Getting In Touch With Designing Capacitive Sensing Interfaces

By Robert Jania, Global Marketing Manager, Cypress Semiconductor Corp.

Capacitive sensing is making its way into more and more uses everyday. These sleek user interfaces are growing in popularity for PMPs, mobile handsets, computers, point-of-service terminals and other home electronics, and are now showing up in industrial and medical applications as well.

But what exactly is capacitive sensing? Capacitive sensing is a form of touch-based sensing. It's an alternative to traditional mechanical buttons and sliders. In addition it can be used to create touch screens, touchpads and proximity sensing. Instead of sensing the physical state of a button, it detects the presence or absence of a conductive object, in many cases a user's finger.

There are several different reasons to implement a touch-based system. One of the most basic reasons is for higher reliability and durability. For example, buttons in a public kiosk are subject to a lot of abuse and traffic. Mechanical buttons can wear very easily and cause failures. Having to replace buttons and fix mechanical sensors can increase the total system cost. Using a touch-based system is more durable and reduces total costs in the long run. Touch-based systems allow more flexibility as buttons can be used in multiple functions. For example, on a traditional industrial keypad, the mechanical buttons can really only serve one function, or possibly represent a menu option when specified. With touch screens, there are several more ways to design the interface since the display can be constantly changing. The only limits are the needs of the design. In the same sense, as a single button can serve many purposes, a touch-based system allows more usage in a smaller amount of space. Finally, one of the key advantages of using touch-based systems over mechanical buttons is that it can improve the end user experience. Touch-based solutions are oftentimes more intuitive and user-friendly.

Touch-based systems can be implemented in several different ways. This includes the use of resistive film, infrared sensors, or even surface acoustic waves. With so many different options available, why use capacitive sensing? First, there is sensitivity. Capacitive sensing is enabled with presence of a finger and does not require a stylus or pressure as resistive films do. Second, there is durability. As previously mentioned, touch-based solutions are more durable than mechanical buttons and switches because there are no moving parts. However, among the touch-based solutions, capacitive sensors are extremely durable. Whereas an infrared solution can be adversely affected by surface contaminants, capacitive sensing is environment resistant. Finally, there is flexibility. Because capacitive sensing can be used with a wide range of overlay materials, with varying degrees of resolution and accuracy, it is not limited to certain applications. Capacitive sensing can be used in consumer electronics like mobile handsets, MP3 players, and digital cameras and it can also be used in industrial or home appliances like washing machines or kiosks.

So how does capacitive sensing work? The diagram below shows a cross section of a single capacitive sensing button. Under some overlay materials, such as in the diagram, there are conductive copper areas and conductive sensors. Whenever two conductive elements are within close proximity to each other, a capacitance is created, noted as C_P in this diagram, which is generated by coupling the sensor pad and ground plane. C_P is the parasitic capacitance and is typically on the order of 10pF to 300pF. The proximity of the sensor and ground planes also creates a fringe electric field that passes through the overlay. The tissue of the human body is basically a conductor as well. Placing a finger near fringing electric fields adds conductive surface area to the capacitive system.

