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Water and condensation safe touch sensing with the NXP capacitive touch sensors

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Application note

Document information

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Abstract	This application note explains the unique auto-calibration feature of the touch sensor family from NXP and provides guidelines for enhanced water and condensation safe operation, focusing on applications with capacitive touch buttons



Revision history

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1. Introduction

Capacitive touch sensing is considered as a revolutionary development to replace mechanical buttons in all application areas. While providing an easy to implement hermetic touch interface with no mechanical parts, factors as accumulated contaminations, condensation and water droplets have been less pleasant topics to deal with. Robustness is a major concern. Especially in harsh environments as workshops where contaminations are usual, in automotive applications where extreme climate conditions apply and also in white goods where wet hands and water splash is encountered, special attention needs to be given.

This application note explains the unique auto-calibration feature of the touch sensor family from NXP and provides guidelines for enhanced water and condensation safe operation, focusing on applications with capacitive touch buttons.

2. Auto-calibration

Most commercially available touch sensors measure the absolute capacitance of the load on the sensor input and decide by comparison to a threshold value whether there is a touch or not. This method works well under ideal circumstances where the sensor plate is kept clean and the climate of the room (temperature and humidity) is controlled. Just to exemplify, temperature and humidity in the air can affect the surface leakage in such a way to change the capacitive load drastically and to trigger a false switch, even when the change in capacitive load is slow.

The NXP PCF8883, PCA8885, PCF8885, and PCA8886 capacitive sensors use a patented auto-calibration technology to detect changes in capacitance. The devices digitally filter out very slow and very quick changes in capacitance at the input. As a result, the performance of the NXP devices is less affected by conditions that can impair or prevent correct functions in other devices. With auto-calibration, such things as dirt, humidity, freezing temperatures, or damage to the electrode do not affect the device function.

The functional diagram of the NXP capacitive sensors is shown in [Figure 1](#). The auto-calibration mechanism, which is based on a voltage-controlled sink current connected to the pin IN, attempts to equalize the discharge time of a capacitive load with the internal reference discharge time. The current source is controlled by the voltage on an external reservoir capacitor C_{CPC} . This current causes the capacitance on pin IN to be discharged more quickly in the case that the voltage on C_{CPC} is rising, thereby compensating for the increase in capacitance on pin IN. This arrangement constitutes a closed-loop control system that constantly attempts to compensate for slow changes in capacitance on the IN pin. Fast changes, for example due to an approaching hand, are not compensated. In the equilibrium state, the discharge times are equal and the pulses alternate between CUP and CDN. For further explanations about the internal operation of the capacitive touch sensors, see the data sheets [Ref. 1 "PCA8885"](#), [Ref. 2 "PCA8886"](#), [Ref. 3 "PCF8883"](#), and [Ref. 4 "PCF8885"](#).

