THE HANDBOOK TO
DESIGNING WITH DISPLAYS

FUTURE
Display Solutions

What is this Display Handbook About?

This handbook's purpose is to help engineers select and implement proper technologies for the panel, touch panel, controller and display accessories to fit their application. Leveraging the collective engineering and marketing expertise of Future Display Solutions, the provided specifications take into account current and future availability, commitment to longevity, and pricing competitiveness for each element of the solution. The handbook begins with explanations and illustrations of the basic theory for each technology and follows with suggesting relevant questions to consider when selecting display and associated parts. To advance to a specific section, colored tabs have been provided.

Future Display Solutions offers technologies from multiple supplier partners, each of whom have an extensive product range. This handbook is augmented with a web-based selector guide that is maintained for current offering and availability in each technology to help quickly narrow your search.

What is the Selector Guide?

The Selector Guide is a database of over one thousand LCDs, touch panels, OLEDs, memory LCDs and display controllers, and is accessible on the Future Display Solutions website at www.FutureElectronics.com/Displays. We will also refer to it throughout this handbook when we refer to best in class parts.

With the Selector Guide, you can select the part you want using the drop down filters.

The Selector Guide will be updated as our manufacturers send updates. This means that a tiny minority of parts may be obsolete. We recommend that you contact your salesperson or your application engineer to confirm your selected part is valid and to obtain a resale for the quantity you need.

Whatever your product environment, cost, style or practicality, remember that the best design is the one that best solves your needs. The Future Display Solutions team is available to assist you every step of the way. Please contact us at 514-694-7710, ext 6363 or LCDTechnicalSupport@FutureElectronics.com

What is a Human Machine Interface?

HMI is where people and machines connect.

This interaction facilitates the human operator to input control of a machine and monitors the information feedback from the machine. HMI can be found in devices from the dial adjustment on a mechanical watch to wearable devices that detect touch.

Basic HMI

Another example of human machine interface is the steering wheel of a car or the touch computer display for self drive cars.

Currently, these HMI interfaces are displays with a touch sensor added to the front. This gives an immediate, intuitive feedback to the user. Designed originally from short life commercial products, touch displays are being demanded as inputs for industrial machinery, points of sale, shopping mall displays, transport information and restaurants.

The main advantage of LCDs over other types of displays is the ability to change the image to suit the needs of the application. This could be a simple button array to control an industrial process or a high definition video for use in media, for example advertising in a shopping mall. Whatever end use you have planned for your product, adding a display will enhance the experience and value of your product; it is the window to your device.

The following sections will break down what is inside a display.

What is in a Display?

Future Display Solutions can provide many displays directly from our suppliers' standard offerings.

If you need to modify a standard display to make it rugged, improve the optical performance, increase the brightness, add a touch panel or add a custom metal frame, then integration services are required to create a custom combination.

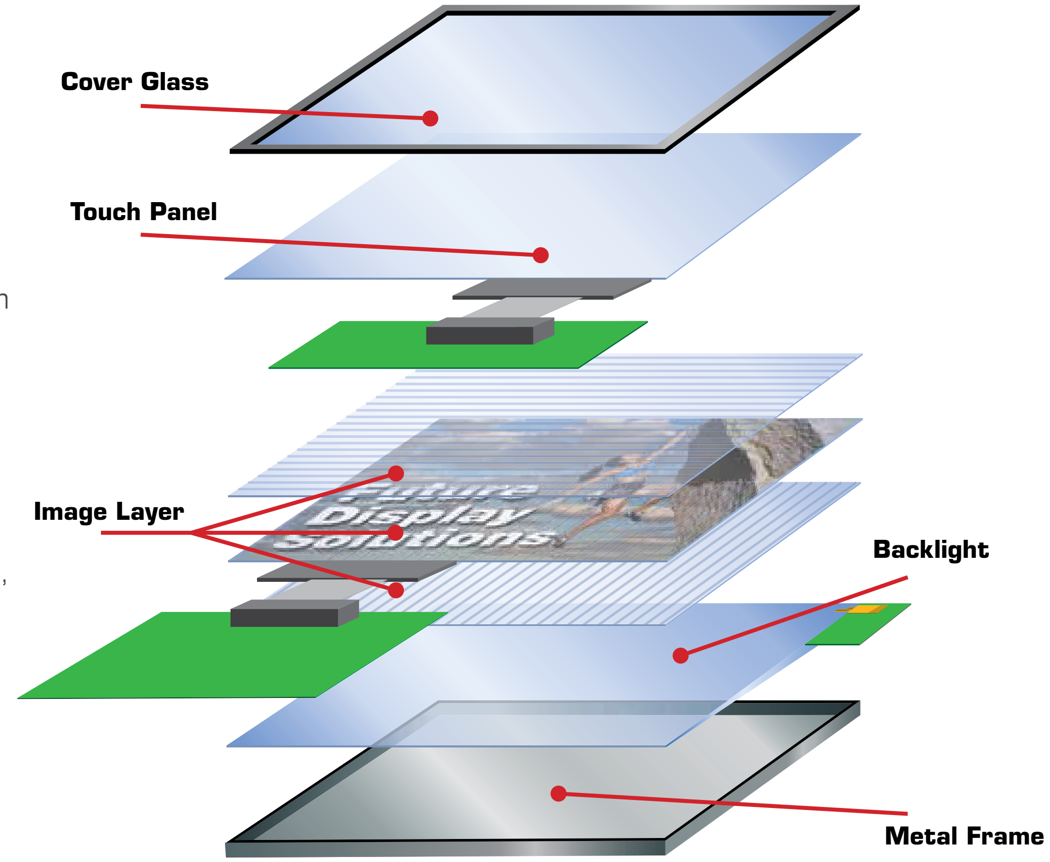
Future Display Solutions' integration program can integrate your display to suit your needs. For more information on integration, refer to page 39.

Basically, displays are layers of glass with fluid in between them, a light source and thin transistors that control the liquid to selectively block the light, creating an image. These layers are called the display "stack up" and can number 10 or more depending on the solution required.

Displays are cut from large sheets of glass, and only a few manufacturers make the sheets from raw glass. The glass is etched and the transistors, etc. are printed onto the glass.

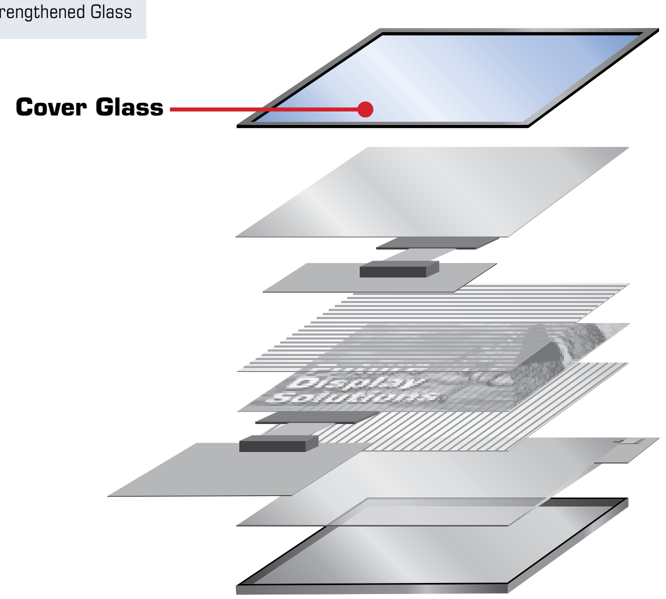
The glass is cut into sizes that obtain the maximum number of displays with the least amount of wasted glass. This is why there are standard sizes and few non-standard or custom sizes. Custom sizes are more expensive, as the tooling has to be changed for this size, thus leaving extra unused glass.

To show how a display works, let us begin by placing the display on its back and starting from the top, discussing each of the layers in detail.



Cover Glass and Films

The cover glass sits at the top layer of the display stack-up:



Cover glass is an additional glass layer that is bonded to the surface of the LCD or the touch panel. This layer is not required to make the display work, but rather adds to the overall display performance by improving the optical characteristics, the strength of the display and to the appearance of the display. This layer may be added in the original factory where the LCD is manufactured or later by an integration company.

Common cover glass options to consider are: strengthened glass, anti-reflectance and anti-fingerprint. The types of bonding required between the glass layers should also be considered early in the design process. Refer to the section on bonding (page 10).

The cover glass may also have custom ink printed on the glass for company logos, symbols or buttons. This is known as silk screening.

Strengthened Glass

Strengthened glass was first required to protect point of sales (POS), ATMs and kiosk applications as vandal shields. Strengthened glass was also used in industrial applications and military applications where rugged glass was imperative and cost was not an issue.

Strengthened glass types have been introduced to the consumer space due to the demand for protection of mobile phones and tablet PCs from being damaged when dropped by the user.

Because of the price vs. performance benefits, many engineers realize they can meet their required durability using standard soda lime chemically strengthened glass. For the high volume consumer market, the strengthened cover glass has been limited to less than 10" sizes, as above that size the glass becomes extremely expensive to use. The automotive market has also seen a limited adoption of strengthened glass types, but the majority of cover glass in cars today uses soda lime glass. Manufacturers, who sell products in volumes of hundreds of thousands, tend to pass the strengthening of their display to either the cover lens manufacturer or to the touch panel manufacturer.

Types of Strengthened Glass

Soda lime float (slight green tint), low iron soda lime float (colorless), Asahi Dragontrail© (.55mm, 0.8mm and 1.1mm), Corning Gorilla Glass© (0.55mm, .7mm, 1.0mm, 1.3mm and 2mm), commercial one sided AR on soda lime substrate, optical-HE (high efficiency), two sided AR on soda lime substrate.

Anti-Reflective Glass

When reflected ambient light is stronger than the emitted luminance from a display, there is a reduction in readability of the display, thus reducing the apparent contrast ratio. To overcome this issue, anti-reflective cover glass is applied to the LCD glass to reduce the reflectance on the display surface. This is not a new idea; it has been manufactured for the avionics industry for years, to improve the performance of their cockpit displays in bright sunlight.

Options for anti-reflective (AR) coated glass include: Optical-HE AR, HITAR AR, Crystal View AR, PAR AR, and commercial AR.

Coatings and Films

Instead of adding the top layer as a glass, it can also be added as a coating or thin film. Commonly used coatings (chemically applied): anti-reflective, anti-glare, UV blocking, liquid coatings applied in-house at the glass converter and oleophobic (anti-smudge/fingerprint-free).

Commonly used films: anti-fog, diffusers, IR blocking and IR transmitting, anti-glare, anti-reflective, safety films and privacy films.

Some common types of 'scratch resistant' cover glass are: Gorilla Glass© and Dragontrail©. Future Display Solutions has a solution for all your display needs.

Contact your display specialist for more detailed help on choosing which cover glass and bonding is suitable for your needs.

DID YOU KNOW?

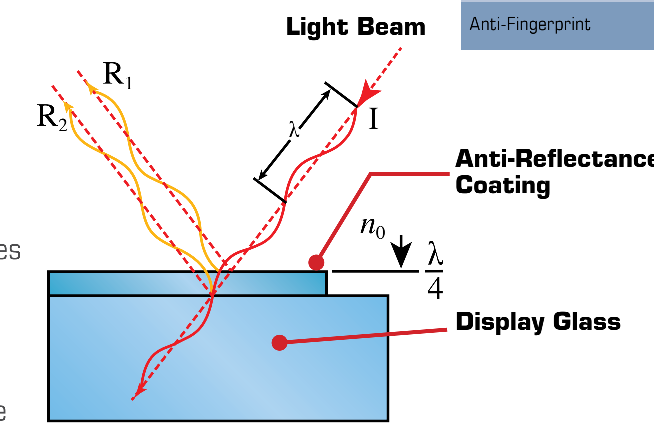
The concept of strengthening glass through ion exchange is not new; it has been known since at least the 1960s.

Hardness	Reference Material	Absolute Hardness
1	Talc	1
2	Gypsum	1.25
2.5	Fingernail	2.5
3	**Film to Glass Resistive Touch**	4
3.5	Copper Penny	4.5
4	Fluorspar	5
4 - 4.5	Platinum	5.5
5	Tooth Enamel	6
5.5	Window Glass, Knife Blade	6.5
6	Pumice	37
6.5	Steel File	37
7	Quartz	100
7	**5 Wire Resistive Glass Film Glass**	100
7	**Projected Capacitive Touch Panel**	100
7	**Surface Acoustic Wave Touch panel**	100
7.5	Hardened Steel File	100
8	Topaz	200
9	Tungsten Carbide	400
9	**Chemically Strengthened Glass**	400
10	Diamond	1500

Anti-Glare

Studies have shown that prolonged work in an environment with glare and light reflections on a display can cause headaches and eye strain.

When light hits between two mediums, for example air and glass, the light can be transmitted, reflected, absorbed, or scattered. Observable effects are that the black level is reduced, contrast degrades and readability is decreased.



Adding a coating on the top layer of the glass will help improve these effects by stopping stray light returning to the viewer's eyes.

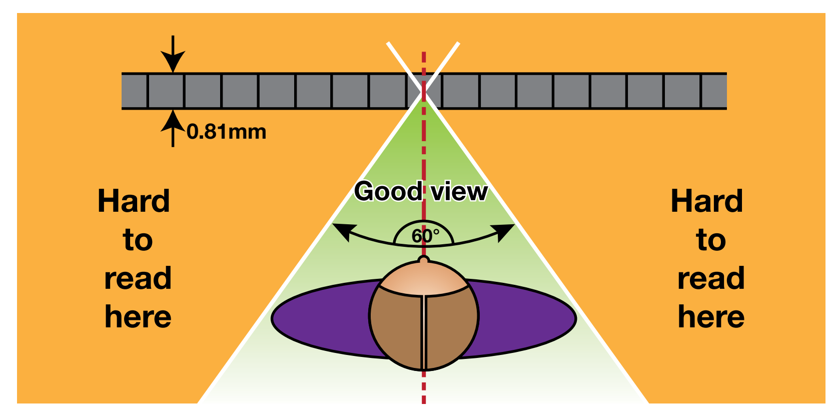
Anti-glare scatters incident light into many angles. This removes reflected images, but creates a uniform gray-level reflection; therefore the black levels are reduced.

The anti-reflectance coating may be a thin film with a specific thickness based on the wavelength of the light that needs to be removed. If the thickness of the layer is precisely controlled to exactly one-quarter of the wavelength of the light to be removed, then the reflections from the front and back sides of the coating will be inverse to each other and therefore will cancel each other out.

Visible light is in a range of 400-700nm, so for a mid range of 550nm a coating of approximately 140nm would reduce the reflected light.

Privacy screens are made by manufacturing micro-louvres within this layer.

These tiny blinds stop the light from being seen from the side of the display, keeping the information on the display private. An additional side effect from this technology is that off-axis ambient light is mostly absorbed, creating a better readable screen when the viewer is directly in front.



Anti-fingerprint or lipophobic for oleophobic coating is used on cover glass to repel the oil from the fingers. It also helps with cleaning of the screen. Similar to Teflon, these oleophobic coatings are based on fluoropolymer solids and will repel both oil and water. Avoid using isopropyl alcohol on the screen to clean it, as it can damage the coating.

DID YOU KNOW?

The first type of anti-reflection was discovered by Lord Rayleigh in 1886. He observed that old tarnished glass transmitted more light than clean pieces of glass due to the reduction in reflectance.

Bonding Glass

The cover glass is normally adhered to the LCD glass by either tape, edge, optical or dry bonding.

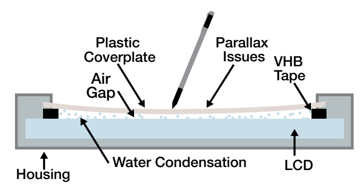
Dry Bonding

Dry bonding uses a pressure sensitive adhesive layer (PSA) instead of a liquid or gel to adhere the layers of the display. By using a special process of either applying a pressure or vacuum to the PSA layers, they bond together. The advantages of dry bonding include:

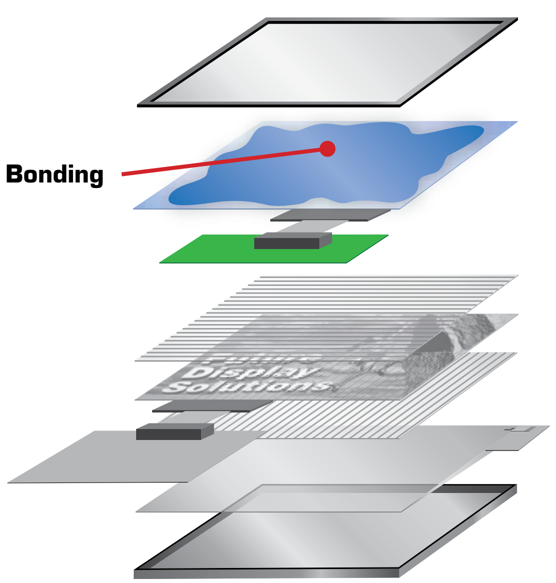
- It is excellent for strengthening.
- There is less waste as the process does not use liquids and cleaning solvents are not required.
- The process is much faster to produce with no residuals to clean up; the tooling is ready for the next display.
- It can be scaled easily for any size of display.

Tape Bonding or Edge Bonding

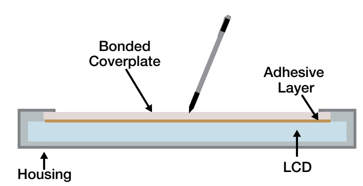
In Tape or Edge bonding, the glass layers are bonded together only at the edges. This is generally a faster, lower cost option. Bonding at the edges creates a small air gap between the cover glass and the LCD glass. Depending on the environment, it is possible that moisture can enter between the layers, affecting the LCD image. This is known as fogging, for example in a marine environment. As there is no central support, this type of bonding might not be a strong as optically bonding the glass. Due to the air gap, ambient light may reflect off the internal surfaces, resulting in as much as 13.5% reflectance or a loss of luminance. Very high bond tape (VHB) is normally used for edge bonding and is available from our integrators.



Optical Bonding



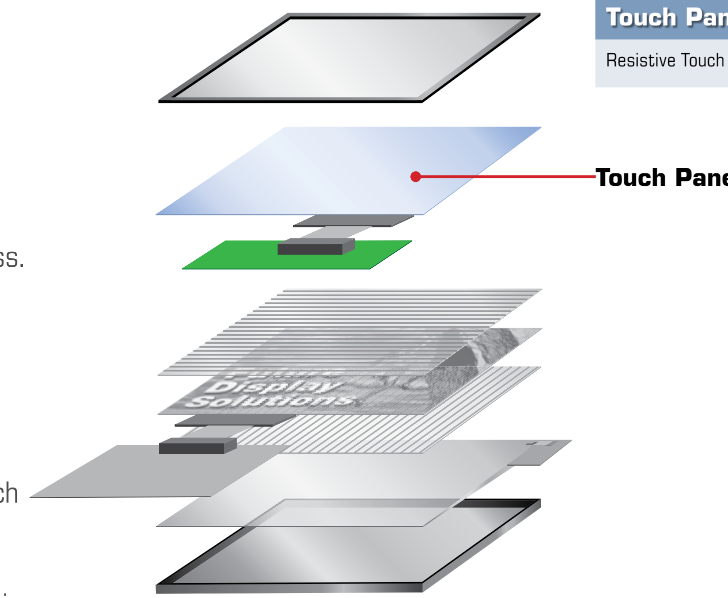
Optical bonding of glass is when a special liquid adhesive is used for bonding the cover glass to the touch panel or the cover glass to the LCD glass. For bonding the entire glass layers, optically clear adhesive (OCA) is normally used.



This method seals the complete layer stackup and has no air gap. A main function of optically bonding glass is that it optically couples the glass, known as index matching. Compared to an edge bonded display, optical bonding also decreases the degradation of internal reflected light and improves the contrast ratio.

As well as the optical performance, the strength and longevity are also improved, as dust or moisture cannot enter between the layers. With as little as a 1mm increase in module thickness, a significant increase in impact strength of the LCD may be obtained.

