overview

A Cornucopia of Touch Technology

Few sectors of the display industry are changing as rapidly as touch panels. Current platforms are constantly being updated and improved, while new technologies are being introduced. This article provides updates on some of the latest developments in touch technology.

by Geoff Walker

FEW DISPLAY TECHNOLOGIES are as omnipresent in every day life as touch-panel technology. Think about how many touch panels are encountered on a daily basis: ATMs; airport check-in kiosks; in-car navigation systems; point-of-sale (POS) kiosks, registers, and computers; diagnostic machines at the local garage; and PDAs, just to name a few.

However, grouping together all of the technologies that encompass "touch-panel displays" would be akin to grouping together all of the different flat-panel-display technologies under one heading. Accordingly, this article explores 13 different developments in the touch-technology arena, focusing on some unique and/or interesting things that have not received much attention lately. The article also mentions the topics of the other three touch-technology articles in this issue in order to put them into some industry context. Topics addressed include the following:

- Acoustic Pulse Recognition (APR)
- Dispersive Signal Technology (DST)
- Dual-Force Resistive Touch
- Spatial Projected Capacitive
- 3-D Touch
- ITO Replacements
- Armored Resistive Touch
- Multiple Independent Touch Displays
- Dual-Mode Pen and Touch
- Infrared Touch in Sunlight
- Circular-Polarizer Film–Film Resistive Touch
- Mobile Surface Acoustic Wave (SAW)
- Optical Touch

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Acoustic Pulse Recognition (APR) and Dispersive Signal Technology (DST)

Recently, the touch-panel industry has seen the emergence of two competing implementations of a very similar technology for touch-panel operation. It is unusual when a totally new detection technology arrives with such vigor, and when two major competitors launch so close in time to each other.

Acoustic Pulse Recognition (APR) technology from Elo TouchSystems and Dispersive Signal Technology (DST) from 3M Touch Systems use the same underlying principle, that of measuring the bending waves that result from touching a glass substrate. In its literature, 3M refers to bending waves created by an impulse. Elo refers to the same phenomena as "sound," referencing their invention of and expertise in Surface Acoustic Wave (SAW) technology. Both technologies use piezoelectric transducers attached to the back surface of the glass to convert the bending waves into analog signals. The key difference in the technologies is in how the analog signals are processed.

DST processes the analog signals in real-time, utilizing a calculation technique that corrects for the significant dispersion of the bending waves due to the glass substrate. This allows a specialized correction that minimizes the negative effects associated with typical time-of-flight methods. A digital signal processor (DSP) in the 3M controller executes algorithms that determine the touch coordinates by continuously analyzing the dispersion of the bending waves as well as their arrival times. During operations such as dragging, when many bending-wave events are generated in sequence, additional proprietary algorithms are employed to minimize the additional processing required. Hence, the processor bandwidth requirements for tap *vs*. dragging calculations are nearly identical. DST touch resolution meets or exceeds that of other current touch-panel technologies (higher than HDTV panel resolutions), and 3M claims accuracy of better than 1% on a 46-in.-diagonal screen. Benefits of 3M's "on-board processing" approach include human-interface device (HID) compliance, as well as zero bandwidth consumption of the host processor by the touch controller (Fig. 1).

In contrast, the APR implementation processes the analog signals into touch "signatures" and performs a look-up comparison with a table of stored signatures, rather than a fairly complex real-time signal-processing exercise. A display-and-touch-panel assembly is characterized during development by storing in ROM the unique vibration/sound pattern (the touch signature) that is produced by touching each of the 4096 × 4096 locations on the touch panel. The controller continuously listens to the analog signals from the

