Abstract

How to design capacitive touch systems for robustness and manufacturability

The user interface of personal electronics has become critical to the success of products. Capacitive touch sensing has become the user interface technology of choice.

Designers face challenges like electromagnetic susceptibility, parasitic capacitance, enclosure effects, variety of overlay materials and demands on low power consumption. Electrode tuning simplifies the design and improves signal to noise ratio (SNR) and reliability.

A touch controller with auto tuning maximizes sensitivity, greatly reducing the conventional constraints on PCB layout, limits to overlay thicknesses & materials and negating the need for calibration during manufacture.

The advantages of automatic tuning are:

- compensation for parasitic capacitances
- higher signal-to-noise (SNR)
- large degree of freedom in PCB layout and materials due to high SNR
- adjustable sensitivity
- calibration free manufacturing
- higher EMI immunity
- lower EMI radiation
- proximity detection from the same touch electrode

Article

How to design capacitive touch systems for robustness and manufacturability

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Introduction

The user interface of personal electronics has become critical to the success of the product. Capacitive touch sensing has become the user interface technology of choice.

Designers face challenges like electromagnetic susceptibility, parasitic capacitance, enclosure effects, variety of overlay materials and demands on low power consumption. Electrode tuning simplifies the design and improves signal to noise ratio (SNR) and reliability.

A touch controller with auto tuning maximizes sensitivity, greatly reducing the conventional constraints on PCB layout, limits to overlay thicknesses & materials and negating the need for calibration during manufacture.

Popular methods to design for sensitivity, robustness and manufacturability

The principle of capacitive sensing is based on the measurement of a disturbance introduced to the long-term steady state capacitance of the sensor. The electrode projects an electric field which is designed to be disturbed by a user touching the designated area. The capacitance of this electrode relative to the surrounding environment is continuously sampled.

Capacitive sensing sensors can achieve very high sensitivity. Due to the nature of small variations in capacitance, the sensitivity is usually very dependent on the influence of external factors. These include:

- Sources of parasitic capacitance related to the PCB layout
- Sources of parasitic capacitance related to the touch sensor housing
- Sources of external noise, including EMC disturbances and noise from the power supply
- The thickness and type of the overlay material
- Presence of air-gaps between the sensor electrode and the touch surface

Popular methods to address these influences and described in touch sensor design application notes include:

- Specific PCB routing suggestions
- Prescriptions on the power supply stability
- Suggestions for larger copper key area to improve sensitivity
- Use of hash-grounds to find an optimal point between improving immunity whilst trying not to introduce too much parasitic capacitance which reduces sensitivity in turn
- Use of active driven shields
- Limits on the thickness and type of allowable overlay materials

Whilst these methods can improve the design, they are often required to make the touch sensor system work at all. Designers will typically require multiple iterations of the touch sensor PCB layout as the design moves towards production and stability and sensitivity problems are discovered as late as pre-production, which causes costly delays.

In an age where designers are well conversed in MCU and embedded design, the design principles for sensitive and robust touch sensing remains black magic to inexperienced designers.

Using Active Parasitic Cancellation

Whilst the design guidelines will certainly improve the system sensitivity and robustness, a device which will auto tune to its environment for optimal sensitivity, will shorten design times with less PCB iterations. More importantly it will save costly delays in production where process variations, often in the mechanical construction, causes production delays due to the non-conformance of the touch sensing circuit.

From the sensor perspective, minute differences in process parameters may render the touch sensor unstable or un-usable. These include variations in the power supply stability, thickness of the overlay material, possible air gaps between sensor electrode and overlay material and in many cases, the nearness of the product’s housing. When housings are manufactured from a conductive material, the nearness of the housing introduces a large parasitic capacitance which has a significant impact on the sensor sensitivity.

Parasitic capacitance is an unwanted capacitance between sensor electrode and a nearby (normally grounded) potential. The aim of achieving a sensitive capacitive sensor is to have the sensor project electric field into a dielectric overlay material and further into free air. The user touching the designated touch sensor area would disturb this electric field.

