Top 4 challenges in touch sensing design

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Abstract

You may be surprised how dependent you are on touch sensors in your daily life. If you have a smart phone, smart watch, or wireless earbuds, you could be interacting with touch sensors for more hours than you sleep!

Plus, designing these touch sensors into devices comes with a number of challenges. This paper will discuss four challenges you might find when designing touch sensors, as well as possible solutions to these challenges.

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Introduction

To start, let's talk about what a touch sensor is. A touch sensor is a device that captures and records a physical touch, typically from a human finger. The two main types of sensing technology are capacitive and resistive.

So which sensing technology should you design with?

Generally, capacitive sensing has more advantages over resistive sensing and is thus more popular. Compared to resistive sensing, capacitive sensing solutions are more durable and do not suffer wear and tear. Capacitive sensing also allows for multi-point input operation; resistive does not. Capacitive sensing screens also generally have an improved picture clarity over their resistive sensing counterparts.

For these reasons, we'll be focusing on capacitive sensing when diving into the challenges that designers face.

Main sensing technology types:

Capacitive sensors

- Use the electrical properties of the human body as input and detect differences in capacitance caused by a human finger when it is in close proximity to the sensor.

Resistive sensors

- Measure changes in electrical resistance caused by the application of force.

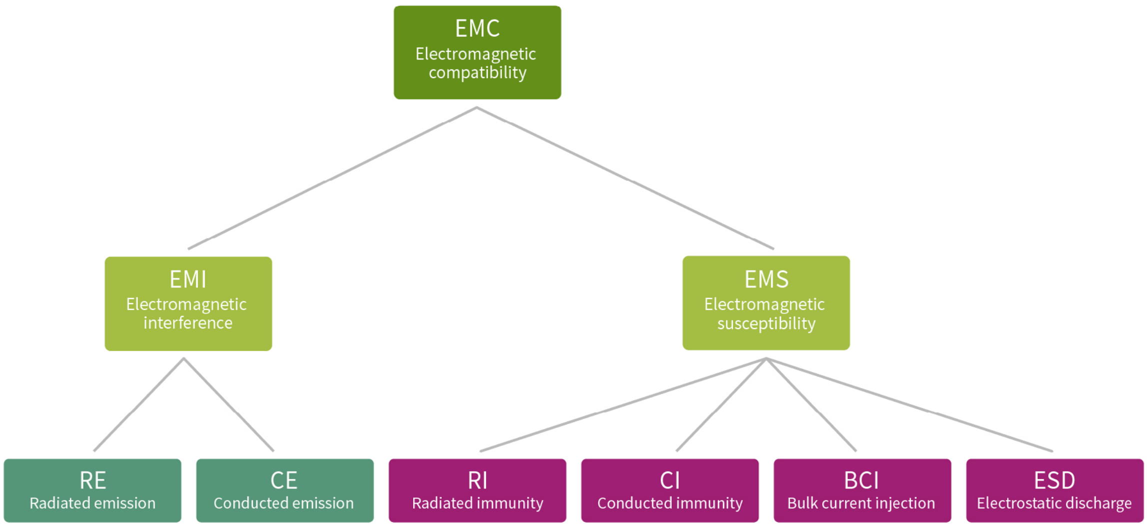
Challenge 1: Robustness

Creating a robust and compelling design is critical in today's market. But ensuring a robust touch sensor design could be more difficult than you might expect.

One challenge that you may encounter while designing is electromagnetic compatibility issues, including meeting both interference and immunity demands. Interference, commonly referred to as "noise," can be caused by a number of different sources.

- Personal electronics like smart phones and Wi-Fi® routers can interfere with touch systems through radiated energy.
- Heavy appliances in the home can all generate noise that can interfere with touch sensor operation through conduction from powerlines.
- Wall power is usually a source of conducted noise that can enter the product when it is plugged into a wall socket.

Unwanted ESD noise is a noise that is physically coupled into the sensor through the product during the user touch event. The influence of all of these noises can be seen as degraded accuracy or linearity of touch, false or phantom touches, or erratic behavior where the touch interface stops working.



