Atmel AVR3002: Moisture Tolerant QTouch Design

Atmel QTouch

Features

- Challenges posed by moisture on capacitive touch sensing
- Moisture conditions
- Objectives of moisture tolerant Atmel® QTouch® design
- Hardware design considerations
- Tuning guidelines
- Performance test scenarios

Introduction

"Nothing in the world is more flexible and yielding than water, yet when it attacks the firm and the strong, none can withstand it" – Lao Tzu.

Touch interfaces have become a very sought after design implementation for providing interaction with the new generation of electronic devices. Touch applications are now incorporated in numerous consumer appliances which are exposed to moisture conditions. Electronic appliances in kitchens and bathrooms are subjected to varying levels of moisture. Automotive and outdoor applications are constantly exposed to environmental conditions such as rain and dew.

Historically, the normal operation of capacitive touch sensing has been highly affected by the presence of moisture. It is very difficult to incorporate a comprehensive solution to the challenges posed by moisture due to its conductive nature. This application note describes the techniques to mitigate the issues caused by moisture in QTouch designs.

The design techniques are targeted to prevent false detects due to the presence of moisture. It aims to improve the user experience when touch panels are operated with wet fingers and avoid any accidental false detects while wiping water off the touch panel.
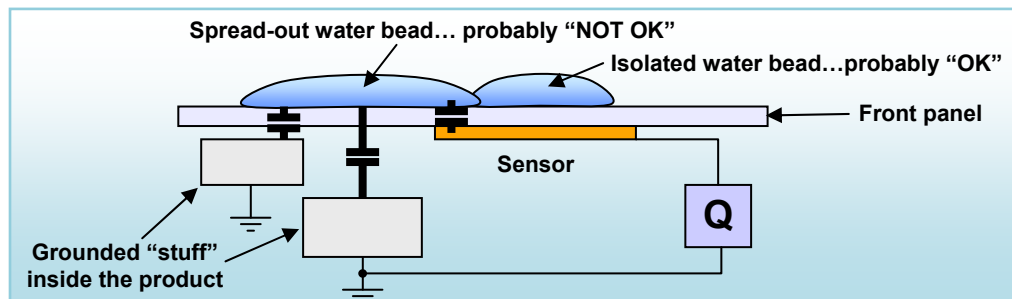
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1. Challenges posed by moisture on capacitive touch sensing

Atmel QTouch, being an open circuit electrode senses the change in capacitance of the electrode and couples back to the microcontroller through any return path.

Figure 1-1.   Water spread on QTouch.

A water film's most serious effect is to cause false detection; this is caused by the fact that water is usually contaminated by dissolved ionic molecules which allow strong electrical conduction. A conductive water film acts very much like a human finger to cause a false detection, provided the film is large and continuous enough to absorb and transport the fields away from a key.

Moisture directly on the key, that also bridges across to any neighboring region that is close to GND, will potentially cause a false detect.

The QTouch technology has drift compensation built into them to compensate for a slow build up of moisture films. This allows the internal signal reference to move slowly over time in the direction of a drifting signal. However, if the moisture build-up happens too quickly, the signal will move faster than the compensation mechanism and a false detection will occur. If the compensation mechanism is made too fast, then it is possible that a slow moving human finger will also be ignored.

2. Moisture conditions

Touch based applications need to operate in environments where they are exposed to the different moisture conditions.

Let us see the common scenarios of moisture build up to which electronic appliances are exposed.

2.1   Fine condensation and dew formation

This kind of moisture layer builds up mostly due to the presence of steam in the surrounding environment. A similar condition can be observed if someone exhales very close to the touch panel. This leads to the formation of minute isolated droplets of water over the touch panels. This buildup of moisture can be very instantaneous, within a few milliseconds, and thus will not provide the drifting algorithms enough time to adjust to the new condition. Appliances placed in kitchens and bathrooms are commonly subjected to this kind of moisture.

Dew is water in the form of droplets that appears on exposed objects in the morning or evening. As the exposed surface cools by radiating its heat, atmospheric moisture condenses at a rate greater than that at which it can evaporate, resulting in the formation of small water droplets. Touch panels mounted in outdoor applications are mostly subjected to such a scenario. This kind of moisture buildup can also occur when there is light rain or when cleaning or wiping the surface.

Figure 2-1. Water droplets formed due to condensation.

