

Choosing a touch technology for handheld-system applications

THE DEMAND FOR LARGER DISPLAYS IN SMALL HANDHELD DEVICES MAKES CHOOSING THE RIGHT TOUCH TECHNOLOGY CRITICAL.

During the last two decades, touch technologies have gained acceptance in a variety of consumer applications, such as touchscreens in ATMs (automated-teller machines), track pads in laptop computers, and scroll wheels in media players. The rise of smartphones as mainstream products has brought touch technologies to mobile phones. Large displays serve a wider variety of software applications, and the overall shrinking of devices makes it critical to choose the right touch technology. A number of touch-technology options are available for handheld-device designers.

Given the prevalence of ATMs, touch technology has become such an integral part of the average consumer's life that it is nearly unremarkable. Similarly, the near-ubiquity of touch and track pads on laptop computers and scroll controls on portable media players may lull us into believing that such technology is past its prime.

However, as Apple's (www.apple.com) launch of the iPhone and Microsoft's (www.microsoft.com) announcement of Surface demonstrate, a great deal of technical innovation continues to drive touch technology as a user interface as well as a core system technology. The recent appearance of touchscreens in high-volume handheld consumer devices, such as smartphones, handheld games, personal-navigation systems, and digital still cameras, has created a new set of requirements and technical challenges for touch-technology providers, system OEMs, and software and application developers. It is helpful for designers to understand the evolution of touch technologies, the current volume drivers for touch technologies, and the emerging technological options for addressing the needs of handheld consumer devices.

Since the invention of touch interfaces in the early '70s, various technologies have emerged and have met varying degrees of success in embedded- and consumer-system applications. Technologists continue to innovate, improve, and invent touch technologies. The two leading touchscreen technologies implemented in handheld devices today are resistive and projected capacitive.

To date, the most common method of touchscreen implementation continues to be resistive touch technology. This technology is based on the simple concept of placing a small, finite gap between two conductive layers (**Figure 1**). The top layer, which the user touches, is typically a flexible clear polyester film, and the bottom layer is typically a rigid substrate

made from glass. The inside surfaces of both layers are uniformly covered with a thin coating of a relatively transparent conductor, ITO (indium-tin-oxide).

A typical resistive touch panel employs a four-wire implementation. Two wires are placed on opposite edges of the touch-panel region and create a uniform voltage gradient along one axis. This is done for both the X and Y axes. The electronic controller circuit alternates applying a voltage gradient in the X direction and then in the Y direction. When the user applies pressure to the outer layer, it makes contact with the inner layer. This point of contact is measured as a voltage whose value directly corresponds to its distance from the sensor's edges. The voltage is then converted to an X- and Y-coordinate position (**Figure 2**).

The other touch technology that has received increasing attention for handheld devices is projected capacitive. This type of touch system uses either an array or a matrix of electrodes that span the touch panel's sensing region. These electrodes are typically separated from a user's touch by an insulating cover lens made from glass or plastic (**Figure 3**). When a finger touches the touch-panel surface, it changes the measured capacitance values of the electrodes closest to it. This change in capacitance can be measured by the controlling electronics, either relative to free space in an absolute capacitive system or relative to a sense electrode in a transcapacitive system. The position of the user's finger, or fingers, can be computed by measuring the changes in capacitance values of the sensing electrodes. The position of the finger, or fingers, is deter-



Figure 1 With resistive touchscreen technology, when you apply pressure to the outer layer, it makes contact with the inner layer, leading to an electrical contact.

mined at a much higher resolution than the electrode spacing through interpolation because the touch panel is designed so that a finger touch will change the capacitance of multiple electrodes simultaneously, not just one at a time.

There are a number of other touch technologies that, though widely deployed, are much less prevalent in handheld devices for a variety of reasons. Another capacitive touch technology, surface capacitive, uses one ITO-coated surface that conducts continuous electrical current across its surface. Manufacturers typically place this coated sensor panel beneath a very thin hard coating for durability, as ITO is very fragile. When a user places his finger on the glass panel, the capacitance of the human body alters the reference capacitance of the sensor panel. Measurements at each corner of the sensor panel help calculate the distortion of the reference field and, from that calculation, derive the X and Y coordinates of the touch point. This technology has received limited deployment in small handheld devices due to electrical implementation challenges. Furthermore, unlike project capacitive systems, in which a cover lens can protect the sense electrodes, surface capacitive systems do not work with a lens, thereby reducing their durability and ruggedness.

