AZD075 - How to design touch electrodes for non-uniform surfaces: Discrete keys

Abstract

Over the last few years, touch has become a standard input method for next-generation user interfaces for everyday applications, from white goods to smart phones and tablets. However, adding touch to modern designs, which are not flat or are made with more shapes and multiple parts, can be challenging.

In the first of a two-part series, this article shows how to accomplish touch detection on non-uniform surfaces, such as those with overlays of varying thickness and curved surfaces. The follow-up article will discuss the design and implementation of 2D trackpads on non-uniform surfaces.

Table of Contents

1 Fill the air gap

When a rigid-sensor PCB is fitted inside a curved surface, an air gap is created between the overlay and the capacitive sensor. Air gaps between the PCB and the overlay material reduce the performance of capacitive touch sensors. The reduction in sensitivity is due to the fact that air has a much lower dielectric constant than most overlay materials. A list of commonly used overlay materials with their dielectric constants compared to air is shown in Table 1.1.

Table 1.1 Material properties[1]

Material	Permittivity (ε_r)	Breakdown voltage (V/mm) (approx.)
Air	1	1,180
Glass (standard)	7.6 – 8.0	7,800
Plexiglass	2.8	17,700
Mylar	3	295,200
FR4	4.7	27,500
Nylon	3.2	16,000

This article will discuss two main options to remove the air gap: spring contacts and flexible PCBs.

1.1 Use of spring contacts

Springs and conductive rubber or carbon contacts work well to remove the air gaps between the PCB and the overlay. In applications where it is not possible to fix the electrode PCB to the overlay, conductive rubber or carbon contacts work well to remove small air gaps, whereas larger air gaps can be removed with springs.

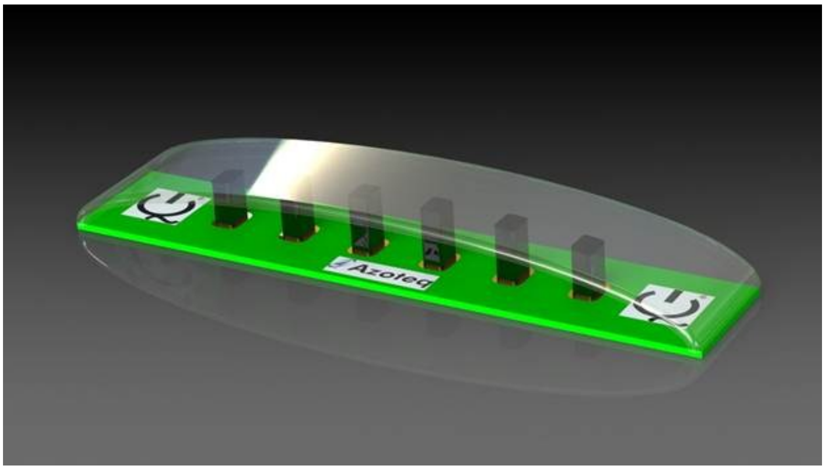

Figure 1.2 Conductive rubber can be used to remove small air gaps between the overlay and the PCB.

[1] Material properties estimated for reference only – Actual values to be confirmed by designers.

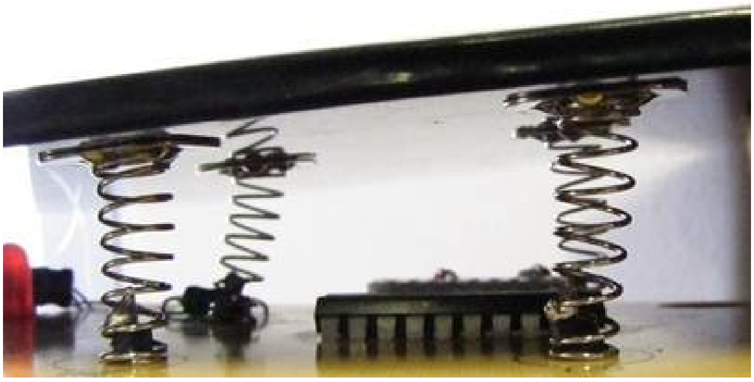

Figure 1.3 Simple helical springs soldered to a PCB pad can remove larger air gaps between the sense electrode and the overlay.