Touch Panels



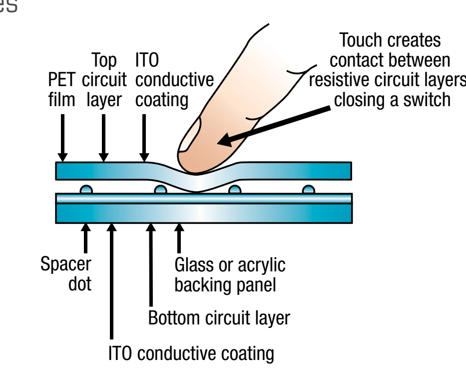
You probably use one of these every day and yet it is invisible to you. The touch panel has taken over as the Human Machine Interface for most devices. Previously we had the electronic keyboard, the mouse, a stylus or a micro thumb sensor to input data to a machine, phone or laptop. One of the biggest advantages of a touch panel is its directness. The touch panel is so intuitive that even kids understand how to get the results they want. Now it is expected that when people see a display, they touch it and swipe it and then are confused if the display image does not change.

A touch panel requires the following to work: a touch sensor, a touch controller and software driver. The touch sensor is a transparent layer of glass on top of a display. The touch controller is an electronic chip (or a board that contains the electronic chip) that translates the electrical signals from the touch sensor and converts them for a computer to understand. The software driver helps the controller work with the operating system being used by the computer.

There are many types of touch panels: resistive, projected capacitive, surface capacitive, surface acoustic wave, infrared, total internal reflection, on-cell and in-cell.

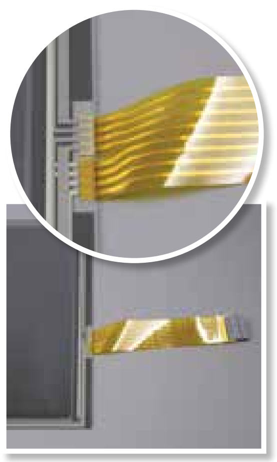
Resistive Touch Panels

For many years the most popular touch panel technology was analog resistive. The touch sensor is able to pick up touch location by having two layers. The bottom layer is normally glass with a plastic layer on top; the two layers are separated by an air gap. The top and bottom layers have thin transparent conductive wires running at 90 degrees to each other. This forms a grid of wires. When the top layer is pushed down the conductive wires touch together. By adding an electrical current to the top and bottom layers it is possible to detect the resistance, and therefore the X and Y positions on the screen that have been pressed. The thin transparent wires are normally made from indium tin oxide (ITO) but some manufacturers actually use thin metal wires on large displays, for example on 21" LCDs and above.

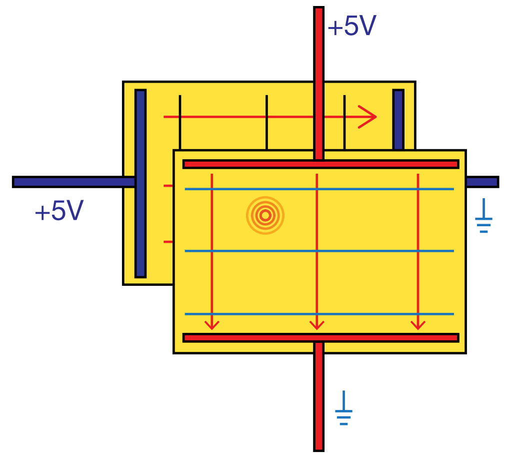


Resistive Touch Panels

There are several types of restive touch panels, typically 4-wire, 5-wire and 8-wire.



8-Wire Touch Panel



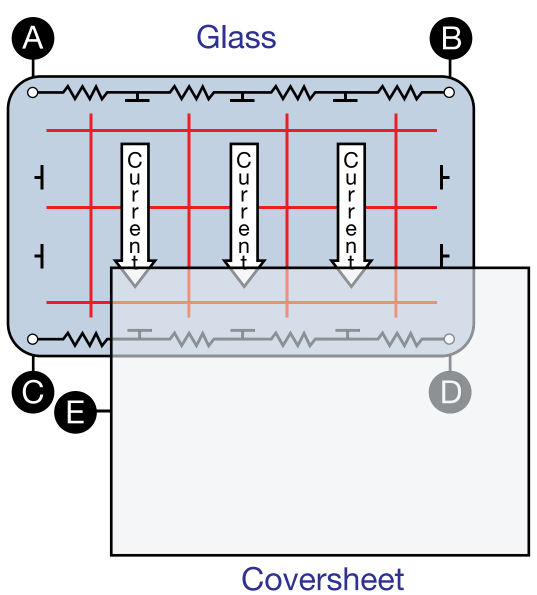
Four-wire resistive touch panel is the simplest type that uses two layers with a resistive coating of indium tin oxide (ITO). One panel will detect the X and Y coordinates of the touch. The controller applies a voltage on the silver buss bars on the edges of the panel to the X layer and analyzes the Y layer for a voltage. The controller then switches and applies a voltage to the Y layer and analyzes the X layer for a voltage. When the touch panel is probed, the two conductive layers touch each other and an electrical contact is made. Constantly switching between the two layer's two voltages will be detected. Based on these voltages the controller can calculate the XY location of the touch. Only three of the conductors (wires) are used at one time. Four-wire touch panels are normally used on smaller displays of under 7 inches.

Eight-wire touch panels are similar to four-wire touch panels except there are additional sensing points. They are normally used on display of 7 inches and above.

The drawback of 4- and 8-wire resistive touch is that the outer layer is flexible and over time this can cause cracking in the conductive ITO film, giving inaccurate readings.

Five-Wire Resistive

Due to the cracking in 4- and 8-wire touch panels, five-wire touch improves this by using the solid bottom layer for both the X and Y measurements. Four wires are connected to the corners of the bottom layer (A, B, C and D on diagram). The touch controller applies a voltage to A and B, points C and D are grounded. The controller then switches and applies a voltage to A and C; points B and D are grounded. The controller alternates back and forth. A flexible cover sheet is added on top of the solid layer. When the flexible layer is pressed against the bottom solid layer, an electrical connection is made. Two voltages are detected when the controller switches between AB/CD and AC/BD, giving the X and Y coordinates of the touch. The 5-wire touch panels have a higher life span than the 4- or 8-wire resistive touch panels, due to the resistive conducting film being on the solid layer that does not flex.



Resistive touch panels are analog systems that may be susceptible to drift and require recalibration for accurate results. You need to be careful, as sharp objects can damage the top touch layer. Also with repeated use over time, the ITO conductors can crack, which can result in a dead spot on the touch panel. The air gap between the layers can cause diffraction of the ambient light, causing external reflected light to reduce the contrast ratio and can make the display look washed out.

Another thing to consider is that resistive touch panels generally only sense one touch position at a time. Most people are getting comfortable with two touch or more to pinch, enlarge, or rotate images on a display. Future Display Solutions has manufacturers that make multi-touch resistive panels that work well where thick gloves are required, e.g. military applications or mining.

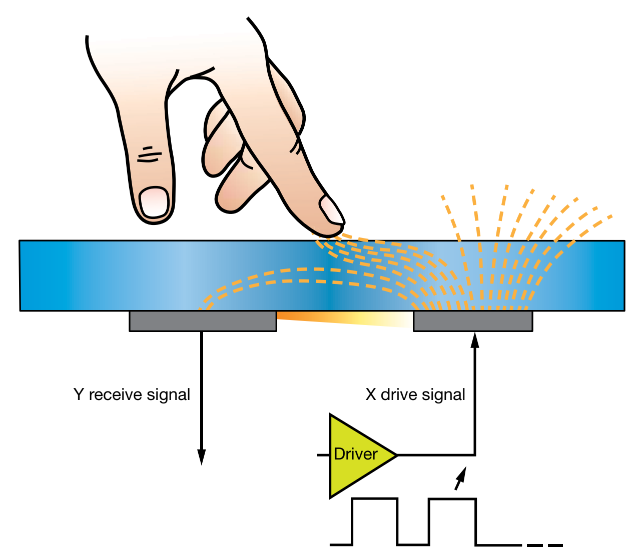
Resistive touch panels are a good choice for industrial machine control, point-of-sale terminals and medical equipment, as they continue to work when there are liquids or contaminants on the surface. They can detect finger, fingernail, gloved or stylus forms of activation.

Projective Capacitive Touch Panel

Resistive touch is losing market share to projective capacitive (PCap) due to the large integration into smartphones, tablets and wearable devices. Industrial projects are requesting PCap as their first design choice.

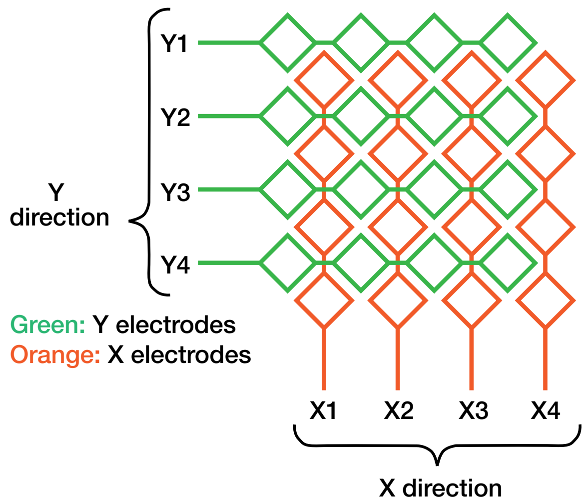
PCap is made of two layers of glass with conductors on each and an insulator in between; normally this insulator is made from glass. The conductors create a capacitance that projects above the top glass layer. When that capacitive field is touched with your finger, the capacitance is changed, and this difference is detected.

As with the resistive designs, the conductors typically are made of transparent ITO layers, except in PCap touch panels where the conductors are enclosed in glass and do not suffer wear as much as resistive touch panels.



Projective Capacitive Touch Panel (continued)

Two conducting layers are manufactured at right angles to each other with an insulating layer between them. The 90 degree difference between the conductor layers creates a grid to detect where on the X and Y coordinates the panel has been touched.



Normally the grids are shaped in a diamond format; this helps with incorrect readings.

Because the conductors are scanned in rapid sequence many times per second, it is also possible to identify multiple simultaneous touch points. This gives additional options to add gestures to your product. For example, you can rotate, pinch and enlarge objects on the screen.

When the PCap touch panel is in a heavy electromagnetic (EMI) environment, for example caused by LCDs or OLEDs, the screen can pick up this EMI noise and give incorrect readings. The touch controller has to be sensitive enough to ignore this noise and recognize real touches. Some of our manufacturers and integrators will tune the PCap panels to the LCD to ensure a high performance.

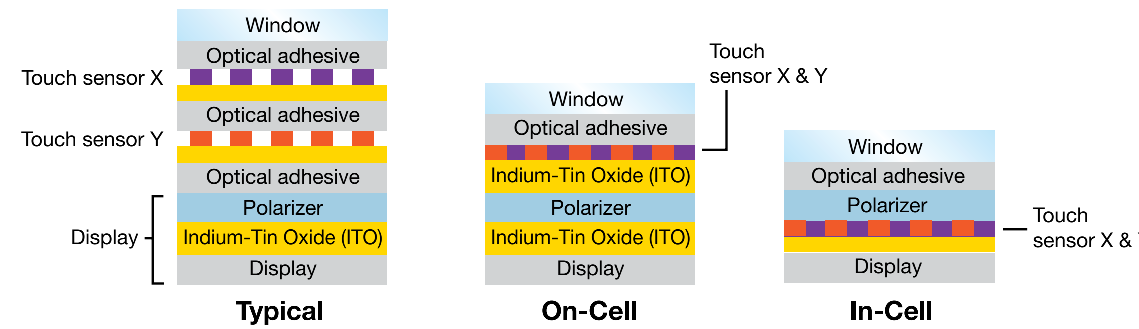
Our System Design Center has tested some PCap touch panels with three pairs of thin surgical gloves. If the user is wearing thick gloves, the touch sensor will need to be tuned for that sensitivity or it will not work correctly. An alternative to this tuning customization is supplying gloves with a built-in conductor in the fingertip.

PCap touch panels can be made with no bezel, are easy to clean, offer multi-point touch capability, have clear optical properties and strengthened glass. Projective capacitive touch panels are great when users are interacting with a small to a medium sized screen (4.3" to 32") to search for information, such as in malls, transport kiosks, museums, sports stadiums, rugged tablets, agriculture, medical and gaming applications.

Trends

Customers are constantly looking for thinner and lighter devices. Manufacturers are now starting to build on-cell, in-cell, metal mesh and nano particle touch panels.

One-glass solution (OGS) removes the layer of insulation glass and replaces it with a thin layer of insulation. By removing the glass insulator layer, there is a 25% reduction in the weight and thickness of the touch sensor. The conductors and insulated layers are added to the bottom side of the cover glass. Then the cover glass is added to the LCD.



On-Cell

Very similar to one glass solution except the conductors and insulated layers are added to the LCD first, and then the cover glass is attached. Although there is no significant difference to the user, there is a difference to the supply chain, as LCD manufacturers can add these layers in their factory and the need to buy a separate sensor from another company or the need to use an integrator is removed, thus saving on costs to the total product, the additional shipping and the lead time.

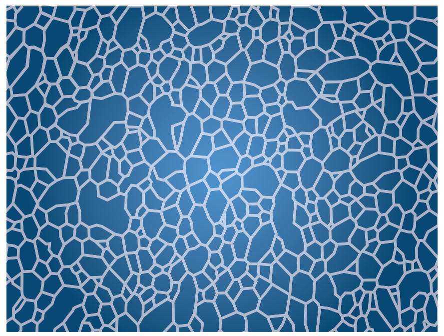
In-Cell

In-Cell takes the On-Cell one step further by adding the PCap conductive layers in the LCD TFT pixel layer, reducing the layers of glass down to one outer layer. This makes the total LCD touch panel thickness thinner and lighter. This is a bonus for mobile phone manufacturers. By combining the conductive layers in the LCD manufacturing process, the LCD controller and the touch controller can be added in the same chip, reducing the number of parts. This method of manufacturing LCDs with touch sensor creates a one stop shop, removing the touch sensor manufacturing additional layer. Currently this process is only available for very high volume displays such as smart phones that are manufactured in the millions of units. Therefore it may take time for this to hit the industrial LCD manufacturers.

DISPLAYS
Touch Panels
Projective Capacitive Touch Panel
• ITO-Replacement

ITO-Replacement

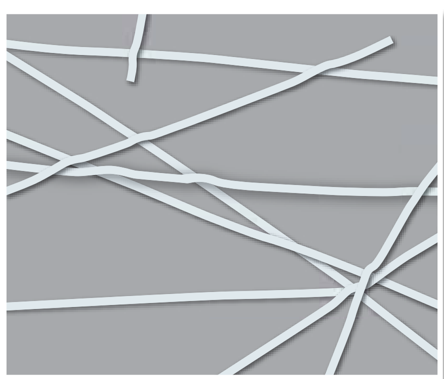
Capacitive touch continues to grow rapidly and in effect will reduce costs as production volume increases. We see that PCap touch will continue as the preferred method to detect touch but the transparent ITO layer is not always very transparent and the diamond pattern can reduce the brightness and can sometimes be seen. There are new methods of adding the layers of conductors that will be thinner, have better optical transparency and better conductivity. These technologies are called ITO-replacement. They are removing the indium tin oxide layers and replacing them with other conductors. These layers include metal mesh, nano particle or nano fiber. They are conductive layers that are arranged in very thin mesh or fibers. By being very thin they let more light from the backlight pass through the touch panel.



ITO-replacement has challenges such as visible metal lines or haze, but the industry is working on overcoming these issues. Some manufacturers use a special form of nano fiber liquid; when it dries it forms bubble shapes. These silver nano particle films are very conductive and also very transparent. The process has a fast production time that should decrease costs. This technology could be used in in-cell and on-cell touch panels.

Other manufacturers have devised an ink that is micro patterned on a polyester (PET) film substrate. The material is highly transparent, has good optical clarity and low haze.

The film can not only cover the small to medium size displays but also larger displays for media and gaming applications.



Unlike ITO products, the new flexible materials can conform to rounded surfaces or edges; this opens the door to unique designs like curves, foldable or roll-able touch panels. PCap is the most requested type of screen, and with the improvements in on-cell and in-cell it looks like it will hold this position for the near future.

Lastly, although people are getting familiar with using their fingers for touch panels, drawing with a pen is still accurate and very natural for most people. Higher-resolution display manufacturers are reverting back to the ability to use a stylus to their PCap touch panels to help with accuracy instead of using a finger.

Surface Capacitive Touch Panel

In S-Cap technology only one side of the insulator glass is coated with a conductive layer that is attached to electrodes. The user touches this layer and conducts a tiny electrical current which is detected by the touch controller, which calculates the location of the touch on the screen. This ITO layer is on the outer glass layer and is exposed, giving a limited life span as the layer can become worn. This type is useful in areas where there may be dirt or dust, as they do not conduct a current. Useful in POS, gaming or kiosk applications, they can also be manufactured to fit large displays.

Infrared Touch Panel

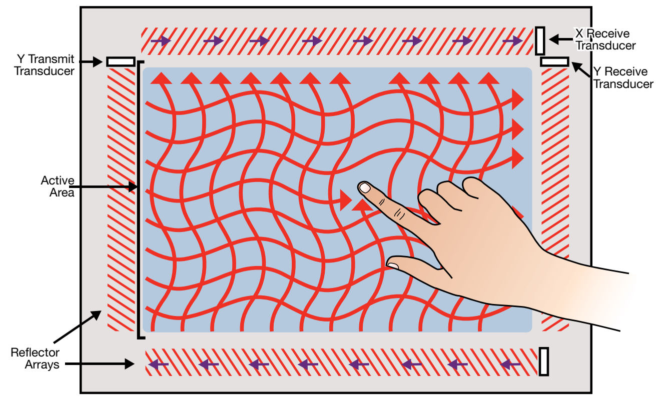
By attaching a thin bezel to the front of a display, it is possible to insert a row of infrared (IR) LEDs along the X and Y axis. Another row of IR receivers is placed on the opposite side of the bezel LEDs. The LEDs are then pulsed in sequence. When the display is touched, the beam of infrared light is interrupted in that area, giving an X and Y location that is detected by the controller. The advantage of this method is that there is no physical layer added to the front of the display that may cause optical degradation. The touch capabilities cannot be worn out, as there is no physical layer, only an optical curtain.

Disadvantages are that they can be sensitive to ambient light, and cleaning the display can build up dust on the receivers, thus giving false readings.

IR can be useful for vandal proof indoor/outdoor environments and can be activated by finger, gloved hand or stylus. It can also be added to large displays, making it useful for ATMs, ticketing machines, and large public information displays.

DISPLAYS
Touch Panels
Surface Capacitive
Infra-Red

Surface Acoustic Wave Touch Panel



Surface Acoustic Wave Touch Panel

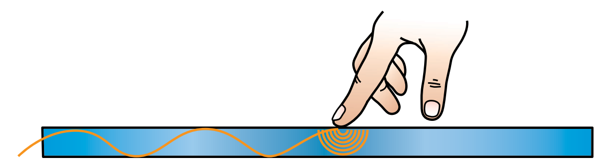
This technology uses inaudible ultra-sonic waves that pass over the touch panel. Part of the wave is absorbed when the panel is touched. The touch controller detects and registers the change in the ultra-sonic wave and calculates where the display has been touched. Surface acoustic wave touch panel panels can be delicate and expensive. They are also sensitive to contaminants on the screen. SAW touch panels are being replaced with other types of touch sensors but may be used in noisy EMI areas.

Touch Panel Comparison

	4 or 5-Wire Resistive	Surface Capacitive	Projected Capacitive	SAW	Infrared
Sensor Substrate	Glass with ITO coating and polyester top sheet	Glass with outer ITO coating	Glass with inner ITO coating	Glass with acoustic wave guides	Any type
Sensor Detection	Any object	Finger or capacitive stylus	Finger, capacitive stylus or surgical glove	Finger, gloves or stylus	Most objects
High Sensitivity	Good	Better	Better	Better	Best
Clarity	75 - 85%	90 - 98%	90 - 98%	90 - 98%	95 - 100%
High Accuracy	Better	Good	Best	Better	Better
Scratch Resistance	Poor	Better	Best	Best	Best
Surface Contaminants	Best	Good	Better	Poor	Poor
Sensitivity to Cleaning Chemicals	Better	Better	Best	Better	Best
Non-Sensitive to Rain	Best	Poor	Better	Poor	Best
Humidity	Poor	Best	Best	Better	Better
EMI	Best	Poor	Poor	Better	Best
Vibration	Best	Better	Better	Better	Best
Calibration Stability	Good (5-wire)	Good	Better	Better	Best

Total Internal Reflection Touch Panel

Total Internal Reflection touch panels use opto-mechanics and signal processing to detect the user's touch. By transmitting a light signal internally on one side of a glass layer and received on the other side, a disturbance on the surface by a touch will be detected by the receiver. Signal processing determines the location of the touch.



