White Paper

Capacitive touchpad solutions

Capacitive touch solutions for wearable applications

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Getting connected

This white paper describes available capacitive touch sensing technologies focusing on wearable applications, and outlines the pros and cons for each technological approach along with practical advice where applicable.

Introduction

Capacitive sensing is widely used in all kinds of industrial, automotive, medical and consumer applications. The popularity of this technology, especially in human interface devices (HIDs), has grown rapidly due to its ability to provide more user friendly products, increase product lifespan by eliminating mechanical components and enhance a product's look-and-feel. Track-pads and touch-screens are the main target applications. However, this technology is also widely used to implemented touch buttons and sliders, the biggest examples being mobile phones, remote controls and industrial controls.

Capacitive sensing-based touch buttons are much more attractive than traditional mechanical switches, both in terms of looks and reliability. These sensors enable a remarkable user interface (UI), and offer a highly robust and reliable solution – provided they are properly designed, calibrated and controlled. The aforementioned conditions essentially summarize the concerns of design engineers trying to develop solutions based on capacitive-touch technology.

Designing low-cost, responsive and low-power capacitive sensors for reliable operation in noisy environments, which are the norm nowadays, has proven challenging for most engineers. This white paper discusses various technological approaches, and provides guidelines and know-how related to designing wearable capacitive sensing keypads and touchscreens, all of which contribute to lower costs and more power efficient designs.

Many wearable devices use large buttons to navigate through the user interface. Others have only one button to turn on the display and click through many options. So space is an issue on most of these products as they must be small, and don't allow much room for multiple buttons.

Capacitive sensors offer many advantages for wearable devices, such as:

- Improved user interface
- Aesthetics
- Contemporary design
- Enhanced battery life

In this paper, we will look at two separate capacitive sensing applications for wearables: touchpads and touchscreens.

Capacitive touchpad solutions

Perhaps the most basic touch sensing application for UIs is the familiar touchpad. Touchpads can be created using numerous different touch sensing technologies. In this paper, we will focus on a variant of capacitive touch technology known as projected capacitive touch (PCT) technology.

PCT touchpads are made up of a matrix of rows and columns of a conductive material layered between sheets of glass. Applying a voltage to this grid generates an electric field that can be measured at every intersection. When a conductive object, like a human finger, approaches and contacts a PCT panel, it alters the electric field at the contact point. This can be measured as a difference in capacitance.

There are two approaches on PCT technologies: self-capacitance and mutual capacitance.

Self-capacitance touchpad

Error! Reference source not found. shows a sample cross section of a self-capacitance touchpad. Here, a capacitive sensor is positioned on a printed circuit board (PCB) and surrounded by a ground pattern. As **Figure 1** shows, each sensor forms a parasitic capacitance (C_p) with the surrounding ground, with the electric field lines at the top of the sensor. An approaching finger introduces an additional capacitance (C_F) which distorts the electric field.

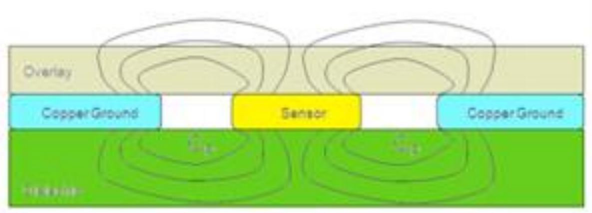


Figure 1: Cross section of a capacitive sensor laid on PCB

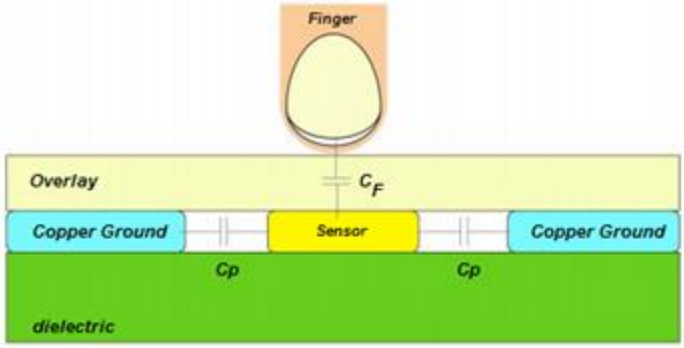


Figure 1: Finger’s added capacitance (Cf)

The presence of the finger results in an increase in the sensor’s capacitance from C_p to $C_p + C_F$. Rapid changes in the sensor’s capacitance can be continuously measured using a microcontroller. If the rapid change in capacitance is above a particular threshold, a finger presence is flagged by the controller.

