INTRODUCTION

One of the greatest advantages of a Metal Over Capacitive (MOC) system is the flexibility of its sensors. Literally, hundreds of different sensor designs are possible, and the same look and feel can be achieved using several different implementations. With this dizzying array of potential solutions, it can be difficult to focus in on a specific design unless the designer is also well acquainted with all of the different design options and their associated strengths/weaknesses. Consulting with a mechanical engineer is also strongly recommended because they will be more knowledgeable about the available materials, their characteristics, and recommended manufacturing processes.

The purpose of this application note is to provide an overview of the available techniques, their advantages, limitations, and general recommendations for implementation in production. While this application note is intended to teach the basic implementation techniques of Metal Over Capacitive, designers are encouraged to discuss their specific needs with a qualified mechanical engineer, as he/she will be more familiar with current technologies/techniques and can provide valuable insight into the design process.

The layout of this application note is as follows:
- General Review of Metal over Cap Technology
- Choosing an Appropriate Fascia and Target Design
- Choosing a Design Implementation for a Spacer Layer
- Backlighting Methods
- Relocating the PCB
- Trouble-Shooting Problems
- Vendors
- The Sticky Business of Adhesion

More information can be obtained on Microchip’s web site http://www.microchip.com.

GENERAL REVIEW OF METAL OVER CAP TECHNOLOGY

The basis of any MOC touch system is a standard mTouch™ capacitive sensor, electronics and software. The difference in a MOC design is the replacement of the user’s finger with a conductive target layer, suspended over the capacitive touch sensor by a thin spacer. When the user presses on the target, it deforms slightly (<10 µm) toward the sensor, creating a detectable change in the sensor capacitance. The capacitive touch interface (electronics and software) detects the change in capacitance and reports the press to the system.

This system has several advantages:
- The sensor is electrically isolated from the environment limiting noise, proximity and cross-talk problems
- The grounded target provides a non-destructive path for ESD energy
- The isolation of the sensor from the environment also eliminates problems with water
- The requirement for physical force to actuate the sensor facilitates the use of Braille and use by gloved users
- Metal coverings often present an appearance of greater value/professionalism

To build a MOC sensor system, a standard capacitive sensor, a spacer (with a hole over the sensor) and a conductive fascia/target are needed. Figure 1 shows a typical sensor stack-up. In this example, the target provides both the conductive second plate of the capacitive sensor and the elastic flex required to return the layer to its original position upon release.

FIGURE 1: TYPICAL METAL OVER CAPACITIVE SENSOR STACK-UP
While this sounds simple, the variety of implementation options can be a bit overwhelming to a first-time designer. So, each layer will be discussed individually with an explanation of the various options, their strengths and their weaknesses.

**CHOOSING AN APPROPRIATE FASCIA AND TARGET DESIGN**

In the previous section, the fascia is defined as the top surface of the assembly with the marking/legends for the button. The target is defined as the conductive layer that provides the second conductive surface for the sensor capacitor. Together, they provide information to the user, the grounded second layer of the sensor capacitor and the mechanical elasticity of the button.

Before choosing materials for the fascia and target, there are a few questions that need to be answered first:

- How much actuation force will be required to press the buttons?
- What is the desired physical appearance of the fascia?
- What kind of environmental factors are important?
- Will the button need to be back-lit?
- Will backlighting of the fascia/target be required?

In this application note, we will consider the design of the fascia and target together, as most of the potential design options rely on both layers working closely together for proper operation. We will also evaluate each of the design options in light of the answers to the above questions.

There are three basic fascia/target design combinations:

- Fascia and target area single layer of metal (see Section “Single Metal Layer”)
- Plastic fascia with a metal flashing as the target (see Section “Plastic Fascia with Metal Flashing for the Target”)
- Fascia and target are a metal and plastic co-molded composite layer (see Section “Co-molded Metal and Plastic”)

**Single Metal Layer**

The simplest implementation is the single metallic layer acting as both the fascia and target. In this design, the fascia layer can either be the markings on the top of the metallic target, or a printed film bonded to the target. The single layer of metal provides all of the mechanical elasticity for the button and the grounded second plate of the sensor capacitor (target). Figure 2 shows a typical example of a single layer metal stack-up.

**Note:** If a printed film is used for the fascia, the legend should be printed on the back of the fascia to protect it from chemical attack and abrasion. Care must also be taken to use an appropriate adhesive that is compatible with the plastic film, the ink used in the legends, the metal and any coating (such as anodize) that may be present on the surface of the metal. This will prevent visible blemishes, air bubbles and delaminating of the fascia. Appendix A: “The Sticky Business of Adhesion” provides some general information on the choice of adhesives.

**FIGURE 2: SINGLE LAYER METAL OVER CAP STACK-UP**

**ACTUATION FORCE**

In this fascia/target configuration, the actuation force is determined by the relationship between several factors:

- The thickness of the metal fascia/target
- The size of the buttons
- The elasticity of the metal used
- Any back-etching of the fascia/target

For the most part, the size of the button and the thickness of the material are the primary factors affecting the actuation force.

