DISPLAY LOGIC

LCD Enhancements and Interfacing

Touch Sensor Technology Brief
Fall 2014

DISPLAY LOGIC
LCD Enhancements and Interfacing

The advent of the iPhone has ushered in a seismic change in the touch-screen business

Since its release in 2007, few devices have had as big an affect on technology driven products as the Apple iPhone and more recently the Apple iTouch/iPad and specifically on how users interact with devices. These devices changed how designers and engineers think about end product user experience.

While touch sensors are not a new technology, advances in technology plus wide user acceptance of touch sensor use has meant we find touch on more and more technology products we interact with at a consumer and industrial level.

Different applications require different touch technologies; it's almost never "one size fits all" – that's why there are 13 touch technologies!

The following material will walk you through the many touch sensor technologies, how they work, where they work best, advantages and disadvantages of each.....

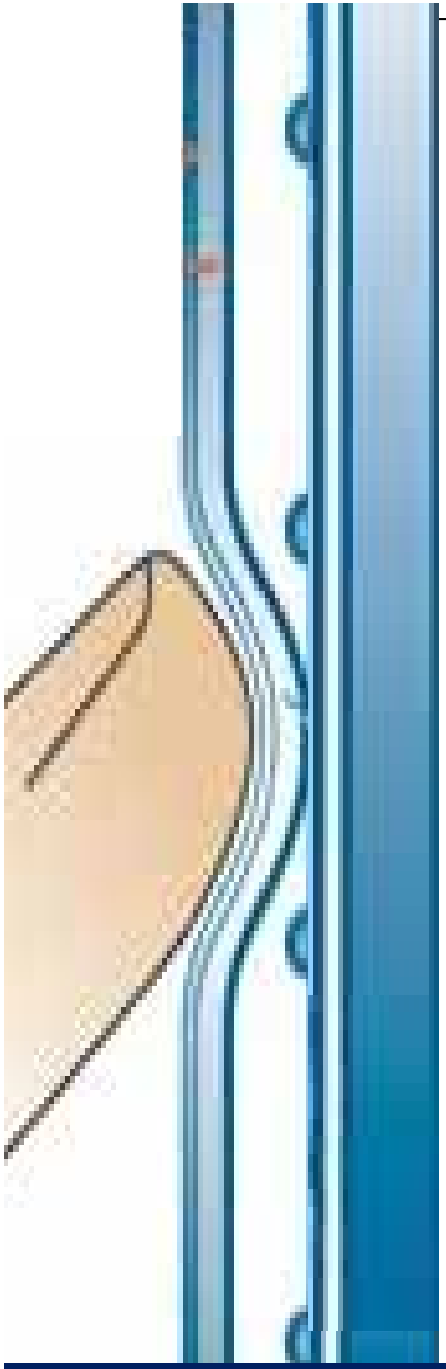


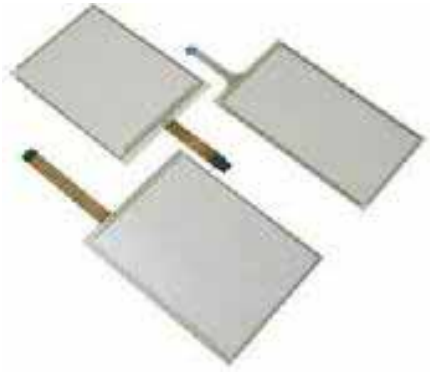
Table of Contents

DISPLAY LOGIC
LCD Enhancements and Interfacing

Touchscreen 101

DISPLAY LOGIC
LCD Enhancements and Interfacing

Touchscreens are generally defined as a device that allows a user to interact with a display directly as opposed to using an intermediate device such as a mouse, keyboard or glide pad.



In most cases, the touch function is accomplished with an overlay that covers the display and some simple electronics. In the following slides, we'll give a brief explanation of the main touch technologies.

Understanding Multi Touch (1/5)

DISPLAY LOGIC
LCD Enhancements and Interfacing

The term "multi-touch" is now in common use to describe any touch screen that can recognize more than one point of contact; in effect the use of two or more fingers simultaneously.

However, there are now several different types of multi-touch, depending on the touch technology employed.

Understanding Multi Touch (2/5)

DISPLAY LOGIC
LCD Enhancements and Interfacing

How many touches are enough? On one hand, some industry participants believe that two touches on a mobile phone are enough; tablets and netbooks/notebooks used in gaming may require four touches and PCs with 15-in. or larger screens may require 10 touches.

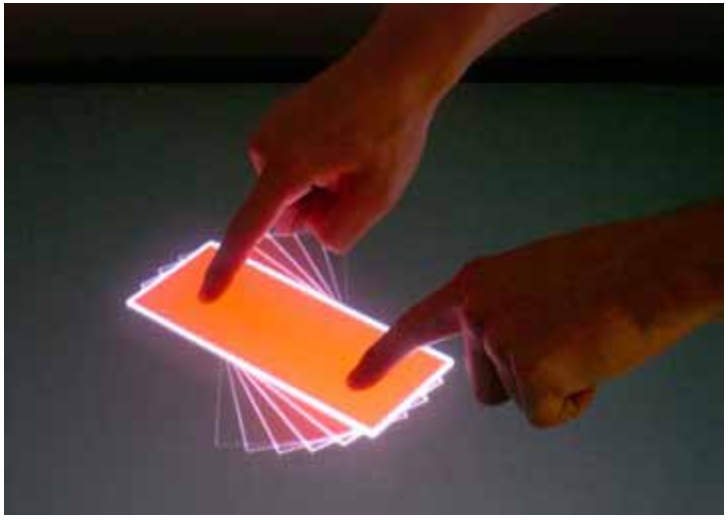
Windows 7 supports up to 100 touches. The reality is that today, other than multi-player games and virtual keyboards, there are very few applications that make use of more than two touches. Other than observing that all humans have 10 fingers, nobody seems to have any clear concept of how real-world applications will use that many touches.

Understanding Multi Touch (3/5)

Two/Dual Touch

Two Touch refers to a touch system that can detect and resolve two discrete, simultaneous touch events.

The best demonstration of Two Touch capability is to draw two parallel lines on the screen at the same time. Two Touch systems can also support gesturing.



Understanding Multi Touch (4/5)

Multi Touch

Multi-touch refers to a touch system´s ability to simultaneously detect and resolve a minimum of 3+ touch points. All 3 or more touches are detected and fully resolved resulting in a dramatically improved touch experience.

Multi-touch is considered by many to become a widely-used interface mainly because of the speed, efficiency and intuitiveness of the technology.

