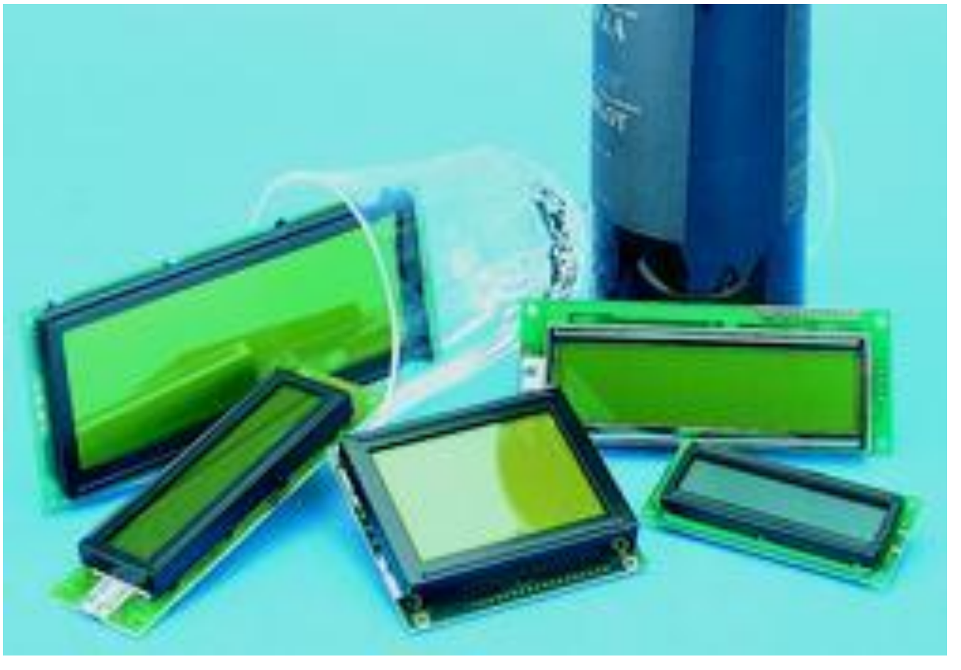
Liquid Crystal Display - LCD



Technology and Application

Version1.1. 2015

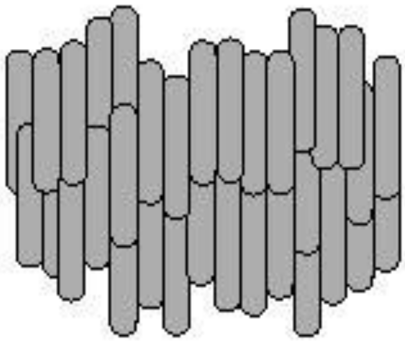
Introduction to LCD

LCD - Liquid Crystal Display

An introduction to LCD technology. What is liquid crystal? How the orientation of the its molecules are changed by electric field? How characters and graphics are displayed?

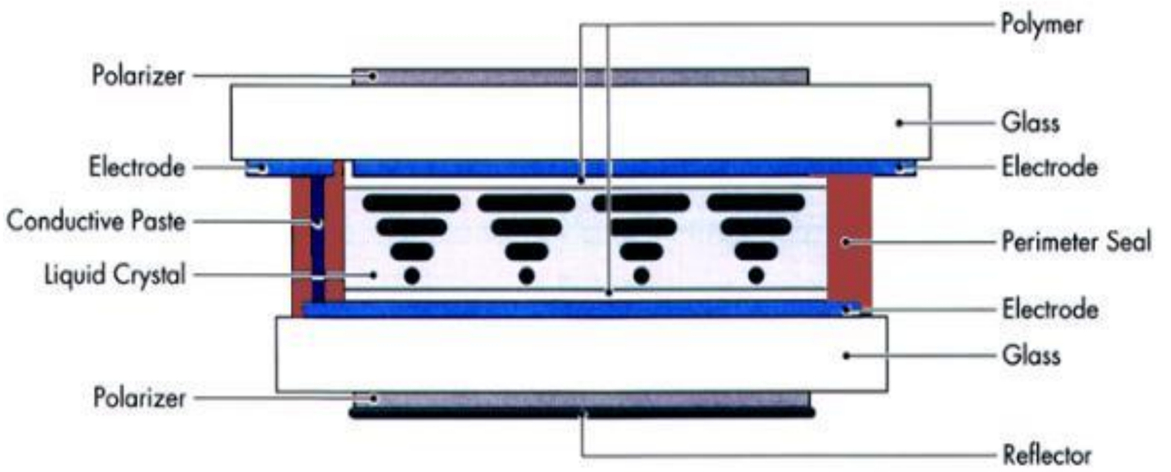
Liquid crystal displays (LCDs) are a passive display technology. This means they do not emit light; instead, they use the ambient light in the environment. By manipulating this light, they display images using very little power. This has made LCDs the preferred technology whenever low power consumption and compact size are critical.

Liquid crystal (LC) is an organic substance that has both a liquid form and a crystal molecular structure. In this liquid, the rod-shaped molecules are normally in a parallel array, and an electric field can be used to control the molecules. Most LCDs today use a type of liquid crystal called Twisted Nematic (TN).



LCD Molecules

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

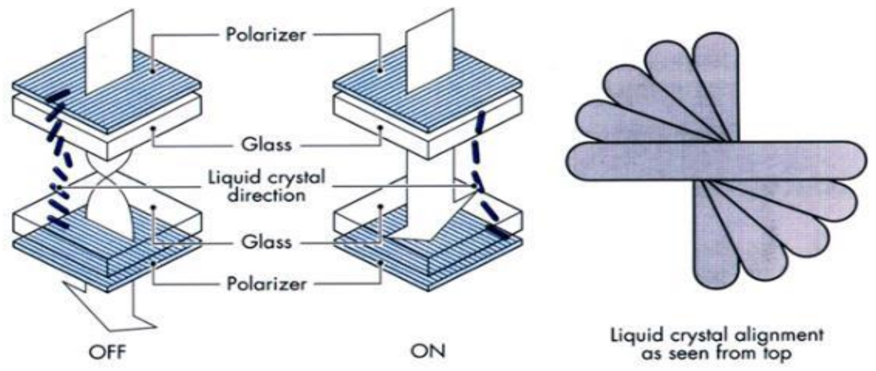


This helical structure has the ability to control light. A polarizer is applied to the front and an analyzer/reflector is applied to the back of the cell. When randomly polarized light passes through the front polarizer it becomes linearly polarized. It then passes through the front glass and is rotated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

LCD Fluid Types

TN, STN, FSTN or other types of LCD liquid. What is their difference in terms of display quality and control strategy?

Field Effect of LCD



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

Many advances in TN LCD have been produced. Super Twisted Nematic (STN) Liquid Crystal 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 compensated 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.
Twisted Nematic (TN), Super Twisted Nematic (STN), Film Compensated STN (FSTN), and Color STN (CSTN) are the terms used to describe four types of Liquid Crystal Displays, each twisting the orientation of the light passing through the Liquid Crystal Display structure differently to effect contrast and coloration. We also compare coloration, viewing angles, and costs between the technologies.

Twisted Nematic (TN) LCDs

TN displays have a twist (the rotation of the molecules from one plane of the display to the other) of 90 degrees or less. All passive direct drive, active matrix, and most passive low level (x2 to x32) multiplexed LCD's have a 90 degree twist.
The basic Twisted Nematic (TN) LCD consists of a layer of liquid crystal material supported by two glass plates. The liquid crystal material is a mixture of long, cylindrically shaped molecules with different electrical and optical properties, depending on direction.
On the inner surfaces of the glass plates are transparent electrodes, which are patterned to form the desired visual image. The inner surfaces are coated with a polymer, which is rubbed so that the liquid crystal material at one surface lies perpendicular to the other. Across the film of liquid crystal, the molecules form a 90° twist.
On the outer surface of the glass plates, polarizers are placed so they are parallel to the liquid crystal orientation and perpendicular to each other. In the "off" state, light entering the first polarizer is guided by the liquid crystal layer twist to the second polarizer, through which it is transmitted. When the cell is energized, the LC material is aligned with the electric field; light transmitted through the first polarizer is blocked by the second polarizer, forming a dark image. The effect may be reversed if the polarizers are placed parallel to each other, and a light image on a dark background is formed.
The TN technology comes in a single coloration, it is Black characters on a gray background. It is the least expensive, but has the lowest visual quality, primarily in viewing angle.

High Twisted Nematic (HTN) LCDs

HTN (High Twisted Nematic) displays are based on a higher molecular twist (usually 110°) than TN (90°) and therefore offer wider viewing angles and improved contrast. In fact, these HTN products offer viewing characteristics close to those of STN technology. As low operating voltage as 2.5V and marginal extra cost over TN means that the products are well suited to hand-held applications.

Super Twisted Nematic (STN) LCDs

Although Twisted Nematic LCDs may be driven in a time multiplexed fashion to increase the amount of information displayed, they are restricted in terms of reduced contrast and limited viewing angle. To achieve more highly multiplexed displays, super twist technology is employed.

Super Twisted Nematic LCD's have a twist that is greater than 90 but less than 360 degrees. Currently most STN displays are made with a twist between 180 and 270 degrees. The higher twist angles cause steeper threshold curves which put the on and off voltages closer together. The steeper thresholds allow multiplex rates greater than 32 to be achieved.

In this type of display, the LC material undergoes a greater than 90° twist from plate to plate; typical values range from 180 to 270°. The polarizers in this case are not mounted parallel to the LC at the surface but rather at some angle. The cell, therefore, does not work on a light "guiding" principle, as in Twisted Nematic LCDs, but instead on a birefringence principle. The position of the polarizers, the cell thickness, and the birefringence of the LC are carefully chosen to result in a particular color in the "off" state. Usually, this is a yellow-green to maximize the contrast ratio. The LC in the cell is "super twisted" that will give it the ability to use a high multiplex rate. As the twist is increased, the LC molecules in the middle of the layer are aligned with the applied electric field by smaller changes in voltage. This gives rise to a very steep transmission vs. voltage curve, allowing up to 240-line multiplexing.