Advantages include:

- Pressure detection that adds another dimension to touch gestures. For example, pressing harder on the touch panel may represent that the user wants to drill down into a file.
- Lower cost: as the display size increases, the cost only increases based on the outer perimeter and not the complete surface area of the panel.
- As the sensor is based on light, a large number of scan lines provides robustness and redundancy in the panel.
- Multi-touch detection.
- Clear glass, as there are no conductive layers reducing the luminance.

Touch Panel Integration

The most common integration request we receive is to overlay a touch panel on top of an LCD module.

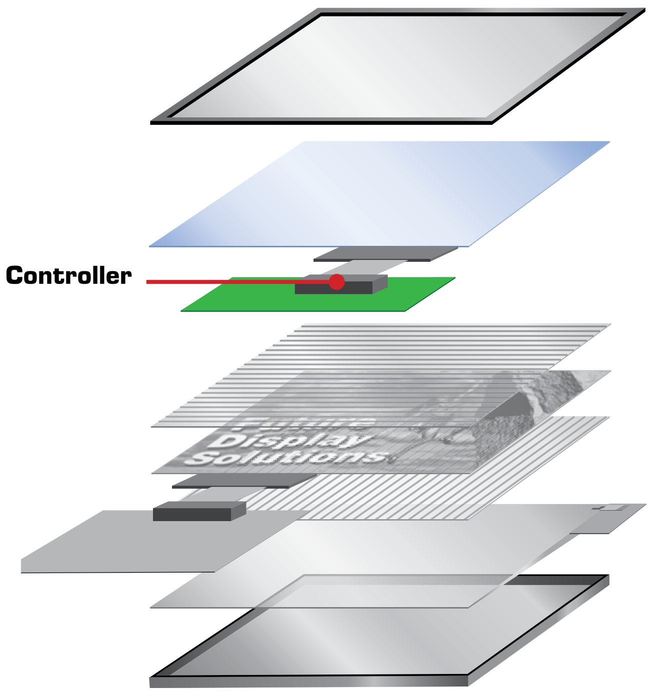
The Future Display Solutions team will help you select the right touch technology for your application. Four/five/eight-wire resistive, resistive multi-touch, surface capacitive, projected capacitive, surface acoustic waves (SAW), infrared (IR), acoustic pulse recognition (APR) and metal mesh are just some of the current touch technologies we offer and integrate.

Key factors in determining which touch technology to use are: the application environment; where the product will be used; durability, and whether it needs to work with a stylus or a glove.

Once the LCD and touch panel have been selected, we then narrow down the type of bonding required. The type of bonding required is determined by the mechanical, optical characteristics and how rugged the applications needs to be. We can recommend whether perimeter airgap bonding, optical bonding or any additional gasket or film is required.

Touch Controller

The touch controller is normally a small circuit board that attaches to the touch panel either by wire or FPC tail and converts the analog signal from the touch panel to a digital signal a computer can use. Most touch panel manufacturers provide recommended controllers to match their touch panel part number. It is important to consider that all the appropriate cables are available to connect the controller during the design.



Typical interfaces to touch panel controllers can be I²C/SPI, Serial, UART or USB.

The touch controller can also be manufactured on the panel.

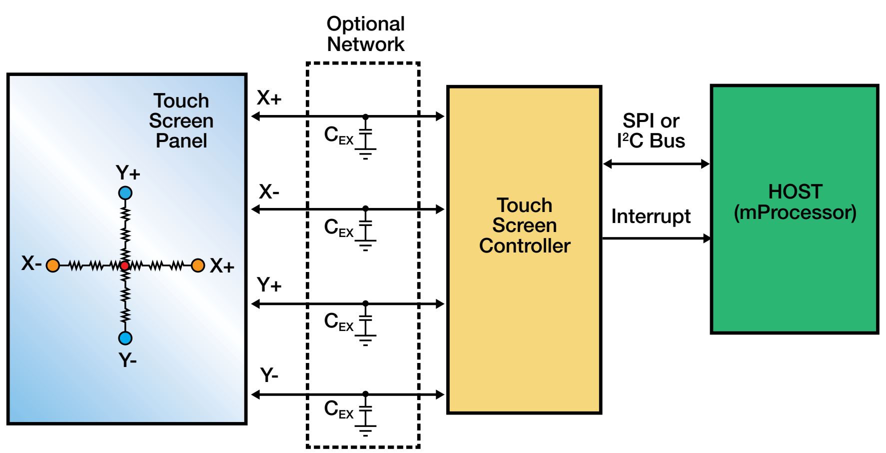
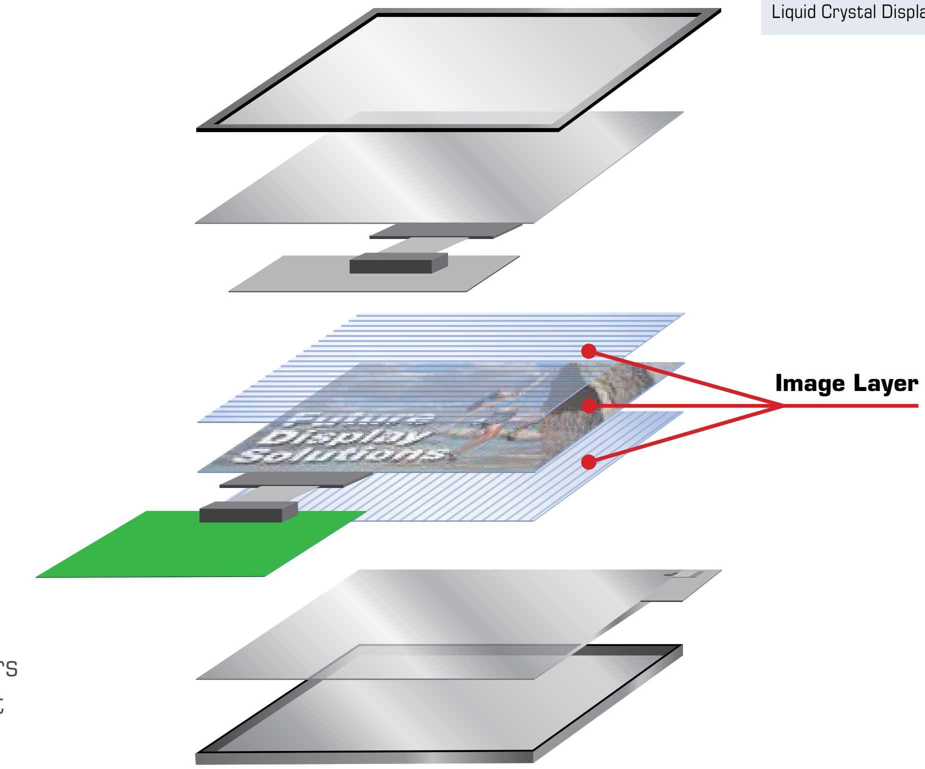


Image Layer

All the common types of displays we will focus on in the image layer:

- Liquid Crystal Display
  - Passive Matrix LCD
  - Active Matrix LCD
  - In Plane Switching
  - Vertical Alignment
- OLED
- AMOLED
- Low Refresh/Memory LCD
- Electronic Paper Displays
- Sub Pixel Rendering

Refer to interfaces on pages 48.



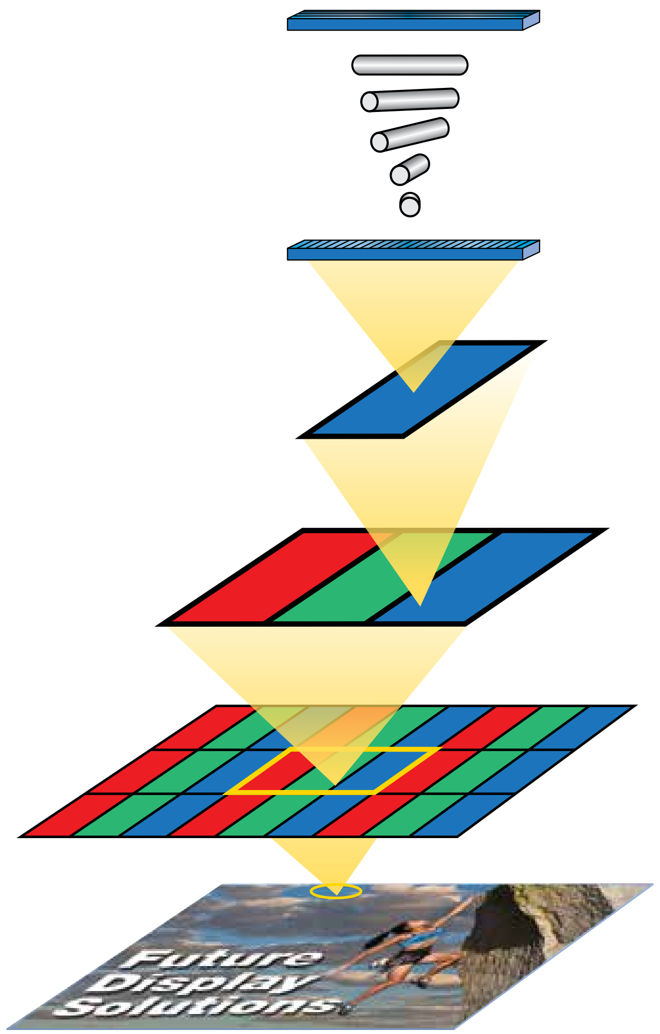
Liquid Crystal Display (LCD): Typical LCD Applications

To fit specific applications, LCDs are available in both monochrome and color. Color LCDs are widely used in applications such as laptop computers and monitors, televisions, instrument panels, drone controllers, aircraft cockpit displays, signage, smart phones, tablets and wearable devices. Monochrome LCDs are common in simpler consumer device applications such as toys, clocks, thermostats, watches, calculators, telephones and assorted Internet of Things (IoT) devices. Due to their relatively low electrical power consumption, LCDs can be used in battery-powered electronic equipment.

LCD Technology

An LCD is an electronically modulated optical device made up of any number of segments or pixels filled with liquid crystals and arrayed in front of a light source (backlight) or reflector to produce images in either color or monochrome. Each pixel of an LCD typically consists of two polarizing filters and a layer of liquid crystals aligned between two transparent electrodes.

Polarizer Layers



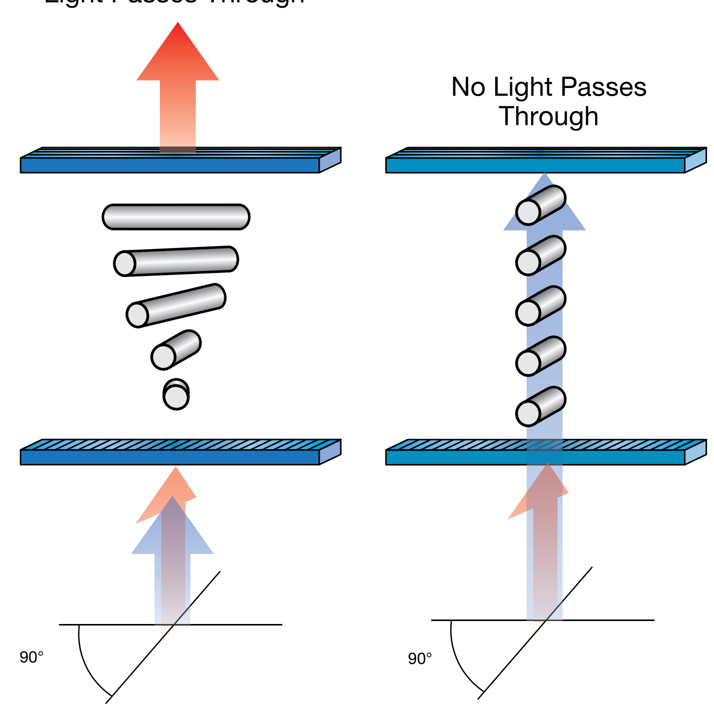
Polarizing Layers

In a piece of polarized glass, the polarizing filter resides on one side of the glass and a special polymer that creates microscopic grooves is applied on the opposite side of the glass. The grooves must be in the same direction as the polarizing film. A coating of nematic liquid crystals is added between two pieces of polarized glass. The grooves will cause the liquid molecules to align with both filters' orientation. The rear piece of glass has its polarizing filter at a 90° right angle to the front piece. This orientation uses the natural structure of the crystals to gradually twist until the uppermost layer is at a 90° angle to the bottom, matching the polarized glass filters and creating a twisted nematic (TN) helix structure.

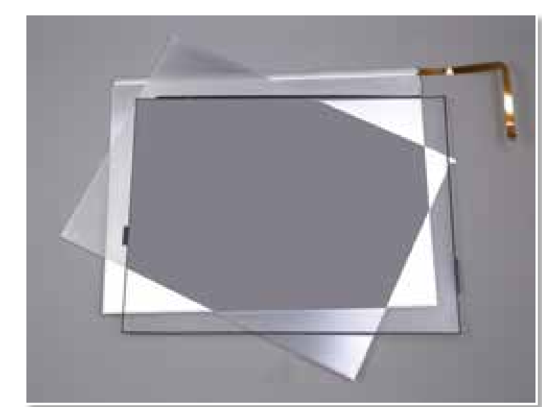
As light strikes the first filter, it is polarized. The molecules in the liquid helix then turn the light wave slightly from molecule to molecule. As the light twists through the helix, it eventually exits at a 90° angle from where it entered, passing through the image layer. This is the natural OFF position where there is no external voltage added.

To allow control of the light, electrodes are added to the glass. When the electrodes are turned ON, the crystal molecules untwist such that the light wave does not bend 90° to match the polarizer orientations. The light is blocked from passing through the image layer that creates a small dark rectangle. Multiple rectangles are arranged in arrays (normally three) called pixels. The greater the number of pixels, the greater resolution with which the image will be portrayed. Greater control is also enabled by varying the voltage applied to the electrodes which then varies the amount of light passing through the second filter, creating different levels of brightness.

The Twisted Nematic structure is still the most common liquid crystal display.



Polarized Layers

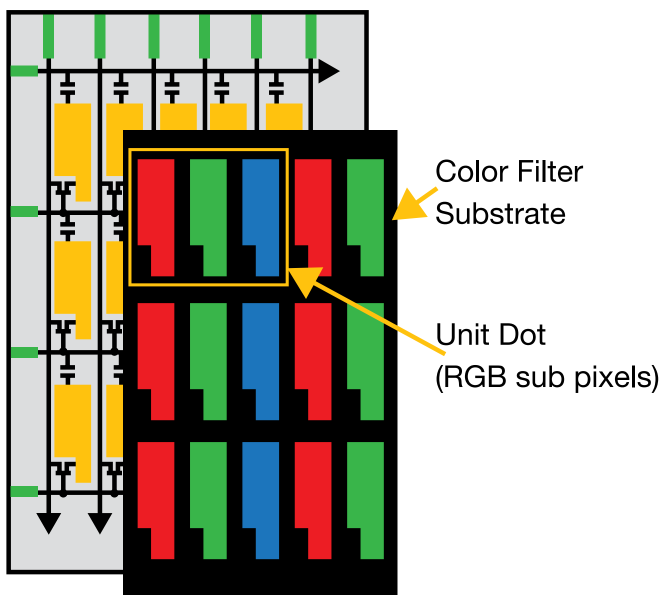


Passive-Matrix

Passive-matrix LCDs are still used today for less-demanding, price-driven applications. Displays with a passive-matrix structure are addressed through row and column addressing and require that the pixels maintain their state passively (without being actively driven) until the next refresh cycle. This results in low power consumption but sacrifices response time and contrast. To improve contrast, newer PM-LCDs use super-twisted nematic (STN) technology, meaning that the crystal molecules are twisted from 180° to 270° instead of the typical 90°. For color applications, color super-twisted nematic (CSTN) displays employ red, green and blue filters at the pixels, providing a viable low cost solution but with a comparatively slow response time of ~100ms.

Active-Matrix

As display applications demanded increased performance, active-matrix addressing was developed by adding a silicon thin-film transistor (TFT) and capacitor to each pixel to drive and hold the state of the pixel in between refresh cycles. While still using row and column addressing, this addition allows the pixel to be individually switched to its desired level and to more accurately maintain that level between refreshes. The technology delivers faster response times of ~8ms, improved contrast and wider viewing angles than passive matrix displays of the same size. As such, high resolution applications such as HDTVs, laptop computers and LCD monitors use an active-matrix structure.



Things to Consider for Active-Matrix LCDs – Pros

- Relatively low power consumption depending on backlight, approximately 4 watts for a 7" LCD with a 200 nit backlight.
- LCD pixels hold their state between refreshes (which are usually done at 200Hz or faster, regardless of the input refresh rate).
- A sharp image that can be made in almost any size or shape.
- Can be made to large sizes (more than 98 inches) easily.
- Temperature range typically -20°C to +70°C. Some displays can handle -30°C to +85°C.

Things to Consider for Active-Matrix LCDs – Cons

Some low cost LCDs have:

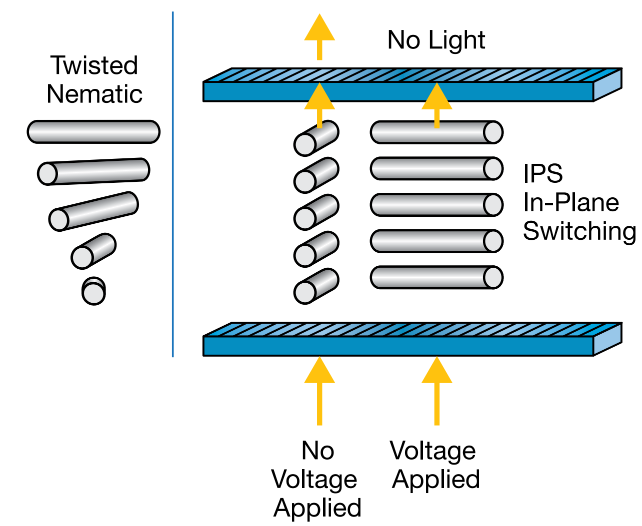
- A limited viewing angle, causing color, saturation, contrast and brightness to vary.
- Uneven backlighting in some displays, causing brightness distortion, especially toward the edges.
- Black levels (contrast) may appear unacceptably bright because individual liquid crystals cannot completely block all light from passing through.
- Display motion blur on moving images caused by slow response times (>40ms) and eye-tracking.
- Dead or stuck pixels may occur during manufacturing or through use.

In-Plane Switching (IPS)

In-plane switching is an LCD technology that aligns the liquid crystals in a plane parallel to the glass substrates. In this method, the electrical field is applied through opposite electrodes on the same glass substrate, so that the liquid crystals can be reoriented (switched) essentially in the same plane. IPS requires two transistors for each pixel instead of the single transistor needed for a standard thin-film transistor (TFT) display.

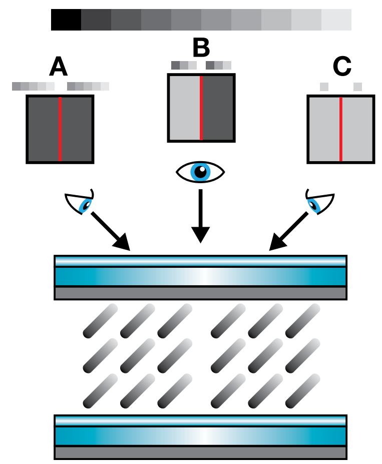
This creates a wide viewing angle LCD, where changes of color tone due to the viewing angle are so slight that the picture can be seen from any angle vertically or horizontally. It also improves the aperture ratio to produce higher brightness with improved color reproducibility.

Initially, the disadvantages of IPS were higher cost and poorer contrast due to blacks not being as dark. Improvements in manufacturing have largely eliminated these detractions.