One of the most significant factors which determine the actuation force of the button is the elasticity of the metal used in the fascia/target layer. For example, stainless steel is flexible, but not as flexible as aircraft-grade aluminum. Aluminum, on the other hand, has a lower yield strength, so while it is more flexible, it is also more susceptible to denting/dimpling when subjected to high actuation force. As a result, the choice of material for the fascia/target is a trade-off between sufficient elasticity for a low actuation force.
and sufficient yield strength to prevent damage when subjected to high actuation forces. To determine which material is best for a design, the user should use the supplied Deflection Calculator from the Microchip web site ([http://www.microchip.com/pagehandler/en-us/technology/mtouchbuttons/technology/metal-over-cap.html](http://www.microchip.com/pagehandler/en-us/technology/mtouchbuttons/technology/metal-over-cap.html)) and try out different combinations of material, material thickness and button sizes until an appropriate compromise can be reached. This is also a subject that should be discussed with mechanical designers, as the metal choice may have an impact on the enclosure of the system.

**APPEARANCE**

Oddly enough, this requirement is one of the least restrictive of the four questions. Modern silk screen and coating techniques allow a sheet of metal to look like anything from granite to wood. In addition, the surface of metal fascia can be completely or selectively plated with other metals for both appearance and legends/markings. Anodized aluminum can even be printed with photo-grade images.

![Note: One potential pitfall in using stainless steel is that the designer should avoid using annealed stainless, as its yield strength is significantly lower than regular stainless.](http://www.microchip.com/pagehandler/en-us/technology/mtouchbuttons/technology/metal-over-cap.html)

The challenge with annealed stainless is that the yield strength is very low to allow easy forming of the metal in production. If annealed stainless is used, it can result in dented or dimpled button cover if the fascia/target is subjected to a high actuation force by the user. While this does not prevent the buttons from continuing to operate, it does detract from the appearance of the button.

**ENVIRONMENT**

The two main concerns with the environment are abrasion and chemical resistance (including water). Stainless steel is resistant to most common cleaning chemicals, including water, and has good resistance to abrasion. Plain steel, on the other hand, is susceptible to rusting, chemical discoloration, and is only moderately resistant to abrasion. Aluminum has good abrasion resistance due to its anodize coating, but the anodize is porous so it can be easily stained if not sealed with a polymer overcoat.

**BACKLITTING**

Many designers tend to avoid a metal fascia/target because they erroneously assume that it cannot be back-lit. In actuality, a metal fascia/target can be back-lit, it is just a little more expensive than a polymer fascia. Typically, back-lighting is accomplished by selectively perforating the metal and back-filling with a polymer to seal out dust and moisture. More information on methods for back-lighting metal fascia/target implementations will be presented in Section “Back-lighting Methods”. See Figure 3 for an example of how micro-perforations can be used to back-light a metal fascia/target.

![FIGURE 3: MICRO-PERFORATIONS BACKLIGHTING](http://www.microchip.com/pagehandler/en-us/technology/mtouchbuttons/technology/metal-over-cap.html)

**SUMMARY**

Using a single metal layer for the fascia and target provides a relatively simple design solution.

- Stainless steel or aircraft grade aluminum are the typical choices for the metal layer.
- A stainless steel design tends to be stiffer than an aluminum one, typically necessitating a thinner layer or larger buttons for the same actuation force.
- The fascia side of the layer can be marked to simulate any appearance.
- Stainless steel and aluminum typically do not have problems with abrasion or chemicals. Aluminum does require a sealing agent to prevent staining of its anodize surface.
- A metal fascia/target can be back-lit, with certain limitations and additional costs.

**Plastic Fascia with Metal Flashing for the Target**

The second easiest implementation is to use a plastic fascia layer with either a silk-screened or vapor-deposited metal flashing for the target. Like the Single Metal Layer design, the plastic fascia provides a surface for the markings, but it also provides the elasticity of the button. The metal flashing on the bottom of the plastic layer only provides a grounded second plate of the sensor capacitor (target). See Figure 4 for a stack-up example.

![Plastic Fascia with Metal Flashing for the Target](http://www.microchip.com/pagehandler/en-us/technology/mtouchbuttons/technology/metal-over-cap.html)
FIGURE 4: EXAMPLE OF A PLASTIC SENSOR STACK-UP

ACTUATION FORCE
In this design configuration, the actuation force is also determined by the relationship between button size and any back etching, but it relies on the thickness and elasticity of the plastic used. As before, the smaller the button and the thicker the material, the more actuation force would be required. However, while stainless and aluminum are relatively stiff, plastic is much more flexible than metal. This allows for a thicker fascia/target layer while retaining the same actuation force. It is also more tolerant of high bending angles, making it relatively immune to denting and permanent deformation. This is the reason why the Deflection Calculator also includes several plastic material specifications and an option to enter the Young’s Modulus of any other material available in the market. Thus, the designer is encouraged once again to download the tool and play with different materials and configurations until an acceptable compromise can be found. The deflection tool can be found at: http://www.microchip.com/pagehandler/en-us/technology/mtouchbuttons/technology/metal-over-cap.html.

APPEARANCE
As with metal, modern silk screen and coating techniques also allow a sheet of plastic to look like any surface the designer might require. The surface of the plastic substrate can also be completely or selectively flashed with metal coatings for both appearance and legends/markings. Figure 5 shows several examples of flashed and texture metal coating.

One difference in plastic designs is the potential problem of maintaining optical clarity in larger thicknesses of material. Polyester can have problems with clarity, but in the thicknesses typically used for sensor designs this is usually not an issue. Both Polycarbonate and Polyethylene have good optical clarity. Adhesives can also be found with good optical clarity but it is necessary to specify optical clarity when choosing an adhesive, as this is not a common feature. Make sure that the combination of plastic and adhesive is appropriate to avoid a cloudy or fuzzy appearance.