The STN technology comes in two colorations, Green STN and Silver STN. The STN-Green has Dark Violet / Black characters on a Green background. The STN-Silver has Dark Blue / Black characters on a Silver background. It is in the middle of the road as far as cost, but has very good visual quality. The contrast is similar to TN technology.

Film Compensated Super Twisted Nematic (FSTN) LCDs

The most recent advance has been the introduction of Film compensated 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 and provides for a higher contrast and wider viewing angle.
The FSTN technology comes in a single coloration, Black characters on a White / Gray background. Of the three technologies listed here, it is the most expensive, but it has better viewing angles and contrast that the STN technology listed above.

Double Super Twisted Nematic (DSTN)

DSTN was the first commercial black and white conversion of the STN display. DSTN displays are actually two distinct STN filled glass cells glued together. The first is a LCD display, the second is a glass cell without electrodes or polarizers filled with LC material for use as a compensator which increases contrast and gives the black on white appearance.
DSTN provides better contrast than STN and FSTN, and offers automatic contrast compensation with temperature. Its response time is significantly enhanced. DSTN reduces the tendency of a screen to be slightly red, green or blue. Since its polarizer mode is negative, DSTN LCDs need backlighting, which is provided by either LED or CCFL only. It provides a resolution up to 122 x 32 dots. DSTN is suitable for use in/with automobiles, gasoline pumps, etc.

Color Super Twisted Nematic (CSTN) LCDs

Color STN Technology is actually STN technology that uses a white backlight and color filters to produce the hues required for a color display. Each visual pixel of a CSTN display is actually physically 3 separate pixels using a colored filter of Red. Green, and Blue. Each of those colors are controlled individually by the graphic controller chip. So in actually; a 320 by 240 pixel CSTN display actually contains 960 by 240 individually colored pixels.

LCD Display Modes

Dark image on light background, or vice versa. How to choose between them in different circumstances?

Positive and Negative Display Modes

What types of image the display creates is a cosmetic issue. There are only two basic display modes, positive and negative.

Positive Mode

A positive image on an LCD display is opaque when the pixel is "ON", and transparent when the pixel is "OFF". On almost all displays the image is smaller than the background, so this mode of operation is favored in an application where ambient light is high and it will help with the contrast of the display, especially for a display utilizing a Reflective rear polarizer. An example would be a alpha-numeric character on a larger background.

The segments or dots on the character would absorb light (appearing dark) and the background (the larger area) would reflect light enhancing the characters. Here are several typical Operational Mode & Viewing Mode combinations and the resulting images (assuming no backlighting which can color the background):

• TN: Black characters on a Gray background
• STN-Green: Dark Violet / Black characters on a Green background
• STN-Silver: Dark Blue / Black characters on a Silver background
• FSTN: Black characters on a White / Gray background

Negative Mode

A negative image on an LCD display is opaque when the pixel is "OFF", and transparent when a pixel in "ON". Since the image area is typically smaller than the background, the portion of the display that could reflect light and give the characters definition in this mode is minimized. Therefore, this mode is typically only used when there is a backlight and the ambient lighting conditions are medium to dim.

Using a backlight, the transparent segments of the display will "glow" because the backlight will be viewable only when the pixels are turned on. A high ambient light condition could wash out the backlight. Here are several typical Operational Mode & Viewing Mode combinations and the resulting images (assuming a backlight with the specified coloration listed):

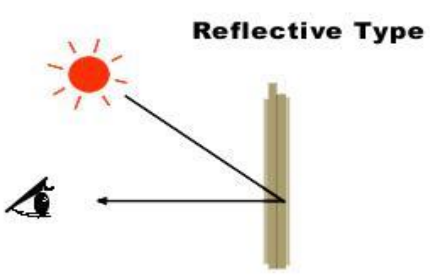
• TN: Glowing Green-Yellow characters on a light Gray background (Green-Yellow Backlight)
• STN ("Blue-Negative"): Glowing Green-Yellow characters on an light Blue background (Green-Yellow Backlight)
• FSTN: Glowing White characters on a Black background (White Backlight)

LCD Polarizer Modes

Reflective, transflective or transmissive. What is their difference? How are they related to backlights?

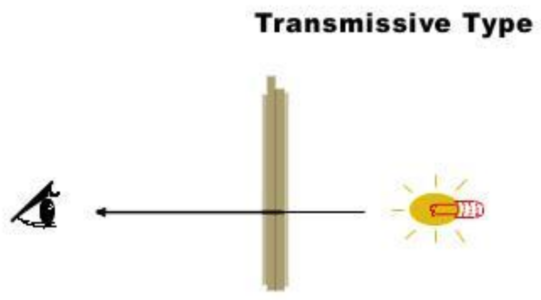
Each LCD has two polarizers, the front and rear polarizers, applied accordingly across the front of the display viewing surface and across the rear of the display to determine how the infuse light into the display. The front polarizer is always transmissive and not selectable by the user, however the rear polarizer has three choices and two grades for each choice.

Reflective Polarizer



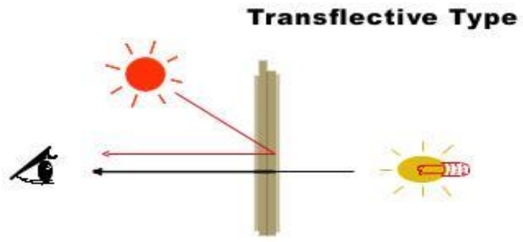
Reflective displays have an opaque rear polarizer that includes a diffuse reflector, such as brushed aluminum. This layer reflects polarized ambient light that has entered the front of the display back trough the LCD cell. Reflective displays require ambient light to be seen. They exhibit high brightness, excellent contrast, and wide viewing angles. They are particularly suitable for use in battery operated equipment where an adequate level of light is always available. Reflective LCD's cannot be backlit, however they can be front lighted in some applications.

Transmissive Polarizer



Transmissive displays have a clear polarizer on the front and the back. The display therefore depends on light coming through from the back of the display toward the observer in order to be seen. Most, but not all transmissive displays are negative image, and we sometimes add colored filters to different areas of the display to highlight different annunciators. Another example of a transmissive polarizer display would be a transparent window where you could see the segments superimposed over your line of vision through the display window (this assumes a sufficient ambient light source exists on either side of the window).

Transflective Polarizer



Transflective displays have a rear polarizer which includes a translucent material which reflects part of the ambient light, and also transmits backlighting. As the name implies, it is a compromise between the transmissive and reflective viewing mode. Used in reflection, it is not as bright and has lower contrast than the reflective type LCD, but it can be backlit for use in low light conditions. This polarizer is the best selection for a display that can be used in all lighting conditions with a backlight.

Commercial Grade Polarizer

The grade of a polarizer determines its operational and storage temperature range. The commercial grade polarizer operates typically between -10°C to +60°C.

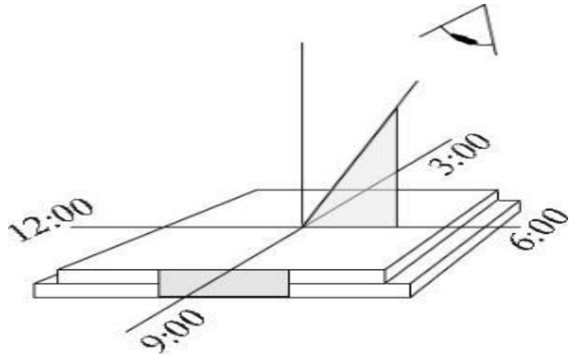
Industrial Grade Polarizer

The grade of a polarizer determines its operational and storage temperature range. The industrial grade polarizer operates typically between -30°C to +80°C. Other temperature ranges are also available.

LCD Viewing Direction (Bias Angle)

6:00 o'clock, 12 o'clock or other directions? How is the viewing direction defined? How to make the right decision that will suit your application?

Viewing direction (or bias angle) is the direction from which the display will look the best. It is set during the manufacturing process, and cannot be changed later by rotating the polarizers. Viewing direction is specified as positions of a clock face. A twelve o'clock viewing direction means that the optimum direction is above the normal to the display, while a part with a six o'clock viewing direction is best viewed from below the normal.



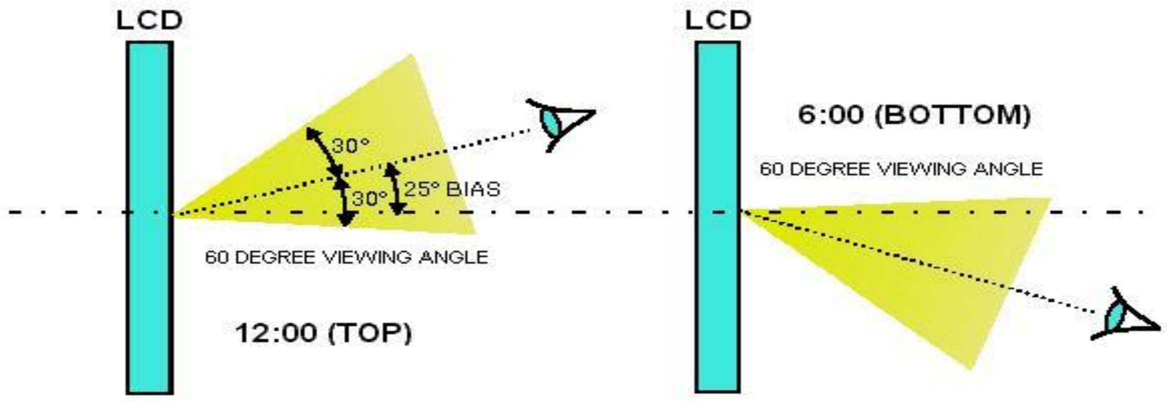
When specifying the viewing direction, one needs to think about how the device is going to be used. For example, a calculator is usually sitting on a desktop or held in the palm of your hand and viewed from the six o'clock direction .

Some instrumentation, like a wall thermostat, may be mounted below the viewer and needs to be viewed from the twelve o'clock direction. Other viewing directions are possible but not common. A car clock display, which is usually to the drivers right, may have a nine o'clock viewing direction, or possibly a ten-thirty one if the clock is low on the dashboard. In a direct drive display, viewing direction is not critical because the display will look good from almost any direction. It becomes critical when the display is multiplexed. The higher the multiplex rate, the greater the problem becomes. In displays with extremely high multiplex rates, great care must be taken when designing the drive circuitry. Special films can also be applied to the front of the display glass to enhance the overall viewability. However they tend to be expensive.

