Informational Document

LCD Group

ATFT LCD Considerations: A General Overview

April 2008

Discusses choosing an LCD panel from the standpoint of Optical Performance, Displayed Content, Environment, Interfacing, and Technology

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Introduction

When choosing an LCD panel, the first thing that comes to mind is the visual appearance of the application on the device. The appearance of the image, whether it be still or moving, is very dependent on the optical characteristics of the LCD panel. The optical characteristics of every panel are limited - or enhanced - by the nature of the technology utilized. Also, the ambient environment will dictate which attributes are desirable and may, therefore, affect which technology should be utilized.

Optical Performance Considerations

Power, Display Thickness, and Brightness

The brightness of the LCD panel is generated by the light behind it (backlight). Two types of devices are used to produce a suitable light source for the backlight: Cold Cathode Fluorescent Tubes/Lamps (CCFTs or CCFLs) and Light Emitting Diodes (LEDs). Panels using LED backlight technology are becoming more prevalent, as these provide some advantages over the CCFT approach. LEDs allow for a slimmer overall panel and reduced power consumption — resulting in increased overall efficiency.

Panels that are larger than 15 inches diagonally primarily use the CCFT backlighting technology, as more overall light energy is required to accommodate performance requirements. On panels that are 15 inches or smaller, LED backlighting is becoming more common as the market demands slimmer designs and increased power efficiency.

Both CCFTs and LEDs can be mounted either behind the glass of a display or on the side. Both approaches require a light guide to direct light through the panel evenly. The preferred method for smaller panels is the side lighting approach (Fig. 1).

In a similar manner, LEDs are mounted on the edge (Fig. 2). In the side-lit configuration, the LEDs are mounted on the edge of a plastic light guide and the light is focused into the light-guide. The edge-lit configuration offers a thinner package with lower power consumption and is the most widely-used system in the industry.

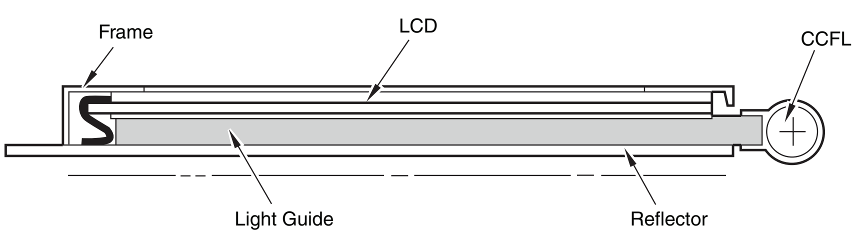


Fig. 1: Side-lighting approach using a CCFL (CCFT)

The amount of light needed to pass through the display is a factor that affects the power consumption to the greatest degree. In order to optimize the efficiency of the backlight, a number of polarizers or optical films, such as Brightness Enhancement Films (BEFs) and Depolarizing Brightness Enhancement Films (DBEFs), are placed between the backlight and the LCD. The optical efficiency of these films is theoretically only 50%, but the actual efficiency can be much less. Additionally, the amount of light going through the LCD itself is affected by the size of the transistors and interconnects that are on the back of the first piece of glass through which the light passes. Overall, the loss of light from the actual source to what is finally measured is considerable.

Terms such as chromaticity, color space, gamut, and spectrum become important when considering the color and uniformity of the backlight. This is true for LED or CCFT backlight options.