TABLE 1: MATERIAL CHARACTERISTICS OF COMMON PLASTICS APPEARANCE

<table>
<thead>
<tr>
<th>Material</th>
<th>Abrasion Chemical Resistance</th>
<th>Optical Clarity</th>
<th>Temperature Range</th>
<th>Available Coatings</th>
<th>Life Cycles</th>
<th>Mechanical Behavior</th>
<th>Cost</th>
<th>Dielectric Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyester</td>
<td>Yes</td>
<td>Poor at thicker gauges</td>
<td>-40°C to 85°C</td>
<td>Gloss Hardcoat</td>
<td>1 million</td>
<td>Formable, durable, dimensionally unstable with temperature</td>
<td>8 mil</td>
<td>$1/sq ft</td>
</tr>
<tr>
<td>Acrylic</td>
<td>Moderate Hardcoat</td>
<td>Good with no UV Yellowing</td>
<td>-35°C to 71°C</td>
<td>Hardcoat</td>
<td>100,000</td>
<td>Lightweight and rigid, Will Chip on impact</td>
<td>60 mil</td>
<td>$2/sq ft</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>Moderate Hardcoat</td>
<td>Good, but prone to UV Yellowing</td>
<td>-40°C to 130°C</td>
<td>Gloss Hardcoat</td>
<td>100,000</td>
<td>Easy to print on, easy to bend and form. Dimensionally stable with temperature</td>
<td>60 mil</td>
<td>$2.40/sq ft</td>
</tr>
</tbody>
</table>

FIGURE 5: EXAMPLES OF TEXTURED METAL COATINGS

ENVIRONMENT
While water is no longer a major concern with a plastic fascia, abrasion and chemical resistance become more significant concerns. Another potential environmental problem is the dimensional stability of the material over temperature. If the fascia material expands at a significantly different rate than the materials it is bonded to, the adhesive can fail, resulting in false triggers, variable sensitivity and significant sensor-to-sensor cross-talk. Therefore, the selection of the plastic to be used for the fascia will likely be dictated solely by the environmental requirements of the design.
An environmental concern for both food preparation and medical markets is the resistance of the material to microbial contamination. Both Polyester and Polycarbonate come with an optional anti-microbial coating, making them a preferred choice for both markets.

If the sensor is also going to be exposed to direct sunlight, anti-fogging and resistance to UV yellowing are also desirable characteristics.

See Table 1 for a comparison of material characteristics.

BACKLIGHTING
While metal has many environmental advantages over plastic, clear and translucent plastics are the easiest materials to backlight. Not only will plastic pass light, but it will also pipe light along its length, allowing the use of side-light LEDs to backlight the entire surface of the sensor design. If a metallic surface plating is used, then a simple etching process can leave pin-hole openings that mimic the much more expensive backlighting options mentioned for solid metal fascia/target layers. More information on methods for backlighting are presented in Section “Backlighting Methods”.

SUMMARY
Using a plastic fascia flashed or silk-screened with a metallic target also provides a relatively simple design solution:

- Polyester, polycarbonate and acrylic provide less stiff options for a fascia/target design than metal.
- The fascia side of the layer can be marked to simulate any appearance, including metallic.
- Plastic designs require that the designer keep in mind the various abrasion and chemical susceptibilities of the plastic, including the effects of direct sunlight.
- Plastics have few restrictions concerning backlighting.

Co-molded Metal and Plastic

The third implementation option is combining plastic and metal into a single-layer fascia/target. The metal layer is etched or stamped, leaving an empty space around the switches. Plastic is then injection-molded in to fill the gaps. The main advantage of using metal with plastic is that it combines the advantages of both. The resulting design enjoys the abrasion resistance of metal, the transparency/translucency of plastic, and an actuation force that is stiffer than plastic, yet softer than metal alone. In fact, the actuation force can be adjusted by varying the ratio of plastic to metal involved in the flex of each button. Figure 6 shows an example of a co-molded fascia/target layer. The lighter gray material is aluminum and the darker gray is the plastic injection molded around the sensor.

ACTUATION FORCE

In a co-molded design, the actuation force is determined by all the same factors as a metal or plastic-only design: button size, material thickness, material elasticity and back-etching. The difference is that the actual force will be determined by a weighted average of the characteristics of the two materials. This will put the actuation force for the design somewhere between the figures for an all-plastic or all-metal design. Unfortunately, an exact calculation of the actuation force is heavily dependent upon the geometry of the sensor. A useful approximation can be made by using an average of the all-metal and all-plastic calculations. Simply start by calculating the actuation forces of two similar buttons, one made from all-plastic and the other from all-metal. Then, calculate how much of the button perimeter is plastic and how much is metal, and scale the two actuation force values by the percentage of each in the perimeter of the button. Taking an average of the two results will give a rough estimate of the actuation force for the co-molded design. The desired actuation force can then be adjusted by varying the ratio of metal to plastic, and any fine tuning can be made by adjusting the button trip threshold in the software (see Equation 1).

EQUATION 1: APPROXIMATION OF ACTUATION FORCE FOR CO-MOLDED FASCIA

\[
F_{\text{act}} = \frac{(F_{\text{metal}} \cdot \%\text{metal}) + (F_{\text{plastic}} \cdot \%\text{plastic})}{2}
\]
APPEARANCE
Sensor appearance is actually the driving force behind this implementation. The metal provides a good wear resistance and the plastic provides a visual outline for the sensor, as well as a means for backlighting the sensor. Modern silk screen and coating techniques can then be used to create the required look using the same techniques discussed above.

