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# Reducing Electrical Noise in a Projected Capacitive Touch Sensor Design


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## Introduction

Projected Capacitive (PCAP) touch technology offers a variety of benefits to industrial and medical applications. The most important benefit is a side effect of the nature of PCAP technology, namely that PCAP uses an electric field to sense a touch. Because the user is interacting with an electric field, the actual conductive components of the touch sensor can be sealed behind a glass faceplate while the field is projected through it. This eliminates wear and tear of the touch sensor itself and eliminates long term degradation caused by temperature and humidity. The fact that PCAP uses an electric field also presents some challenges when designing a PCAP based system, particularly when it comes to electrical noise which can impact the field and generate false touches. This article addresses some of these challenges and offers design suggestions that will eliminate false touches caused by electrical noise.

## PCAP Structure

A mutual PCAP touch sensor, which is the type typically used for touch sensors over displays, has a layer of driving electrodes and a layer of sense electrodes. Sometimes these two layers are co-planer, and sometimes they are on separate layers stacked on top of each other. In either case, the sense layer acts as an antenna that picks up the energy being emitted by the drive layer. In other words, a PCAP touch sensor is essentially a large antenna array tuned to the drive signal frequency, typically between 50kHz and 300kHz. And as with all antennas, a PCAP sensor will pick up any ambient radiated noise that is in its frequency range. Therefore, when designing a PCAP based system, the first thing to consider is what components in the system are generating noise that the PCAP might pick up.

## Display Noise Sources

The most common culprit of noise is of course the display. It's directly behind the PCAP touch sensor and is radiating straight into the sensor's electrodes. A display contains a variety of digital signals which may have frequency components in the hundreds of kilohertz, the exact frequency range that can cause problems for a PCAP. The backlight can be one of the worst noise radiation sources on the display. When choosing a display for a PCAP-based project, try to avoid displays with CCFL backlights. The inverter used to drive a CCFL is very noisy and may cause localized noise issues on the PCAP (localized meaning the noise is present directly above the location of the inverter). An LED backlight is generally the best option when available. Fortunately in the last few years most displays have been designed with LED backlights.

Another common source of noise is the display drive circuit, particularly the switching of the transistors in the display and the VCOM circuit used to drive many displays. These noise sources are often in the same frequency range as the touch sensor. The noise radiates directly from the display and gets coupled into the sensor's electrodes. There are a few ways to mitigate this type of noise. One option is to design the touch sensor to be self-shielding. In this arrangement the bottom electrode layer of the touch sensor is a nearly solid layer of conductive material with very thin nonconductive lines separating each electrode. One electrode is driven at a time while the others are grounded, creating an effective ground shield against the radiated noise. This sensor design, referred to as Flooded X or Manhattan, is less common now than it was ten years ago because it's not compatible with some of the newer drive techniques used by today's touch controllers.

When not using a self-shielding sensor design, the best way to eliminate radiated noise from the display is to use noise reduction techniques in the touch controller. These can include using specific frequencies not used by the display, frequency hopping to adapt to changes in the display's frequencies as the images on the display change, noise cancellation in the analog front end of the touch controller, and noise cancellation software techniques in the touch processing. These types of features are some of the biggest differentiators between low-csot touch controllers and more expensive controllers.

Another consideration when selecting a display is the bezel. Some displays have a metal bezel and some have plastic. A metal bezel can act as a shield keeping noise from other system components from reaching the PCAP. If the display does have a metal bezel, it must be well grounded to provide the best immunity. If the display doesn't have a metal bezel, consider using an metal mounting plate connected to chassis ground for the display.