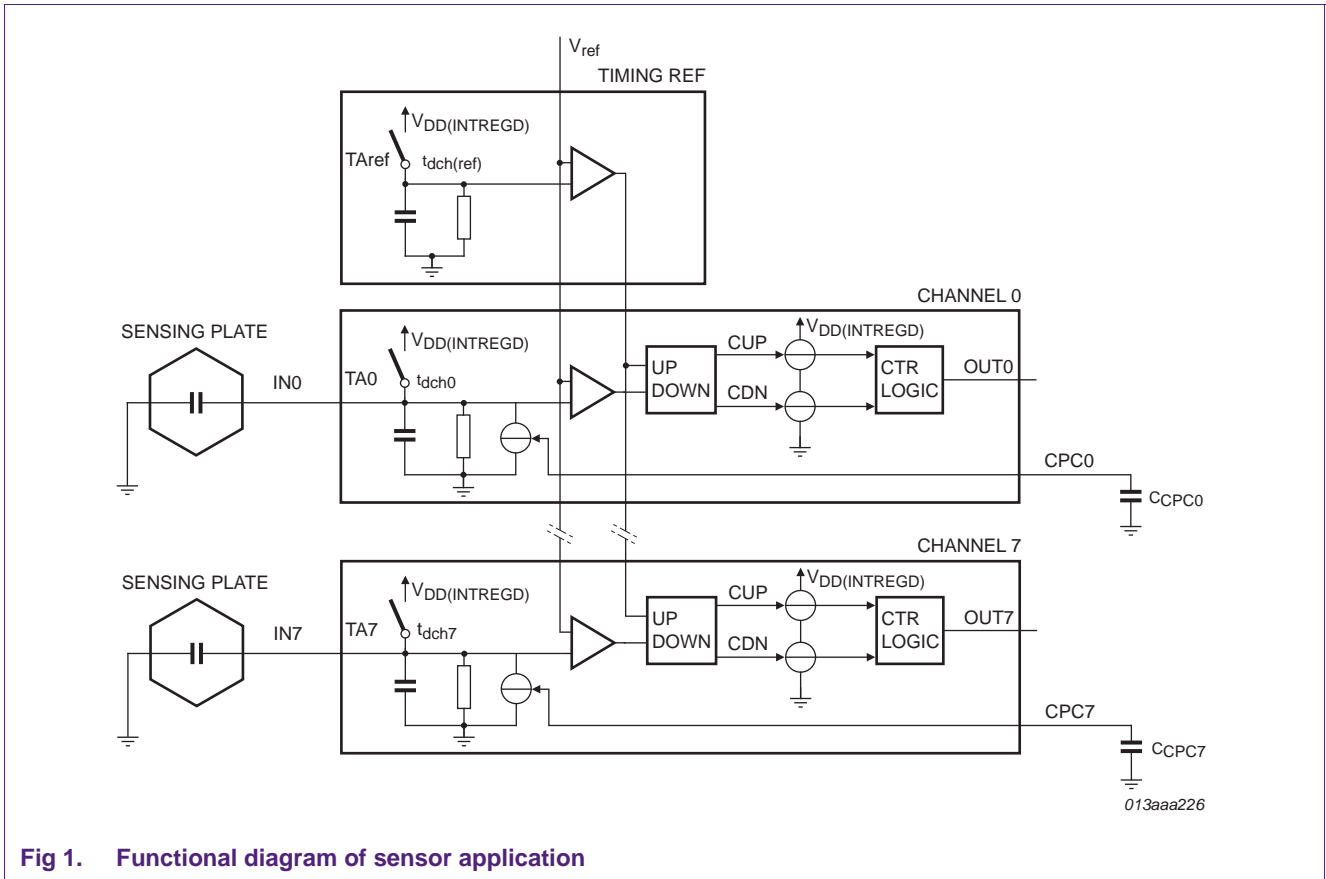
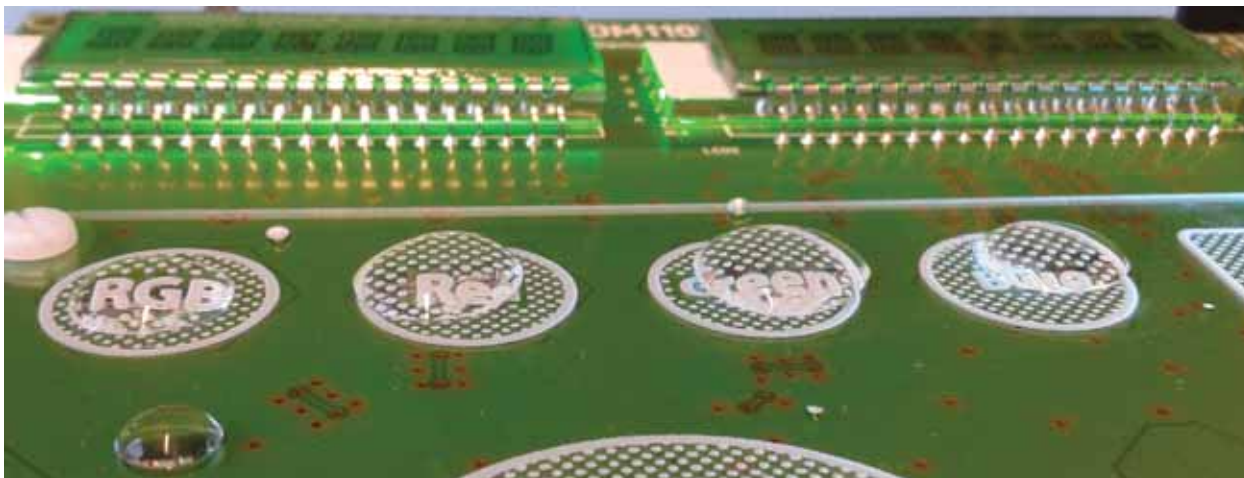


Fig 1. Functional diagram of sensor application

3. Water droplets

[Figure 2](#) shows a demonstration board where water droplets are dispensed before powering up the board. After the initial fast auto-calibration, the board is functional with no restrictions.