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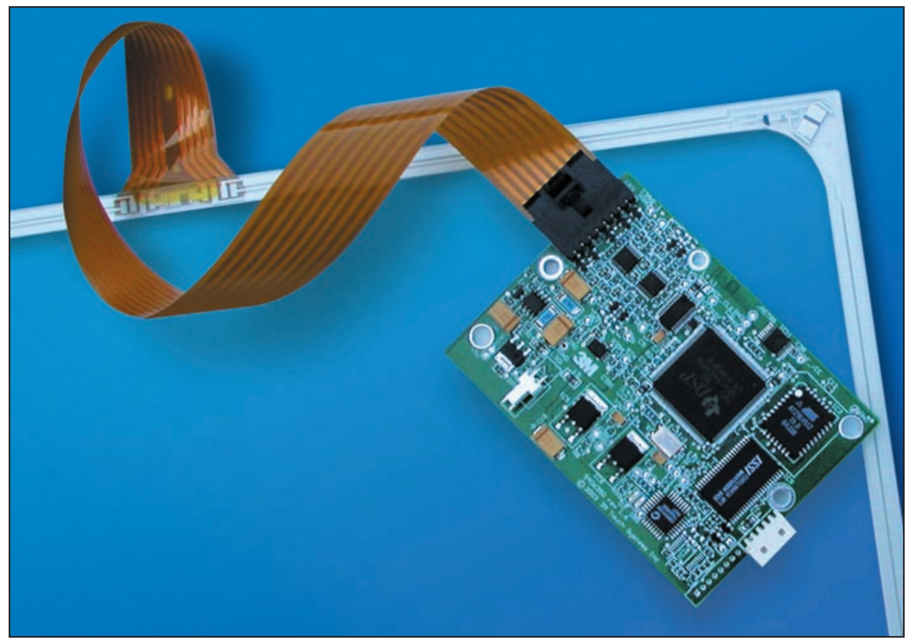
transducers. When a touch creates a signal that exceeds a dynamic frequency-domain threshold, the signal is filtered to remove known ambient non-touch vibrations/sounds, then digitized and further processed to yield a touch signature. This touch signature is compared against the ROM-based table of stored signatures; when there is a match, the controller returns the touch coordinates of the stored signature.

Both implementations are attractive to display designers because there is no electrical or mechanical interaction with the underlying display, and therefore it appears that this technology will work well with a variety of display technologies, including plasma, which can cause interference with some other touch technologies. 3M positions this as a distinct advantage, noting that its DST system evaluates only the dispersion characteristics of the touch-panel glass substrate.

Both products are still at a very early stage of development. Elo began shipping APR in the summer of 2006 and expects to be ramped up to full production by the spring of 2007. Elo is currently shipping APR integrated into one 15-in. monitor (model 1529L); its initial focus is on the retail and restaurant POS markets because the benefits of APR clearly fit that touch application. However, Elo expects to broaden its market focus, expand the range of product sizes, and offer a stand-alone APR product in the future.

3M did an initial release of the DST product during 2005 with Richardson Electronics' Pixelink Division as the primary systems integrator. After gaining some experience with a variety of applications under a range of environmental conditions, 3M has made further refinements and plans to re-introduce the DST product in the spring of 2007. 3M intends to aim the product at the interactive large-display market mainly because of the success of its capacitive-touch product in POS applications.



3M Corp.

Fig. 1: *3M DST sensor and controller.*

Dual-Force Resistive Touch

CyberTouch has developed a resistive touch panel that emulates the hover ability of a mouse. The user can press the screen lightly to move the cursor to a given location, then press harder to activate a function. This is accomplished through the use of two stacked sensors. The first sensor is actuated at 20 grams of pressure, while the second sensor is actuated at 60 grams of pressure. These force levels are controlled by adjusting the size and shape of the spacer dots, along with the thickness and material of the substrate. At these relatively low actuation forces, the target application for this technology is clearly finger-touch (*e.g.*, in stand-up kiosks) rather than stylus-use. The transmissivity of the stacked sensors is relatively high at 76%, considering that the dual sensors have a total of four ITO-coated surfaces. CyberTouch has manufactured some dual-force touch panels with anti-reflective (AR) coatings and a circular polarizer to improve their sunlight readability.

