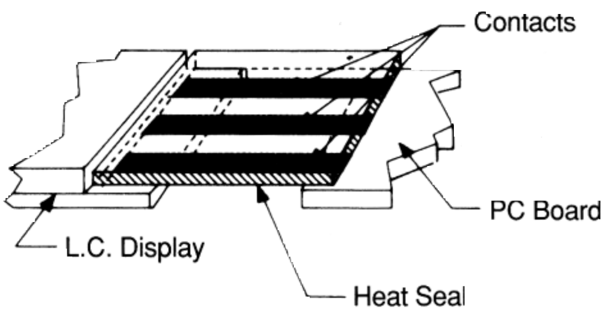


Diagram 14.
Flex connector

LCD Drivers

General Considerations

There are two types of LCD drivers: direct and multiplexing. Both types have advantages and disadvantages.

**TABLE 4:
COMPARISON BETWEEN DIRECT & MULTIPLEXING DRIVERS**

Consideration	Direct	Multiplex
Number of Terminals	Many	Few
Number of IC Drivers	Many	Few
Driver Cost	Highest	Lowest
Crosstalk	None	Low to High
Operating Voltage Range	Wide	Almost Fixed
Temperature Compensation	None	–8mV per °C
Driving Wave Form	Simple	Complex
High Temperatures	Excellent	Good
Low Temperatures	Very Good	Good
Segments	1 to 160	40 to 6,000
Viewing Angle	Wide	Narrow—Is a function of the MUX Radio
Contrast Ratio	High	Low—Is a function of the MUX Ratio
Negative Images	Excellent	Poor

Direct Drive

Direct drive (also known as "static" or "simplex" drive) means that each segment of the LCD has an independent connection to the driver. Direct drive LCDs have the highest contrast over the widest temperature ranges. They are frequently used in outdoor applications.

Direct drives typically require drive frequencies between 30Hz and 60Hz. Frequencies below 30Hz can make the display flicker, while frequencies above 60Hz will cause excessive current draw. This is an important consideration, especially for battery-mode operations. If a LCD exceeds its voltage and frequency limits, OFF segments can become inadvertently energized. This partial activation of a segment is known as "crosstalk" or "ghosting."

As you increase the number of segments, the number of independent connections and drive circuits can become complex, as shown in Table 4.

LCD Drivers

TABLE 5

Product	Backplanes	Drive Lines	Total
3½ digit watch	1 2	23 12	24 14
8 digit calculator	1 4 8	64 16 8	65 20 16
2 x 16 char. DMM 5 x 7 plus cursor	1 8 16	1,280 160 80	1,281 168 96
128 x 240 graphic display	1 64 128	30,720 480 240	30,721 544 368

LCD Pin-Out Requirements as a function of the number of backplanes (direct drive LCDs have only one backplane; multiplex drive LCDs have more than one).

Multiplex Drive

Multiplex (or "MUX") drives can simplify the connection requirements of a LCD. MUX displays have more than one backplane. Multiplexing means that a common connection can sequentially address a segment on each of the backplanes (see Table 5 above). The number of segments that one common connection addresses is the multiplexing ratio. For example, a "driving duty of 1/3 MUX" means the LCD has three backplanes.

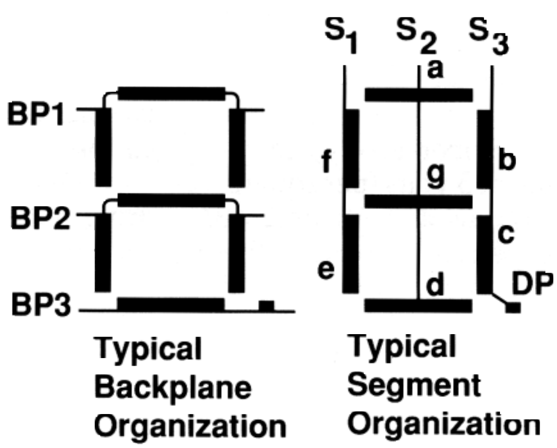


Diagram 15.
Typical Backplane Organization
Typical Segment Organization

LCD Drivers

Multiplexed segments are grouped into a matrix. MUX drives produce amplitude-varying, time-synchronized waveforms for both a row line and a column line so as to address a particular segment.