DISPLAY LOGIC
LCD Enhancements and Interfacing

Multi Touch Defined (5/5)

Common Gesturing Techniques

GESTURE	WINDOWS USAGE	GESTURE ACTION	ACTION (○+ finger down | ◌+ finger up)	Single Contact	Multi Contact
Tap / Double Tap	Click / Double Click			★	★
Panning with Inertia	Scrolling	Drag 1 or 2 fingers up and down			★
Selection / Drag (left to right with one finger)	Mouse Drag / Selection	Drag one finger left / right		★	★
Press and Tap	Right-click	Press on target and tap using a second finger			★
Zoom	Zoom (defaults to CTRL key + Scroll wheel)	Move two fingers apart / toward each other			★
Rotate	No system default unless handled by Application (using WM_GESTURE API)	Move two fingers in opposing directions -or- Use one finger to pivot around another			★
Two-Finger Tap	N/A – Exposed through Gesture API, used by Application discretion.	Tap two fingers at the same time (where the target is the midpoint between the fingers)			★
Press and Hold	Right-click	Press, wait for blue ring animation to complete, then release		★	★
Flicks	Default: Pan up/ Pan Down/ Back, and Forward	Make quick drag gestures in the desired direction		★	★

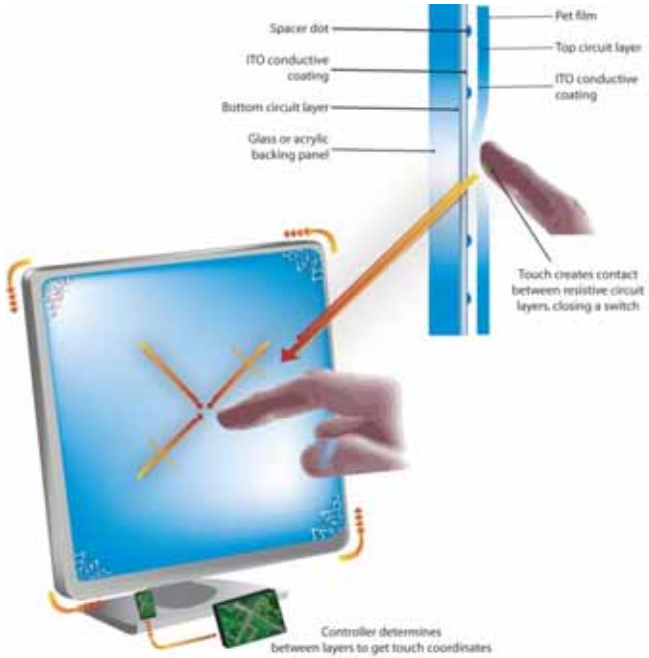
Touch Screen Technologies

Resistive Touch Sensor Technology

DISPLAY LOGIC
LCD Enhancements and Interfacing

A simple and reliable technology. Resistive touch screens have a flexible top layer and a rigid bottom layer separated by insulating dots, with the inside surface of each layer coated with a transparent conductive coating. Voltage applied to the layers produces a gradient across each layer. Pressing the flexible top sheet creates electrical contact between the resistive layers, essentially closing a switch in the circuit. This technology will work in most applications and is less expensive than the other technologies.

Options are 4, 5,7 and 8 wire. 5, 7 and 8 wire are generally more robust and do not require re-calibration. (details on next slide)



Advantages

- Cost effective
- Ease of design
- Use with Gloves
- Activates with Stylus

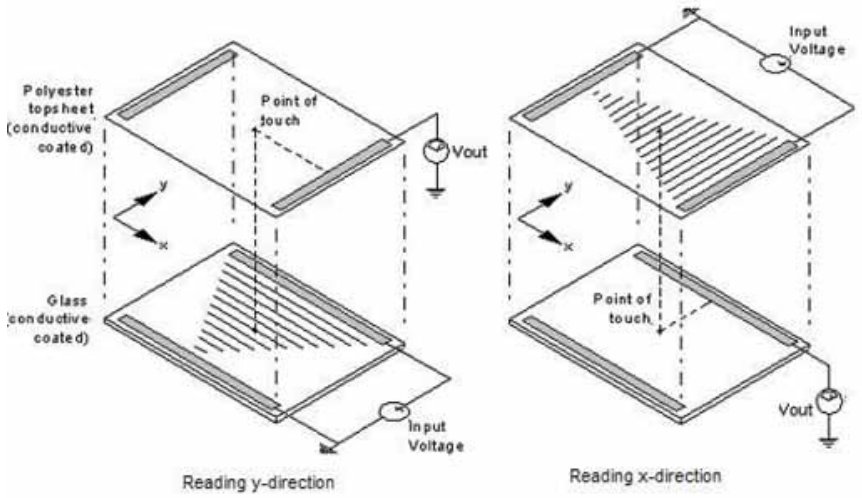
Disadvantages

- 70-80% transmissivity lowers brightness performance of LCD
- Front surface durability*
- Single Touch Only

* “Glass on top” or Glass-film-glass resistive adds a top glass layer to increase surface hardness

4 Wire Resistive Touch Sensor Technology

Touch measurement in 4 Wire technology is a 2 step process. First, the distance along the x axis at the point of touch is measured by creating a horizontal voltage gradient on the top sheet, with the bottom acting as the return layer. Second a vertical voltage gradient is created on the bottom layer, to measure the y axis.



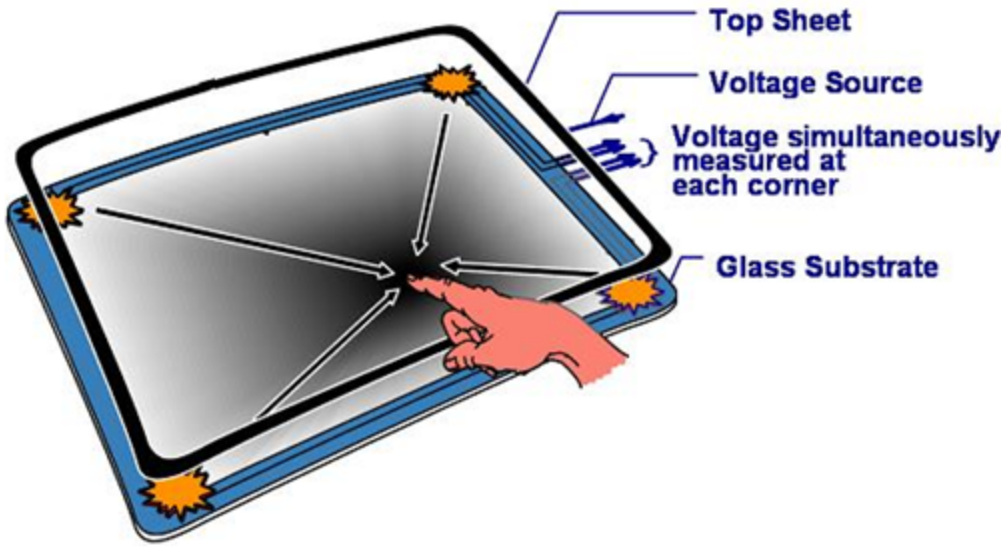
The technology and electronics are simple, making 4 wire the cheapest touchscreen technology. But since the voltage gradient is needed on both the layers, any damage to either layer causes the touchscreen to stop functioning.