LCD Viewing Angle

What is viewing angle vs. viewing direction? How viewing angle is affected by the types of liquid and driving methods?

The viewing angle is the angle formed on either side of the viewing direction (or bias angle), where the contrast of the display is still considered acceptable. The term "viewing angle" is often used erroneously with the term "viewing direction" or "bias angle".



Liquid Crystal Displays have a limited viewing angle. They lose contrast and become hard to read at some viewing angles and they have more contrast and are easier to read at others. The size of the viewing angle is determined by several factors, primarily the type of Liquid Crystal Display fluid and the duty cycle. Because the viewing angle tends to be smaller than most people would like, certain viewing direction (or bias angle) is designed into the module at the time it is manufactured. This means the nominal viewing angle is offset from the perpendicular by some amount. Several versions of the LCD module are then offered with this bias set to different angles or positions to accommodate as many applications as possible.

An STN character display running at a duty cycle of 1/16 has a viewing angle of ±20 degrees, and a bias angle of 25 degrees. For this example, assume the display is a 12:00 (top viewing) type. When the display is viewed from 25 degrees above the vertical, it will have its maximum contrast and best “look”. If the viewer moves his eye further above the display by an additional 30 degrees, he will see the display reduce in contrast (but still be easily readable). Moving the viewing position any further above the display will reduce its contrast to an unacceptable degree.

Contrast Adjustment and Viewing Angle

Adjusting the contrast voltage, VO, will effect the viewing direction (bias angle) to some extent, but not the viewing angle. 12:00 display can be optimized for a 6:00 viewing position by adjusting the contrast voltage. A 12:00 display set for 6:00 viewing position will not have as great a contrast as a 6:00 display set for 6:00 viewing position, and vice versa. Designers often want a display to be optimized for straight-on viewing. Either a 12:00 or a 6:00 module can be used; and the contrast voltage can be adjusted slightly to optimize the display for that viewing position. In the example used above, the viewing angles of both the 6:00 and 12:00 modules actually overlap the perpendicular (or straight on) viewing position.

LCD Temperature Ranges

LCD can work properly in a certain temperature range, which is determined by the LCD fluid, polarizers, operational voltage, and multiplex rate. LCD can also be optimized to work in certain temperature ranges.

When selecting a Liquid Crystal Display Module or LCD Glass, it is very important to identify the the range of its environmental temperature. Standard Liquid Crystal Displays do not have an extremely wide temperature range, and that range can be effected by solar radiation, ventilation and extremes at different times of the year. Also, you need to be aware of the type of backlighting and control circuitry selected can influence the overall temperature range of the environment.

Another thing to consider that is pertinent to the LCDs temperature range, is that the contrast of the display will change over that range. Your design needs to make allowances for this fact by either adding temperature compensating circuitry to your design, or selecting one of our LCD modules that already have build in temperature compensation circuitry.

TN Temperature Ranges

The operational and storage temperature range of a Twisted Nematic (TN) Liquid Crystal Display is dependant on the drive and voltage of a part. The following parameters are for general reference.

TN Standard Temperature Range
• Operating Temperature: -10°C to +60°C
• Storage Temperature: -20°C to +60°C

TN Wide Temperature Range
• Operating Temperature: -30°C to +80°C
• Storage Temperature: -40°C to +80°C

There are also specially designed TN LCD that operates at an especially higher temperature (-20 to 105) or lower temperature (-55 to 85).

STN/FSTN Temperature Ranges

The operational and storage temperature range of a super Twisted Nematic (STN) and Film compensated STN (FSTN) LCDs are set pretty much into two ranges for standard products.

STN/FSTN Standard Temperature Range
• Operating Temperature: 0°C to +50°C
• Storage Temperature: -10°C to +60°C

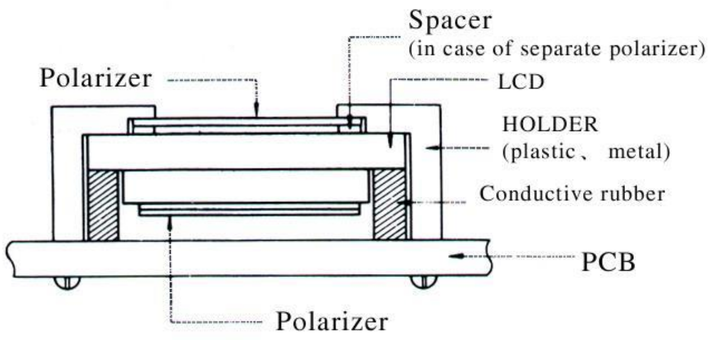
STN/FSTN Wide Temperature Range
• Operating Temperature: -20°C to +70°C
• Storage Temperature: -30°C to +80°C

LCD Connection Types

Elastomer (zebra strip), pin or heat seal are major types of connection for LCD glasses to the rest of the circuitry. What is their advantages and disadvantages?

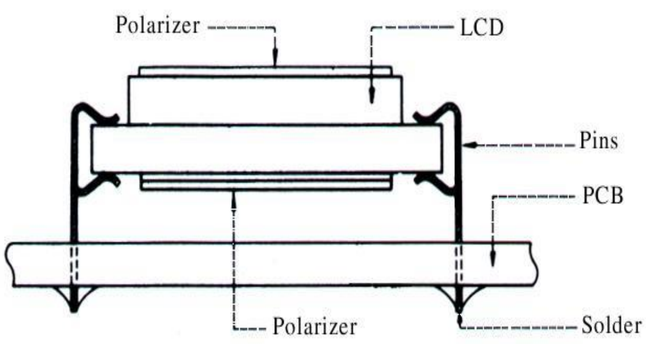
There are three primary methods to connect the LCD with its control circuitry.

Elastomers (Zebra Strips)



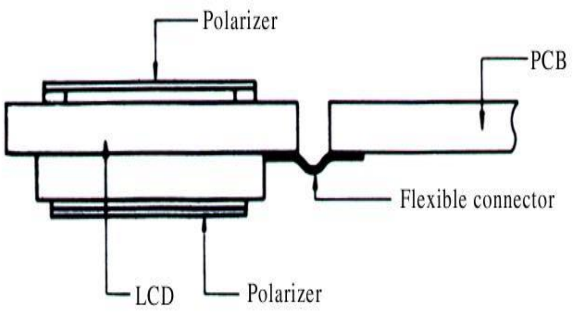
Elastomers are silicon strips of alternating conductors and insulators. These materials are generally soft and compliant and can be easily compressed between the Liquid Crystal Display and circuit board. Elastomers require a bezel to squeeze the display and circuit board together. This method will yield a higher conductor interconnection than pins, potentially less costly than pins, but requires a specialized compression bezel.

Pins



Pins are attached to the display to allow the user to either mount the display in a socket or solder it directly into a circuit board. From an end user standpoint, pins are the easiest to use since there is no requirement for a compression bezel or expensive heat seal bonding equipment.
The pins are attached to the glass with a structural epoxy on the back. On the top, we apply an electrically conductive epoxy with an RTV overcoating. Pins are the most reliable connection method, they are also the easiest to deal with for prototyping and smaller production runs. However, of all three methods, they have the lowest number of interconnects per inch.

Heat Seals



Heat seals are similar to flexible circuit boards with the difference being that the interface tabs are made of a conductive hot melt adhesive. Generally, particles such as carbon, gold, or silver are added to the adhesive to make it conductive. The pads of the heat seal are aligned with the pads of the display and a hot bar is brought down under pressure and the conductive adhesive is melted and bonded to the display. The adhesive is allowed to cool and an electrical bond is made with the display. This method is the most cost effective for the higher volume applications, but due to the expensive setup and equipment required in this process, Heat Seals are typically not used for lower volume / low interconnection density requirements.

Other Types of Connection

• FPC (Flexible Print Circuit) is a circuit substrate of patterning Cu electrode with Polyimide film as a base. Usually offers more flexibility than Flexible Flat Cables.
• FFC (Flexible Flat Cable) is a cable with two smooth or corrugated, but essentially flat, surfaces. Attached to the PCB by soldering or plugging into a zero insertion force connector. Very reliable.

LCD Backlighting

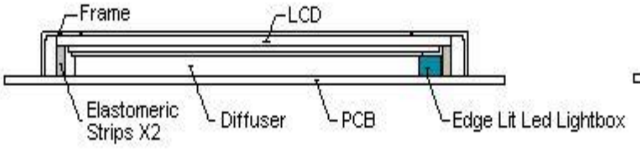
LED, ELP, CCFL or other types of backlighting methods. Detailed explanation on their application in different circumstances.

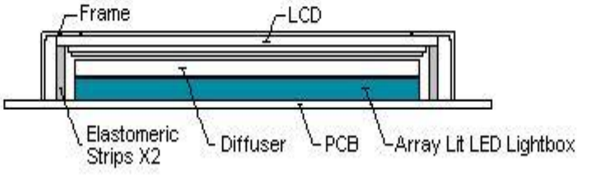
LCDs create their display with the manipulation of visible ambient light. In the absence of this light, we must add backlighting to make these LCD displays visible. There are many choices to consider when backlighting an LCD. Once again the choice comes down to appearance vs. cost. Each approach has its advantages and disadvantages, and no one method is right for all applications. The data below will only give the highlights of each technology with general comments. For our LCD modules we integrate most of these types of backlights into our displays.

Here are the 5 most common methods of backlight and information on how to drive LED backlighting.

LED Backlighting

Light Emitting Diode, or LED, backlight is the most popular backlighting for small and medium LCDs. The advantages of LED backlighting are its low cost, long life, immunity to vibration, low operational voltage, and precise control over its intensity. The main drawback is it does require more power than most of the other methods, and this is a major drawback if the LCD size is large enough. LED backlights come in a variety of colors, with yellow-green being the most common, and now white is becoming cost effective and very popular. LED backlights offer a longer operating life - 50,000 hours minimum - and are brighter than ELPs. Being a solid state device, they are configured to operate with typically a +5VDC power (and optionally 12VDC power), so they do not require an inverter.