The disadvantage of using springs to connect the electrode to the overlay is that the surface area of the touch electrode is limited to the size of the spring used. According to the parallel plate equation shown in Equation 1, small surface areas are less sensitive. This limits the possible thickness of the overlay or the relative permittivity of the overlay for a set thickness. To improve sensitivity, conductive tape (metal foil) can be used. The tape can be stuck onto the overlay to give a larger surface area when the spring presses up against it. In applications where the overlay is required to be transparent (for example to accommodate backlighting) transparent conductive films such as ITO (indium-doped tin oxide) could be considered. Alternatively a metal plate could be used at the top of the spring, as commonly used in battery terminals.

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} \quad \text{.....................................(1)}$$

Equation 1 shows the parallel plate capacitor equation where A is the area of the pad, ε_0 is the permittivity of the air, ε_r is the relative permittivity of the overlay material and d is the thickness of the overlay.

Springs could also be connected to a surface of conductive paint. Conductive paint could be used around the touch key area to provide a larger surface area (A) to increase the proximity detection distance. Conductive paint can be applied to any non-uniform surface.

1.2 Molding pillars in the overlay

The latest generation of touch controllers from Azoteq provides another alternative for removing air-gaps. New controllers, such as IQS333 and IQS360, allow the designer to remove any air gaps with non-conductive materials that are less expensive. An example would be adding pillars at the touch positions when creating a molded part as overlay, as shown in Figure 1.4.

Figure 1.4 Molded overlay to form pillars over the electrodes, thus removing air gaps.

1.3 Flexible PCBs

In some applications, the spacing of the touch keys could require the sense electrodes to be placed close together. In these applications, spring or rubber contacts are not the best option. The designer might require the more directional approach of projected capacitive sensing. Some applications require shielding between keys, which requires ground to be added between the self-capacitive electrodes to reduce the risk of multi-touching.

In these types of applications, the designer can remove the air gap by matching the curved surface. This is accomplished by fixing a flexible PCB (FPC) to the curved surface with double-sided adhesive tape. The designer may choose to create a complete FPC module, which includes the touch controller as well as the sense electrodes. Alternatively, only the sense electrodes could be placed on the FPC, which can connect to the controller through a cable connector or FPC tail.

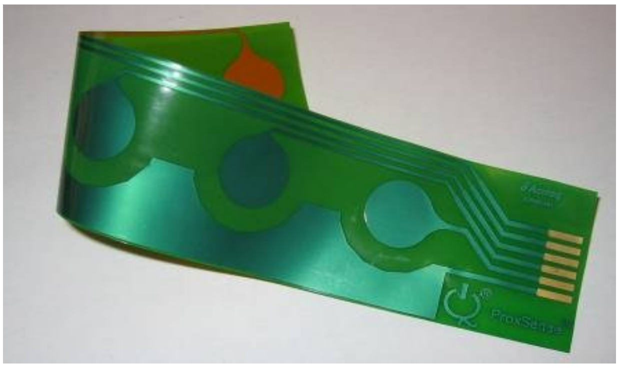

Figure 1.5 FPC with self-capacitive touch electrodes and FPC tail.

Care should be taken when designing for 3D surfaces (curves in two or more directions – see Figure 1.6). Fitting FPC to 3D curved surfaces may require cutouts to fit smoothly without creating air gaps (more details to follow in the second article). In cases where there are large curves and a risk of air gaps appearing, the simplest option would be to use a fixed PCB with spring contacts.

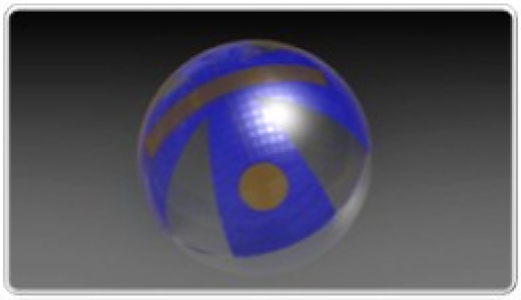

Figure 1.6 Illustration of a 3D curved surface.