The original development of this technology was driven by CyberTouch's military and aerospace customers, but currently it is in demand from customers with automotive/truck navigation and Web-browser applications. As a result of specific customer demand, CyberTouch's initial dual-force products are available in 8-wire only, although there is no technical reason why dual-force cannot also be applied to 4- and 5-wire. Available sizes in the first quarter of 2007 will include 17, 18, 19, and 20 in.

Spatial Projected Capacitive

Projected capacitive touch uses a three-dimensional electrostatic field to enable the recognition of a touch at a distance from the sensor. This capability is commonly used to allow placement of the sensor behind a protective layer of glass. This differs from surface-capacitive touch, where the use of a two-dimensional electrostatic field requires the user to physically contact a transparent conductive coating (covered by a very thin insulating layer). Most implementations of transparent projected-capacitive touch in the past 10 years have used one of two sensor designs: embedded wires or patterned indium tin oxide (ITO). Zytronic is the leader in using a sensor consisting of a two-layer (X-Y) grid of very thin (10-μm) wires embedded into glass. Elo resells Zytronic's technology integrated into some monitor products. Until 3M exited the projected capacitive market (which it called "near-field imaging" or NFI) earlier this year, it was the leader in using a sensor consisting of an X-Y grid of patterned ITO. Touch International also uses the same sensor design. Both the embedded-wire and patterned-ITO implementations are capable of sensing touch up to about 1 in. from the sensor.

TouchKO has created something substantially different in this area. TouchKO's branded "Spatial Capacitive" touch sensor uses a single, non-patterned layer of ITO. This lower-cost approach contrasts markedly with embedded-wire and patterned-ITO sensors, where each wire or ITO trace in each layer is connected to a separate input on the controller. The independence of each wire or ITO trace makes it much easier for the controller to determine the location of the touch at a distance. Exactly how the TouchKO controller determines the location of a touch at a distance from a single, non-patterned layer of ITO is unknown – TouchKO will not discuss it, and the company has not filed any published patent applications on the technology.

What is even more remarkable is that the TouchKO controller can sense touch (proximity) at up to 4 ft. from the sensor! This puts TouchKO into the same ballpark as EtherTouch's 3-D touch product that is described in the next paragraph. Applications for this "far-touch" capability are still emerging, but the one getting the most traction is a store-window display. A large display with spatial capacitive touch can be placed inside a closed store, allowing passers-by to interact with the display from outside the store. Another application is at a trade show where, as a prospect approaches, the display can automatically switch from an "attraction" program to an "information" program.

3-D Touch

Fabless semiconductor company EtherTouch has created a three-axis capacitive sensor application-specific integrated circuit (ASIC) designed for high-resolution 3-D position sensing using projected capacitance. EtherTouch performed a lab experiment in which a doorframe outlined in aluminum foil was connected to the chip; the speed and height of people approaching the door frame could be determined 8 ft. away. Now that's 3-D! The chip's very high sensitivity to changes in capacitance (4×10^{-18} farads per root Hertz) allows sensing z-axis direction and velocity at a considerable distance. On a 17-in. monitor, finger motion can be sensed 1 ft. away from the screen with enough resolution to control Windows.

The 40-pin ASIC has three distinct inputs (X, Y, and Z), each of which in turn has four sensor electrode inputs. Each sensor electrode is connected to the input of a differential amplifier; the output of the amplifier is routed through signal-conditioning circuitry to a 16-bit analog-to-digital converter (ADC). The electrodes are charged with a sinusoidal excitation signal between 20 and 40 kHz that is picked up by the user's body. With proper arrangement of the X, Y, and Z sensor electrodes in a two-dimensional plane, differential changes in capacitance between the user's body and the three sets of sensor electrodes can be used to determine unambiguously the location and velocity of the user's finger (or entire body, as in the lab experiment above) in 3-D space. The ASIC is available from Analog Devices as part number AD7103; considerably more detail on how it works can be found in the ASIC's technical datasheet. Note that this product is only one of the components necessary to create a functional touch panel; sensors, supporting hardware circuits, and software drivers must be developed by OEM customers. An evaluation kit is available from EtherTouch to provide a starting point.