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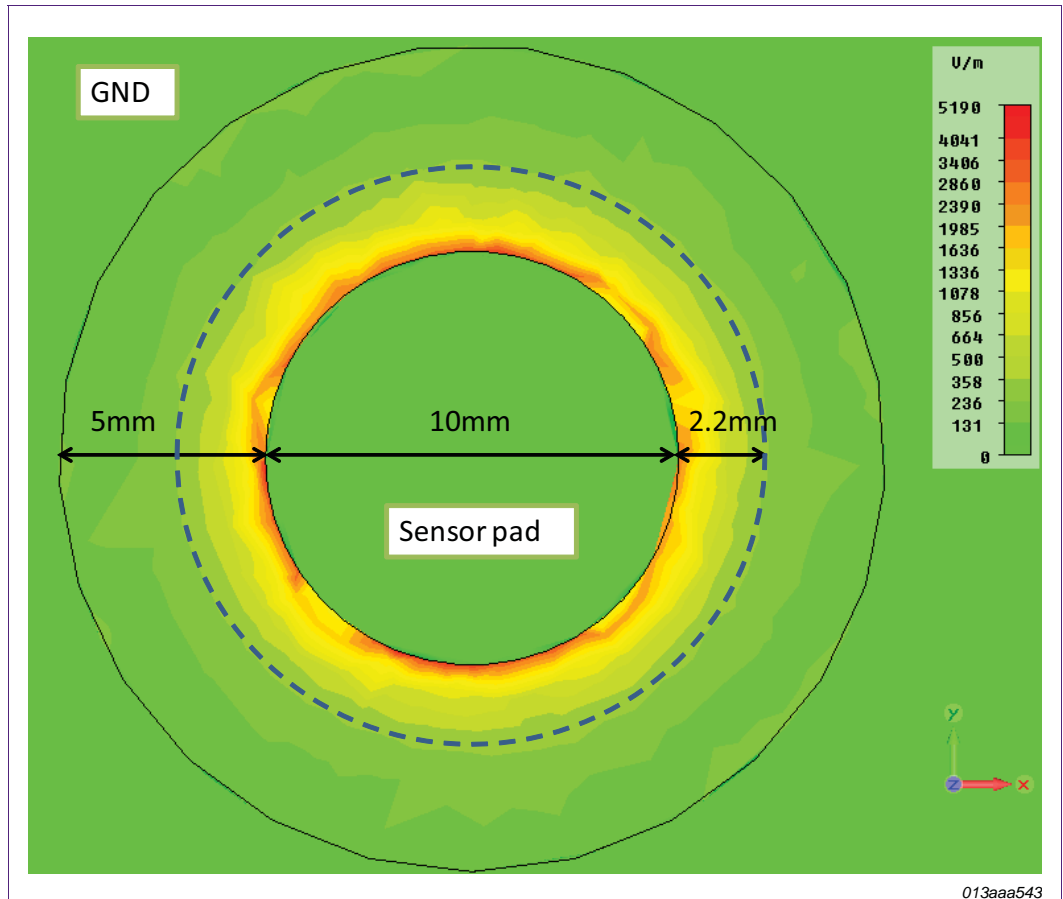
Fig 2. Water droplet test on a demonstration board

Due to the high dielectric constant of water ($\epsilon_r = 80$ compared to $\epsilon_r = 1$ for air) the static capacitance between the sensor plates and surrounding ground increases dramatically. For a capacitive sensor measuring the absolute capacitance, the threshold value could be reached easily and a false switch could be triggered. However the auto-calibration mechanism compensates for the water droplets and the sensor plate remains functional.

The mutual capacitance between the sensor plate and the surrounding Ground (GND) decreases with increasing gap between the sensor plate and the GND. Increasing the gap in combination with a 3 mm to 5 mm thick overlay will decrease the impact from water droplets occurring during operation.