An alternative is to keep the PCB area flat (to enable the use of normal flat PCBs with no air gap to the overlay), and only have the curve on the other side, where the user will interact. This could also ease the manufacturing process, especially for more difficult materials such as wood overlays. This does create a non-uniform overlay thickness, and can be compensated for in electrode design. Different electrode designs are discussed in Section 2.1.

The designer would do well to remember that thin FR4 PCBs (0.1 mm to 0.2 mm) provide a more cost-effective solution to FPC in applications where the required curve in the PCB is not too large.

Care must be taken in all instances when placing components on flexible PCBs, to place them in areas that will not be bent. This will reduce the risk of component failure such as capacitor cracking.

A variation of standard FPC is to use ITO or PEDOT films for transparent overlays requiring transparent electrodes for backlighting purposes.

2 How to compensate for curved surfaces

In some applications, it is not always possible to keep a constant thickness in the overlay material. This may be due to injection molding of plastic parts to conform to a designed shape and stiffness, or the requirement for uniform backlighting to accommodate light diffusion layers.

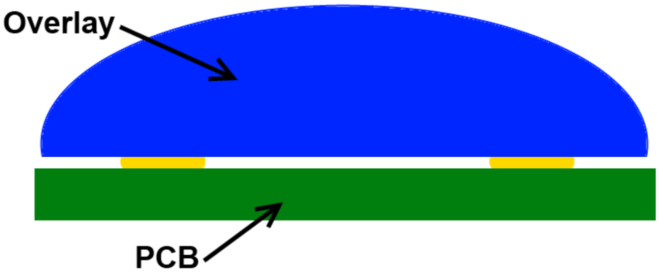

Figure 2.1 Fitting a flat PCB to an overlay with a curved exterior creates a non-uniform thickness. Electrode layout can compensate for this.

2.1 Electrode shapes for thicker overlays

Although capacitive touch sensors from Azoteq are fully customizable for sensitivity settings on each channel, as well as adjustable detection thresholds for set sensitivity selections, the designer could save time in fine tuning the sensitivity of each electrode by compensating for variations in the thickness of the overlay material in the electrode design. For projected capacitance, bigger gaps between the Tx and Rx electrodes will give more sensitivity (but reduce stability), or using thicker receivers in the electrode will allow for thicker overlays (but reduce conductive noise immunity). The figure below shows different electrode variations of the same design (for projected capacitive sensing) for different overlay thicknesses (in order of increasing sensitivity).

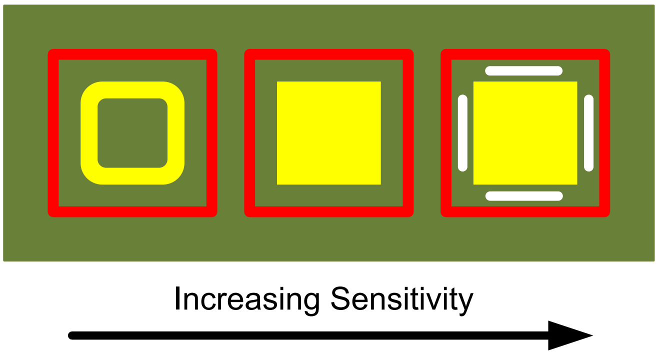

Figure 2.2 Projected button layouts in order of increasing sensitivity. Red represents the Tx electrodes, yellow represents the Rx electrodes and white represents the PCB cut-outs. The dimensions of all three buttons illustrated are the same.

For self-capacitive sensing, bigger electrodes will give more sensitivity, and avoiding sharp corners that form concentrations in field lines will allow for thicker overlays. The figure below shows different electrode variations of the same design (for self-capacitive sensing) for different overlay thicknesses (in order of increasing sensitivity).

