Touchscreen basics: Technology, design

By Steve Kolokowsky
Technical Staff

Trevor Davis
Director of Marketing

Consumer and Computation Division
Cypress Semiconductor Corp.

Touchscreens (sometimes spelled as touch screen) are everywhere: they are embedded in phones, office equipment, speakers, digital photo frames, TV control buttons, remote controls, GPS systems, automotive keyless entry, and medical monitoring equipment. As a component, they have reached into every industry, every product type, every size, and every application at every price point. In fact, if a product has an LCD or buttons, a designer somewhere is probably evaluating how that product, too, can implement touchscreen technology. As with any technology, there are many different ways to implementation approaches, many promises of performance, and many different technical considerations when designing a touchscreen.

Anatomy of touchscreen

Knowing what you need is an important first step in designing a touchscreen product. Vendors in the touchscreen supply chain frequently offer different pieces of the puzzle, often times combining several to create a value chain for the end customer. Figure 1 shows a blowup of the touchscreen ecosystem. This ecosystem is the same whether it is in the latest Notebook PC or the latest touch-enabled mobile phone.

There are six key elements:

1. *Front panel or bezel*—The front panel or bezel is the outermost skin of the end product. In some products, this bezel will encompass a protective clear overlay to keep weather and moisture out of the system, and to resist scratching and vandalism to the underlying sensor technology (see item 3 below). Other times, the outmost bezel simply covers the edges of the underlying touch sensor; in this case, it is purely decorative.
2. *Touch controller*—The touch-controller is generally a small microcontroller-based IC that sits between the touch sensor and the embedded system controller. This IC can either be located on a controller board inside the system or it can be located on a flexible printed circuit (FPC) affixed to the glass touch sensor. This touch controller takes information from the touch sensor and translates it into information that the PC or embedded system controller can understand.
3. *Touch sensor*—A touchscreen "sensor" is a clear glass panel with a touch-responsive surface. This sensor is placed over an LCD so that the touch area of the panel covers the viewable area of the video screen. There are many different touch-sensor technologies on the market today, each using a different method to detect touch input. Fundamentally, these technologies all use an electrical current running through the panel that, when touched, causes a voltage or signal change. This voltage change is sensed by the touch controller to determine the location of the touch on the screen.
4. *Liquid crystal display*—Most touchscreen systems work over traditional LCDs. LCDs for a touch-enabled product should be chosen for the same reasons they would in a traditional system: resolution, clarity, refresh speed, and cost. One major consideration for a touchscreen, however, is the level of electrical emission. Because the technology in the touch sensor is based on small electrical changes when the panel is touched, an LCD that emits a lot of electrical noise can be difficult to design around. Touch sensor vendors should be consulted before choosing an LCD for a touchscreen system.
5. *System software*—Touchscreen driver software can be either shipped from the factory (within the embedded OS of a cell phone) or offered as add-on software (like adding a touchscreen to a traditional PC). This software allows the touchscreen and system controller to work together and tells the product's operating system how to interpret the touch-event information that is sent from the controller. In a PC-style application, most touchscreen drivers work like a PC mouse. This makes touching the screen similar to clicking the mouse at the same location on the screen. In embedded systems, the embedded controller driver must compare the information presented on the screen to the location of the received touch.

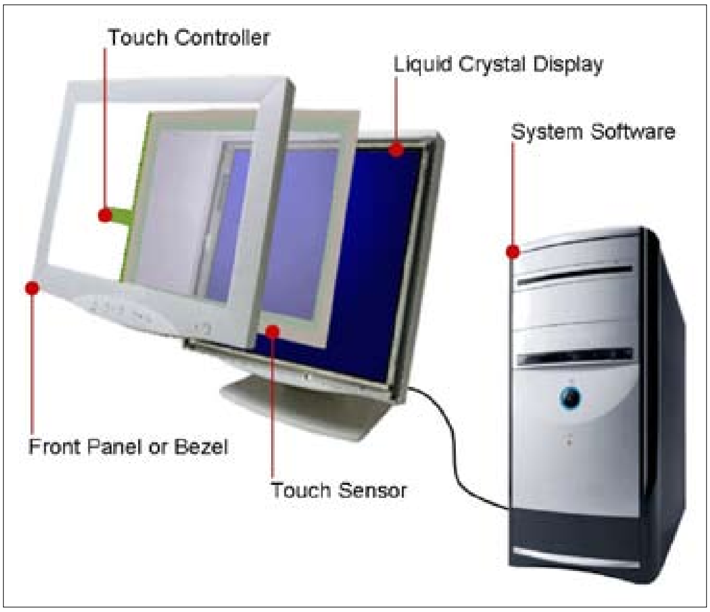

Figure 1: Touchscreen contoller "autopsy".

