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Water-Resistant Capacitive Sensing

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INTRODUCTION

This application note describes a new hardware sensing method which is resilient to water drops appearing on the surface of the touch sensing area. In other touch systems, a drop of water will act in the same manner as if a user touches the system. This makes it difficult to determine a real press from a user or a false press from a drop of water. This new method, called Capacitive Transient Coupling (CTC), will clearly distinguish a drop of water from a finger touch.

THEORY OF OPERATION

Sensor construction is critical to this design. The sensor for a single button must be constructed of an ADC channel and an I/O. An E with another E backwards interlocked is an example of a simple sensor (Figure 1). The sensor does not have to be interleaved fingers; instead, the critical requirement is a strong coupling between the two pads. This will create a capacitance between these two lines. One line will be used as a driving line, and the other will be a sensing line. For more than a single key, these sensing lines may be matrixed and reused to minimize resources used. Typically, 2 ADC channel pins are used, one for each pad in a matrix configuration. The 2 pins will take turns driving and sensing.

FIGURE 1: AN EXAMPLE SENSOR DESIGN

Sensing Steps

To perform the sensing, do the following:

- 1. Ground drive line
- 2. Ground sensor line
- 3. Point ADC channel to the sensor line, prepare ADC (any time here or before)
- Delay short time, allow ringing to settle (1 NOP is usually ok)
- 5. Turn sensor line as input (TRISx = 1)
- 6. Output driving line high (PORTy = 1)
- Delay short time, allow ringing to settle (1 NOP is usually ok)
- 8. Begin ADC conversion
- 9. Reading is in ADRESH: ADRESL

Sensing Steps Description

Figure 2 shows how the signals on the two lines work throughout these steps. Grounding the sensor and drive lines creates a known discharged state. Then once the sensor line is configured as an input, raising the drive line to VDD from Vss will create a large transient on the drive line pad (one E of the paired E's). This transient couples into the other pad, causing a positive voltage shift. The higher the capacitance between these two pads, the better coupling, and the higher the induced voltage created on the sensor pad.





This induced voltage would be VDD if the sense line was unconnected and left perfectly floating. In this application, the sensing line is high-impedance and is connected to the ADC's internal holding capacitor as shown in Figure 3.





Once the transient occurs, VDD will be present on the sensor's drive line, and a certain amount of charge, Q, is present on CSENSOR. This charge is the same amount as on CHOLD. The voltage at the ADC can be derived – the result is in Equation 1; this is done using the capacitance equation Q = CV for each capacitor shown. This equation describes the voltage that will appear on the ADC as a function of the sensor capacitor and the ADC's internal capacitor.

EQUATION 1:

 $V_ADC = VDD^* CSENSOR / (CHOLD + CSENSOR)$

WATER OPERATION

When a drop of water appears above the sensing surface, the water creates a stronger coupling from the drive pad to the sensing pad, but it does not couple to earth ground (Figure 4). This is a key point. Additional water increases CSENSOR and V_ADC by Equation 1. The stronger the coupling between the drive pad and the sensing pad, the more induced voltage will occur on the sensing line. This boosts the voltage of the reading when water appears, opposite of what a finger does. Since the reaction for water is in the opposite direction of a normal touch, it is easy to prevent false triggers due to water contacting the touch surface.

FIGURE 4: MODEL OF SENSOR WITH WATER



A user's finger will couple the sensor pads to earth ground. When the user touches the sensor through the water, the user couples both pads to ground. With water present, the coupling to ground is usually stronger than without water. A normal touch may still be detected this way. This is explained more in the next section. This method can prevent triggers from water coming into contact over the touch area. It can also work with water sitting on one key, but it cannot prevent the problem with water over all keys. If water is spread across the entire keypad, and a user touches one key, all keys covered by the water will see the coupling to ground.

FINGER TOUCH OPERATION

When a user touches the system, their finger will couple to earth ground naturally through the body. By design of the sensor, the user will touch above both the drive and sensor pads. The finger will then couple from the drive pad to ground, and from the sense pad to ground. This additional capacitor to ground from the drive pad actually has no effect, but the additional finger capacitance to ground from the sensor pad results in a capacitor in parallel with CHOLD, which reduces the voltage induced, V_ADC. The finger capacitance is shown in Figure 5, as CF1 and CF2.

Thus, a finger will cause a reduction in the voltage on the sensing line, and this reduction will be what is detected as a press. The equation for this condition is derived the same way as Equation 1 was, and is simply now replacing CHOLD from Equation 1 with (CHOLD || CF1). In Equation 2, it is still clear that a water drop (increasing CSENSOR) will increase the voltage V_ADC, and a user touch (adding CF1) will decrease the induced voltage.

EQUATION 2:







ANALYZING OPERATION

Figure 6 shows a sensor's reading over time to illustrate increasing the coupling between the sensor and drive pads. Two sets of data were taken. First, the sensor was tested on a PCB with only a piece of scotch tape (0.002") covering the sensor from the water added, and second, a piece of 1/8" acrylic (0.124") was also tested. The dramatic edge, visible in Figure 6, is where the water was applied to the sensor only covered by scotch tape (around sample 1000). This will have the strongest coupling since the water makes a very good dielectric right by the sensor pads. The sensor was then touched three times.

For the 1/8" acrylic, the effect of the water is minimal. The water actually causes a small shift down briefly, and then has almost no effect after. The key reason the water has less effect is due to the distance it is from the sensor pads is further (72 times further) than the scotch tape. The sensor was then touched three times to show a touch still functioning.

It is also worth noting that the acrylic itself adds superior coupling between the pads, compared to the tape, which is essentially no cover. It is a small effect, but this is shown by the acrylic's average reading being slightly higher before the water is present.

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In Figure 7, the sensor was touched three times during each stage. This figure shows a similar progression. It starts with a plastic cover and then water applied. The water has a very small effect to raise the voltage. This is due to the thickness of the plastic; the water makes only a weak coupling between the two pads. The effect of water will be stronger when using a thinner plastic. The sensor still shows a significant press for a touch in each condition. With water present, the touches are very consistent.

CONCLUSION

This method is unique in its ability to react differently to water than a finger.

The reason is because the water creates a coupling between the two sensor pads, and a user's finger couples to earth ground. This method also works well in a matrix, since one pad can be used as a drive pad and a sensor pad at different times.

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