AN11157

Capacitive touch sensing with high EMC performance

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Document information

Info	Content
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Abstract	NXP's touch sensor family provides one of the highest immunity sensor circuits on the market. Nevertheless some considerations in the design are necessary to get a high EMC performance in the application. A description and discussion about the EMC immunity and how it can be improved are made in this document.

Revision history

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1	20120203	new application note, first revision

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1. Introduction

NXP's touch sensor family provides one of the highest immunity sensor circuits on the market. Nevertheless some considerations in the design are necessary to get a high EMC performance in the application. A description and discussion about the EMC immunity and how it can be improved are made in this document.

2. High-immunity cap sensing

There are four important features of NXP's touch sensor family which provides one of the highest immunity sensor circuits on the market.

1. **Wide input capacitance range:** The steady state input capacitance on the sensor input is allowed to be in the range of 10 pF to 40 pF (60 pF for PCF8883 and PCF8886) without affecting the sensitivity.
2. **External low-pass filter:** There may be a resistor (up to 5 kΩ) in series between the sensor plate and the sensor input with minor impact on the sensitivity.
3. **Internal low-pass filter:** There is also an internal low-pass filter suppressing high-frequency noise.
4. **Digital signal processing:** The decision on capacitive events is based on a simple and yet very efficient digital signal processing.

Thanks to the auto-calibration feature of the NXP touch sensors, the steady state capacitance is compensated for by unloading the input through an internal shunting current source. The distributed capacitance between traces and GND and the parallel plate capacitance between sensor plates and GND layers is considered as parasitic capacitance. Many applications with competitor products will either fill the entire input capacitance range or reduce sensitivity dramatically. This will also force the designers to make a trade-off between noise immunity and sensitivity. Just to exemplify, a sensor plate with 10 mm diameter built on a 1.5 mm FR-4 material with GND on the reverse side will have a capcitance of approx. 2.2 pF. Reduced dielectric thickness, small GND-separation and larger sensor plates will easily add up 20 pF which is the maximum value for most of the touch sensor circuits on the market. **The wide range for NXP touch sensors allows smallest possible GND separation for maximum noise immunity without any concerns for sensitivity.** In addition, a GND layer on the reverse side of the board will provide high immunity without reducing sensitivity.

As a direct benefit of the wide input capacitance range and auto-calibration feature, a low-pass filter might be built as illustrated in Figure 1.

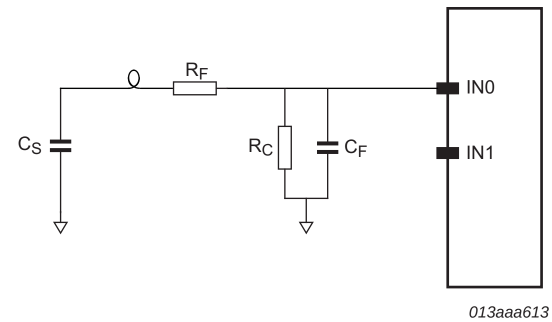


Fig 1. Low-pass filter

The 3 dB bandwidth of this low-pass filter (RF - CF) is plotted in Figure 2. It is shown that RF noise is filtered efficiently with a resistor in series thanks to the 30 pF capacitance in parallel.

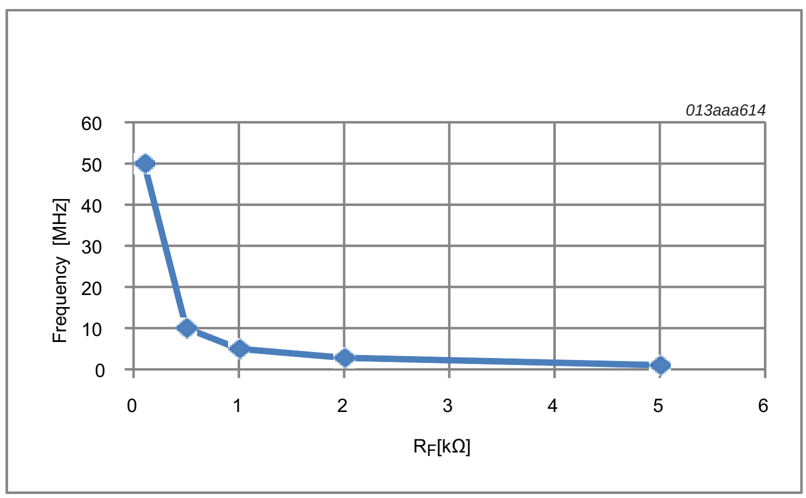


Fig 2. Low-pass filter on sensor input

3. Simple and efficient signal processing

In addition to the low-pass filter on the sensor input, there is also an internal digital mechanism that enhances noise immunity of the NXP touch sensors. As explained in the functional description part of the data sheets: when the capacitive load on the sensor input is increased, the discharge time of the RC network will be longer than the one of the internal reference circuitry. At every cycle, where it happens, the logics after the comparator will increase the counter. If the comparator result alternates, then the counter will be reset to zero. Consecutive 64 samples with same logic results are needed to decide on a capacitive touch. The sampling frequency can be optimized for an application-specific approach sensitivity to detect slow movements or quick movements.

