AN1325

mTouch™ Metal Over Cap Technology

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INTRODUCTION

As a user interface, capacitive touch has several advantages: it is low power, low cost, simple to implement, reliable mechanically, and it allows designers a great deal of freedom in the shape of the buttons. However, for all its advantages, the field effect nature of capacitive touch still has some limitations.

1. Standard capacitive touch systems normally do not work through metal coverings.
2. It requires special software to operate in environments with radiated and/or conducted noise.
3. Reading buttons in the presence of water or other contaminants can be difficult.
4. It is problematic for visually impaired users that rely on Braille.
5. It has trouble detecting a touch through gloves.

Microchip's new Metal Over Capacitive user interface system overcomes all of these limitations without compromising power consumption or design simplicity. This application note describes how to create an interface using the Metal Over Capacitive touch system.

THEORY OF OPERATION

In a traditional capacitive system, the user changes the capacitance of a touch sensor by placing their finger in close proximity to the sensor. The user's finger then forms the second plate of the capacitor, raising the sensor's capacitance.

The Metal Over Cap touch system uses a conductive target, suspended over the capacitive touch sensors, to form the second plate of the capacitor. When a user applies a downward pressure on the target, the resulting deformation of the target moves it closer to the capacitive sensor. The change in spacing produces a change in capacitance which is then measured by a microcontroller. See Figure 1A for a cross-section of a typical metal over capacitive touch sensor. Figure 1B demonstrates the deformation due to a user's press.

Figure 1C shows an alternate configuration that employs a metal target bonded to the back of a plastic fascia layer. The target in this configuration can be either a thin sheet of metal bonded to the back of the plastic fascia, or a metal flashing onto the plastic sheet.

Note: While the metal target still performs the same electrIcal function as a metal fascia system, it is the physical characteristics of the plastic which determine the mechanical deviation to the user's press in this configuration.

FIGURE 1A: CROSS SECTION OF METAL OVER CAPACITIVE (UNPRESSED)

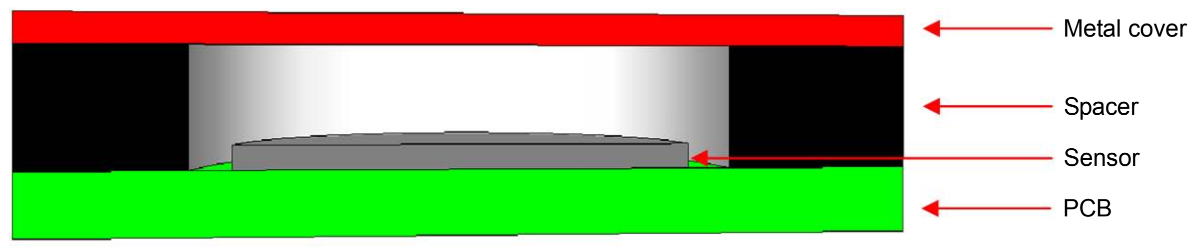


FIGURE 1B: CROSS SECTION OF METAL OVER CAPACITIVE (PRESSED)