Because multiplex LCDs have voltage applied to the OFF segments, the designer must be careful to minimize voltages that could produce crosstalk. Voltage bias levels are used to divide the voltage, and thereby reduce the probability of crosstalk. For example, a driver with a 1/3 bias is divided into three levels: V_{dd}, 2/3 V_{dd}, and 1/3 V_{dd}.

Segment contrast is relative to the rms voltage on the backplane minus the frontplane waveforms at a given matrix location. Waveforms and their resulting rms voltage can either be above the saturation voltage (V_{on}) or below the visual threshold voltage (V_{off}). The voltages can be adjusted to optimize the contrast of the segments.

IC manufacturers will choose bias levels and waveforms that will optimize the LCD's performance. The end-user can fine tune the voltage levels to match the properties of the LC cell by varying the external resistor dividers. The drive voltage can also be set with a trim pot.

As the number of backplanes increases, the V_{on}/V_{off} ratio approaches unity (1:1) because of the correlation of properties of the driver waveforms. Maximum acceptable multiplexing is ultimately a subjective decision for the end-user, for as you increase the MUX ratio you will:

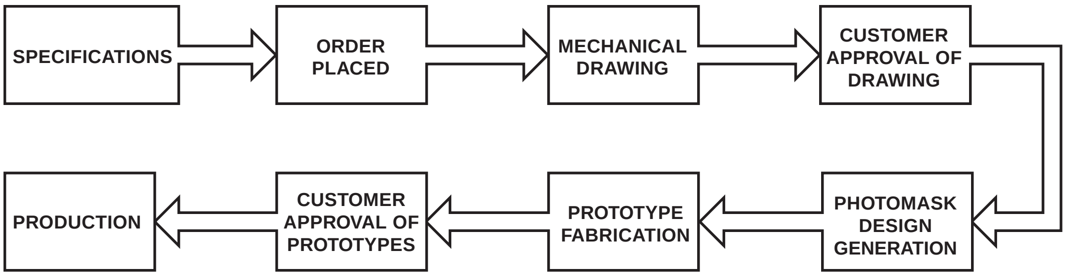
- *Decrease* the segment contrast.
- *Decrease* the viewing cone (viewing angles).
- *Decrease* the temperature range.