Classification of noise affecting touch sensing system

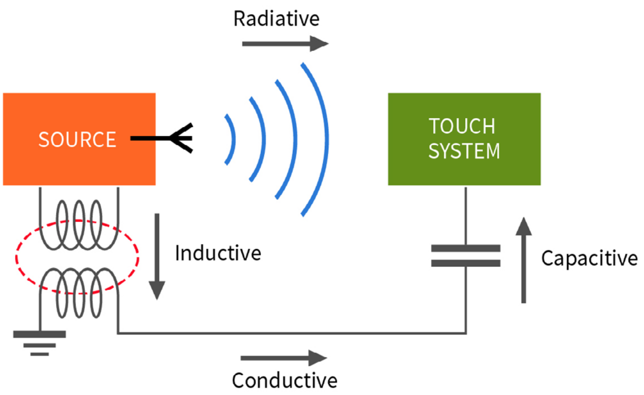
Bulk current injection testing is done to confirm that the RF signals, when coupled onto interconnecting cables and/or power supply lines, will not cause degradation of performance or deviation from specifications of the product. The emission is the noise generated and transmitted by touch sub-systems, which can influence the operation of other sub-systems in the same product, or other products itself. For example, during the development of the system you may find radiated noise from some of the touch controllers affecting the FM radio near to touch product, or noise from the touchscreen in a car interfering with wireless key fobs.

Not only does the design need to be immune to noise within their environments, but even before hitting store shelves the products must undergo a mandatory certification process in which designs are subjected to various conducted and radiated noise for sources so the consumers are protected from these problems.

All of these sources of noise and certification requirements need to be accounted for in the design process. If they're not, then serious issues can arise in the sensor performance. False triggers, ghost touches, or missed touches are common issues that may be caused by unwanted noise. This could lead to you spending months troubleshooting and possibly redesigning the user interface subsystem, as well.

Not to mention, you may have many unhappy customers and experience a loss of revenue and brand value if the user interface of your product is not robust and reliable.

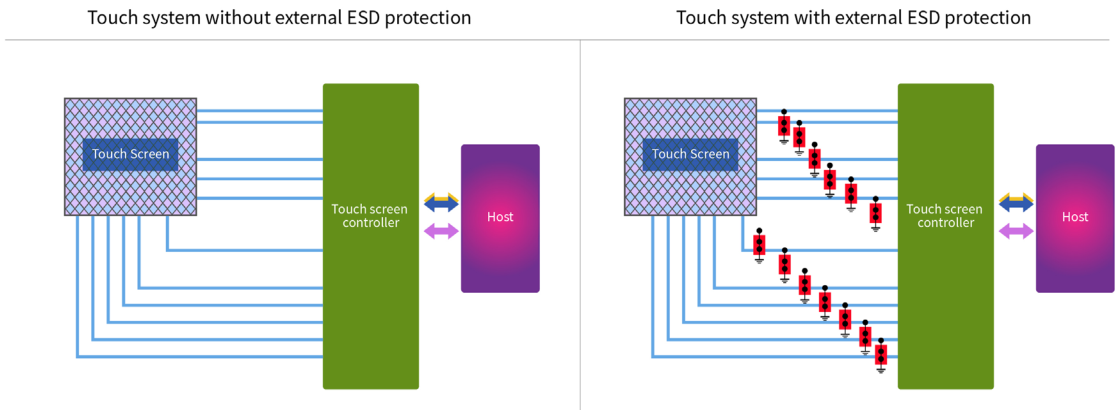
These noise sources can affect touch systems in four different ways as shown in diagram below.



[How do you mitigate unwanted noise?]() Resolving EMC/EMI issues at system level is a complex process, time consuming, and often requires several hardware revisions.

