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Environmental Compensation on the AD7142: The Effects of Temperature and Humidity on Capacitance Sensors

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INTRODUCTION

Capacitance sensing has the potential to replace current user input mechanisms in consumer devices. Products as diverse as cell phones, digital cameras, MP3 players, and other portable media players are all suitable for implementing capacitance sensing.

Capacitance sensing has many benefits. It gives the user an interface with greater sensitivity and control. Capacitance sensors are easy to manufacture and reliable, and have advantages over current mechanical interfaces. However, all types of capacitance sensors are affected by capacitance changes in the surrounding environment. Changes in humidity or temperature can interfere with the operation of the sensors, in some cases stopping the sensor from working altogether.

Analog Devices' capacitance sensing solution consists of the AD7142 capacitive-to-digital converter IC, sensors on the PCB, and software to communicate with the AD7142. A crucial element of the AD7142 is the on-chip digital logic that performs environmental compensation. This ensures that the capacitance sensor is automatically compensated for the effect of environmental changes. This application note describes the importance of this on-chip logic by quantifying the effects changing environmental factors have on typical sensor configurations. This document also explains how the compensation routines on the AD7142 ensure that the sensors continue to operate correctly in changing environmental conditions.

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REVISION HISTORY

12/05—Revision 0: Initial Version

SENSOR CONFIGURATIONS

Three types of sensor configuration were tested to quantify the effect of temperature and humidity changes on the measured capacitance. The sensor configurations included a joy pad, a button, and a slider, all connected to the AD7142 as shown in Figure 1.

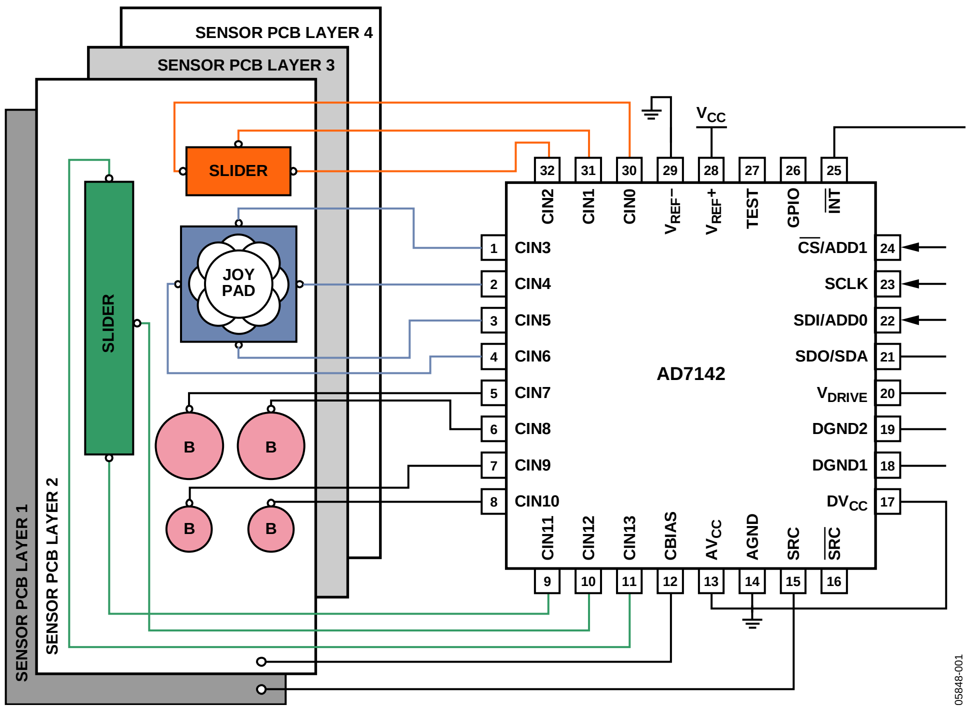

Figure 1. Sensor Configurations

EFFECTS OF TEMPERATURE AND HUMIDITY

Figure 2 through Figure 4 show the changes in the measured ADC value that occur when the ambient temperature or humidity in and around the sensors change. The measured value here is on the ambient capacitance—that is, when the sensor is not touched.