ENVIRONMENT
Concerns with the environment effects of abrasion and chemical resistance also get more complicated with a composite fascia/target design. Not only must both the metal and the plastic be appropriate for the intended environment, but the compatibility and adhesion of the plastic with the metal must be considered in the design. For example, if the metal has a higher coefficient of expansion than the plastic, then at extreme low or high temperatures dust and moisture may leak into the sensor when the metal edge pulls away from plastic. If the plastic has a higher coefficient of expansion, the plastic may generate stresses that cause the metal to rapidly deform at higher temperature, generating a false press. It is strongly suggested that the designer talk with their suppliers about the extremes of temperature to which the design will be subjected.

BACKLIGHTING
This is one of the main reasons for selecting a co-molded sensor. The plastic provides a means for the light to pass through the metal fascia/target, both to highlight the button function, but also to outline the buttons for ease of recognition by the user. Unfortunately, the plastic is often isolated in the design, so it may be necessary for separate locations to be individually lit. More information on methods for backlighting metal fascia/target designs will be presented in Section “Backlighting Methods”.

SUMMARY
Using a co-molded layer for the fascia and target layers provide a nice compromise between a single metal or plastic design:
• The plastic reduces the stiffness of the metal allowing lower actuation forces on small sensors.
• The fascia side can be marked using the same techniques at a plastic fascia/target, plus the plastic will provide a visual outline for the sensor.
• Designers must take into account the abrasion and chemical resistance of both the plastic and metal.
• Plastic removes most restrictions concerning backlighting a metal surface.
• This configuration does carry a tooling charge for the creation of the mold.

CHOOSING A DESIGN IMPLEMENTATION FOR A SPACER LAYER
The next layer in the sensor design is the spacer layer. This layer provides the 50-100 µm spacing between the target and sensor substrate and must maintain this spacing when subjected to both mechanical stress and environmental conditions. The adhesive spacer must also sufficiently bond the fascia/target such that pressing one button does not cause a distortion in the fascia/target layer of adjacent buttons, causing potential false triggers.

Polymer Spacer Layers
The spacer layer is typically implemented as a polymer film with an appropriate adhesive on both sides. In addition to maintaining the mechanical spacing of the buttons under normal use, the spacer must also provide a good bonding surface for the adhesives used to bond it to both the sensor substrate and the target material.

Note: Because the fascia/target layers and the sensor substrate are typically constructed from a variety of different materials, it is nearly impossible to recommend a one size fits all adhesive. Rather, the adhesive and spacer plastic must be selected in such a way that they are compatible with the fascia/target on one side, and the sensor substrate on the other. Therefore, it is strongly recommended that the designer consult with an appropriate party vendor specializing in adhesives or vendors versed in MOC design when choosing the adhesive for the spacer layer.

Appendix A: “The Sticky Business of Adhesion” contains background information on adhesion and cohesion, but it is included for general reference and is not recommended as a replacement for consulting a qualified supplier.

Back-etching as a Spacer Option
An alternative to the use of a polymer spacer is to modify the fascia/target to provide the appropriate spacing by etching the underside of the target. Figure 7 shows an example of etching. Etching the back of the fascia/target also has the advantage that it will increase the flexibility of the fascia/target in the area of the button, while maintaining the rigidity of the surrounding material. This is an easy way to maintain structural strength in the chassis, while providing much needed sensitivity to MOC button designs.
Typically, the underside of the fascia/target is chemically etched to provide the necessary spacing between the sensor and the underside of the target. The depth of the etch is generally limited to no more than 1/3 the thickness of the fascia/target material. It is important to note that the depth of the etch and the thickness of the fascia/target material must take into account several factors:

- The required spacing between the sensor and the target (50-100 µm)
- The thickness of the adhesive used to bond the fascia to the sensor substrate
- The height of the sensor pad
- The thickness of any solder mask or silk screen on the top surface of the substrate

**FIGURE 7: ETCHED FASCIA/TARGET**

This implementation method also assumes that the metal flashing on the etched area of a plastic fascia/target combination can be electrically grounded. If the target layer above the sensor cannot be grounded, then the use of a split sensor pad, as shown in Figure 9, is recommended.

**Pedestal Spacer Systems**

For designs with significantly thicker metal or plastic fascia/target layers, the fascia/target can be back-etched to depths greater than 1/3 of the material thickness by using a pedestal system. Figure 8 shows a typical design employing a pedestal system.

**FIGURE 8: EXAMPLE OF A PEDESTAL DESIGN**

In Figure 8 above, the target is a conductive disk suspended below the fascia on a post, allowing a significant thinning of the fascia by machining/etching. This allows the use of significantly thicker material for the chassis of the device, while retaining the lower actuation force of a thinner material. Further, the cavity/pedestal can be formed directly during the injection-molding of the fascia.

**Note 1:** In a pedestal design, the spacing between the target and the sensor is dependent upon two mechanical stacks. The first is the combined thickness of the adhesive, silk-screen and solder-mask between the fascia and the sensor substrate. The second is the height of the pedestal plus the combined thickness of the adhesive and target.

2: Directly grounding the target in a pedestal design can be problematic. The best option is to use a split sensor pad as shown in Figure 9.

