Making A Product People Want – Inspired Concepts in Capacitive Touchscreens

By Steve Kolokowsky, Elect Design Engrg Sr MTS and Trevor Davis, Marketing Director, Cypress Semiconductor Corp.

Touchscreen technology has existed for quite a while. Why did it take the iPhone to set the mobile world on fire for touchscreens? The key is in technology inflections. With the market shift from resistive to capacitive touchscreens, the invention of "gesture" motions, and the crystal clear, solid feel of glass screens, touchscreens have once again caught the attention of the worldwide electronics buyer.

According to a report from iSupply, nearly 400 million touch-screen handsets are expected to ship in 2012. The technology has been in use in other devices like PDAs for years and had its first major introduction in the United States by Taiwan's HTC, which began selling its HTC Touch in June 2007, just before the iPhone was introduced. But let's not be mistaken, it was the introduction of the iPhone that has ignited the touchscreen craze in consumer electronics. Interestingly, the key to the iPhone's success was very creative use and introduction of four key technology advantages: Capacitive vs. resistive touchscreen, glass vs. plastic coverlens, "edgeless" industrial design, and gesture-based navigation. Every one of these features was enabled (and will continue to be advanced) because of the technology behind the capacitive touchscreen.

"Out" with Resistive and "In" with Projected Capacitive

Perhaps the single most significant technology inflection was the shift from resistive to capacitive touchscreens. iSupply forecasts that nearly 25% of the mobile handsets with touchscreens will have shifted from resistive to capacitive screens by 2011. In years past, PDA touchscreens had encouraged the use of a stylus for navigation and employed a resistive touch technology. A resistive touchscreen consists of a flexible top layer, then a layer of ITO (Indium-Tin-Oxide – a conductive, clear metal oxide layer), an air gap and then another layer of ITO. The panel has 4 wires attached to the ITO layers: one on the left and right sides of the 'X' layer, and one on the top and bottom sides of the 'Y' layer.

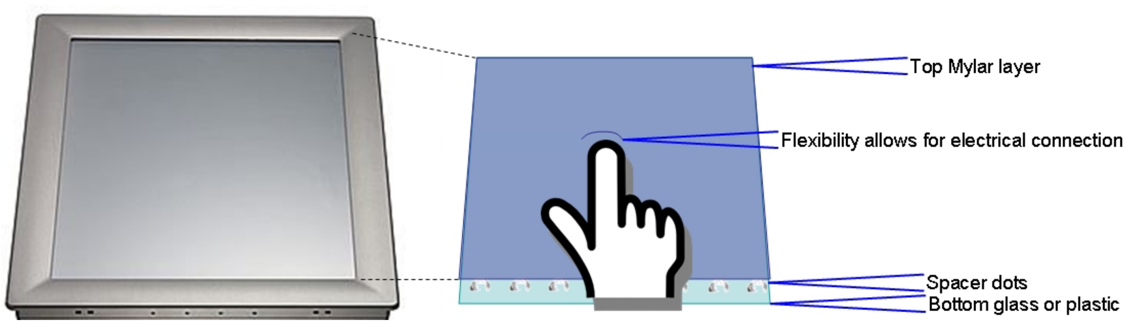

FIGURE 1: Resistive Panel with flexible upper layer is being absorbed by Projected Capacitive

In a resistive panel, a touch is detected when the flexible top layer is pressed down to contact the lower layer. The location of a touch is measured in two steps: First, the 'X right' is driven to a known voltage, and the 'X left' is driven to ground and the voltage is read from a Y sensor. This provides the X coordinate. This process is repeated for the other axis to determine the exact touch position.

There are many well-known problems with resistive systems:

1) The topmost layer is flexible and feels "squishy" to the touch.
2) The flexible top layer scratches easily, especially if a stylus is used.
3) Resistive panels tend to lose sensitivity over time because of the wear of the flexible upper layer and spacer dots
4) The average clarity of a resistive panel is 75% while a projected capacitive panel is ~90% transmissive.
5) Resistive touchscreens require periodic calibration to align detected finger position to on-screen icons.

Projected capacitance screens, conversely, have no moving parts. The only thing between the LCD and the user is ITO and glass, which have near 100% optical clarity. The projected capacitance sensing hardware consists of a glass top layer, followed by an array of X sensors, an insulating layer, then an array of Y sensors on a glass substrate. Some sensor suppliers create a single-layer sensor that includes both X and Y sensors in a single layer of ITO with small bridges where they cross.

This all-glass touch surface gives the user a solid, smooth feel across the entire screen. Glass screens are preferred by customers because glass gives the end product a smooth industrial design, and provides a good capacitive signal for measuring touch.

Glass – Clear is Sexy

Aside from its clear industrial design advantages (pun intended), glass is a superior technology choice for use in touchscreens because of its inherent electrical properties. What most people don't fully comprehend is that a touchscreen is actually measuring an electrical charge from the user's finger. In fact, the user changing the capacitance of the system in such a way that the touchscreen controller can measure the touch.

Glass has, from the advent of electricity, been known and used as an insulator, also called a *dielectric*, which is a material that resists the flow of electric current. Very often glass has been used to discourage the flow of electricity. However, when used in a capacitive circuit for touchscreens, the use of glass can be quite an advantage.