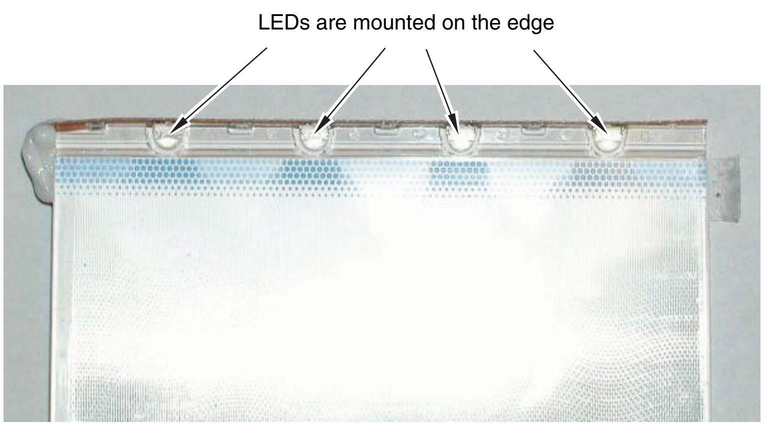


Fig. 2: LEDs mounted on the edge

Viewing Angle

Historically, LCD viewing angles were rather limited. To see the image clearly, it had to be viewed straight on so that contrast ratio and color gamut would be optimal. When moving from side to side or up and down, the contrast ratio dropped and the colors became less saturated. This was especially obvious with early LCD-based laptop computers.

LCD technological advances have improved this situation dramatically. There are technologies today that provide very wide X and Y axis viewing angles and maintain contrast ratio and color gamut, such as Sharp's Advanced Super View (ASV) panels.

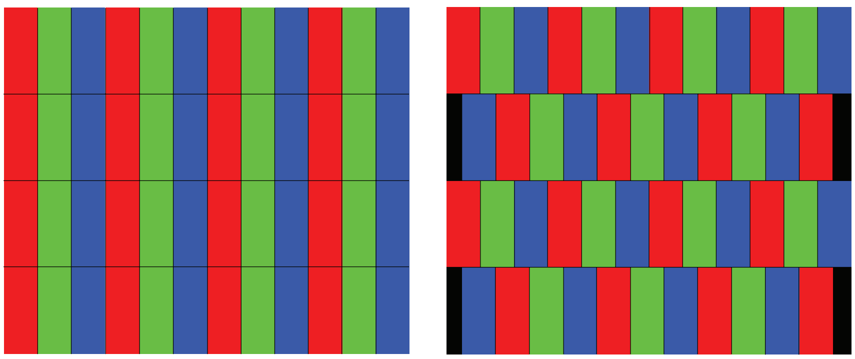
Contrast Ratio

To achieve very high contrast ratios, some newer displays are normally black — meaning when no field is applied, these displays will look black. Conventional amorphous Silicon Thin-Film Transistor (TFT) displays are normally white. By going to a normally black display, it is much easier to achieve zero bright pixel defects.

Selecting LCDs for Viewing Video Content

Stripe and Delta Dot Format

When designing a display, the viewing content is an important factor. Optimum displays for viewing graphics can be different from those used exclusively for video. The first step — especially for small displays — is to determine the format of the pixels. There are two different configurations: stripe and delta. In general, for video only (especially in small formats), using a delta format is advantageous. For graphics only (particularly small text), using the stripe format provides the most benefit. For larger formats and higher resolutions, stripe format is generally used for both types of content.



RGB Stripe RGB Delta

Fig. 3: Dot format patterns

Response Time

Response time is an important consideration that is also content dependent (video versus graphics). With new, larger, flat panel television displays, and higher contrast ratios, the ability to see an image trail in conjunction with fast motion is enhanced. These panels need faster response times; not just full-on to full-off, but also faster transitions for grayscale or pastel colors. Response time is affected by such things as the LC (space between the two glass panels), viscosity, dielectric anisotropy, and elastic constant.

The liquid crystal material may be adapted to improve response times, but may result in a loss of contrast ratio if not done properly. When such enhancements are made, vendors such as Sharp have paid considerable attention to guarantee a high-quality result. By tuning between response time and contrast ratio with Sharp's Advanced Super View technology, a satisfactory result is obtained.

Power Management

With mobile displays, conserving power is important - and there is also the consideration of video versus graphics in terms of power usage. Full motion video, which is updated constantly, is a worst-case scenario for power consumption. If a simple line status display or steady graphics are shown on the display, the power consumption is less. To address this, Sharp has developed a technology called Ultra Low Consumption (ULC). It recognizes the difference between three different modes of display, from static text to full graphics to full video, and switches automatically between them to conserve power.