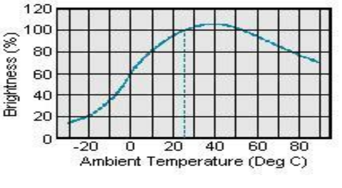


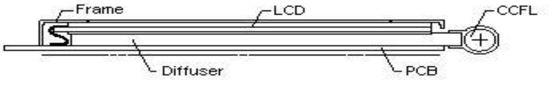


The LED backlight has two basic configurations; Array and edge lit. In both types the LEDs are the light source that are focused into a diffuser that distributes the light evenly behind the viewing area. In Array lit configuration there are many LEDs mounted uniformly behind the display, it offers more uniform and brighter lighting and consumes more power. In Edge lit configuration, the LEDs are mounted to on side (typically the top) focused edge on into the diffuser, it offers a thinner package and consumes less power.

Electroluminescence Panel (ELP) Backlighting

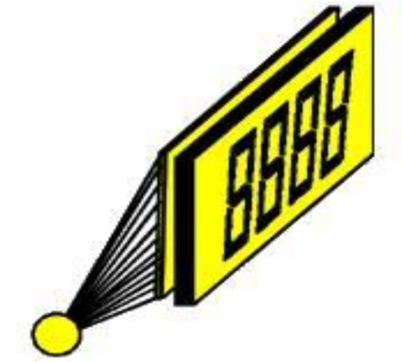
Cold Cathode Fluorescent Lamp, or CCFL, backlights offer low power consumption and a very bright white light. The primary CCFL configuration used in LCD backlighting is edge lighting. A cold cathode fluorescent lamp is the light source with a diffuser distributing the light evenly across the viewing area. CCFLs require an inverter to supply the 270 to 300 VAC @ 35KHz used by the CCFL tube. Information about these inverters can be found in the Power Supply section of our website. They are used primarily in graphic LCDs and have a longer life - 10,000 to 20,000 hours - than ELPs do. Their biggest drawbacks are: cold weather will reduce the light output by as much as 60% (see graph below).





They require an inverter to generate the 350VAC (please note that the inverters do not function well at low temperatures), the light intensity cannot be varied (it is either on or off), and vibration can reduce the life expectancy of up to 50%.

Woven Fiber Optic Mesh Backlighting



Woven Fiber Optic Mesh backlighting provide extremely uniform backlight, without the need for an inverter. The lifetime is dependent on the type of bulb used, with halogen (which generate high heat) or LED sources providing up to 100,000 hours. The bulbs themselves are usually mounted away from the LCD, where they can be easily replaced when necessary. Woven fiber optic panels tend to be somewhat expensive, but the uniformity and brightness are worth the extra cost for some applications.

Incandescent Backlighting

Incandescent Lamp backlighting is only used where cost is a major factor. While Incandescent lights are very bright, they are not uniform, generate a significant amount of heat (which can cause problems at high temperatures), have short life spans, and use significant power for the brightness achieved. They can provide very white light, but the color can change with changing supply voltages, and they can be sensitive to shock and vibration.

LCD Display Types

Segment (alphanumeric) display, dot matrix (character) display or graphic display. How to make a choice for your specific application?

There are three LCD display types: segment (or alphanumeric), dot matrix (or character) and graphic LCD.

1. Segment LCD (or Alphanumeric LCD)

Segment LCD can display Arabic numbers represented by 7 segments or Arabic numbers and Roman letters represented by 14 segments. Symbols, such as plus/minus signs, measurement units and any custom icons, can also be displayed. Each symbol is treated as one segment. Segment LCD is widely used on the displays of scientific instruments. It is easy to control and most cost-effective to develop. Segment LCD is limited to displaying numbers, Roman letters and fixed symbols. If you need to display anything else, you have to use either the dot matrix display or graphic display.

2. Dot Matrix LCD (or Character LCD)

Dot matrix LCD is used to display a number of lines of characters. The most commonly used dot matrix LCD displays 1 to 4 lines of 16 to 40 characters. Each character is represented by 5x7 dots plus cursor (actually 5x8 dots including the cursor). Each character block is addressed separately and can form numbers, Roman letters, character in other languages and a limited number of symbols. Dot matrix LCD is used when you need to display more characters than those in English alphabet. It is relatively simple to control and also inexpensive than graphic models.

3. Graphic LCD

Graphic LCD provides users with a greater degree of flexibility. They are composed of pixels arranged in rows and columns. Each pixel can be addressed individually for text, graphics or any combination of the two. Graphic LCD is used in applications when the use need to have total control of the whole viewing area. However, flexibility also comes with the difficulty in designing the control circuitry. Fortunately there are special controller chips available for this purpose.

LCD Glass vs. LCD Modules

Should I buy LCD glasses (panels) or LCD modules? Things you should know before you talk with the supplier.

The most fundamental decision to make is whether the display will have the drive circuitry attached (module), or not (glass only). There are advantages and disadvantages to each approach. When purchasing a Custom LCD Module, the basic electronic design work will be done by the manufacturer. This obviously saves design time and reduces the manpower needed to bring a product to market. You can benefit from the experience we have gained during our previous designs to shorten the design cycle and deliver an optimized product. The major decisions you need to make are the interface type, with standard serial or parallel interfaces being the most common, and the type of integrated backlighting desired. The temperature range, viewing angle, viewing mode, and contrast will need to be considered, but those decisions are common to both approaches.

A glass only design puts the design burden on the end user. You will need to learn a great deal about LCD's in order to complete your design. Luckily, our website provides Application Information and Web Links to assist you in the search for the information you may need.

The main reasons to buy just the LCD glass are to reduce costs, and provide design flexibility. The total cost of the components necessary to build the drive circuitry is typically less than the cost of a pre-built module, and as long as you have space on your existing PC board, you won't have to pay for an extra PC board on which to mount the display, and have access to cost effective assembly and test . By doing a little homework, your design will work just as well as a module, and will allow the flexibility most designers need to adapt their design to ever changing demands.

LCD Module Assembly Types

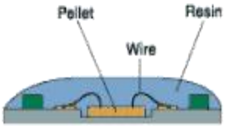
SMT, COB, TAB, COG, COF and more. Those are terms to describe how LCD controllers/drivers are mounted on an LCD module. How to choose among them? What to expect?

Assembly types refers to how LCD controller/driver IC chips are mounted. The most common types are SMT, COB, TAB and COG. There are also other variants based on the these types.

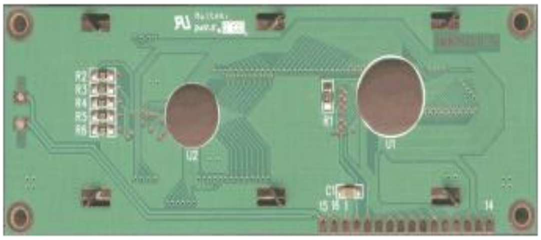
SMT (Surface Mount Technology)

Using quad flat packages on printed circuit boards is the most popular in LCD industry, and is available for mass production of most LCD modules. It remains the most reliable and robust method for LCD assembly. Plastic Quad Flat Package (QFP) represents itself as a flat rectangular integrated circuit package with its leads projecting from all four sides of the package.

COB (Chip On Board)



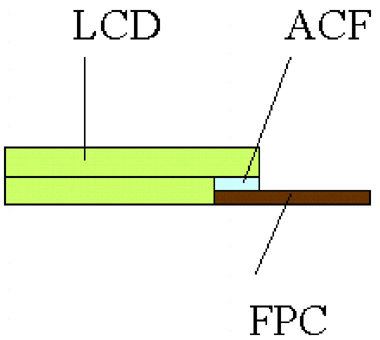
COB is a popular IC mounting method that provides wire bonding as the direct attachment of bare die to laminated printed circuit boards. The LCD driver is formatted into an area on the PCB. Electrical connections are made by micro diameter gold wires. The entire area is then covered with epoxy. Most of the LCD modules use COB mounting method.



Advantages:

• Very compact
• Space savings over SMT assembly
• Cost savvy compared with SMT, since there is no plastic package

TAB (Tape Automated Bonding)

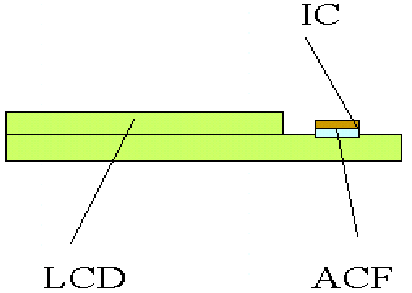


LCD controller and/or driver electronics are encapsulated in a thin, hard bubble package, of which the drive leads extend from the bubble package on a thin plastic substrate. The adhesive along the edges is used to attach the TAB to the LCD glass and/or PCB.

TAB mounting method uses the same type of integrated circuits as COG technology - Gold Bumped Flip Chips. After this type of IC chip is produced, a gold bump is placed on the IC chip and then sealed onto the polymide board. (This procedure is called ILB or Inner Lead Bonding) and is how the TCP IC is produced.

Advantages:	Disadvantages
• Offers compactness (IC and its interfacing circuitry can be bent behind the LCD glass panel). • Some times more cost-effective than COG, if a designer has to integrate a keypad or indicator around the display. • The active area is centered (differently from COG). • Can provide interfacing at very fine pitches.	•The bonding area is weak. Less reliable than COG. • More expensive than COG. Even though TAB LCD modules use the same type of IC as COG, tape automated bonding requires a package.

COG (Chip On Glass) Note 1



COG is one of the high-tech mounting methods that uses gold bump or flip chip ICs, and implemented in most compact applications. COG integrated circuits were first introduced by Epson. In flip-chip mounting, the IC chip is not packaged but is mounted directly onto the PCB as a bare chip. Because there is no package, the mounted footprint of the IC can be minimized, along with the required size of the PCB. This technology reduces the mounting area and is better suited to handling high-speed or high-frequency signals.

