Application Note: AZD042

IQ Switch® - ProxSense® Series

CAPPO Hardware Design for Metal and Waterproof Touch

1 Introduction

Traditional capacitive touch sensing has several advantages which include; reduced cost, no mechanical moving parts, low power, systems can be waterproofed without the need for additional mechanical considerations when adding buttons which leaves the product with a professional finish. There are, however, some application that aesthetically require touch on metal surfaces, which can still be addressed by capacitive sensing, but in another form: CAPPO.

The advantages of CAPPO over traditional capacitive sensing are:

- Water no longer affects the measurements of the capacitive sensing. For traditional capacitive sensing, special design considerations have to be met for applications that can get water / other contaminants on the sensor.
- Users with gloves will have not have a problem anymore.
- Traditional capacitive sensing cannot have a metallic finish.
- Higher RF immunity.
- Braille-friendly touch sensing.
- Robust against false detections as a small force is required for an actuation.

This document outlines the hardware design for the CAPPO "CAPacitive Pressure Only" family of Proximity and Touch sensors

2 Principle of operation

Both, for the traditional and CAPPO capacitive sensing technologies, the sensor measure the change in capacitance caused by the user. In traditional capacitive sensing, the sensor pad forms the one side of a parallel capacitor and the users' finger, the other side. If the user brings the finger closer to the pad, the distance (d) will decrease between the finger and sensor pad and according to the parallel plate capacitor formula: C = ErEoA/d, the capacitance (C) will increase.

The concept of the parallel plate capacitor in the CAPPO technology still applies, except, now the second plate is no longer the finger of the user but a conductive material with a fixed potential suspended over the sensor pad. With a user applying a force above the sensor pad on the conductive material, it will cause the material to have a very slight local deflection, once again changing the distance (d) between the two plates.

The conductive material used as top cover / overlay should be grounded to keep it at a fixed potential.

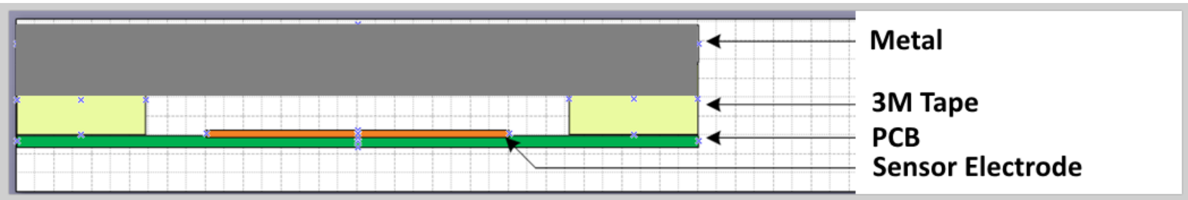

Figure 2.1 CAPPO cross section of a button (no press).

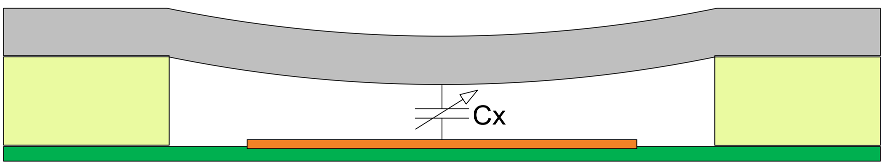

Figure 2.2 CAPPO cross section (deflection due to press)

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3 Azoteq ICs for CAPPO

Azoteq recommends ProxSense® & ProxFusion™ IC's for the CAPPO applications due to its superior sensitivity and ability to compensate for very large parasitic capacitances.

It is possible to use the surface capacitive sensing technology, or projected capacitive sensing for CAPPO.

4 Mechanical design

4.1 Stack-up

The mechanical stack up is shown in Figure 4.1. The top cover is normally metal, but could also be a softer material such as Perspex, with a metallic foil or coating. The middle layer is a spacer with cut-outs to allow for a deflection of the top cover at predetermined positions. The spacer is only adhesive tape, which is also used to bond the metal to the sensor PCB. The bottom layer is the PCB with the sensor pads.

Additionally, a mechanical bracket / support layer can be added to ensure that the module does not bend / move when a force is applied on a button. Only local deflection over the button is permitted.