In acoustic touch technology, a user's touch induces a vibration, which piezoelectric transducers around the touchscreen convert into electronic signals; they in turn convert these signals into audio signals. By comparing these audio signals with the characterized library of audio signals, the technology establishes the exact location of contact.

Acoustic touch technology is ideal for large displays and is fairly insensitive to dust or scratches. Because the screen has no embedded wires, you can use a pure-glass touchscreen with inherent durability and excellent optical properties. One key disadvantage of acoustic touch technology is its inability to detect a motionless finger. IR touchscreens typically employ an array of IR photodiodes and sensors in horizontal and vertical arrays, which detect the interruption of the optical grid across the screen. When a user makes contact with the screen, the system measures the drop in the sensor-output signal; this measurement allows the system to compute the location of the touch. IR screens are among the most durable surfaces and can handle hostile environments, making them well-suited for military applications.

Last year's announcement of the Microsoft Surface has brought attention to the use of optical imaging as a touch technology. This technology uses multiple image sensors around one side of the touch surface and IR backlights on the other side. When a user places his finger on the surface, intercepting the infrared beam, the device projects a shadow. Using multiple cameras, the unit converts this shadow into a touch point through triangulation. This technique suits large surfaces and multiuser environments. Although still early in implementation, this technology promises scalability and affordability for large displays.

Engineers have long used strain gauges to measure the amount of force a user applies. Designers usually make these measurements on the platform on which the screen sits, rather than directly on the touchscreen. Therefore, such strain-gauge-based systems must account for vibration and gravity, as well as the stress that the user's contact produces. A number of newer methods of force sensing have evolved. When high

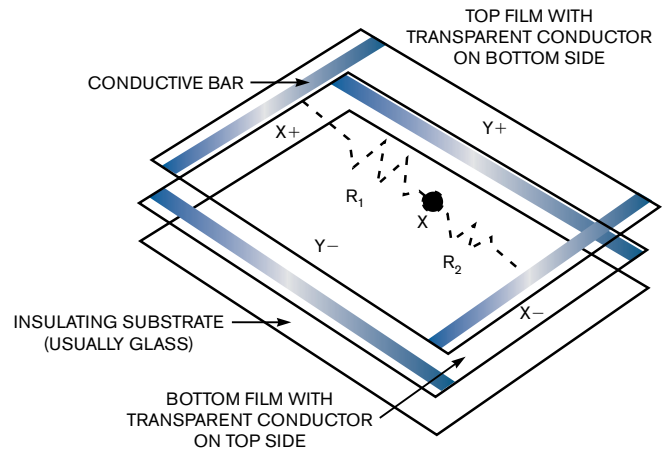


Figure 2 The most common method of manufacturing resistive touchscreens is four-wire resistive technology.

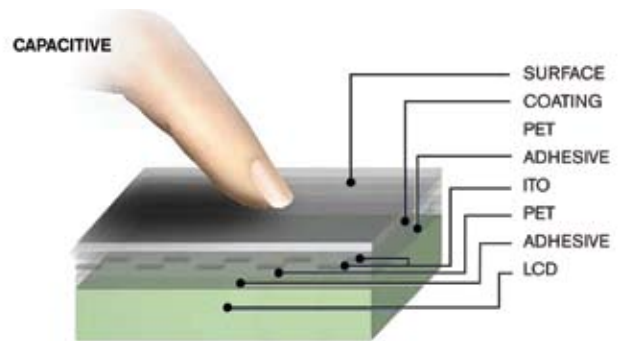


Figure 3 With capacitive touch technology, measurements at each corner of the sensor panel help calculate the distortion of the reference field and, from that calculation, derive the X and Y coordinates of the touch point.

accuracy is not a requirement, you can use force-sensing resistors—thick-film polymers that demonstrate a decrease in resistance proportional to the increase in applied pressure. For applications requiring high accuracy, position a capacitive-force sensor comprising two metal plates close together with a small air gap between them. Applying force on one of the plates changes the capacitance between them.