Because EtherTouch's chip works well with a very-high-impedance input, it is possible to create sensors using thinner transparent conductors that have higher resistivity than ITO. For example, EtherTouch has tested sensors with 94% transmissivity that were made with Eikos's carbon-nanotube transparent conductor material (see the next section) – that's as good as bare glass.

The ultimate application of EtherTouch's technology is 3-D touch on 3-D displays, but that market has barely begun to emerge. In the meantime, EtherTouch is working closely with several partners under NDA on three key applications: automotive displays, mobile communications devices, and 3-D touch on large 2-D displays. EtherTouch will not say anything about the automotive application, but the mobile communications application includes a combination of gestures to control the device at a distance along with handwriting recognition. Applying 3-D touch to a 3-D application on a large 2-D display is probably the most obvious application of the technology.

ITO Replacements

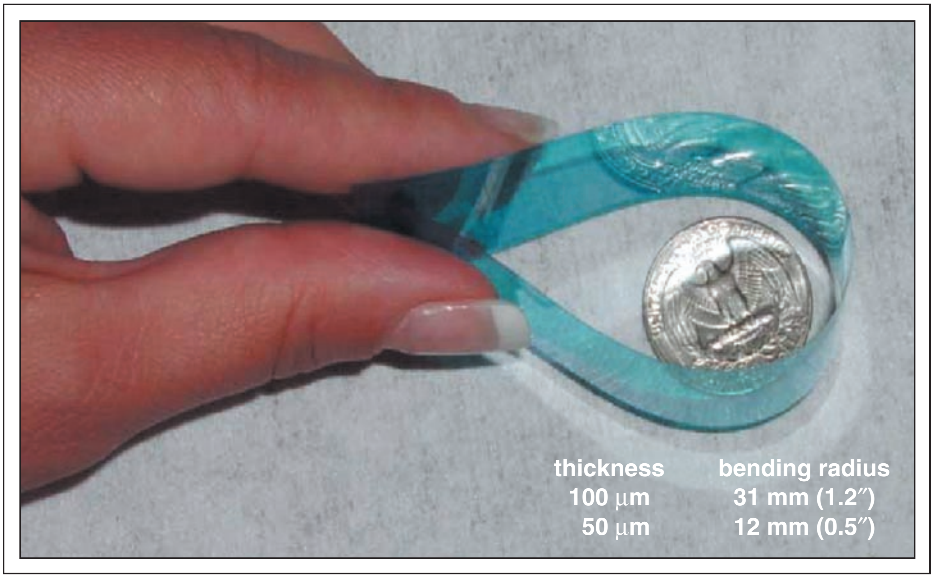
ITO is not an ideal transparent conductor for use on a flexible material such as polyethylene terephthalate (PET) film – because it is a form of ceramic, it is quite brittle. This is the reason that most resistive touch panels are rated for much shorter life when used with a stylus rather than a finger. Indium has increased in price significantly in recent years due to increasing use and decreasing supply. As a result, there are a number of development projects under way to find a replacement for ITO. The article by Fujitsu appearing in this issue, describing their progress in transparent conductive polymers, is a good example.

Several other companies are developing ITO replacements. Eikos has developed a transparent conductor material based on single-walled carbon nanotubes. An article in the October 2006 issue of the Veritas et Visus *Touch Panel* newsletter described some of Eikos's very positive test results. These included higher and flatter transmissivity across the entire visible spectrum, higher flexibility, and more-neutral color than either ITO or transparent conductive polymer (PEDOT/PSS).

Cambrios Technologies has developed a transparent conductor material through the application of three core technologies: (1) discovery of peptide agents (proteins) that control synthesis and assembly of inorganic materials from soluble precursors, (2) creation of biomorphic nanostructures out of a wide variety of materials, and (3) precise placement of nanostructures *via* self-assembly and molecular affinity. Both Eikos's and Cambrios's new conductor materials are very appropriate for touch panels and can be applied *via* solution processing in a roll-to-roll environment – a much more desirable and lower-cost method than the high-vacuum sputtering required in the application of ITO. Both companies are working with partners to commercialize their materials.