Mutual-capacitance touchpad

The main disadvantage of the self-capacitance touchpad is that it can only detect one touch at a time; multi-touch detection is not possible. This can be addressed by using a mutual capacitance sensing method as shown in Error! Reference source not found..

The term mutual capacitance refers to the capacitance that exists between any two charge holding objects. During a finger touch, the mutual capacitance between the two objects is reduced. This reduction can be detected to identify the presence of a finger. Crucially, each intersection has its own **unique** mutual capacitance that can be independently tracked by a touch controller.

In most people’s minds, the term “wearable” and the technological aspects associated with it usually refer to devices such as smart watches and wristbands. However, wearable technology goes far beyond this. Wearable devices can be worn on a person’s body and have the capability to connect and communicate to a network. They do this either directly, through embedded cellular connectivity, or via another device, primarily a smartphone using wireless technology such as Wi-Fi or Bluetooth®.

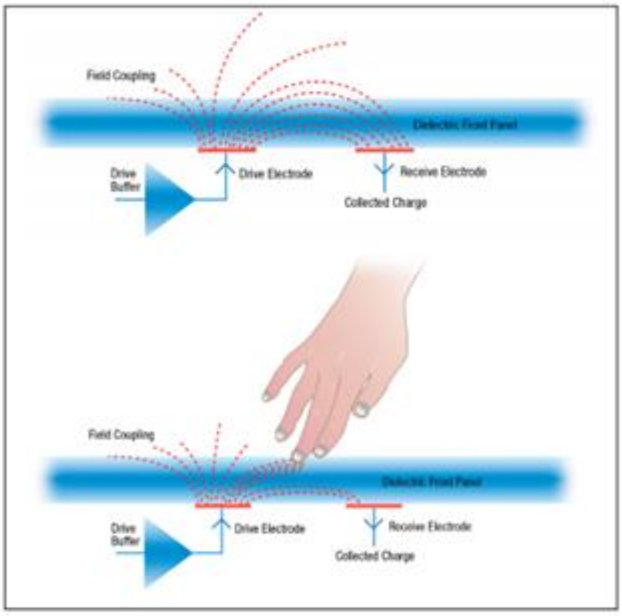


Figure 3: Mutual capacitance touch panel consisting of multiple touchpads

Summary of capacitive touchpad technologies

The graphs in **Figure 4** show the change in capacitance for mutual- and self-capacitance touchpads when a finger is in contact with the pad. For mutual-capacitance pads, the presence of a finger causes a decrease in the capacitance. Conversely, in a self-capacitance pad, the additional capacitance of the finger increases the overall capacitance measured by the sensor.

This variation in capacitance can be measured by the touch controller. A common technique involves using an internal capacitor that is quickly charged and then discharged, normally via a resistor. By tracing the time taken to discharge, a good estimation of the increase (or decrease) in capacitance can be made.

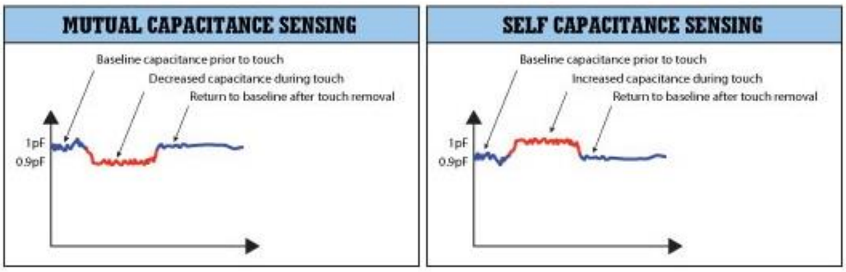


Figure 4: Mutual- and self-capacitance sensing

Table 1 shows a comparision of the characteristics and target applications for the two PCT approaches.