This lack of durability means that 4 wire technology should not be used for applications like public access kiosks, industrial locations or on displays larger than 10.4".

DISPLAY LOGIC
LCD Enhancements and Interfacing

5 Wire Resistive Touch Sensor Technology

In 5 Wire resistive, the main electronics are on the glass bottom layer. A uniform voltage is applied to the top plastic layer. A touch causes an electrical contact between the top and bottom layers. Depending on the point of touch the voltages at the 4 corners of the glass are different—these are measured, and used by a complex algorithm in the controller to calculate the x-y coordinate of the point of touch. More stability in calibration negates the need for re-calibration.



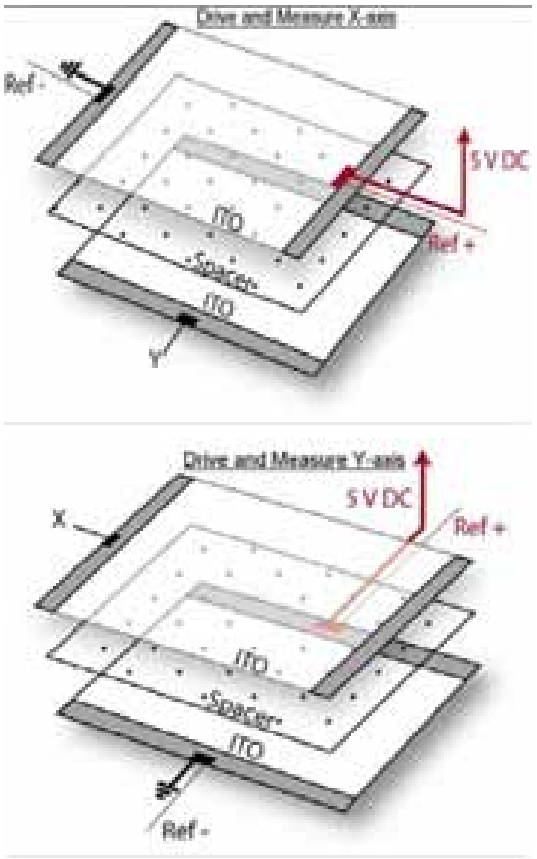
The technology and electronics are more complex then 4 wire, however costs of 5 wire sensors are closing in on 4 wire sensor cost. More complex electronics makes it possible to use 5 wire for sizes up to 22", larger than with 4 wire. Also, since the voltage measurement is on the stable glass bottom layer, despite damage to one portion of the top layer, the touchscreen keeps working

8 Wire Resistive Touch Sensor Technology

The basic decoding of an 8-wire sensor is similar to a 4-wire. The difference is that an 8-wire sensor has four additional interconnects used to reference sensor voltage back to the controller.

A touch system may experience voltage losses due resistance changes in the bus bars and connection between the controller and sensor. The losses can vary with product use, temperature, and humidity.

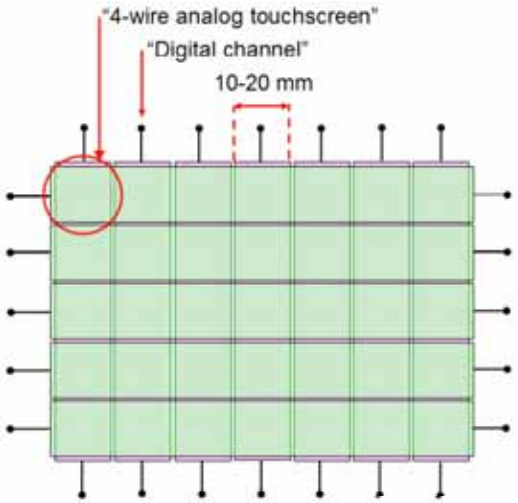
In a 4-wire sensor, variations in the losses manifest themselves as error or drift in the reported touch location. An 8-wire touch sensor automatically adjusts for the changes, with the additional four reference lines. The reference lines allow the controller to know what the voltage is, at the touch sensor bus bars this in turn eliminates the need for recalibration.



Resistive Touch Sensor Technology
Analog/Digital Matrix

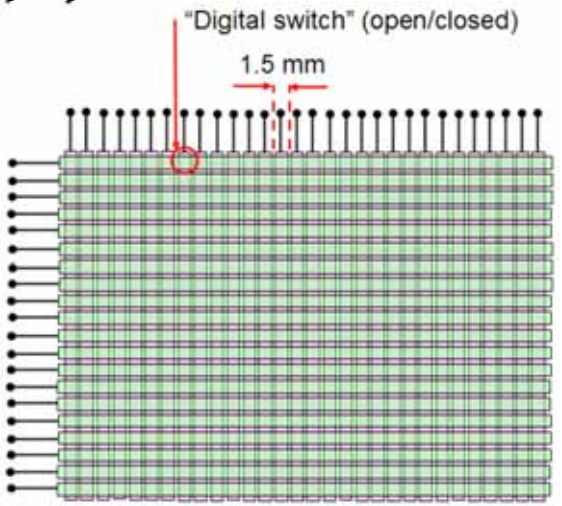
DISPLAY LOGIC
LCD Enhancements and Interfacing

Analog/Digital Matrix Resistive (AMR/DMR) touch screens, are essentially a grid of mini 4 or 5 wire resistive touch sensors or cells. The characteristics of resistive sensors previously describe apply. A typical sensor may be divided into 16 cells(4✕4), 70 cells(7✕10) or 60 cells(6✕10).



Analog Matrix

Dual touch can be achieved when the coordinate values of more than two points are detected in two different cells.