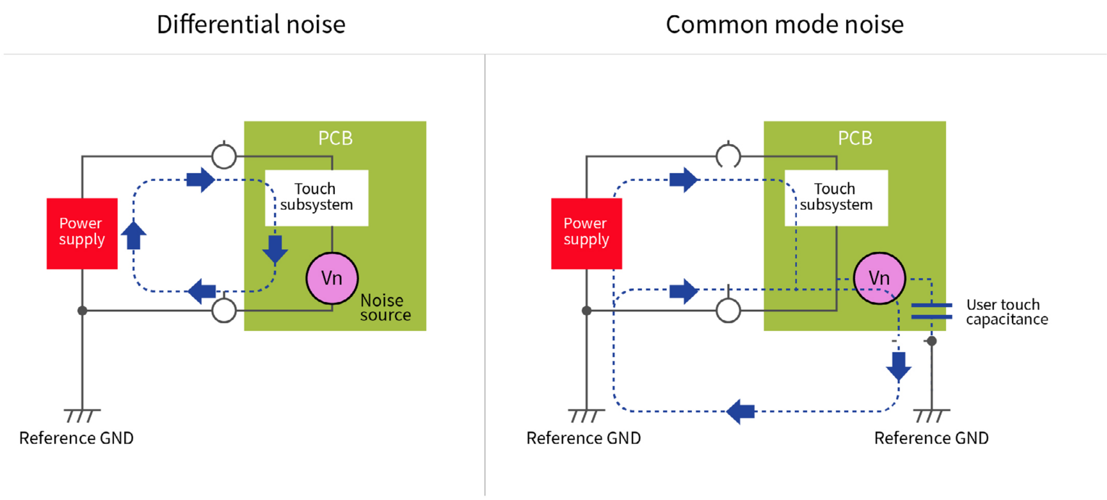
The culprits include marginal layouts, poor sensor, and system designs. These prove to be significant sources of noise immunity and emission concerns. Selecting a touch controller inherently immune to common noise sources can significantly simplify the design process. For a higher level of immunity, several general considerations can be followed in the early phases of design, including schematic design and PCB layout design.

Selecting a touch controller with sufficient on-chip ESD protection on sensor input pins and general purpose pins and designing cover-lens stack-up on top of touch interface with appropriate thickness and material can help address challenges from ESD noise. For extremely high ESD protection, inexpensive external circuits such as single channel ESD protection or low pass filer coupled with ESD circuits can be designed to work synergistically with the complex impedance of the touch sensor. The combination can provide an effective level of ESD control that is hard to achieve by using only on-chip, integrated protection circuitry.



At the schematics level, use of appropriate supply line filters including bypass, bulk and decoupling capacitors, TVS diodes, LC filters, and common mode chokes can help avoid conducted noise. The interfaces of touch subsystems, such as communication lines, can be protected by adding pull-up/down or series resistors and capacitors to avoid the influence of noise. Capacitor or RC networks can protect the reset, interrupt, and other critical control inputs from transients.

The conducted emission can be classified into two types. Differential mode noise and common mode noise. These are explained using the diagram below. Here, the discussion is based on power supplies and touch subsystem, with power fed from outside.



Common mode noise is noise in which a noise current that has leaked via a stray capacitance, such as noise that passes through ground and returns to the power supply line. The electric field intensity of radiation due to common mode noise is proportional to the length of current loop, which makes the noise due to common mode current far greater than differential mode current for the same noise current values. In touch products, the human body is capacitively coupled to earth ground (reference GND) forms a larger current loop, which makes common mode noise a challenging problem for touch interface designs. In particular, when considering measures to address radiated emission, it should be noted that the measures to deal with common mode noise are particularly important.

When designing the sensor stack up and PCB layout, you need to keep in mind two basic principles for greater immunity from noise sources. The first is that currents should be returned to their source as locally and compactly as possible. That is, through the smallest possible and least-impedance path. The second is that a system should have only one reference plane. A reference plane is placed adjacent to a signal layer in a PCB for return currents to flow. Having two reference planes causes signal integrity issues and intensifies transient noise affects.

Another factor for robustness is the ability to reliably work when subjected to liquids, known as liquid tolerance. A capacitive touch sensor produces a signal by detecting the changes in the electric field and capacitance of the sensors. Unfortunately, this operating principle makes capacitive touch sensor influenced not only by human finger touch but also other electrically conductive objects which can influence capacitance of the sensor. Liquids are electrically conductive and when in close proximity to capacitive sensors, liquids can often create false positives on user interfaces, leading to malfunctions of the product. Liquid tolerance needs to be considered for applications where liquids or moisture can come in contact with the user interface of the product, such as in kitchen appliances, smart watches, or wireless earbuds.

Self-capacitance and mutual-capacitance are the two types of capacitive sensing methods commonly used to detect touch events. And these methods behave differently when exposed to ungrounded conductive objects such as liquids.