In real life the electric field from the sensor would rather terminate to the nearby grounded potential, than be projected through a die-electric overlay and into free air. Parasitic capacitance can often account for up to 95% of the total capacitance as seen from the sensor. When 95% of the sensor capacitance is static, touching the electrode, can only impact the remaining 5% of variable capacitance. Once overlay materials exceed 1mm, the effect of the touch is as little as 5%, meaning the sensor only sees a 0.25% change between touch and non-touch. This may be very close the noise level of the system.

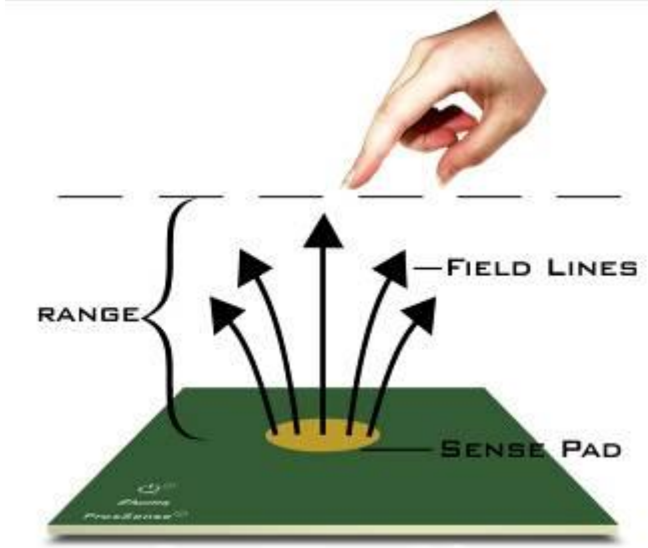


Figure 1 The 'ideal' case has the field lines projecting freely into free air

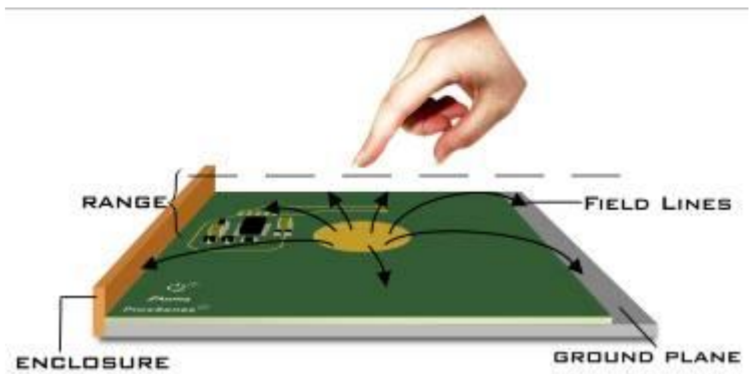


Figure 2 The real life case has the sensitivity reduced by filed lines terminating to surrounding components, tracks, ground planes and the housing

By using hardware compensation circuits, the effect of static parasitic capacitance could be greatly reduced. This would entail the 'subtraction' of the unwanted capacitance from the sensor sample, which in turn means the sensor only sees the variable capacitance, which is disturbed by the user touch. (In another analogy, this can be seen as the removal of a large DC component from a signal with a very small AC component). Once the parasitic capacitance is removed (or greatly reduced), the sensor sensitivity is recovered.

Azoteq's range of ProxSense® capacitive touch and proximity sensors has very effective compensation circuits implemented on-chip. The on-chip implementation means that the designer does not need to worry about the design of complex analog circuits and sensitivity variation, as these are all performed on-chip.

The Azoteq technology is aptly dubbed ATI, or Automatic Tuning Implementation. The on-chip circuits will recover most of the sensor sensitivity, yielding industry leading sensitivity even in environments with severe parasitic capacitance. This further allows for the use of much thicker overlay materials, few constraints on PCB design and much greater degrees of freedom in the nearness of the product housing.