Digital Matrix

Advantages

- Dual Touch
- Cost effective
- Customizable
- Input with Glove and Pen
- Recognize gesture input
- Palm rejection possible
- Customize Zones

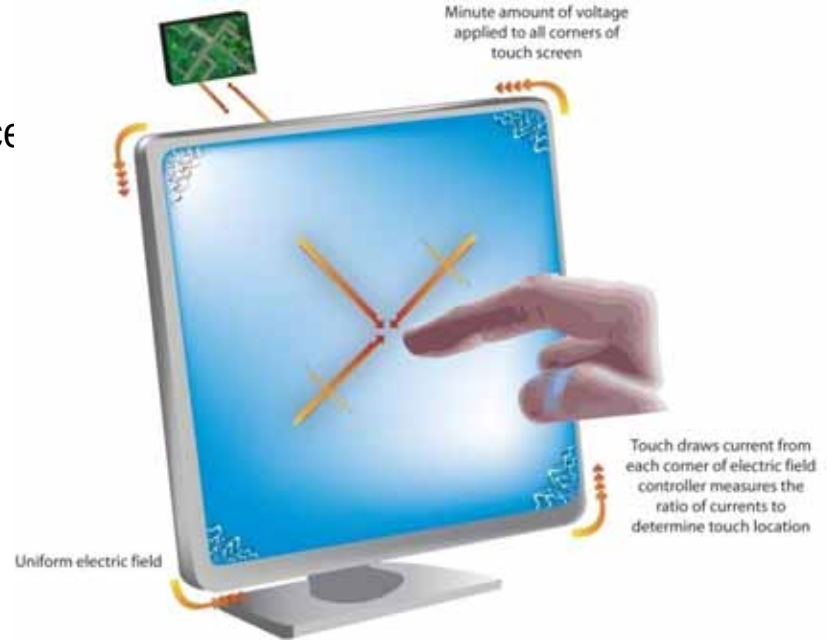
Disadvantages

- 70-80% transmissivity lowers brightness performance of LCD
- Front surface durability
- Dual Touch not possible inside same cell

Surface Capacitive Touch Sensor Technology

DISPLAY LOGIC
LCD Enhancements and Interfacing

A capacitive touch screen sensor consists of an insulator such as glass, coated with a transparent conductor. When a conductor, such as a human finger, touches the uncoated surface, a capacitor is dynamically formed. The sensor's controller can determine the location of the touch indirectly from the change in the capacitance as measured from the four corners of the panel.



Advantages

- 85-93% Transmissive
- Glass surface durability
- Long life expectancy
- Chemical resistant
- NEMA Sealable
- Fast Response Time

Disadvantages

- Only activated with a finger
- Not scalable to large format LCD's
- Single Touch Only
- Proper application required, susceptible to false signals from outside influences

Projected Capacitive Touch Sensor Technology Overview (1/4)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Capacitive sensing in touch screens has been around since the 1970's, but with the recent explosion in popularity of the smart phone, projected capacitive sensors (PCAP) have come to the forefront of touch screen technology.

As a result of the success of advanced smartphones, users have discovered the many benefits of projected capacitive touch panels. Users are realizing that the gesturing interface used on the advanced smartphones is a natural way of interacting with electronic devices. Now that projected capacitive touch panels are available in larger panel sizes, designers can bring this same experience to a variety of embedded systems where the durability, reliability and overall performance of this technology can also add substantial value to the system.

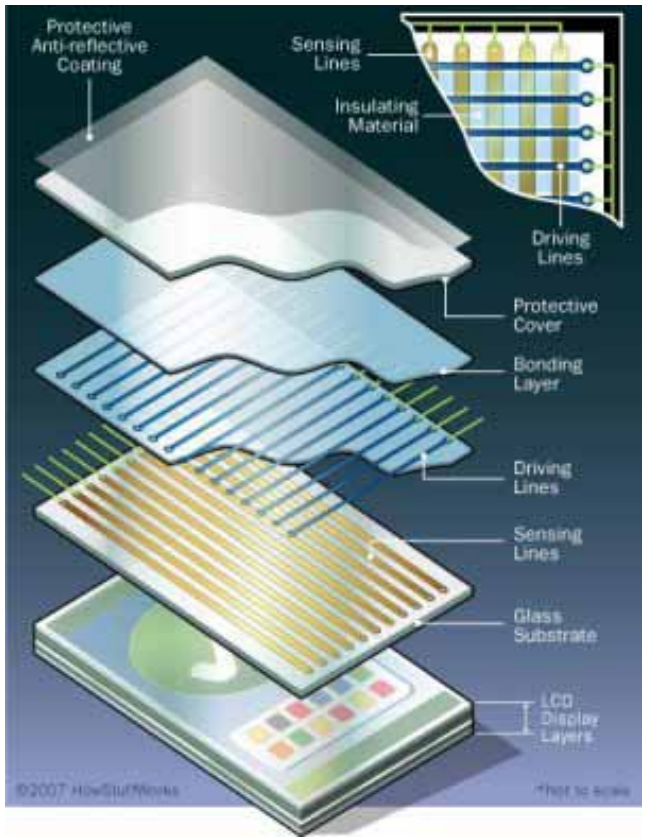
Projected Capacitive Touch Sensor Technology Why so Special? (2/4)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Projected Capacitive touch (PCT) technology is similar to Surface Capacitive touch technology (see Surface Capacitive Touch Technology section). However PCT technology is a capacitive technology which permits more accurate and flexible operation, projection of the touch field through additional layers of material plus full mutli-touch capability.

Typical construction of a PCT technology sensor allows for operation without direct contact to the touch sensor. Thus the touch sensor can be located behind further insulating layers, and operate even under screen protectors, or behind weather and vandal-proof glass. Due to the top layer of a PCT being glass, PCT is a more robust solution versus resistive touch technology.

Since PCT technology construction is an X and Y matrix of capacitors capable of locating multiple distinct touch points, PCAP touch sensors are true multi touch capable.



Projected Capacitive Touch Sensor Technology Advantages/Disadvantages (3/4)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Advantages

- Functional through multiple layers
- Works outdoors
- True flat front surface design possible
- Long life reliability
- Durable and easily customizable front surfaces
- Excellent Optical Properties
- True Multi-Touch capable
- Easy Integration
- Drift free Operation

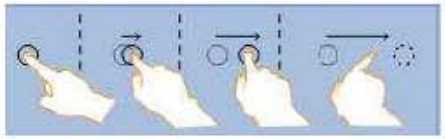
Disadvantages

- Best activated with a bare finger
- Doesn't work well with heavy gloves
- Proper application required, susceptible to false signals from outside influences
- Possible interference from conductive smudges
- Higher Cost

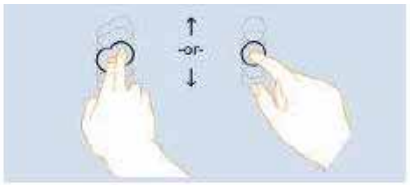
Projected Capacitive Touch Sensor Technology Multi Touch Features (4/4)