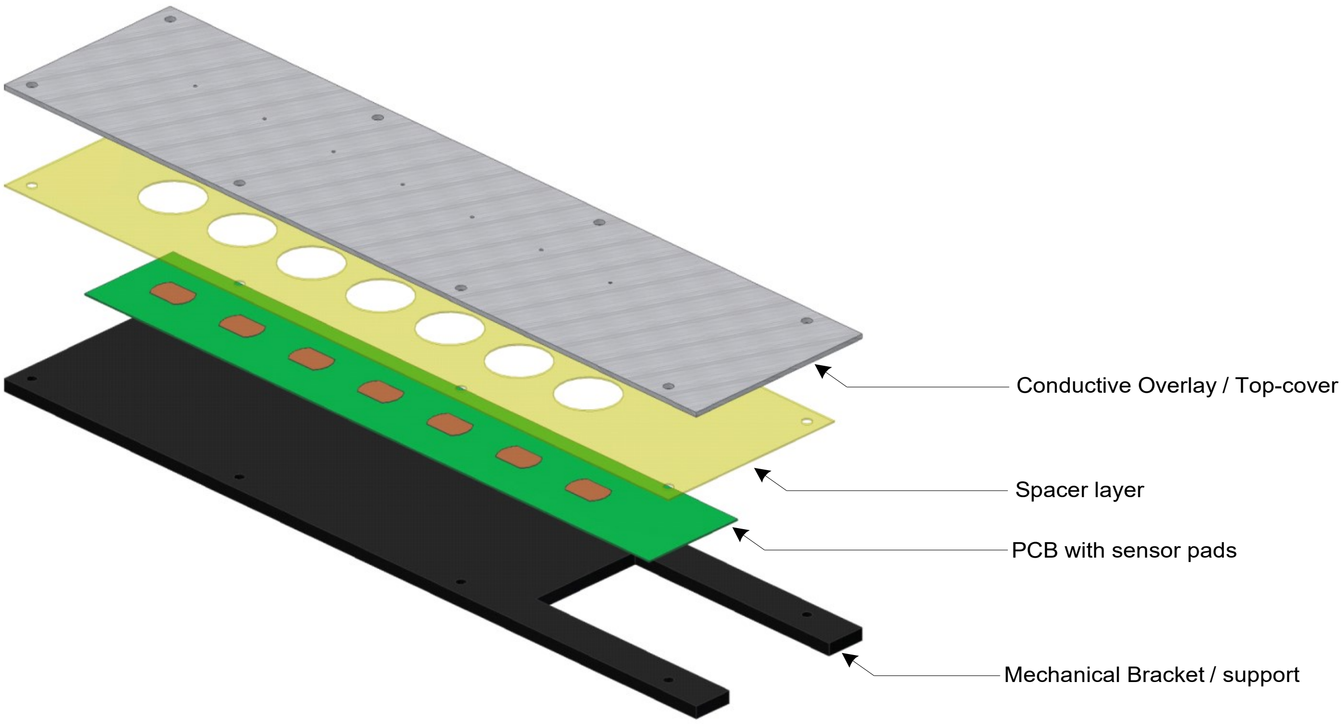

Figure 4.1 Mechanical stack-up

4.2 Considerations for Mechanics:

1. Top Cover
2. Spacer layer / Adhesive
3. Mechanical Support
4. Buttons / Electrodes

4.2.1 Top Cover

The top cover should be designed so that it has a measurable non-permanent deflection when pressed in the desired sensor area. This material can be chosen theoretically as shown below.

For all materials, there exist a "Young's Modulus" (E), this determines the linear elongation (stretching) of a material if a certain stress is applied on the material E = σ/Ɛ. There, however, also exists an "Elastic Limit" for a material, where the material will be deformed permanently if the stress applied is too high.