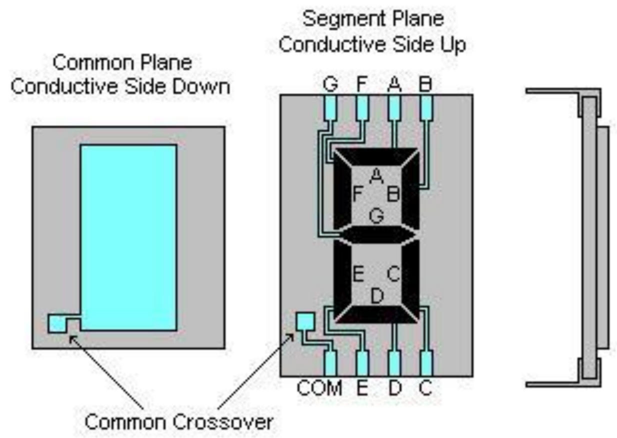
Advantages	Disadvantages
• Very space economical. COG LCD modules can be as thin as 2 mm. • Cost effective over COB, especially in graphic LCD modules, because much less IC's are required. • More reliable than TAB, because of the weakness in the bond area of TAB.	• COG can only be used at a certain resolution level where the lines are not too fine. At very fine pitches COG becomes difficult to test, and TAB is the preferred approach. • It may be more cost-effective to use TAB or COB, if a designer has to integrate a keypad or indicator around the display. • The active area is not centered within the outline but offset, because of the area where the circuits are.

Note 1: See Appendix Titled “ Chip-On-Glass Value Proposition”

LCD Control Circuitry

LCD Driving Circuitry: Static

The configuration for Liquid Crystal Display Static Drive technique is that one side of all of the Liquid Crystal Display segments are tied to a common, or backplane, and the other side of each of the segments are routed to individual connection points that are tied to the driver control circuitry. This method uses a large number of interconnects and is not feasible for complex displays, but it does produce the best looking display.



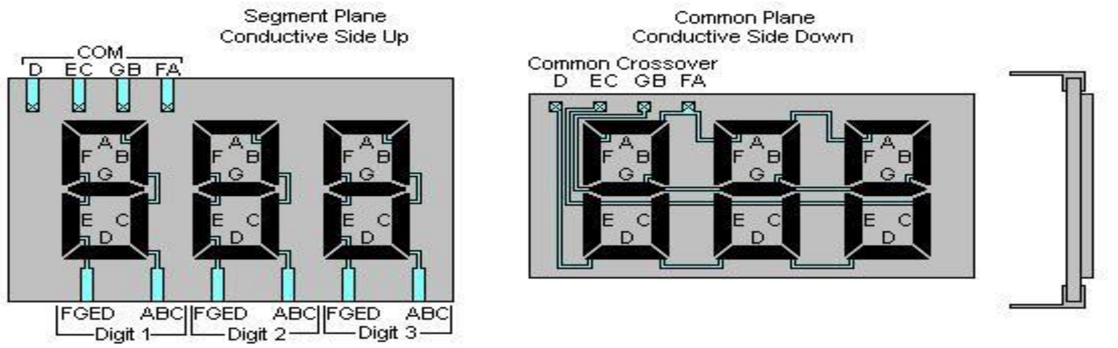
LCD's require an AC drive voltage with virtually no DC component. Segments are controlled by the magnitude of the AC voltage across the LCD segment, but there must always be AC voltage across ALL segments of the LCD. Prolonged DC operation may cause electrochemical reactions inside the displays which will cause significantly reduced life. The initial indications of display degradation because of excessive DC current is a loss of alignment along the edges of some of the characters. The visual indication will be a "fuzzy" appearance of some of the characters.

The TN LCD is an RMS voltage responsive device, that is, the contrast of a given segment is dependent upon the RMS value of the applied voltage across it, measured with respect to the common plane. This fact, which seems obvious now, is very important when discussing drive schemes.
Drive frequencies for direct drive displays are typically between 30Hz and 100Hz. Depending on the display size and design, displays can be operated at higher frequencies, but this will result in increased power consumption. LCDs portray a capacitive load, which reduces the load impedance as frequency increases. However, operation below 30Hz typically results in display flicker.
LCD's can be overdriven by a combination of voltage and frequency, which will result in cross talk or "ghosting". Ghosting is the appearance or partial activation of an "off" segment. This condition occurs when high drive voltage and frequency are applied. Since the current is directly proportional to the frequency, there is a voltage-frequency product which must not be exceeded. These values are very dependent on the design and layout of any given part, so proper display design and choice of driving conditions is important. It is also very important that all unused segments be connected to the backplane, and not allowed to float.

LCD Driving Circuitry: Multiplex

The configuration for Liquid Crystal Display Multiplex Drive technique differs from a Static Drive technique is that it uses more than a single "backplane" or segment common. With this configuration, each segment control line can be connected to as many segments as there are backplanes, providing that each of the segments that it is connected to are tied to a separate backplanes. This method "Multiplexes" each of the segment control lines and minimizes the number of interconnects. This is the method used with complex displays that have limited interconnection surface area or available drive circuits. This reduction in the number of external connections enhances device reliability and increases the potential display density. The liability of a higher multiplex rate will effect display quality, operational temperature range, and the increased complexity of drive circuitry (or perhaps microprocessor software) may necessary for their operation.

The method of drive for multiplexed displays is essentially a time division multiplex with the number of time divisions equal to twice the number of common planes used in a given format. As is the case with conventional LCDs, in order to prevent irreversible electrochemical action from destroying the display, the voltage at all segment locations must be caused to reverse polarity periodically so that zero net DC voltage is applied. This is the reason for the doubling in time divisions: Each common plane must be alternately driven with a voltage pulse of opposite polarity.



As is the case with non multiplexed displays, the drive frequency should be chosen to be above the flicker-fusion rate, i.e. >30 Hz. Since increasing the drive frequency significantly above this value increases current demand by the CMOS drive electronics, and to prevent problems due to the finite conductivity of the display segment and common electrodes, an upper drive frequency limit of 60-90 Hz is recommended.

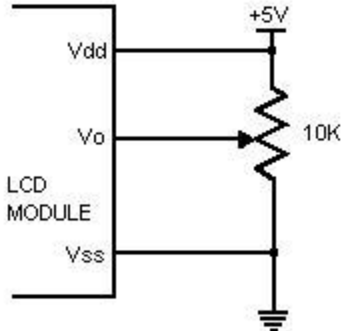
LCD Contrast Adjustment and Temperature Compensation

Contrast, or more appropriately put, the contrast ratio of a liquid crystal display is the ratio of the light area of a display to the dark area. When an LCD is used in a product, an allowance must be made to adjust the LCD bias voltage. This adjustment will control the contrast between the LCD segment being on and off, and this voltage needs to be optimized for the best appearance. This adjustment needs to be made in production for most LCD designs, and it may also need to be adjusted dynamically during your products usage since temperature extremes may effect the LCDs contrast. This section covers information on LCD contrast adjustment required to make the display viewable, and also how to compensate for the correct contrast over the full temperature range of your product

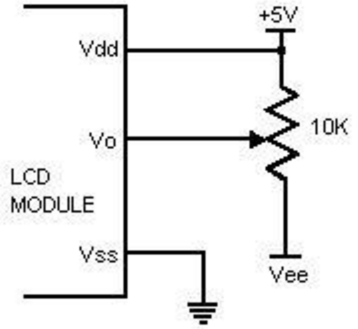
LCD Contrast Adjustment

The LCD bias voltage that effects the LCD contrast, also effects the bias angle of the display. So at what angle you view the display will influence the setting of the LCD bias voltage. Adjusting the contrast voltage, V , will effect the bias angle to some extent, but not the viewing angle. A 12:00 display can be optimized for a 6:00 viewing position by adjusting the contrast voltage. A 12:00 display set for 6:00 viewing position will not have as great a contrast as a 6:00 display set for 6:00 viewing position, and vice versa. Designers often want a display to be optimized for straight-on viewing. Either a 12:00 or a 6:00 module can be used; and the contrast voltage can be adjusted slightly to optimize the display for that viewing position.

Once the viewing position has been established for a design, the contrast setting can be determined. This is normally done during product development on the prototype unit. A potentiometer is connected between the appropriate power supply rails (Vdd and Vss for single supply, and Vee and Vdd for higher voltage LCD modules). The wiper of the pot is connected to Vo (LCD bias voltage input, see below). The LCD is then positioned at the nominal viewing position, and the pot is adjusted to obtain the desired LCD appearance. Depending on the optimum contrast requirement, and the ability to use more than one vendors LCD module, you can either leave the potentiometer in the design, or measure the voltage on the Vo pin and select a pair of resistors to produce this voltage in the production units.



SINGLE VOLTAGE



DUAL VOLTAGE

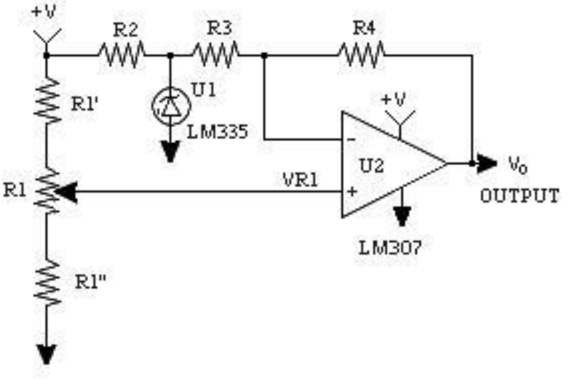
LCD Contrast Adjustment with Temperature Compensation

Due to the contrast versus voltage versus temperature characteristics of liquid crystal fluids, and the sensitive nature of display drive voltage during multiplex operation, it may become necessary to compensate the LCD drive voltage for applications where the display is subjected to wide temperature excursions. For a typical Liquid Crystal fluid, with a negative temperature coefficient, an under voltage condition with diminished display contrast will result at low temperatures, and a "ghosting" or overdrive condition will occur at high temperatures, if no compensation techniques are employed. So if your application requires good contrast over a large temperature range, you may need to consider temperature compensation for your contrast adjustment circuitry.

When using an LCD module, one solution is to order an automatic temperature compensation option. However, if you are using one of our modules without this option, or if you are using one of our glass products, you need to make your own temperature compensation circuitry. Listed below are two possible temperature compensation circuits for your reference.