Combining the hardware cancellation with signal processing algorithms to provide auto tuning

A further advantage of an on-chip compensation implementation is that the compensation circuit can be dynamically adjusted by control algorithms. A dedicated optimization algorithm will run at power up and adjust the compensation circuit to achieve a pre-determined target. This target can be chosen to allow for maximum sensitivity, or to achieve an optimized point within a variety of parameters including:

- Sensitivity
- Power consumption
- Sampling frequency
- Noise suppression

The control algorithm will continuously monitor sensor performance and adjust the compensation circuits dynamically, should variations occur due to age, temperature, changes in the mechanical stack-up or even the addition of a static object to the touch panel area. In controllers, which are primarily designed to be used standalone, the control algorithm settings are predetermined and no intervention from a host is required. On multi channel devices, the algorithm can run autonomously. However, the host has a choice to perform partial intervention by only setting target values, or the host may take over the full control algorithm.

Advantages of parasitic cancellation and auto tune algorithms

The foremost advantage of parasitic cancellation is that sensor sensitivity is maximized, even in environments with severe parasitic capacitance. In real life cases, the reduction of parasitic capacitance is one of the biggest challenges faced by designers. With compensation circuits, the designer has much greater degrees of freedom, resulting is much smaller PCB's and optimal performance within a product where the enclosure may add a significant parasitic capacitance.

On-chip compensation circuits allow for accurate compensation without adding to the BOM cost or PCB real estate. The on-chip circuits are calibrated during the semiconductor manufacturing and require no design skills.

Once the on-chip circuits are combined with control algorithms, the sensor may auto-tune to achieve a predetermined target. The auto-tuning algorithm will further ensure that all sensors perform similarly over manufacturing variation.

Control algorithms that allow for host intervention can be dynamically tuned to optimize the sensor. This implies that the sensor may be optimally configured for a long proximity range and low power in a standby state, whilst tuned for a high response rate in operational mode.

Table 1 – Experimental setup

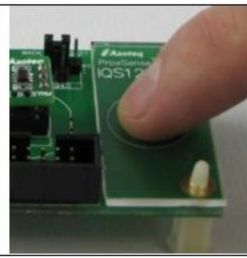
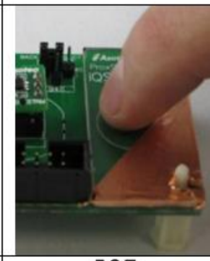
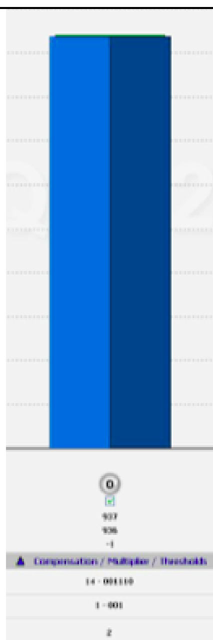
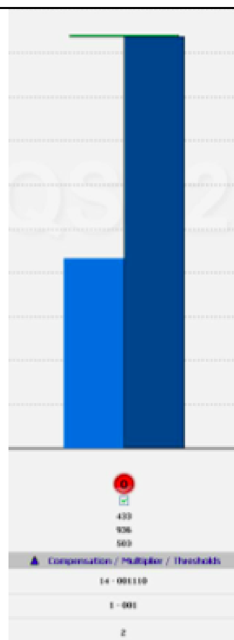
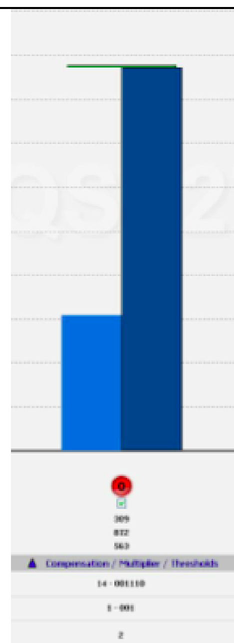
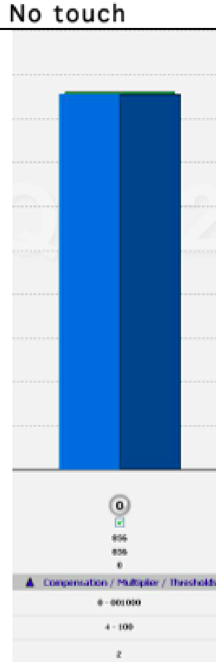
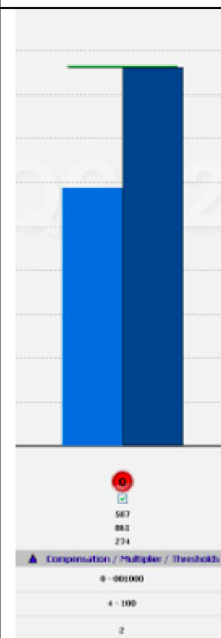
Scenario	1	2	3	4	5
	No touch, no load	Touch, no load	No Touch, Load added	Sensor recalibrated No touch	Touch with load added
					
