



Projected Capacitive Touch Screens

Gary L. Barrett, *Chief Technical Officer at Touch International*

Ryomei Omote, *General Manager at Nissha Printing*

Published in the Information Display Magazine,
Official Monthly Publication of the Society for Information Display

Introduction

The advent of the iPhone has ushered in a seismic change in the touch screen business. The technology, called projected capacitive touch, is the first choice for most touch products now in development. The technology is not just Apple-trendy but incorporates the best of the competing touch technologies.

There are several benefits to using projected capacitive technology but the four most important are:

1. Long Life
2. Excellent Optical Properties
3. Multi-Touch
4. Ease of Integration

In addition, the projected capacitive touch screens are scanned, eliminating coordinate drift and the need calibrate it to the display.

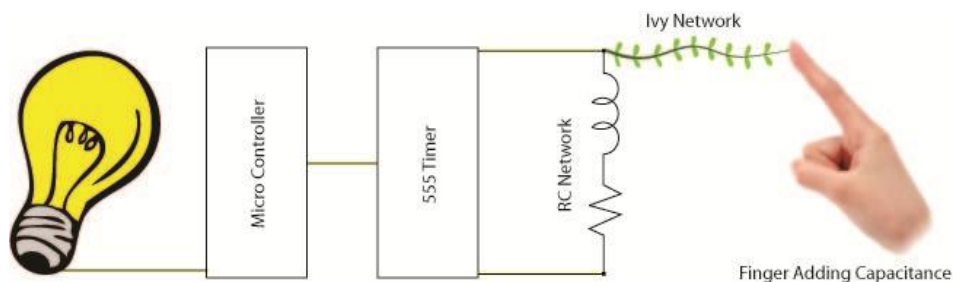
Projected capacitive touch screens can be made entirely of plastic, allowing them to be virtually unbreakable and have the flexibility to be contoured or bent. The touch screens are sensitive to cotton or surgical gloves and when the sensing range extended, proximity sensing can be built into the product. These rugged touch screens are immune to most chemicals due to it's typically glass first surface, can operate in extreme temperatures and can be sealed to meet the requirements for most wash-down and explosive environments. In all, when compared to the price of resistive and surface capacitive touch systems, projected capacitive technology is relatively inexpensive.

There are currently only two drawbacks to most projected capacitive solutions. The most important is that the touch screens are not pressure sensitive, so they will not react to any input device other than a finger or specially designed probe. The second is that touch screens larger than twenty-four inches (diagonal) are difficult to build.

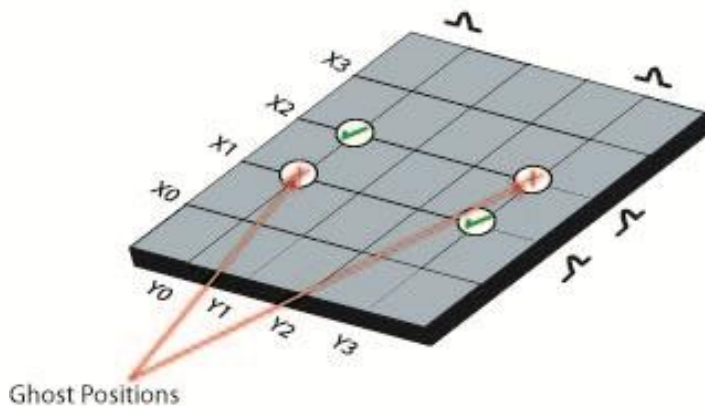
How Capacitance Works

Capacitive sensing is a very old technology. For example, earlier generations may remember the novel room lamps that would turn on by touching a growing plant and everyone has used capacitive elevator buttons at least once in their life. These primitive applications used a solid-state timer (usually a 555 chip) which “clicked” at a steady rate as determined by an external resistor/capacitor (RC) circuit. A microcontroller was then programmed to monitor the clicks from the timer and when the rate increased or decreased, it would react. A wire (or piece of ivy, in the case of the novel lamp) was routed to a touch point and when a human touched it, additional body capacitance was added to the RC circuit which, in turn, altered the click rate. Voila, a touch was detected. This type of projected capacitive is often called self-capacitance.