For good noise immunity, the target layer should be directly connected to the system ground. This provides low-impedance shielding and a direct path to ground for any ESD discharge. In a MOC design, this usually requires a physical connection between the fascia/target layer and the sensor substrate. This can be accomplished using a variety of methods:

- A conductive fastener can be used to both mechanically and electrically bond the target to the underlying sensor substrate ground.
- A grounding pin can be welded to the underside of the target and soldered to the sensor substrate ground.
- The fascia/target can be soldered to an exposed ground plane on the top of PCB.
- Or a conductive adhesive can be used to bond the fascia/target to the sensor substrate. An example of this type of adhesive is the 3M adhesive 9703.
For systems that will not be subject to excessive noise or are battery-operated hand-held systems, the fascia/target can be grounded capacitively by placing a large grounded copper pour surrounding the sensors. A third option is to use a split sensor pad. One half of the sensor pad is grounded and the other half is used as the capacitive touch input (see Figure 9).

**FIGURE 9: EXAMPLE OF A SPLIT PAD GROUNDING SYSTEM**

![Diagram](image)

**BACKLIGHTING METHODS**

One of the most common requests with MOC designs are methods for backlighting the button legends. Because the techniques for a single-layer metal design and a co-molded metal and plastic design are so similar, they will be covered together in this section. Plastic fascias with metal flashing will be discussed separately in Section “Plastic with Metal Flashing”.

**Backlighting Metal and Co-Molded Designs**

Until transparent metal is discovered, it will be necessary to perforate a metal fascia to allow backlighting. The perforation can be accomplished by punching, water jet, etching or laser cutting. Punching is typically less expensive in large quantities, but expensive for low volumes due to the cost of creating the customer metal punch. Water jet is cheaper for small quantities, but is limited in how small a cut can be made due to the diameter of the water jet. Chemical etch can cut at finer resolutions, but can be more expensive in large quantities. Laser is typically the most practical for prototype volumes as it has a smaller aperture than the water jet, and requires only a simple cad file to specify the cuts. Figure 10 shows an example of a back-lit single metal layer fascia/target.

**FIGURE 10: BACKLIGHTING A METAL FASCIA**

![Diagram](image)

However, once the opening is cut in the metal fascia, it provides a pathway for moisture and dust. To alleviate this problem, the cutouts are typically filled with a clear polymer using either a silk-screen or injection molding process. The polymer also typically acts as a light diffuser, helping to spread out the lighting and preventing hot spots in the backlight.

**Note:** This technique is basically a co-molded design. The only difference is that these perforations are in the legend of the sensor and not of the outline. All other aspects of the design are the same.

Another option for single metal layer and co-molded designs is the use of micro-perforation holes. These are very tiny laser cut holes in the metal that the light can shine through. The metal looks normal until the LED is lit. Typically, the holes are filled with a polymer to prevent moisture and dust from penetrating the fascia/target. See Figure 11 for an example. However, there is a trade-off with this method: for good light density there must be either a smaller number of large holes, or a larger quantity of smaller holes. Larger holes are more visible and the larger quantity of smaller holes increases the production cost.

**FIGURE 11: EXAMPLE OF MICRO-PERFORATION BACKLIGHT**

![Diagram](image)

**Plastic with Metal Flashing**

Designs that employ plastic with metal flashing for their fascia/target layers are actually easier to backlight because the sensor substrate can be made from a clear polymer. This allows the use of a variety of backlight options, including the use of a thicker diffuser layer mounted behind the sensor substrate, rather than between the sensor and the target. So, nearly any surface and backlighting effect possible with a single metal layer design can be duplicated in a plastic
system. In addition, combining the use of a clear substrate with common sensor and LCD transparent conductive inks, such as Antimony Tin Oxide (ATO) or Indium Tin Oxide (ITO), allows the backlight of nearly any printed image.

Note: ATO and ITO have significantly higher resistivity than silver ink. To prevent impedance problems, ATO and ITO should only be used for areas that must be transparent; all other connections should use silver ink.

DEAD-FRONT
A dead-front system utilizes a semi-transparent printing effect on the back of the plastic fascia to show a solid black appearance until the sensor is back-lit. See Figure 12 for an example.

FIGURE 12: EXAMPLE OF DEAD-FRONT EFFECT

The effect is similar to the older practice of using a Smoke acrylic cover on LED displays to hide the outline of the display while showing the lit numerals. To make a dead-front effect work, both the target and sensor must be printed with ATO or ITO transparent ink to allow light to shine through the legend printed on the back of the fascia.

Note 1: The semi-transparent printing on the fascia will reduce the amount of light passed through the image. Therefore, it is necessary to increase the amount of backlight to get a clear image. This is especially true in applications that must be sunlight readable.

Lighting
Lighting to drive the backlights is typically supplied from either the side of the sensor using side light LEDs or from the back side of the sensor substrate PCB, through the use of back mount LEDs.

SIDE LIGHT LEDS
There are a number of side light LEDs currently available from suppliers. They come in a variety of colors and typically have minimal heights to prevent interference with the fascia layer. The main challenge with side light LEDs is to couple the majority of the light energy into the side of the sensor. This is particularly problematic for single metal layer and co-molded designs. For both types of designs it is typically recommended to use back-mounted LEDs. Plastic fascia/target designs that employ transparent plastic layers, however, can take advantage of the fiber optic behavior of the plastic layer to pipe the light from the edges of the designs into the sensors. See Figure 14 for an example of a side-lit light pipe design.