The self-capacitance method measures changes in capacitance with respect to earth ground. When a user's finger touches the self-capacitance-based touch interface sensor, the human finger provides path to coupling the sensor to ground, thus increasing the self-capacitance of the sensor, which will be detected as a touch event. The liquid, which is electrically conductive covering both the sensor and the ground around the sensor, provides a coupling path to the circuit ground, thus increasing the sensor capacitance which can falsely detected a user touch event.

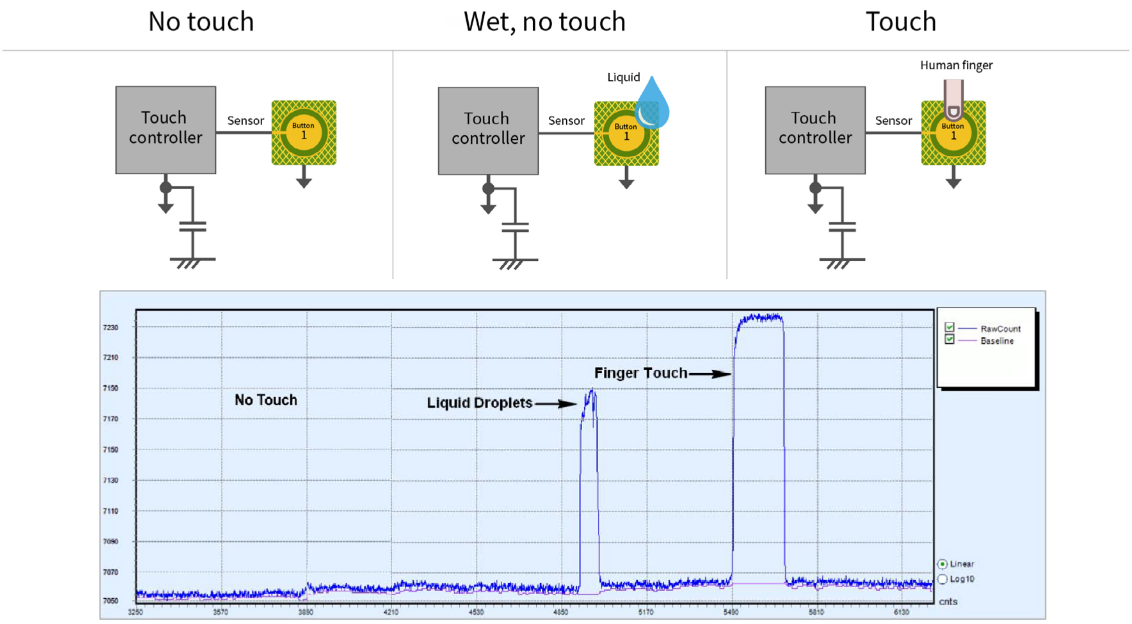
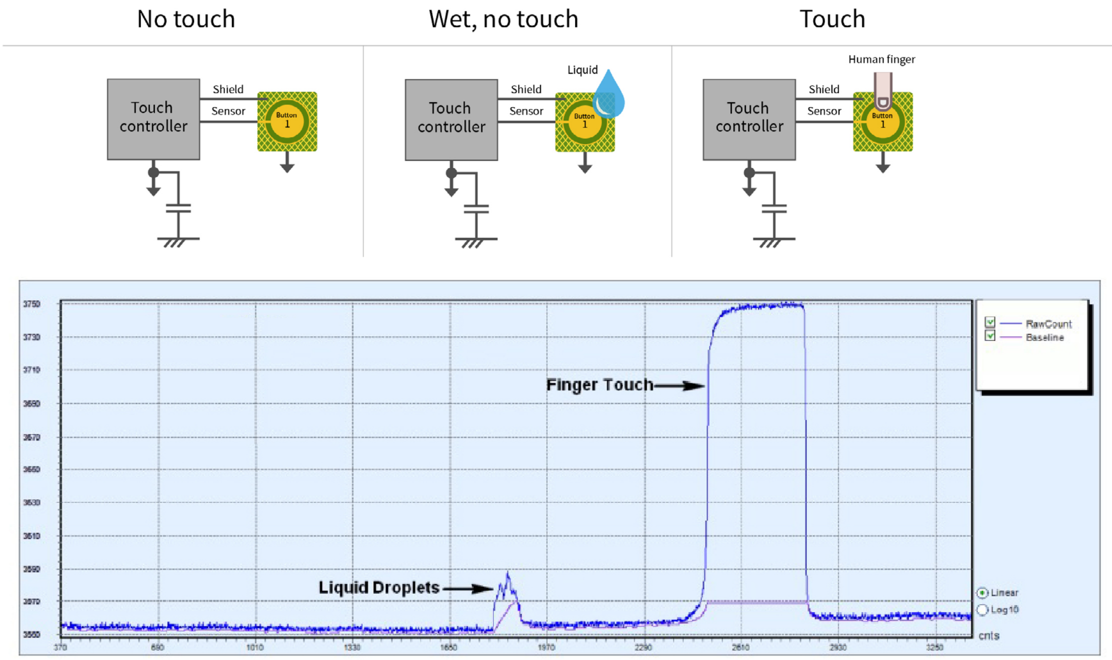