Figure 2-1 shows few images of moisture buildup due to condensation on some surfaces. We can notice that there are small water droplets distributed over the entire surface. Since the droplets are mostly isolated from each other, they are unable to provide a conducting path for the charge to couple with any nearby ground.

Although the presence of these small drops can affect touch sensing, a well tuned design can handle it. The problems can start to occur when the small droplets start to coalesce and form bigger drops.

2.2 Wet touch

A wet finger is more conductive compared to a dry finger. This is the reason the touch sensors are more sensitive when we touch with a wet finger.

While operating appliances with wet hands, users tend to leave drops of water on the touch keys. Touching a surface which has minute water droplets due to condensation can lead to formation of bigger water bead. Both of these can lead to stuck-on condition or false detect.

Figure 2-2. Water on surface due to wet touch.
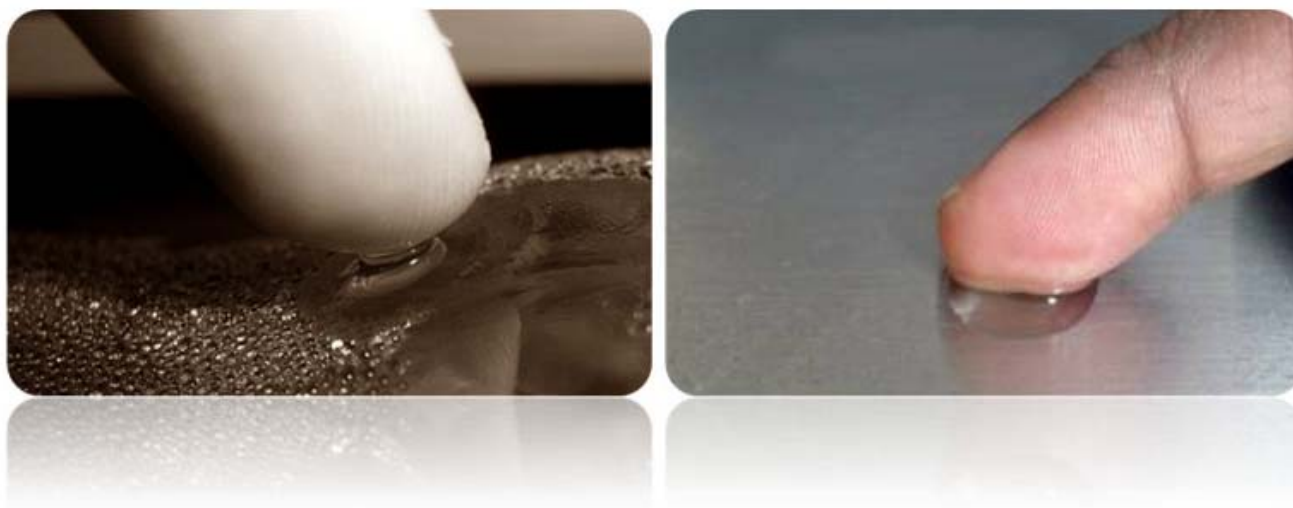
2.3 Water puddles

Water puddles are generally formed by accidental spills. These cause a partial area of the touch panel to be under water. The water puddle normally spreads over multiple keys and causes keys to go into detection by coupling charge to nearby ground lines in the sensor board. A finger touch in such cases leads to false detects in all the sensors that are coupled by the water puddle.

Figure 2-3.   Water puddle.
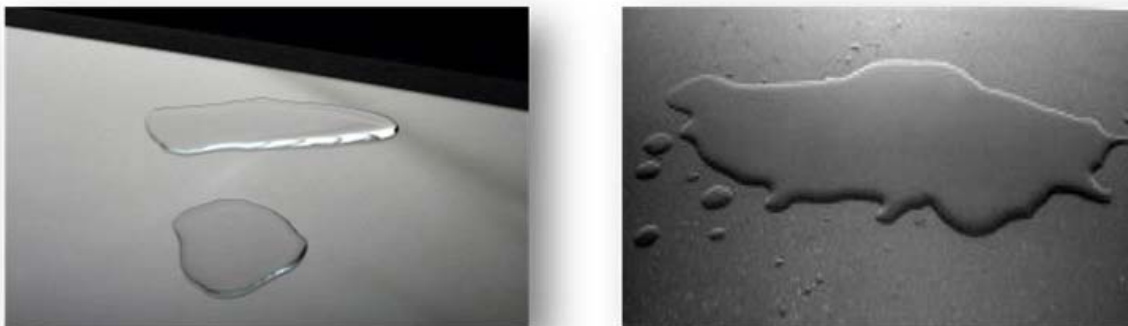
2.4 Flowing water

This kind of water exposure is observed in cases of heavy rain and leakage. In such cases mostly all the sensors are under water. The quantity of water is generally enough to simulate a finger touch and thus leads to false detections.