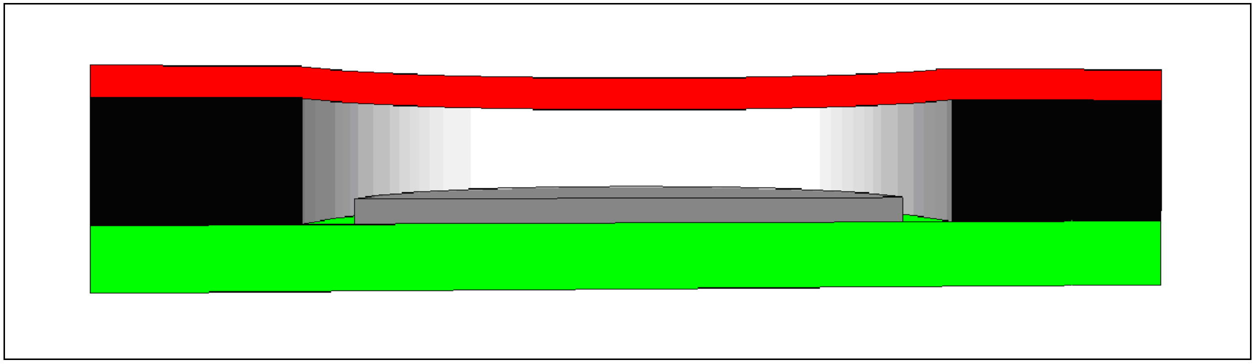
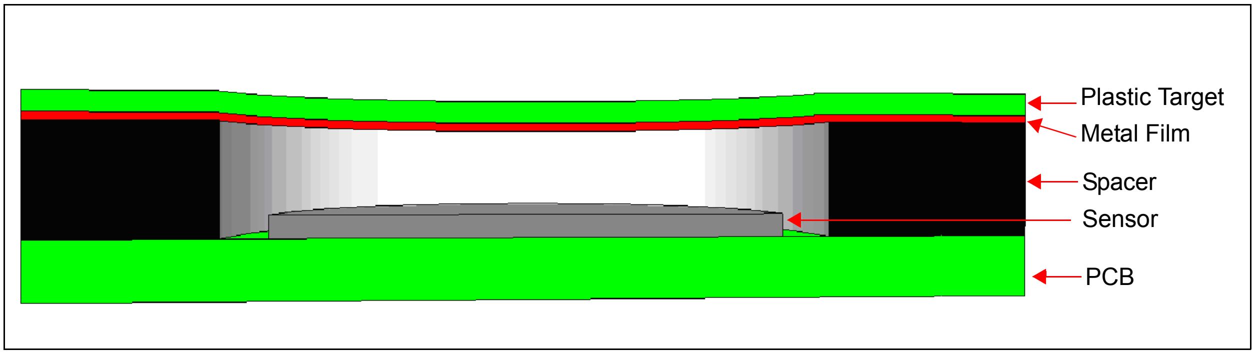


FIGURE 1C: CROSS SECTION OF METAL OVER CAPACITIVE (PRESSED) USING A PLASTIC TARGET



MECHANICAL DESIGN

The mechanical design of the system involves 5 factors:

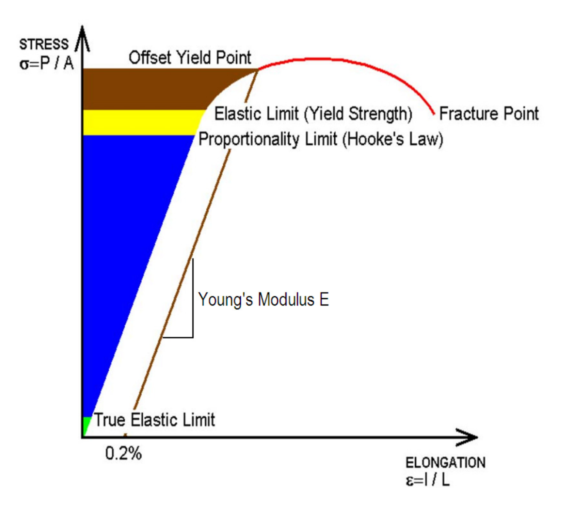
1. Thickness of the fascia layer
2. The size of the buttons
3. The spacing of the buttons
4. The adhesives used to bond the spacer and target layers to the PCB
5. Thickness of the spacer layer

The Thickness of Fascia and/or Target

When properly designed, the user's press on the target should create a measurable non-permanent deflection in the target of the desired sensor, while minimizing the movement of any adjacent sensors.

The first step is to choose a target material and determine/research its physical characteristics. Figure 2 shows a typical graph of stress versus elongation. The origin of the graph shows the at-rest state for the material, no stress and no change in the physical dimensions of the material. When stress (force) is applied to the material, it will elongate (stretch) elastically, with the amount of stretch being proportional to the amount of force applied. As long as the amount of stress does not exceed the yield strength of the material, then removal of the force will result in the material returning to its original dimensions. However, if excessive force is applied, the material can bend permanently or even break.

FIGURE 2: CHART OF STRESS VERSUS ELONGATION



The two important numbers to take away from this kind of material graph are the proportionality constant (Young's Modulus E), which determines the amount of stretch for a given force, and the yield strength, which determines the maximum force before bending (σ_y).