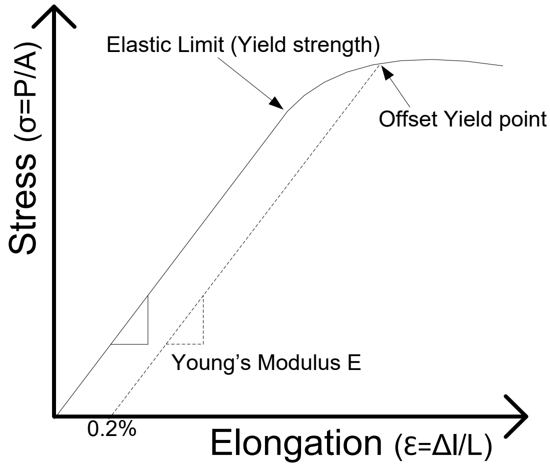

Figure 4.2 Stress vs. Elongation

A material should be chosen so that the physical properties of the material (type of material and thickness) will allow enough elongation when applying a force (stress) but should not cause a permanent bend (the stress should not exceed the Elastic Limit). Choosing the adhesive thickness small enough, will prevent the metal from bending too far, and will aid the design in preventing plastic deformation by limiting the elongation.

Options as Top Cover: The top cover can be metal or even a conductively coated material / plastic. The most common metal for light touches (100-200g) is Aluminium. See graph below (properties for a specific composition).

Table 4.1 Material properties

Material	Young's Modulus -E- (GPA)	Yield Strength -Sy- (MPA)
Aluminium	69	95
Steel	200	250-1650
Copper	100-128	70
Polycarbonate	2.6	70
Titanium	105-120	730

It can be seen from Table 4.1

- Aluminium has a very favorable E and Sy. Aluminium is also widely available as it is the most abundant metal in the earth's crust.
- The other listed metals can also be used, but the higher force required should be considered. Designing with stringent design parameters can still yield a soft touch on these metals.
- Polycarbonate is a very easy workable plastic used as electronic components, construction materials, automotive, aircraft & security components, niche applications.

The recommended maximum thickness of metal for "light" touch forces are shown in the table below.

Table 4.2 Maximum metal thickness.

Metal	Nominal Thickness	Suggested Maximum
Aluminium	0.6 ~ 0.75 mm	1.00 mm
Stainless Steel	0.5 ~ 0.7 mm	0.75 mm

These thicknesses were tested on a Ø14 mm electrodes with Ø18mm square cut-outs, using < 200 grams' force.

If the metal is too thin, resulting in smaller actuating force, a higher risk of false detections can be expected.

4.2.2 Spacer layer / Adhesive

The spacer layer is used to create an air-gap between the overlay and sensor pad on the PCB. With a user pressing on the overlay (above sensor pad area) the slight deflection of the overlay material into the air-gap, increases the capacitance measured.

The recommended adhesive or spacer layer :

- Type: 3M 468 200MP
- Thickness = 0.13mm

Because the adhesive is used as a separator between the metal and electrodes, varying the cut-out shape and size can increase the amount of bend that a piece of metal can achieve with the same force, and therefore influence the sensitivity of the touch key.

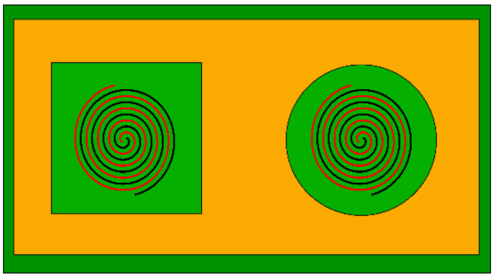

Figure 4.3 Adhesive cut-outs in 3M tape around touch areas.

In the Figure 4.3 above, the square cut-out (left) and round cut-out (right) have the same inscribed circle diameter, but because of the increased distance over the diagonal of the sphere, the metal overlay over the square will be able to deform further than the round cut-out for the same amount of force. Resulting in a more sensitive button. However, for the square cut-outs, the amount of adhesive between adjacent buttons will be less, therefore the metal overlay could deform more over other buttons when a given button is pressed. This could cause false touches on adjacent buttons. The trade-off between desired force, button size, and cut-out size & shape will vary between applications.

4.2.3 Mechanical Support

It is strongly recommended to have a backing support, pressing the PCB uniformly against the top cover to avoid bending in the PCB when a force is applied.