DISPLAY LOGIC
LCD Enhancements and Interfacing

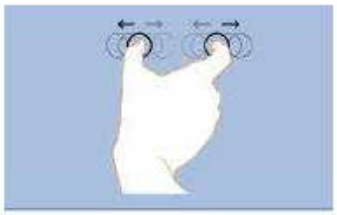
Select & Drag



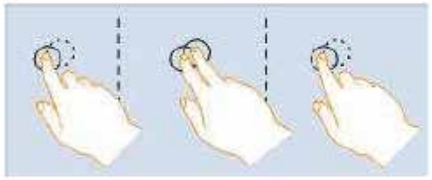
Flicks



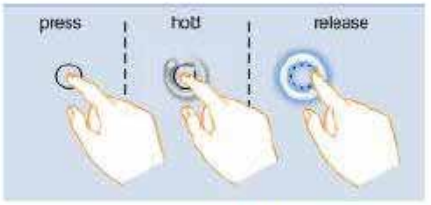
Panning



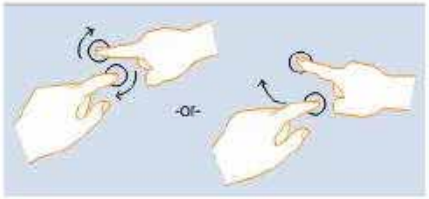
Zoom



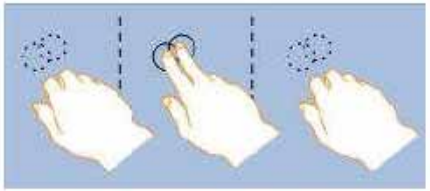
Press & Tap



Press & Hold



Rotation



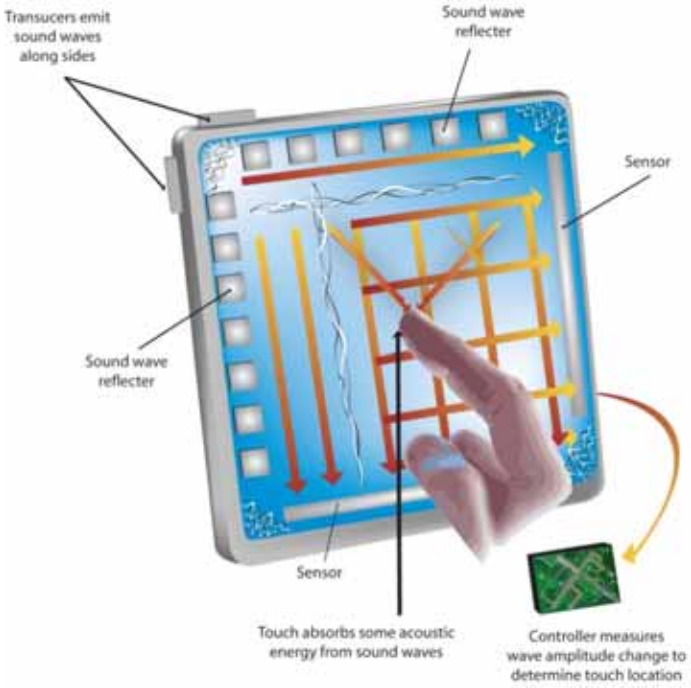
Two Finger Tap

Surface Acoustic Wave Touch Screen Technology (1/2)

DISPLAY LOGIC
LCD Enhancements and Interfacing

With Surface Acoustic Wave (SAW,) piezoelectric transducers, located at different positions of the screen, are used to turn the waves of mechanical energy of a touch (vibration) into an electronic signal.

The waves are spread across the screen by bouncing off reflector arrays along the edges of the sensor and are detected by two "receivers". The acoustic wave weakens when the user touches the sensor. The coordinates are then determined by the controller and report the touch location.



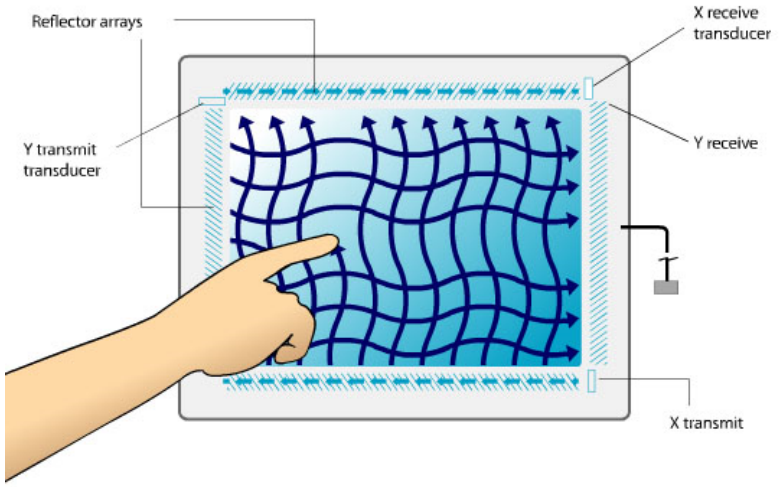
Surface Acoustic Wave Touch Screen Technology (2/2)

DISPLAY LOGIC
LCD Enhancements and Interfacing

The touch screen itself is made of ordinary glass, giving it good durability and optical clarity. The technology is also well suited to displays that are physically larger. After the initial touch, a motionless finger cannot be detected. However, for the same reason, the touch recognition is not disrupted by any resting objects on the screen (e.g. hand palm or elbows).

It has excellent durability that allows it to continue working if scratched since the overlay for the touch sensor is a solid glass display.

The disadvantage to this glass overlay is that is breakable and won't work in wash down conditions (e.g. hard rain on the display).



Advantages

- ~95% Transmissive
- Glass surface durability
- Long life expectancy
- Chemical resistant
- Can be operated with a finger, glove, soft Stylus

Disadvantages

- More expensive then other technologies
- Can not be sealed
- Integration difficulty
- Can be affected by dirt/water on the surface

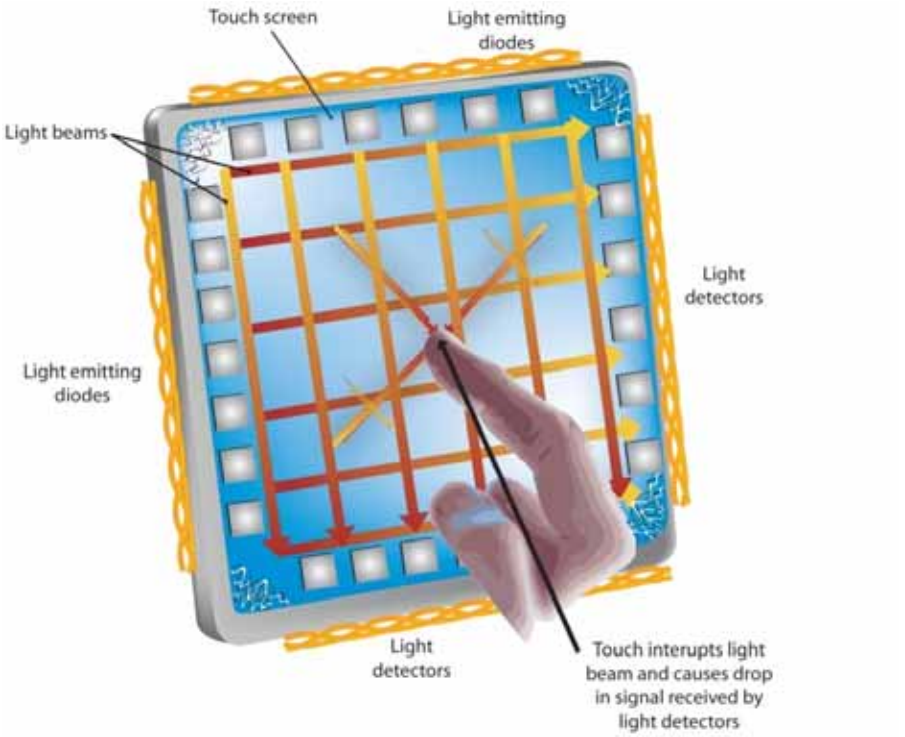
Infra-Red Touch Screen Technology (1/2)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Infrared (IR) optical-touch systems use an array of infrared light-emitting diodes on two adjacent bezel edges of a display, with photo sensors placed on the two opposite bezel edges to analyze the system and determine a touch event.