Armored Resistive Touch

Substituting polycarbonate for the glass substrate in a resistive touch panel is readily available from many touch-panel manufacturers. However, while this makes a resistive touch panel unbreakable, it does not address any of the durability issues of resistive touch. A much lesser known technique is "armoring" a resistive touch panel by laminating a thin (0.1 mm) sheet of glass on top of the PET film. Glass this thin is very flexible, having a bending radius of about 31 mm (see Fig. 2). The result is a resistive touch panel that can be hit with a hammer (when used with a tempered glass substrate) or deeply scratched with a diamond-point glass cutter, yet operates normally. Because it is still a resistive touch panel, it can be used with fingers, gloves, stylus, or any object. It is unaffected by dirt, water, or chemical contamination, and it can even operate submerged or completely frozen. Among the more than two-dozen resistive



Schott Corp.

Fig. 2: Flexible glass used as armoring in A D Metro's and TouchKO's resistive touch panels. The sample shown is 0.05 mm thick, while the glass used for armoring is 0.1 mm thick. The sample has been dyed blue to make it more visible.

touch-panel vendors with which the author is familiar, only two offer armoring: A D Metro and TouchKO. Table 1 compares the key specifications of an A D Metro 5-wire resistive touch panel with and without the armoring.

Multiple Independent Touch Displays

It is well-known that Windows supports multiple monitors and multiple pointing devices. However, a key limitation is that only one pointing device can be used at a time because there is only one "cursor," *i.e.*, Windows can only use one source of X-Y coordinate data at a time, even if there are multiple physical screens. This can be a serious problem in an application such as an ATM, where a consumer may be using the "outside" monitor and touch panel at the same time that a maintenance engineer is using the "inside" monitor and mouse. Both pointing devices are connected to a single computer, yet one cannot be allowed to interfere with the other.

Hampshire, a touch-controller manufacturer in Wisconsin, has solved this problem. They have developed a custom driver for their touch-panel controllers that allows Windows to use two simultaneous and independent sources of pointing device data – one for the consumer and one for the maintenance engineer in the above example. The same concept could be applied in an information-kiosk application in order to support two monitors and two touch panels from a single computer.

This example highlights an aspect of touch technology that is often forgotten – it is a system! Touch-enabling always includes a sensor, a controller, and a hardware/software interface to a host computer. Because the sensor provides the critical user interface to the computer, it is often the primary focus of attention. Yet without an appropriate controller and software, it may not be possible to accomplish the task at hand. In the ATM example above, the sensor technology is irrelevant – it is the driver that solved the customer's problem.

Table 1: A D Metro's 5-wire resistive touch panel with and without armoring

	Standard	Armored
Activation Force	85 g	85 g
Transmissivity	83% (clear)	84% (clear)
Surface Hardness	4H	6.5 Mohs
Thickness	2.54 mm	2.64 mm
Sensor Life	35M touches	200M touches

Dual-Mode Pen and Touch

N-trig Innovative Technologies has developed a dual-mode pen and touch digitizer aimed at the tablet-PC market. N-trig first showed a public demo of the technology embedded in a Motion Computing tablet PC at Microsoft's WinHEC 2006 conference. The technology is expected to be utilized in several new Vista-equipped tablet-PC models shipping from major OEMs during the first quarter of 2007.

As shown in Fig. 3, the core of N-trig's sensor consists of a two-layer (X-Y) grid of