Vertical Alignment (VA) and Multi-Domain Vertical Alignment (MVA)

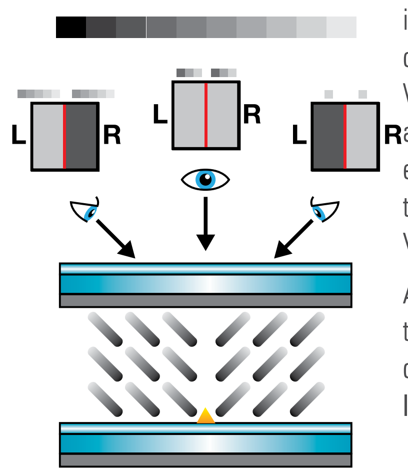
Vertical alignment (VA) displays are LCDs in which the liquid crystals naturally align vertically to the glass layers when no voltage is applied. By placing polarizers perpendicular to each other on the glass layers, the light will not pass through. This gives a dark black when viewed. When a voltage is applied the liquid crystals tilt their position, letting light pass through and giving a grey scale depending on the voltage. Compared to TN LCDs, the VA LCDs have a higher contrast ratio, a wider viewing angle and a deeper black background. The response time is also improved, as the crystal does not have to twist and untwist when the voltage is changed; they only rotate between vertical and horizontal.



Mono-domain VA

In VA LCDs the liquid crystal tilts in a uniform direction. If a grey screen is displayed to a viewer and the viewer is looking straight on to the display (B), the screen will show a grey image. If the viewer is viewing in the direction of the liquid crystal tilt (C), the display will look whiter than from the center position. If the viewer is looking from a position opposite the tilt (A), the display will look darker than from the center position.

Multi-Domain Vertical Alignment (MVA) solves this VA problem by adding protrusions in the pixel and dividing the pixel into domains. The protrusion causes the liquid crystals to tilt in more than one direction. When viewed to the side, one domain in the pixel will look dark and the other will look bright but, as the areas are small, the eye combines the difference to 'see' a grey pixel. This improves the contrast ratio, brightness and viewing angle uniformity over VA LCDs.



MVA

Although the multi-domain technique is adopted in S-IPS LCD technology, the two technologies differ enough that MVA panels offer generally better blacks and contrast than either TN or IPS panels.

Organic Light-Emitting Diode (OLED)

An OLED is an organic light-emitting diode in which a thin layer of organic molecules emit light in response to an electric current between two electrodes. OLEDs use phosphorescence that can convert four times more electricity into light than other materials, making them more efficient than LCDs. The organic layer emits light and a backlight is not required; therefore the OLED can be thinner and lighter than a liquid crystal display (LCD). With no backlight used, the power consumption of OLED displays is dependent on the image being displayed, for example dark images use less power and bright images use more power. In comparison, the backlight in an LCD is always on when displaying any image, hence always drawing power.

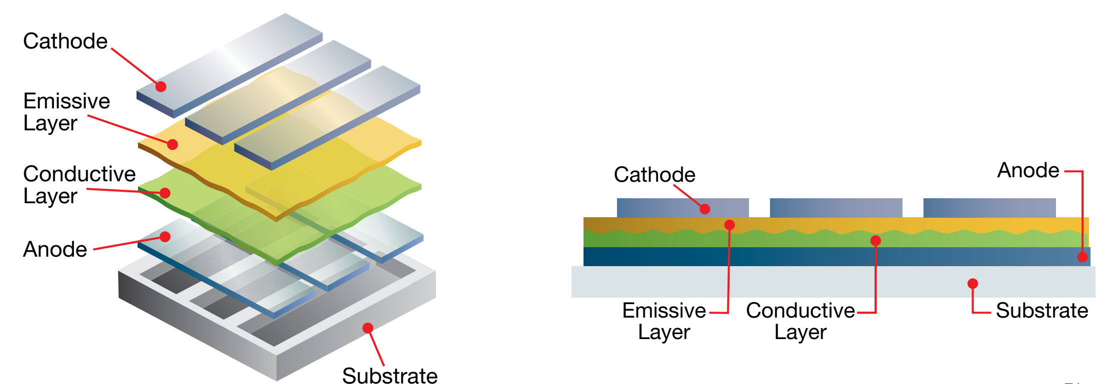
When OLED displays were first introduced, they demonstrated lower lifetime (the time it takes for the display to reach 50% of the original luminance) than comparable TFT LCD backlights. However, this has greatly improved, with lifetimes now exceeding 50k hours.

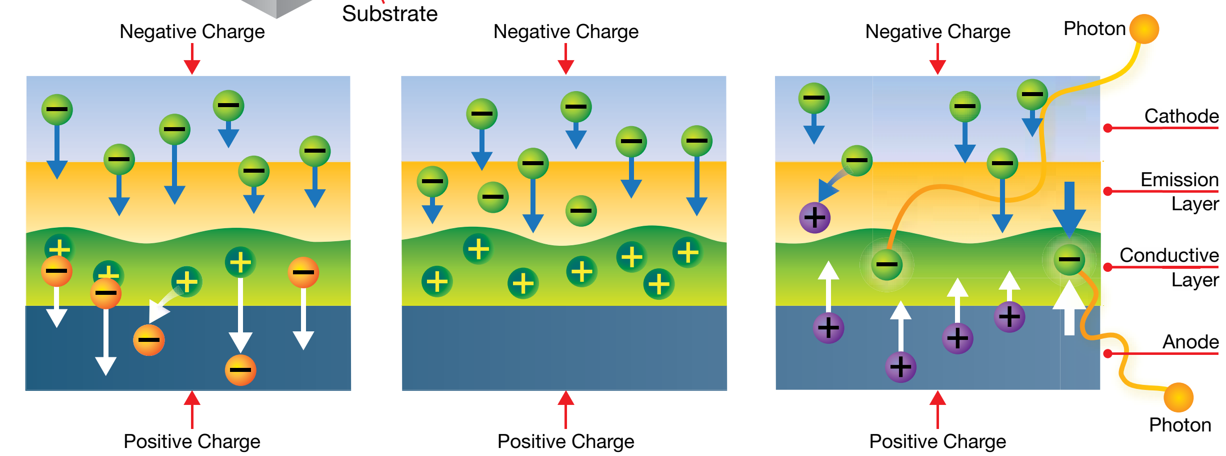
OLED Technology

Electrical current flows from the cathode to the anode through the organic layers, moving electrons to the emissive layer and removing electrons from the conductive layer.

Removing electrons from the conductive layer leaves positively charged holes that need to be filled with the electrons from the emissive layer.

The holes jump to the emissive layer and combine with the electrons. When the electrons drop into the holes, they release their extra energy as a photon of light.





OLED: Passive-Matrix vs Active-Matrix

As with LCDs, both passive-matrix and active-matrix technologies are used in OLEDs. The majority of OLED displays used are monochrome passive-matrix technology, offering higher contrast ratio (2000:1) than TFT technology at competitive costs. Smartphones introduced active-matrix OLED displays which offer a very high contrast ratio of 1,000,000:1 producing the darkest black and whitest white. In comparison, active-matrix OLEDs provide an improved color reproduction to passive-matrix OLEDs with faster response times (<1ms) and lower power.

Things to Consider – Pros

- OLEDs exhibit wide viewing angles in all directions.
- OLEDs allow a very slim display with a thickness of 1.5mm to 2mm.
- OLEDs are all glass modules that weigh less than 1g for small displays and up to 12g for larger sizes.
- OLED displays use very simple interfaces like serial, I^{2}C or parallel CPU, making them compatible with simple 8-bit microcontrollers and above.
- Most OLED displays use passive technology, so they don't require active refreshing rates.

Things to Consider – Cons

- Most passive OLED displays emit < 100nits brightness, so they are not sunlight readable; however, newer modules can now offer as much as 2000nits for outdoor sunlight usage.
- OLED displays are relatively fragile where the glass and the flex cable can break or tear, so they require special handling and protection against shock.

OLED Typical Applications

OLEDs are used to create digital displays in devices such as automobiles, television screens, computer monitors, portable systems such as mobile phones, handheld game consoles and PDAs. A major area of research is the development of white OLED devices for use in solid-state lighting applications.

Wearables: Personal watches, GPS devices, smart watches, exercise bands.

Medical: Glucose meters, blood pressure meters, hair removal machines

Appliances: Blenders, weight scales, control for cooking ranges

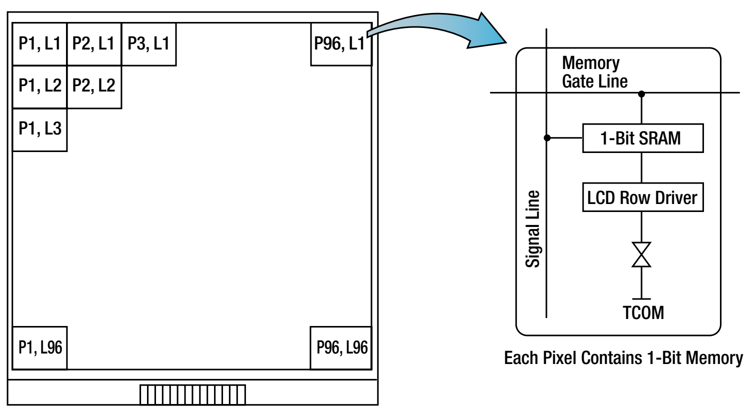
Replacement for Industrial Meters: Signal meters, electrical meters, sound level meters

Future Trends

- Amorphous and polysilicone technology advancements have allowed the offering of curved OLEDs and continued development of flexible OLEDs in the market.
- OLED PCB modules are now available to replace STN graphics and character displays, so customers can easily refresh the look of their product with a drop in replacement.
- The lifetime of OLEDs is increasing to 50K hours for white and yellow. Other colors are improving as well.
- OLED proliferation into broader consumer and industrial applications is underway.

Low Refresh/Memory LCD

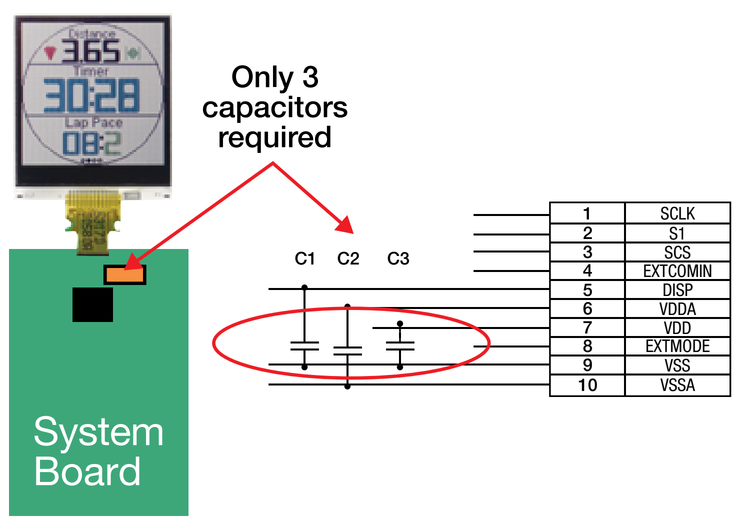
Memory LCD is a highly reflective display without backlight, that has a memory bit in each pixel to store its state without refresh, providing ultra low power display of static content, although still being powered.



Given its high resolution, contrast and reflectance, combined with a wide viewing angle up to 170° x 170°, the memory LCD is suitable for both indoor and outdoor usage and is available in either monochrome or color.

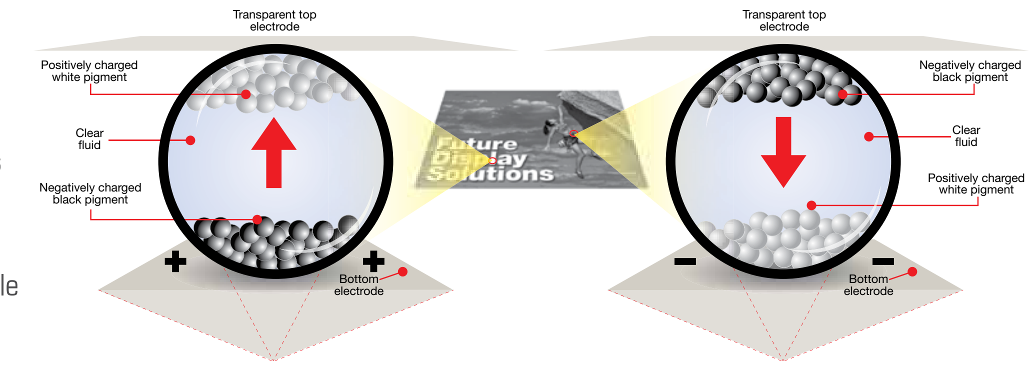
Memory LCDs can be found in wearable gear, Internet of Things (IoT) applications and anywhere that low power and high contrast are required.

The interface uses only three capacitors for 3-wire serial I/F (SI, SCS, SCLK), and a single power supply voltage of either 3V or 5V can be utilized. With the driver chip and peripheral circuit embedded on the LCD glass, a reduced total thickness of the end product is achievable.



Electronic Paper Displays

Electronic paper displays (EPDs) were developed to emulate and replace paper for digital books and other applications. The technology is based on the principle of electrophoresis, where particles suspended in a fluid are controlled by an electric field. The technology was commercialized in the late 1990s and the e-reader soon became a common device. Many names have been given to the technology but the most common are E-paper, electrophoretic displays and E-ink (the name of the leading electronic paper display supplier).



Electronic paper displays are bi-stable or tri-stable technologies, meaning that they can rest in one of two or three natural states without power. Bi-stable EPDs are made up of millions of tiny microcapsules serving as a pixel, each containing a clear fluid, and suspended within are positively charged white particles and negatively charged black particles. When a negative electric field is applied, black particles move to the top of the microcapsule and are seen as a black pixel. The reverse happens when a positive field is applied, making the same pixel white. Tri-stable EPDs add a third color, currently red or yellow.

Bi-Stable EPD

EPD

The true value of EPDs is that the pixel retains its state when power is removed. No refresh cycles are required and in practice, this means that the display is consuming power only when the image is changing. This provides significant advantage in battery powered applications compared with TFT LCD displays that need to be refreshed around 30 times per second.

Rather than relying on a backlight, electronic paper displays are reflective, using ambient light reflected from the surface of the display to create brightness and contrast. As with any reflective surface, the more ambient light, the brighter the display looks. As such EPDs have excellent sunlight readability. To provide readability in low light conditions, front-light/side-light solutions can be added to illuminate the surface.

EPDs initially suffered from “ghosting” where the previous image remained slightly visible when a new image was written. Executing multiple write cycles for an image has largely resolved this issue. Driving EPDs requires a dedicated controller IC to manage the precise timing and voltage requirements. Controllers are offered standalone or integrated on application-specific microprocessors.

Applications for electronic paper displays have expanded beyond e-readers to include tablets, watches, key fob status indicators, accessory displays to cell phones, and retail shelf pricing tags. They replace LCD displays in many applications where low power is critical. As EPDs can now be implemented on glass or on flexible material, the applications are endless.

Future Trends

Optical Head-Mounted Display (OHMD)

Some manufacturers have designed glasses or goggles that have displays built into the lens. The market for augmented reality wearable displays (or AR glasses) is potentially huge.

These heads-up display technologies have been available since around 1995 and the techniques used range from diffraction, holographic, polarized, and reflective optics.

These types of displays are generally expensive to produce unless it is in very large volumes.

Although originally targeted for either military use, gaming or enhancing multi-media experiences, these wearable near-eye systems could be used in certain industrial applications, for example in medical applications where vital information could be displayed in front of a surgeon's eyes.

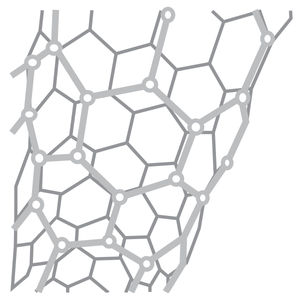
HMI input to the device may also include a touchpad, buttons, speech recognition, gesture recognition or eye tracking. The devices may be stand alone or in conjunction with compatible devices such as a smart phone or a home network.

Factors that effect wearable displays are size, battery life, weight, eyestrain and style.

The main problem is that low cost optical head-mounted displays have been difficult to achieve, but with constant reduction in size of microelectronics and techniques, these types of displays should be something to 'watch out' for in the future.

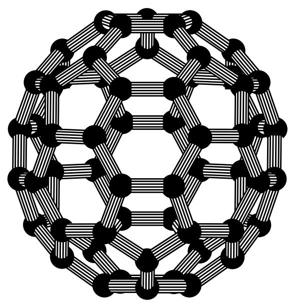
Carbon Nanotube Technology

A carbon nanotube is a tube-shaped material, made of carbon, having a diameter measuring one-billionth of a meter. It is being developed for many applications, including replacing the ITO in TFTs and improving OLED technology. Carbon nanotube can be made to be either a metal or a semiconductor. As they are so thin they would be almost invisible as a conducting layer on a TFT or OLED display. Nanotubes are also very strong with good elasticity, which is great if you need to build a curved or flexible display.



Quantum Dot Technology

Quantum dots are crystals of a semiconductor and are severalnanometers in size. They are in an experimental stage but they look interesting as a future technology. Quantum dot LEDs are basically the same layers as standard OLEDs, but are characterized by pure colors with narrow bandwidths. This is because during manufacturing the wavelength is tuned by changing the size of the quantum dots to cover the visible wavelength ranging from 460nm (blue) to 650nm (red).



Quantum Dot Technology has a similar low manufacturing cost as OLEDs. It should be possible to make large displays because they are more efficient and stronger than OLED displays. Some manufacturers have used quantum dots to filter light from the backlight in TFT displays but are not used as displays on their own.

Small Display Comparison

	Passive LCD	Memory LCD	Electronic Ink	Passive OLED
Typical power consumption (still image, refresh image) and driving voltage	20 mW, +5V and Negative voltage	15 uW, +5V (1.26" Still image) 50 uW, +5V (1.26", 1Hz Refresh image)	Zero power still image, 100 mW when refreshing image	100 mW, +15V
Visibility - bright environment	Good (reflective)	Good (reflective)	Good (reflective)	Good (self-luminous)
Visibility - dark environment	Limited (reflective without backlight) Good with backlight	Limited (reflective)	Limited (reflective)	Excellent (self-luminous)
Reflectance	20	20	37	-
Contrast	10 to 1	20 to 1	7 to 1	350 to 1
Response time	100ms	16ms	100ms	20ms
Always-on capability	No	Yes	Yes	No

DISPLAYS
Image Layer

Sub-Pixel Rendering

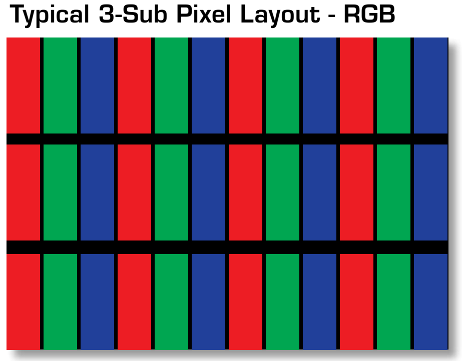
Companies are now building displays that 'look' like a higher resolution than they actually are. Instead of addressing the red, green and blue (RGB) pattern in the pixel, they are using algorithms and adding an additional sub pixel color to the pixel array. The additional colors could be yellow, white, cyan or even magenta. Some of the algorithms address each of the four subpixels at a higher speed of 240 frames per second, to give a combined image of 60fps. This gives the viewer the impression of seeing a higher resolution, for example an 8K resolution image, on a 4K display.

Some of the displays use pairs of colors for example red with green and blue with white (RG/BW) and address them in various combinations.

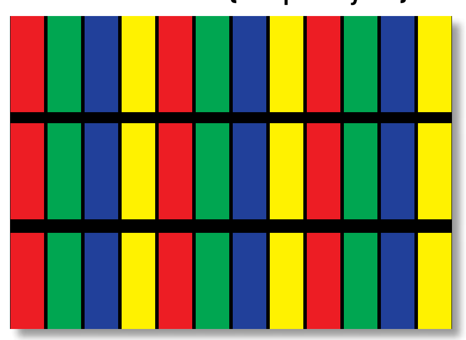
The advantages of sub pixel rendering are sharpness, contrast and brightness are improved; power is also reduced as the overall display has less sub-pixels than an equivalent higher resolution display. This reduces both battery power in mobile products and energy consumption in larger monitors, which is welcome news to product manufacturers.

Building lower resolution displays helps the display manufacturer reduce the number of rejected displays in the manufacturing process due to less pixel failure, ultimately reducing the cost of the display.

