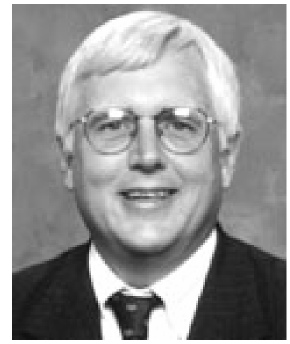
A tough touch challenge

by Gary Barrett



Gary Barrett, Chief Technology Officer, founded Touch International in 2002. He has held executive staff/director positions at Touch Technology, Carroll Touch (now part of Elo TouchSystems), Gunze Corporation, and The Graphics Technology Company. Barrett holds five key patents related to analog resistive and capacitive touch sensing technology, and has consulted in the development of touch panels with companies around the world. He founded two touch development companies, which he later sold. AMP (now Elo TouchSystems) acquired his first company, and 3M Touch Systems (formerly MicroTouch) acquired his second.

What do you do when you've got a touch application where you'd normally use resistive touch technology but you can't live with resistive's high susceptibility to damage? What if the touch surface must be curved rather than flat? And what if the product's mechanical constraints are so tight that the touch sensor must be less than half a millimeter thick? Sounds like an impossible challenge, doesn't it?

Actually there is a commercially available product that can meet all of these requirements. It's called ExtremeTouch and it's made by Touch International, a worldwide supplier of touch screens and touch-screen components. ExtremeTouch uses a flexible touch sensor that's less than 0.4 mm thick. The sensor is optically bonded to the back side of whatever material is used for the touch surface (usually highly durable glass or plastic). The sensor is able to accurately sense touches through any transparent material, even half-inch-thick vandal-resistant glass, so the touch surface takes all the abuse rather than the sensor. Because it's flexible, the sensor can be bonded to the inside of curved transparent surfaces such as are sometimes used in high-style, high-tech handheld gadgets.

How ExtremeTouch Works: ExtremeTouch is based on "projected capacitive" touch technology. This is quite different from the "surface capacitive" touch technology that's often used in point-of-sale terminals and information kiosks. Surface-capacitive touch screens measure the transfer of energy through a capacitance formed between the surface of the touch screen and the surrounding environment. A surface-capacitive touch sensor consists of a substrate covered with a uniform transparent conductive coating and a very thin insulating top layer. An AC voltage of appropriate amplitude and frequency is applied to the four corners of the conductive coating. When the conductive coating is touched by a conductive human finger, a very small current is drawn from each corner towards the point of contact. A controller measures the ratio of the current flow from each corner and calculates the touch location. Although the conductive layer is always covered with a protective coating, the coating must be very thin to allow the finger to draw sufficient current. Surface-capacitive touch screens are therefore "resistant" to scratches and abrasions, but far from truly durable.

A projected-capacitive touch sensor is constructed very differently. It has two sets of parallel rows of transparent conductors, one on each side of a substrate. The parallel rows are at right angles to each other, forming an X-Y grid. Because they are on different surfaces, each intersection of an X and a Y conductor forms a capacitive node. An AC voltage of appropriate amplitude and frequency is applied to the conductor rows on one side (the driving lines), while the conductor rows on the other side (the sensing lines) are connected to a capacitance-measuring circuit. In operation, a controller energizes each driving line one at a time; the capacitive coupling at each node causes a very small current to flow between that driving line and each intersecting sensing line. When a finger gets near one or more of the intersections, it absorbs some of the current, thus changing the capacitance at those nodes. The controller scans each intersecting sensing line one at a time; changes in capacitance at three or more adjacent intersections are used to calculate the touch location.

Because the transparent conductors are like individual "wires", the electric field surrounding each transparent conductor in a projected-capacitive sensor is more three-dimensional than the electric field produced by the uniform conductive layer in a surface-capacitive sensor. The field is "projected" beyond the sensor surface, which is what allows a touch to be sensed at a distance from the sensor. This in turn allows the sensor to be totally protected behind an extremely tough top surface such as tempered or chemically-strengthened glass. Projected-capacitive touch screens are therefore extremely durable.

Comparing ExtremeTouch and Resistive Touch: The challenge at the beginning of this article involved an application that would normally use resistive touch technology. Resistive is in fact the most commonly used of all touch technologies, making it the most common alternative to ExtremeTouch.