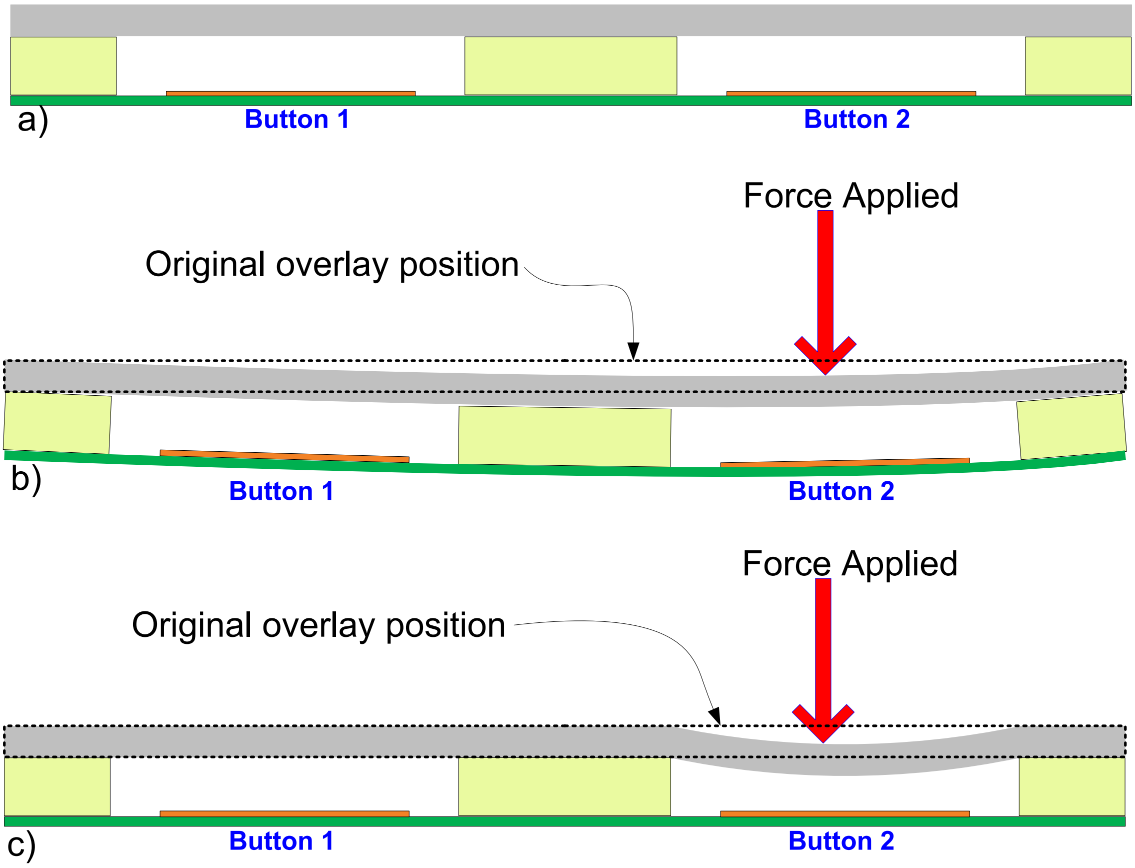

Figure 4.4 Two adjacent buttons. a) No Force applied. b) Force applied (incorrect movement). c) Force applied (correct movement).

4.2.4 Buttons / Electrodes

Projected capacitive sensing is suggested above self capacitive sensing for touch key only CAPPO applications. The stack up is shown below in .

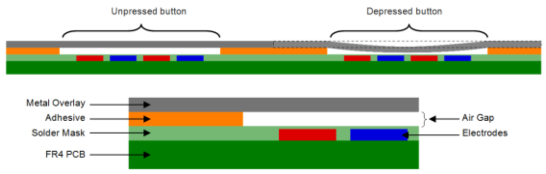

Figure 4.5 Cross-section of PCB with Metal Overlay, Adhesive and Projected Electrodes.

Tx-Rx pairs in parallel spirals have been found to be the best performing designs, with square parallel spirals performing better than round parallel spirals – as seen in previous figures. Typical of Capacitive Sensing, the track spacing between Tx & Rx, as well as the total area of the electrode pail will affect the sensitivity.