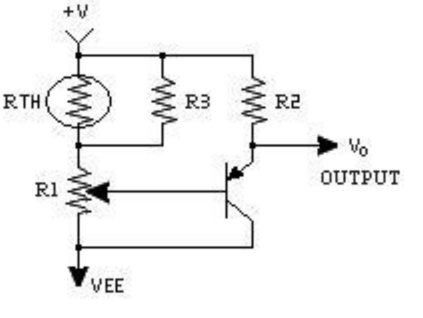
Example 1

The first thing that needs to be determined in a particular application is the typical LCD bias voltage (Vo) and the temperature coefficient of the LCD module. The figure below shows the basic temperature regulation circuit. The heart of the circuit is U1, a National Semiconductor LM335 monolithic temperature sensor, which should be placed in close proximity to the LCD. The LC335 has a basic output voltage coefficient of 110mV/C. Resistor R2 supplies operating current to U1, 1mA nominal. Difference amplifier U2 inverts and scales this coefficient consistent with LCD driver requirements. Potentiometer R1 provides a means by which the display operating voltage can be set.



Example 2

This example is more simplistic and is directed toward LCD module applications. As with the first example, you need to determine the typical LCD bias voltage (Vo) and the temperature coefficient of the LCD module. Based on the temperature coefficient requirements, a thermistor (Rth + R3) need to be selected to provide the correct offset for the temperature coefficient generated by the LCD module. Resistor R1 will provide the adjustment to select the correct initial voltage (or 2 fixed voltage divider resistors) and transistor Q1 will provide the current buffer to allow the Thermistor to operate with minimum loading. R2 is just used as a minimum bias resistor for open circuit conditions. Vee must be a regulated voltage source.



LCD Design Guide

The following sections provide basic information on LCD glass and LCD modules, which is useful when you start designing your own LCD or submit requests to LCD manufacturers

Types of LCD Products - Glass or Modules

The most fundamental decision to make is whether the display will have the drive circuitry attached (module), or not (glass only). There are advantages and disadvantages to each approach.
When purchasing a Custom LCD Module, the basic electronic design work will be done by the manufacturer. This obviously saves design time and reduces the manpower needed to bring a product to market. You can benefit from the experience we have gained during our previous designs to shorten the design cycle and deliver an optimized product. The major decisions you need to make are the interface type, with standard serial or parallel interfaces being the most common, and the type of integrated backlighting desired. The temperature range, viewing angle, viewing mode, and contrast will need to be considered, but those decisions are common to both approaches.

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The main reasons to buy just the LCD glass are to reduce costs, and provide design flexibility. The total cost of the components necessary to build the drive circuitry is typically less than the cost of a pre-built module, and as long as you have space on your existing PC board, you won't have to pay for an extra PC board on which to mount the display, and have access to cost effective assembly and test . By doing a little homework, your design will work just as well as a module, and will allow the flexibility most designers need to adapt their design to ever changing demands.

Types of LCD Images

• Icons: By making a custom LCD, you can place images on the glass that specifically complement your produce, these are called "Icons". These silhouettes can take the shape of any image you may need and count as one pixel or dot on the LCD. Examples would be a "°C", "+/-", or a cat silhouette (if you make a product that interacted with cats).
• Segments: Segments on an LCD display make up a larger character, such as a segment in a seven segment numeric character (displays 0-9), or a segment in a 14 segment alpha-numeric character (displays 0-9 & A-Z).
• Dot Arrays: These dot arrays can be made in almost any size and dot count. Examples would be character displays that use a series of 5x7 dot arrays to create a string of alpha numeric characters, or the larger 320 x 240 graphic arrays that make images along with variable size alpha-numeric characters.

Types of Liquid and Technology – TN/ STN/ FSTN/ DSTN/ CSTN

The type of technology used is determined by the specific performance requirements you set for the display that you are designing. Since several variations will do a fine job, the ultimate consideration is cost. So here is a quick breakdown of the technologies we offer.

• TN: Low production and NRE costs, poor viewing angle, average contrast. Coloration: Black on Gray. Static preferred, but operates well up to a 32:1 Multiplex rate. LCD Glass favorite.
• STN: Medium production and NRE costs, average viewing angle, average contrast. Coloration Black on Green, or Dark Blue on Gray. Works well at high Multiplex rates. LCD Module favorite, high end LCD glass choice.
• FSTN: Medium high production and NRE costs. Good viewing angle, excellent contrast. Coloration Black on White. Works well at high Multiplex rates. Higher end LCD Module favorite.

Negative Image: This is an effect that reverses the image on the display and is only offered with transmissive displays. The visual effect is to allow the backlight to define the pixels turned "on" (transparent), while the "off" pixels remain opaque. This configuration works best in moderate to low light conditions.

Viewing Mode and Polarizers

The viewing mode is controlled by the rear polarizer, and how much it does or does not reflect light. We offer three modes

• Reflective: This type of polarizer gives the display the brightest appearance in high to moderate ambient light conditions, with the highest contrast ratio possible. Unfortunately, it will be difficult to read at night or under changing lightning conditions (think Game Boy).

• Transflective: (Favorite solution) If your display must be readable under a wide range of lighting conditions, you will generally want a transflective display so that it will look very good in the bright sunlight, but will also be back-lightable at twilight and at night. The tradeoff with a transflective display is that it will not look as good as a reflective display during the day, and it will not look as good as a transmissive display at night. It will however enable you to have an acceptable compromise between the two, and provides a very acceptable appearance.

• Transmissive: This display needs to have a working backlight, unless it gets its light from being a "window" type of device where the area behind the LCD has a light source room ambient light. Where it is in a contained display, the backlight may have a problem overpowering high ambient light. This type of display looks great for an indoor application, but is not very good in applications where power consumption is a problem and it needs a strong backlight. Remember, this choice of polarizer will not operate unless there is an active backlight.

The polarizers are also affected by temperature, and a quality grade must be specified when choosing a polarizer. After you have determined your environmental temperature requirements, you then need to choose the polarizer grade. Here are your typical choices.

• Commercial Grade Polarizers: Displays which will be indoors, or mostly indoors, can use commercial grade polarizers. These polarizers will hold up very well when used in most instrumentation, office and home products, and other applications where the products will be protected from high temperature, sunlight, and humidity.
• Industrial Grade Polarizers: For harsh environments, a polarizer specifically designed for outdoor, extremely humid conditions should be used. We call these polarizers industrial grade

Viewing Direction

The viewing direction of a LCD part is defined as the angles above, below, left, and right of the point-of-view that is perpendicular to the center of the display.

• 6:00 viewing direction has optimum contrast from below the perpendicular viewing plane (most popular).
• 12:00 viewing direction has optimum contrast from above the perpendicular viewing plane.
• 9:00 viewing direction has optimum contrast to the left side of the perpendicular viewing plane (uncommon).
• 3:00 viewing direction has optimum contrast to right side of the perpendicular viewing plane (uncommon).

Please keep in mind that viewing direction is less important for a direct drive display. As a general rule, the higher the multiplex rate, the more important the viewing direction becomes. Also, if your display is going to be viewed by a person wearing polarized sunglasses, you must specify this in the comment section to ensure that the display will not look blank to an observer wearing polarized sunglasses. However keep in mind that for quoting purposes, the price of the display will not change much (usually only a few cents) if you change your mind for the final viewing direction of the display.

Drive Method

The Drive Method specifies how each segment of the LCD display is connected to the LCD driving circuitry. There are two methods offered.

• Static Drive: LCD Glass or LCD Modules with a simple segment displays are the only parts that have an option of Static Drive. The Static Drive configuration means that there is an individual control line to select each LCD segment and there is only a single common line that connects to them all. This configuration produces the best display with the widest temperature range, but it requires more interconnections (>Cost in pins and controller) that a multiplexed display would require.
• Multiplexed Drive: The Multiplexed Drive configuration means that each control line selects several LCD segments and the final selection is made by selecting the correct backplane/common that also connects to several LCD segments. This configuration uses less interconnections which is cost effective for smaller displays, and mandatory for high density dot array displays where there are more dots than LCD ledge space to provide interconnects. This configuration degrades the temperature and image performance slightly.

Environmental Considerations - Temperature Range

The operating and storage temperature range of an LCD are important considerations, since operating outside of those ranges will result in a display that is not readable (outside operational range) or permanently damage the LCD (outside storage range). The combination of the LCD fluid, polarizers, operational voltage, and multiplex rate determine the temperature range of the part. So instead of going through the different combinations of these parameters, here are some general guidelines you can use when specifying the temperature range of your LCD, and manufacturer can then assist you in the process of selecting the correct fluid, polarizers, and voltage for your application. These values are typical operating temperature ranges.

• LCD TN Glass / Static or Low Multiplex Rates:
  • Standard Temp Range: -10°C to +60°C,
  • Wide Temp Range: -40°C to +80°C,
  • Specialized Temp range: down to -55°C, or up to +110°C
• LCD TN Modules / Multiplexed:
  • Standard Temp Range: -0°C to +50°C,
  • Wide Temp Range: -20°C to +70°C,
  • Specialized Temp range: -40°C to +90°C
• LCD STN & FSTN Modules / Multiplexed:
  •Standard Temp Range: 0°C to +50°C,
  • Wide Temp Range: -20°C to +70°C,
  • Specialized Temp range: -40°C to +80°C

Another note to remember is the LCD Glass and Polarizers are not the only limiting factors in the temperature range of the LCDs. You also need to take into consideration the temperature limitations of the backlight and controller ICs that may be present along with the LCD.

Connection Method for LCD Glasses

There are three ways to bring the conductive traces on the surface of the glass to your control circuitry.