Self-Capacitance Circuit



Below is an example showing how self capacitance technology is implemented on a touch screen:

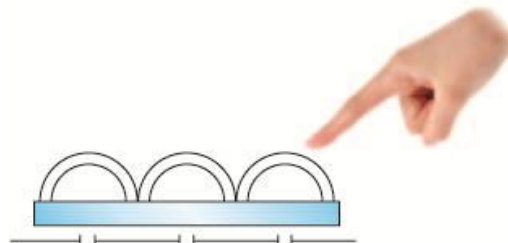


Result	
X3 & X0	0
X2 & X1	1
Y0 & Y3	1
Y1 & Y2	0
Conclusion	
X2, Y0	1
X2, Y3	1
X1, Y1	1
X1, Y3	1

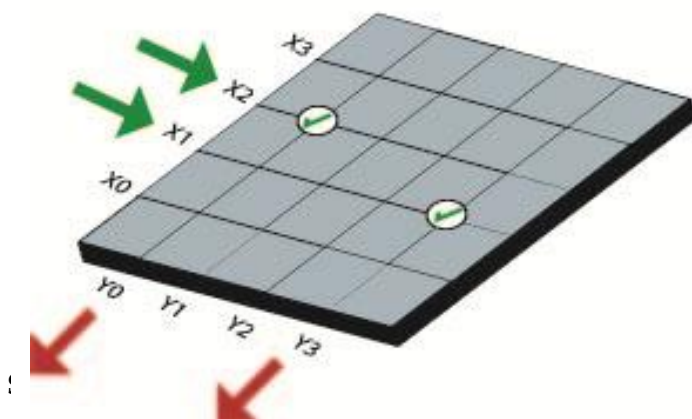
4 + 4 = 8 Touch Screens

Mutual Capacitance Design

Mutual Capacitance is now becoming the more common projected capacitive approach. Mutual capacitance makes use of the fact that most conductive objects are able to hold a charge if they are very close together. If another conductive object, in this case a finger, bridges the gap, the charge field is interrupted and detected by the microcontroller. Mutual capacitance, compared to self-capacitance systems, makes it easier to identify specific points and thus meet the five-finger or all points addressable need.



Below is an example showing how mutual capacitance technology is implemented on a touch screen:



Result	
X2 * Y1	1
X1 * Y3	1
Conclusion	
X2, Y0	1
X1, Y3	1

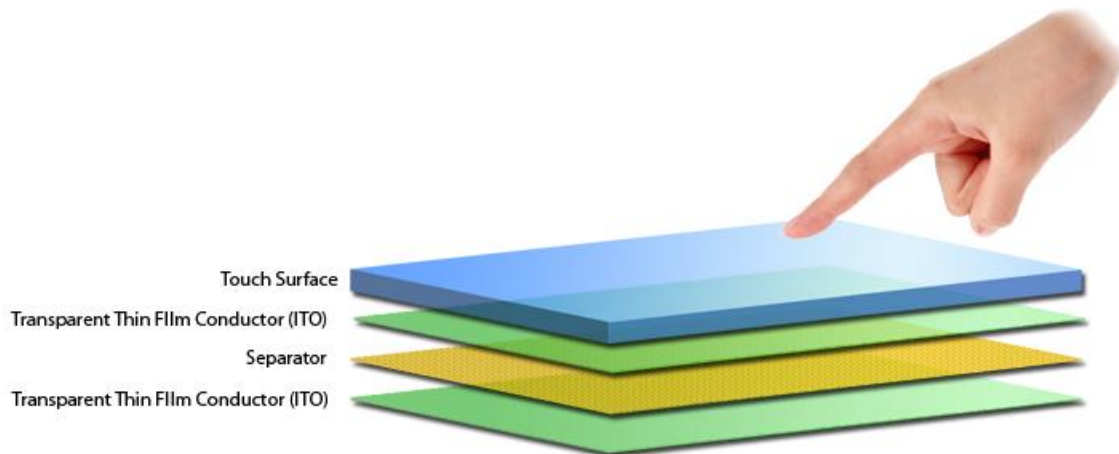
4 * 4 = 16 Touch Screens

Projected Capacitive touch screens are “scanned”, meaning most of these touch screens are made up of a matrix of rows and columns that are “read” one by one to get a reading or count. To get an exact coordinate, the results from several row/column intersections are read and the counts used to triangulate the exact touch location. The results are extremely precise and the resolution is usually 1024 by 1024 (ten bit).