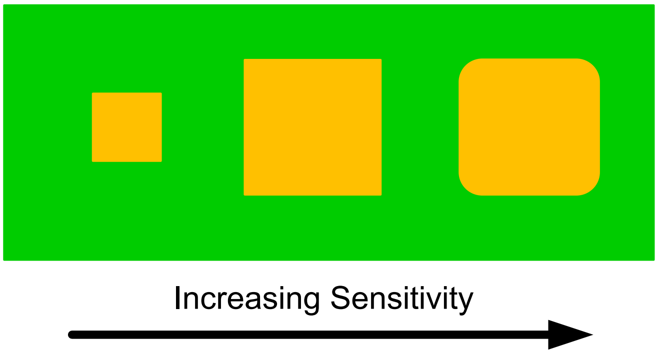

Figure 2.3 Self-capacitive buttons illustrated in order of increasing sensitivity by increasing the size of the electrode and removing sharp edges that form concentrations in field lines.

3 Moving parts

In some applications the overlay is not fully fixed. This is possible in applications with thin overlays, where a small air gap is also possible. This could result in movement of the overlay when excessive touch force is applied. In these instances it is important to choose the correct touch controller. For example, using a device from Azoteq with Dycal capability (for example IQS228) can avoid stuck conditions by recalibrating the sense electrode upon touch release events (when the user releases the overlay).

In some applications, the designer wishes the overlay to be able to move by design. An example of this could be applications in which a second level of touch activation is required - the first being a zero force touch trigger, whit the second activation occurring when the button is pushed to depress a metal dome.

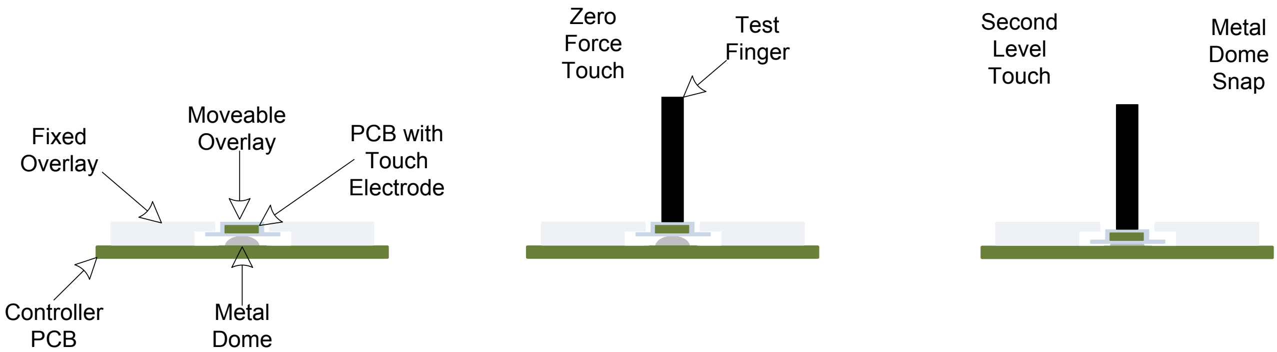

Figure 3.1 Two levels of touch available, with a zero force touch and a push to depress a metal dome.

In these situations the designer could opt to place a second PCB for the touch electrode in the moving part (refer to Figure 3.1). This electrode PCB could connect to the main PCB with an FPC tail, which is flexible enough to accommodate the movement. The second option is to design the touch electrode to sense around the metal dome, as illustrated in Figure 3.2, instead of sitting on top of it.

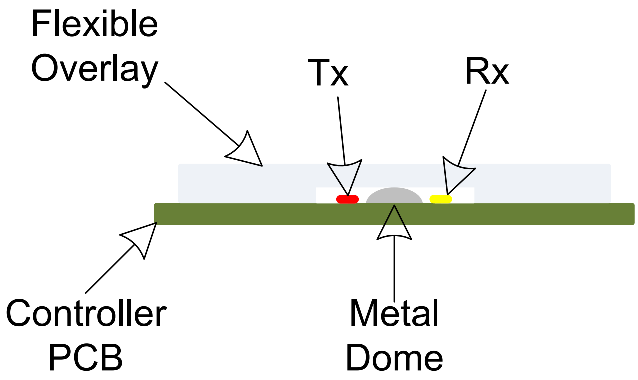

Figure 3.2 Projected electrode layout for sensing around a metal snap dome.