In a typical resistive touch screen, a top and bottom substrate (typically PET plastic film and glass, respectively) are covered with a uniform transparent-conductor coating. The coated substrates are separated by an air gap maintained by tiny, insulating spacer-dots. When the top substrate is pressed, it flexes so that the two conductive coatings make contact. A controller alternately applies a voltage gradient in X and Y directions across the conductive coatings and measures the corresponding voltage drops to calculate the touch position.

Characteristic	ExtremeTouch	Resistive Touch
Durability of top surface	Glass: Extremely scratch-resistant; continues working even when cracked; resistant to most chemicals; unaffected by long exposure to UV	PET: Easily scratched or abraded; stops working when cut with a knife; damaged by many chemicals; turns yellow with long exposure to UV
Typical lifetime touches in a single location	250M pen & finger	100K pen, 1M finger (4-wire) 1M pen, 35M finger (5-wire)
Typical transmissivity	92%	80%
Substrates	1	2
Reflective surfaces	2	4
Fully-coated transparent-conductive surfaces	0	2
Air gap	No	Yes

Table 1: Durability and optical performance differences

Table 1 above summarizes the key differences in durability and optical performance between ExtremeTouch and resistive touch. The very large difference in durability between ExtremeTouch and resistive touch is due mainly to the location of the sensor. Resistive touch requires a flexible PET top layer because it's basically a mechanical pressure switch. The PET top layer is very susceptible to damage from users, vandals, chemicals and the environment. In addition, even if the top surface miraculously remains undamaged, resistive touch eventually stops working due to cracking of the transparent-conductor coating on the top substrate – that's what limits the number of lifetime touches. In contrast, the ExtremeTouch sensor is located behind a (typically) glass top surface, which provides an extremely high level of protection and a very long touch lifetime.

The very large difference in optical performance between ExtremeTouch and resistive touch is due mainly to the simplicity of ExtremeTouch's sensor. As described above in "How It Works", an ExtremeTouch sensor is a single substrate with parallel rows of transparent conductors on each side. Each conductor is extremely narrow so that the area occupied by transparent-conductor material is less than 0.1% of the total substrate area. In contrast, a resistive touch screen has four surfaces, two of which are fully coated with transparent-conductor material, making it much more difficult (and expensive) to control reflections. A resistive touch screen always has an air gap between the two substrates, which adds to the reflection-control problems, while the ExtremeTouch sensor is optically bonded to the top glass with no air gap.

The primary benefit of ExtremeTouch's higher optical performance is a brighter screen. If a given LCD has a rated light output of 200 cd/m^2, the light output would be 184 cd/m^2 with ExtremeTouch and only 160 cd/m^2 with a resistive touch screen.

Exploring Some of ExtremeTouch's Performance Characteristics

- Activation Pressure: ExtremeTouch registers a touch when the change in capacitance measured at a given location on the sensor exceeds a set threshold. This is quite different than resistive touch, where a mechanical force of around 60 grams on the top surface of the touch screen is required to register a touch. Once a resistive touch screen is manufactured, its activation pressure can't be changed. ExtremeTouch's touch sensitivity (i.e., the capacitance-change threshold) is adjustable. When the sensitivity is set high, a user doesn't actually have to touch the surface of the top glass; just approaching within a few millimeters is close enough to register a touch. When the sensitivity is set low, a user may have to press relatively hard on the top glass to register a touch. This adjustability provides the ability to customize the touch activation pressure to suit a particular application. Note, however, that it's not actually the amount of finger pressure that controls the touch activation; it's the amount of skin area. As a user presses harder, his or her finger flattens out so that the amount of skin area near the sensor increases, which changes the capacitance. One effect of this is that for a given sensitivity setting, skinny fingers may have to press a little harder than fat fingers to register a touch. This also means that the range of capacitance that's reported from minimum skin contact to maximum skin contact can't actually be interpreted as an absolute measure of finger pressure.

