“New Touch Sensors” -- A White Paper

Introduction

Touch sensitive devices have become increasingly common – from cell phones to industrial touch panels to appliances. These devices typically use capacitive sensors to create the ‘touch’ surface. In reality capacitive does not require touch, but merely close proximity of an object capable of changing the capacitance of the system. Capacitive systems are typically limited to non-metallic materials, may not work well with gloves and can be susceptible to false activations caused by water. Even with these limitation capacitive works well for many consumer applications.

For situations with more stringent requirements – requiring a definitive touch, wet/underwater applications or high vandalism potential – another technology is possible. Trapped Acoustic Resonance technology expands touch-sensitive capabilities into metallic substrates. The technology, referred to simply as ActiveTouch, was developed by ITW (Illinois Tools Works) over the past seven years, and can turn a solid steel plate up to 0.5” thick into a touch sensitive surface with multiple switch points. The technology even works with ballistic steel, creating the potential for putting a switch in a bullet proof steel plate with no seams.

What is Trapped Acoustic Resonance?

Trapped Acoustic Resonance is most simply described with an analogy – the ringing of a bell. When a metal bell is struck a sound wave is produced by the vibration of the metal. As the metal’s vibrating energy dissipates, the sound slowly decays into silence. Strike the bell again, and quickly touch the bell, the sound dies very quickly as the vibrating energy is dampened by the touch. This change in vibration decay rate can be detected and used to indicate when an individual is touching the surface where it is ringing.

Principles of Operation

In practice this requires a substrate material capable of supporting shear and torsional mechanical waves at ultrasonic frequencies. This property is described as a high Quality Factor or high Q. When the surface of the high Q material is contoured as depicted below, the material can trap and localize ultrasonic energy. These trapped energy regions are referred to as Resonant Cavities.
When a resonator is set into vibration in the MHz range by a properly positioned piezo transducer, a wave motion is induced. The motion is confined to the shape of a cylinder, and it extends through the thickness of the metal.

The transducer serves double duty – both to create the mechanical resonance and to monitor its decay. A microprocessor controls the frequency and duration of the electrical input into the transducer – the hammer striking the bell. When the transducer is no longer being driven electrically by the microprocessor, the resonant vibrating energy in the substrate drives the transducer to create an electrical output signal – listening to the bell. This signal defines the characteristic decay of the resonance in the substrate.

The microprocessor develops an understanding of the normal decay rate for the system. Much like the bell, when the surface of the resonant cavity is touched, a finger absorbs the energy in the substrate creating a much faster energy decay rate. The left two oscilloscope traces below represent the untouched state of a switch, while the two traces on the right are indicative of what a touched state would look like. This continuous process of pinging, listening and evaluating occurs hundreds of times a second.

When the time to reach a threshold value in the decay curve is shorter than a predetermined value, the microcontroller registers a touch. Controlled by the microprocessor, the touch sensor is programmed to function like a switch – either Normally Open or Normally Closed, momentary, latching or with a time delay.
The rate at which the vibration decay is reduced to the threshold can be used to determine relative pressure sensitivity. The decay rate is a function of the contact material and normal force driving the contact. Some rubber materials dampen the ringing better than a finger, while some fabrics such as a fleece or silk dampen less. Leather work gloves dampen well. For a human-machine interface, the harder a user pushes on the switch surface, the quicker the decay to the threshold. This pressure sensitivity could be used to increase the scroll speed of a menu – the harder the user presses, the faster the menu scrolls.

Water, it was noted earlier, can be a concern for capacitive switches. Water also transmits acoustic energy well – compression waves (sound) travel well in water. However, the torsional and shear vibration that is created in the ActiveTouch substrate does not couple well with liquids. This greatly reduces the water sensitivity of an ActiveTouch sensor to water. Algorithms employed in the microprocessor filter any residual effect of water to eliminate water sensitivity.

Benefits beyond a typical switch
As the sensor goes through its ‘pinging, listening and evaluating’ hundreds of times a second, it can be thought of as having a heartbeat. The microprocessor is constantly monitoring the switch for a decay signal. If that decay signal is not evident, in either a touched or untouched state, the microprocessor can register an error and communicate this appropriately. In this manner the sensor can self-monitor performance and report abnormalities, aiding in trouble shooting or preventive maintenance. The failure of a traditional switch is not known until it is pressed and the desired response does not happen.

Because the shear and torsional energy can be trapped in the resonant cavities, putting multiple switch point into one substrate is possible. With microprocessor advances, a single processor can monitor multiple resonant cavities simultaneously. These two factors make multiple switch points very economical. And by incorporating multiple cavities in close proximity to one another, much like capacitive sensors, a scroll pad or slider can be created – only this time it is in a metal surface.

Traditional Piezo Switches
While the ActiveTouch technology use a piezo electric transducer, the similarities to traditional piezo switches end there. A traditional piezo electric switch requires a stress to be created in the piezo electric crystal, creating an electric pulse output. The force an individual applies to the metal surface of a piezo switch creates a stress in both the metal substrate and the piezo crystal. To reduce the force required to generate the stress on the crystal, the metal substrate often becomes quite thin.
This can be problematic for a couple of reasons. A thin substrate can be susceptible to external shocks and vibrations. These external shocks may couple with the metal substrate to create erroneous switch activations. ActiveTouch is not susceptible to external shocks and vibrations as the ultrasonic energy must be absorbed to trigger a switch. The ultrasonic frequency and narrow frequency band monitored prevent the ActiveTouch technology from being impacted by vibrations.

The thin metal substrate required for traditional piezo can also impact the spacing of piezo switch points. The switch points must be spaced so that a deflection on one location does not create a false trigger on an adjacent switch point. This leads to sense points spaced sufficiently far that a scroll pad or slider is no longer practical. Resonant cavities in the thicker ActiveTouch substrate eliminate this problem.

Finally, ActiveTouch’s thicker substrate also makes the switches less prone to vandalism. A typical piezo switch’s surface is less than 0.030” thick. Keypads using ActiveTouch technology are over 0.100”.

Limitations to ActiveTouch
While the ActiveTouch technology has many advantages over conventional switches, it does have its limitations:

- It is truly a three wire sensor programmed to function as a switch. The output can be modified via secondary circuits to meet virtually any application. But unlike a mechanical switch, switching high current or voltage will require a relay.

- The sensor requires a material with a high Q. This eliminates many popular plastics such as ABS or Polycarbonate. The technology does work well with a high glass filled PPS.

- A material capable of dampening the ultrasonic vibrations is required to trigger the switch. Fingers and leather gloves work well. Very thick synthetic fleece mittens require more force. Hard surfaces generally will not trigger a switch at all.

There are many benefits to the ActiveTouch technology which previously did not exist in input devices. There are numerous switch and interface technologies to choose from for benign environment applications. ActiveTouch technology provides an interface for the extremely rugged, mission critical applications.