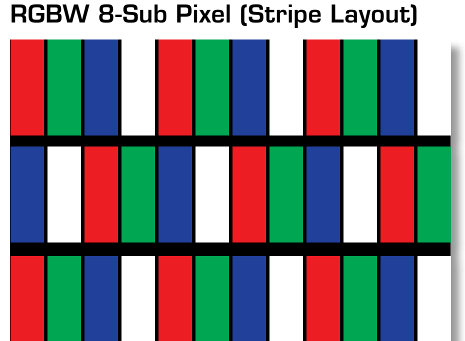
Typical 3-Sub Pixel Layout - RGB



RGBY 4-Sub Pixel (Stripe Layout)



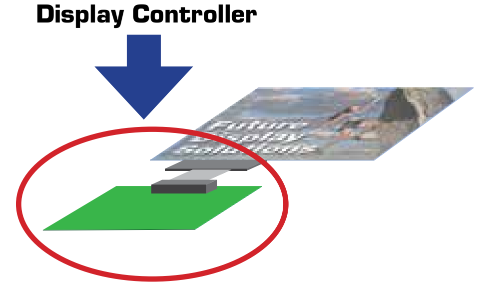
RGBW 8-Sub Pixel (Stripe Layout)

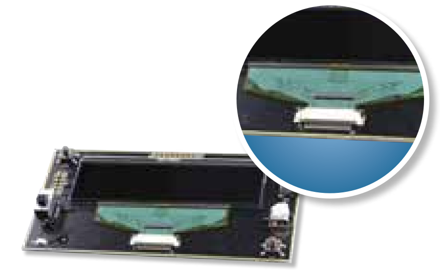


Display Controller

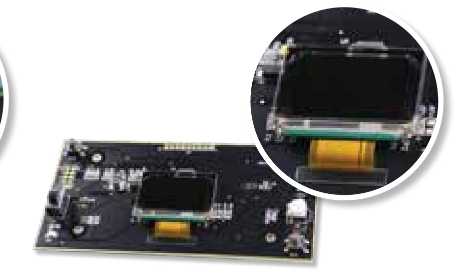
A display controller board is an interface board that converts a variety of embedded signals to drive the liquid crystal display. All displays require a controller to provide a suitable interface, a range of display functions and possibly buttons. Most of our display manufacturers either build a controller or recommend a controller to drive the display. A display driver is the chip and may be placed on a separate circuit board (controller board), on the Flex connector (Chip On Flex - COF) or on the display glass itself (Chip-on-Glass - COG).

Display Controller





Chip-On-Flex



Chip-On-Glass

Selecting a Controller

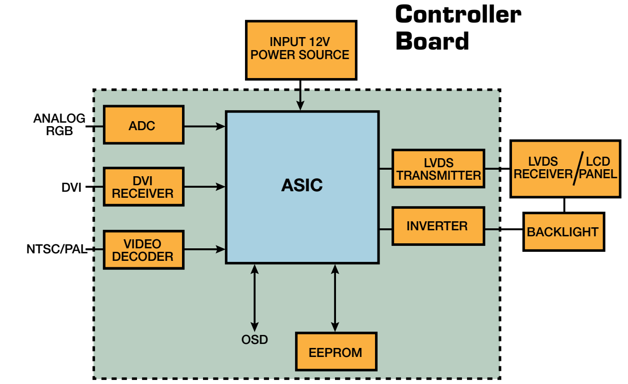
If you do not want to use the display manufacturer's controller board, you can build your own board or buy a ready made board. Standard off-the-shelf boards are generally lower cost, as they are being manufactured in volume to use with other displays. You will also get a board that supports multiple input signals, quick time to market, design support and the MTBF has already been calculated.

There are many different kinds of display controller boards; the most common types are categorized by resolution, packaging type and input type.

Things to consider when building your controller board or selecting an off-the-shelf board:

- Select the display resolution. Some controllers can upscale and downscale the video resolution to fit the selected display.
- What do you connect to on the video input side? Is it HDMI, DVI, DisplayPort, component, VGA, S-Video or composite?
- On the controller output side, what is the input to the display – TTL, LVDS, RGB or MIPI?
- How are you going to interface with the display to control brightness or contrast? Will you use buttons, a mouse or a remote control?
- Which voltage will you use for the controller – 5V, 8V, 12V or 18V?
- Will you design the display controller to be built onto the microcontroller board?
- Do you plan on having an alternative display part as a backup for possible supply shortages? Then you need to build this capability into your design.

Controller Board



Note: Display backlights are not normally controlled through the display controller. You may require a separate backlight controller.

Another alterative is to use a single board computer (SBC) that has the LCD drivers and backlight drivers already built-in. Although more expensive it saves on the design issues and speeds time to market.

Flexible Printed Circuit (FPC) or Flexible Flat Cable (FFC)

Flexible flat cable is a cable designed to be lighter, easier to install than round cables and to reduce space in computers or mobile devices. They do not contain electronic components.

Flexible printed circuit is a flexible flat cable that includes a electronic circuit built into the cable.

FPCs and FFCs are sometimes used to refer to the same thing but that is inaccurate.

Both FPCs and FFCs are flat and normally contain stiffeners on the ends to assist with easy insertion into the connector.

Lighting Layer

Backlight

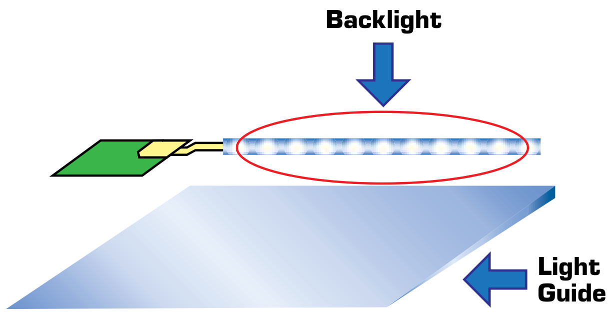
As mentioned previously, the image layer does not produce light. Typically the light is created by LEDs that are placed on either the edge, the back, or the front of the display. The LEDs are normally white and the pixels in the image layer delete the light or let it pass to create the image.

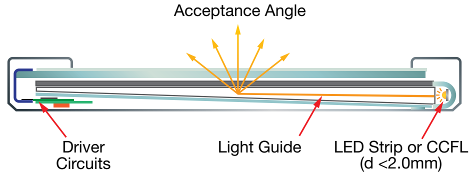
Edge Light

In an LCD display, the light is channeled from the strip of LEDs attached to the inside of the frame through a transparent, wedge shaped, waveguide. As the light hits the edge of the waveguide it is redirected forward through the liquid crystal layers.

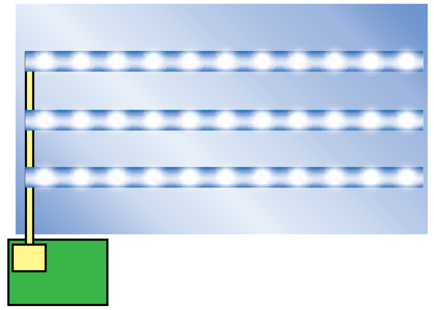
Some lower quality edge lit backlights do not give a uniform brightness, as the light is brighter nearest the LEDs; this is known as hot spots. You will notice this on a dark screen where some areas are brighter than others. They sometimes look like small flashlights shining across the dark screen.

The LEDs are normally always turned on and it is difficult to get really dark black levels on the LCD screen, as there are leaks between the pixels. Also, the backlight uses the majority of the power in a LCD module. To save energy, the backlight LED strip can normally be dimmed to save power or be set to sleep mode. Edge lighting is the more common way to light LCDs.





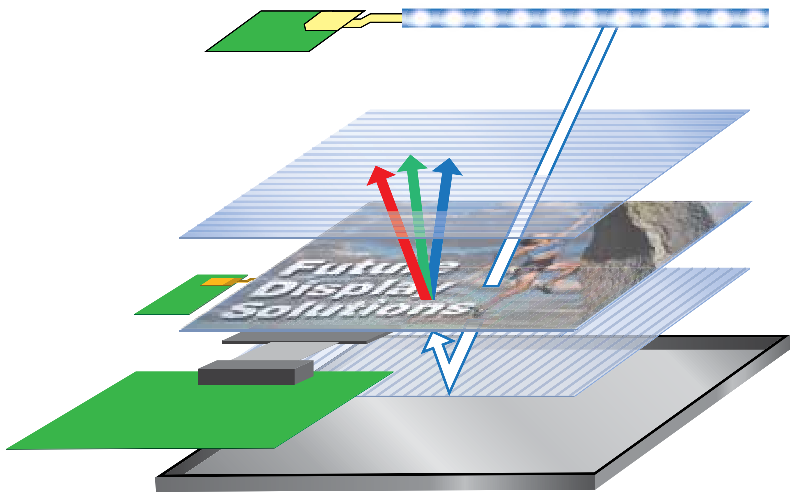
Direct Backlight



Direct Backlight is when there are many rows of LEDs that are attached on the rear of the LCD module and face forward towards the viewer. This gives a uniform light across the LCD. It is more expensive and uses more power than edge lighting. It is possible to control the LED brightness in certain areas to obtain darker black levels by Local Dimming.

Front Lighting

Some displays such as reflective displays are not very transmissive, so a front light may be used to bounce light into the front of the display and reflect back the image in the LCD layer. Reflective displays are low cost and low power; by adding the front lighting there is an added cost and power requirements to be taken into account in the overall design. This is normally a custom part and may require high minimum order quantities (MOQs).



DID YOU KNOW?

Did you know that Future Display Solutions can change the backlight to enhance the brightness of the display to accommodate the customer's needs?

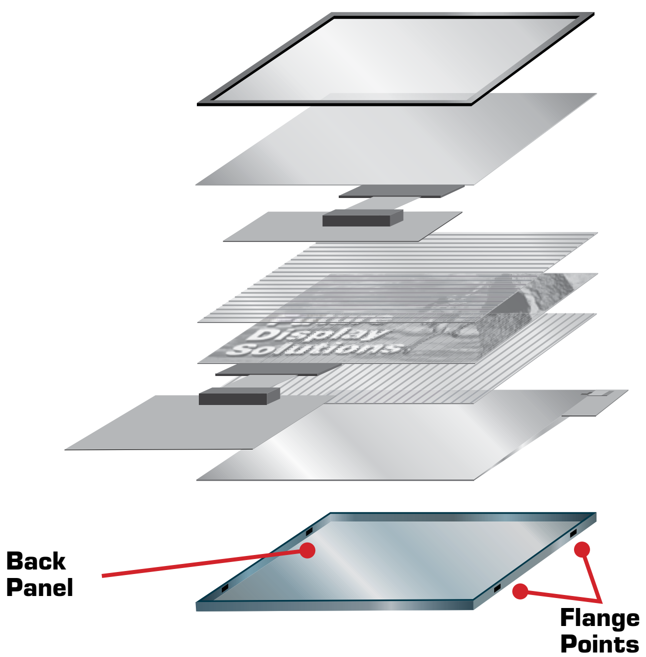
Back Panel/Frame

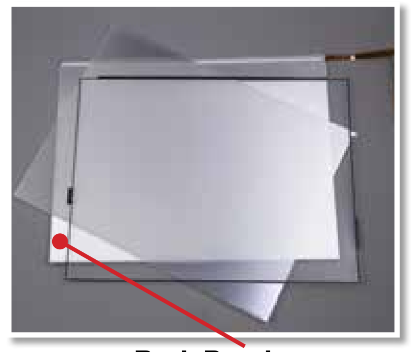
The bottom or back of the display can be made with metal, plastic or a mixture of both.

It holds all of the display layers together in a mechanical frame. The frame uses perimeter flange-mount points compared to back-end VESA mount. Often the frame will have controllers and cables for the video signals, touch signals and backlight. This is commonly refered to as an open frame monitor.

Future Display Solutions provides a wide range of displays with various mounting options that include LCD panels, open frame monitors, outdoor displays, panel mount monitors, and digital signage.

In our integration program we provide ruggedization, custom metal work, buttons, additional touch panels, optical enhancement, built-in controllers and single board computers.




Back Panel


Open Frame Monitor


Panel Mount Monitor

Kits/Open Frame/Integration

A custom enclosure can be designed to fit the needs of the application around this open frame display. To drive a display, it may require different electronics/boards that may or may not have an off-the-shelf solution. Depending on the size of your project, it may be easier to inquire about kits or open frame solutions from us. Future Display Solutions can work with you to develop a custom kit solution, along with fixtures or brackets that include the LCD, optional touch panel and its controller, backlight controller, cables and an LCD driver board or even a single board computer.

Future Display Solutions' engineers will help you choose all the parts needed to drive the specific LCDs that meet your project requirements.

Ruggedization

For applications used in harsh environments, ruggedization of the product may be required. Some of the ruggedization services we offer include:

- Polarizer edge seal/encapsulation
- Electronics protection
  - Sealing, coating, strain relief
- Glass bonding
- Vandal shield
- LCD/lamp heaters
- EMI filter bonding
- Complete box built with a case

Future Display Solutions is partnered with industry leaders in display integration to offer world-class services. Our display engineers work closely with these experts to ensure best quality solutions are provided to you. From a restaurant display application that needs an optical bonding of a PCap touchscreen to a marine display application that needs backlight enhancement, anti-reflective glass bonding, water proofing to endure high/low temperatures, high humidity and salt water/fog, Future Display Solutions provides display solutions that are tailored to your design requirements.


Integrated Solutions

What is the Application of Your Product?

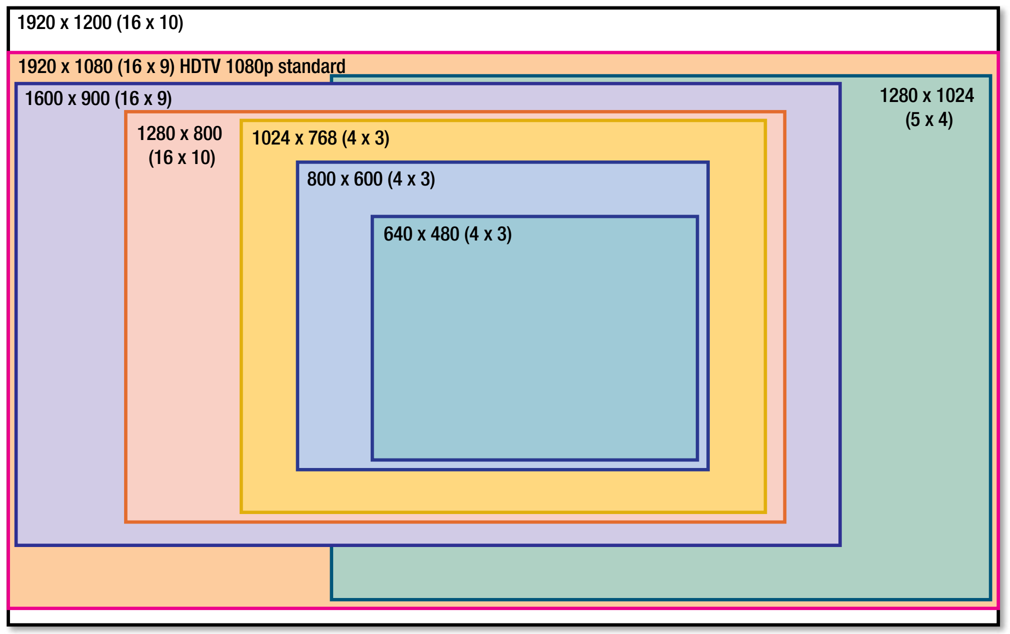
Application Table

Application	Product Longevity	Long Production Life >5 years	Wide Viewing Angle	High Contrast	Fast Response	Thick Gloves	Latex Gloves	Rugged	Strengthened Glass	Privacy Required	Anti- Reflective	Sunlight Readable	Battery Powered
Medical	•	•	•	•	•		•				•		
Military	•	•	•	•	•	•	•	•	•		•	•	
Marine	•	•	•	•				•			•	•	
Industrial Automation	•	•				•		•	•		•		
HVAC	•	•		•									
Alarm Clock				•									•
GPS	•	•	•						•			•	•
Automotive	•	•	•	•	•				•		•	•	
Wearable High End											•	•	•
Wearable Basic				•								•	•
Desk Monitor					•						•		
Smart Phone			•		•				•		•	•	•
Tablet			•		•				•		•	•	•
Point of Sales											•		
Kiosk	•				•			•	•		•	•	
ATM	•				•	•		•	•	•	•	•	
Transportation	•	•	•		•			•	•		•	•	
Agriculture	•	•	•			•		•	•		•	•	
Security	•				•	•				•			
Spa/Pool Controller	•			•							•	•	•

What Size of Display Do You Need?

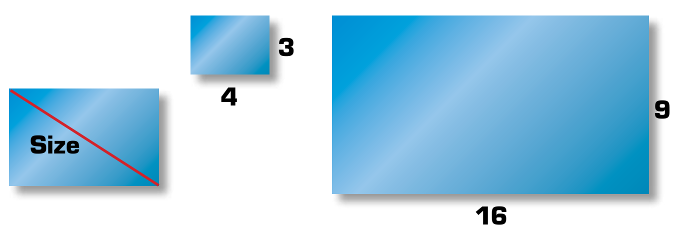
Displays sizes are measured by the diagonal length of the active area, as with televisions. Although this is a great reference, the shape can be variable, for example: 4:3 aspect ratio, 16:9, landscape, portrait, or span (custom cut).

Resolution



Typical Sizes and Shapes

3.5" – 4:3	10.1" – 16:9	15" – 4:3
4.3" - 16:9	10.4" – 4:3	15.6" – 16:9
7" – 16:9	12.1" – 4:3	21.5" – 16:9



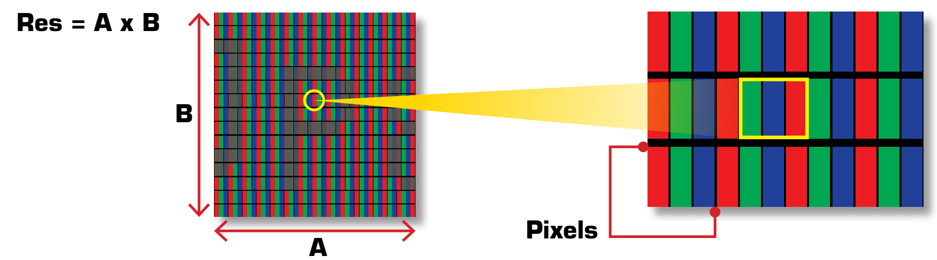
It is also possible to buy parts that are non-standard or customized, for example SpanPixel from Litemax. They have a very wide displays for transport or signage - SSD3840 - 38" resized, 2000 nits, ultra high brightness LED backlight, 1920 x 502 pixels, ultra wide aspect ratio 16:4.2.

Manufacturer	Part Number	Size (In)	Resolution Name	Resolution Pixels
AZ Displays	ATM0177B3A-T	1.8	N/A	128 x 160
Tianma NLT USA	TM035HBHT6	3.5	QVGA	240 x 320
Tianma NLT USA	NL6448BC20-30C	6.5	VGA	640 x 480
Tianma NLT USA	NLB150XG01L-01	15	XGA	1024 x 768
Sharp	LQ156M1LG21	15.6	FHD1080	1920 x 1080
Litemax	DLF1825-ETN	18.5	WXGA	1280 x 800

What is the Preferred Resolution?

The resolution is the number of pixels left to right multiplied by the number of pixels top to bottom. The resolution will define the quality of the final image displayed.

Typical resolutions are: 640 x 480 (VGA), 1920 x 1080 (Full HD), 3840 x 2160 (UHD), 4096 x 2160 (True 4K HD).



In resolution when the first number is larger than the second number, the display has been manufactured for landscape mode (typical or larger size displays above 5"). Some displays have been designed to be switched between landscape or portrait. This is typical on mobile devices. Care has to be taken in the design as not all displays can switch between either landscape or portrait.