BACK-MOUNTED LEDS
Back-mounted LEDs are designed to be installed from the back of the substrate so that they shine through a clearance hole and connect to pads on either side. This has the advantage of removing the LED from the mechanical stack-up of the sensor design, while allowing the backlight of specific areas in the button panel.

Note: When using back-mounted LEDs, care must be taken to insure that the clearance hole is not plated, as this will short the LED connections. See Figure 13 for an example.

FIGURE 13: BACK-MOUNTED LEDS

One of the greatest challenges in backlighting a button is generating even lighting. Hot Spots can occur when there is insufficient diffusion of the point source backlight. This typically occurs when the fascia/target/spacer layer are too thin for even light distribution. Given that the maximum spacing between the sensor and the target must be 50-100 µm and the fascia/target must be thin enough to allow deflections, there is also only a limited amount of room for an effective diffuser in the stack-up.

The simplest solution is to abandon the PCB sensor substrate and go with a clear polymer substrate with the sensors printed on the sensor layer. Using this method, a thicker light pipe layer can be bonded on the back of the sensor layer without impacting the flexibility of the fascia/target layer. This method uses the metal screening/flashing techniques discussed in plastic fascia/target design and applies it to the sensor
substrate, as well. This makes the sensor system a stack-up of polymer layers bonded to the back of the metal, plastic, or co-molded fascia/target. The connector tail of the sensor is then connected to the system PCB via a connector or through the use of vertically conductive adhesive between the tail and pads on the PCB (3M #9703).

Another option is to use a clear diffuser material with side firing LEDs to illuminate the material via its edges. This eliminates Hot Spots in the backlight and moves the LEDs away from the sensor. Selective abrasion or etching of the material is also employed to concentrate the backlight behind the various buttons. See Figure 14 for an example.

**FIGURE 14:** EXAMPLE OF SIDE LIT DIFFUSER

Another option is to use optic fibers, molded into a flat diffuser, with a single tail for the light source. See Figure 15 for an example.

**FIGURE 15:** FIBER OPTIC-BASED DIFFUSER

**RELOCATING THE PCB**

While using the PCB as a substrate for the sensors is convenient for connecting the sensors to the microcontroller, it can be problematic if the shape of the interface is not flat, if the PCB must be located in another area chassis due to large components or the need for heat dissipation, or if a thicker light guide is needed for backlighting.

In these situations, the sensor substrate can be built from a polymer sheet and the connection made to the microcontroller via a connector tail. This tail can either connect to the electronics board through a connector such as a FFC connector, or can be bonded directly to the microcontroller PCB using vertically conductive ink.

**Note:** The silver ink used for connecting the individual sensors to the connector tail is susceptible to damage due to abrasion by the connector. To protect the contacts, a hard carbon coating is often used to cover the contacts on the tail to prevent damage. Figure 16 shows an example of this technique.

**FIGURE 16:** EXAMPLES OF CONNECTIONS TO SILVER INK TRACES

Another advantage of using a polymer substrate for the sensors is that the substrate can be vacuum-formed to create a 3D surface. Using this technique, it is possible to build interfaces that wrap-around the product. For example:

- A joy stick with multiple triggers and buttons
- Controls for an ergonomically-designed control handle on a vacuum cleaner
- A speed control for a hand-held shaver

It is even possible to mold the fascia/target/spacer/sensor stack-up into the enclosure of the product using In Mold Laminating (IML) techniques. See Figure 17 for an example.
Another option possible with a polymer substrate is the inclusion of LEDs in the stack-up. The LEDs are typically side-light LED, bonded to the polymer substrate using a silver bearing epoxy glue capable of handling the current consumption of the LEDs. This removes the need for separate lighting boards to provide backlighting for a remotely located sensor substrate. However, care should be taken with the layout of the traces connecting the LEDs because the silver ink does have a higher resistivity than copper traces, and excessively long traces can produce significant voltage drops in the connection to the LEDs.

Shielding Options

In addition to lighting, selective shielding can also be included in the stack-up for handling EMI/RFI/ESD. This shielding can be implemented as either mylar layers or conductive inks. See Figure 18 for examples.

One final option for relocating the PCB is to mold a pedestal into the back of a flexible section in the chassis, so that when the user presses on the flexible section, the pedestal presses on the fascia/target/sensor mounted on the PCB substrate. This is similar to the practice of using molded button covers to actuate PCB mounted switches.

TROUBLE-SHOOTING PROBLEMS

Because metal over capacitive systems are largely immune to interference and noise due to either water or conducted/radiated noise, noise problems are typically mechanical in nature. These fall into three categories:

- Adhesion problems
- Mechanical design problems
- Pneumatic problems

Adhesion Problems

Adhesion problems typically appear as variable sensitivity on the pressed button and cross-talk on adjacent buttons with false triggering. See Figure 19 for an example of button behavior affected by adhesive release.

This underlying problem is the peeling apart of the various layers of the button during a press and the resulting mechanical offset of the fascia/target from the sensor layer upon release (see Figure 20).
When the adhesive is not properly set, pressing on the button can cause the peeling up of the layers surrounding the button. When the button is released, the de-bonded areas cause the fascia/target to lift away from the sensor. When the button is then pressed again, the fascia/target presses back into the adhesive, resulting in the surrounding buttons false-triggering in a cross-talk-like behavior and the pressed button will appear to have abnormally high sensitivity due to the greater than expected movement of the fascia/target relative to the sensor.

The solution to this problem is to separate the various layers, replace the adhesive and properly set the adhesive in accordance with the manufacturer’s specified procedures for the adhesive.