• Solder Pins: For reliability sake, pins are the most desirable connection method available. These are metal pins crimped to the edge of the glass that allow the LCD to be soldered to PCB. In general, if you can keep the multiplex rate low, we recommend designing a part with pins, even if we have to put them on three sides. So, unless your design begs for a heat seal or an elastomer (commonly called a "Zebra-Strip"), the only good reason not to use pins is that we cannot fit them all onto the part, i.e., there are more segments to drive than there are pins on the part.
• Elastomer Strip: The Elastomer Strip (commonly called a "Zebra-Strip") are small rubber strips that alternate conductive and insulating layers that allows the conductive pads on the surface of the glass (Contact Ledge) to mate with similar pads on the surface of the PCB. They require a bezel frame or other form of glass restraint that will compress Elastomer Strip between the glass and the PCB.
• Heat Seal: The heat seal flex cable is a flexible cable with conductive traces that is bonded to the LCD glass that can either be bonded to the PCB or plugged into a specialized connector on the PCB. The advantage of a heat seal cable is the high density of conductors that can be used on this cable and it has reach. However, the setup charges are much higher even though the per piece cost is reasonable (compared to pins and Elastomer Strip along with the interconnection length).

LCD Module Backlighting

When developing an LCD Module, a backlight can be added to light the LCD and there are several options available to backlight a LCD module. The considerations in backlighting a display are the lighting intensity, life of the backlight, and the power it consumes. Here is a quick comparison of the backlights available.

• LED: Offered in both edge and array lit, this technology is preferred due to its variety of colors, intensity, long life (>100K Hrs), wide temperature range, and low voltage requirements. The downsides are the power consumption of some configurations (large sizes), and the uniformity of the lighting for those same configurations.
• EL Panel: This backlight is very low power, but it requires a high voltage (120VAC @ 400Hz Typically) and it has a relatively short life (half intensity life <4K Hrs), and medium temperature range.
• Cold Cathode Florescent Lamp: This backlight has a lot of intensity for the power consumed, and has its applications for the larger LCD displays. The downsides are a short life span (<20K Hrs), vibration will reduce the lifespan of the tube, limited temperature range, and the high voltage it needs to operate (>300VAC @ 30-80KHz).

LCD Glare Filter

It is possible to put an anti-reflective filter over the front of a display to improve view-ability in harsh lighting conditions. This filter is bonded directly to the front polarizer of the display and its front surface either physically or chemically roughened. This surface re-direct the light waves so that they continue traveling forward instead of reflecting back toward the observer. New anti-reflective materials can reduce the front surface reflections to less than 0.3% or less.

Physical Size

In general, the larger the display, the higher the price. The most expensive part of the Glass or Module LCD in most cases is the glass. Manufacturers usually use a master laminate (Sheet of glass) which is 14" x 16". We can produce a single display that size, or we can partition the array into hundreds of smaller displays . Our strategy is to maximize the number of individual displays which we can get onto this laminate. We therefore recommend display sizes that give our customers maximum glass utilization

LCD Module Considerations

• **Chip on Board (COB) and Surface Mount Technology (SMT)** uses a PCB that is mounted behind the LCD Glass. The support PCB for the LCD Module may be larger than the LCD display and supports the driver ICs and backlight. It can also be specified to contain any amount of customer circuitry in addition to the LCD Module support circuitry.

• **Chip On Glass (COG)** uses the actual LCD glass that acts as the circuit board and the controller ICs can be mounted on to any side of the display as required by the mechanical packaging. The COG LCD then is electrically connected to the user circuitry through Edge Mount Solder Pins, Heat Seal Cable, or Elastomer Strip.

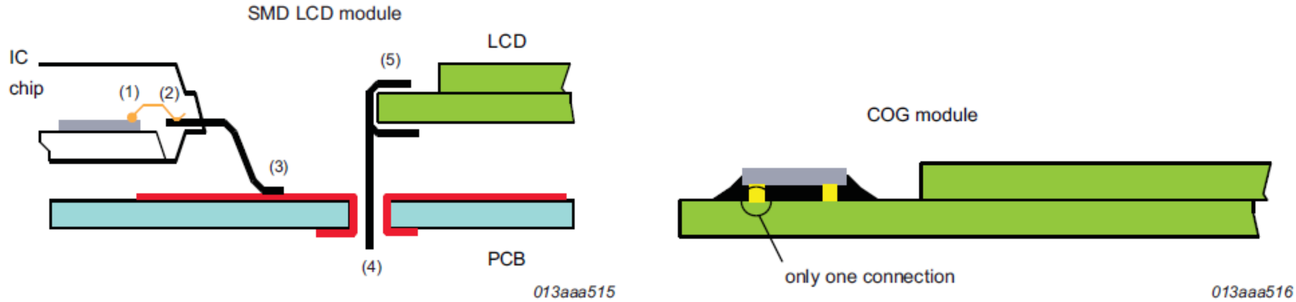
Appendix:

Chip-On-Glass (COG) : A cost-effective and reliable technology for LCD displays

1. The Chip-On-Glass value proposition

Today, many LCD displays are implemented by connecting a cased1 LCD driver IC with the physical display module via a Printed Circuit Board (PCB) (see Figure 1a). This approach - referred to in the following as the Surface Mount Device or SMD approach - provides a robust mechanical solution but requires a more complex and more area intense PCB design. Chip-On-Glass (COG) technology is an alternative design methodology in which the LCD driver is mounted directly on the display glass (see Figure 1b). This approach - in the following referred to as COG approach - reduces the number of tracks and layers on the PCB, cutting the board size and complexity, and eliminates the IC package used in the SMD approach. The overall impact is a reduction in system cost.

In contrast to the SMD approach, COG requires tight production and design coordination between the IC and the LCD module manufacturers.



In SMD modules, five connections are needed:
(1) and (2) wire bond from chip to lead frame,
(3) solder connection to PCB,
(4) and (5) connection from the PCB to the display

a. SMD LCD module

In COG modules, only one connection from driver to display is needed.

b. COG LCD module

Fig 1. SMD and COG LCD modules

2. The Surface Mount Device concept

In an SMD LCD module, the display and the display driver are directly mounted onto the PCB. The connection between the display and the PCB is made by using either fixed-pins or elastomeric connectors. With today's LCD segment drivers ICs, featuring up to 640 segments in multiplex 1:4 mode this results in up to 164 connections between the display driver and the PCB as well as between the PCB and the display. (see Figure 2 for an example with a 128 segment display and 36 connections).

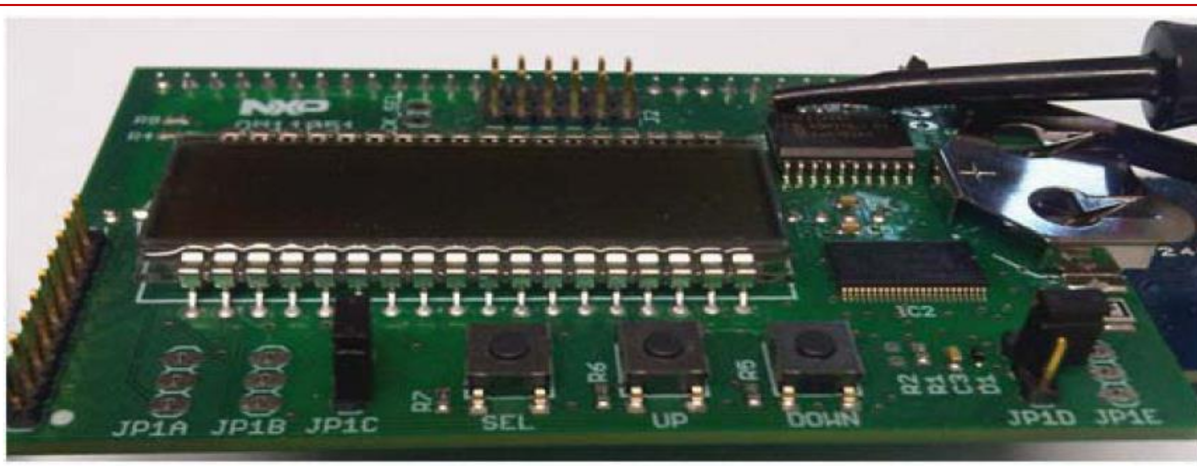


Fig 2. SMD LCD module

In Figure 3 the construction of an SMD LCD module with elastomeric connector – also known as ZEBRA connector - is illustrated. The module consists of the LCD cell, a metal or plastic bezel which clamps down the cell onto the elastomeric connector which then makes the contact with the tracks on the PCB. The elastomeric connector is composed of fine pitch conductive segments alternating with isolating segments, embedded between 2 isolating strips. The bezel, metal or plastic, applies as a force and squeezes the ZEBRA slightly to guarantee a firm contact between the LCD and the PCB.

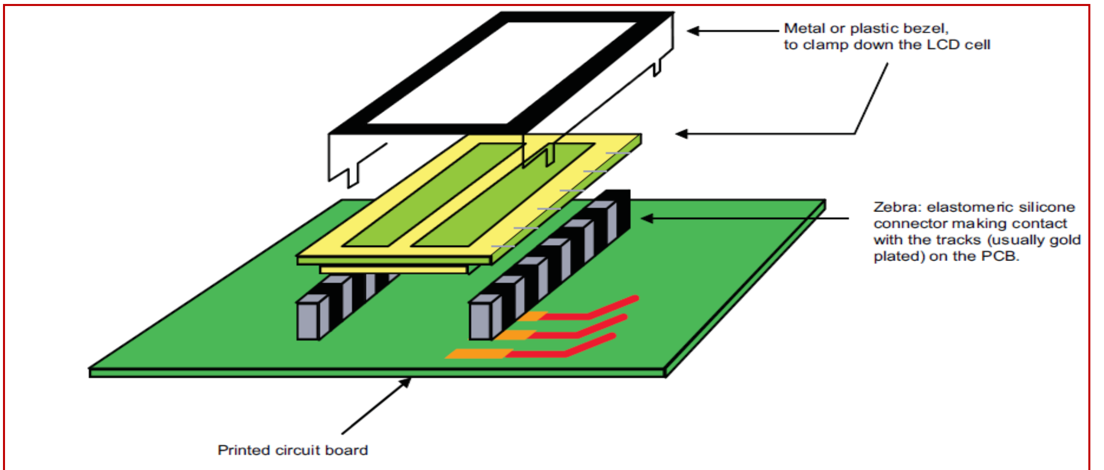


Fig 3. Illustration of an SMD LCD module with elastomeric connector

3. Chip-On-Glass LCD concept

A COG module consists of: A display glass that represents the active display area. A seal ring around the display glass protects and seals the display glass. A contact ledge gives room for the LCD driver IC. The LCD driver IC itself generates the display control and the driving signals. A flex connector connects the display driver IC to the microcontroller (see Figure 4).