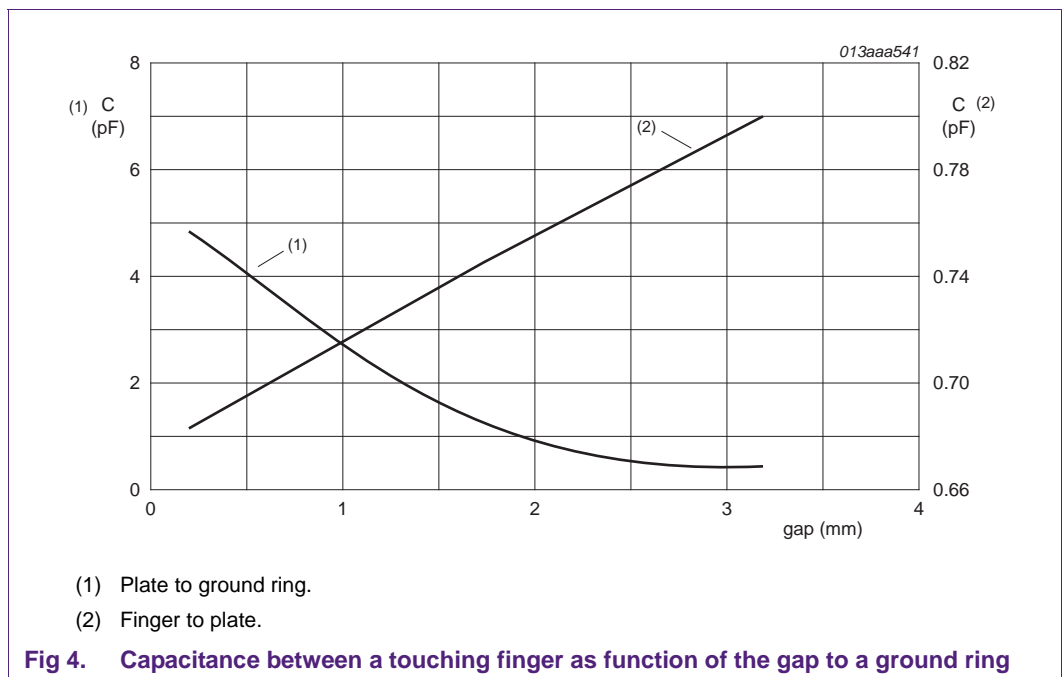
[Figure 3](#) shows the electrical field strength between the sensor pad and the surrounding GND-ring. In order to minimize the impact from water droplets and increase the sensitivity to a finger touch, it is recommended that the gap between the sensor plate and the surrounding GND is kept larger than the overlay thickness. However, a 2.2 mm gap is enough even when the overlay thickness is greater than 2 mm.

For a given overlay of acrylic glass (3 mm) and a sensor plate diameter of 10 mm, the capacitive connection between the finger, the sensor plate and the GND ring would be as shown in [Figure 4](#).



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Fig 3. The electrical field around a sensor plate declines to a negligible level at a distance of 2.2 mm



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- (1) Plate to ground ring.
- (2) Finger to plate.

Fig 4. Capacitance between a touching finger as function of the gap to a ground ring

4. Water flash

In some applications, the sensor plates might be exposed to a water flash or, for instance, with a pot on a stove, there might be an overflow. As shown in the water droplets test above, the auto-calibration mechanism is likely to step in and maintain the functionality. However, it is recommended that for the safest operation, the reservoir capacitor voltage is monitored and the system management gets informed about the overflow to take appropriate measures. The method presented here makes a trade-off between safety and touch sensitivity and should be utilized where redundancy is required for safety.

4.1 Adding redundancy in critical applications

In applications where a conductive extension is used between the sensor pad and the overlay (see [Figure 5](#)) the risk for false switching due to connection to nearby GND by conductive water film or droplets is reduced and this is recommended for horizontally positioned control panels on, for instance stove tops.