**Note:** Trying to salvage the situation by resetting the adhesive after it has peeled up is not recommended. The best procedure is to start over with fresh adhesive and following the manufacturer’s recommendations for setting the adhesive.

**Mechanical Design Problems**

These problems can also appear as false-trigger and cross-talk issues and, typically, they also fall into a couple of different categories:

- The spacing between buttons
- The location of traces in close proximity to buttons
- Mechanical stress on connecting traces

When buttons are placed too close together, a press on one button can cause the rise of the fascia/target of an adjacent button, much like a child’s teeter totter (see Figure 21). When this happens, the capacitive touch software will interpret the negative motion of the fascia/target as an environmental shift and readjust the button’s average. When the button is released, the adjacent fascia/target will move back down and create a false trigger in adjacent buttons. This can be especially common in all metal fascia/target designs, as the metal is stiffer than plastic and more likely to pull on adjacent material during a press.

**FIGURE 21: EXAMPLE OF BUTTONS TOO CLOSE TOGETHER**

The solution to the problem is to increase the spacing between the affected buttons. Microchip recommends a minimum of \( \frac{1}{2} \) the diameter of the largest button as the minimum button-to-button spacing. It is also important that the adhesion of the fascia/target to the spacer/sensor layer be solid to prevent adhesion-related issues.

If the traces from other buttons are located too close to a button, a couple of different problems can appear. The adjacent buttons can fail to open during a press of the buttons and cross-talk between the buttons can appear.

The first problem is due to the mechanical flexing of the trace near the button. The movement of the fascia/target puts stress on the trace and minute cracks can appear in the traces. These cracks in the traces can open up during a press and cause the button to look like an open circuit.

Additionally, real cross-talk can also occur due to the motion of the fascia/target relative to the trace. This will appear as traditional capacitive touch cross-talk, although not to the extent seen in capacitive touch applications.

The best solution for both problems is to move the trace away from the button, this decreasing the capacitive coupling between the moving section of the fascia/target, and reducing the stress on the trace. It is also a good idea to make all traces out of silver ink as ITO and ATO traces tend to be more brittle, while silver ink is more flexible and tolerant of mechanical movement.

**Pneumatic Problems**

An interesting problem that can occur with MOC touch systems is that air pressure can affect the spacing between the fascia/target and the sensor. This can manifest in a couple of different problems. Pressing a button can push air under adjacent buttons causing a negative shift on the adjacent button, and a press can also push air out from under a button creating a low pressure which holds the button pressed (see Figure 22).
FIGURE 22: PNEUMATIC PROBLEMS

The top two red circles show an example of how one button press can push air under an adjacent button, creating a negative shift. This negative shift will offset the average and press thresholds, making the button harder to press and potentially preventing a legitimate press.

The lower red circle shows an example of a press-and-hold situation. A press on the button forced air out from under the button, creating a low pressure that kept the button partially pressed upon release. Note the slow release of the low pressure condition and the return of the button to its normal level. This often will create a false trigger as the average will often track to the higher value before the pressure release.

The button compression problem appears as a failure to completely release after a user’s press. This offset typically releases slowly over time, resulting in a loss of sensitivity during the release, or the release can be sudden due to the press of an adjacent button, manifesting as a sudden recovery of the button’s sensitivity.

To solve both problems, the designer should either vent the buttons into the chassis to prevent pumping, or open air channels between all buttons so the change in pressure is distributed over a larger area, reducing the effect on individual buttons.

VENDORS

The robust operation of a sensor design relies on both the materials used in the design and the adhesives that bond the sensors together. Unfortunately, designers are typically more comfortable with hardware and software than adhesives and material selection. This is where the expertise of a third-party vendor can be most valuable.

The best sources for material and construction advice are vendors which produce Membrane or Snap Dome switch designs, as they use many of the same techniques discussed in this application note. Areas in which these vendors can be useful are:

- Material selection for chemical and wear resistance
- Printing on metal and plastic surfaces
- Choosing appropriate adhesives for the materials to be used
- Alignment and construction of the various layers in a sensor design
- Laser and die cutting of materials
- Incorporating switch and sensor systems into injection-molded plastic assemblies

Together, these areas of expertise can make the production of a sensor system both easy and cost-effective. On the other hand, trying to do it all yourself can be a frustrating and difficult proposition. In addition, having a vendor supply a complete sensor stack-up can remove the need for complex assembly jigs, spoilage in the form of bent or misaligned layers, and problems associated with the use of incorrect or improperly set adhesives. Therefore, to aid customers who may not have the requisite expertise in-house, Microchip has partnered with a variety of vendors with the appropriate experience and can make available their contact information upon request.

CONCLUSIONS

The various sensor design techniques presented here give designers a significant level of freedom in the creation of novel user interfaces. The variety of materials, configurations and techniques can be combined in a wide variety of configurations to produce truly unique controls from both an aesthetic and ergonomic point of view. However, the techniques discussed here are, by no means, all the possible options and designers are strongly encouraged to both think outside the traditional box and talk with their creative third-party design suppliers for additional ideas. Designers should also visit the Microchip web site (www.microchip.com) for additional ideas and information.
APPENDIX A: THE STICKY BUSINESS OF ADHESION

Cohesion and adhesion are the process of bonding two materials together. Cohesion is the bonding of identical materials and adhesion is the bonding of different materials. Typically, adhesion (and cohesion) methods fall into one or more of the following five categories:

- Mechanical adhesion
- Chemical adhesion
- Dispersive adhesion
- Electrostatic adhesion and
- Diffusive adhesion

A.1 Mechanical Adhesion

Mechanical adhesion is based on a mechanical connection between the two surfaces being bonded. For example, riveting two pieces of metal together is a form of mechanical bonding, and so is sewing two pieces of cloth together. Both of these examples are referred to as large-scale mechanical bonds.