- Calibration Stability: In a resistive touch screen, the transparent conductive surfaces are basically big resistors (that's why it's called "resistive technology"). Unfortunately, this means that the measured voltages can drift with time and temperature, causing a need for periodic recalibration. (If you've ever owned a PDA, you're probably very familiar with this effect.) In contrast, ExtremeTouch's transparent conductors are more like an antenna array than resistors. There's no voltage measurement to drift. Also, ExtremeTouch's sensor is rigid and has no moving parts. Since it's laminated to the front glass, the physical arrangement of the X-Y intersections never changes and so the calibration remains constant.

- Accuracy: ExtremeTouch's rigid and unchanging sensor structure also produces a high degree of repeatability in reported touch locations – it's better than 1 mm. Expressed as a percentage it depends on the size of the touch screen; for a 10.4-inch screen it's 0.5%.

- Linearity: Yet another benefit of ExtremeTouch's sensor structure is excellent linearity. In a resistive touch screen, linearity is controlled by the uniformity of the transparent-conductor coatings. It's difficult and expensive to produce very uniform coatings, so the typical linearity specification for a resistive touch screen is in the range of 1.5% to 3%. In contrast, ExtremeTouch's linearity is controlled mostly by the degree of precision with which the parallel rows of transparent conductors are formed, which is easier to control. The result is a linearity specification of 0.8% for ExtremeTouch, more than twice as good as the average resistive touch screen.

- Resolution: Following touch-screen convention, ExtremeTouch reports resolution at 4,096 x 4,096 points. On the long side of a 10.4" touch screen, that's a resolution of 0.05 mm. Expressed in terms of dots per inch, it's 492 dpi, or roughly five times higher resolution than the typical 100 dpi LCD screen. Coupled with ExtremeTouch's maximum data rate of 120 samples per second, this resolution is more than adequate for accurately capturing pen-writing strokes.

Applications: ExtremeTouch's applications are constrained to some degree by the maximum size of the sensor, which is currently limited to 10.4 inches diagonal. Applications in this size range tend to be more common in mobile or portable products than in stationary products. Any product that requires an exceptionally durable and/or unbreakable, lightweight, thin, flat or curved touch screen is an excellent candidate for ExtremeTouch. This includes POS signature-capture terminals, VoIP phones, GPS systems, portable gaming devices, mobile phones, portable medical instruments, in-car devices, remote controls, set-top boxes, industrial control panels and security systems. ExtremeTouch's ability to turn almost any transparent surface into a functioning touch screen also allows applying it in a variety of more unusual environments such as in store windows, underneath glass table tops or inside art objects.

Summary of ExtremeTouch Benefits

Benefit	Source
Extreme durability	Embedded sensor
Enables very thin products	0.4 mm thick sensor
Applicable to curved touch surfaces	Flexible sensor
Senses through any transparent material	Projected capacitive architecture
Survives in extreme environments	Wide environmental specifications
Never requires recalibration	Zero drift
Usable with finger, gloved hand or tethered pen	Projected capacitive architecture
Customizable touch performance	Adjustable touch activation pressure
Brighter screens without increasing power	Very high optical transmissivity
Exceptionally long product lifetime	10-year warranty

Table 2: Summary of ExtremeTouch benefits and their sources

Summary of ExtremeTouch Specifications

Key Performance Specifications	
Resolution	4,096 x 4,096
Accuracy	< 1 mm
Linearity	0.8%
Maximum Data Rate	120 samples/sec
Response Time	< 10 ms
Maximum Pen Tracking Speed	1,016 mm/sec
Calibration Stability	Zero drift
Optical Transmissivity	92%; higher with customization
Touch Activation Pressure Range	Infinitely adjustable
Touch Durability	250M touches in a single location (glass)
Surface Hardness	Up to 9H (glass)
Surface Chemical Resistance	Standard (glass)

Table 3: Summary of key performance specifications

Key Functional Specifications	
Sensor Size	Up to 10.4" diagonal
Sensor Thickness	0.4 mm; thinner with customization
Sensor Weight	0.5 grams/in^2
Sensor Connector	Integrated tail
Touch Surface Thickness	Up to 15 mm
Touch Methods	Finger, gloved hand or tethered pen
Interfaces	Serial or USB
Operating Systems	Windows, XP-E, CE, Linux, Mac
Mouse Emulation	Full functionality
Controller	Touch International ASIC
Warranty	10 years

Table 4: Summary of key functional specifications