Optimizing LCDs for Outdoor or Direct Sunlight Viewability

A display becomes less viewable in bright ambient light. This is true for both light-emitting panels such as an Organic LED (OLED) or for a transmissive LCD displays that use a backlight. In a bright ambient setting, light from the sun competes with the light from the display, reducing the perceived contrast. Fortunately, there are several ways to deal with this inherent problem.

Backlighting Methods

One solution is to build a bigger backlight behind the display. Several companies have produced displays using this “brute-force” approach. This has been done, for example, in kiosk applications where the colors are quite viewable in bright sunlight. It is difficult, however, to dim such a display; thus, in a changeable environment, it is a challenge to reduce the brightness for lower ambient conditions.

Contrast Enhancement Films

Another approach is to take a moderately bright backlight and add contrast-enhancement films to the front. Interference films exist that can be applied so that reflections from the face of the display are reduced. Using index coupling fluids as an alternative to these films further reduces reflections and allows relatively more of the display light to pass through.

An important consideration regarding contrast enhancement films is that when the film is added, it must be on the very top layer of the LCD panel stack (surface) for maximum effect. If another optical layer is added, such as a touch overlay sensor or vandal glass, this can create an issue because of the light-attenuating properties of the glass or film, and also because the contrast enhancement film is no longer the top layer (thus reversing some of its benefits).

Reflective Mode

Another method of designing for bright ambient light levels is to make a purely reflective display. Sharp has developed a technology called Highly Reflective TFT (HR-TFT), most commonly seen in handheld video games. HR-TFT works in a range from bright sunlight down to a relatively well-lit room. Of course, in a darkened room, the display performance is not sufficient.

Transflective Mode

Beginning with a reflective display, a display can be crafted that works well in a bright ambient or moderately bright environment. By adding an aperture in the reflector (this reflector is the drain pad of the field effect transistor), it is possible to get enough light from a backlight (either CCFT or LED) to see the display in darker environments. Moving to a brighter ambient condition, the reflected light will begin to dominate.

In a well designed system, there is a seamless transition between the backlit and reflective modes. The rear polarizer is in essence a one-way mirror, reflecting light from the front and transmitting light from the rear. Sharp's Advanced TFTs have one further innovation: selective cell-gap control. In the transmissive region (where light only passes in one direction), the thickness of the cell gap is equal to *2n*. In the reflective region, the cell gap is equal to *n*. The light coming through the display is reflected and goes back a second time; therefore, the optical path length is uniform between the transmissive and reflective areas.

Sharp also deposits different color filters in the reflective and transmissive regions. The combination of these two techniques provides optimal uniformity of color, making Sharp's transflective technology (Advanced TFTs) unique compared to other transflective products.

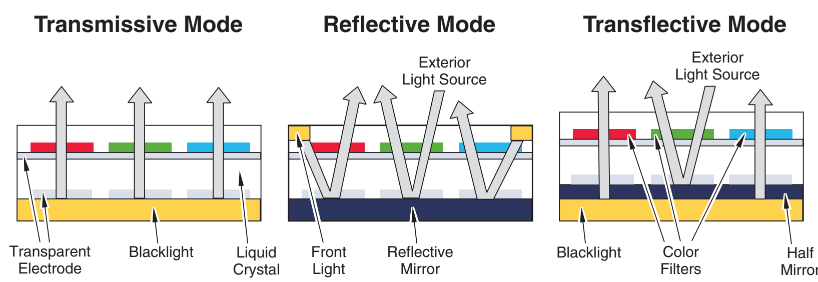


Fig. 4: Mode comparisons

LCD Interface Options: The Three Common Ways to Interface to an LCD

Third Party A/D Boards

A third-party A/D board takes the video output from a computer that is intended for a CRT and translates the signals into LCD flat panel-compatible signals. These interfaces are the simplest because they use existing solutions that are commonly available on PCs. These solutions are often used to replace an existing CRT monitor with an LCD and often include cable solutions and power supplies, offering an almost "plug-and-play" approach. The downside is that they can be comparatively expensive.

Single Board Computers with Integrated Controllers

At this level of interface, a single-board computer with a built-in LCD controller is utilized. Many of these products are available in kits with all of the accessories included. The difference from the first approach is that the controller is embedded with a processor that must be included. These can be very expensive. The advantage of this approach is tight integration on a single board.