Current Sample	937	433	309	856	587
Long Term Average	936	936	872	856	861
Delta	1	503	563	0	274
Compensation	14	14	14	8	8
Multiplier	1	1	1	4	4

Table 2 – Readings with the combination of techniques discussed

	No touch, no load	Touch, no load	No Touch, Load added	Sensor recalibrated No touch	Touch with load added
					
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Delta	1	503	563	0	274
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In Table 1 five scenarios are depicted. In scenario 3 an artificial parasitic load is added which is effectively more than an average touch. In scenario 4 an auto tune has been performed by the sensor and sensitivity is recovered, despite the large load.

Conclusion

One of the biggest challenges designers of capacitive touch solutions have to deal with is parasitic capacitance that reduces sensitivity. With a hardware compensation circuit, most of the unwanted parasitic capacitance can be removed. With such a circuit implemented on-chip, no cost is added to the BOM and the designer does not need any special skills to use the compensation circuits.

The compensation circuit can be combined with an auto-tuning algorithm that will tune the sensor to optimal performance automatically. A further benefit is that all touch sensors will have similar performance, even over variations in manufacturing.

Capacitive sensitivity is greatly increased which, allows greater degrees of freedom in PCB design, the overlay thickness and limitations on the touch sensor housing. The Azoteq implementation of on-chip compensation circuits means smaller PCB's that function optimally in environments with severe parasitic capacitance. These controllers offer a superior touch performance and unrivalled proximity detection.

Azoteq offers a full range of high performance proximity and touch controllers with signal to noise ratio's exceeding 1000:1. The controllers all feature internal compensation circuits combined and on-chip control algorithms.

For more information, visit the website at www.azoteq.com, or contact Mr. Viljoen at jean.viljoen@azoteq.com

Biography

Jean Viljoen - Marketing Manager for Europe and Asia

Jean Viljoen joined Azoteq in 2000 as a DSP Application Engineer. Mr. Viljoen was one of the key architects who created the ProxSense® product line in 2004 and has been involved with the product line ever since. In 2005 Mr. Viljoen moved into a marketing role and also took on responsibility for the application group at the Paarl Development Centre. Since 2010 Mr. Viljoen has been the Marketing Manager for Europe and Asia where he established a distribution network and support structure for the ProxSense® product line.

Mr. Viljoen holds a Bachelors degree in Electrical and Electronic Engineering from the University of Stellenbosch and an MBA from the University of Stellenbosch Business School.

The following patents relate to the device or usage of the device: US 6,249,089 B1, US 6,621,225 B2, US 6,650,066 B2, US 6,952,084 B2, US 6,984,900 B1, US 7,084,526 B2, US 7,084,531 B2, US 7,119,459 B2, US 7,265,494 B2, US 7,291,940 B2, US 7,329,970 B2, US 7,336,037 B2, US 7,443,101 B2, US 7,466,040 B2, US 7,498,749 B2, US 7,528,508 B2, US 7,755,219 B2, US 7,772,781, US 7,781,980 B2, US 7,915,765 B2, EP 1 120 018 B1, EP 1 206 168 B1, EP 1 308 913 B1, EP 1 530 178 B1, ZL 99 8 14357.X, AUS 761094