The infrared bezel is mounted to the front of the display screen where the LED and photo sensor pairs create a grid of light beams across the display.

An object (such as a finger or pen) that touches the screen interrupts the light beams, causing a measured decrease in light at the corresponding photo sensors. The measured photo sensor outputs can be used to locate a touch-point coordinate.

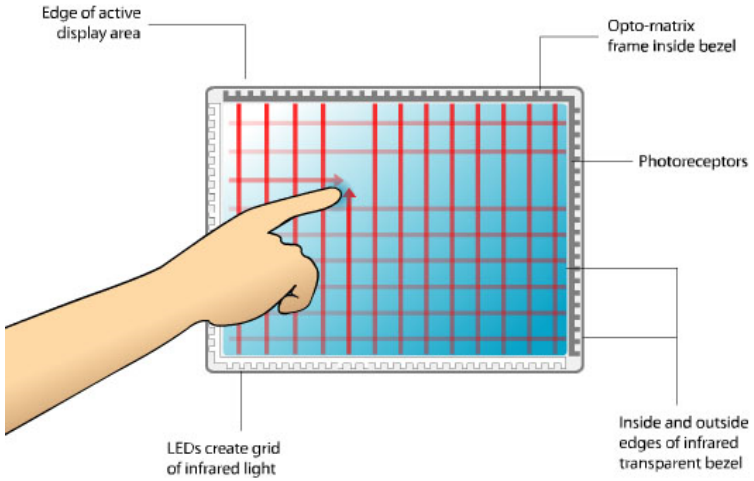


Infra-Red Touch Screen Technology (2/2)

DISPLAY LOGIC
LCD Enhancements and Interfacing

A feature of infrared touch which has been long desired is the digital nature of the sensor output when compared to many other touch systems that rely on analog-signal processing to determine a touch position. These competing analog systems normally require continual re-calibration, have complex signal-processing demands (which adds cost and power consumption), demonstrate reduced accuracy and precision compared to a digital system, and have longer-term system-failure modes due to the operating environment.

IR, has become one of the more versatile and flexible touch technologies given its scale, high performance and resolution, durability, ease of use, and cost-effectiveness for all devices 15 inches and larger.



Advantages

- Digital Sensor requiring less re-calibration
- 100% Light Transmission
- Scalable to 40+”
- Can be operated with Finger or object
- High tolerance to Shock and Vibration

Disadvantages

- More expensive then other technologies
- Can not be sealed
- Doesn’t perform well in high ambient light applications
- Integration difficulty
- Can be affected by dirt/water on the surface

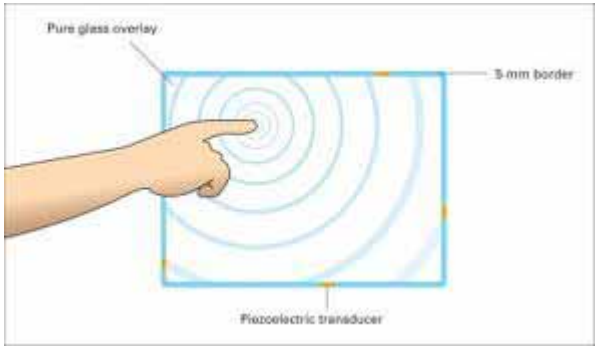
Acoustic Pulse Recognition Technology (APR)

DISPLAY LOGIC
LCD Enhancements and Interfacing

When any object contacts the APR glass overlay, an acoustic pulse is generated . This pulse is measured by transducers located on the four edges of the glass and converted to an electric signal. The signal is then matched to a pre recorded acoustic profile to every location on the glass, and the touch point is located.

There are many advantages to this technology.

- Optics and durability of pure glass
- Works with finger, glove, pen, credit card, fingernail
- Resistant to water, dust, grease
- No wear-out mechanism
- Works even with scratches
- Excellent drag performance
- Sealable to NEMA 4/IP65 standards
- One time factory calibration, no drift
- Thin borders—only 5mm
- True flat surface
- Small and large sizes
- Palm rejection



This technology is patented by ELO and is not sold as a component part , but is ONLY available when integrated into ELO touch monitor and computers.

Dispersive Signal Technology (DST)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Dispersive Signal Technology, specifically developed for interactive digital signage applications, sets new large-format touch standards for fast, accurate repeatable touch Response. DST's operation is unaffected by contaminants, static objects or other touches on the touch screen. Other key characteristics of this patented technology are exceptional optics, ease of integration, and input flexibility.

DST is 3M's proprietary implementation of "bending wave technology". The DST touchscreen controller precisely calculates touch locations by analyzing the bending waves within the glass substrate that are created by the user's touch. DST is good choice for large format LCDs and is available in large sizes only- 32", 40", 42" and 46"

3M

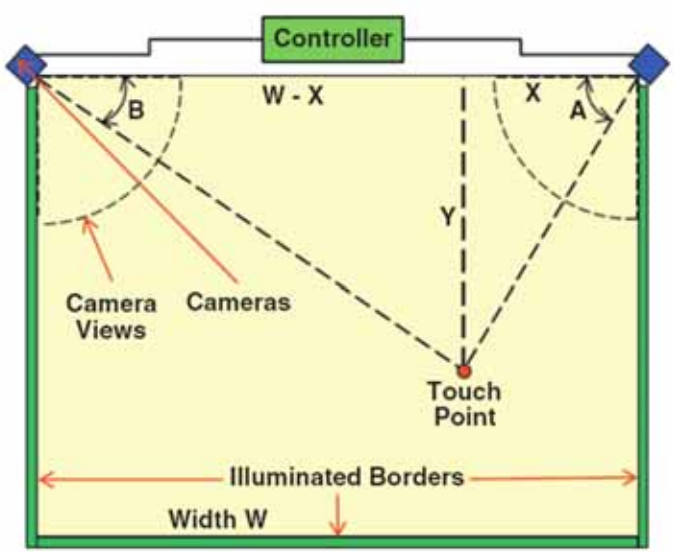
Key Technology Characteristics

- Fast, accurate and repeatable touch response
- Operation unaffected by surface damage, including Scratches
- Input flexibility, accepting touch from finger, pencil, credit card, fingernail, or almost any type of stylus
- Operates with static objects or other touches on the screen
- Exceptional optical characteristics
- Scalable for sizes above 32" diameter

Camera Based Touch Technology Overview (1/2)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Camera-based optical touch in which two or more CMOS infrared (IR) cameras are placed on top of a display, looking across the surface of the display in order to detect the presence of a touching object are typically characterized by a high degree of scalability, stylus independence, zero-force touch, high optical performance, object-size-recognition capability, and low cost.