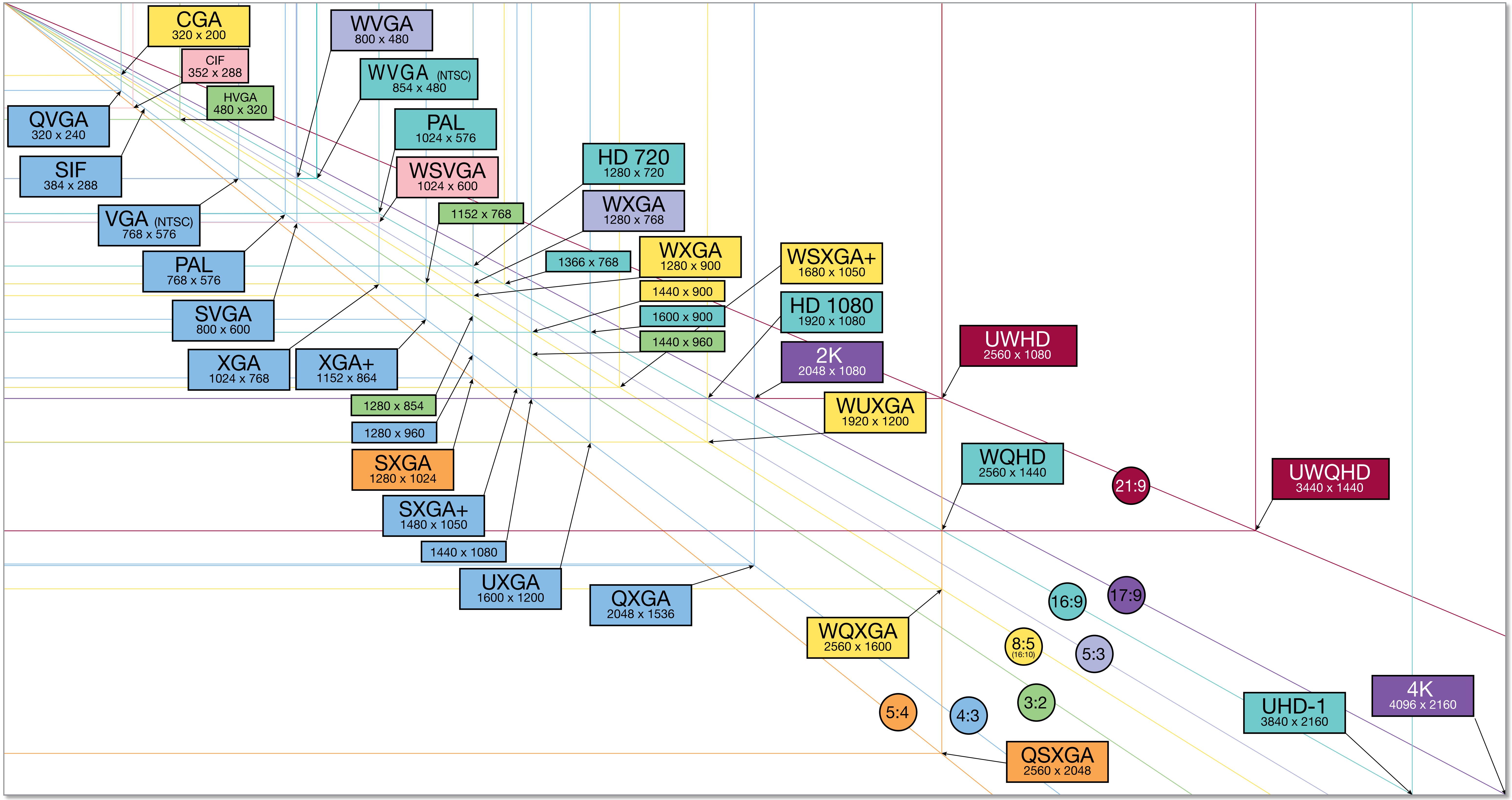
Pixels and Resolution

The display resolution of an LCD is the number of distinct pixels horizontally and vertically that can be displayed. It is usually quoted as width × height, with the units in pixels. For example, the full HD resolution of 1920 x 1080 means 1920 pixels wide and the height is 1080 pixels from top to bottom. Full HD is also a 16 x 9 aspect ratio commonly called wide screen.

Refer to the chart on page 44 for more details on standard resolutions and aspect ratios.

DID YOU KNOW?

In 1987 IBM introduced Video Graphics Array (VGA) for their computer hardware. This standard was cloned by other manufacturers and became a standard resolution of 640 x 480.

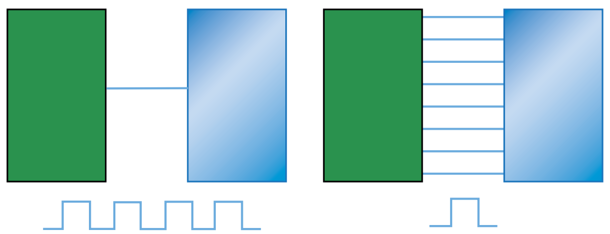

CGA
320 x 200
CIF
352 x 288
HVGA
480 x 320
QVGA
320 x 240
SIF
384 x 288
VGA (NTSC)
768 x 576
PAL
768 x 576
SVGA
800 x 600
XGA
1024 x 768
XGA+
1152 x 864
WVGA
800 x 480
WVGA (NTSC)
854 x 480
PAL
1024 x 576
WSVGA
1024 x 600
1152 x 768
1280 x 854
1280 x 960
SXGA
1280 x 1024
SXGA+
1480 x 1050
1440 x 1080
UXGA
1600 x 1200
HD 720
1280 x 720
WXGA
1280 x 768
1366 x 768
WXGA
1280 x 900
1440 x 900
1600 x 900
1440 x 960
QXGA
2048 x 1536
WSXGA+
1680 x 1050
HD 1080
1920 x 1080
2K
2048 x 1080
WUXGA
1920 x 1200
UWHD
2560 x 1080
WQHD
2560 x 1440
21:9
UWQHD
3440 x 1440
WQXGA
2560 x 1600
16:9
17:9
8:5
(16:10)
5:3
3:2
5:4
4:3
QSXGA
2560 x 2048
UHD-1
3840 x 2160
4K
4096 x 2160

Choosing the Right Interface

Displays have many different interfaces; sometimes a single display may use more than one type. Typically, one interface carries the image information and a second interface is used for configuration.

The interface for the image can be divided in two major categories: serial or parallel. With the serial method, the information is sent as a series of bits or logic levels (0 or 1), where as in parallel the bits are sent simultaneously across multiple wires. Refer to the diagrams below.

The biggest advantage of the serial interface displays is that they use fewer pins with smaller connectors. However, compared to a parallel interface, a serial interface will require a faster speed to transfer the same amount of information over fewer wires. Depending on the panel data rate requirement, there may be many serial channels transmitted in parallel.



Serial Interface (one bit at a time) | Parallel Interface (multiple bits at a time)

For color TFT panels, both serial or parallel interfaces can handle a different number of bits, which are typically related to the amount of colors that can be displayed. For monochrome displays, the amount of bits may refer to the resolution of the grayscale or a single color scale.

Parallel interfaces are typically used to transfer image content to a display. Serial interfaces can also be used to either transfer image content and/or to act as a configuration serial bus. For example:

- High speed serial for high resolution panels: LVDS, MIPI
- Low speed configuration bus: I²C, SPI, UART

Parallel Interface (also known as RGB or Parallel CMOS)

Examples of LCD parallel interfaces (but not limited to):

- 24-bits - 8-bits Red, 8-bits Blue, 8-bits Green – up to 16 million colors
- 16-bits - 5-bits Red, 6-bits Green, 6-bits – up to 65,536 colors
- 8-bits - Most common - used on graphic and character controllers
- 4-bits - Used on some monochrome QVGA modules

Parallel CMOS LCDs are typically used for medium resolutions in the 480 x 272 range and may have up to 8-bits per color channel (red, green and blue). Typical color depths are 8-bits per pixel color channel (8 x 3 = 24-bit display) and 5 + 6 + 5-bits for each respective pixel color for a total of 16-bits.

Serial Interface

Main Serial Interface Types:

- RS232/UART Interface
- LVDS
- MIPI
- SPI (Serial Peripheral Interface)
- I²C (Inter-Integrated Circuit)

SPI Interface

SPI, or Serial Peripheral Interface bus, is a synchronous (data is synchronized to the clock) serial data link standard that operates in full duplex mode, which means that devices that can communicate with one another simultaneously. To do this, two data lines are required (MISO/MOSI). With this standard, devices communicate in a master/slave mode, where the master device (host processor) initiates the data, the clock and the slave select. The LCD module is the (or one of the) peripheral slave device(s) attached to the data bus. Multiple peripherals (display modules and other devices) can be addressed on the same serial data bus. However, the LCD module will only listen to the data it sees when the slave select line is active (usually low). If the slave select line is inactive (usually high), the LCD module listens to the data on the bus, but ignores it. The SDO line is not active when this state occurs.

The SPI bus is comprised of four logic signals, two control lines and two data lines and is commonly referred to as 'SPI (4 wire)'.

I²C (Inter-Integrated Circuit)

I²C uses only two bi-directional lines, serial data line (SDA) and serial clock (SCL), which are both typically pulled up with resistors. Typical voltages used are +5V or +3.3V. One of the strengths of the I²C interface is that a microcontroller can control multiple devices with just the two I/O pins (+ground) and software. Because of the I²C design using a single data line, it is therefore only half-duplex. The interface generally transmits 8-bit words, sending the most significant bit first.

RS232/UART Interface

The RS232 or UART serial interface uses 3 (up to 5) lines to control the LCD module. These are transmit, receive, and ground (also RTS and CTS if necessary). This is an asynchronous interface; therefore the pattern on the data line will determine the start and stop ends of a message frame, which frame conveys a single byte of data at a time.

It is used most often as a side configuration serial bus since it is low speed, but also as main data lines for slow displays.

LVDS (Low-Voltage Differential Signaling)

LVDS is typically used on displays from resolutions of 800 x 600 and above. The interface can handle color depths of 8 bits per pixel color channel (24-bit display) or 6-bits per pixel color channel (18-bit display). Some newer LCD panels are increasing their color depths to beyond 8-bits per color channel.

LVDS is the mechanical hardware method of transmitting data across wires and is not an interface protocol. It is generally used for high speed data transfer over longer distances and can be used with a either serial or a parallel protocol.

By transmitting the same voltage level across two wires then subtracting them at the LCD module, the common noise is removed, leaving the desired logic signal. The wires are typically in twisted pairs which reduces the amount of radiated electromagnetic noise. The fact that it is low voltage swing means the power losses are reduced for a given bit rate compared to CMOS or similar higher voltage interfaces.

Using coupled twisted pairs with odd mode differential signaling (180 degree opposed waveforms) will tend to radiate much less than single wire data signals, due to the canceling of the induced magnetic fields.

MIPI (Mobile Industry Processor Interface)

MIPI was created by the MIPI Alliance companies and was designed for mobile devices that were battery powered and where power consumption is a design requirement. The MIPI standard for displays is the display serial interface or DSI (a low-power high speed interface). Following trends in the electronic industry moving from parallel to serial, an OEM can use the standardized interconnect protocol to run seamless integration from either one IC supplier or another as long as they comply with the same MIPI interfaces.

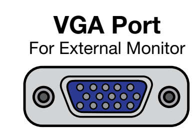
Because it was intended for the mobile handheld markets, it is mostly used in the consumer products. Larger displays are expected to continue to be either parallel CMOS, LVDS or eDP for FHD resolution panels.

Future Display Solutions provides displays with MIPI interfaces or controllers that can convert MIPI signals. MIPI is increasing as video resolutions and power demands for mobile type applications grow.

Indirect Display Interfaces

The following interfaces are common connections that are not on the display glass but on the finished product, for example on a monitor or an LCD controller. They do not connect directly to the display module. These types of interfaces require some processing of the video signal to activate the display module. The interfaces are VGA, USB, S-Video, HDMI, DVI and DisplayPort. Interfaces that connect directly to the display are RGB, Parallel CMOS, SPI, I^{2}C, RS232/UART, LVDS or MIPI. These interfaces are covered in the previous section.

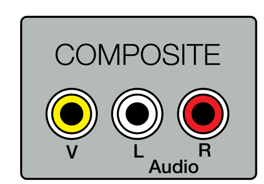
VGA (Video Graphic Array)



VGA is the most common connection for external monitors and the standard for displaying color graphics. Created by IBM in 1987 for their computers, it was originally capable of a resolution of 640 x 480 colored pixels, which was a breakthrough at the time. Although the VGA analog interface has been superseded by 4K UHD resolution (3840 x 2160) monitors and TVs (with HDMI, DVI and DisplayPort interfaces), it is still used in industry applications. VGA can handle resolutions of up to WUXGA (1920 x 1200), although the picture quality can degrade depending on the length or quality of the cable. You also find VGA interfaces on laptops to connect to projectors.

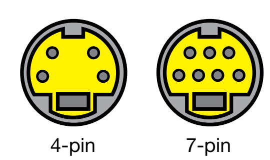
Composite Video

A composite video interface is typically a single yellow RCA connector on most consumer devices.



The composite video signal carries all the line, frame synchronization and the video information on a single coax cable. The cable is normally combined with the left and right audio that are carried on separate wires. Details of the composite encoding process vary among the NTSC, PAL and SECAM systems. The resolution is typically 480i or 576i.

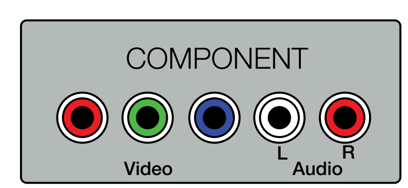
S-Video



Separate video (sometimes referred to as super video) separates the video data as two signals, lumen (luminance or the black and white levels) and chroma (color signals) is typically 480i or 576i. It is a higher quality of video than composite video but lower quality than component video.

Component Video

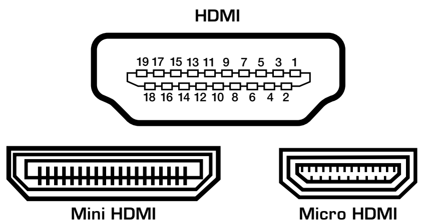
Similar to analog composite video except the color is typically split into three RCA connectors, red, green and blue. In the format of YPBPR the green cable carries the Luma (Y) which includes the brightness as well as the synchronization signal.



Luma Y = 0.2126 R + 0.7152 G + 0.0722 B. Including a separate wire for the green is not required, as it can be calculated from the red, blue and Luma information.

HDMI: High Definition Multi-media Interface

HDMI carries uncompressed digital data that includes video and audio on a single cable. It is designed as a digital replacement for analog video and audio. In a home theater system, one HDMI cable can replace as many as eleven older cables. It can handle resolutions of full HD and 4K with refresh rates of 120Hz. It also includes Ethernet connectivity, enabling other connected devices to share an Internet connection.



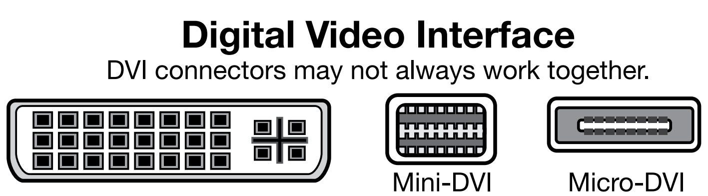
Pin #	Signal	Pin #	Signal
1	TMDS data 2+	11	TMDS clock shield
2	TMDS data 2 shield	12	TMDS clock -
3	TMDS data 2-	13	CEC
4	TMDS data 1+	14	No connected
5	TMDS data1 shield	15	DDC clock
6	TMDS data 1-	16	DDC data
7	TMDS data 0+	17	Ground
8	TMDS data 0 shield	18	+5V power
9	TMDS data 0-	19	Hot plug detect
10	TMDS clock+		

DVI: Digital Video Interface

DVI is a standard developed by the Digital Display Working Group (DDWG), designed to provide very high video quality on digital displays and digital projectors. It can be configured to support multiple modes such as DVI-D (digital only), DVI-A (analog only), or DVI-I (digital and analog).

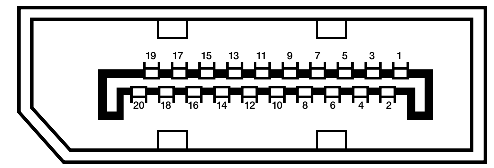
DVI is backward compatible with VGA and includes some of the contacts within the DVI connector. It is required to handle 640 × 480 at 60Hz, but can handle up to a resolution of 1920 x 1200 at 60Hz with a provision for Dual-link DVI which doubles the number of TMDS pairs, doubling the video bandwidth up to 2560 x 1600 supported at 60Hz.

In a single-link DVI connection, the video pixel data is digitally encoded and transported using four TMDS (transition-minimized differential signaling) links: the pixel clock, red, green, and blue video signals = 24 bits per pixel. These TMDS links are highly resistant to electrical noise and distortion, as each link transmits over one twisted pair.



DisplayPort

The Video Electronics Standards Association (VESA) developed the DisplayPort standard using packetized data transmission. It can carry video, audio, USB and other data. DisplayPort is able to transmit audio and video individually or at the same time.

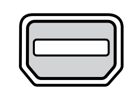


Although it is designed to replace VGA and DVI, it is backward compatible with the use of adapters.

Embedding the clock signal within the data stream using micro packets, DisplayPort can have higher resolutions with fewer pins. The protocol has additional packets to extend features over time without changing the connector.

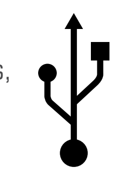
DisplayPort version 1.3 can support a resolution of 4K UHD at a 120Hz refresh rate using 24-bit pixels, and in the future should handle displays that support 8K at 60Hz.

Mini DisplayPort

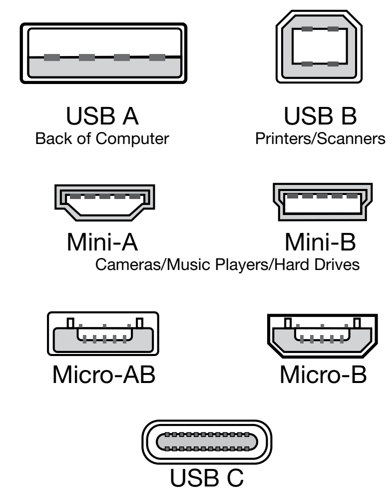


The Mini DisplayPort was designed to replace the bulky DVI and VGA connections on devices to transport the video signals to a monitor. Mini DisplayPort 1.2 can handle resolutions up to 4096 x 2160 (4K). Mini DisplayPort can drive older display devices with VGA, DVI, or HDMI interfaces with the addition of an adapter.

USB - Universal Serial Bus



USB is an industry standard developed in the mid-1990s defining the protocols for cables, connectors and communications between computers and electronic devices, designed to replace serial and parallel ports and also used as power connector.



USB-A: Originally used to connect a mouse, memory or a touch panel to a computer.

USB-B: Normally used to connect to a printer or similar device.

Mini-B: Smaller in size to the USB, as these connect to touch panels and can supply power to display controllers.

Micro-B: Micro connectors are about half the thickness of the Mini-Bs and are used for smaller portable devices such as smart phones.

Micro-AB: A type of connector that can accept either a Micro-A plug or a Micro-B plug.

USB-C: A reversible 24-pin double-sided connector similar in size to the Micro-B USB connector for USB devices and USB cabling. The Type-C replaces Type-B and Type-A connectors and cables, designed to be future-proof. Type-C is backward compatible and is possible to connect an Type-A or Type-B device to Type-C with a cable or adapter.

APPLICATIONS
Mitigate Obsolescence
Display Brightness

Designing to Mitigate Obsolescence

In the previous section, we outlined a myriad of different interfaces a display can use. If your application is likely to outlive the availability of your selected display, it may be prudent to make some design provisions to accommodate the eventual replacement of the initial display by another that may not leverage the same interface protocol. The inclusion of a bridge chip, such as a low cost FPGA (Field Programmable Gate Array) from Lattice, can future proof your application.

Basically, a bridge chip architecture allows users to navigate interface mismatches between processor and displays.

It can also allow users to leverage lower cost display options without incurring a complete board redesign.

In the example design below, the DSI transmit accepts RGB (Red, Green and Blue) pixel bus data from a processor or other display control output device. The output of the design interfaces to a D-PHY (high speed MIPI bus) interface IP core, allowing the FPGA to directly drive a DSI (Display Serial Interface) receiving device, such as a display.

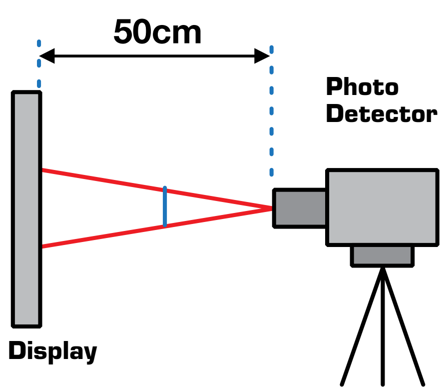
DSI Transmit Example Block Diagram

The parallel RGB to DSI transmit design illustrates how low density FPGAs can be used to connect various processors to DSI displays. The DSI transmit design enables embedded designers to utilize low cost screens with embedded processors.

How Bright do You Need the Display?

The brightness of a display is called luminance and is measured in nits or candelas.