Table 1: ***Mutual- and self-capacitance touchpad comparison***

Self-capacitance touchpad	Mutual capacitance touchpad
Low cost approach	High cost approach
Suitable for limited space designs	Suitable for complicated designs with large displays
Can only detect one touch at a time	Multiple touch detection

Capacitive touchscreens

Multiple capacitive touchpads can be combined to form a touchscreen that detects the location of one or more fingers on a screen. Capacitive touchscreens are widely used in mobile phones, tablets and high-end wearables where space is limited.

Capacitive touchscreen technologies can be summarized into 3 main categories:

- PCB touch panel
- Capacitive touch panel
- Single-layer ITO touch panel

PCB touch panel

A PCB touch panel is basically two or more PCB self-capacitance touch pads placed close to the display. It is an ideal choice for building prototypes and commercial equipment where space is not an issue as it involves standard PCB manufacturing processes that are widely accessible at low cost.

When designing touch buttons to form a PCB touch panel, size is usually the critical parameter to be considered. However, shape and pad pitch (the spacing between pads) should also be taken into account to minimize false detection.

As seen in Error! Reference source not found., a round button is the best choice but other shapes can be used. Whatever shape is chosen, any corners should be as rounded as possible. This minimizes stray field lines and focuses the strongest field right above the button itself.

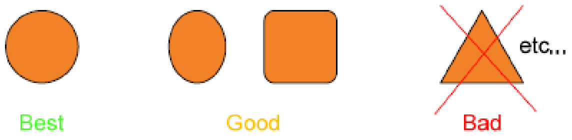


Figure 5: PCB button shape recommendations

Any diameter between 10 mm and 20 mm is fine. If the capacitive touch controllers support proximity sensing as well, and especially through thick plastic frames (as in smart watches), field strength should be increased further by making the pad larger. Pitch is also an important parameter (as shown in Error! Reference source not found.) to avoid false detection. For this reason the touchpads should be spaced far enough apart so that a touch cannot be triggered accidently. This can also be handled by the capacitive touch controller, because in most cases one pad will have the strongest signal.

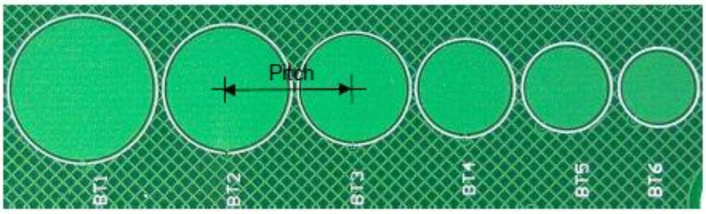


Figure 6: PCB touchpad pitch

Figure 7 shows a typical example of a PCB touch panel with two touchpads placed as a daughterboard on an actual reference design board.