Camera based touch sensors are found primarily in applications using large format displays. Since this technology has nearly unlimited scalability results in one of the best combinations of performance vs. cost.

It's the only touch technology that can do true object-recognition which enables integrating the physical world and the virtual (digital) world more closely which makes digital information more easily accessible when users interact with a physical object

Camera Based Touch Technology
How does it work? (2/2)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Most optical touch systems today use some form of backlighting. Typically light is emitted or reflected from the periphery of the display across the top surface. Cameras in two or more corners of the display look across the top surface; when an IR-opaque object such as a finger touches the surface of the display, it interrupts the light and creates a shadow that is seen by the cameras. Because the touching object can be anything that blocks IR, optical touch systems are stylus independent.

Key Features

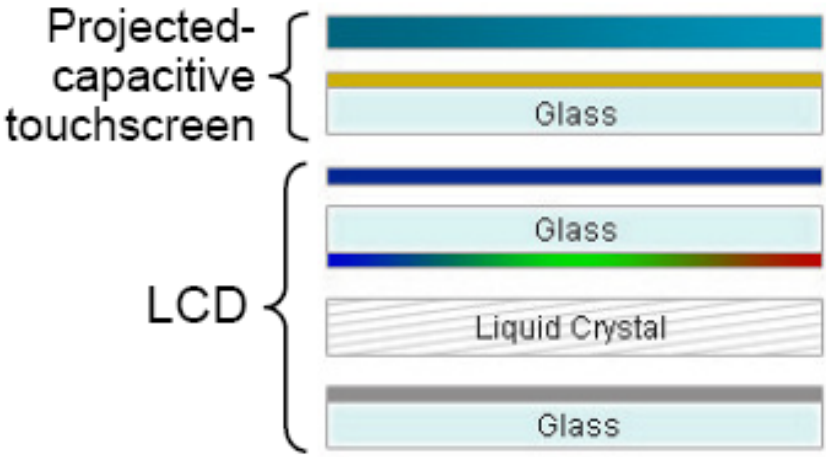
- High resolution / High accuracy
- 4 Touch Multi User
- Glass transparency
- High clarity and color fidelity
- Activated by any object; finger, glove, pen, stylus etc. – No Pressure required
- No calibration is required - Automatic Self Calibration
- Automatic Drift Correction
- No aging or temperature drift
- Long lifetime with high reliability
- Scratches do not effect performance
- Two simultaneous hand writing for white board applications

Physical Integration Methods

Physical Integration Methods (1/6)
Common Method (Outside LCD)

DISPLAY LOGIC
LCD Enhancements and Interfacing

- Standard touchscreen laminated directly on top of the LCD
  - Most common method for customers
  - Can be taped or optically bonded to LCD
  - Some LCD makers are offering Analog Resistive or Projected Capacitive Out Cell integration options at the factory during LCD manufacture



Typical LCD/PCap Stackup

Physical Integration Methods (2/6)
Common Method (Outside LCD)

DISPLAY LOGIC
LCD Enhancements and Interfacing

Integration Difficulty

Touch Technology	Outside LCD Integration Difficulties
Analog and Digital Resistive	None
Camera Based	Cameras and reflectors on top of LCD, Mounting Technique is critical
Infrared	PCB around entire screen, no cover glass required
Projected Capacitive	None however possible electrical interference from surrounding components
Surface Capacitive	Metal Frame can not contact touch screen and must be grounded
Surface Acoustic Wave	Reflectors and Transducers on touch sensor must be protected
Acoustic Pulse Recognition (ELO)	Mounting technique is critical
Dispersive Signal Technology (3M)	Mounting technique is critical

Physical Integration Methods (3/6)
"In Cell" / "On Cell"

DISPLAY LOGIC
LCD Enhancements and Interfacing

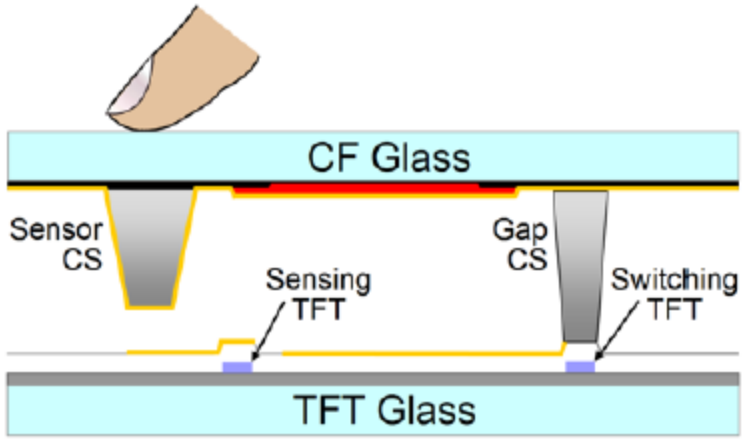
In Cell

Capacitive-sensing ITO electrodes added inside the LCD cell during assembly at the factory

Principle:

Pressing the LCD changes the dielectric constant of the liquid crystal, which changes the capacitance between the electrodes

- Requires touching the LCD surface (low durability)
- Works with finger or stylus; human body capacitance isn't a factor



Source: LG Display

Physical Integration Methods (4/6)
"In Cell" / "On Cell"

DISPLAY LOGIC
LCD Enhancements and Interfacing

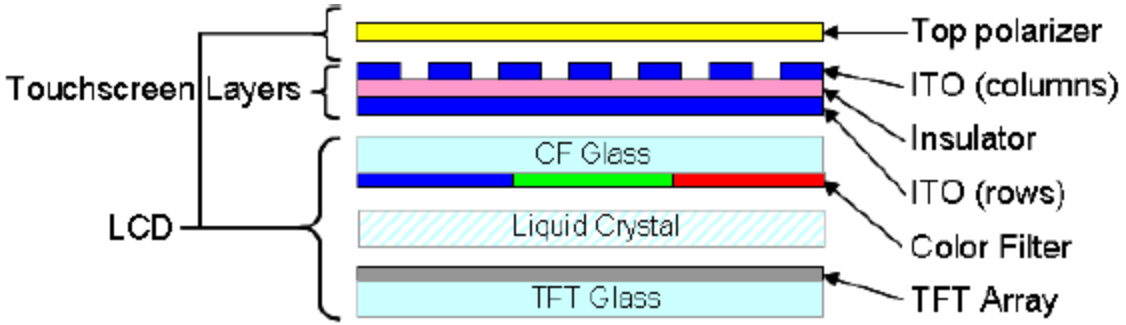
On Cell

Projected-capacitive X-Y electrode array added on top of the color filter glass, under the top polarizer, applied during LCD assembly at the factory