Custom Designs Using Off-the-Shelf Chip Controllers

The previous levels of interface are basically self-contained solutions that do not require extensive design expertise. This level of interface requires higher-level design capability. It is appropriate for the customer who is already developing their own custom CPU board and wants to integrate a flat panel controller, such as those available from a number of vendors. The advantage is that these components are much less expensive. This approach requires software expertise to write (or integrate) the required drivers for the operating system. Some vendors offer microcontrollers with integrated hardware that provide LCD interface capabilities, which may help reduce time to market.

TFT Specific Interfaces: The Lowest Level of Integration

Digital LCD Interfaces

CMOS and TTL display interfaces are still in use today, but we are seeing more and more Low Voltage Differential Signaling (LVDS) or LVDS variants being used — especially for larger displays. LVDS provides the benefit of being able to send signals over a relatively long distance though a cable. Other advantages include a reduction in the number of conductors needed, as well as reduced EMI/RFI emissions and greater noise immunity. The drawback is that the cable is more difficult to fabricate and a transmitter-receiver chip is required on both ends.

The Digital Video Interface (DVI) interface is becoming more commonly utilized as an emerging standard. Often, with respect to smaller displays, the graphics interface chip or the controller chip must be provided separately to the display. DVI is being used as a digital interface from LCD to PC to take advantage of the full capability of high-end graphics engines.

Another set of interfaces exist for video applications for which video interfaces such as NTSC, PAL and RGB are built into the display. They are quite different from conventional graphics interfaces.

The DVI interface was authored by the Digital Display Working Group (DDWG), formed in September of 1998 to provide an open IP, royalty free-environment for digital display standardization. The DDWG is lead by Intel, Silicon Image, Compaq, Fujitsu, HP, IBM and NEC.

TFT LCD Interface Signals

Interface signals follow three categories: Control Signals, Data Enable Signals, and Data Lines.

- Control Signals: These may differ by type and manufacturer; in general, the control signals include the CK, Hsync, and Vsync (mentioned below), plus Data Enable and the RGB data lines.
- Clock Signals (CK): These are for shifting RGB data into the LCD panel.
- Horizontal Synchronization Signals (Hsync): There are n number of CK periods per Hsync period where n is the number of RGB pixels in a line. This signal marks the point at which the current line ends and the new line begins.
- Vertical Synchronization Signals (Vsync): There are m number of Hsync periods per Vsync period where m is the number of vertical lines in the display. This signal marks the point at which the current frame ends and the new frame begins.
- Data Enable Signal (ENAB): This signal indicates when screen data is being sent to the display. The signal determines the horizontal position of the data on the LCD screen,
- Data Lines (18 or 24 data lines)

Techniques to Increase Viewing Angles

The typical approach to increasing viewing angle is to add a compensation film to the front of a display. Compensation film works fairly well, but only gets as large as approximately140 x 120 degrees. The simplest alternative solution is to use In Plane Switching (IPS) technology. IPS uses lateral electric fields applied within the cell structure, and requires higher driving voltages that limit the operating temperature range. Sharp Advanced Super View Technology provides the best overall performance.