The "big three"

- Resistive touchscreens are the most common touchscreen technology. They are used in high-traffic applications and are immune to water or other debris on the screen. Resistive touchscreens are usually the lowest-cost touchscreen implementation. Because they react to pressure, they can be activated by a finger, gloved hand, stylus, or other object, such as a credit card.
- Surface-capacitive touchscreens provide a much clearer display than the plastic cover typically used in a resistive touchscreen. In a surface-capacitive display,

sensors in the four corners of the display detect capacitance changes due to touch. These touchscreens can only be activated by a finger or other conductive object.
- Projected-capacitive touchscreens are the latest entry to the market. This technology also offers superior optical clarity, but it has significant advantages over surface-capacitive screens. Projected capacitive sensors require no positional calibration and provide much higher positional accuracy. Projected-capacitive touchscreens are also very exciting because they can detect multiple touches simultaneously.

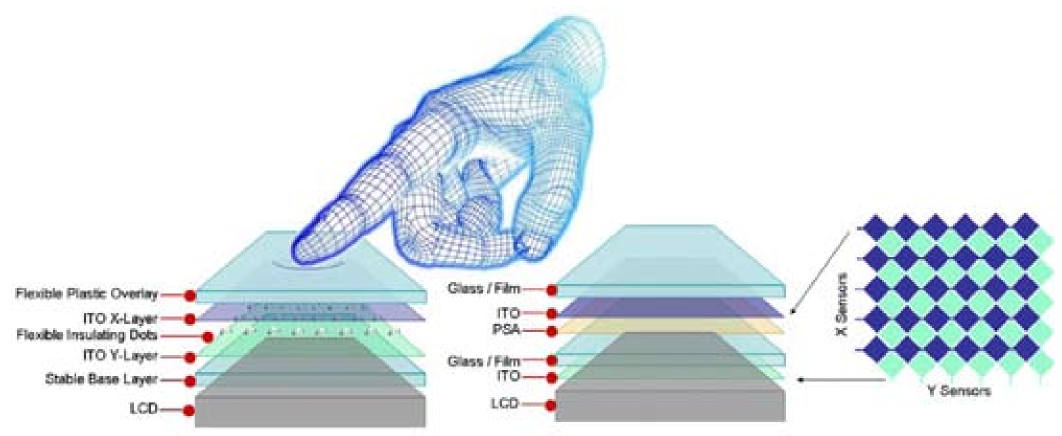

Figure 2: Stackup layers for "resistive" (left) and "capacitive" (right) screen.