3. Objectives of a moisture tolerant Atmel QTouch design

The objective is to apply solutions to mitigate the above mentioned conditions in a QTouch design. For a QTouch design to be considered moisture tolerant it should exhibit the following features:

    a.   It should avoid false detects when there is water over the sensor electrode.

    b.   It should be reliable enough to detect touch with a wet finger.

    c.   It should avoid stuck-on condition when being operated with a wet finger.

    d.   It should understand the wiping condition and should allow the user to clean the touch panel without any false detects.

    e.   The normal touch sensing should be restored immediately after wiping the water off the panel.

4. Hardware design considerations

Special considerations are needed to achieve a moisture tolerant QTouch design as described in the Section 4.1. This includes the descriptions for two kinds of electrodes, sensor electrode (sensor keys) and the guard electrode (guard key).

4.1 Guard key

The guard key is a special key that is strategically located. This key has slightly higher sensitivity so that if any unintentional touch occurs, it gets activated first. This indicates that a false touch has occurred. Usually the electrode for the guard key is a copper fill that surrounds the electrodes for sensor keys.

In moisture tolerant QTouch design, the guard key plays an important role in detecting the presence of water and helps to suppress the false detects. An oversensitive guard key will have proximity effects and an under-sensitive guard key will not be able to detect the presence of moisture accurately. This greatly increases the complexity of designing the guard key.

- Following are the recommendations for designing the guard electrode:
  a. The guard electrode should be on the same plane as the sensor electrodes. If the sensor electrodes are on top layer of the PCB, the guard electrode should also be in the top layer.
  b. The guard electrode should completely surround the sensor electrodes. By this we ensure that any two sensor electrodes cannot be coupled by a water puddle without interacting with the guard electrode.
  c. There should be a uniform gap between the guard electrode and the sensor electrode. The purpose of the gap is to reduce the influence of the finger on the guard key when the sensor key is touched. This gap should be at least equal to the sensing distance. The sensing distance for any touch application is the thickness of the front panel (T).
  d. The width of guard electrode between two sensor electrodes should be around 50% of the width of the sensor electrodes.

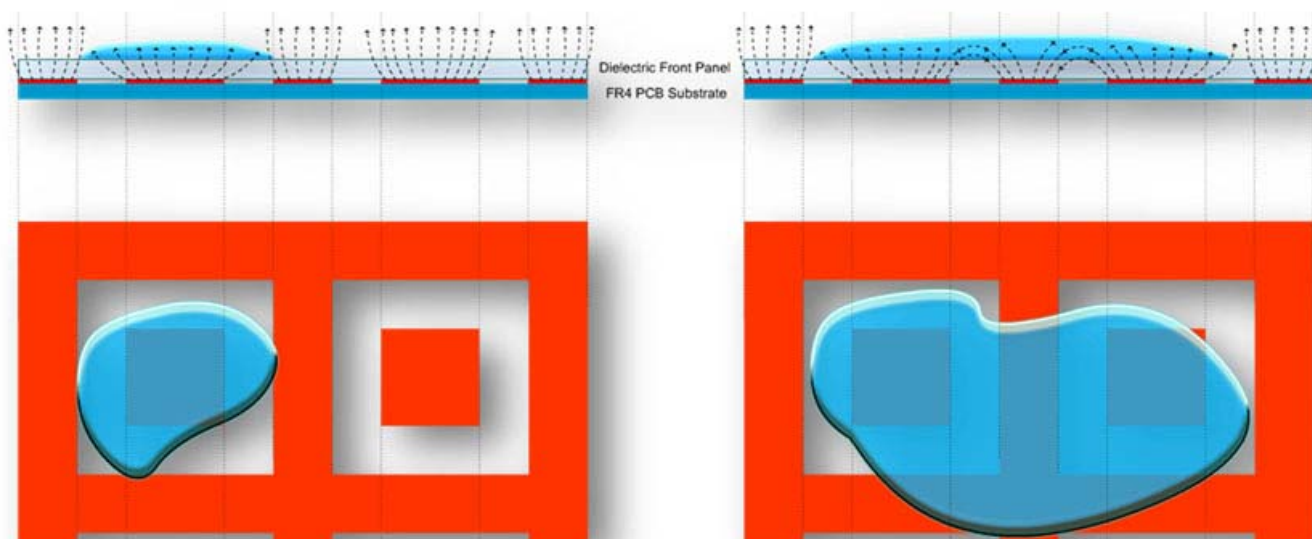**Figure 4-1.   Water puddle coupling sensor channels.**

Figure 4-1 shows two different scenarios of water puddle formation.