Size of the Buttons

These two factors (E + σ_y), when combined with the size of the thickness of the target and the size of the buttons, will determine the minimum and maximum amount of force that can be applied to the target. The minimum force V determines the minimum detectable deflection or sensitivity, and the maximum force will determine the bending strength of the button.

Balancing these factors provides the trade-off between the size of the buttons, the minimum actuation force, and the type of material used for the target.

The Spacing of the Buttons

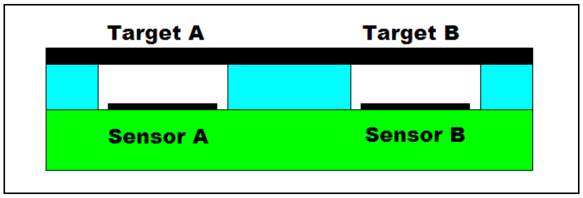
The next consideration is the spacing of the buttons. Figure 3 shows a typical mechanical design for two adjacent buttons.

One of the basic assumptions of the mechanical design is that a force applied to one button should not have a measurable affect on an adjacent button. The two factors that affect how the buttons interact are the elasticity of the target material and the adhesion of the adhesive used to bond the target to the spacer.

Adhesive to Bond Layers

If the target is too stiff and the adhesive is elastic, then a force applied to button A will cause the target over sensor B to lift. The result is a decrease in the capacitance of sensor B, a decrease in the average value for sensor B and a reduction in its sensitivity due to the offset of its threshold. To combat this problem, it is suggested that the space between buttons be at least 1/3 to 1/2 the diameter of the buttons. Furthermore, the adhesive used to bond the target to the spacer should be a permanent adhesive with good adhesion to both the target and spacer materials. Given the variety of materials that could be used for both layers, it is suggested that the manufacturer of the adhesive be contacted concerning the requirements and applicable adhesives.

FIGURE 3: MECHANICAL CONFIGURATIONS OF 2 ADJACENT BUTTONS



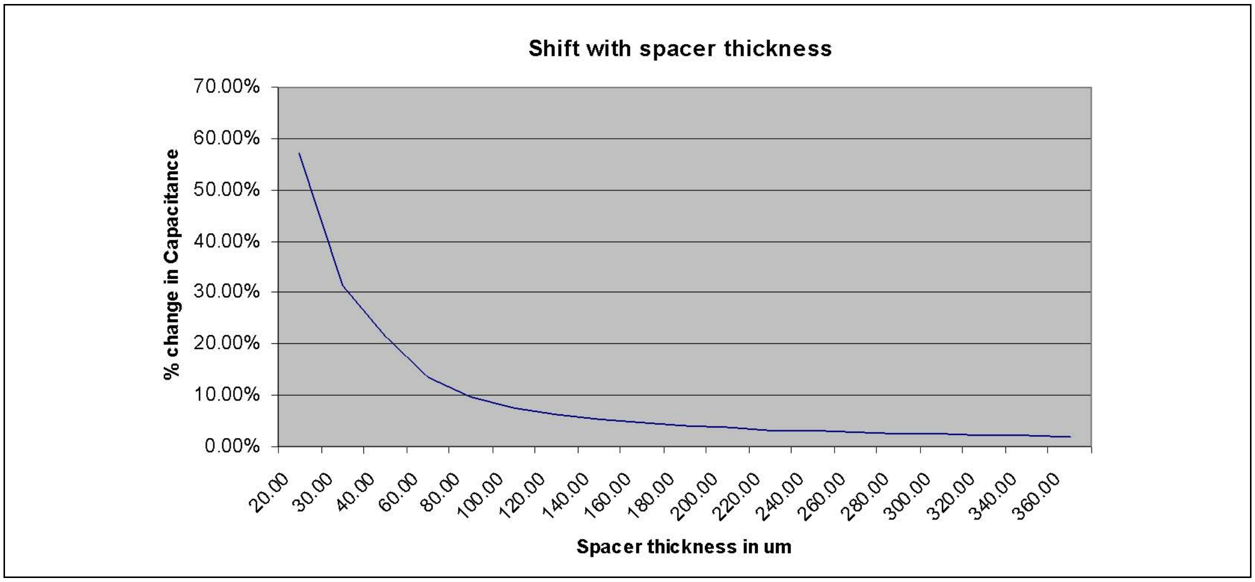
Thickness of the Spacer Layer

The final factor to consider in the mechanical design is the thickness of the spacer material. The operation of the sensor is based on the movement of the target layer, in response to the user's press. This deflection results in an increase in the sensor capacitance because the distance between the plates of the capacitor is decreased.