Scanning also has an advantage of being free of coordinate drift. This is possible because the rows and columns are physically fixed and each measurement is made in a small area. Without the issue of coordinate drift, projected capacitive touch screens do not have to be calibrated by the end-user as long as the touch screen is mounted on the same place on the display. Typically, the only “error” that occurs happens if the user draws very slowly across the screen, in which case a tiny amount of stair stepping will be noted.

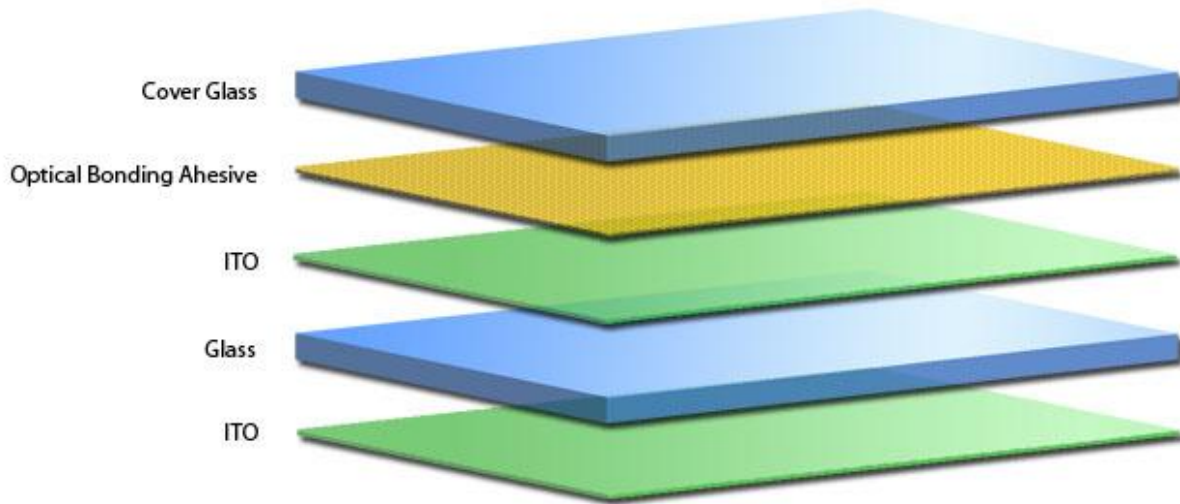
Touch Panel Construction

In the short time since the introduction of projected capacitive touch screens in iPhones, a myriad of construction methods have been developed. All projected capacitive designs have two key features in common - the sensing mechanism that lies behind the touch surface and the use of no moving parts. The most common design incorporates the simple concept shown below.

