Capacitive Touch Technology Guide

A Quick & Easy Guide to Enhance your Product's Interface by leveraging Capacitive Touch Technology

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Overview

Boyd Corporation has been developing capacitive touch solutions for decades for applications ranging from commercial appliance to medical devices. With the fundamental shift from tactile feedback towards touch technology, more and more companies are integrating non-tactile feedback in their device's user interface. By detecting and utilizing changes in the projected capacitive field, capacitive sensing technology allows you detect touch and thereby, spin a wide gamut of contemporary touch interfaces. Capacitive touch technology offers easy cleanability, higher reliability, and compact designs. This brief guide will walk you through the fundamentals of capacitive touch technology, including the various construction and integration approaches you can take. It will also equip you with important design and technical considerations to optimize the performance of your device.

INTRODUCTION

From clunky typewriters to sleek smartphones, tactile feedback in user interfaces has undergone significant changes in the last few decades. When typewriters were first introduced, they were designed to offer a strong tactile feedback to the user. The distinct sound and rebound of the keys after every registration was a crucial facet of the user experience.

Typewriters gradually paved the path for electronic keyboards. Once people adapted to using keyboards, the discrete "click" of every key was no longer important, thus making way for quieter keyboards. The next development was membrane switches. While they were initially viewed as a non-compelling alternative to keyboards because they did not provide the same feedback as a keyboard, but the addition of metal domes led to improved feedback, thus propelling their popularity.

Capacitive touch keypad

In recent times, touchscreens have revolutionized the world of user interface devices and transformed the way we interact with them. From home appliances to airplane cabins, from vending machines to medical devices, touch technology has truly conquered our lives. As people have moved toward expecting less and less feedback from their devices, the time is ripe for the adoption of the flat, noiseless, non-tactile interfaces.

WHAT IS CAPACITIVE TOUCH?

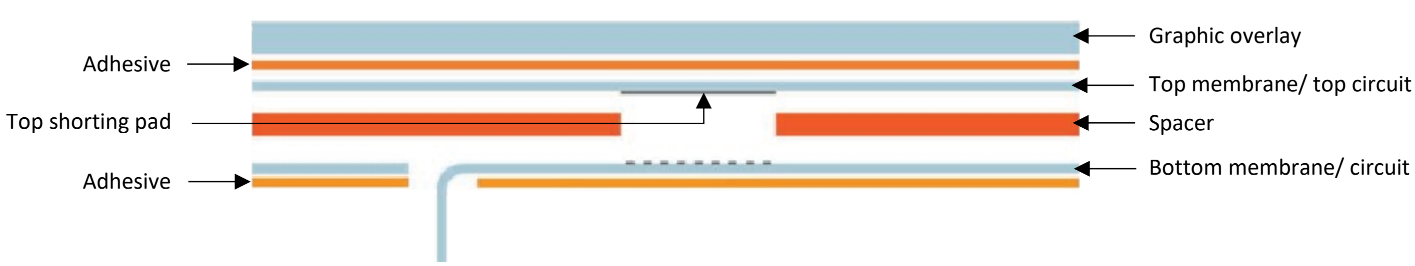
Capacitive sensing technology works by measuring the change in capacitance within its projected field due to the presence of a conductive object, such as the human finger. Projected capacitive touch (PCAP) is a method of using changes in capacitive fields to detect touch and create sleek, modern touch interfaces.

Advantages of Capacitive Touch Technology

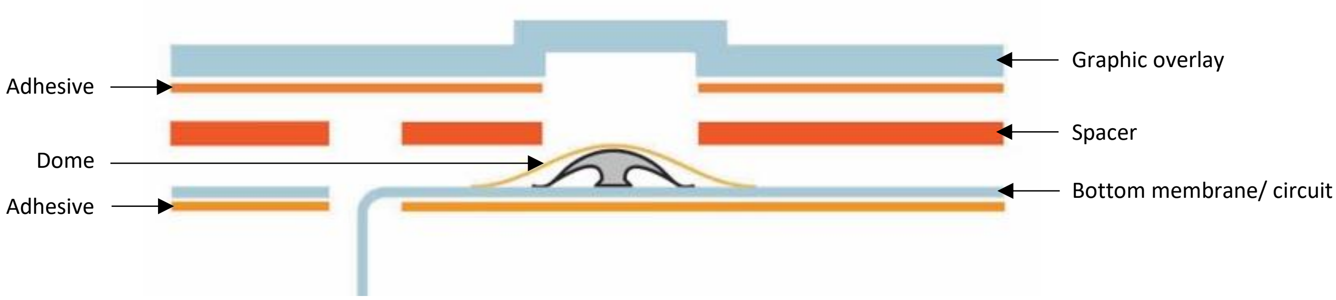
In today's touch-centric era, consumers have not only adapted to non-tactile technologies, but also expect a broader range of devices to offer this functionality and user experience. Capacitive switches do not have any moving parts or mechanical components, resulting in superior durability and prolonged life. Since these devices do not have any crevices, they reduce tooling costs and do not allow any ingress of moisture, dirt, or dust. Their flat surface also makes it easier to clean them regularly. While mechanical buttons can attract dust and tend to wear after repeated use over the years, capacitive technology can replace buttons with a clean and crisp user interface.