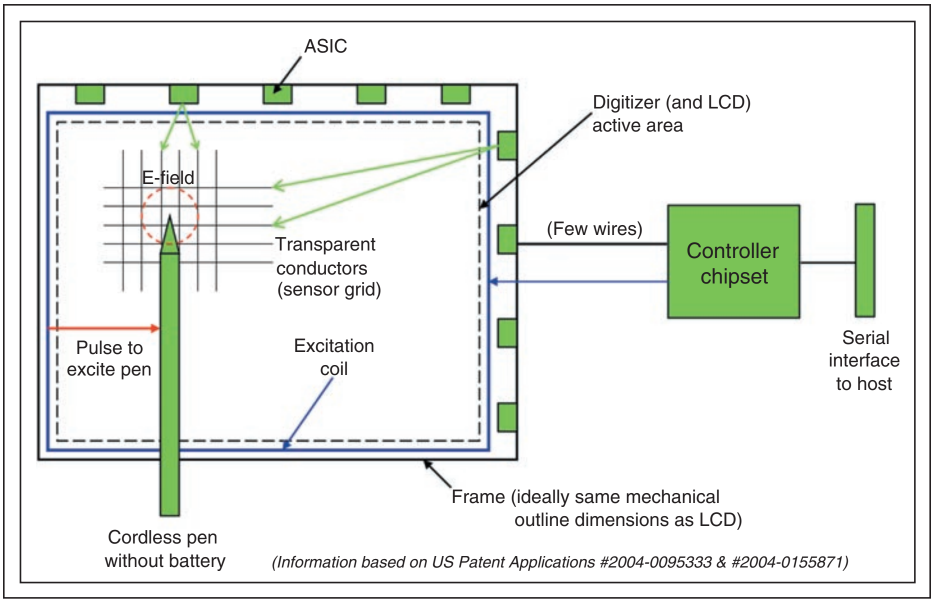


Fig. 3: Architecture of N-trig's dual-mode pen and touch digitizer.

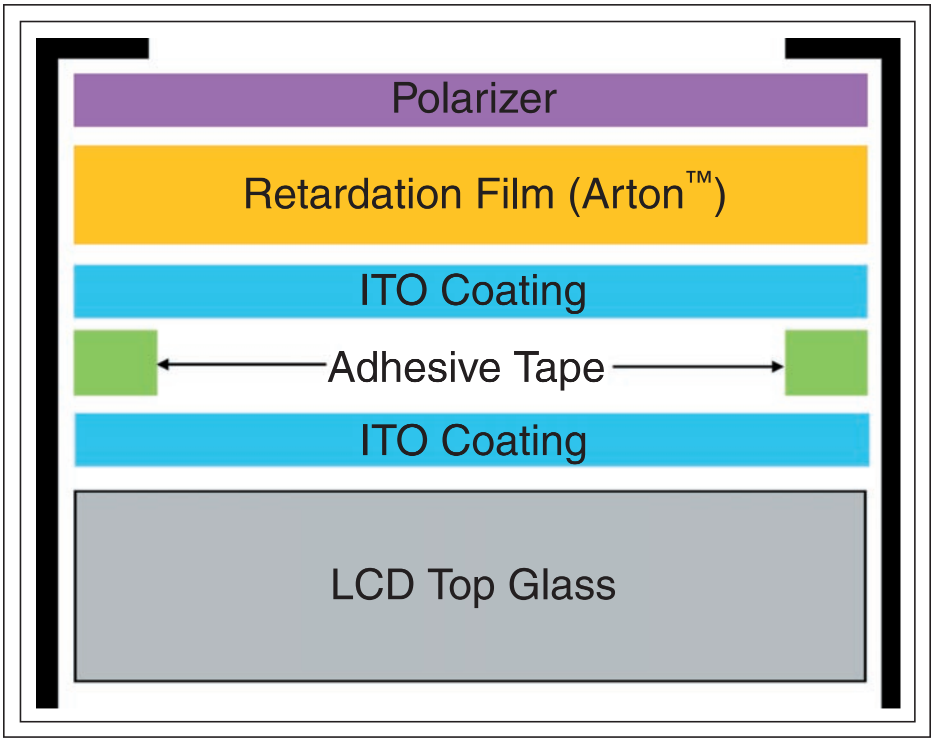


Fig. 4: Construction of DigiTech System's circular polarizer film–film resistive touch panel.

transparent ITO conductors that is shared between finger-touch and pen use. When the touch panel is used in finger-touch mode, it operates exactly like a standard projected-capacitive touch panel. When the touch panel is used in active-pen (high-resolution) mode, it operates as an electrostatic digitizer. This is very different from the standard Wacom electromagnetic digitizer that is used on almost all current tablet PCs. Because the Wacom digitizer is electromagnetic, it requires a low-impedance sensor using copper traces on a printed circuit board (PCB); this means the sensor is opaque and must be located behind the liquid-crystal display (LCD). Because the N-trig digitizer is electrostatic, it can use a high-impedance sensor using transparent conductors that can be located in front of the LCD.