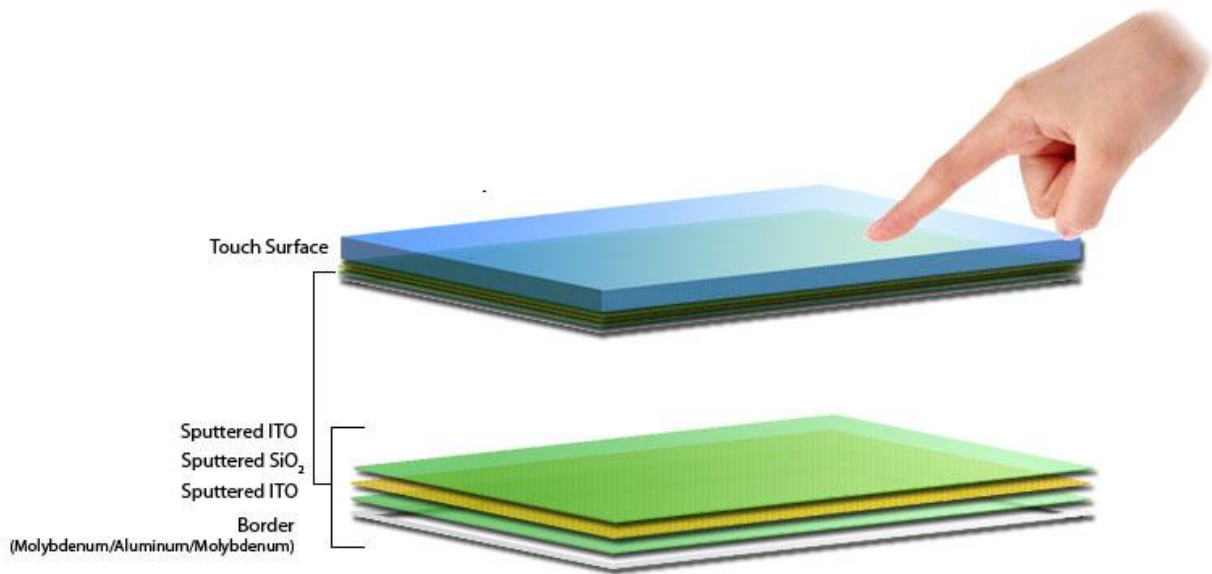


In many applications, especially portable devices, the construction is similar to that of the iPhone:

- **Cover Glass**
Chemically strengthened with holes and slots cut into it, either 0.75mm or 1.1mm thick.
- **Optical Bonding Adhesive**
- **Indium Tin Oxide (ITO)**
Deposited onto the top side of a piece of glass, with molybdenum/aluminum/molybdenum signal lines at the edge.
- **Glass**
0.55mm or 0.75mm
- **Indium Tin Oxide (ITO)**
Deposited onto bottom side of glass, with molybdenum/aluminum/molybdenum signal lines at the edge.



Single layer design is a newer construction, which achieves the thinnest possible projected capacitive touch screen. The trick to this design, is that all of the layers are deposited by sputtering.



There are innumerable variations on the basic design of single layer projected capacitive. For instance, one can substitute thin wires for the sputtered ITO. Most of the credit card/signature processing terminals use ITO on PET for each of the layers. Also common are touch screens that use two one-sided ITO coated layers of glass.

Cover Glass and Touch Surface

Smaller, typically mobile, touch screen designs use a cover glass (or lens as it is sometimes) called that is bonded to the touch screen. This allows product designers to make the touch screen flush with the surface of the device. The cover layer is usually decorated with ink on the rear surface. The ink hides the touch panel circuitry, incorporates a logo, can have ruby coatings for the camera and can act as a diffuser for backlights.

The cover glass is typically 0.55mm, 0.75mm or 1.1mm thick for mobile devices and up to 3mm for kiosk applications. The dielectric strength of the cover glass and the thickness has a direct bearing on the sensitivity of the projected capacitive touch panel – the thinner the cover glass and the higher the dielectric constant, the better the performance. Plastic (PMMA) can be used in place of glass, however it has a lower dielectric constant and must be half the thickness of glass to achieve the same performance.

Since the cover glass is usually very thin, some designers choose to chemically strengthen it to reduce the chance of breaking. Float glass or soda-lime and alumina silicate are the most commonly used types of glass. If float glass has a breakage value of 1 and will be half as likely to break if it is chemically strengthened. Alumina silicate, if chemically strengthened, it will be less than one-third as likely to break.

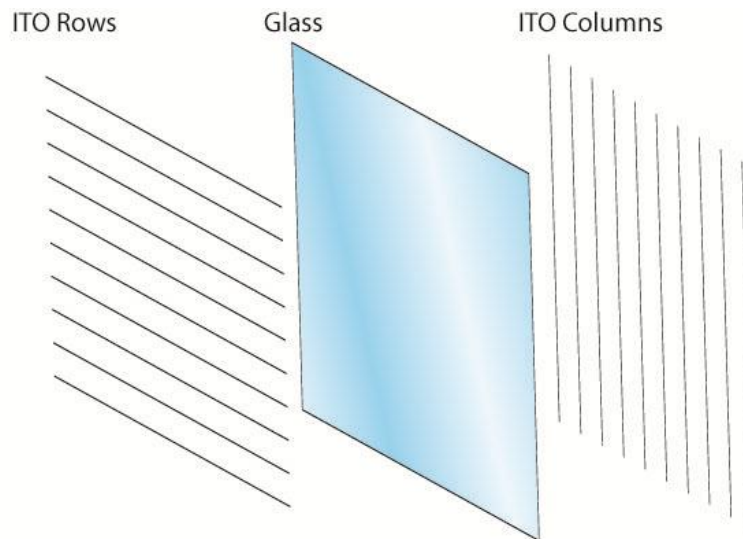
Some cover glass designs have become extremely complex with multiple holes and slots, rounded corners and even bent edges. Any of these processes must be done before the glass is chemically strengthened.