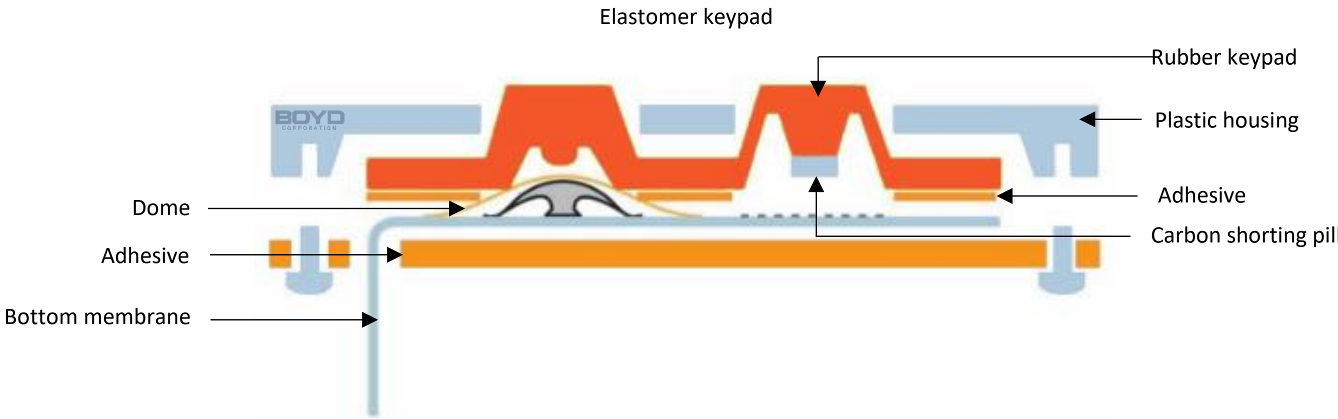
Compared to other mature user-interface (UI) technologies, capacitive switches have a thinner stack-up, resulting in sleek, elegant, and compact designs. They eliminate many design layers and components from the circuitry, thereby reducing the cost of the device. The images below provide a comparison between the stack-up layers of the most common UI technologies available in the market today.