With the internal clock frequency being nominal 70 kHz:
$f_{osc(nom)} = 70$ kHz
Internal clock frequency may be set as:

$f_{clk} = f_{osc} / n$, where n = 1, 4, 16, 64, and 16 is the default value.

The sensor sampling frequency (fs) is derived from the internal clock frequency with

$f_s = f_{clk} / 8$

The eight sensors are sampled sequentially, which results in a default sensor sampling rate of f_S = 0.55 kHz.

Running autonomously, this method provides efficient immunity against RF noise down to kHz ranges. There is no need for advanced computing of the absolute capacitance level, noise level in the system, and so on.

Not even a fly nor a turtle will activate the sensor!

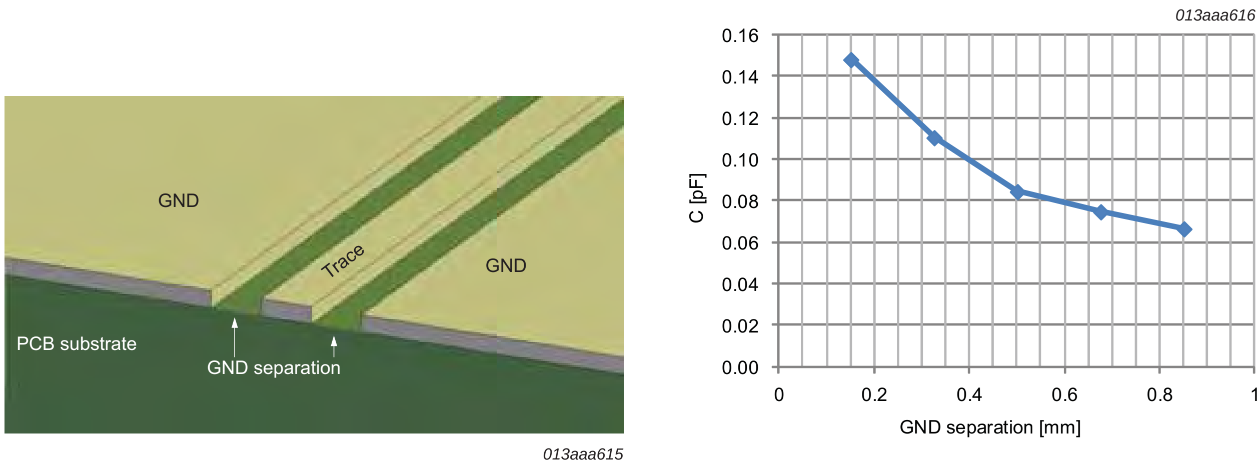
4. EMC design considerations for board layout

Thanks to the properties explained in the previous section, the sensor plates and routing may be done with high immunity in mind and without major concerns for reducing sensitivity.

For a two-layer FR-4 based PCB taken as a reference, the following design rules are recommended:

- Components and routing should be on the bottom layer.
- On the top layer, the sensor plates should be surrounded by GND. The separation to GND is recommended to be equal to the overlay thickness. However a minimum of 2.2 mm will work for a wide range of thicknesses. The GND is needed for high immunity. There will be stray capacitance between a touching finger and GND which is not good for sensitivity. So, a simple way of providing high immunity without decreasing the sensitivity is to make hatched GND around sensor plates.
- On the bottom layer, the GND under sensor plates is recommended to be hatched with 20 % metallization. The gap between traces and GND should be kept as small as possible; 0.1 mm to 0.15 mm but the total capacitance budget on each channel must not be exceeded. The width of traces may be kept small since the resistance and inductance is not critical. The traces should be kept as short as possible for immunity reasons.