Touch Screen Conductor Patterns

ITO can be etched in several different patterns, all of which cost the same to manufacture, and it is difficult to say that one pattern out-performs another since touch screen and electronics together affect the results.

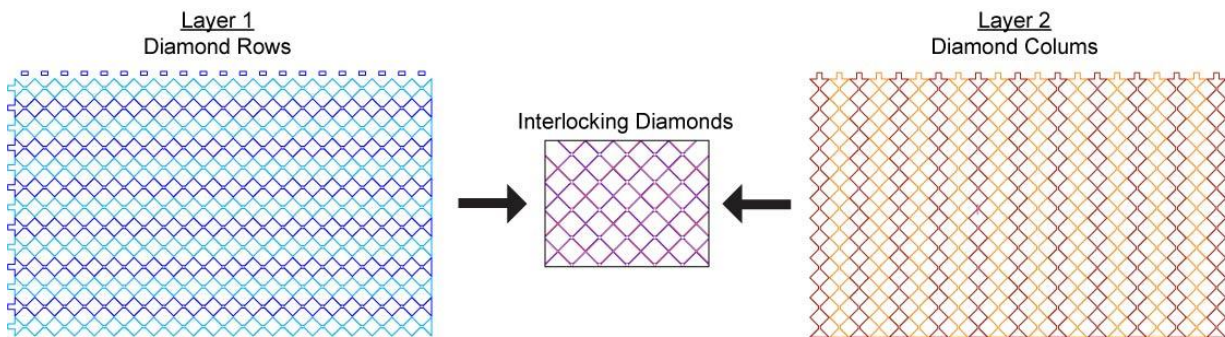
iPhone Pattern

The iPhone pattern is the simplest pattern, consisting of tiny (50 micron) rows of ITO on one side of the glass and columns on the other side. This design works well but the geometry requires substantial processing power to generate an accurate coordinate.



Diamond Pattern

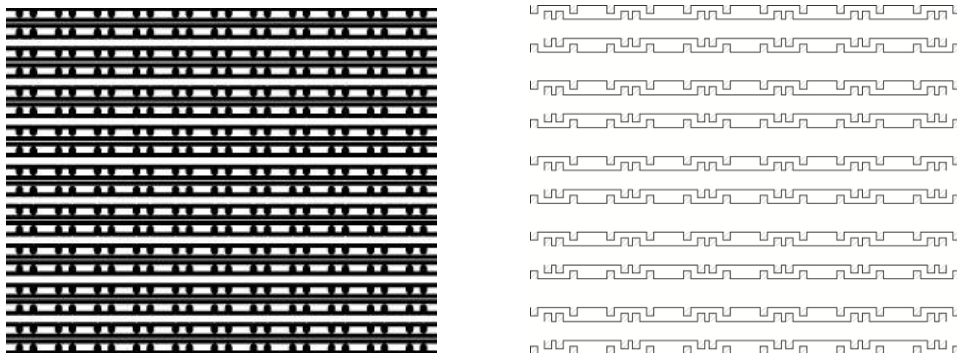
The most common pattern is an interlocking diamond that consists of squares on a forty-five degree axis, connected at two corners via a small bridge. This pattern is applied in two layers – one layer of horizontal diamond rows and one layer of vertical diamond columns. Each layer adheres to the inner side of two pieces of glass which are then combined together, interlocking the diamond rows and columns. The diamond size varies by manufacturer but is in the range of 4mm to 8mm; almost all electronic controllers work with the diamond pattern.