CHALLENGES OF TOUCH TECHNOLOGY

Resistive touch has served users well during the last three decades, and resistive-touch-technology vendors have delivered continuous and sustained innovation. The resulting improvements have addressed several of the shortcomings of resistive technology, enabling it to achieve high volumes and the associated cost benefits across a range of applications. OEMs and end users benefit from the use of resistive touch technology because of its maturity, low cost, and input flexibility.

Vendors over the last two decades have derived approaches to overcome each shortcoming of resistive touch technology, so OEMs have the advantage of working with a well-characterized technology component when working with resistive touchscreens. Furthermore, advances in manufacturing tech-

nology, the maturity of resistive touch technology, and high-volume usage have made resistive touch technologies the most cost-competitive choice. In applications in which cost is critical and “good-enough” performance is sufficient, resistive touch has few peers and reigns supreme. Resistive touchscreens can use a variety of objects, including plastic or metallic styli, chopsticks, and—in a pinch—fingernails, as input devices. The only input criterion for a resistive touchscreen is that it allows you to apply sufficient force in a narrow target area, yielding flexibility in how you interact with it.

However, the mechanical wear and tear in resistive touch panels, particularly of the outer polymeric membrane, causes tiny cracks in the indium-tin-oxide coating, changing its resistance and degrading the linearity of the voltage across the membrane and therefore the measured accuracy along one axis. The mechanical nature of resistive touch devices makes them less than ideal for harsh environments. They are susceptible to moisture, and the expansion and contraction of the polymeric layer due to temperature and humidity changes can negatively affect the coatings and degrade accuracy. Users of such touchscreens experience this decrease in accuracy as drift, and the touchscreens may require recalibration. The requirement to use a bezel or well makes resistive touch sensors prone to collecting dust, and the need for a touch layer separate from the display can result in poor optical properties due to transmittance loss, reflection, and haze.

By moving beyond a four-wire-measurement approach, resistive-touch-technology vendors have tried to address issues such as the need for recalibration. For instance, eight-wire systems with four additional sensing points use voltage-gradient measurements with high sensitivity, allowing operation across a wide temperature range. They also help mitigate drift but do not address issues stemming from environmental or mechanical degradation of the outer layer. Five-wire systems, which use four wires on the substrate and use the polymeric outer layer only as a probe, are less susceptible to mechanical and environmental degradation of the outer coating. However, five- and eight-wire systems drive up the implementation cost, so manufacturers employ them primarily in nonhandheld devices.

In the early '90s, capacitive technology made its first volume appearance in notebook computers as track or touch pads and, since then, has achieved high volumes as a de facto tracking input. In 2001, capacitive touch made

its first appearance in MP3-player scroll wheels and, since then, in the smartphone segment. The advantages of capacitive touch include ruggedness, design flexibility, the ability to sense more than a single finger, and an enhanced user experience.

As a solid-state sensing technology, capacitive sensing is inherently suitable for rugged environments because you can integrate it in ruggedized surfaces. The Android-based T-Mobile (www.t-mobile.com) G1, for example, integrates its sensing element underneath the cover or casing, giving it the advantage of a solid-state sensor. Industrial designs using capacitive

touch have greater flexibility because, unlike resistive touch designs, they have no bezel or case opening. The designers of the LG (www.lge.com) Prada phone used the device's surface as part of the user interface employing capacitive touch technology. Similarly, the use of solid-state capacitive technology avoids any penalty on optical clarity that a resistive touch approach would impose.

Although some vendors have demonstrated that resistive technologies can work with multiple contact points, these technologies were not designed to do so. Projected capacitive touchscreens, on the other hand, are inherently suited to mul-

tifinger use. They typically report only one point of contact as the resistive sensor averages measurements across the entire touch surface. The detection of multiple contacts, or touch points, in a capacitive touchscreen enables the multifinger-use cases, such as pinching to zoom in or out on a screen or simultaneous use by multiple users.

Capacitive sensing also offers a better user experience because the system can self-calibrate for environmental changes and is better able to adapt to environmental issues than resistive technology. The ability to use your finger instead of a stylus, as in resistive touchscreens, provides for greater user flexibility. Furthermore, the ability to use finger-based gestures, such as flicking for scrolling or dragging and dropping, is easier with capacitive touchscreens. The need to apply and maintain pressure to ensure contact in a resistive touchscreen makes the use of fingers impractical and requires a stylus to achieve the same effect as in a drag-and-drop action.