Energy Consumption

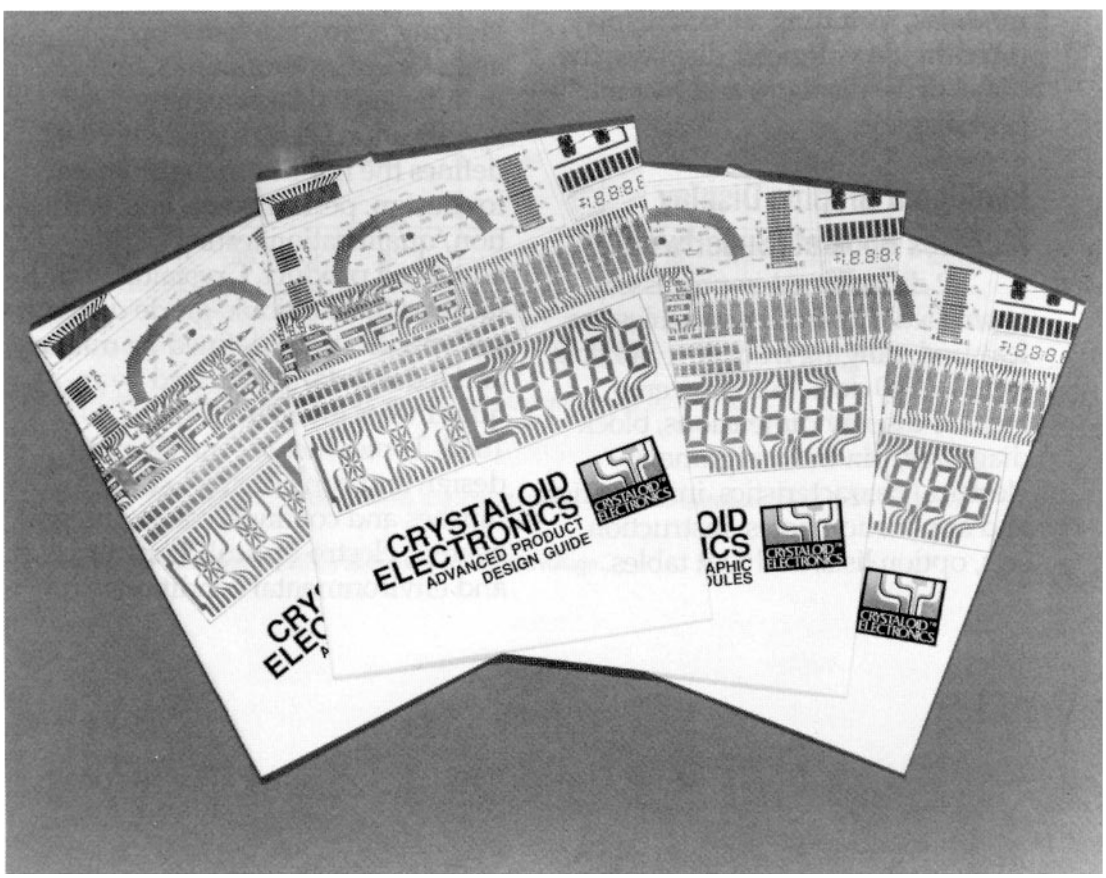
LCDs normally require very little energy to operate—typically 5μA to 25μA at 5 volts (per square inch) for a TN display. As discussed in the 'Temperatures" section, there is a low temperature voltage coefficient which is particularly important for MUX LCDs. In addition, auxiliary lighting or heating will require supplementary energy.

All LCDs require a pure AC drive voltage. Inadvertent DC voltage, such as a DC component in an AC signal, can significantly reduce the life of LCDs and must be limited to 50mVdc.

The Next Step For LCD Specifiers



Crystaloid has several publications, specification aids and resource materials to assist designers and specifiers of LCDs. These are shown in the adjacent illustration and described on the following page. The next page also provides guidelines for creating LCD specifications.



The Next Step For LCD Specifiers

Besides this primer, the publications below can help in creating an LCD specification to meet your requirements. Most of these are available on Crystaloid's Web site (www.crystaloid.com) or by calling toll free 1-888-BEST-LCD.

Machine Design Reprint

Edward M. Stiles, III, Director of Engineering at Crystaloid, authored "Not Just for Laptops Anymore", which was published by Machine Design magazine. This article contains some of the same information as this primer, but has additional information on multiplexing, including a MUX drive waveform diagram that is helpful in visualizing this drive concept. (Not available on Web site.)

Short Form Catalog

This 24-page catalog contains information on TN and STN LCDs, including alphanumeric segmented and dot matrix displays, intelligent graphic modules, and information on the safe handling and use of LCD assemblies. Catalog data is comprised of outline drawings with installation dimensions, pinout data, electrical specifications, and a custom display design checklist.

Liquid Crystal Displays Product Guide

For those who want a concise overview of Crystaloid's most popular LCDs, this guide provides three tables organized by product type and part number. Each table also provides a description of display configuration, character size, glass or module size, drive configuration, backlighting options, and operating temperature range.