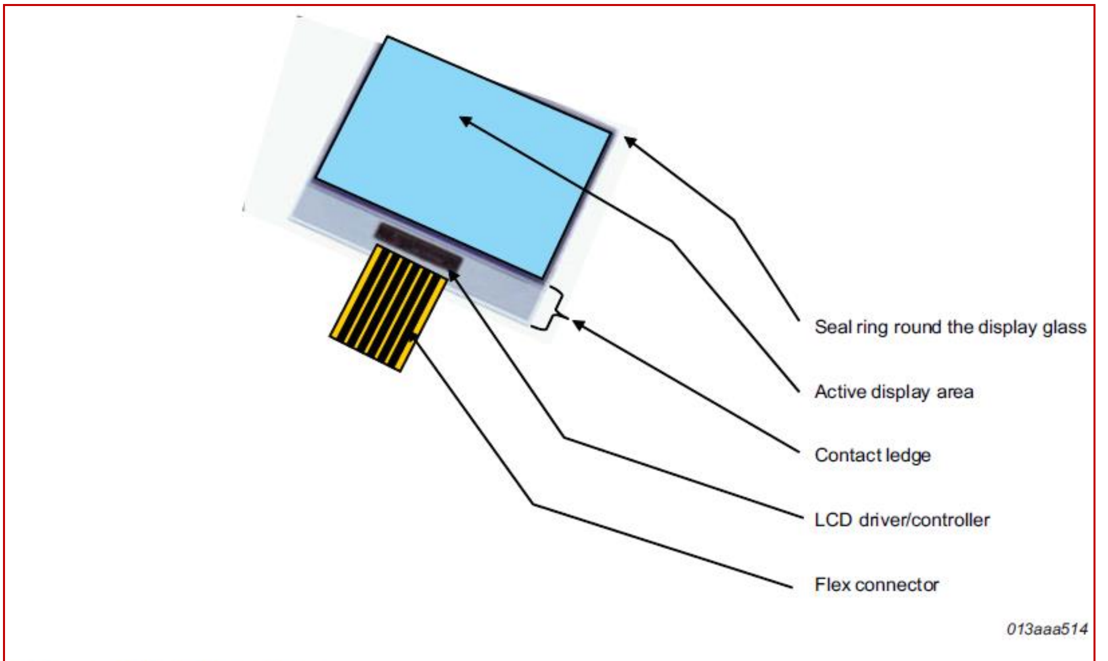


Fig 4. COG LCD module

In a COG module, one of the two glass plates that make up the LCD is extended to give room for an LCD driver to be mounted and connected (see Figure 5). The connections to the display are realized with Indium Tin Oxide (ITO) electrodes which are integrated in the surface of the glass plates and connected via an Anisotropic Conductive Film (ACF) to the gold bumps mounted on the connecting pads of the driver IC.

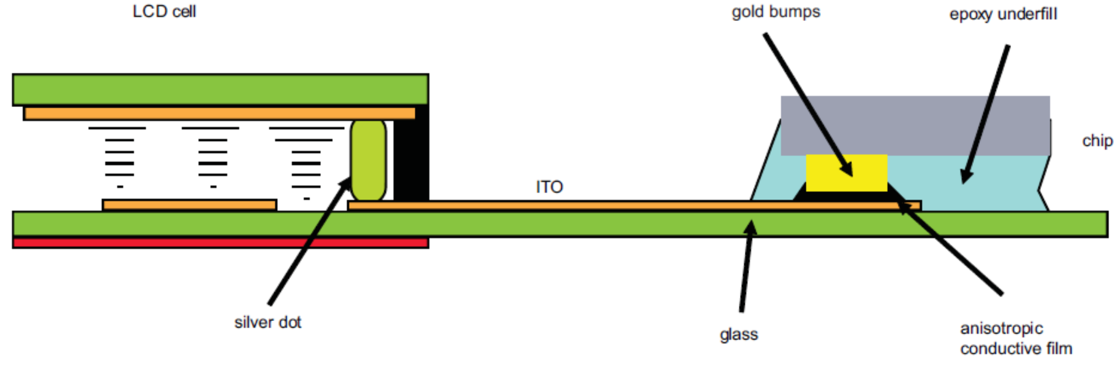


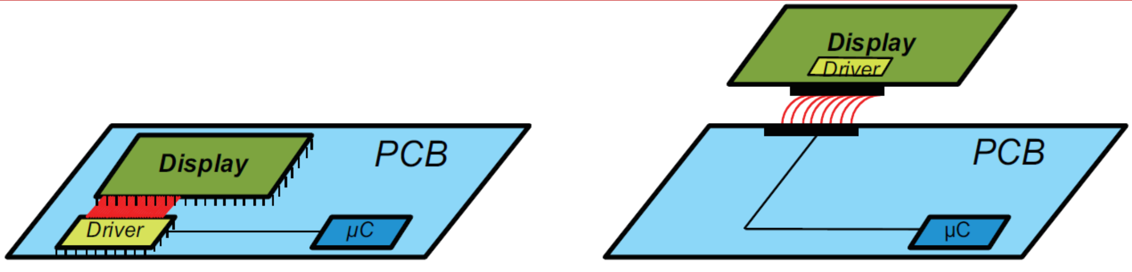
Fig 5. Illustration of an COG LCD module

COG technology sets very few limitations on the LCD display module design:

•For COG, an uncased display driver IC (display driver without a package) is sufficient; the only requirements are that the display driver IC has gold bumps to enable the contact to the ITO tracks on the LCD glass.
•The placement of the LCD driver IC can be on any side of the active display area. This allows placing the LCD driver IC on the smaller side to minimize the required contact ledge and therewith save cost.
•The COG technology allows the cascading of several LCD driver ICs directly on the contact ledge in order to allow for driving larger display resolutions.
•COG technology allows for connecting the display to the PCB wherever it is most suitable, even some distance away from the microcontroller.

4. Surface-Mount Device compared to Chip-On-Glass

In the following an SMD and a COG display system will be compared (see Figure 6). As outlined earlier, in the SMD approach, the display as well as the display driver are directly mounted onto the PCB whereas in the COG approach, the display driver is mounted onto the display module and connected to the PCB via flex foil.



a. Surface-Mount Device b. Chip-On-Glass

Fig 6. Surface-Mount Device compared to Chip-On-Glass

The two systems require the following components (see Table 1).

Table 1. Components

Surface-Mount Device (SMD)	**Chip-On-Glass (COG)**
•PCB •Microcontroller •Cased LCD driver IC (LCD driver in a package): ○ Bezel ○ Display glass ○ ITO tracks ○ Elastomeric connectors	• PCB • Microcontroller • COG LCD module, consisting of (see Fig.5): ○ Display glass ○ Uncased LCD Driver IC (die with gold bumps) ○ Anisotropic Conductive Film (ACF) ○ ITO tracks ○ Flex cable and connector

Given these components, the following design and effort considerations must be taken into account (see Table 2).

Table 2. Design and effort considerations

Surface-Mount Device (SMD)	**Chip-On-Glass (COG)**
• Board space: ❑ Sufficient board space is required to accommodate the cased LCD driver IC as well as the SMD LCD display module.	• Board space: ❑ No board space required neither for the LCD display driver IC nor for the COG LCD module. ❑ Space is only required for the flex foil connector.
• Connectors and Connections: ❑ A large number of connections are required on the PCB between the cased LCD driver IC and the SMD LCD display module. ❑ An elastomeric connector or fixed pins are required to mount the SMD LCD display module onto the PCB.	• Connectors and Connections: ❑ Only very few connections are required between the micro controller and the connector of the COG LCD display module.
• Display location: ❑ The location of the SMD LCD display module is given by the physical location on the PCB.	• Display location: ❑ Location of the COG LCD display module is unconstrained.
• Driver IC location: ❑ The cased LCD display driver should ideally be placed as close to the SMD LCD display module as possible to avoid disturbances on the LCD driving signals	• Driver IC location: ❑ The uncased LCD display driver must be located on the COG LCD display module.
• Flexibility/upgradability: ❑ No flexibility/upgradability to easily replace/upgrade the cased LCD driver IC and/or SMD LCD display	• Flexibility/upgradability: ❑ High flexibility in changing/ upgrading the COG LCD display module (simply exchange the module and the driver software)
• Soldering, inspection and verification: ❑ Soldering, inspection and verification of cased LCD driver IC and SMD LCD display module is required.	• Soldering, inspection and verification: ❑ Only soldering, inspection and verification of connector to COG display module required

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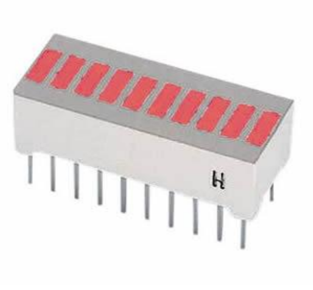

10-Segments LED Bar Display

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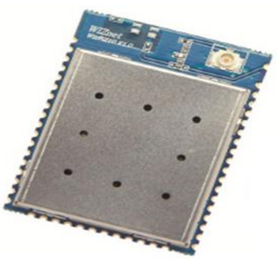
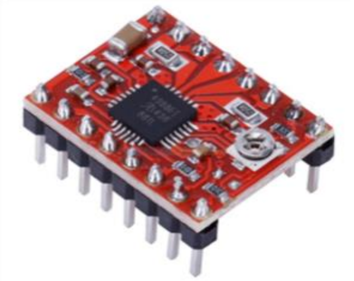
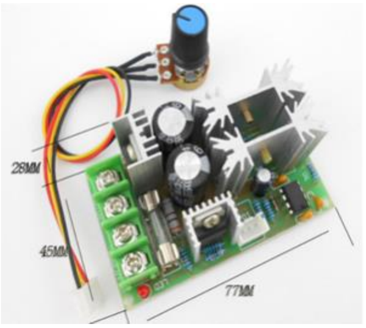


WiFi Module

20x4 LCD Display Module



Stepper Motor Driver



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