An isolated water puddle sitting on a single sensor key is not likely to cause false detects in other keys. But when two sensor keys are connected by a water puddle, the surrounding guard key also interacts with the water.

- MCU pin selection recommendation:

An important consideration for designing the guard key is the selection of MCU PORT pins to be used. The guard key should not be connected to the PORTs which are connected to the other sensor keys. Tuning of sensor keys becomes very difficult when the guard key and sensor keys share the same PORTs. This ensures that the measurement and acquisition for the guard key does not happen simultaneously with the other sensor keys.

Example: Consider an Atmel QTouch design for seven keys using PORT B and PORT D. Do not use the unused pins of PORT B and PORT D for the guard key. Instead you can use another PORT (say PORT C or PORT A) for the guard key.
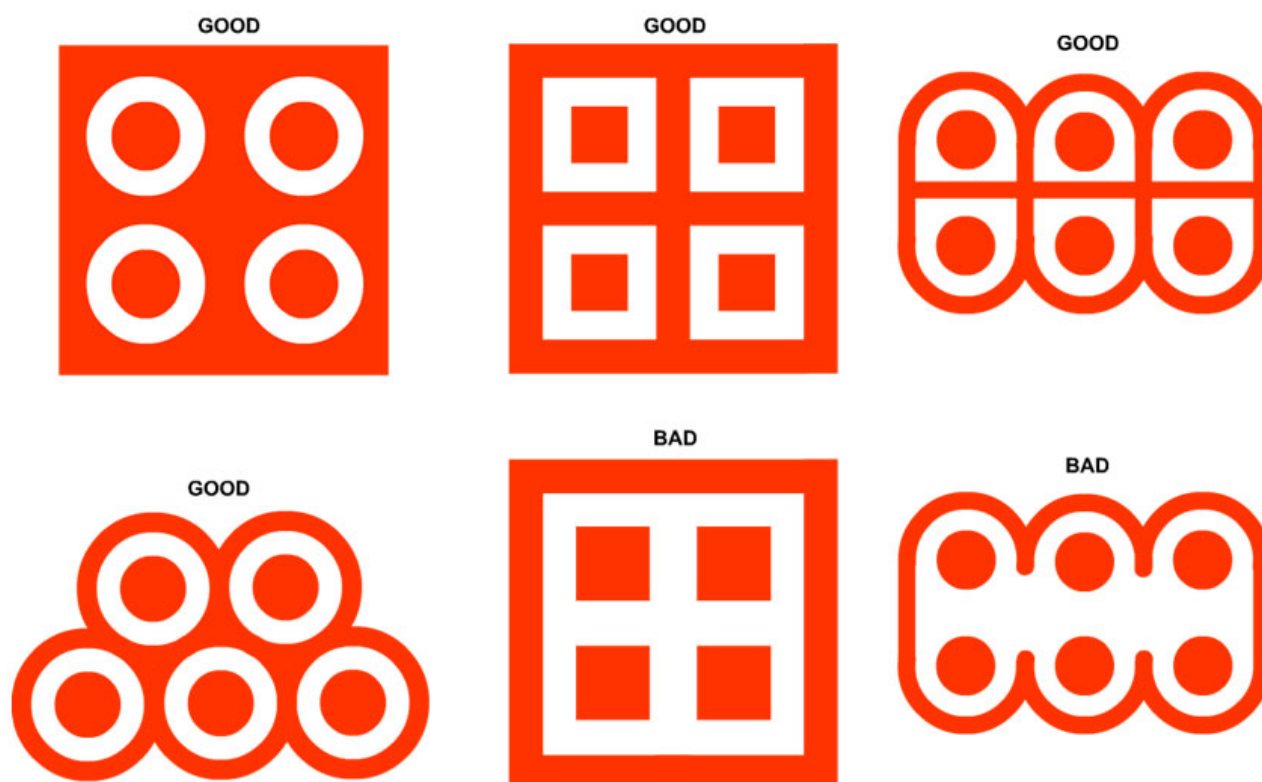
4.2   Sensor keys

The electrode shape and size of sensor keys is important for a moisture tolerant QTouch design. This greatly influences the tuning of the sensor keys in presence of moisture conditions.