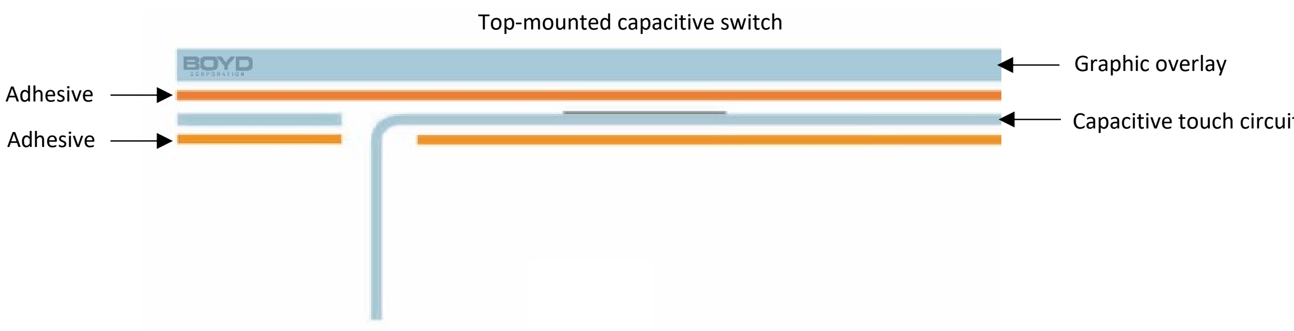
Non-tactile membrane switch

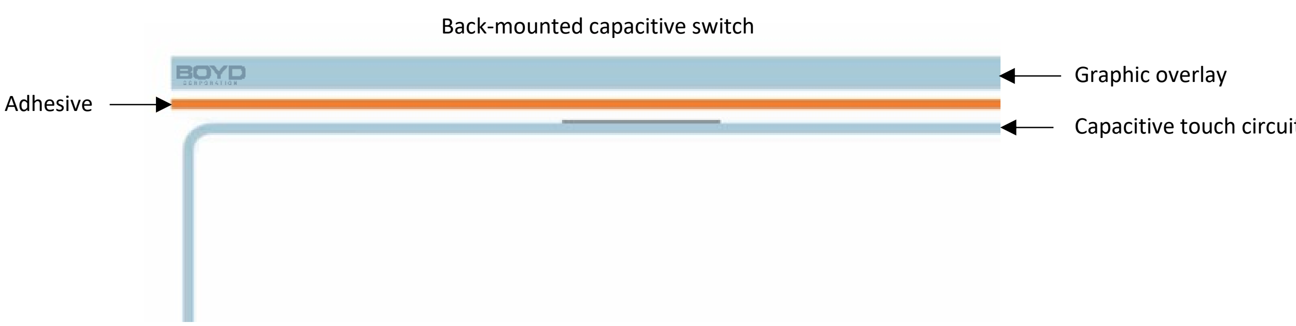


Tactile membrane switch









Although the early development of capacitive switches utilized only printed circuit boards (PCBs), the design possibilities have greatly expanded by employing flexible printed circuits. It allows engineers to spin a wide gamut of design layouts. Capacitive sensor technologies also give you the additional freedom of enhancing the user experience by integrating feedback mechanism like backlighting or haptics.

The key advantages of capacitive touch technology include:

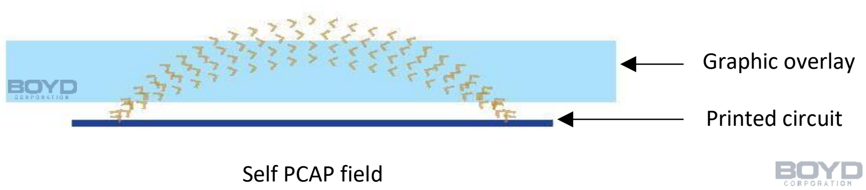
- No moving mechanics
- Thinner stack-up
- Improved reliability
- Easy cleanability
- Higher durability
- Design flexibility
- Sleek and modern aesthetics
- Backlighting and haptics capability

TYPES OF PROJECTED CAPACITANCE

Projected capacitance (PCAP) sensing uses embedded touch detection algorithms in your hardware and firmware to detect changes in capacitive coupling between users and a touch enabled surface to register them as a switch activation. By defining specific switching thresholds, user interfaces can be optimized to create the level of sensitivity desired for your unique application. There are many different implementations of capacitive touch sensors, but the primary approaches to detection are utilizing either self or mutual capacitive sensing.

Self-Capacitive Sensing

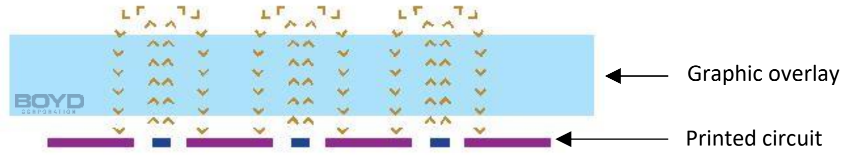
Self-capacitive sensing utilizes a projected capacitive field to detect an increase in capacitive charge when a user interacts with your device. It is often seen in conjunction with a shielded layer that mitigates crosstalk from the adjacent switches and makes the parts more robust against electromagnetic interference (EMI). In addition to requiring less space for circuit routing, these sensors often allow for simplified circuit layouts that help bring down manufacturing costs. Self-capacitive sensing is widely employed in backlit touch switches with large lit areas. However, they might face hurdles in sensitive touch applications or while operating in an environment with high moisture or humidity.



Self PCAP field

Mutual Capacitive Sensing

Mutual capacitive sensing utilizes a projected capacitive field between the X and Y lines (also known as the send and receive lines) and detects a decrease in the charge of this coupled field when a user interacts with your device. This can be an advantage for devices with a high switch count and a limited number of available pins on your microcontroller, since designs can be matrixed to utilize fewer pins.