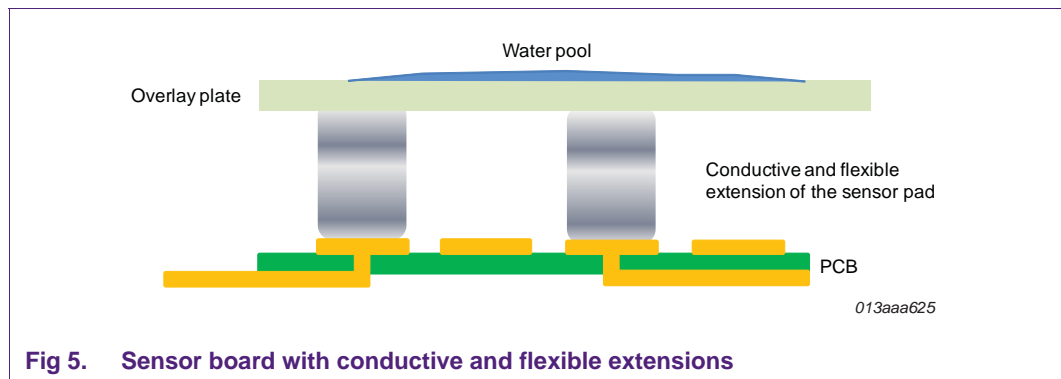


Fig 5. Sensor board with conductive and flexible extensions

However, water-caused interference with nearby sensor pads might still be an issue and can be addressed with dedicated additional safety bars not marked with key graphics on the overlay plate as shown in [Figure 6](#).

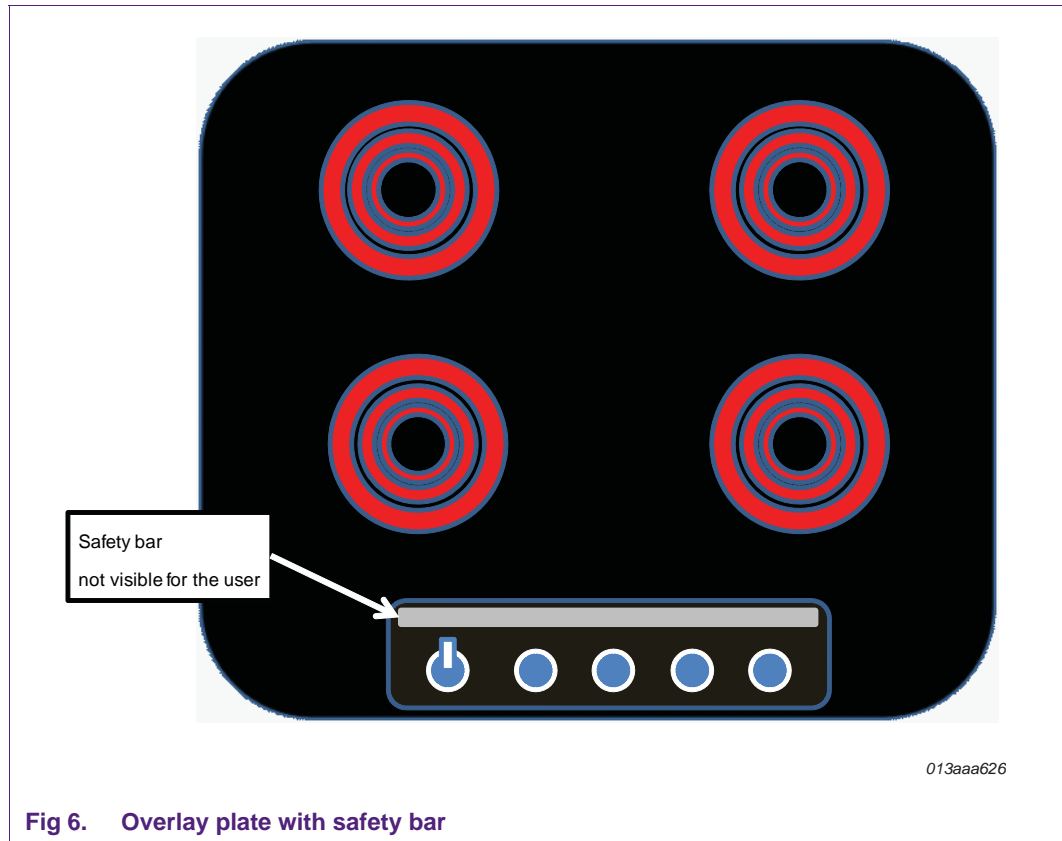


Fig 6. Overlay plate with safety bar

The recommended approach is to ignore all touches in case there are ambiguous key touches or two keys are touched at the same time. In case of sudden water pool on the control panel, the sensor bar will increase the chance to detect more than one touch and the system management (micro controller) will take appropriate measures.

