A Comparison of Trapped Acoustic Technology and Standard Piezo Switching Elements

By: Donald Sweeney

Buffalo Grove, IL. - Experts in switch design have developed the next generation in switches and sensors, allowing design engineers the capability to achieve a higher level of functionality within electronic systems. ITW ActiveTouch, a division of Illinois Tool Works Inc. (ITW), has developed this advanced technology which utilizes principle of Trapped Acoustic Resonance and manufactures standard and custom solutions using it. With this unique innovation-driven technology, a detailed comparison to Piezo switching is needed to inform engineers of the capabilities, advantages, and design possibilities offered by ITW's ActiveTouch technology.

With the trend towards solid-state switching and sensing, a number of technologies have been implemented in production design including Hall Effect, electro-magnetic field (EMF), capacitive, reed, and piezo. Individually, these technologies have many advantages but also have a number of limitations. This document will detail the differences between Piezo Switch elements and ITW's ActiveTouch technology.

Piezo-Electric Switches

Overview:

A Piezo electric switch is a solid-state switching technology that uses the direct piezoelectric effect. The physics behind this mechanism are such that when a mechanical force is applied to a piezoelectric element there is a small displacement and subsequent strain on the dielectric material. This strain causes a build up of an electric field that outputs a discrete voltage signal. Piezo switch elements typically have a piezoelectric transducer physically mounted on the back of a thin metal surface (0.4mm to 0.7mm thick), the size of which is based on desired force requirements of the user (2-4 N). There have also been recent advances in design that can identify if a user is continuously pressing on a switch location versus pressing and quickly releasing.

Advantages:

There are a number of advantages to piezo switch devices. The first is that there are no moving parts such as contacts, springs, or actuator systems, resulting in fewer failure modes, reduced wear, and a long life (i.e., 50 million cycles). The electronics within a piezo switch can also be fully potted protecting the components from the environment and making it impervious to water, oil or dirt. Having the 'behind panel' design provides advantages similar to glass-capacitive in accomplishing a sleek contemporary appearance, protection of control components, seamless, smooth and easily cleaned surface, and a system not affected by spills (either intrusion or causing havoc on electronics). Many solid-state devices are limited by activation with insulated materials such as gloves, but since the technology is force related, piezo switches can be activated by non-conductive materials.

Disadvantages:

The above advantages make piezo switches attractive for a number of designs. However, there are also many limitations that must be considered during the design stage. These include factors such as vibration and pressure, material properties, cost, capability, and design flexibility. This technology is typically thought of for applications such as vending machines, ATM's, and security control panels due to its perceived robustness. However, consider some of the following points:

Since piezo switches are actuated by a strain in the material, they can be falsely activated in a number of ways such as objects inadvertently coming into contact with the switch (i.e., an object falling onto or a person bumping up against a switch, wiping a control panel down for cleaning, etc.), or pressure effects (i.e., high G forces, underwater applications, etc.).

The piezo switch can be a stand-alone switch element or designed in as part of a panel. There are a number of limitations on the panel design when using piezo. First, due to the physics of material thickness and mechanical deflection, the switch elements must be physically isolated from each other in order to prevent a false activation on adjacent switch points. For example, if placed too closely together, applying a force to one switch point might inadvertently activate adjacent switch points due to the strain that was displaced across the surface. A second limitation is the material thickness. The material thickness must typically be 0.030" or less in order to produce the required deflection. Thicker surfaces would be incapable of providing a sufficient strain on the piezo or require such a large force by the user that it would be difficult to operate. This reduction in material thickness can ultimately introduce a weak point, susceptible to vandalization, impact, etc., and objects such as screwdrivers can easily puncture through the switch surface (see Figure 1).

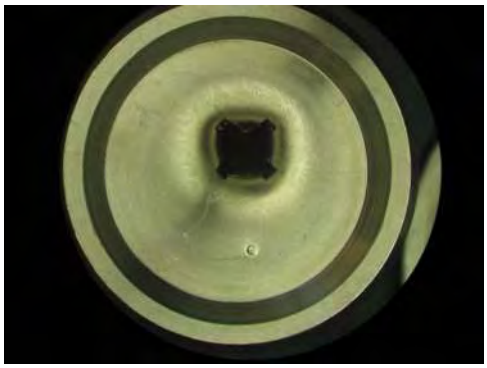

Figure 1: A piezo switch that was punctured with a screw driver

Another disadvantage of piezo is that, unless advanced circuitry is provided, the output is typically only a discrete pulse output (i.e., 5V for a millisecond) regardless of the duration of time the user is pressing on the switch surface.

Overall, piezo switches do offer some distinct advantages, however, they are also limited by a number of disadvantages. But what if you want more…?

ActiveTouch

Figure 2: ITW Switches 'ActiveMetal' line of panel mount switches

Overview:

ActiveTouch is also a solid-state technology that uses the piezoelectric effect, but in a truly revolutionary manner. First, using the indirect piezoelectric effect of converting an electrical charge into mechanical energy, a piezo element bonded to a switch/sensor surface is energized to

introduce a mechanical vibration into the medium in the MHz frequency range. The piezo element is then de-energized, and as the material continues to resonate, the direct piezoelectric effect works to convert the mechanical energy back into electrical energy. A microprocessor is used in the system to send and receive these electrical signals to and from the piezo element, as specified by the governing firmware. The returned electrical signal has a distinct decaying electrical waveform that is processed. Based on the acoustic properties of the medium and specific material geometries, the waveform has minimal loss under normal untouched circumstances. In order to create an activation, the user must dampen the mechanical energy in the material – typically by a fingertip, gloved hand, or other acoustically absorbing material.