Following are the recommendations for designing the sensor electrode:

a.   The sensor keys can be circular or square in shape but it is advised to keep all of them of same shape and size. Avoid choosing random electrode shapes unless and until there is a strict requirement for such an electrode shape. This will allow for more uniform electrode capacitance and make the tuning process easier.

b.   Making sensor electrodes bigger or smaller than normal finger size will have its own demerits. Smaller sensor electrodes will not have adequate coupling with the finger and will exhibit lower sensitivity. Bigger sensor electrodes can be oversensitive and are easily affected by moisture.

**Figure 4-2.   Diagrammatic representation of sensor pattern.**

4.3 Layout routing considerations

Following are the routing considerations for moisture tolerant Atmel QTouch design:

a. The routing for all the sensor keys should be on the bottom layer. Only the sensor electrodes should be on the top layer. This will help to avoid coupling of charge between two sensor traces due to small water drops over them.

b. Ground traces should be avoided near the sensor electrodes. Water droplets can form a bridge between the sensor electrode and ground, causing false detects.

c. The routing for sensor keys should be under the guard electrode wherever possible. Sense traces not protected by guard electrode can potentially be exposed to the effects of moisture leading to undesired behavior. Please refer to Figure 4.3.

Figure 4-3.   Routing of sense lines.
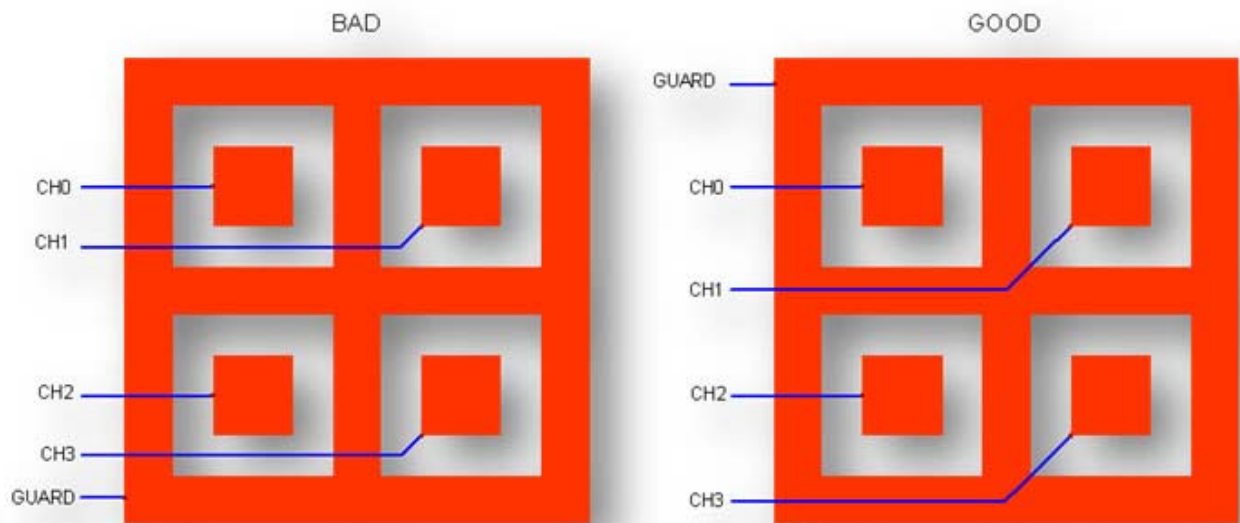
The red area is the top layer and forms the sensor electrodes and the guard electrode. The blue lines are the sense traces on the bottom layer which are to be connected to the MCU pins.

For other general details and guidelines on how to design Atmel QTouch sensors please refer to the BSW Sensor Design Guide available on the Atmel website.

4.4 General guidelines

Apart from hardware considerations that are to be implemented during the PCB design there are a few more general considerations which could be implemented into the final product to avoid moisture conditions.

a. Water has high adhesion properties because of its polar nature. It is always advised to select a front panel material which has low adhesion to water and thus act as a water repellent. Special surface treatments to the front panel can also be incorporated.

b. Mounting the touch panel at an inclined angle in the final product is highly beneficial since it allows the water to flow down and thereby prevents the formation of water puddles. A slight inclination of even 10 degrees from the horizontal can reduce the probability of water accumulation.