4.2 Monitoring voltage over CPC

Providing there is a GND conductor surrounding the sensor plates and the overlay plate is thin, like a insulating protection film, the capacitive load increases significantly in presence of water on the overlay. As soon as the increase is detected, the auto-calibration mechanism starts ramping up the voltage over the reservoir capacitors (CPC) to sink more currents through the voltage controlled current source on the input. This increase in voltage follows the capacitive load regardless of whether the capacitance increases as a result of slowly accumulated contaminations or a deliberate finger touch. This voltage can be monitored with a high impedance CMOS comparator to indicate for the system management that an extreme value has been reached.

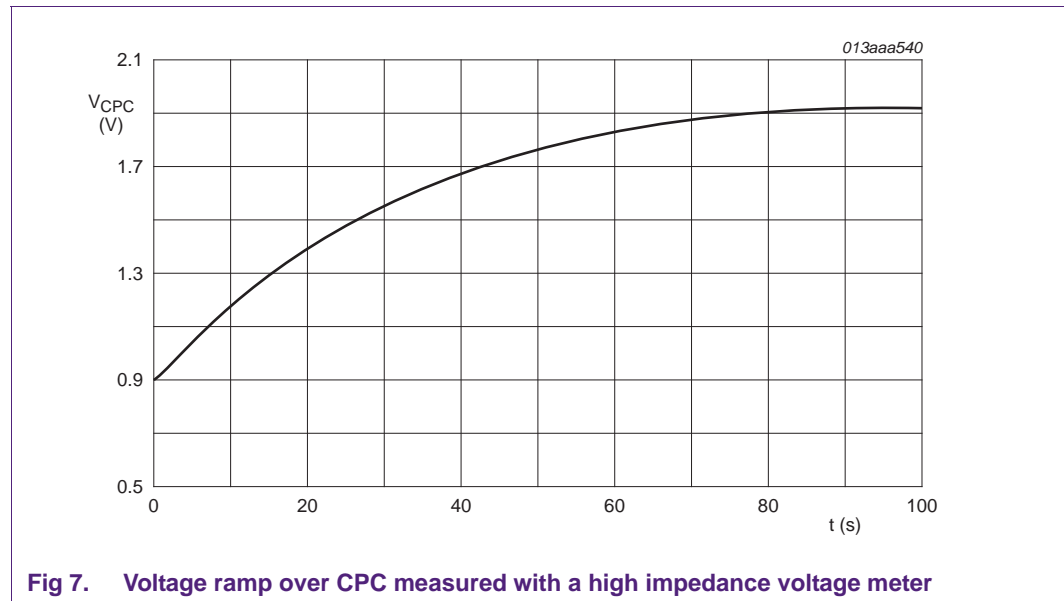
The voltage over CPC capacitors should nominally be about $V_{DD(INTEGRD)}/2$. This voltage is affected by the input network, and therefore the input network should be tuned to preserve this value. However, it might vary significantly with the capacitance and resistance on the sensor input. Measuring this voltage requires instruments with high impedance. On a Printed Board Assembly (PBA), a CMOS comparator with high input impedance can be used. Alternatively, by using a high impedance voltage follower

($Z_i > 5 \text{ G}\Omega$), this voltage can be measured with an Analog-Digital Converter (ADC). The latter method requires a minimum of components and also allows the threshold to be software determined.