Specifically, in a parallel-plate capacitor, the circuit is composed of two conductive surfaces with an insulator (glass) between them. The ITO layer is a conductor, a user's body is a conductor, and the glass is an insulator. When a user touches the screen, they've actually become part of a capacitor. The touchscreen controller measures this change in capacitance to detect the presense and location of the touch.

The system's "capacitance" is proportional to the area (A) of one of the plates and inversely proportional to the separation between the plates (d). This relationship is described by: C = □

A / d where □ is the permittivity of the insulating material (or dielectric) between the plates. In a capacitive touchscreen, one plate is the ITO sensor, the other "plate" is your finger!

Glass and acrylic (plastic) covers are both used today. Glass has significant sensing advantages over plastic. Glass has a dielectric constant of 6, while Plexiglas has a dielectric constant of 3. For comparison, air's dielectric constant is 1. Assuming equal thicknesses, a glass cover will provide double the signal strength compared to an acrylic cover. A stronger signal allows greater sensing accuracy and better tolerance to LCD noise.

Glass has other advantages: it is more scratch-resistant than plastic, it has a consistent surface upon which to deposit ITO, and it can be heated to very high temperatures. This allows ITO to be deposited very uniformly which gives consistent electrical performance. High temperature is important because ITO changes from a yellowish hue to clear when baked at high temperatures.

In addition to physical changes to the touchscreen, the technology of the touchscreen also ushered in a new wave of software interaction on mobile devices.

Innovations in User Experience (UX) – The Gesture Revolution

Perhaps the most significant User Experience or "UX" change that was made has been the move from the menu-based touch products of the past to the finger-navigation based on icons and graphics. Previously, the touchscreen relied on a stylus. Today, however, capacitive touchscreens can accurately predict finger center to 0.5mm. With this level of accuracy, a stylus is no longer needed and completely new interface techniques can be developed.

One of the most significant steps beyond icon-based navigation was the invention of the "gesture". Today, gestures are known simply as a "swipe", "pan", "pinch" or "zoom", and others. These are simply ways to take a combination of finger activity on a touchscreen and to convert them into meaningful, organic, movement on the screen. Until the implementation of capacitive touchscreens, however, gestures were not possible due to the slow response time of other designs. Projected capacitance touchscreens combine high resolution with high-speed sensing. This powerful combination opens up new User Experience possibilities.

Figure 2. User Interface revolutionized by "Gestures" enabled by X/Y tracking and multi-touch

Once people become used to gestures, they will demand more. The exciting thing about gestures is that they don't have to be related to the current application. Imagine adjusting the volume of your music player player while you're in another application. So far, gestures have replaced the scroll wheel on your mouse by adding scroll and zoom functions. The next step will be "always on" global gestures that work like the multimedia keys on your laptop. One gesture immediately opens your phone application, another moves to the next song in your playlist.

The next generation of touch devices will be enabled through the capability of "multitouch" or "All Points". This is the ability to recognize an unlimited number of touches on a screen. Being able to determine exactly where each touch occurs allows for intelligent design of algorithms that can reject false finger touches (fingers wrapped around a phone), complicated gestures (three or four finger gestures for unique features), palm rejection (phone "on" and "off" on pickup), and so on. In fact, new innovations in the touchscreen ecosystem will continue to enable the market.

Innovations on the Way – New Touchscreen Capability

Windows 7 is set to be released this fall with more gesture-recognition built directly into the operating system. Windows Mobile 7 is reportedly not too far behind. It is expected that more PC makers are planning to take advantage of the new touch capabilities in Windows 7. While touch-screen PC products are not yet wildly popular, there haven't been many consumer-friendly touchscreen notebooks yet, and the draw for software applications employing touch has been low. But that will change soon. Recently Sony said it plans to release a touchscreen Vaio notebook this fall, and Hewlett-Packard and Asus have already released products earlier this year.

Last year, according to IDC, just 1 percent of the notebook market, or 1.4 million units, were touch-screen notebooks. With the wave of new Netbooks (screens ~10") coming to market, it is expected that this level of penetration of touchscreens will change. One of the key contributors will be changes in price for larger screen projected capacitance products. As the ecosystem of touch software continues to build, so will consumer demand for other advanced features.

Significant capabilities for capacitive touch will continue to be developed in the areas of water rejection, using a passive (or untethered or non-powered) stylus, handwriting and Kanji recognition, and hover or near-touch capabilities (growing a button or icon before it is depressed).

So while the world marvels at the success of the iPhone and other new touch-based competitive products, there are few people who really understand the technology behind the success. Without advancements in touchscreen technology, today's successful touch-based phones would likely be yet another modestly successful stylus-based resistive touch phone. Instead, with of the conversion from resistive to capacitive touchscreens, the invention of "gesture" motions, and the crystal clear, solid feel of glass screens, touchscreens have set the consumer marketplace on fire for touch – will your next product take advantage of this movement?

Cypress Semiconductor
198 Champion Court
San Jose, CA 95134-1709
Phone: 408-943-2600
Fax: 408-943-4730
http://www.cypress.com