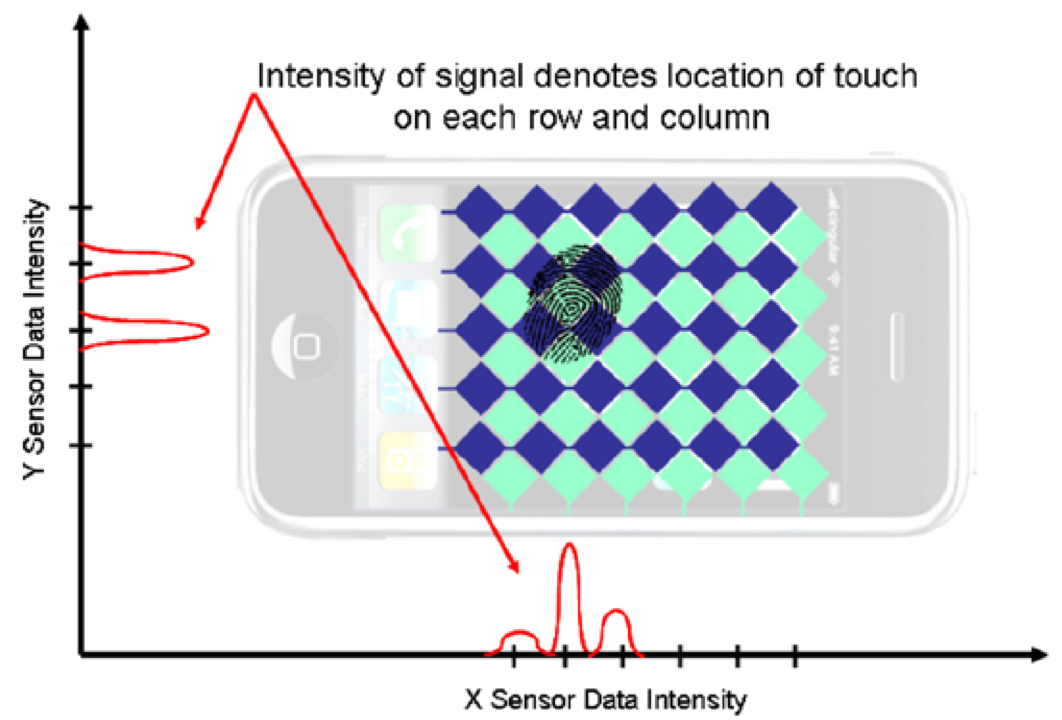

Figure 3: Signal intensity at rows and columns denote location of touch.

How touchscreens work

Let's look inside the two most common touchscreen technologies.

The most widely used touchscreen technology is resistive. Most people have used one of these resistive touchscreens already, in the ATM at the bank, in the credit card checkout in most stores, or even for entering an order in a restaurant. Projective-capacitance touchscreens, on the other hand, are not as broadly available yet, but are gaining market momentum. Many cellphones and portable music players are beginning to come to market with projective-capacitance interfaces. Both resistive and capacitive technologies have a strong electrical component, both use ITO (Indium-Tin-Oxide, a clear conductor), and both will be around for a long time to come.

A resistive touchscreen (Figure 2, left side) consists of a flexible top layer, then a layer of Indium-Tin-Oxide (ITO), an air gap and then another layer of ITO. The panel has four 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.

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 finger position.

Resistive touchscreens also come in 5-wire, and 8-wire versions. The 5-wire version replaces the top ITO layer with a low-resistance "conductive layer" that provides better durability. The 8-wire panel was developed to enable higher resolution by enabling better calibration of the panel's characteristics.

There are several drawbacks to resistive technology. The flexible top layer has only 75%-80% clarity and the resistive touchscreen measurement process has several error sources. If the ITO layers are not uniform, the resistance will not vary linearly across the sensor. Measuring voltage to 10- or 12-bit precision is required, which is difficult in many environments. Many of the existing resistive touchscreens also require periodic calibration to realign the touch points with the underlying LCD image.

Conversely, projected-capacitive touchscreens 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 (Figure 2, right side), followed by an array of X sensors, an insulating layer, then an array of Y sensors on a glass substrate. The panel will have a wire for each X and Y sensor, so a 5 x 6 panel will have 11 connections (Figure 3), while a 10 x 14 panel will have 24 sensor connections.

As a finger or other conductive object approaches the screen, it creates a capacitor between the sensors and the finger. This capacitor is small relative to the others in the system (about 0.5 pF out of 20 pF), but it is readily measured. One common measuring technique known as Capacitive Sensing using a Sigma-Delta Modulator (CSD) involves rapidly charging the capacitor and measuring the discharge time through a bleed resistor.

A projected capacitive sensor array is designed so that a finger will interact with more than one X sensor and more than one Y sensor at a time (Figure 3). This enables software to accurately determine finger position to a very fine degree through interpolation. For example, if sensors 1, 2 and 3 see signals of 3, 10, and 7, the center of the finger is at:

$[(1 \times 3) + (2 \times 10) + (7 \times 3)]/(3 + 10 + 7) = 2.2$

Since projected-capacitive panels have multiple sensors, they can detect multiple fingers simultaneously, which is impossible with other technologies. In fact, projective capacitance has been shown to detect up to ten fingers at the same time. This enables exciting new applications based on multiple finger presses, including multiplayer gaming on handheld electronics or playing a touchscreen piano.

Without question, touchscreens are great looking. They have begun to define a new user interface and industrial design standard that is being adopted the world over. In everything from heart-rate monitors to the latest all-in-one printers, touchscreens are quickly becoming the standard of technology design.

Beyond just looks, however, touchscreens provide an unparalleled level of security from tampering, resistance from weather, durability from wear, and even enable entirely new markets with unique features such as multi-touch touchscreens. With touchscreens making their way into so many types of products, it's imperative that design engineers understand the technology ecosystem and technology availability.