In operation, a pulse from the excitation coil around the periphery of the touch panel energizes the active cordless pen, producing a concentrated electric field at the tip that is detected by the transparent sensor grid. ASICs containing differential amplifiers and switches resolve individual sensor line signals into the differences between the closest sensor lines. The differences are amplified and then converted from analog to digital by high-speed A/D converters in the ASICs. The controller processes the digitized samples, calculates the pen or touch location, and outputs ASCII data packets.

Infrared Touch in Sunlight

Infrared touch has long had a reputation for not working well in direct sunlight. IRTouch has improved the technology to the point where it now works reliably in any orientation at 100,000 lx, the illuminance of direct sunlight outdoors at noon in the summer. For comparison, the same sunlight at 4 pm is around 40,000 lx, while sunrise or sunset on a clear day is about 400 lx. IRTouch says it has accomplished this by using a combination of advanced bezel filter design (material and shape), sophisticated algorithms for detecting the pulsed IR signal in the presence of strong noise (the infrared in sunlight), and improvements in the overall optical system. Unfortunately, IRTouch is unwilling to disclose any additional technical details.

Circular-Polarizer Film–Film Resistive Touch

The article from Gunze USA in this issue describes the technique of using a circular polarizer to greatly reduce reflections in resistive touch panels. The article includes an example of a reduced-structure film–film touch panel. DigiTech Systems, a touch-panel manufacturer located in Korea, has developed an alternative structure. As shown in Fig. 4, the DigiTech touch panel consists of only a polarizer, one sheet of ITO-coated retardation film, and an ITO coating on the LCD's top glass. This construction results in a total touch-panel thickness of only 0.3 mm and a reflectivity of 4–6% without AR and 1–2% with AR on only the top surface of the polarizer.

This construction relies on the ability of the touch-panel manufacturer to work closely enough with LCD manufacturers to be able to purchase LCDs without a top polarizer. It also relies on the LCD manufacturer not changing the absorption axis angle of the bottom polarizer in the middle of mass production. As always, the volume of the sale is likely to be a critical factor, which makes the mobile handset business a good candidate for this construction – if the touch-panel manufacturer can convince the LCD manufacturer to take the risk of working together through the development phase. DigiTech Systems plans to launch this product in the first half of 2007.

Mobile Surface Acoustic Wave (SAW)

Fujitsu has been working on mobile surface acoustic wave (SAW) touch since 2002, when the company announced its initial prototype in a press release. Fujitsu has continued development of the technology and has conducted successful test marketing in several countries. From a user's perspective, the primary advantage of SAW touch is the minimal degradation of the display image compared with that for resistive touch. The basic specs of Fujitsu's latest PDA-sized prototype (Fig. 5) are shown in Table 2.

Table 2: Specifications of Fujitsu's mobile SAW prototype

Specification	Value
Diagonal Size	95 mm (3.7 in.)
Thickness	0.7 mm
Frame Width	1.4 mm
Transparency	≥ 92%
Position Resolution	100 ppi
Sampling Rate	100 samples/sec

The key development that enables this touch technology is that of a thin-film piezo-electric transducer that is only 2 μm thick. The transducer is sandwiched in an electrode structure consisting of an array of repeating V-shaped electrodes; the structure enables a very narrow frame width with high-accuracy position detection.

One of the fundamental requirements of SAW is a stylus that must be able to absorb sound – a typical hard-plastic fine-point PDA stylus will not work at all. To handle this problem, Fujitsu has designed a new stylus with a sound-absorbing tip. Although it sounds as though the company is making good progress, Fujitsu says that the prototype has not been commercialized yet because some further refinements must be made to enable practical use, such as making it shock-proof.