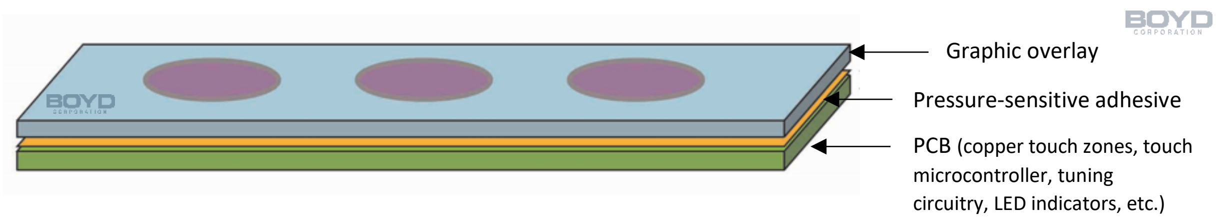
Mutual PCAP field

CAPACITIVE SWITCH CONSTRUCTION

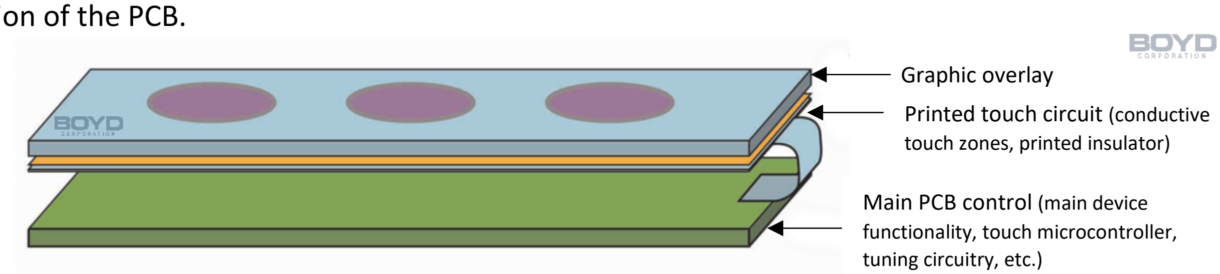
A typical capacitive switch consists of a graphic overlay and a circuit. The graphic overlay, acting as the face of the circuit underneath, directly interacts with the final user. Hence, striking a synergy between aesthetics and functionality is crucial here. In most cases, a non-conductive material with high dielectric constant, such as glass, polycarbonate, polyester, or plastic injected bezel, is selected for the graphic overlay. For optimum performance, there should be no air gap between the circuit and the overlay. While the early capacitive switches only utilized PCBs, the popularity of printed flex circuits has greatly propelled the design possibilities.

A standard panel construction could include one of the following options:

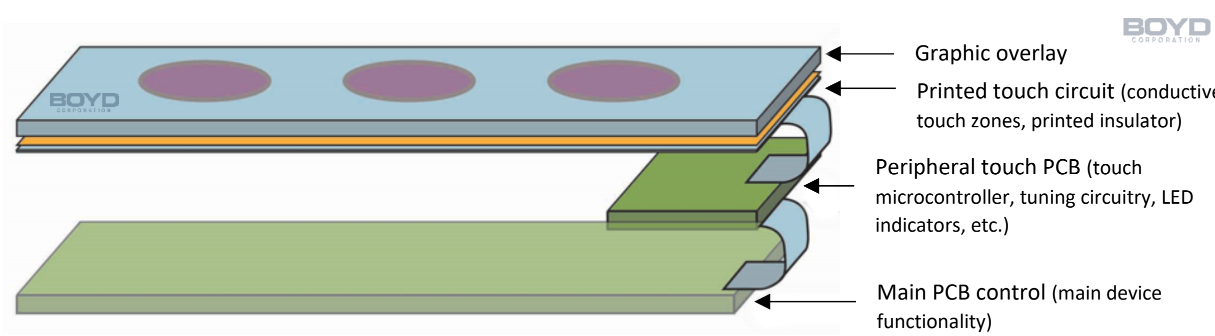
- **Only PCB** - While this can be a cost-effective solution in applications where the design is extremely simple, this construction does put some restrictions on size, form, and backlighting options.



- **PCB and Flex Circuit** - Allowing more modular designs, this construction gives you the freedom to mount the circuit to curved and non-planar surfaces. Any changes or adjustments made to the circuit during the development phase is relatively easy and cost-effective because it doesn't require modification of the PCB.

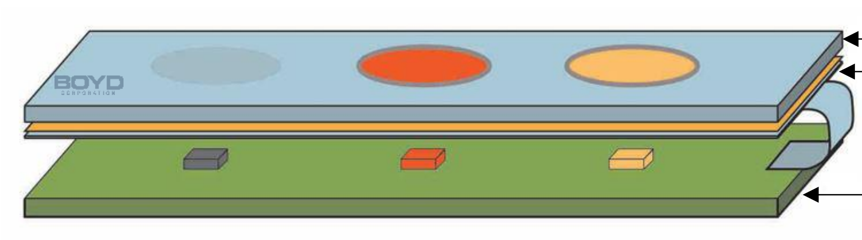


- **Touch PCB and Flex Circuit** - By employing a peripheral touch PCB, this construction allows the touch controller to stay close to the touch surface. It is particularly useful when the space is limited to incorporate the main PCB control close to the overlay.