5. Tuning guidelines

Performance of any capacitive touch interface depends upon how well it has been tuned. For moisture tolerant QTouch design there are some special considerations. These are listed below:

- The sensor keys should have a higher Detect Threshold (NTHR) than the delta rise caused by the isolated water puddles
- The guard key must be tuned to go into detect with presence of water on the touch panel. The guard key should go into detect before delta values of other sensor keys reach their respective detect thresholds
- The guard key and all the other sensor keys need to be in the same Adjacent Key Suppression® (AKS®) group. Once the guard key is in detect the AKS feature will block any false detects caused due to accumulation of water over the touch panel
- Since the guard electrode covers a bigger area, it will be more sensitive and prone to exhibit proximity effect. With careful tuning it has to be ensured that the guard key does not go into detect due to the proximity effect of the hand when touching a sensor key

5.1 Desired response of an Atmel QTouch design tuned for moisture tolerance

Figure 5-1 is a graph recorded from a well tuned system for a sensor key and a guard key. The green plot represents the delta values of the sensor key and the red plot represents the delta values of the guard key. The detect threshold for the sensor key as well as the guard key has been represented by the blue lines. The three events in the graph are highlighted in light blue and are explained below.

Figure 5-1.   Graph of touch delta vs. time.

In the first event, the sensor key is touched. It is observed that the delta value for that particular sensor key quickly crosses it's detect threshold and reports touch detection. Due to proximity effect there is a rise in the delta value of the guard key as well, but the delta value is not high enough to cross the detect threshold for the guard key.

In the next case the guard key is touched. The guard key immediately crosses it's detect threshold. Some rise in delta value is observed in the sensor key due to proximity effect.

In the last event, water is poured over the sensor key and it forms a water puddle spreading across the touch panel. The delta values start to steadily increase in both the guard key as well as the sensor key. The delta value is proportional to the amount of water accumulated over the sensor key. After a certain amount of water accumulation, the delta value of the guard key reaches it's detect threshold. In this scenario the AKS feature will prevent all other sensor keys from going into detect. Water over the touch panel needs to be wiped off to restore the normal operation of the sensor keys.

5.2 Tuning parameters

The tuning parameters used are as below:

- **Sampling Capacitor (CS)**

Increasing the sampling capacitor increases the burst length and signal resolution, resulting in increased sensitivity. Conversely, decreasing the sampling capacitor will decrease sensitivity.

- **Detect Threshold (NTHR)**

A sensor's negative (detect) threshold defines how much its signal must drop below its reference level to qualify as a potential touch detect. Larger threshold values desensitize sensors since the signal must change more (that is, requires larger touch) in order to exceed the threshold level. Conversely, lower threshold levels make sensors more sensitive.

- **Adjacent Key Suppression (AKS)**

Adjacent Key Suppression is a patented Atmel method designed to resolve multiple key presses by comparing signal strength changes before making a decision as to which key to report.

- **Hysteresis**

Once a sensor goes into detect its threshold level is reduced by the hysteresis value in order to avoid the sensor dither in and out of detect if the signal level is close to original threshold level. It is expressed as a percentage of the sensor detection threshold setting.