Note: This also means that the spacer layer must be rigid to provide the necessary deviation in the target layer without flexing in the PCB. To prevent movement in the spacer, it is recommended that the spacer layer be made from a rigid material such as FR4, or non-deformable plastic film. It may also be necessary to provide rigid mechanical support to the back of the PCB to prevent flexing of the entire target/spacer/PCB stack and loss of sensitivity.

To create a sensitive touch sensor, it follows that the amount of shift generated by the user's press should be a significant percentage (6% minimum) of the unpressed spacing between the target and the sensor. Figure 4 is a graphic showing the shift in capacitance versus spacer thickness. Note that a capacitance shift of 6% is advocated as a minimum. This amount of shift is required because any parasitic capacitances in the system, when combined with the resolution limit of the conversion technique, will reduce a 6% shift at the sensor down to a 3-4% shift in the conversion result.

FIGURE 4: CAPACITANCE SHIFT VERSUS SPACER THICKNESS



ELECTRICAL DESIGN

The electrical design for converting the capacitance of the sensor into a digital value is identical to the methods used for traditional capacitive touch interfaces. Microchip offers two systems, CVD and CTMU, both of which are covered in their own individual application notes. CVD is discussed in AN1298, "*Capacitive Touch Using Only an ADC*", and CTMU is discussed in AN1250, "*Microchip CTMU for Capacitive Touch Applications.*" Please refer to these publications for the appropriate hardware and firmware design information.

A simple method for increasing the resolution of the conversion is to average together multiple samples for each sensor (oversampling). This method works because each conversion by the ADC, in both CVD and CTMU, is subject to ambient noise present on the sensor input. This noise produces output values both above and below the actual voltage on the sensor. The summation of these sample values yields a sample with additional bits of resolution which are proportional to the actual input voltage relative to the conversion values. For implementation information, refer to the next section on the system firmware.

In a typical application, one or both of the above methods are typically combined to provide a 12 to 14-bit result. This typically yields a shift of 60-100 counts for a 6% shift in capacitance, assuming reasonable care in the PCB layout.

NOISE

In addition to software-based systems for limiting noise; there are both mechanical and electrical techniques included in the design to limit noise.

For the target layer to work effectively as the second plate of the capacitive touch sensor, it must be AC grounded. Typically this is accomplished by putting a ground plane on the top of the PCB, around the sensor pads. However, DC grounding the target over the sensors is highly recommended to limit noise in the system. A good ground connection, at multiple points, will provide a kind of Faraday Cage for the sensors, protecting them from electrical interface from external sources. Placing a ground plane, both behind the sensors and around the sensors beneath the target layer also help to limit the introduction of noise. Finally, routing the connections to the sensors, on the top side, will also protect the inputs from external noise sources.

Good bypass capacitor selection in the design is also a recommended practice for the design. The best bypass capacitor choice is actually the paired combination of a 1nF capacitor in parallel with a 0.1 µF capacitor. All capacitors have a series resonant characteristic, which is a function of their bulk capacitance and the parasitic inductance of the capacitor and its leads. The self-resonant frequencies for the different values are typically on the order of several hundred kilohertz and 10s of megahertz. In parallel, they provide a noise trap that is effective across the majority of the microcontroller’s operating frequency range.

CONCLUSION

The combination of a deformable target layer and the low power/simplicity of capacitive touch create a very powerful combination for the designer. Challenges with water and noise are eliminated, the proximity trigger effect is replaced with a designer specified actuation force, and the system retains the low-power operation of capacitive touch.

- Works through metal and plastic
- Works when submerged under water
- Works with gloves
- Works with Braille
- Low Cost and Low Power
- Simple to implement
- Flexible button shape

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