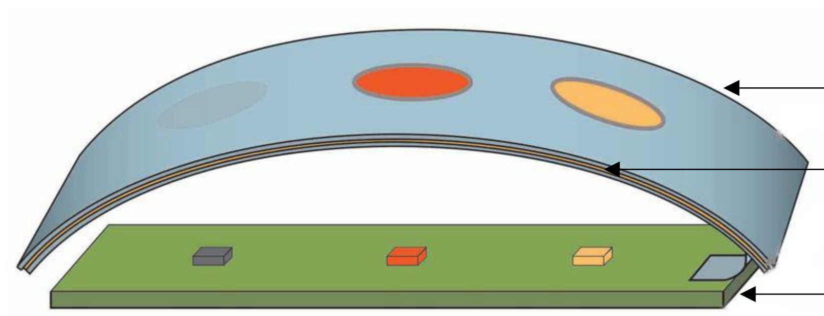


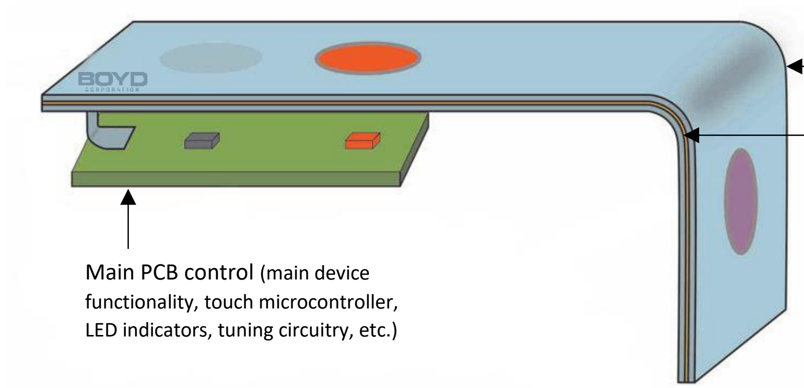
A modern capacitive touch panel design can also include one or more of the following options:

- **Backlit Icons** - Transparent or translucent printed flexible circuits gives way for discretely lit touch icons. LEDs allow for change of color state and other modern effects.

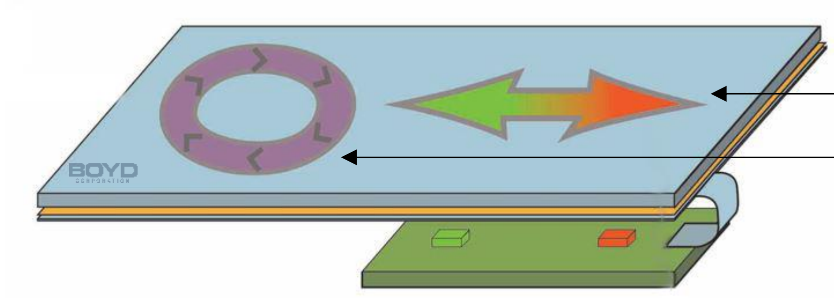


- **Curved and Non-Planar Surfaces** - Cost-effective printed flex circuits can be laminated to simple curves, creating surfaces with a more modern form-factor. Discretely lit icons can be easily incorporated as well.





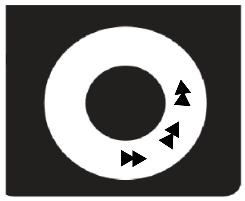
- **Unique Touch Surfaces** - This option allows the creation for multi-touch surfaces and multi-interface types from a single flex circuit. Tactile switches can also be incorporated into the same circuit for additional feedback on critical functions.