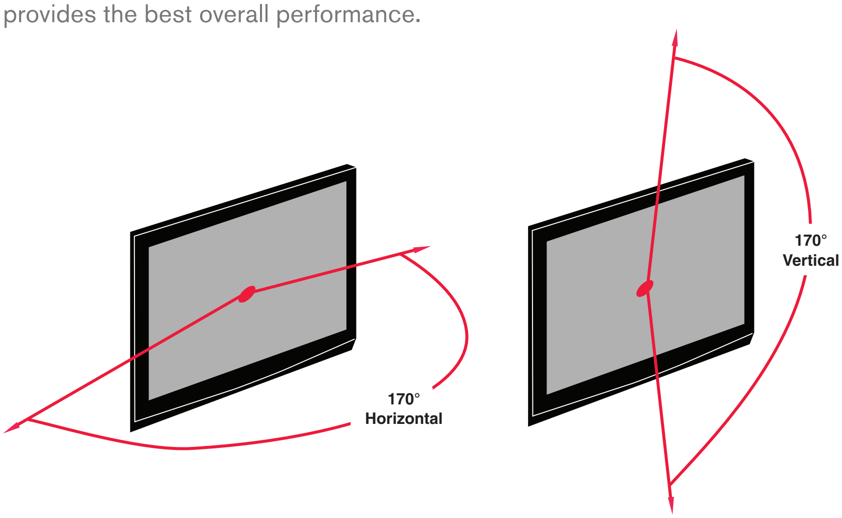


Fig. 5: Horizontal and vertical viewing angles

Special Considerations for Automotive Applications

The automotive environment is one of the most demanding in terms of shock and vibration, temperature, and humidity. LCDs are typically used in rear seat entertainment, information displays with GPS, and back-up cameras. Rather than conventional Tape Automated Bonding (TAB) interconnections, most Sharp displays for automotive applications use the more robust Chip on Glass (COG) technology in order to withstand shock and vibration. The displays must also be sufficiently bright and able to work in a wide range of ambient light levels, from complete darkness to noonday sun.

Automotive manufacturers are also demanding further environmental considerations. For example, Sharp is rapidly moving toward production of mercury-free backlights for automotive applications.

Another innovation for automotive displays is the self-heating backlight, CCFTs have poor performance at low temperatures and have traditionally been warmed in applications requiring operation at lower temperature ranges. The self-heating backlight uses a unique power supply control method to rapidly bring the CCFT up to a proper operating temperature.

The resulting automotive product improvements are also being made available for factory automation, Test and Measurement, and other non-automotive uses where ruggedness is a key factor.

CCFT Inverter Selection

Many LCD displays use a Cold Cathode Fluorescent Tube (CCFT) for a backlight. These tubes typically require a 600-1,100 volt AC driving source. This voltage is generally supplied by an inverter from a DC source. It is very important to select an inverter with proper electrical characteristics. The two critical parameters are the initial strike voltage and the run-time current.

The strike voltage is the minimum voltage required to assure the tube will always turn on. Once a tube begins to conduct, the voltage required to maintain the light drops dramatically. Also, as a display ages, the strike voltage will generally increase. Sharp specifies a minimum strike voltage and a designer must insure that the inverter can meet or exceed this value. Exceeding the strike voltage is of little concern because when the tube strikes, it will self-regulate. Current will flow, cutting off the rising voltage from the inverter as soon as it strikes.

Most inverters are designed as constant current devices that will adjust voltage to supply the required current. To strike the tube, they ramp the voltage up until the tube conducts. The constant current level must match the display's specifications. If a higher current than the rated value is supplied, the tube will operate, but its life will drop dramatically. Many vendors actually make inverters specified for a given display type, which makes the selection process very easy.

Touch Screen Technologies

There are multiple technologies for touch screens. The most common three are:

- Resistive
- Capacitive
- Surface Acoustic Wave

The Resistive Scheme

The resistive scheme consists of a normal glass panel that is covered with a conductive and a resistive metallic layer. These two layers are held apart by spacers, and a scratch-resistant layer is placed on top of the whole setup. An electrical current runs through the two layers when the touch panel is activated. When a user touches the screen, the two layers make contact underneath the touched area. The change in the electrical field is noted and the coordinates of the point of contact are calculated. Once the coordinates are known to the system processor, a special driver translates the touch into something that the operating system can understand, much as a computer mouse driver translates a mouse's movements into a "click" or a "drag."

The Capacitive Scheme

In the capacitive scheme, a layer that stores electrical charge is placed on the glass panel of the monitor. When a user touches the monitor with his or her finger, some of the charge is transferred to the user, so the charge on the capacitive layer decreases. This decrease is measured in circuits located at each corner of the monitor. The system processor calculates, from the relative differences in charge at each corner, exactly where the touch event took place and then relays that information to the touch-screen driver software. One advantage the capacitive system has over the resistive system is that it transmits almost 90 percent of the light from the panel, whereas the resistive system only transmits about 75 percent. This gives the capacitive system a much brighter and clearer picture than the resistive system.