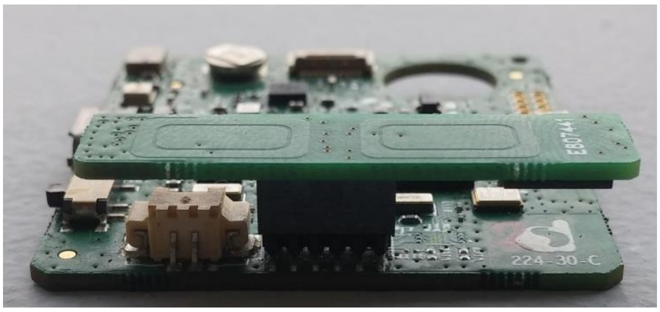
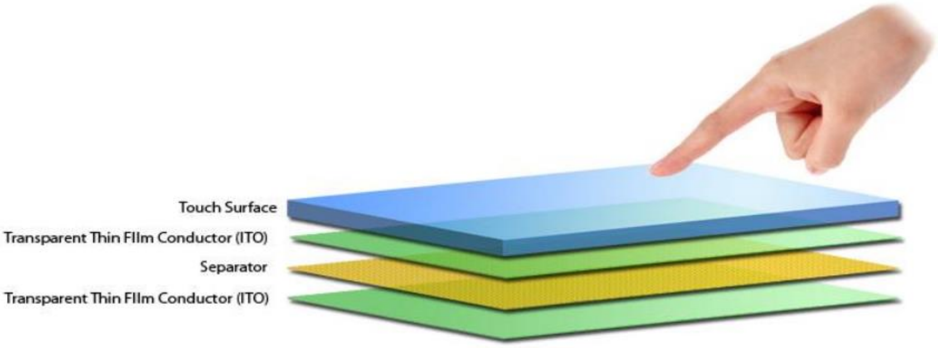


Figure 7: Example of PCB touch panel implemented as a daughterboard in a reference design

Capacitive touch panel

Capacitive touch panels have two conductive layers of indium tin oxide (ITO) stacked vertically – one for the columns and one for the rows (see **Figure 8**). The key point here is that every intersection has its own unique mutual capacitance which can be independently tracked by a touch controller.



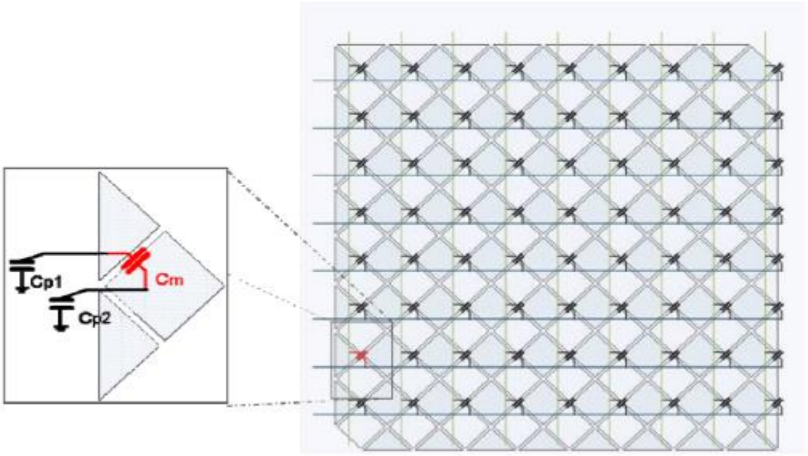


Figure 2: Mutual capacitance (Cm) between rows and columns of a capacitive touch panel

Projected capacitance touch screens intentionally create mutual capacitance between elements of columns and rows (**Figure 2**) in the area where they intersect. This allows the system electronics to measure each node (intersection) individually and detect multiple touches on the screen during one screen scan. Capacitive touch screens are targeted at more complicated systems where large displays are required. A summary of the plusses and minuses of capacitive touch panels is shown in Table 2.

Table 1: ***Capacitive touch panel pros and cons***

Capacitive touch panel	
Pros	Cons
Multi-point touch	High cost due to two layers of ITO
Easily configurable to support 2 or more touchpads	Capacitive touch controller with high demand in power resources
Ultra-thin module	High sleep current and power consumption
Suitable for larger screen sizes	Unsuitable for the small screens used in wearables

Single-layer ITO touch panel

The single-layer ITO touch panel approach offers many of the advantages of the capacitive touchscreen at a lower cost. The main difference is that the number of touchpads is predefined and cannot be altered dynamically as it can be in a capacitive touch panel. This predefined nature brings great benefits in terms of size and controller computing resources. From a manufacturing point of view, this approach is very similar to the capacitive touch panel except that only one ITO layer is used. **Figure 10** shows a cross section of an ITO sample.