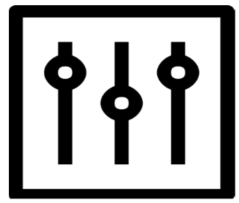


TYPES OF INPUT TECHNOLOGY

Expanding your input methods beyond a regular button, capacitive sensing technology lets you combine the following options in your devices:


Button


Wheel


Slider


Touch pad

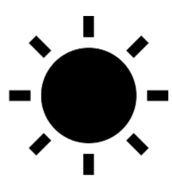
- **Buttons** - A button or a single point of contact, is the simplest form of input. However, the shape, size, and distance between the buttons on a device does have an affect the performance. For optimal performance, round or square buttons with rounded corners are commonly seen. The distance between the buttons and the substrate thickness is crucial to prevent any false detection when the neighboring button is triggered.
- **Wheels and Sliders** - Wheels and sliders allow for higher resolution sensing of finger locations. Multiple sensors are designed to interface with each other in a way that allows the relative signal level to be used to interpret finger position. These input technologies are useful in devices to perform functions such as control ling the brightness, adjusting the volume, or scrolling down a list.
- **Touch Pads** - These allow movement along both the X and Y axes. They give you the flexibility to create user interactive designs by integrating different gestures seen in a modern-day mobile device like zooming, pinching, and striking.

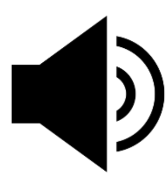
By taking advantage of the large sensitive touch electrodes, proximity sensing can also be integrated into your device. Proximity sensing detects the presence of a large body (such as the hand) even before the user interacts or touches the device. The signal is triggered as the user arrives in close proximity of the device. They are often seen in alarm sensors, security systems, home appliances and electronics.

FEEDBACK MECHANISMS

As mentioned earlier, one of the advantages of capacitive touch devices is the ability to add feedback mechanisms, thereby adding another layer of communication with the end user and improving usability.

- **Backlighting** - Backlighting is a common form of visual feedback that is used in conjunction with capacitive switches to convey the status of a button or slider to the user. It is an effective solution for devices operated in low lit environments.


Visual feedback


Audio feedback


Tactile feedback

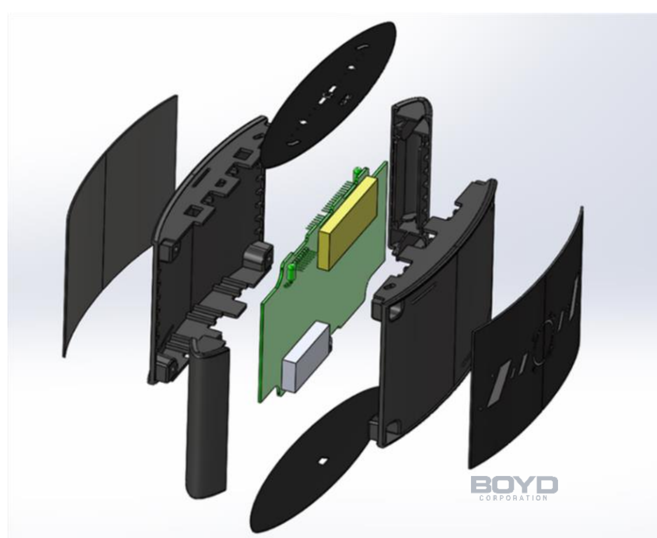
Many lighting options are available in the market today including discrete LEDs, light guide films, and fiber optic weave. Some of the factors that can help you evaluate the correct backlighting solution for your device include power requirements, space constraints, area to be backlit and the environment in which the device will be installed. Backlighting is commonly seen in kitchen appliances and medical devices.

- **Audio Feedback** - This is constructed to make different sounds, such as a discrete click, when the user interacts with the device. Like haptics, it also confirms the registration of keys to the user and prevents confused interactions. Various sound effects can be integrated depending on the message you wish to communicate. For example, the user hears a simple click whenever they tap on the correct (desired) button, hears a beep sound whenever he taps a wrong button, and hears a swoosh sound every time the interaction is complete.
- **Haptics** – Have you played a race car video game and felt a vibration on your controller as you hit a bump on the road? While we can thank the haptics technology for enriching our gaming experience, this technology has significantly evolved over the years and has found itself new territories to enter. Haptic technology provides a tactile sensation in the form of a subtle vibration, thus confirming the registration of the desired key to the user. It is particularly useful when a device is installed in a noisy environment. The alert vibration that we receive on our smartphones is one of the most popular examples seen in recent times. By discretely communicating with the user, it avoids any confused interactions. As touchscreens and capacitive touch have started cropping up in various facet of our lives, the applications of haptics are broadening to medical devices, consumer electronics, industrial controllers, and car dashboards to name a few.

INTEGRATING CAPACITIVE TOUCH TECHNOLOGY

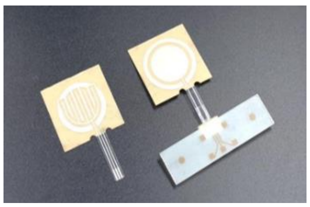
There are many approaches that can be used to integrate capacitive touch into your design. Often the simplest and most cost-effective approach is laminating a printed conductive layer to the underside of your touch surface. This can then be interfaced to the touch microcontroller through several interconnection methods.