The Surface Acoustic Wave Scheme

The surface acoustic wave scheme uses two transducers (one receiving and one sending) that are placed along the X and Y axes of the monitor's glass plate. Also placed on the glass are reflectors that reflect an electrical signal sent from one transducer to the other. The receiving transducer is able to tell if the wave has been disturbed by a touch event at any instant and can locate it accordingly. The wave setup has no metallic layers on the screen, allowing for 100-percent light throughput and perfect image clarity. This makes the surface acoustic wave system best for displaying detailed graphics (the other systems have significant degradation in clarity).

Another area in which the systems differ is in which stimuli will register as a touch event. A resistive system registers a touch as long as the two layers make contact, which means that it doesn't matter if you touch it with your finger or a rubber ball. A capacitive system, on the other hand, must have a conductive input, usually your finger, in order to register a touch. The surface acoustic wave system works much like the resistive system, allowing a touch with almost any object, except hard and small objects like a pen tip.

As far as price, the resistive system is the least expensive; but, its clarity is the lowest of the three, and its layers can be damaged by sharp objects. The surface acoustic wave system is usually the most expensive.

Various Active Matrix LCD Technologies

Twisted Nematic (TN)

TN displays contain liquid crystal elements which twist and untwist at varying degrees to allow light to pass through. When no voltage is applied to a TN liquid crystal cell, the light is polarized to pass through the cell. In proportion to the voltage applied, the Liquid Crystal (LC) cells twist up to 90 degrees, changing the polarization and blocking the light's path. By properly adjusting the level of the voltage, almost any grey level or transmission can be achieved.

The voltage applied to the LC cells is switched "ON" and "OFF." The difference between the ON and OFF voltages can be very small in TN displays with many rows and columns. For this reason, the TN device is impractical for large displays with conventional addressing schemes. This problem was solved in the mid-1980s with the invention of the super-twisted nematic (STN) display. In this type of display, the director rotates through an angle of 270 degrees, compared with the 90 degrees for the TN cell.

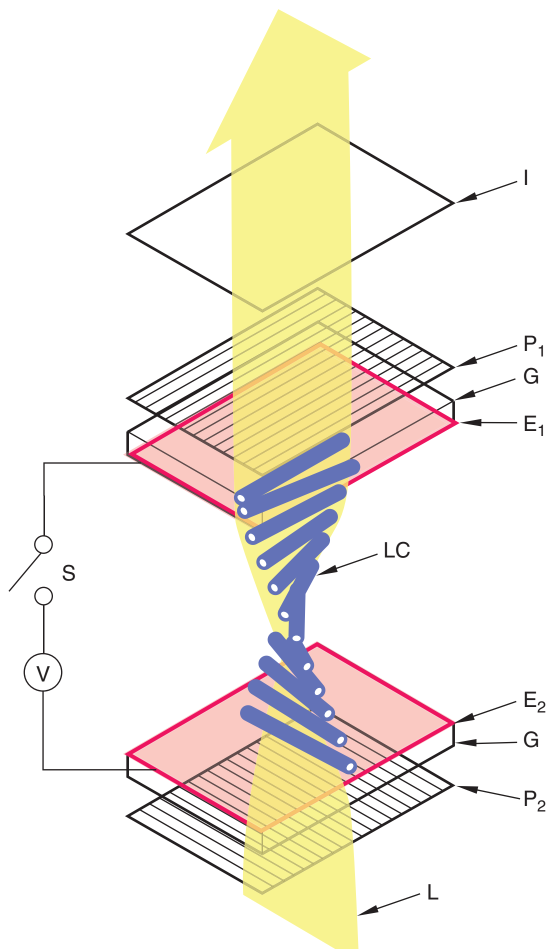


Fig. 6: Construction and operation of a single pixel of a twisted nematic (TN) LC-cell. No voltage applied = field-OFF state

Addressing is the technique used to switch the pixels on and off so that an image may be created. There are two main addressing methodologies: direct and multiplexing. Direct addressing is good for displays where there are only a few elements that need to be controlled. With direct addressing, each pixel in the display has its own drive circuit. A microprocessor must individually apply a voltage to each element. An example is found in older wristwatches and similar devices.