The parallel spiral arrangement is suggested because these arrangements were found to have the highest Signal-to-Noise ratio.

Square shapes are suggested over round shapes, as the corners concentrate the electric field lines.

Trace sizes for the electrodes should not be smaller than 0.15mm, and inter-trace spacing should not be smaller than 0.15mm.

Trace sizes should be kept smaller than 0.5mm and 0.5mm spacing, as these influence the overall area of the final button. The button size will depend on the design, it is suggested (where possible) that electrode designs are prototyped through at least one iteration to see which trace size and winding numbers best fit the design.

Traces between Electrodes and IC should follow the standard design criteria that are typically required for ProxSense®.

5 Touch Force

Figure 5.1 below shows typical activation forces for other types of switches.

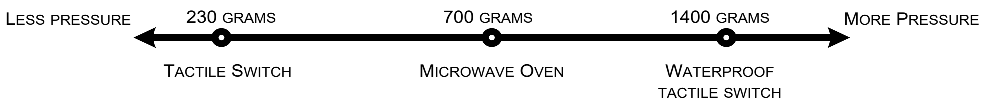

Figure 5.1 Activation Forces for Tactile switches.

To reach a touch force of less than 250 grams, a comparison of 2 touch keys are shown below in Figure 5.2.

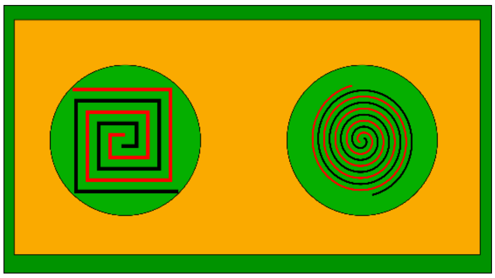

Figure 5.2 Comparison of square and round touch key.

In both examples, an Ø14mm inscribed circle was used for the sensor are, and an Ø18mm cut-out in 3M double-sided adhesive was made in the spacer layer.

For the Square Design:

0.2 mm traces with 0.2mm spacing could yield touch force below 250gram with 0.75mm aluminium metal over-lay.

For the Circular Design:

0.15 mm traces with 0.15mm spacing could yield touch force below 250gram with 0.6mm aluminium metal over-lay.

5.2 Temperature Effects

It is important to note that the temperature effects discussed herein are not a result of the IC experiencing temperature effects – IC performance regarding temperature can be found in the relevant datasheets for a given IC.

All metals expand and contract when subjected to changes in temperature, different metals do so at different rates, as given by the *Coefficient of Thermal Expansion*, as listed in the material properties of a given metal.

The metal overlay is no different, and microscopic deformation of the metal overlay due to temperature is expected. However, given the complexity of the underlying mechanics, the effects of thin-plate deformation due to temperature cannot easily be modelled. Therefore, it is important to include temperature sensitivity tests during the prototyping phase of a product.

5.2.1 Measure Effect

The following graphs shows the reaction to temperature of the metal over-lay above a round-spiral electrode (as presented previously):