A trace on a typical FR4 board with GND both on the rear side and on the primary side is illustrated in Figure 3. The graph shows that the parasitic capacitance contribution from the trace will decrease with increased separation to GND on the sides. In order to obtain lower capacitance, the GND metallization on the rear side of the board might be hatched or removed with lower RF immunity as a consequence for the latter case.



a. Trace on a PCB   b. Contribution to parasitic capacitance

Fig 3. A traces on a PCB and its contribution to parasitic capacitance

5. IEC testing

Every electronic device is required to comply with certain regulations for appropriate application areas and level of importance. Thanks to the use of an internal low-frequency RC oscillator, radiation from the NXP touch sensors is not an issue. However immunity against conducted and radiated disturbance has to be proven. In order to create the most immune electronics possible it is also crucial for application board designers to know the susceptibility of touch sensors for such disturbances. The Ref. 1 “IEC 61000-4-4” and Ref. 2 “IEC 61000-4-6” standards define immunity against bursts of electrical fast transients (EFT) and injected RF disturbances respectively. In addition to these standards applying on complete electronic apparatus with power supplies and interface to auxiliary devices, there are also standards for testing integrated circuits (ICs).

Philips Innovation Services-EMC Center has been chosen for application level testing and Langer EMV has been chosen for IC level testing.

5.1 ESD testing

ESD testing has been performed according to applicable norms, Human Body Model (HBM) according to Ref. 6 “JESD22-A114” and is classified for 1.9 kV. Charged device model (CDM according to JESD22-C101C) level has been tested to be 500 V for all pins and 750 V for the corner pins.

NXP’s PRTR5V0U8S is an 8 channel (Integrated octal low-capacity ESD protection to IEC 61000-4-2, level 4) ESD protection component from NXP to be recommended for if higher ESD protection is desired. It provides protection for up to 8 kV discharges from human bodies.

5.2 Tests at Langer EMV-Technik

Langer EMV-Technik from Germany has developed test systems and methods that have become a de facto industry standard especially for white goods. The purpose of the tests done by Langer is to evaluate the immunity of an IC to electrical fast transients and RF disturbances. These tests provide crucial information and guidelines to the user as well as feedback to the IC designers.

5.2.1 Electrical Fast Transients

The Ref. 1 “IEC 61000-4-4” defines immunity requirements and test methods for electrical and electronic equipment to repetitive electrical fast transients such as those originating from switching transients interruption of inductive loads, relay contact bounce…). The standard also defines the test voltage, waveform, the range of the test levels as well as the test equipment and setup for coupling transients into power supply, control and signal ports of electrical and electronic equipment.

Langer EMV has transferred the test method and requirements from equipment to IC level and a test system with EFT generator and set up has been developed (see Ref. 3 “Characterizing the Immunity of Integrated Circuits against Electrical Fast Transient Disturbances”).

In order to evaluate the immunity for electric and magnetic fields and the impact of induced currents thereof, bursts of electrical fast transients are applied on one pin at a time and an indicator output pin is monitored. Disturbing electrical fields are simulated with high-impedance probes and magnetic fields are simulated with low-impedance probes.

PCF8885 was mounted on a PCB as shown in Figure 4 according to the typical application circuit diagram described in the data sheets.