5.3   Tuning phase I

Following are the steps to tune the touch panel to meet the basic requirements for increasing moisture tolerance of an Atmel QTouch design. At the end of this phase of the tuning it is expected that the touch panel will be able to avoid stuck-on conditions and avoid false detects when the panel is subjected to moisture droplets.
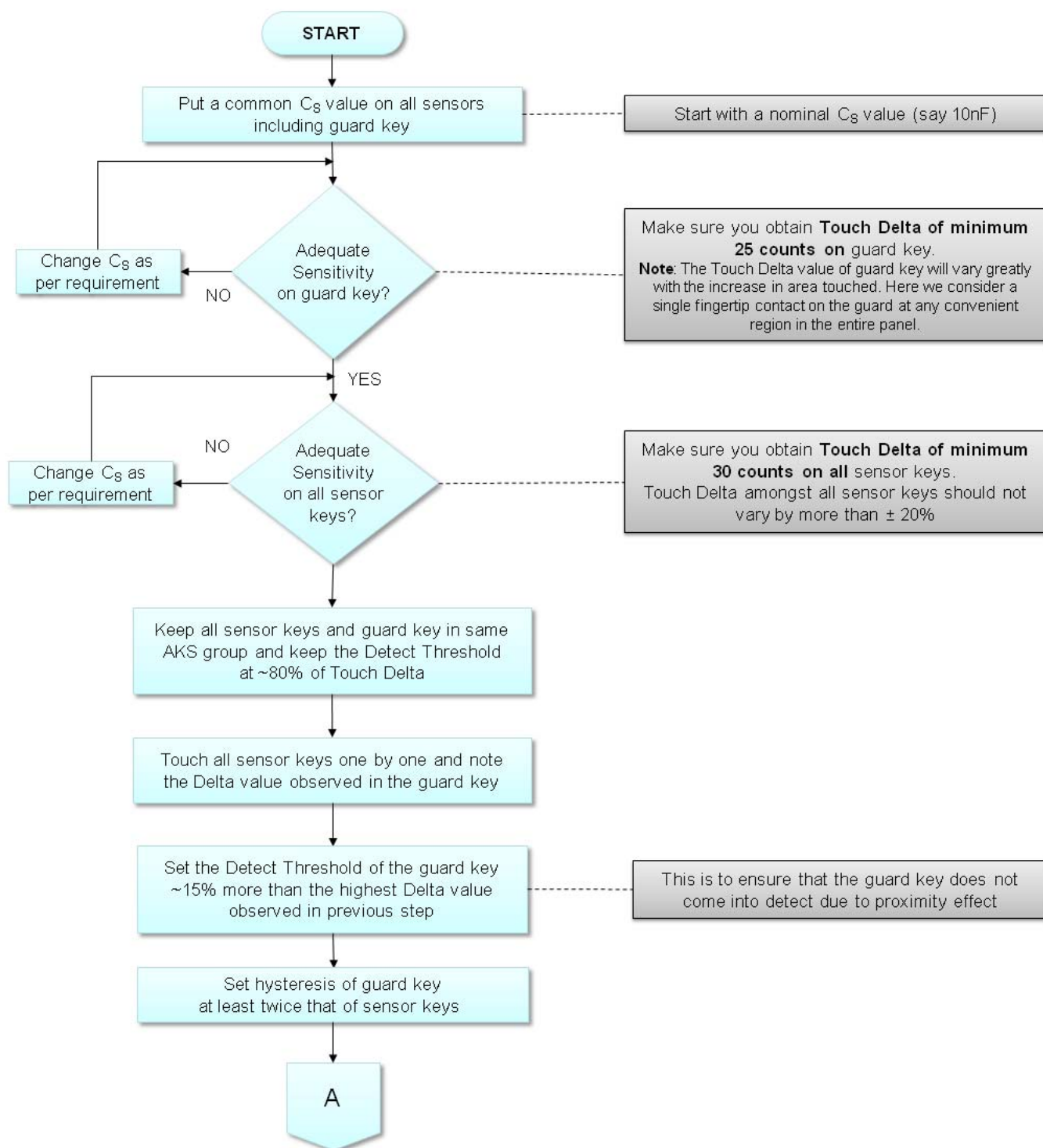
5.4   Tuning phase II