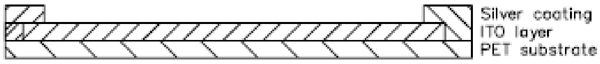


Figure 10: Indicative ITO cross section

The PET coating is attached underneath the top cover of the display. It is essential to have an air gap between the ITO and the actual display of at least 0.7 mm to minimize noise (see **Figure 11**).

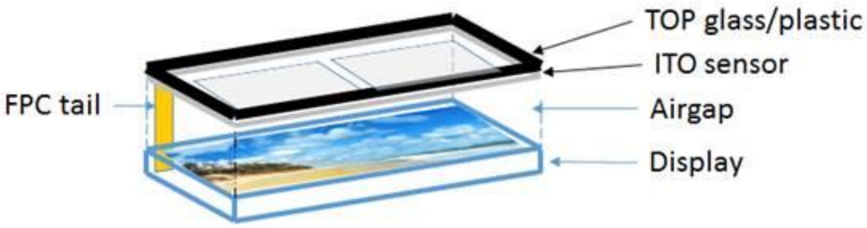


Figure 11: ITO placement underneath the top glass cover

Figure 12 shows an actual implementation of the single-layer ITO concept in a reference design for a wearable device. The ITO layer is placed beneath the top glass and the flexible printed circuits (FPC) tail attached to a connector at the top of the PCB.

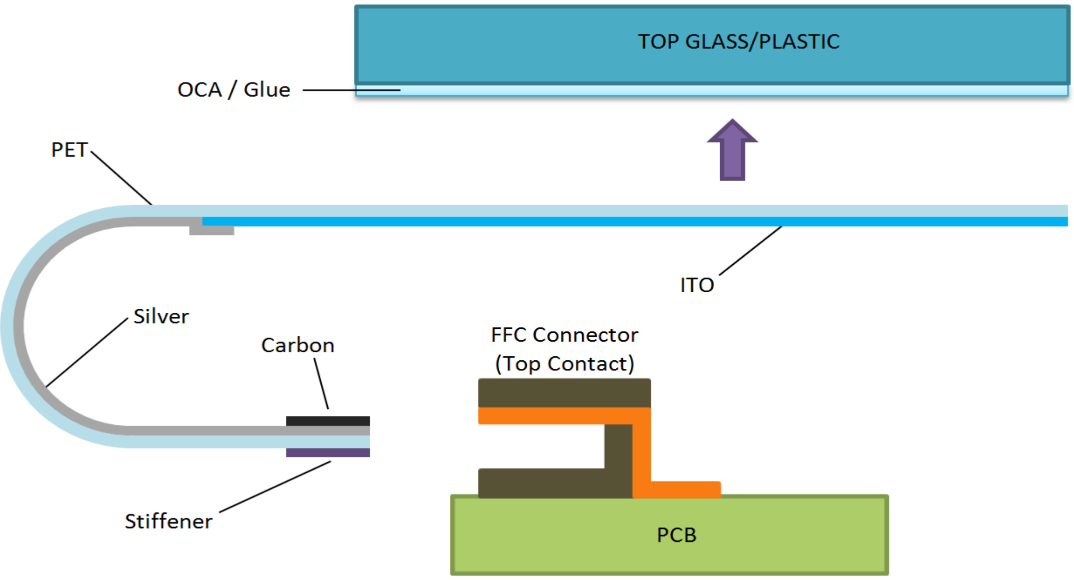


Figure 12: Complete top-level ITO placement on a PCB

Summary of touchscreen solutions

Table 3 summarizes the touchscreen solutions and their key characteristics taking into account parameters like cost, size, controller power consumption and ease of manufacture.

Table 3: ***Summary of touchscreen solutions***

Touch sensing technology	Pre-defined number of touchpads	Small size	Low cost	Low power controller	Ability to dynamically configure number of touchpads	Ease of manufacture
PCB touch panel	**X**		**X**	**X**		High
Capacitive touch panel		**X**			**X**	Medium
Single-layer ITO touch panel	**X**	**X**	**X (In large quantities)**	**X**		Low

References

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