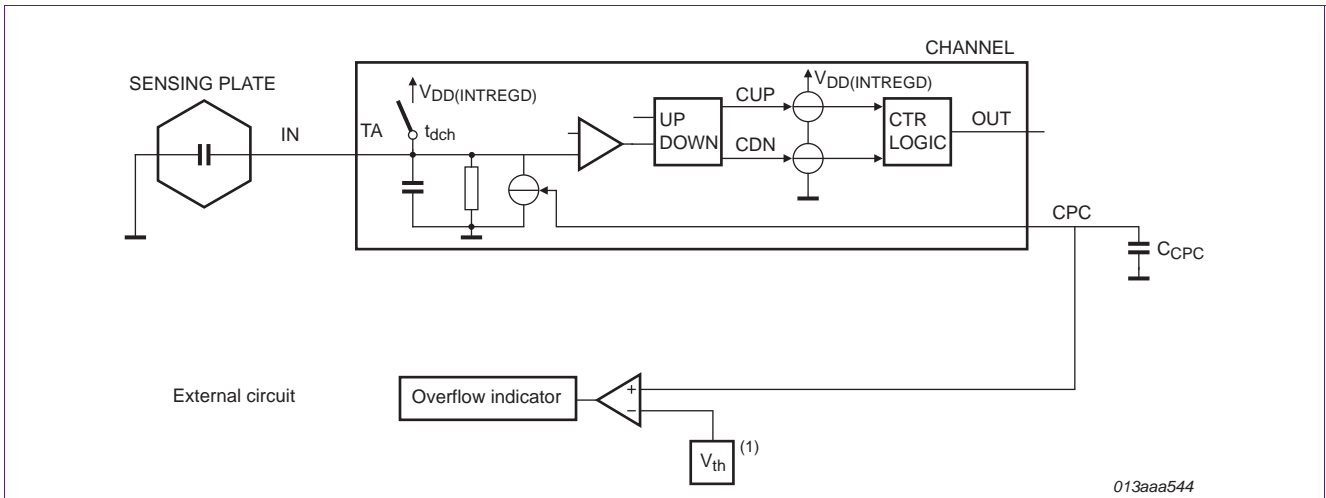
The NXP low voltage comparator NCX2202 is a suitable part for this application. In order to determine a threshold for this voltage, it has to be measured on the actual application with and without touching the sensor plate. In case of a touch on the sensor plate, the voltage on CPC increases slowly; it will reach its final value after about 20 seconds. If the power is turned on while a finger is touching the sensor plate, the voltage over CPC reaches its final value within a few milliseconds.

Assuming that an intentional touch on a sensor plate would not last more than a few seconds, the threshold for an alarm can be set at a voltage corresponding to a safe period of time with a capacitive load on the sensor plate.

[Figure 7](#) shows the typical ramp for the V_{CPC} when a finger is kept on the plate with a thin insulating sheet in between.



For this particular application, the alarm threshold could be set at, for instance, 1.1 V. This means, if a finger is kept over the sensor plate during 8 seconds, or if an overflow of water occurs during 8 seconds, the comparator will indicate this and the system manager would take appropriate measures. This will also happen when a slow flow of water occurs on the plates without triggering a switch on the output.



(1) $V_{th} > V_{DD(INTREGD)} / 2 + \text{margin}$.

Fig 8. Comparator used to generate an overflow indicator

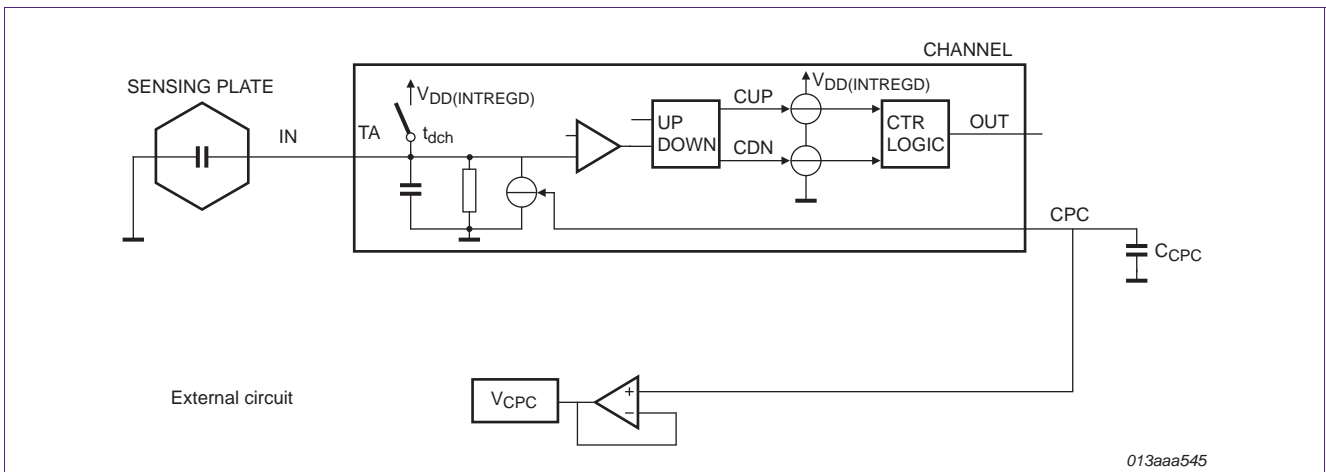


Fig 9. Voltage over CPC may be monitored with an ADC for software determined threshold