The following flowchart describes the procedure to check if the sensor keys are still vulnerable to the moisture conditions.
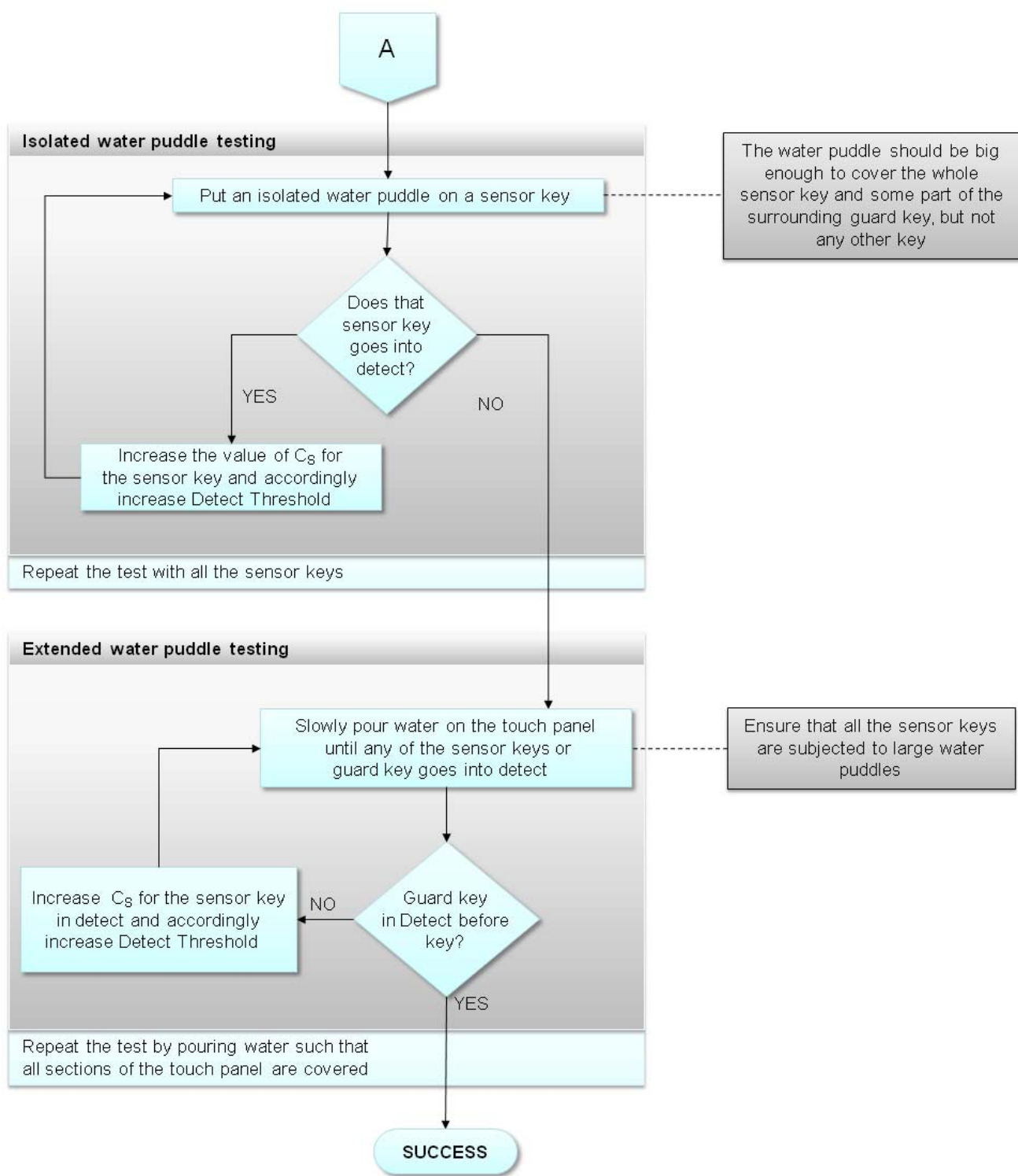
6. Test scenarios

A few tests that can be performed on the tuned touch panel to check its moisture tolerance are mentioned below:

- Subject the touch panel to steam testing, in which hot steam is directed on to the touch panel
  - Even with the condensation layer on the touch panel it should not report any false detects and the touch operation should be normal
- Operate the dry touch panel with wet finger
  - The touch operation should be normal
- Spill a little water over touch panel such that the puddle connects two or more sensor keys
  - No sensor key goes into detect
  - When one of the sensor keys is touched, the guard key goes into detect
- Pour water over the entire touch panel covering all keys
  - Only guard key goes into detect
- Wipe the touch panel
  - Only guard key goes into detect

7. Summary

The basic conductive nature of water poses a great challenge to capacitive touch technology. This is aggravated by the varying salinity of water and the presence of impurities. Water accumulation can occur in a variety of unpredictable ways, thereby making it even more difficult to handle.

However, after careful study and experimentation, several innovative techniques have been developed to mitigate the effects of moisture to a great extent. The design recommendations mentioned in this application note will enable the QTouch design to behave more robustly in moisture conditions. Thus expanding the range of applications in which Atmel QTouch Technology can be implemented.

8. Recommended readings

Following are some documents that you can refer to enhance your understanding of Atmel QTouch Technology.

- QTAN0079: BSW Sensor Design Guide
- Atmel QTouch Library User Guide
- Secrets of a Successful QTouch Design
- QTAN0062: QTouch and QMatrix Sensitivity Tuning

9. Revision history

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