Multiplex addressing involves a larger number of pixels. When the elements are in a regular order, they can be addressed by their row and column, instead of each element being driven separately - thus reducing the complexity of the circuitry since each pixel no longer needs its own driver circuit. With direct addressing, if you have a 10x10 matrix of pixels, you need 100 individual drivers. However, if you use multiplex addressing, you only need 20 drivers, one for each row and one for each column.

Matrix addressing can be passive or active. Passive addressing-based LCDs are easier and less expensive to manufacture. Active matrix LCDs are more complex and cost more to manufacture, but have significant performance advantage over the passive approach.

The silicon layer for TFT-LCDs is usually placed using the Plasma Enhanced Chemical Vapor Deposition (PECVD) process from a silane gas originator to create an amorphous silicon film. Polycrystalline silicon - frequently low-temperature poly-Si (LTPS) is occasionally used in displays requiring higher TFT performance. For example, high-resolution displays, high-frequency displays, or displays where performing some fast video imaging on the display itself is desirable. Amorphous silicon-based TFTs have the lowest performance, polycrystalline silicon TFTs have higher performance (notably mobility), and single-crystal silicon transistors are the best performers.

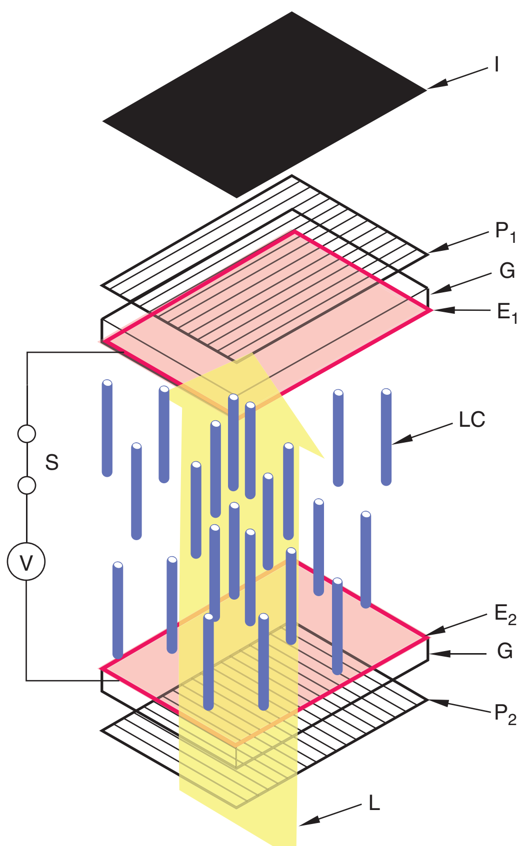
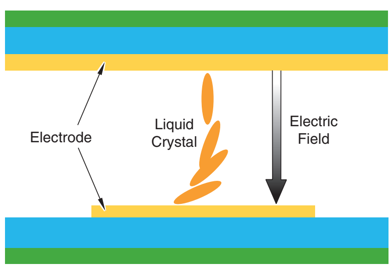


Fig. 7: Construction and operation of a single pixel of a twisted nematic (TN) LC-cell, voltage V applied (some volts) = field-ON-state.

In-plane switching (IPS)

In-plane Switching is an LC technology which aligns the liquid crystal cells in a horizontal direction. In this method, the electrical field is applied through each end of the crystal, but this requires two transistors for each pixel instead of the single transistor needed for a standard thin-film transistor (TFT) display. This will result in blocking more transmission area, and thus require a brighter backlight that will consume more power — making this type of display less desirable for notebook computers, for example.

IPS Technology from Hitachi uses pairs of electrodes on the sides of each cell with a horizontal electric field through the material. The liquid crystals are parallel to the front of the panel for an increased viewing angle.