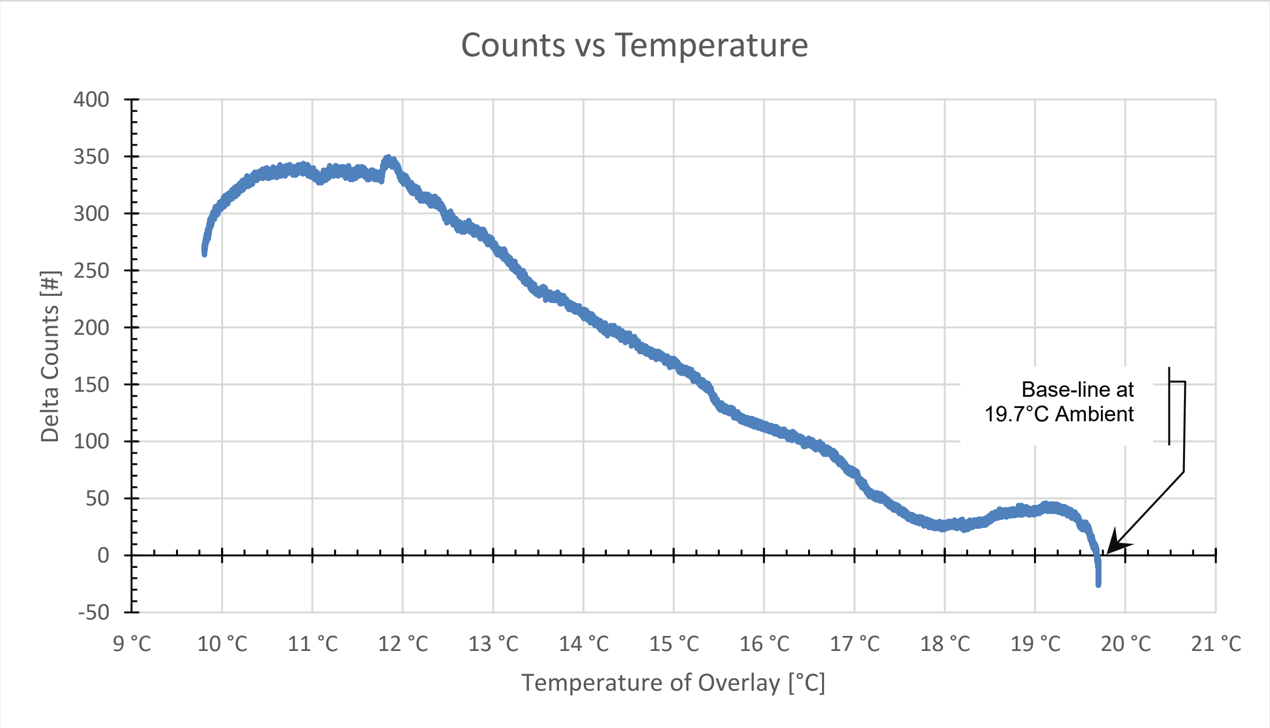

Figure 1 - Count Changes due to Temperature Effects on the Metal Overlay

Here the IC was ATI'd at 19.7°C ambient temperature – such that the delta signal was 0 counts at ambient. With no other force applied to the overlay, the overlay was rapidly cooled to below 10°C. Note, the IC remained at ambient temperature – only the overlay was cooled. Then, over-time the overlay was allowed to warm back to ambient under natural convection (i.e. in free air, open on a desk), which took approximately 17 minutes 20 seconds.

5.2.2 Mitigating Temperature Effects

Temperature effects can be mitigated through a number of strategies:

- through direct temperature measurement, re-ATI the IC if the temperature drifts by more than a defined amount.
- With multiple keys, if all channels move in the same direction, assume a temperature drift and re-ATI the IC

6 Waterproof Touch Applications

For touch application requiring very strict water immunity, one solution is to use the CAPPO technique by replacing the metal top cover with Perspex or acrylic material.

Given the much softer nature of Perspex (compared to most metals), the metal top cover can be replaced by Perspex or acrylic of up to 2mm with a conductive foil or tape applied. The conductive foil is then connected to GND, while the rest of the design remains unchanged from normal “metal touch” CAPPO stack up.

6.1 CAPPO using a Perspex/acrylic sheet

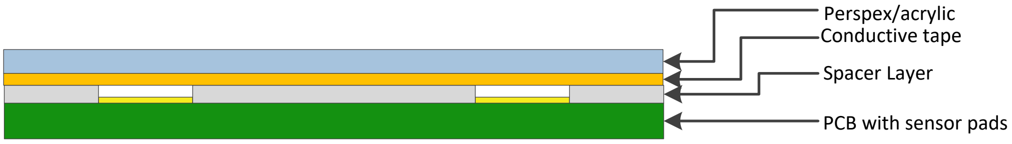

Figure 6.1 CAPPO with Perspex to cover.

Typical applications

Typical applications that are best suited for the CAPPO series are:

- Stoves
- Waterproof housing
- Microwave ovens
- Industrial applications
- Kitchen appliance
- Waterproof keypads
- User operating with gloves
- Braille-friendly touch keypads
- Vandal-proof keypads

Appendix A. Contact Information

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