Figure: Response from self-capacitance sensor for no-touch, a valid use touch, and liquid droplet on sensor panel.

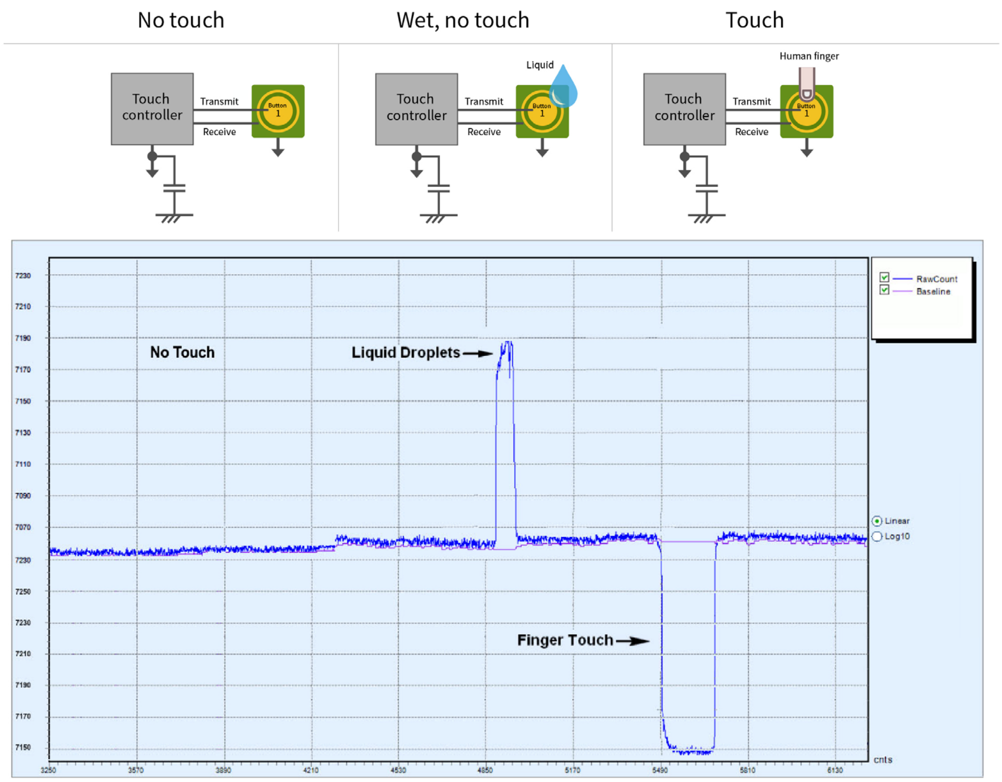
Fingers and water influence sensors in a similar, but not identical, way with electric fields. There is enough of a difference between the two to make possible techniques for discriminating between a touch and a liquid spill.

A practical level of liquid can be achieved in self-capacitance-based systems with the use of a shield electrode. These shield electrodes replace ground around the sensor with an electrode driven by [touch controllers] itself, usually replicating the waveform on sensor electrode, therefore removing the coupling to ground for the liquid droplet and making the sensor insensitive to "ungrounded" liquids droplets.



As shown in the graph above, signal due to liquid droplets are significantly small enough not to be falsely interpreted as touches.