TS-LCD Module Data Sheet

This data sheet contains detailed data on Crystaloid's touch screen LCD modules. General specifications include dot matrix and touch screen patterns, display addressing, cycle time, power consumption and controller output. Touch screen scanning options are described in detail. Tables and drawings provide I/O data and pinouts. Installation drawings and block diagrams complete the data sheet.

Using Customized LCDs

This white paper was authored by Charles E. Holland, Crystaloid's sales manager. It describes recent technology developments in passive TN, STN and dichroic display technology. It also discusses the implications of these developments in the use and specification of LCDs. (Available only on Crystaloid's Web site — www.crystaloid.com.)

FastQuote Form

This form can be used to specify the critical characteristics of custom-designed LCDs. There are 12 different categories of information encompassing 44 possible data fields. By completing and submitting this form, Crystaloid will supply a fast, customized LCD quotation tailored to your exact specifications. The form can be completed on-line at Crystaloid's Web site, by faxing a hard copy or by sending a business reply mail version to our Hudson, OH office.

Glossary

Active Addressing—A multiplexing drive method that helps overcome response time limitations and reduces ghosting in passive matrix STN displays.

Active Area (a.k.a. Effective Area, Image Area)—Within the viewing area of LCD glass, the area inside a perimeter containing the conductive electrodes (ITO pattern).

Active Elements—The electrically conductive parts of an LCD, which form an image that contrasts with the LCD background when voltage is applied.

Active Matrix (a.k.a. AMLCD, TFTLCD)—A type of LCD flat-panel display in which each pixel is controlled by one to four thin film transistors (TFTs), which provides high resolution and allows video rate information, such as that found in VGA monitors on portable computers. Compare to Passive Matrix.

Additive Color—Color produced by combining colored light, usually red, green and blue (typically employed in VGA displays).

Annunciator—Within the LCD image, a word or symbol (i.e., active element) with a dedicated meaning. For example, "Lo BAT."

Array Process—Method of manufacturing whereby displays are arranged in rows and columns on a large laminate, and separated just prior to filling them with liquid crystal fluid.

Backlight—A light source that allows LCD use in low or no ambient light conditions; found in transmissive and transflective LCDs.

Bezel—A frame of plastic or metal, fitting over the LCD glass, to protect the edges of the glass and act as a pressure device, compressing the elastomer connector between the PCB and LCD glass.

Birefringence—The separation of a light beam into two diverging beams as it penetrates a doubly refracting object. The two beams are orthogonal to each other and known as ordinary and extraordinary.

Cell, LCD—Device used for information transfer, containing liquid crystal material, sandwiched between two electrodes, typically a common plate and pattern plate.

Cell Gap (a.k.a. Cell Spacing)—Usually expressed in microns, this is the thickness of the liquid crystal layer between the LCD's glass plates.

Chip-On-Board—Typically, an IC driver chip mounted on the PCB used in an LCD module, usually covered with epoxy for environmental protection.

Chip-On-Glass—Technology used to mounts an LCD driver to the contact edge of the LCD glass.

Chip-On-Flex—Technology used to mount an LCD driver to a flex connector that is mounted to the LCD contact edge.

Cold Cathode Backlight (CCFT)—A type of fluorescent tube backlighting or edge lighting, typically used in medium to large LCD graphic modules.

Common Plane—The LCDÕs patterned electrode (ITO) common to all segments on the same substrate plane. In multiplexed addressing of an LCDÕs active segment, duty ratio is determined by the number of common planes.

Contact Edge (a.k.a. Contact Ledge, Contact Pad, Pads)—The electrical connection area of an LCD, usually an extension of the segmented pattern plate, which contains conductive leads and traces.

Contrast—The numerical value, that represents the luminance difference between light and dark areas of a display, i.e., between active elements and the background.

C-N Transition Point—The transition temperature, below which liquid crystal molecules lose their nematic characteristics (parallel orientation) and become solid or crystalline.

Glossary

Chromaticity—The numerical quantification of color. Typically this is specified on the CIE 1931 chromaticity chart as (always lowercase) x and y.