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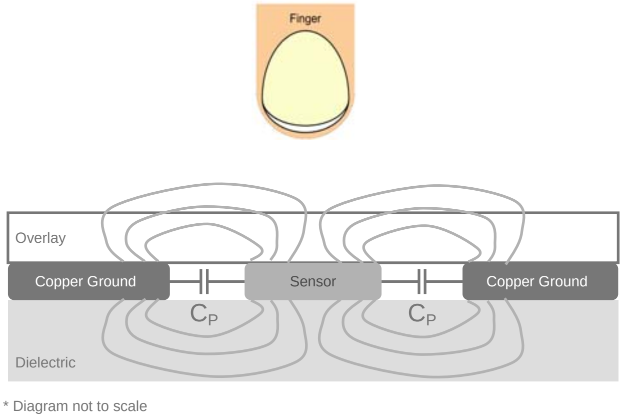
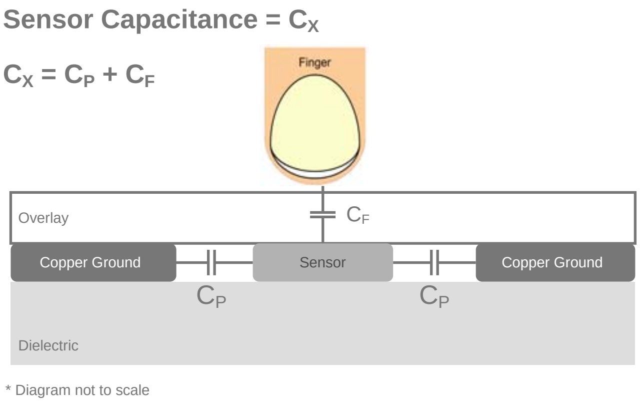
Figure 1. Capacitance from a finger



This additional finger capacitance, noted here as C_F, is however, on the order of 0.1pF to 10pF. Although the presence of a finger induces change, the scale of the change in comparison to the parasitic capacitance is quite small.

The sensor's measured capacitance is called C_X. With no finger present, C_X is basically equal to C_P. When a finger is present, then, C_X is a combination of C_P and C_F.

Figure 2. A sensor's measured capacitance



So with the knowledge of how capacitive sensing works in hand, how does one begin designing a capacitive sensing interface for a particular product? It's important to think about the needs of the design. Where will this product be used? Will the environment be harsh? Is battery life the most important factor in the design or is it durability? Different factors affect the design in different ways.

Depending on the type of product being designed, power consumption may or may not be crucial. For example, in a battery-powered, handheld device, power consumption is extremely important. One method to manage the overall average power consumption, and thus battery-life, is to setup three different operating zones. One zone would be the fast-response zone, where each sensor is scanned every 200 us. The system would enter this zone when the buttons and sliders were under constant activity. In periods of little to no activity, the system could enter a slow response zone which reduces the number of scans to approximately one every 100 ms. Finally, if there has been no activity for a long time, the system could enter a deep sleep mode, thereby saving power. By implementing the power-saving, slow-response mode with a three-button scan every 100 ms in a portable handheld device, the system can consume less than 50 µA of average current.

In today's electronic world, noise is another important consideration. Both conductive noise, like from power lines, and radiated noise, from mobile handsets or fluorescent lights, are always present and have to be accounted for. To be effective, the goal is to increase the signal-to-noise ratio, thereby eliminating false touches.

The type of overlay material selected and the thickness of that overlay will have a large effect on the design's signal-to-noise ratio, durability, ESD resistance, as well as accuracy. Again, there are many tradeoffs when considering the type of material and thickness which will have to be based on the products needs. As the thickness of the overlay material increases, both signal and noise decreases. However, the thicker the overlay material, the more resistant it is to ESD. The electrostatic voltage on the human body can reach 15 KV, and the overlay in a capacitive sensing system can help protect the IC from permanent damage when exposed to this ESD. Another way to address this is with a layer of Kapton tape, which works well in applications needing extra ESD protection. Of course, the thicker the overlay, the harder it is to break and be vandalized as well.

An ideal way to ease the challenges of a design is with a programmable and flexible capacitive sensing solution that can be fine-tuned to fit design needs. One such programmable solution Cypress Semiconductor's CapSense solution based on the PSoC mixed-signal array architecture. CapSense is implemented with two touch sensing methods, CapSense Successive Approximation (CSA) and CapSense Sigma-Delta (CSD), which are optimized to deal with the challenges of designing a capacitive sensing system. Both the CSA and CSD methods regularly update a dynamic baseline from scan to scan to account for environmental changes. So as temperature changes on a particular device, the baseline is adjusted as well. The trend that is tracked by the baseline automatically compensates for the effects of temperature and humidity. In this way, a programmable capacitive sensing solution gives designer's a larger sweet spot to address multiple factors of the design's requirements.

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References

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