The candela per square meter (cd/m2) is the unit of luminance. Nit (nt) is a name also used for this unit (1 nt = 1 cd/m^2). This measurement is used to specify the brightness of a display device. For example, most LCDs range from 100 to about 1000 cd/m2 (or nits).



Nits are measured by a photodetector focused at the center area of the LCD panel, with a white screen on in a dark room normally positioned 50cm from the display.

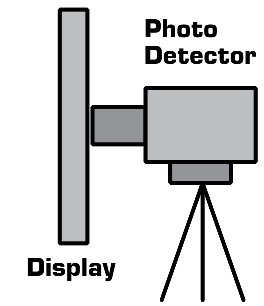
The application of the end product will dictate the luminance you require. If it is for a wearable device to be read only at night, then a lower nit level would be recommended. If the device is a kiosk in a brightly lit shopping mall or an operating room, for example, then a higher nit value would be required to compensate for the ambient surrounding light.

Normal ambient light levels indoors with the lights on, are typically less than 1k nits, and the display should be in the range of from 200 - 300 nits (computer monitor). Outdoors in indirect sunlight, the ambient light is around 3k - 7k nits so the LCD need to be emitting 500 - 800 nits (airport display). In bright direct sunlight the ambient light level can be as high as 10k nits, requiring the display to have 1k nit output (gas station display).

APPLICATIONS
Sunlight Readable

Do You Need a Sunlight Readable Display?

Sunlight readable is typically referred to as 1000 nits and above. The request for sunlight readable has to be questioned. For example, a device that will be placed in an automobile may request sunlight readable but the roof of the vehicle will reduce the direct sunlight hitting the device and a lower brightness may be acceptable, say 600 nits. Care has to be taken as glare and the contrast ratio may also affects the view-ability of the display.



Contrast ratio is the difference between the brightest and the darkest parts of a screen and would be in the 500:1 range or above. The contrast ratio is calculated by using the following formula.

Contrast ratio (CR) = Luminance of white screen/Luminance of black screen

Manufacturer	Part Number	Size (In)	Resolution Pixels	Brightness in NITS	Contrast Ratio (xxx)
AZ Displays	ATM0700D6J-CT	7	800 x 480	830	500
Tianma NLT America	NL6448BC20-30C	6.5	640 x 480	1000	800
Litemax	DLF1085-ENN	10.4	1024 x 768	1000	600
Sharp	LQ150X1LG96	15	1024 x 768	1000	800
Litemax	DLF1825-ETN	18.5	1280 x 800	1000	1000
Tianma NLT America	NL13676BC25-03F	15.6	1366 x 768	1100	900
Sharp	LS044Q7DH01	4.4	320 x 240	Reflective Display	14

Glare

Glare is a result of the light emitted from a display backlight and ambient light reflected back from the LCD glass. Glare should be considered when designing the display to be placed in a brightly lit room or used where sunlight could reflect on it. Both glossy and matte displays are made the same, except the matte display has a light diffusing coating on the front of the display.

Glossy displays have brighter, clearer colors, better contrast and deeper black levels than matte displays. The issue arises when light shines on the display creating reflections and the display image is difficult to see. Matte displays have an anti-glare coating that reduces the reflections but the LCD colors look more dull. If the display is to be used in a darker room, a glossy display might be better. If a display requires an anti-glare coating refer to page 6.

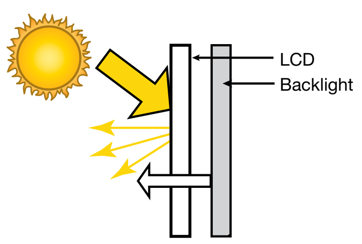
For a sunlight readable display our recommendation is to choose a display early in your design cycle of at least 900 nits luminance, a minimum contrast ratio of 500:1 with anti-glare film added.

Future Display Solutions can provide off-the-shelf sunlight readable displays or take existing displays and enhance them with brighter backlights, anti-glare or anti-reflecting films to make them better suited to the application.

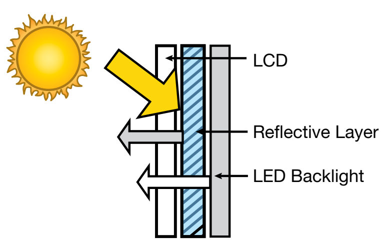
APPLICATIONS
Sunlight Readable
Transflective

Transflective

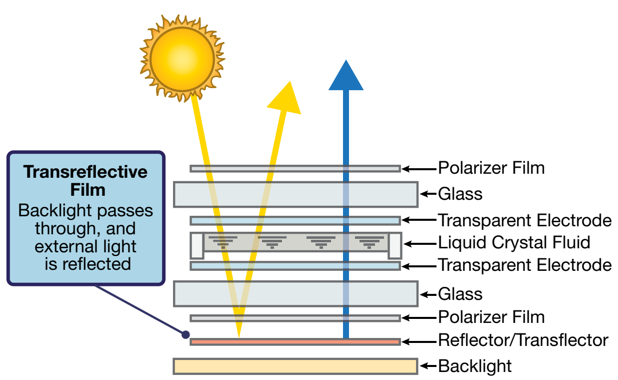
Transflective LCDs are displays that reflect back sunlight through the LCD layer as well as the emitted luminance from the backlight. This results in a display that uses lower power and is measured as a lower nits value but is a great display for outdoor use. Building a transflective display is difficult to manufacture but some of our suppliers have mastered it, creating great looking, long lasting displays.



Standard LCDs are difficult or impossible to read in daylight or sunlight



Transflective LCD Technology uses the ambient light to add to the screen brightness



Transreflective = Transflective

Other options for sunlight readable displays are memory LCDs, electrophoretic and OLED displays that have high contrast ratios. They are typically monochrome and smaller (below 6 inches) but they normally have lower power consumption than a comparable LCD. Refer to pages 30-33 for memory LCDs, electrophoretic and OLEDs.

We also recommend that you ask Future Display Solutions for demonstrations to compare displays side by side and then choose the preferred display for your product. Your display specialist can assist you with choosing your sunlight readable display.

Manufacturer	Part Number	Size (In)	Resolution Pixels	Brightness in NITS	Contrast Ratio(xxx)	Viewing Angle° (up/down; left/right)	Notes
Tianma NLT America	TM035HBHT6	3.5	240 x 320	80	150	95/85	Transflective
Tianma NLT USA	TM035HDHT1	3.5	240 x 320	100	150	95/85	Transflective
Sharp	LS037V7DW03A	3.7	640 x 480	200	200	160/160	AG Portrait mode, w/o TS, 4% Transflective, CGS
Sharp	LS037V7DW05	3.7	480 x 640	240	450	160/160	AG Portrait mode, w/ TS, 4% Transflective, CGS
Sharp	LS037V7DW06	3.7	480 x 640	300	500	160/160	AG Portrait mode, w/o TS, 4% Transflective, CGS
Tianma NLT USA	NL6448BC26-26C	8.4	640 x 480	900	900	160/160	Transflective, T-EVT
Tianma NLT USA	NL8060BC21-11C	8.4	800 x 600	800	800	160/160	Transflective, T-EVT, Color Xcell

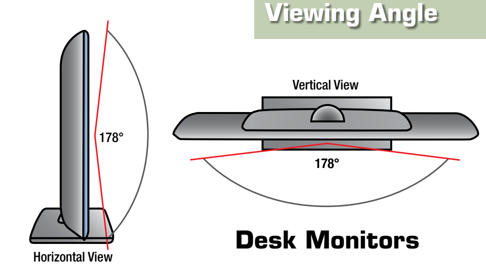
What is the Viewing Angle Required?

APPLICATIONS
Viewing Angle

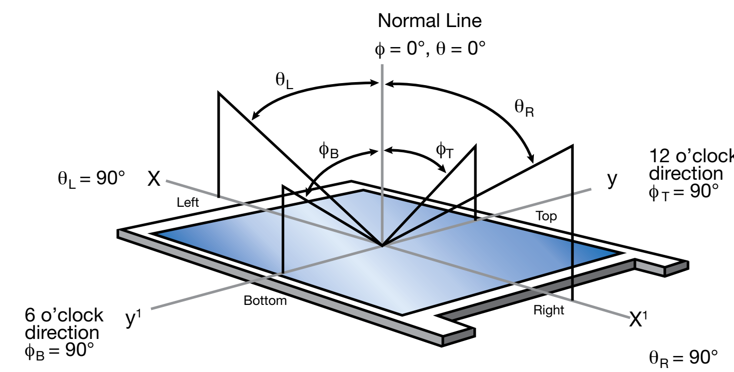
Viewing angle is the angle from the center of the display, either tilting it up or down and panning it left or right. The angles range from 0 to 90 degrees from the center point. Depending on the manufacturing process, the maximum angle you can view the display at is set during production.

An example would be 60° top view looking down, 60° bottom view looking up, 70° looking from the left and 70° looking from the right = 60, 60, 70, 70.

This can also be expressed as Up Down and Left Right = 120/140.



Desk Monitors



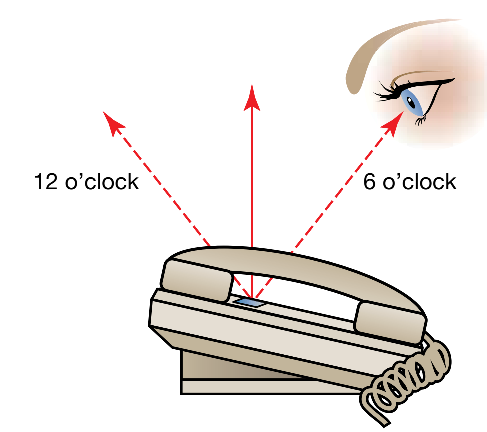
Note (1) Definition of Viewing Angle: Viewing angle range (10≤ CR)

Note (2) Definition of Contrast Ration (CR): Ration of gray max (Gmax), gray min (Gmin) at the center of the screen

$$CR = \frac{\text{Luminance with all pixels white (Gmax)}}{\text{Luminance with all pixels black (Gmax)}}$$

If the display is for a bedside clock, a wide angle may not be required, where as a clock display in a car should have a wide angle so that all the passengers can view the image.

The angle can be improved by adding special films to the front of the display, but the angle can also deteriorate with additional films or touch panels added to the display. Future Display Solutions uses reputable integrators to add the correct films or touch panels to achieve the best display image.



Displays that have a better viewing angle on the top are commonly referred to as a 12 o'clock display (top view), and displays that have a better viewing angle at the bottom are normally refer to as a 6 o'clock display (bottom view). This is an important design point depending on whether the viewer is looking up at the display or down on the display. For example, a desk phone would be 6 o'clock, as the viewer is looking from the bottom of the display.

Manufacturer	Part Number	Size (In)	Resolution Pixels	Brightness in NITS	Viewing Angle° (up/down; left/right)
Sharp	LQ065Y5DZ01A	6.5	800 x 480	675	170/170
Tianma NLT America	NL10276BC16-06D	8.4	1024 x 768	600	176/176
Innolux	G101ICE-L01	10.1	1280 x 800	500	170/170
Innolux	G104X1-L04	10.4	1024 x 768	500	176/176
Innolux	G121AGE-L03	12.1	800 x 600	450	178/178
Tianma NLT America	NL12876BC26-32D	15.3	1280 x 800	470	176/176

APPLICATIONS
Power Consumption

Is Power Consumption an Issue?

If the product is a portable device that runs on batteries, then the power of the display is a key design component. Generally, the larger the display the higher the power requirements.

Previously, backlights were made with cold cathode fluorescent (CCFL) lights. This required more power to drive. Now the backlight is powered by LEDs and manufacturers are continuously improving the efficiency of the LEDs in their displays.

The power consumption can be reduced by using a smaller display, dimming the backlight brightness, limiting the time the backlight/ display is on (sleep mode), selecting a transflective display, a reflective LCD (memory LCD), an electrophoretic display or an emissive display (for example OLED).

For more in-depth information on backlights go to page 36.

Manufacturer	Part Number	Size (In)	Resolution Pixels	Brightness in NITS	Total Power (Watts)
Sharp	LS013B7DH01	1.26	144 x 168	xx	uW Range
Sharp	LS013B7DH03	1.28	128 x 128	xx	uW Range
AZ Displays	ATM0350D19-T	3.5	320 x 240	500	0.434

APPLICATIONS
Extended Temperature

Do You Require Extended Temperature Range?

The typical temperature range for a display is -20°C to +70°C, and some displays can handle wider operating ranges from -35°C to +85°C. LCDs contain liquid, which can slow down or stop working in extreme heat or cold.

Do not confuse the operating range with the storage range. Storage range is normally wider than the operating range and will not affect the display after it is turned on in a normal ambient temperature.

An example is a device added to an ATV that is stored in a cold shed in the winter, but is actually used in milder conditions -20/70°C. Therefore a standard display temperature range could be sufficient in this design.

For wider temperature ranges, Future Display Solutions can add heaters or fans to the display as required. Ask your display specialist for more information.

Refer to the section on Integration, page 59.

Manufacturer	Part Number	Size (In)	Resolution Pixels	Operating Temperature °C (min/max)
Sharp	LQ065Y5DZ01A	6.5	800 x 480	-40/85
Innolux	G070Y2-L01	7	800 x 480	-30/85
Tianma NLT America	NL6448BC20-30C	6.5	640 x 480	-30/80
Sharp	LQ104S1LG81	10.4	800 x 600	-30/80
Innolux	G121AGE-L03	12.1	800 x 600	-30/80
Sharp	LQ084S3LG03	8.4	800 x 600	-30/75

What is the Desired Response Time?

Motion blur is caused when the liquid crystal is unable to change its state rapidly enough from one frame to the next. For HD video, the standard rate is 60 frames per second or 16.7 milli-seconds. The time it takes to switch states is called the Response Time. It is the time taken for a pixel to go from black to peak intensity white and then back to black again.

This response time is an industry standard but it has to be treated with caution, as switching from complete black to white and back to complete black again is not typical with most video. Normally, video has more subtle changes from grey to grey that is harder to measure.

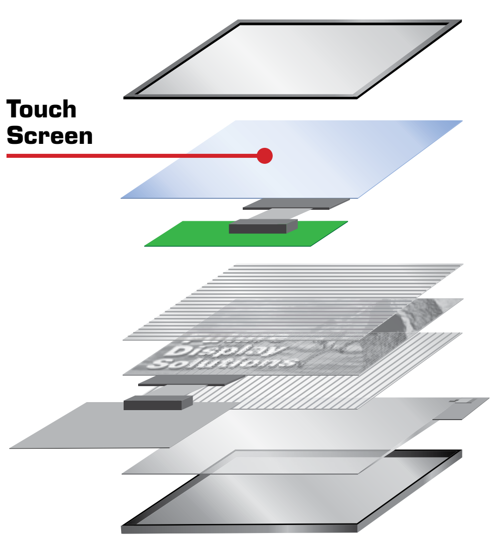
Some caution is also required, as certain manufacturers only measure the time taken to switch from black to white, and therefore the time documented is only half the typical standard response time.

Based on the application, visually examining displays simultaneously side by side early in the design stage is recommended. That way, even subtle differences become obvious. Using the human eye for evaluation rather than instrumentation is preferred, because that is exactly what all the end viewers will be using.

Contact the Future Display Solutions team for demonstrations.

Manufacturer	Part Number	Size (In)	Resolution Pixels	Response Time (Typ) in ms
Innolux	G185BGE-L01	18.5	1366 x 768	5
Litemax	DLF1825-ETN	18.5	1280 x 800	5
Innolux	G156BGE-L01	15.6	1366 x 768	7
Tianma NLT America	NLB150XG01L-01	15	1024 x 768	8

Do You Require a Touch Panel on Your Product?



To communicate with the device that you are designing, you will need an interface. This interface could be in the form of buttons, a keyboard or a mouse, but more commonly a touch panel is the desired input.

The touch panels that cover the majority of applications are resistive (4, 5 or 8-wire) or projective capacitive.

The touch panel may be added to the display during manufacturing or afterward by an integrator. Future Display Solutions will assist you in selecting the best touch solution for your application.

Remember to add a touch panel controller.

For more detailed information, go to page 11 for touch panels and page 20 for touch controllers.

Display Integration

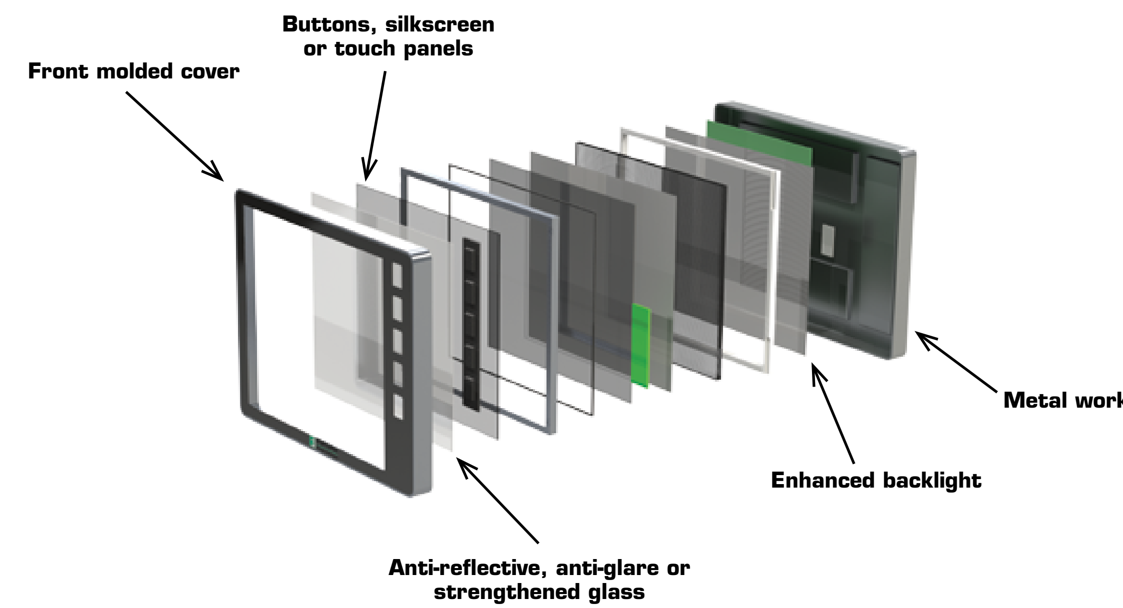
Most projects that Future Display Solutions supports require either integration, customization or enhancement of the display.

Future Display Solutions can integrate your display for the following additions: touch panel, cover glass, strengthened glass, custom interface boards, high brightness, anti-glare film, anti-reflective film and enhancing viewing angles.

We also offer third party value added options, including keypads, enclosures, bezels, assembly and custom cables.

The Future Display Solutions team is available to assist you every step of the way.

Please contact us at 514-694-7710, ext 6363 or
LCDTechnicalSupport@FutureElectronics.com



Integrated Solutions

Do You Want to Use an All-In-One Solution?

For minimal engineering, or when timeline is a factor, Future Display Solutions can provide all-in-one solutions from our suppliers, where the integration of the display, touch panel, interfaces and software are already completed. All-in-one solutions have passed lengthy medical certifications, creating a fast time to market, and can normally be purchased in smaller volumes to get the project or prototype off the ground. A typical application is point-of-care equipment for medical staff to assist patients.