The mutual capacitance method measures changes in capacitance between two electrodes. When a finger touches the area between the TX electrode and RX electrode, the finger reduces the electric field coupling between them, which reduces the mutual capacitance. When liquid covers the touch surface, because liquid has higher dielectric constant than air, the liquid between sensor electrodes increases the electric field coupling between the electrodes, which increases the mutual capacitance. The increase of mutual capacitance causes the measurement result to go in the opposite direction of a touch.



The increase of mutual capacitance with liquid droplet does not produce a false trigger, as touch and liquid droplets are in opposite directions. However, the liquids present on panel for longer duration may results in the sensor settling to “new normal” (a.k.a. baseline). In this case, removal of liquid droplet (e.g. user wipes the panel) will decrease mutual capacitance that will look like a touch and can lead to false detection.

Additionally, mutual capacitance sensors may have a ground around the sensors for improved noise immunity. If a liquid droplet falls over the sensor while covering some part of the grounded hatch, the mutual capacitance decreases similar to the effect of placing a finger on the sensor. The amount of increase in the raw count depends on the size and characteristics of the liquid drop.

A “grounded” water droplet on touch panels is a challenging problem for designers. A touch controller with multi-sense sensing capabilities (self and mutual capacitance sensing, inductive sensing) and machine learning supported touch firmware, can distinguish human touch from interference by “grounded” or “ungrounded” liquids.

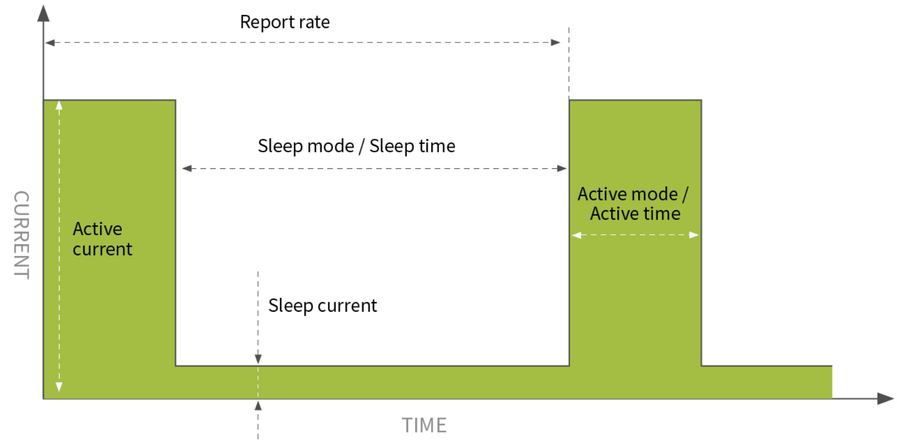
Challenge 2: Low power requirements

Power will always be a design challenge as products need to meet energy efficiency demands. It is critically important for battery-powered devices like smart watches, wearables, and hearables to provide long battery life between recharge cycles. But why are low power consuming touch interfaces such an important requirement?

Generally, products consume power when they are in use or actively operating. When not in use or not actively operating, they transition to sleep mode (a.k.a. standby mode) by turning off most of the features and subsystems to conserve energy. This is not entirely true for user interface subsystems where, at least with limited capability, they need to be active all the time as the users may wake up the product from sleep mode using the user interface of the product. As a result, even though user interfaces consume a relatively small amount of power compared to other sub-systems in the product, the fact that it needs to be always active puts the user interface on a critical path in optimizing the power profile of the product to achieve longer battery life, especially in modern, tiny wearable and hearable products.

There are several factors that affect the average power consumption of a user interface. Electrical properties of touch sensors, such as parasitic capacitance, design and construction of sensors, report rate of user interfaces, type of interface, and the touch controller itself and its low power capabilities can all be factors.

When a touch controller is performing sensing operation, it is in active mode consuming several milliwatts of power. When a sensor is not scanned, the touch controller can be put into a deep sleep mode, in which the controller consumes only a few microwatts. Therefore, it is a common technique to put a touch controller into deep sleep when not sensing the user inputs, as well as periodically placing the touch controller in deep sleep mode between sensing to optimize power. All touch controllers in the market today support these capabilities.



To further optimizes power consumption, it is important to minimize the time the controller spends performing sensing operation. To accurately detect a finger touch, the touch converter detects capacitance change caused by the user's touch relative to the parasitic capacitance of the sensor. The smaller the ratio between the capacitance introduced by the user's touch and sensor parasitic capacitance, the quicker the capacitance to digital conversion can be performed. Therefore, a design should minimize sensor parasitic capacitance while increasing the touch capacitance.