Medium-scale bonds are best exemplified by product Velcro®. The bond between the two layers is solely due to the intertwining of the hooks and loops of the two layers.

Small-scale mechanical bonding occurs when an adhesive fills in the pits and crevasses in the surface of both mating surfaces. This is why roughing up both surfaces, prior to introducing an adhesive layer, is typically recommended to improve the grip of chemical, dispersive and diffusive adhesives.

A.2 Chemical Adhesion

Chemical adhesion is a process whereby the adhesive forms a chemical bond with both surfaces. This is typically accomplished by trading or sharing electrons to form ionic or covalent bonds. A natural requirement of this kind of bonding is that the materials must come into close proximity to one another and both surfaces must be able to form similar bonds to the adhesive.

An example of chemical adhesion is the common practices of soldering and brazing. In both systems, a third-party metal that can alloy with both surfaces is introduced. The two surfaces need not to be the same material, but they must be materials that will alloy with the solder or brazing metal. A similar form of adhesion is also possible with polymer materials, and for materials that cannot bond with the same adhesive, a third intermediate material is typically introduced between the two adhesives to bridge the bond.

A.3 Dispersive Adhesion

Dispersive adhesion relies on the slight positive and negative charges present in the surface of a material. These forces are referred to as Van der Waals forces. The charges in the surface of the materials may be permanent (Keesom forces) or transient (London forces) (e.g., they can be permanently generated by polar molecules in the surface of the material, or transient charges due to the constant movement of electrons in their orbital). When there is sufficient difference in charge, the materials will bond based on an electrical attraction. Most common adhesives rely on dispersive adhesion.

A good example of dispersive adhesion is the behavior of water on the hood of a car. When the dispersive adhesion of the water to itself is greater than the adhesion to the low surface energy waxed hood, the water beads up and does not adhere to the hood. However, when the hood is not waxed, the high surface energy of the hood exhibits greater adhesion to the water than the water does to itself and the water wets the surface of the hood.

In the first example (waxed hood), the Van der Waals forces between the water and the hood are low and there is poor adhesion between the two materials. If the water is pressed between two unwaxed surfaces, it can be pressed flat, but when the pressure is released, the surface tension of the water will actually separate the two surfaces allowing them to slide over each other.

In the second example (unwaxed hood), the Van der Waals forces between the water and the hood are high and very good adhesion is exhibited. If the water is pressed between the two surfaces, it will actually hold the two surfaces together with just a small layer of water between them. This is the same technique used by small automotive window sticker that reminds us to change the motor oil. The ambient moisture in the air acts as an adhesive because both surfaces (the glass and the sticker) wet very easily and, hence, form a dispersive adhesion.

This also explains why we wax our cars with a low surface energy wax to prevent dirt and grime from adhering to the finish. Alternately, an unwaxed hood will adhere very well to dust and dirt. Basically, car hoods are waxed to make them poor surfaces for adhesion.

Note: This appendix is supplied as general background information and is not intended as a guideline for selecting the appropriate adhesive for sensor designs. Rather, it is strongly recommended that the reader contact one of Microchip's third-party design partners for help in selecting the appropriate adhesive system.
A.4 Electrostatic Adhesion

Electrostatic adhesion occurs when there is a DC bias across the interface between two materials. For example, when a balloon is rubbed on a cotton sweater, it will adhere to any uncharged surface, such as a wall or ceiling. The adhesive force is the attraction of the different charges present on the two surfaces.

While electrostatic adhesion can be quite strong, it is dependent upon the static charge present between the two surfaces. Once the static charge is equalized, the attractive force is eliminated and the adhesion disappears. As a result, this is not typically used as a common form of adhesive, although it does regularly adhere socks to sweaters and other clothing.

A.5 Diffusive Adhesion

The final form of adhesion that we will discuss is diffusive adhesion. This form of adhesion is related to mechanical adhesion on the molecular level. It is also the mechanism behind Sintering, where metals and ceramics can be bonded under pressure and heat.

The basic mechanism of diffusive adhesion is the diffusion of molecules from one material to another when subjected to heat or solvents.

The process is especially effective in long-chain polymer molecules when the merging of the materials creates a Velcro™ like the merging of the molecules from both surfaces.

Note: Cross-linked long-chain polymers, materials in which molecules connect at more than one point, do not easily form diffusive bonds, due to their inability to freely move into the other surface to form mechanical bonds.

In sensor designs, the forms of adhesion that are the most common are mechanical, dispersive and diffusive. Mechanical combined with dispersive covers the majority of bonding adhesives that adhere polymers to one another and metals. Dispersive adhesion covers soldering and the bonds between the various inks used. Diffusive adhesion is typically used when bonding selected polymer films together.

While an understanding of these various forms of adhesive will help the designer understand the various production options for sensor designs, it is not recommended that designers attempt to become experts in the science of adhesion. First of all, it is not really necessary as there is a wealth of advice available through the various adhesive manufacturers. And second, most adhesive manufacturers do not provide in-depth chemical information concerning their adhesives, as their exact chemistries are typically proprietary.
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