Disadvantages:
The disadvantages of the ActiveTouch technology are minimal and can be designed for based on specific customer applications. The advantages shown below will identify factors that allow for design flexibility and why this technology is best suited for a number of applications.

Advantages:
One of the great advantages is that the technology is always 'Active' – i.e., sending, receiving, and interpreting the electrical signals (once every microsecond). The microprocessor-based nature of the technology provides a number of advanced features.

Input/Output: The ActiveTouch technology offers a number of input/output combinations based on the application as opposed to only simulating a contact closing as piezo switches do. Inputs can vary in voltage from standard offerings of 5VDC or 10-24VDC to custom electrical requirements (i.e., overload protection). Outputs are typically either digital or sinking open collector with the particular switch function easily modified. Controlled by firmware, switch activation can be normally open (NO), normally closed (NC), normally high (NH), normally low (NL), momentary, latched (maintained), or proportional (i.e., 0.5-4.5V), CAN bus, serial, in series or in parallel, or a number of customer specified outputs. Signal processing also eliminates the need to perform contact bounce analysis or have complicated algorithms within a control system. The advanced input/output offerings provided by ActiveTouch requires wiring to accommodate power, ground, and signal whereas Piezo switches have just a 2-wire connection. Piezo elements do not consume power whereas the ActiveTouch technology must be constantly powered. However, the power consumption is minimal with 25 microamps typical of most designs and there is also the capability for power saving features within the microprocessor. Similar to Piezo switches, ActiveTouch can handle logic level loads whereas high current applications can be driven with the addition of a relay or other circuitry.

Material Properties: The ActiveTouch technology is offered as an individual switch module in ITW's ActiveMetal product line, but can also be integrated directly into custom metal panels. This mounting provides the same advantages as Piezo including no moving parts, fully sealed, highly aesthetic appearance, and seamless design. However, there are also many differences in this area that give ActiveTouch distinct functional advantages over Piezo switches. First, the panel can be much thicker (up to 0.500"), creating an extremely robust system (see Figure 3). Switch locations can be placed closely together (six within a linear inch), have high sensing accuracy that can be defined by the user, and are independent of adjacent switch elements. With a grounded metallic enclosure, electrostatic discharge (ESD) is of no concern due to the Faraday cage effect. In addition to metals, ActiveTouch can be applied to glass, some rigid plastics, ceramic, and other resonating materials. ActiveTouch, however, is not limited to a small switch diameter. Large, curved, or irregularly shaped surfaces can be made touch sensitive providing unmatched design freedom.

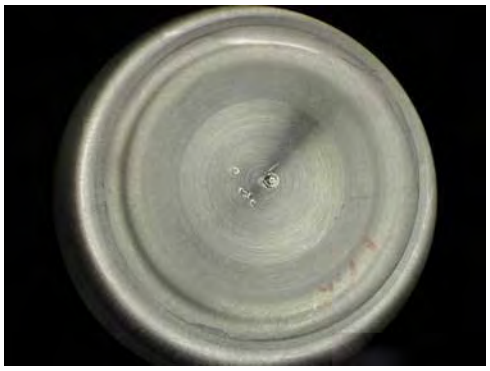

Figure 3: An ITW ActiveMetal switch that was attempted to be punctured. The switch still functioned after being tampered with.

Adaptability and Diagnostics: The activation by a user is not related to 'force' but rather 'dampening' which can prevent a number of inadvertent switch activations. Software can even identify a length of time that the switch must be dampened before outputting a signal. Similarly, if the sensor identifies a change in state, it can calibrate to adjust (i.e., changes in temperature, deformation of the material surface, etc.). The sensitivity threshold can be modified to meet customer desires (from zero force to much higher levels). Again, being always 'Active', the sensor can communicate with a controller its present state (working, loss of connection, mean time until failure, etc.). This makes the technology ideal for mission critical applications, allows for fast troubleshooting and repair, and can reduce or eliminate down time.

Can't Compete: There are certain features of the ActiveTouch that make it one of a kind and therefore ideal for many products and applications. First, there are no known technologies that can offer a proportional output with no moving parts. By using multiple threshold levels in processing the waveform, ActiveTouch can output a linear signal with no moving parts simply by dampening further. Second, many technologies are adversely affected by liquids, ruling them out for outdoor, underwater, or similar applications where liquids may be present. Liquids, however, do not affect the ActiveTouch technology which can even be used in underwater applications. Third, the technology can not only be a 'switch', but a sensor as well. Passenger presence detection, ice detection, fluid level, and a number of other potential sensing capabilities make the technology attractive. Finally, the ActiveTouch technology is a proprietary technology to ITW making it nearly impossible for competitors to duplicate design efforts – providing a potentially a huge competitive advantage.

Costing Analysis: The ActiveTouch technology is a value-add solution that can provide functionality not available by other technologies, improved reliability due to durability and diagnostic capabilities, and a strong competitive advantage.

The Bottom Line:

There is a trend and a number of advantages in moving toward solid state switching devices such as Piezo or ActiveTouch. At the same time, many other technologies work well for their intended applications. The difference, however, is that the ActiveTouch technology can now offer engineers nearly unlimited flexibility when challenged with a switch or sensor design.

For more information on this analysis or the ActiveTouch technology, please contact ITW ActiveTouch online at www.itwactivetouch.com or by calling 800-544-3354.

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