Design Eye Position (DEP)—The specific angle or angles at which an individual will view a display.

Dichroic LCD (a.k.a. Guest-Host LCD)—An LCD that uses a liquid crystal fluid (host) containing a dye (guest) to manipulate light, instead of using polarizers.

DIL—Dual-In-Line, a type of connection with two parallel rows of pins or contacts.

Direct Drive (a.k.a. Static Drive or Simplex Drive)—An addressing method in which each conductive lead on the LCD's contact edge has an independent connection to only one active element. Compare to Multiplexing Drive.

Dot Pitch—A measure of distance between the centers of LCD matrix dots; the closer the dots, the smaller the dot pitch and the finer the image resolution.

Dot Matrix—A group of dots/pixels that can be electronically addressed to form a character or symbol. Generally, the minimum matrix size is five dots across by seven dots down, which can be used to form Arabic letters and numbers.

Dot—The smallest active element of an LCD matrix display that can be individually addressed (turned on). Also see Pixel.

DSTN—Double-layer Supertwist Nematic, a passive matrix LCD technology that uses two display layers to counteract the color shifting that occurs with conventional supertwist displays.

Duty Ratio (a.k.a. Mux Rate)—In a multiplexing drive scheme, 1/N, where N is the number of common planes in the LCD, sometimes expressed as 1/N MUX.

Elastomeric Connector—an LCD connection method consisting of sequentially spaced conductive and non-conductive material typically made from flexible silicon rubber.

Electrophoresis (a.k.a. DC Plating)—An unintended effect whereby conductive particles from one piece of LCD glass are transferred through the liquid crystal fluid and deposited on the conductive surface of the opposite piece of glass, ultimately creating a low resistance path or electrical short. This results from a DC component in the LCD's applied voltage, which ideally should be pure AC.

Fill Hole (a.k.a. Fill Port)—A gap left in the epoxy seal at one end of an LCD assembly and used to fill the cell space with liquid crystal fluid; it may be evidenced by the small mound of epoxy used to seal the cell after filling.

First Minima—An LCD construction technique in which the cell spacing is optimized with the liquid crystal material, to allow a maximum extinction at a specific wavelength. This technique is typically used to maximum contrast and viewing angle. The spacing is different for each LCD fluid, but is always narrower than in second minima LCDs.

Flat Panel Display—A thin display screen with minimal curvature that could use any of several technologies, including liquid crystal devices.

Font—The style of character or digit used to form an LCD's active element pattern that displays alphanumeric information.

Ghosting (a.k.a. Crosstalk)—A condition where OFF pixels, dots or segments are partially activated, producing faint images. This is more of a problem with Multiplexing Drives than Simplex Drives.

Guest-Host LCD—See Dichroic LCD.

Heat Seal—A flexible adhesive connector bonded by heat to the contact edge of the LCD glass.

Image Area—See Active Area.

Ink Overlay (a.k.a. Ink Process)—Screen printing of transflective or opaque inks on the display for the purpose of adding color or masking active areas.

Interconnect Dot (a.k.a Common Dot)—A drop of silver impregnated epoxy used to make an

Glossary

electrical connection between the common plate and a point on the LCD's pattern plate. This allows an electrical connection to the common plate.

Inverter, DC to AC—Converts DC to AC at a high frequency, which is useful in powering electroluminescent lamps used for LCD backlighting.

Isocontrast Plot (a.k.a. Radar Plot)—Usually, a polar plot showing contrast versus viewing angle; the individual curves represent the display contrast at a specific viewing angle. This plot is very similar to a topographical map.

Isotropic Stage—A condition in which liquid crystal molecules do not exhibit nematic characteristics. Since the molecules can no longer twist light, there is no discernable difference between activated and inactivated areas. (Also see N-I Transition Point.)

ITO—Indium tin oxide, the material used to form the electrodes on the common and pattern plates of an LCD.