There is no simple relationship between sensor parasitic capacitance and sensor design, but in general, increasing the distance between sensor and ground and decreasing the trace length can help reduce sensor parasitic capacitance. Unfortunately, widening the distance between the sensor and ground will decrease noise immunity. Following capacitive touch sensor design best practices to optimize sensor parasitic capacitance and design an optimal sensor without impact noise immunity is an important step in optimizing for low power.

Optimizing the report rate based on use mode can help optimize power consumption in different use cases. This requires a touch controller that is flexible and offers a customizable touch library. Having the reducing report rate too low can lead to sluggish user experience with the product, so it is vitally important to strike the right balance between low power and report rate.

Lastly, a touch controller with lower system level power specifications and features, such as "ganged sensing" and "wake on proximity sensing," can optimize power as well as enhance the user experience of the product.

During the standby mode of the system, ganged sensing is when all of the physical sensors which can wake up the system are connected together to form a single virtual "ganged sensor" in the design. It will save time scanning only the ganged sensor than scanning all of the sensors. Therefore, the capacitive controller can be in sleep mode for a longer time, which reduces the average power consumed.

Proximity sensing is used to wake up the capacitive controller from standby mode. This method is similar to the ganged sensor mode but involves using a capacitive proximity sensor instead of the virtual ganged sensor. This capacitive proximity sensor can detect the presence of a hand when it is near the sensor without it actually touching the sensor.

Challenge 3: Fast response time

Nobody likes delays between pressing a button and seeing your device take action. In some cases, it might not just be frustrating, but actually dangerous, such as an Electric Vehicle touch screen failing while driving.

The response time, a measure of how quickly a user action is detected, directly effects how many times the user interface of your product refreshes or updates every second. Higher refresh rates allow quicker responses to user actions, and give the feeling of greater fluidity. So, the higher refresh rate the better when it comes to better user experience. Typical touch button interfaces require about a 40 to 80 Hz refresh rate, and touchscreens require about a 60 to 120 Hz refresh rate to provide a seamless user experience for your product.

A common cause of slow response time is poor capacitive sensor design. A finger touch on a user interface generally produces a change in the capacitance sensors in the order of several hundreds of attofarads to several picofarads. The larger the change in sensor capacitance (a.k.a. touch signal), the quicker the touch controller can sample the signal and detect the touch signal. Therefore, it is important to optimize sensor design so that it provides the maximum change in sensor capacitance with a finger touch to improve response time.

In the case of touch buttons, number sensors, and touchscreens, the size of screen also affects response time of the system. Therefore, it is important to select a touch controller which can meet the response time requirements in your specific use case. Additionally, you will need a touch controller which can quickly transition between power modes to maintain report rate when transitioning between power modes to optimize power consumption of user interface.

Challenge 4: Small form factor

The final challenge we will discuss is achieving a small form factor. With consumers demanding smaller and more powerful devices, every component of your design needs to become smaller and more powerful as well.

Let's first look at hearable and wearable devices. Earbuds today require a user interface on a very small area, as opposed to large touchscreens on smart phones or touch buttons on an appliance. These touch sensors need to fit into an area between 2 and 4 mm in size. Other touch interface dependent devices with small surface areas for interaction, like smart glasses and watches, also require small form factor sensors.

There are factors that make designing with smaller sensors difficult or impractical. A finger touch on a user interface produces a change in the capacitance of the sensors proportional to the area of overlap between the user's finger. The smaller the sensor, the smaller the overlapping area between the sensor and the user's finger, leading to smaller change in sensor capacitance from a user's touch. This is sometimes too small to be reliably detected or differentiated from noise sources.

To address these challenges from smaller touch sensors, the most important step is to select a high performance controller that is capable of sensing a change in capacitance in the range of few hundreds of attofarads for your product. These controllers will need to be more sensitive and resilient against noise sources, so they can detect signals that are 5 to 6 times smaller than the normal sensors.

Conclusion

Yes, touch sensing design comes with challenges. But with the right support team, you can traverse these challenges with ease. Infineon's design experts can help walk you through any design challenges you may have. Contact Infineon's support for answers to any of your design questions at the link here.

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