## Noise From System Components

Some of the key considerations when designing a system that uses PCAP are the location of the touch controller and the locations of the flexible printed circuit (FPCs) tails that connect the touch sensor to the touch controller. Avoid running the FPCs directly over the display drive circuits to avoid noise radiated from those circuits infecting the touch signals. For the same reason it's also best not to place the touch controller board directly over the display drive circuits. If these issues cannot be avoided due to mechanical constraints, then shielded FPCs may be necessary to prevent the noise from the drive circuit coupling onto the FPC signals. Also consider other system components that may be near the touch control board and FPCs once the entire system is assembled. For example, if in the final system assembly the main power supply components are behind the touch controller or the FPCs, then AC noise from the power supply could get coupled onto the touch signals.

Another potential source of noise for a PCAP touch sensor is internal noise on the power rails or ground. The touch controller of a PCAP touch sensor is measuring capacitances in the low picofarad range, which translates to voltages in the low millivolts range. As with any system that measures low voltages, it is important that the system rails and ground be as noise free as possible. At the system level, utilize a star topology ground design connected to chassis ground (or earth ground if available). Also design in high quality power supply components with good transient response and possibly other filter components depending on what noise sources are present in the system. If possible, design the system so that sources of noise are physically separated and possibly even electrically isolated from the touch controller. Ideally the touch controller will have a dedicated LDO or other power device to filter the system power before it reaches the touch controller. If not, it's even more important that the system power be as quiet as possible.

Once internally generated noise has been eliminated or reduced, the next noise source to consider is noise coming into the system on the power rails or ground. This type of "wall noise" can be particularly difficult to diagnose because it may only happen at certain locations, or only during certain times of the day. In one particularly difficult instance, an end user had daisy chained several power strips together to drive multiple systems, each with its own PCAP touch sensor. One of the power strips did not have a ground plug. As a result, all of the noise generated by the devices downstream from that power strip was infecting all the systems downstream causing false touches on those systems. The false touches were eliminated by replacing the ground strip with one that included a ground plug.

## Power Over Ethernet (POE) and Common Mode Noise

When designing a system to use a PCAP touch sensor, there are a number of good design choices that must be made ahead of time to eliminate or reduce noise sources. However, it is not always possible to eliminate all potential noise sources. Devices that use Power Over Ethernet (POE) are susceptible to a particular noise issue that illustrates this. A POE power supply electrically isolates the system from earth ground. POE supplies are notoriously noisy and very often inject common mode noise into the system. Because the noise is common mode, it doesn't usually affect the PCAP when the touch sensor is idle. However, when someone touches the sensor they are providing a relatively stable ground reference to the system. Now that the system ground is stable, the noise is no longer common mode and will begin to interfere with the touch sensor behavior. As soon as the user removes their finger, the stable ground reference is gone and the system returns to normal operation without false touches. As with wall noise, this problem can be particularly difficult to diagnose because it can depend on the type of POE supply used, the load on the supply, and the user themselves. If your system runs on POE, consider providing a known-good POE power supply with each system. That allows you to select and test the power supply instead of relying on whatever power supply the end user happens to pick.

## Noise Avoidance and Noise Cancellation

Eventually some kind of noise will make it to the touch controller, whether it's radiated into the sensor electrodes, radiated into the touch controller board, coupled onto the voltage driving the touch controller, or common mode noise affecting the touch controller's voltage and ground. The best defense against this is a touch controller that implements active noise avoidance and noise cancellation. The touch controller should be able to avoid the noise through techniques like good analog front-end design, frequency selection, and frequency hopping. It should also cancel the noise using advanced DSP techniques. Some controllers use higher drive voltages, increasing the SNR of the touch sensor and swamping out the noise. Other controllers use sinusoidal drive signals with finely tuned filters so that most of the noise is filtered before the voltages are digitized. In general, it's always better to have a higher end touch controller with these kinds of features since you don't know what noise issues you will encounter until the design is finished.

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## Plan Ahead

As projected capacitive touch sensors become the default choice for industrial and medical systems, the designers of embedded systems must become aware of the benefits of PCAP as well as the challenges. Selecting the right touch controller, the right touch sensor vendor, and following a few basic design rules up front will assure a projected capacitive touch sensor that successfully avoids or cancels out any noise sources in the system.