Despite its obvious benefits, projected capacitive touch technology has some disadvantages, including higher cost, software dependency, input inaccuracy, and limits on using a stylus or a gloved finger to make inputs. Many of these problems arise because the technology is in a relatively early stage of adoption. Capacitive touchscreens have yet to achieve the cost economics of resistive touchscreens and are more expensive than resistive devices. This drawback can pose a financial barrier to OEM adoption or result in higher cost for the end user.

Although capacitive touchscreens can provide a better user experience through finger-based gestures or multifinger use, such a user experience requires tight integration between the end-user interface and the underlying touch technology. This situation means that device OEMs or their suppliers of user applications must create and integrate the software necessary for such user interactions. User education and experience with such advanced features will create demand that will validate OEMs' investment in software development and integration. The release of products such as the Apple iPhone is beginning to validate these user scenarios, and, over time, this disadvantage will disappear.

The premise of capacitive technology is that the object you use as an input device, such as your finger, is conductive in nature. This fact means that you cannot use any old stylus or favorite chopstick as an input device; you instead need a special broad-tipped conductive stylus. This limitation also poses a problem when you are

wearing gloves; in that case, finger-based input becomes unpredictable or nonworking altogether. Additionally, if a user has large fingers or long fingernails, inserting input between two letters

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can pose a challenge. Similarly, when pecking letters or other input on screens, a finger is less precise than a pointed stylus. Although software implementations can mitigate this problem, the ability to achieve fine positioning with finger input remains a challenge. You can work around the seeming shortcomings of projected capacitive technology, especially with tight software integration and creative user-interface design.

APPLICATION-DRIVEN CHOICES

Several factors play into the decision of which touch technology to use for a given application. These factors include the cost of the technology, the environment of the application, the size or dimension of the touchscreen itself, and the touchscreen's life cycle or frequency of use. Historically, the use of touchscreens in applications such as ATMs or information and tourist kiosks has imposed restrictions on the minimum size of the screen, the required ruggedness, and protection from vandalism or other damage. Small-screen applications, such as point-of-sale terminals, and first-generation handheld systems, such as United Parcel Service or Federal Express delivery terminals, also need durability as a key criterion for handling millions of touches without significantly degrading performance.

Similarly, the available choices of next-generation handheld systems, including smart and feature-rich mobile phones, digital still cameras, portable music players, remote controls, and handheld gaming devices, impose their own constraints on the choice of touch technology. These constraints include low power consumption for battery-powered handheld systems, cost-competitiveness, software configurability as screen sizes grow at the cost of hardware buttons, flexibility of product design for changing consumer tastes, ease of use, and a quick learning curve for consumers. For mobile phones, the ever-growing set of features, such as megapixel cameras, high-capacity audio and video storage, Wi-Fi Internet connectivity, and voice functions, demands a variety of user-input controls, even as screen real es-

tate increases and hardware buttons become fewer.

A touchscreen system is efficient because it allows the display area in a device to serve as both an output system and an input system. A

touchscreen leads to more efficient use of space in a smartphone because designers can make the display larger by eliminating the need for mechanical buttons and controls. By putting controls in a touchscreen, you can easily repurpose those controls in software to match an application's needs. This repurposing makes the device easier to use despite having a large number of functions. Controls can appear or disappear as necessary, so designers can use the display area for many purposes.

In contrast, you cannot reuse the real estate that contains the mechanical buttons. Capacitive touchscreen technology suits these devices because they require the flexibility of industrial design; ruggedness to accommodate large displays; and software configurability for superior user experiences, such as multitouch capability.

Resistive touchscreens, the workhorses of touch technologies, have during the last two decades delivered sturdy, reliable, and economical touch-based user interaction in a variety of applications. Emerging power-sensitive handheld devices, such as MP3 players and mobile handsets, rarely target single use, find use in multiple applications, and are rich in multimedia features. These devices require low-power touch technologies that allow greater flexibility for industrial designers and new user paradigms, such as multitouch and even multiuser, for system and software designers. Projected capacitive technology has emerged as the choice for the next phase of handheld designs, and optical-based technologies bear watching for future multiuser scenarios. **EDN**

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