Marine Display

Front **Back**

Span Displays for Transport or Multimedia

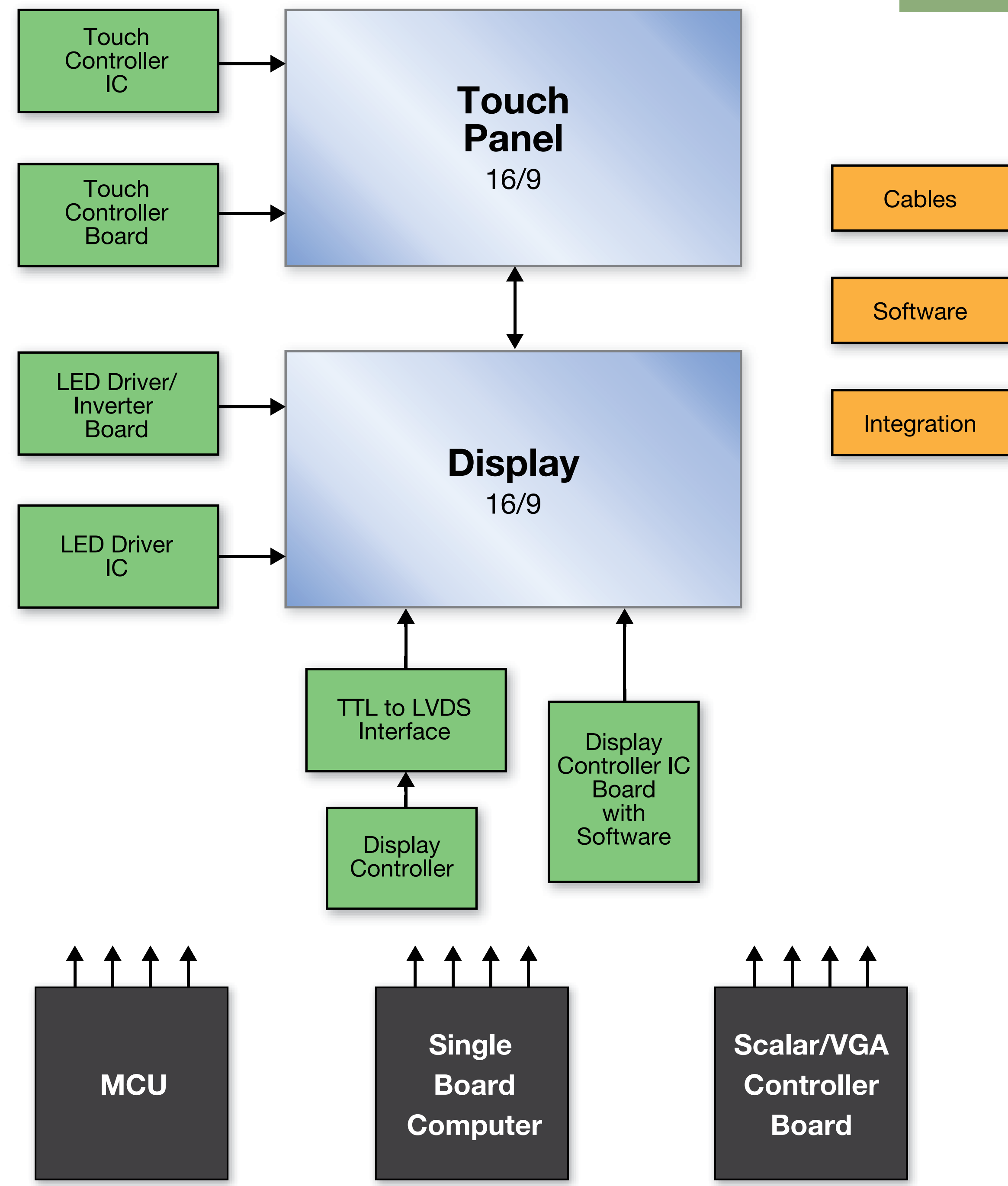
We hope this handbook, in conjunction with the Selector Guide, will assist in the initial design of your product.

Remember that with an extensive product range, expansive knowledge and experience, the Future Display Solutions team is available to assist you every step of the way.

Please contact us at 514-694-7710, ext 6363 or LCDTechnicalSupport@FutureElectronics.com.

Whatever your product environment, cost, style or practicality, remember that the best design is the one that best meets your requirements.

Associated Parts to Consider



GLOSSARY

Glossary

Word	Description
Active Area	Area of the LCD that has active segments or pixels. Typically shown as (W x H) in mm e.g. 154.08 x 85.92.
Active Matrix Display	Transistors are built into each pixel within the screen to improve response times.
AF (Anti-Fingerprint)	A coating or thin film that can be added to the top layer of a display to reduce smears.
AG (Anti-Glare)	A coating or thin film that can be added to the top layer of a display to reduce glare.
All-In-One Solution	The display module that can include: a single board computer, a media converter and interfaces.
Ambient Light	The light surrounding an environment or display.
AMOLED (Active Matrix OLED)	A hybrid display technology that pairs the active matrix backplane from a traditional TFT display with an OLED display.
AR (Anti-Reflective)	A coating or thin film that can be added to the top layer of a display to reduce reflections.
Aspect Ratio	The ratio of width to height of the active area of the display (also the ratio of the horizontal versus vertical pixels), e.g. 4:3 or 16:9.
ATM (Automatic Teller Machine)	A banking machine that provides cash and performs other banking services to an account holder.
Back Panel	Rear mechanical housing of a display normally made with metal or plastic.
Backlight	Rear illumination used in displays to assist with viewing the image, normally LED lights.
Bezel	A frame fitting over the LCD glass to protect the edge of the glass (normally of plastic or metal).
Bit Depth	The number of bits used to indicate the color of a single pixel e.g. 16-bits = 5 Red, 6 Green, 6 Blue – up to 65536 colors. Also known as color depth.
Bonding	The process to join the display glass with a touch panel or cover glass using an adhesive.
Bottom View	A type of display that is best viewed from below. Also known as 6 o'clock.
Candela	An SI unit of luminance or the measurement of the intensity of light. 1 candela per square metre = 1 cd/m^2 = 1 nit.
CCFL (Cold Cathode Fluorescent Tube)	A light source for older LCD screens.
Cell Gap	The spacing between the two pieces of glass containing the liquid crystal fluid.
Character Display	A display that is used to display letters, numbers and symbols only.
Chemically Strengthened Glass	A type of glass that has increased strength as a result of a post-production chemical process.
Chip-On-Board (COB)	When the driver IC is mounted directly on the PCB.
Chip-On-Flex (COF)	When the driver IC is mounted directly onto the flex connector.
Chip-On-Glass (COG)	When the driver IC is mounted directly on the LCD glass.
CMOS (Complementary Metal-Oxide Semiconductor)	The technology used in the transistors that are used in the majority of today's computer microchips.
Color Depth	The number of bits used to indicate the color of a single pixel – 16-bits = 5 red bits +6 blue bits + 5 green bits.
Color LCD	A Liquid Crystal Display that uses color filters, usually Red, Green and Blue (RGB).
Commercial AR	Type of Anti-Reflective (AR) glass that reduces reflective light and improves contrast (98% transmission).
Component Video	A video input that has been split into three component channels, red, green and blue.
Composite Video	An analog video channel typically at 480i or 576i resolution (without audio).
Contact Edge	The conductive area on the edge of the display glass to electrically interface with the controller.

Glossary

GLOSSARY

Word	Description
Contrast Ratio	The ratio of the luminance of the brightest color (white) to that of the darkest color (black).
Controller	An IC that generates the timing of the video signals, the blanking interval signal and tells the display which pixels to turn on or off.
COTS (Commercial Off-The-Shelf)	Refers to ready-made display or accessory that is available for sale as opposed to a custom-built display.
Cover Film	An additional layer that is bonded to the surface of the display that improves the overall display performance.
Cover Glass	An additional glass layer that is bonded to the surface of the display that improves the overall display performance.
Crystal View AR	Type of Anti-Reflective (AR) glass that reduces reflective light and improves contrast.
CSTN (Color Super Twisted Nematic LCD)	A color form of passive matrix LCD displays that uses red, green and blue filters to display color.
Diffraction	The effect by which a beam of light is spread out as a result of passing across the edge of two different types of glass.
Direct Backlight	Rows of LEDs on the rear of the display that face towards the viewer.
Display Controller	Generates the timing of the video signals and the blanking interval signal.
Display Integration	Customized display components that are built, as a module, to suit the customers requirements.
Display Port	A digital display interface developed by the Video Electronics Standards Association (VESA).
Dry Bonding	A method of adhering glass to the display by using a special process of either applying a pressure or vacuum.
DVI (Digital Video Interface)	A video display interface developed by the Digital Display Working Group (DDWG).
Edge Light	Side illumination used in displays to assist with viewing the image (normally LED).
Electronic Paper Displays	An electrophoretic display that replicates the look and experience of ink on paper.
Electrophoretic	The movement of charged particles through a stationary medium when an electric field is applied.
EMI (Electromagnetic Interference)	The noise that effects the operation of an electronic device.
Enhanced Backlight	Improving the brightness of a display by changing the number of LEDs or brightness of LEDs.
Extended Temperature Range	The temperature range a device can operate at beyond the standard -20 to +70°C.
FDS (Future Display Solutions)	LCDTechnicalSupport@FutureElectronics.com
Flexible Flat Cable	A cable designed to be easier to install than round cables. They do not contain electronic components.
Flexible Printed Circuit FPC	A thin cable manufactured with electronic components built in.
Fluoropolymer Coating	Oleophobic coatings are based on fluoropolymer solids and will repel both oil and water.
Foot Lamberts (fL)	A unit of luminance sometimes used in the United States. 1fL equals 1/π candela per square foot, or 3.426 candela per square meter.
Format	Format is the term defining the pixel matrix on a display; i.e. 640 x 480.
Frame	A metal fixture for holding the display glass into an electronic enclosure.
Front Lighting	A method to light a display by bouncing the light from the front instead of the back (normally LEDs).
FSTN	Film Super Twisted Nematic type of LCD fluid within a liquid crystal display.
Glare	Glare is a result of the light emitted from a display backlight plus the ambient light reflected back from the LCD glass.
Graphic Display	A display made up of an array of pixels that is used to display graphics, pictures and text.

GLOSSARY

Glossary

Word	Description
Gray Scale	The ability of a display to be in a state between full ON and full OFF.
Hardness	Resistance of material to indentation, scratching, abrasion, or cutting.
HDMI (High Definition Multimedia Interface)	Uncompressed digital data that includes video and audio on a single cable.
Hitar AR	Type of Anti-Reflective (AR) glass that reduces reflective light and improves contrast (98% transmission).
HMI (Human Machine interface)	A method for the human operator to input control of a machine and to monitor the information feedback from the machine.
i²C (Inter-Integrated Circuit)	An interface that uses only two bi-directional lines, serial data line (SDA) and serial clock (SCL), which are both typically pulled up with resistors.
In-Plane Switching (IPS)	In-plane switching is an LCD technology that aligns the liquid crystals in a plane parallel to the glass substrates, this improving the viewing angles.
In-Cell Touch Panel	By adding the PCap conductive layers in the LCD TFT, the layers of glass are reduced down to one outer layer making it thiner and lighter.
Index matching	Optically bonding the glass with an OCA solution with the same refractive index.
Indirect Display Interface	An interface that need to be converted before connecting to a display driver.
Infrared Touch Panel	A touch panel that sends infra-red beams of light to detect the operator's finger.
Integration	The use of standard off-the-shelf products in combination with other products forming a completed assembly.
ITO (Indium Tin Oxide)	A thin, almost transparent, conductive film that is used in LCDs.
ITO-Replacement	An alternative to ITO that uses nano conductors that can detect touch that are almost invisible.
Landscape	A page or screen orientation that is wider than it is tall.
LCD (Liquid Crystal Display)	A display that has a layer of liquid between two sheets of glass. The liquid contains crystals that react to an electrical charge creating an image.
LCD Module	An LCD Module includes the LCD glass, backlight, controller and driver.
LED Backlight	A rear LED light source for displays.
Light Guide	A thin wedge of a transparent material, such as glass or plastic, which is capable of transmitting light.
Lighting Enhancement	A method of improving the brightness of a display.
Liquid Crystal	The compound found in liquid crystal displays, that is both a fluid and a crystalline material at room temperature.
Luminance	The brightness of a display. Commonly referred to in nits e.g. 1000 nits
LVDS (Low Voltage Differential Signaling)	A transmission method for sending digital information.
Memory LCD	A low power Liquid Crystal Display that uses light reflectance instead of a backlight.
Mini Display Port	A VESA designed interface to replace the bulky DVI and VGA connections on devices to transport the video signals to a monitor.
MIPI (Mobile Industry Processor Interface)	A standard created by the MIPI Alliance companies, designed for mobile devices where power consumption is a design requirement.
Module	An LCD with drive and control electronics built in.
Monitor	A complete plug & play display unit that includes the driver, control electronics, interfaces and power supply.
Monochrome	A display that has only one color.

Glossary

GLOSSARY

Word	Description
MTBF (Mean Time Between Failure)	The predicted elapsed time between inherent failures of a system during operation.
Multi-Touch	Detecting multiple points of contact made on the surface of a touch panel simultaneously.
MVA (Multi-Domain Vertical Alignment)	A display technology that has wide viewing angles by using the alignment of the liquid crystals in multiple directions. There are several technologies based on MVA.
Nano Tube	A cylindrical carbon structure that made of hexagonal graphite molecules equal to a billionth of a meter (10^{-9} m) thick.
NIT	A unit of visible-light intensity, commonly used to specify the brightness of a display. A non SI unit of measurement 1 nit = 1 cd/m² (candela per square meter).
Nm (Nanometer)	A unit of length equal to 10^{-9} meter, or one billionth of a meter. Used in visible light, a range of 400 - 700 nanometers (nm).
NVIS	Night Vision Imaging System02
OCA (Optically Clear Adhesive)	Commonly used to bond cover glass, touch panels and displays and improves optical characteristics and durability. The "goop".
OLED (Organic Light Emitting Diode)	A diode that has a film of organic compounds which emits light in response to an electric current.
Oleophobic	A coating used on touch panels and coverglass to prevent fingerprint marks. Also known as lipophobic (Greek - Fear of fat).
On-Cell	A thin touch panel to which the conductors and insulated layers are added to the LCD first, and then the cover glass is attached.
One Glass Solution	A touch panel technology that reduces the thickness of displays by removing one of the layers of glass from the stack up.
Operating Temp °C (Min/Max)	The range of temperatures a device can operate at, typically -20 to +70°C.
Optical Bonding	When a special liquid adhesive (OCA) is used for bonding the cover glass to the touch panel or the cover glass to the LCD glass.
Optical-HE AR	Type of Anti-Reflective (AR) glass that reduces reflective light and improves contrast (98% transmission).
Orientation	When a display is used in either landscape or portrait mode.
Outline Dimensions (W) x (H) x (D) mm	The total outer dimensions in mm of the display given in width, height and depth.
PAR AR	Type of Anti-Reflective (AR) glass that reduces reflective light and improves contrast (94% transmission).
Parallel Interface	A connection where the bits are sent simultaneously across multiple wires to a display.
Passive-Matrix	A display where each row and column of the display are multiplexed or addressed in turn.
PCB (Printed Circuit Board)	A manufactured board containing electronics components.
PET FILM (Polyethylene Terephthalate)	A film that has a high tensile strength and good electrical insulation.
Pixel	The smallest point of information on a display.
Polarizer	Polarizers will let only half the lightwave pass and will stop the perpendicular vibration of the lightwave.
Portrait	A page or screen orientation that is taller than it is wide.
POS (Point of Sales)	The display located where the customer makes a payment in exchange for goods or a service.
Power Consumption	The electrical energy over time, supplied to operate a display.
Projective Capacitive Touch Panel	A touch panel that detects the capacitance from the users finger or a PCap stylus.
QSXGA (Quad Super XGA)	A screen resolution of 2560 x 2048 pixels.

GLOSSARY

Glossary

Word	Description
Quantum Dot	A semiconducting material that can be embedded in displays or touch panels equal to a billionth of a meter (10^{-9} m) thick.
QVGA (Quarter VGA)	A screen resolution of 320 x 240 pixels.
Reflective	A display without a backlight. Relies on the reflecting ambient light to provide the image. Good for bright lighting conditions.
Resistive Touch Panel	A touch panel composed of two layers coated with ITO, separated by an air gap. The top sheet is made with a flexible, resistive material.
Resolution Name	The number of distinct pixels in a standard format e.g. Video Graphics Array (VGA) has a resolution of 640 x 480 pixels
Resolution Pixels	The number of distinct pixels horizontally and vertically that can be displayed e.g.640 (W) x 480 (H).
Response Time	The time taken for a display to change its state when subjected to a change in input signal.
RGB (Red Green Blue)	A standard interface that also refers to the primary display colors: red, green, and blue. When these colors are mixed together in a display, it will create white light.
ROTS (Ruggedized Off-The-Shelf)	Refers to ready-made merchandise that is made for ruggedized applications.
Rs232/UART Interface	A serial interface for asynchronous data communication over distances up to a few hundred feet.
SAW (Surface Acoustic Wave)	A touch panel that uses ultrasonic wave technology to detect the user's finger or stylus.
SBC (Single Board Computer)	A printed circuit board that contains a complete computer, including: processor, memory, I/O and clock.
S-Cap (Surface Capacitive)	A touch panel in which only one side is coated with a conductive layer. It detects the user's finger when the uncoated surface is touched.
SDC (Systems Design Center)	Future Electronics' System Design Center of display expertise.
Segment	Part of a character display, usually 7 or 14 segments for alpha/numeric characters.
Selector Guide	The Selector Guide is a database of LCDs from Future Display Solutions.
Serial Interface	A method of sending information as a series of bits or logic levels (0 or 1).
Silk Screening	A method of printing an additional ink layer for customised logos or text.
Size (in)	Diagonal viewing dimension of a display given in inches, e.g. 10.1" medical monitor.
Soda Lime Glass	A standard type of glass that is relatively inexpensive, chemically stable, reasonably hard, and extremely workable.
SPI Interface (Serial Peripheral Interface bus)	A synchronous serial data link standard with which devices can communicate with one another simultaneously.
STN (Super Twisted Nematic)	A type of base fluid of the LCD that twists more than 180 degrees.
Strengthened Glass	A type of glass either thermally or chemically treated to increase its strength compared with normal glass.
Stylus Pen	A touch panel activation interface device used in place of a finger with a capacitive or resistive touch panel.
Sub Pixel Rendering	A method to increase the apparent resolution of a computer's liquid crystal display by taking into account the display's physical properties.
Sub-Pixel	Part of a pixel, normally either the red, green or blue.
Sunlight Readable	A display that can be viewed directly under sunlight. Typcally reflective displays or with a brightness of over 1000 nits.
SVGA (Super VGA)	A screen resolution of 800 x 600 pixels.
S-Video (Super-Video)	Separates the video data as two signals, lumen (luminance or the black and white levels) and chroma (color signals).
SXGA (Super XGA)	A screen resolution of 1280 x 1024 pixels.

Glossary

GLOSSARY

Word	Description
Tape or Edge Bonding	A method of bonding glass at the edges, creating a small air gap between the cover glass and the LCD glass.
TFT (Thin Film Transistor)	A kind of transistor made by depositing thin films of semiconductors and metallic contacts over a glass substrate.
TFT Display	Also called Active Matrix Display. Transistors are built into each pixel within the screen to improve response times.
TMDS (Transition Minimized Differential Signaling)	A transmission method for sending digital information from a microprocessor to a display.
Top View	A type of display that is best viewed from above. Also known as 12 o'clock.
Total Internal Reflection	A touch panel type that detects touch by transmitting a light signal internally on one side of a glass layer and received on the adjacent side.
Total Power (Watts)	Is the maximum power that the display will consume.
Touch Panel/Touch Screen	A display screen that can detect a finger or stylus pressing on it.
Touch Controller	The hardware element that translates the information between the touch panel and the host system.
Transflective	A display incorporating both reflective and transmissive techniques that can be read in both bright light and low light environments.
Transmissive	A type of LCD which uses a built-in light source and does not have a reflector or transflector on the rear polarizer.
Transparent	A material that passes light without diffusion or scattering.
Twisted Nematic	A type of display where the liquid crystal twists 90 degrees from the angle of alignment in the liquid crystal layer.
UART Interface/Rs232	A serial interface for asynchronous data communication over distances up to a few hundred feet.
USB (Universal Serial Bus)	Universal Serial Bus, is an industry standard that defines the cables, connectors and communications protocols.
UXGA (Ultra XGA)	A screen resolution of 1600 x 1200 pixels.
VA (Vertical Alignment)	Displays in which the liquid crystals naturally align vertically to the glass layers when no voltage is applied.
VESA (Video Electronics Standards Association)	Established in 1989 to set and support interface standards designed for the PC, workstation, and other computing environments.
VGA (Video Graphics Array)	The display standard for the personal computer that is in a 640 x 480 pixel format.
VHB Tape (Very High Bonding Tape)	Used for edge bonding cover glass in a display or touch panel.
Viewing Angle	The maximum angle a person can view a display measured as up/down and left/right e.g. (85/85)(85/85) or 170/170.
WSXGA (Wide Super XGA)	A wide screen resolution of 1680 x 1050 pixels.
WUXGA (Wide Ultra XGA)	A wide screen resolution of 1900 x 1200 pixels.
XGA (EXtended Graphics Array)	A screen resolution of 1024 x 768 pixels. The term stems from IBM computers.

To obtain a soft copy of this handbook or the Selector Guide,
go to www.FutureElectronics.com/Displays

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