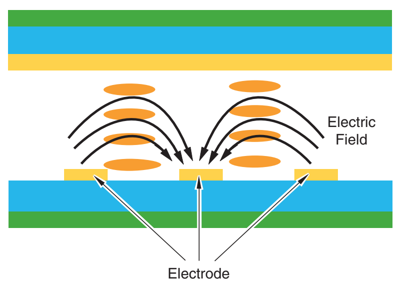
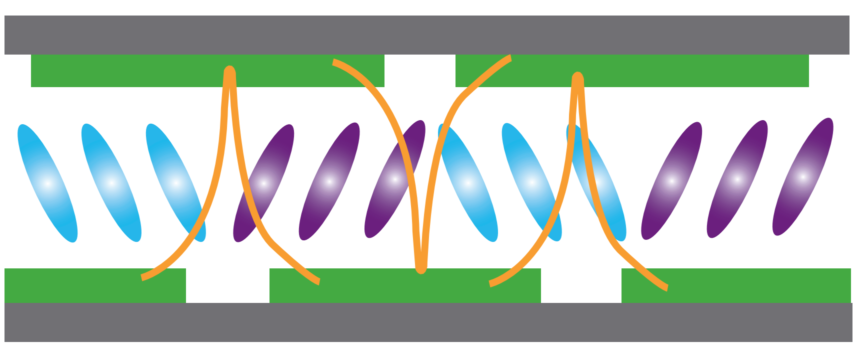


Fig. 8: TN Technology (left)

Fig. 9: IPS Technology (right)

Vertical alignment (VA)

Vertical Alignment displays are a form of LC technology in which the liquid crystal material naturally exists in a horizontal state, removing the need for extra transistors (as in IPS). When no voltage is applied to the liquid crystal cell it remains perpendicular to the substrate, creating a normally black display. When voltage is applied, the liquid crystal cells shift to a horizontal position, parallel to the substrate, allowing light to pass through and creating a white display. VA liquid crystal displays provide some of the same advantages as IPS panels, particularly an improved viewing angle and improved black level.



VA

Fig. 10: Vertical alignment

Multi-domain Vertical Alignment (MVA)

Multi-domain Vertical alignment from Fujitsu has the liquid crystal molecules oriented in multiple directions within a single cell. This is done by dividing the cell into two or more regions, called domains, by means of a mechanical feature on the glass surfaces to pre-tilt the molecules in the desired direction. By viewing areas of molecules oriented in one direction together with areas of molecules oriented in the opposite direction, and by making these areas very small, the overall color can be made to appear uniform over a wide range of viewing angles.

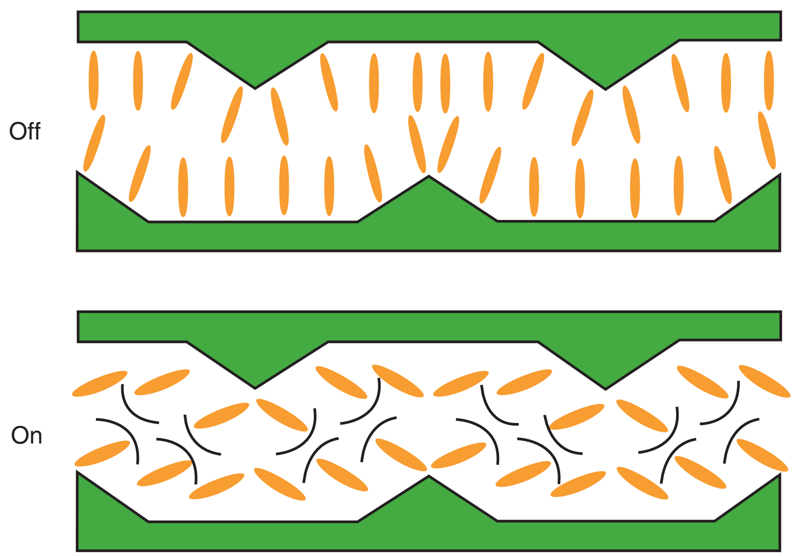


Fig. 11: Multi-domain Vertical Alignment

For further information go to the website at Sharp Microelectronics of the Americas, LCD Reference Information: http://www.sharpsma.com/Page.aspx/americas/en/8cbb0ad8-b24a-41c7-8d13-2ddcec863c84/LCD_Reference_Information/

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