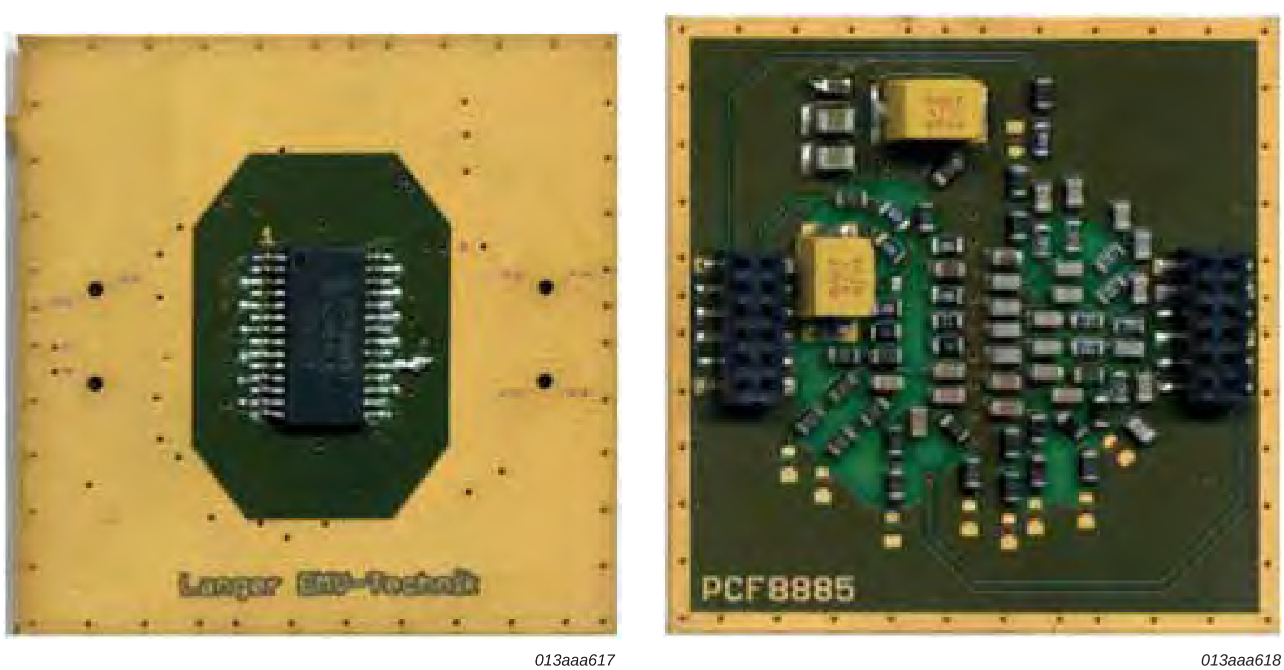


Fig 4. Test PCB with PCF8885 used at Langer EMV

The test results demonstrate high immunity level to bursts of fast electrical transients which makes PCF8885 a reliable capacitive touch sensor for harsh electrical systems where transients due to powerful motors, relays and other switching elements are present.

5.2.2 Direct RF Power Injection

IEC 62132-4 defines a method of evaluating the immunity of integrated circuits to RF disturbances. Langer EMV has developed a test system where an RF signal is applied directly to package pins. RF signals in the range of 150 kHz to 1 GHz are applied to one pin at a time while the power is increased and an indicator pin is monitored. The PCB in Figure 4 is also used for this test.

5.3 Tests at Philips Innovation Services-EMC Center

In order to test immunity to electrical fast transients and conducted RF disturbances a controller board from a leading manufacturer of home appliances was tested. The board was assembled with PCF8885 and the power supply unit from the customer was used to create identical test conditions to real applications.

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Fig 5. Controller board for a water heater

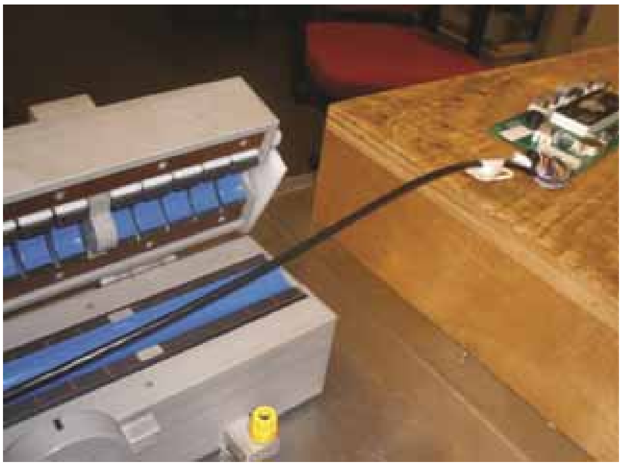

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Fig 6. Test set-up at Philips for IEC61000-4-X testing

6. References

[1] **IEC 61000-4-4 —** Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test.
The 61000-4-4 (Electrical Fast Transient/bursts) tests relate to immunity of electrical and electronic equipment to repetitive electrical fast transients. It additionally defines ranges of test levels and establishes test procedures. The disturbance was both applied on the mains power and on the IO ports of the controller board. 1 kV to 4 kV voltage range was tested and no aberrations occurred.

[2] **IEC 61000-4-6 —** Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields.
This part of IEC 61000 relates to the conducted immunity requirements of electrical and electronic equipment to electromagnetic disturbances coming from intended radio-frequency (RF) transmitters in the frequency range 9 kHz up to 80 MHz. This range was extended to 230 MHz during the tests. Disturbances were applied both on the mains power and on the IO ports of the controller board. These tests were passed with no aberrations in function.

[3] **Characterizing the Immunity of Integrated Circuits against Electrical Fast Transient Disturbances —** LANGER EMV-Technik GmbH

[4] **AN10832 —** PCF8883 - capacitive proximity switch with auto-calibration

[5] **AN11122 —** Water and condensation safe touch sensing with the NXP capacitive touch sensors, Application Note

[6] **AN11155 —** General design guidelines for the NXP capacitive sensors, Application Note

[7] **PCA8885 —** Capacitive 8-channel proximity switch with auto-calibration and very low-power consumption, Data Sheet

[8] **PCA8886 —** Dual channel capacitive proximity switch with auto-calibration and large voltage operating range, Data Sheet

[9] **PCF8883 —** Capacitive proximity switch with auto-calibration, large voltage operating range and very low power consumption, Data Sheet

[10] **PCF8885 —** Capacitive 8-channel proximity switch with auto-calibration and very low-power consumption, Data Sheet

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