Complicated Patterns

Some electronic controllers use complicated ITO patterns that sometimes require a license fee from the electronics manufacturer. In other instances, the electronics vendor may provide simulation tools for developer to use as a model of the touch screens performance with the pattern. Some of the complicated patterns are cannot be used with a single-layer design.

Example of Complicated Patterns



Other Patterns

Patterns can take on other forms, such as simple buttons and imbedded zones which have been used for a long time. One manufacturer, for example, uses “wavy wires” instead of etched ITO and spaced apart grids are used some pen-entry systems.

Border Area

One of the most important cost drivers in touch screen design is the border area. Unlike traditional analog touch screens which have four or five signal lines, projected capacitive touch screens often have forty or more connections; this is due to each row and column needing at least one connection requiring the border to extend past the active area of the touch screen. Historically, signal lines have been silk-screen printed 1mm wide with a 1mm gap using silver inks.

If the design requires a narrow border, a technique similar to that utilized for TFT LCDs is used. This technique adds multiple layers of thin films to the touch screen because it requires the touch screen to be sputtered and etched again which, of course, adds additional cost.

Fine line silver printing, 50 to 100 micron lines and gaps, achieves a lower cost than the sputtering technique. However, Polyamide tails remains the most common method which requires the material to hang off the edge and is also expensive.

Costs can be reduced substantially if your device does not require flush mounting and can allow for a larger area under the bezel.

Electronic Designs

Currently, there are seventeen companies selling projected capacitive controller chips; several of which offer both self-capacitance (two-finger) and mutual-capacitance (multi-finger) capabilities. Multi-capacitance or all-points-addressable is fast becoming a standard.

The projected capacitive solutions include dedicated controllers that are specific to size and row-column configuration to fully programmable micro-controllers with built-in circuitry.

Controller Firmware

Traditionally, touch controllers have generally generated only one X and Y coordinate. With projected capacitive, the controllers must now be capable of generating at least two points (two X and Y coordinate pairs) and often up to ten points. Until recently, the output format has varied, however, Microsoft® has now established a standard to which most electronic controllers are expected to meet.

Ghosting

Initially, projected capacitive controllers used self-capacitance technology which generated coordinates for each touch. However, when two fingers were present and they were oriented diagonally, the controller could detect two touches but could not detect on which diagonal - of a rectangle formed by the two points - the fingers positioned. This ambiguity is called "ghosting".

In the first generation of the iPhone, the "pinching" and "expanding" gestures did not require information on which diagonal the fingers rested. The only information needed was which image was being touched and what gesture the fingers were portraying.

All Points Addressable

All Points Addressable, also known as "True Multi-Touch", provides the exact coordinates of each finger touching the screen. Different controller suppliers generally allow from five to ten fingers on the screen at the same time and will provide X and Y coordinates for each. Most commonly, these systems are mutual-capacitance systems.

Cheek Check and Z-axis

Most controllers are capable of sending a message indicating when a large number of locations are being activated at the same time. On stand-alone devices, attribute is customarily used to determine the phone is next to the face or the device has been put away in a pocket – signaling that the touches to the screen should be ignored.

Another attribute of projected capacitive technology is that the touch screen does not actually need to be touched to be activated. The touch screen's level of sensitivity can be controlled by the electronics. In most cases, the designer will require a physical touch to activate a coordinate. However, the sensitivity can be increased, adding what is sometimes called a Z-axis or Z-coordinate, so that the simple placement of a hand near the touch screen can be detected.

Microsoft®

Most projected capacitive electronics are compatible with the Windows 7® tablet and will run directly through the USB port. This is true even for electronics with ghosting (self- capacitance). Microsoft® has a standard which includes a number of points per second and minimum number of coordinate pairs that not all projected capacitive electronics meet.

Projected Capacitive Suppliers

The companies below have supplied in excess of one million projected capacitive products.

Electronics	Touch screens	Systems
3M TouchSystems	CEC Nanjing Wally	EloTouchSystems
Atmel	Digitech	N-trig
Broadcom	DMC	Synaptics
Cirque	EELY	Wacom
Cypress	Gunze	Zytronics
EETI	J-touch	
Elan	Nissha	
MicroChip	Touch International	
Pixcir	TPK	
Touch International	Wintec	
Synaptics	YoungFast	