Thin flexible circuits can conform to a variety of surface geometries, allowing touch sensitive surfaces to fit in areas that would not be feasible with traditional switches. By adding an insert molding or over-molding process, touch sensitive surfaces can be encapsulated in injection molded plastics, providing extra protection, and simplifying final integration. Integration of capacitive touch is often driven by factors including shielding, overlay material, and the location of the main PCB location.

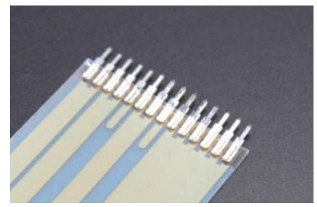


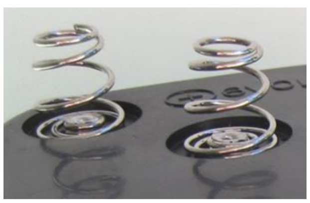
Exploded view of a capacitive touch device

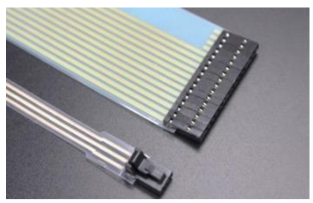
When connecting the capacitive touch circuits to the microcontrollers, it is important to minimize the distance from the touch area to the microcontroller by keeping the connection point as close to the microcontroller as possible. Some of the widely used capacitive touch interconnects include spring pins, solder tabs, Zero Insertion Force (ZIF) connectors, latching and non-latching connectors, conductive foam, plated springs, and zebra stripes. While each of these have their own pros and cons, there are several factors that influence the selection of interconnects such as the circuit type and layout, space constraints, cost, and product application.

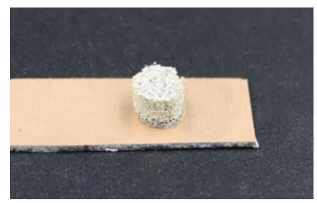

ZIF connector


Spring pins


Solder tabs


Springs


Latching & non-latching


Conductive foam

FACTORS INFLUENCING DESIGN & PERFORMANCE

While designing capacitive switches, the goal is to minimize external noises and enhance the signal strength for better performance. There are multiple factors that influence the design of a user interface device with capacitive sensor technology, each of which is important when examining the cost structure of the switch. In addition, there are other external interferences that can potentially lead to false triggers and actuations or prevent the touch from being registered, thus impacting the performance of the device. The presence of water or moisture, temperature variations, gloved hands, and external noise (from fluorescent lamps, electronic devices, etc.) remain among the most common issues. It is the interplay of all these internal and external factors that eventually dictate the design and performance of each capacitive switch device.

Some of the key factors influencing design and performance entail:

- External noise
- Feedback system
- Type of input
- Substrate materials
- EMI shielding
- Operating environment
- Product application
- Operating temperature
- Dielectric properties of overlay
- Electrical requirements
- Firmware
- Form factor
- Gloved hands
- Internal noise
- Water & moisture

Design and Performance Optimization

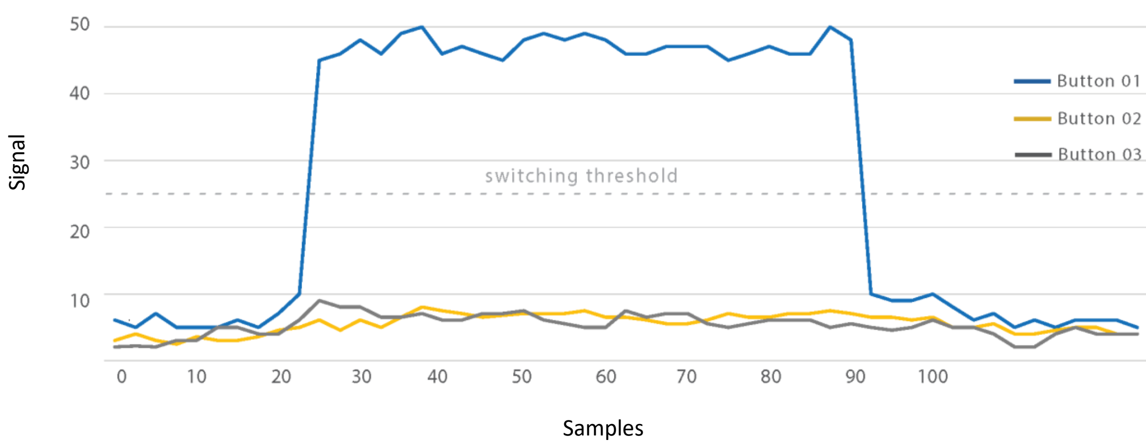
Depending on the specific application and operating environment, there are various methods of adjusting capacitive touch performance to match the design intent. Some of the most common ways include:

- **Alternate Capacitive Implementations** - While self and mutual capacitance are the primary sensing methods for detecting touch, often the use of features such as a driven shield are required to address some of the challenges associated with use in harsh environments and external noises. Shielding traces also help prevent signal crosstalk while minimizing capacitive coupling that can reduce signal deltas. By combining self-capacitive sensing with a driven shield, more resilience from internal noise sources and better moisture resistance can be achieved.

  By coupling an embedded self-capacitive touch sensor with a grounded conductive top plane and a flexible spacer layer, changes in capacitive signal when the touch surface is deflected can be detected. However, these designs can be more complicated and switch locations can be restricted by the material properties of the top plane material. This approach is often used in outdoor applications where gloves and standing moisture are expected.

- **Switching Thresholds** - Capacitive touch switches typically work by establishing a baseline level of capacitance and then monitoring the change (delta) between this level and the capacitance imparted when the user interacts with the touch sensor. As seen in the picture below, a switching threshold can be defined to determine what level of delta constitutes an intentional touch. Gain levels on touch sensors can also be adjusted to selectively increase touch deltas for less sensitive areas. As the gain increases, the level of signal noise can also increase. Defined switching thresholds needs to take this increased signal noise into account.

Button ID	Name	State	Delta	Delta RMS	Channel ID	Signal	Reference
01	Button 01	ON	45	0	0	2100	2055
02	Button 02	OFF	8	0	1	2060	2052
03	Button 03	OFF	9	0	2	2065	2056

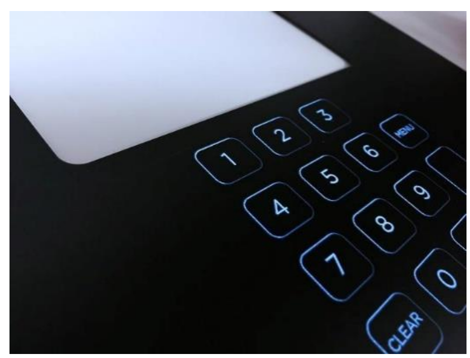


- **Adjacent Key Suppression** - Adjacent key suppression can be used effectively to help avoid unwanted activations of adjacent switches. Adjacent key groups can be defined to allow for multiple switches to be activated at the same time if needed, while avoiding false activations in critical areas.

- **Reducing Crosstalk and Improving Sensitivity** - Circuit designs often need to be tuned once initial performance has been evaluated. Crosstalk can be caused by inadequate shielding between switches and touch lines, but excessive shielding can adversely impact switch sensitivity. Careful placement of ground traces and ground shielding crosshatches can help to shield areas of concern from crosstalk without excessive switch desensitization. Touch sensor patterns can also be adjusted to further optimize performance and sensitivity.

APPLICATIONS OF CAPACITIVE TOUCH TECHNOLOGY

With the shift towards touch technology, an increasing number of companies are flocking towards integrating capacitive touch in their products. Given the host of advantages that capacitive sensors bring to your user interface, they are deployed in a wide array of industries such as medical, automotive, consumer electronics and appliances, aerospace, instrumentation, and industrial controllers. Common applications of capacitive touch technology include smartphones and tablets, home appliances and electronics, medical devices, car consoles, ATM machines, gaming consoles, vending machines, security and communication systems, hand-held devices, electronic sensors, fluid-level sensing machines, proximity sensors, and even airplane cabins.



Applications of capacitive touch technology

WHAT'S NEXT?

The demand for capacitive switches is growing and will continue to do so as we migrate towards a non-tactile world. Capacitive touch technology brings together a blend of enhanced usability, modern aesthetics, and gives you the freedom to augment user experience by adding various visual and audio feedback mechanisms. Compared to membrane switches and elastomer keypads, capacitive sensing offers several advantages including thinner stack ups, easy cleanability and improved durability.

If you are looking to enhance your product's user interface without tipping the scales out of your budget, look no further than capacitive touch. Start by contacting Boyd Corporation to discuss your current design challenges or learn more about capacitive switch technology. With decades of expertise and manufacturing experience, Boyd Corporation is here to help you integrate multiple technologies into a streamlined product.

To receive more information, please visit www.boydcorp.com.