LCD (Liquid Crystal Display)—A visual display device that uses liquid crystal material and an electrical field to manipulate light and produce an image.

Leads—The conductive traces on the contact edge of the LCD glass.

Liquid Crystal—A liquid compound that has a combination of liquid and crystalline properties over a specified temperature range. The most common type used for LCDs is a nematic fluid, consisting of rod-shaped bipolar molecules and capable of twisting (rotating) polarized light when in the OFF state (i.e., with no electric field applied).

Luminance (fL)—A unit measure of light that is transmitted through or radiated from a material or surface, expressed per unit of area.

Module, LCD—A display device consisting of an LCD connected to a PCB containing drive electronics and possibly other features, such as controllers, temperature compensation circuits and backlight power supply.

Multiplexing Drive (a.k.a. MUX)—An LCD connection method using multiple backplanes with common connections to sequentially address more than one active element, thereby reducing the number of connections between the LCD and its electronic drive.

N-I Transition Point—The transition temperature, above which liquid crystal molecules lose their nematic characteristics (parallel orientation) and become isotropic (randomly orientated).

Negative Image—Light LCD image on a dark background.

Passive Matrix—An LCD configuration, commonly using STN technology, that creates images by selectively addressing individual dots in a matrix with a multiplexing drive scheme. Compare to Active Matrix.

Pattern Plane—LCD glass plate having the image pattern and active element connections.

PCB—Printed Circuit Board.

Pin-Out—The connector pin configurations of a LCD where the electronic drive lines are attached.

Pitch—The center dimension of adjacent conductive traces, dots, or connector holes.

Pixel—An abbreviation for picture element, which is the smallest active element that can be electronically addressed in a display.

Polarizer—A material that causes light to be transmitted along only one axis. Polaraizers are critical in the operation of most LCDÕs, as the liquid crystal manipulates polarized light. A TN LCD typically has polarizers on both sides of the LCD cell.

Positive Image—Dark LCD image on a light background.

Reflective LCD—An LCD that uses only ambient light, which is bounced back to the viewer's eye from a reflector (typically aluminum foil) or diffusing material bonded to the rear of the display.

Glossary

Response Time—The time required for a display element to fully activate from the moment power is applied, or the time required for an element to fully deactivate from the moment power is removed.

Saturation Voltage—RMS voltage required to turn LCD fluid 90% on.

Segment—An active element of a digit, typically one of seven in a numeric-only digit, or one of 16 in an alphanumeric digit.

SIL— Single-In-Line, a type of connection with a single row of pins or contacts, typically used as an edge connector on LCD glass.

Static Drive—See Direct Drive.

Supertwist (STN)—A type of liquid crystal cell in which the bipolar liquid crystal molecules are rotated as much as 270 degrees between each surface of the glass plates that form the cell. This technologyÕs operation is based on changing from one birefringent state to another, allowing improved contrast and viewing angles at very high multiplex rates.

Threshold Voltage—RMS voltage required to turn LCD fluid 10% on.

Total Specular Reflectance (TSR)—The total amount of reflection from the displayÕs front or first surface.

Transflective LCD—An LCD constructed with both a backlight and reflective backing bonded to the rear of the display, which enables light to pass through as well as reflecting ambient light from the front.

Transflector—A material that has both transmissive and reflective properties. This type of material is applied to the rear of a display to form a transflective display.

Transmissive LCD—An LCD that does not have a reflector or transflector laminated to the rear of the display; a backlight must be used in this type of LCD design.

Twisted Nematic (TN)—A type of liquid crystal cell in which the bipolar liquid crystal molecules are rotated 90 degrees between each surface of the glass plates that form the cell.

Viewing Angle—The included angle, defined by a cone whose axis is perpendicular to the display surface, over which image contrast is acceptable.

Viewing Area—The area contained within the inside perimeter of the LCD bezel or LCD glass epoxy seal.

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