5. Condensation on sensor plates and PBA

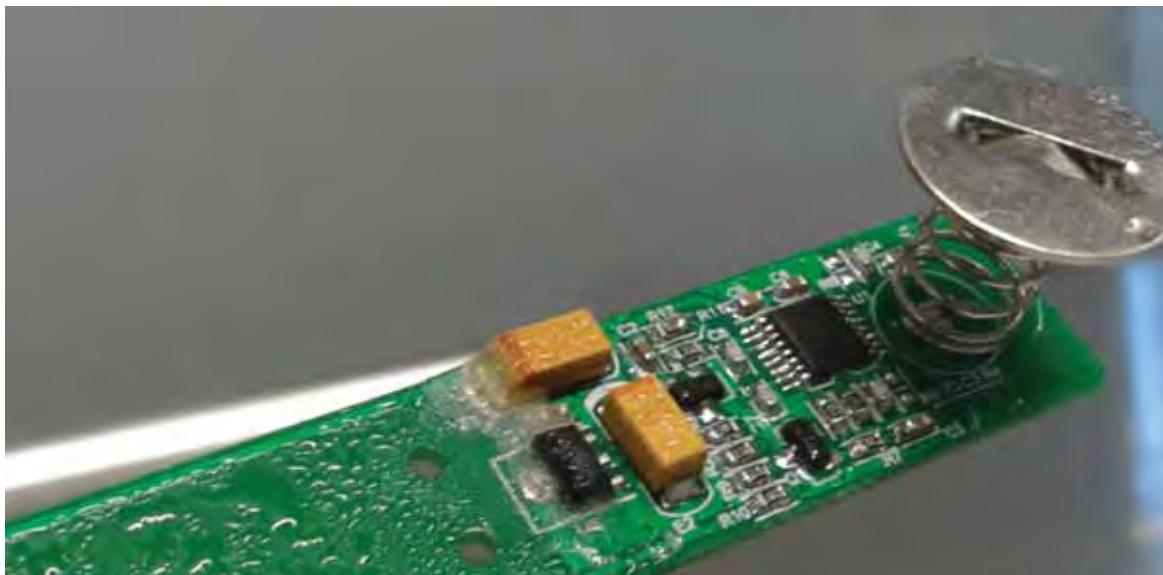
Accumulation and the dry out processes can both render slow but significant changes in the capacitance of the sensor plates. As explained before, even these changes are compensated for by the auto-calibration mechanism.

In case there are fast changes in the ambient temperature, there may be condensation on the PBA. This may cause larger changes in capacitance on the sensor inputs due to geometry, adjacent package pins and conductor-to-GND separation.

There are also critical components such as reservoir capacitors. These have to be kept leakage free for proper functionality. (The reservoir capacitors should be made of high quality foil or ceramic. C0G or X7R capacitors are recommended.)

Even if the PBA is usually mounted in a sealed space, steam or vapor may diffuse into the space and following a quick decrease in temperature it will condensate on the surface which will cause fatal failure. Protecting the components and the conductors on PBA can simply be done by immersing it into a low viscosity epoxy or any other appropriate coating to create a permanent isolation. Using a low viscosity epoxy will reduce the risk for voids in the isolation. For improved results, the coating process can be repeated.

In order to demonstrate which extreme condensation is possible, an application board for a door handle is shown in [Figure 10](#). The board is still fully functional thanks to the coating.



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Fig 10. Application example for protection with coating on the PBA

6. References

- [1] **PCA8885** — Capacitive 8-channel proximity switch with auto-calibration and very low-power consumption, Data Sheet
- [2] **PCA8886** — Dual channel capacitive proximity switch with auto-calibration and large voltage operating range, Data Sheet
- [3] **PCF8883** — Capacitive proximity switch with auto-calibration, large voltage operating range and very low power consumption, Data Sheet
- [4] **PCF8885** — Capacitive 8-channel proximity switch with auto-calibration and very low-power consumption, Data Sheet

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