Principle:

Same as standard projected-capacitive

- Works only with finger; human body capacitance changes mutual capacitance between electrodes
- Cover-glass (0.5 mm) can be added on top of polarizer to protect LCD surface



Physical Integration Methods (5/6)
"In Cell" / "On Cell"

DISPLAY LOGIC
LCD Enhancements and Interfacing

Three Different Technologies for In Cell and On Cell Touch . All are only possible during LCD manufacture

- Light-sensing or "optical"
  - Addition of a photo-sensing element into some or all pixels
  - Works with finger, stylus, light-pen or laser pointer; also works as a scanner; cover glass is OK

- Voltage-sensing or "switch-sensing"
  - Addition of micro-switches for X & Y into some or all pixels
  - Works with finger or stylus, within damage limits of LCD
  - No cover-glass

- Charge-sensing or "capacitive-sensing"
  - Addition of electrodes in-cell or on-cell for capacitive sensing
  - In-cell = works with finger or stylus, within damage limits of LCD; no cover-glass
  - On-cell = works with finger-only; cover-glass is OK

Most focus

Physical Integration Methods (6/6)
"In Cell" / "On Cell"

DISPLAY LOGIC
LCD Enhancements and Interfacing

Possible Advantages of In Cell / On Cell

- Minimal or no added size, thickness or weight, so no effect on the end product's industrial design
- Unlimited multi-touch functionality (controller-dependent)
- Conceptually very high touch-performance
  - Low parallax error (assuming no cover-glass)
  - Very accurate and linear touch-point data (fixed pixel matrix)
  - Potentially higher resolution than the LCD through inter-pixel interpolation
- Much lower cost for the touch function, since changes in an LCD's manufacturing cost should be minimal

Summaries

Touch Sensor Technology Guide

DISPLAY LOGIC
LCD Enhancements and Interfacing

Touch Feature	4 Wire Resistive	5 Wire Resistive	7 Wire Resistive	8 Wire Resistive	Surface Capacitive	Projected Capacitive	SAW (Surface Acustic Wave)	IR (Infrared)	APR (Acustic Pulse Recognition - ELO)	DST (Dispersive Signal Technology - 3M)
Cost	Low	Low-Med	Low	Low	Low-Med	High	Medium	High	Med-High	Med-High
Light Transmisivity	75-85%	75-85%	75-85%	75-85%	85-93%	90-95%	90-95%	up to 100%	92%	92%
Number of Touches	1M	35-50M	10M	3-5M	50-100M	Unlimited	100M	Unlimited	50M+	50M+
Durability	Low	Medium	Medium	Medium	Med-High	High	Med-High	High	High	High
Bare Finger Activation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gloved Finger Activation	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Sealability	High	High	High	High	High	High	Low	Medium	High	High
Shock and Vibration	High	High	High	High	Modrate	High	High	High	Medium	Med-High
Chemical Resistance	Low	Low	Low	Low	Med-High	High	High	High	High	High
Scratch Resistance	Low	Low	Low	Low	Med-High	High	High	High	High	High
Stylus/Pen	Yes	Yes	Yes	Yes	Tether	Tether	Some	Yes	Yes	Yes
Signature	Yes	Yes	Yes	Yes	Tether	Tether	No	No	Yes	Yes
Calibration Stability	Low	Medium	High	High	Low-Med	High	Medium	High	High	High
Resistance to FOD	Medium	Medium	Medium	Medium	Medium	High	Low	Low	High	High
Muti-User	No	No	No	No	No	Yes	No	Yes	Yes	Yes
Gesture	*Yes	*Yes	*Yes	*Yes	No	Yes	Yes	Yes	No	No
Ease of Integration	High	High	High	High	Medium	Low-Med	Medium	Low-Med	Low	Low
Metal Bezel	High	High	High	High	Low	Low	High	High	High	High
Linearity	0.015	0.015	0.015	0.015	0.015	0.005	2mm	NoA	0.01	0.01

There is no perfect Touch Technology

DISPLAY LOGIC
LCD Enhancements and Interfacing

Technology	Major Advantage	Major Flaw
Analog Resistive	Low cost	Low durability
Digital Resistive	Multi-touch	Low durability
Surface Capacitive	Touch sensitivity	High drift
Projected Capacitive	Multi-touch	Finger-only
Surface Acoustic Wave	Durability	Soft touch object
Traditional Infrared	Reliability	High cost
Waveguide Infrared	Low cost	Contamination
Optical	Scalability	Profile height
Acoustic Pulse Recognition	Any touch-object	No touch & hold
Dispersive Signal Technology	Any touch-object	No touch & hold
Force Sensing	3D substrate	Vibration sensitivity
Vision-Based	Multi-touch	Projection only
LCD In-Cell (Light-Sensing)	Integration	Sensitivity
LCD In-Cell (Voltage-Sensing)	Integration	Durability
LCD In-Cell (Charge-Sensing)	Integration	Durability
LCD On-Cell (Charge-Sensing)	Integration	Finger-only

Acknowledgements

- LCD In-Cell Touch , Geoff Walker –NextWindow, March, 2010
- Information Display 3/10, Projected-Capacitive Touch Technology, Gary Barrett and Ryomei Omote, March 2010
- Information Display 3/10, Camera-Based Optical Touch Technology, Geoff Walker, March 2011
- New Developments In Touch Technologies, Geoff Walker –NextWindow, FPD China Conference March 17, 2011
- Whitepaper: Projected Capacitive Touch Technology, Tony Gray, Principal Engineer & Larry Mozdzyn, CTO, Ocular LCD, Inc.

CONTACT US

DISPLAY LOGIC
LCD Enhancements and Interfacing

Display Logic is located in the heart of Long Island, in New York. We are approximately one hour east of major NY airports, within 20 minutes of Long Island MacArthur Airport and easily accessible from the Long Island Expressway, Exit 55.

Address: 40 Oser Ave | Suite 3
Hauppauge, NY 11788

Telephone: 631.406.1922

Web-Site: www.displaylogic.com

Email: sales@displaylogic.com

Sales and Marketing Inquires:
Andrew Blum
andrew.blum@displaylogic.com
516.983.0266 (C)