Figure 3.3 shows electrode layouts with enough sensitivity to detect the zero force touch event before the overlay is depressed. This type of layout can also be used with a thick rubber overlay, or with overlays that have the snap dome molded into them.

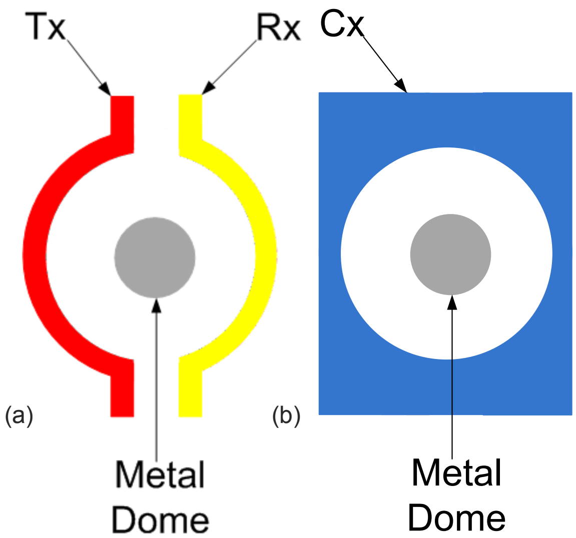

Figure 3.3 Electrode designs to accommodate touch sensing around a metal dome. (a) Projected capacitive electrode layout and (b) Self-capacitive layout.

Some sensors, such as the IQS360, have a snap detection, enabling the designer to place small Tx and Rx extracts from the button (as shown below) underneath the metal dome. Touch is detected when the user touches the overlay, and the snap output is generated upon depressing the metal dome.

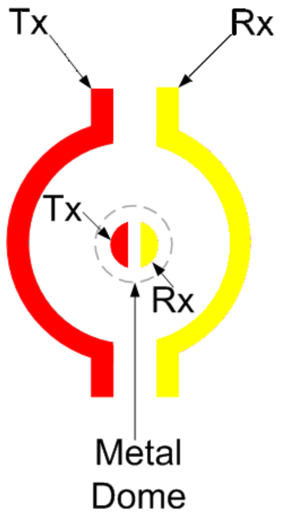

Figure 3.4 Round projected button layout with Tx and Rx tails to provide stability. Enough spacing between Tx and Rx allows sensing through thick overlays and space on the inside for a metal dome to enable snap/click functionality.

4 Connecting FPC/FFC to PCB

In applications where FPC is used for touch and proximity electrodes, as discussed earlier, the designer has multiple options to connect the FPC to the main PCB.

FFC cables can connect between the FPC electrode and the main PCB. Various flex connectors are available, with different pin counts and pitches. Although convenient to use, flex connectors can be costly.

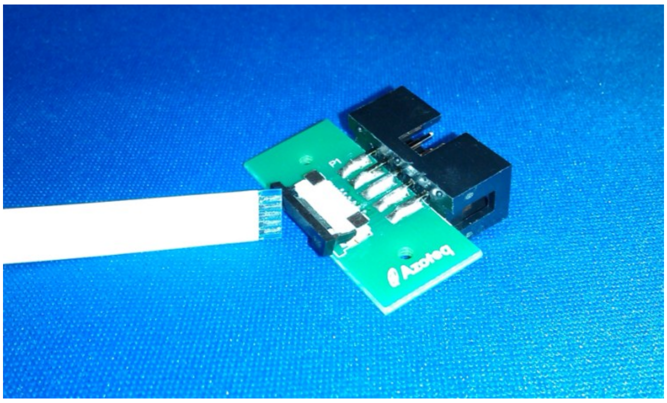

Figure 4.1 Example of a five pin flex connector, used to connect FFC cables to PCBs.

A more cost-effective approach is to use ACF (anisotropic conductive film) thermal compression bonding. ACF is a mature assembly technology that entails a process in which the FPC tail is soldered directly to the PCB with a combination of heat and pressure during the final assembly.