Optical Touch

Optical touch suffers from low visibility. It is almost never included in "touch technology comparison" tables. And yet, it is a viable technology, as demonstrated by the success of NextWindow's optical touch-panel technology which uses two scanning cameras located at the corners of the screen. The cameras track the movement of any object close to the surface by detecting the interruption of an infrared light source. The light is emitted in a plane across the surface of the screen and can be either active [infrared light-emitting diodes (LEDs)] or passive (special reflective surfaces).

Fujitsu Components of America, Inc.

Fig. 5: The "Mobile SAW" prototype from Fujitsu Components of America, Inc.

While NextWindow's optical touch technology can be used over a range of 15–110 in., it is particularly interesting in the large-display market (32 in. and up). For screen sizes larger than 42 in., the available touch technologies narrow considerably. Neither resistive nor surface capacitive work well in excess of about 30 in.; SAW is limited to about 42 in. due to sensitivity issues; DST and APR both seem to have good potential for larger than 42 in., but neither is actually available today; projected capacitance using

Table 3: Companies refered to in this article

Company	URL	Company	URL
3M Touch Systems	www.3mtouch.com	Hampshire	www.hampshirecompany.com
A D Metro	www.admetro.com	IRTouch	www.irtouchusa.com
Analog Devices	www.analog.com	Microsoft	www.microsoft.com/windowsxp/tabletpc/
Cambrios Technologies	www.cambrios.com	N-trig Innovative Technologies	www.n-trig.com
CyberTouch	www.cybertouch.com	NextWindow	www.nextwindow.com
DigiTech Systems	www.digitechsys.co.kr/index_en.html	Richardson Electronics	www.rell.com
Eikos	www.eikos.com	TouchKO	www.touchko.com
Elo TouchSystems	www.elotouch.com	Touch International	www.touchinternational.com
EtherTouch	www.ethertouch.com	Wacom	www.wacom-components.com/english/
Fujitsu	www.fcai.fujitsu.com	Veritas et Visus	www.veritasetvisus.com
Gunze USA	www.gunzeusa.com	Zytronic	www.zytronic.co.uk

embedded wires has been demonstrated with large rear-projection screens by Zytronic, but there is not an actual product on the market yet. That leaves only two available touch technologies to compete with optical touch in sizes 42 in. and up: (1) projected capacitance using an ITO-coated sensor from TouchKO and (2) infrared from about a half-dozen suppliers, of which IRTouch appears to be the largest.

Optical and IR touch are a close match in many ways, but optical touch has two key architectural advantages: scalability and resolution. As an IR touch panel gets bigger, the number of IR-touch emitters and sensors must increase proportionally, which increases the cost; optical touch's sensor cost stays constant with just two cameras. IR touch's resolution is relatively low (4096 × 4096 interpolated) because it depends on the spacing of the IR sensors (higher resolution incurs higher cost). Optical touch's resolution (32,768 × 32,768) and data rate (66 samples/sec *vs.* 30 samples/sec for IR touch) is high enough to support good handwriting recognition – with any type or size of stylus! The battle for touch on large displays is just beginning.

Conclusion

Touch technologies are increasing in number, not consolidating. Just a few years ago, there were only four touch platforms: resistive, capacitive, SAW, and infrared; now there are two more (optical touch and bending-wave). (See Table 3 for a list of touch-panel companies mentioned in this article.) If the variations within each technology is counted (*e.g.*, APR and DST in bending-wave), there are actually a total of 12 technologies. This is far too many for an orderly market. Pity the poor engineer who has to make sense out of this chaos. Claims and counterclaims, incomplete specifications and performance data, overlapping capabilities, a pervasive lack of standards – it's a mess out there! And yet, as evidenced by the developments described in this article, innovation in touch technologies continues unabated. If you can stand the heat, it's a great time to be in the kitchen! ■