The figures show that as the ambient temperature increases, the capacitance measured from each of the sensors changes. (The measured value is the ADC code output from the capacitive-to-digital converter on the AD7142). These changes are not predictable, because the capacitance measured can increase or decrease. For example, at 30°C, the Button 1 sensor measures at roughly 48550. When the temperature increases to 50°C, the sensor output also increases. However, when the temperature increases further to 70°C, the output from the sensor drops to below 48500, which is less than the measured value at 30°C.

The effect of an increase in humidity in the ambient environment is also shown in Figure 2 through Figure 4. Again, the outputs from the sensors change in response to the humidity, but not in a predictable way.

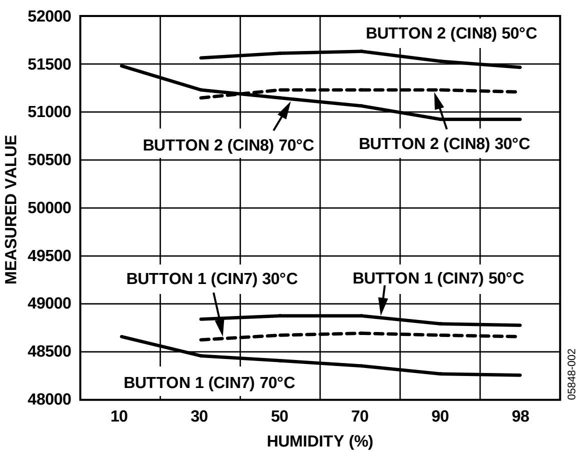

Figure 2. Environmental Effect on Button Sensors

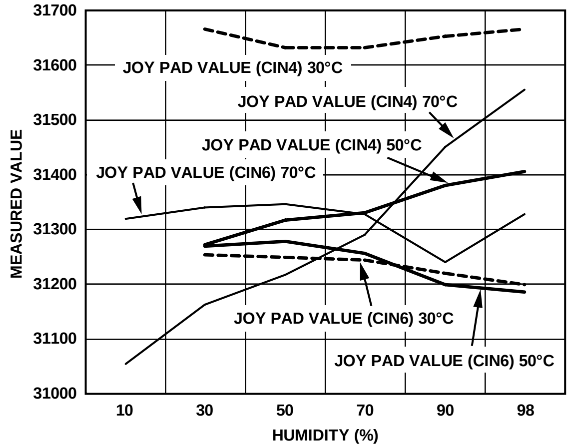

Figure 3. Environmental Effects on Joy Pad Sensor

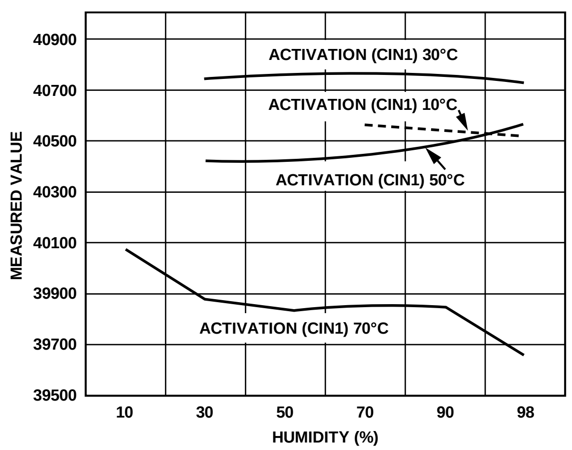

Figure 4. Environmental Effects on Slider Sensor

SENSOR OPERATION

When a sensor is touched, the total capacitance associated with that sensor, and measured by the AD7142, changes. When the capacitance changes to such an extent that a set threshold is exceeded, the AD7142 registers this as a sensor activation.

For example, consider the case of a button sensor that is connected to the AD7142. When the button is pressed, the AD7142 registers an increase in capacitance. If the button is not pressed, the AD7142 measures the background or ambient capacitance level. Preprogrammed threshold levels are used to determine if a change in capacitance is due to a button being pressed. If the capacitance exceeds the threshold limit, the AD7142 registers this as a true button press.

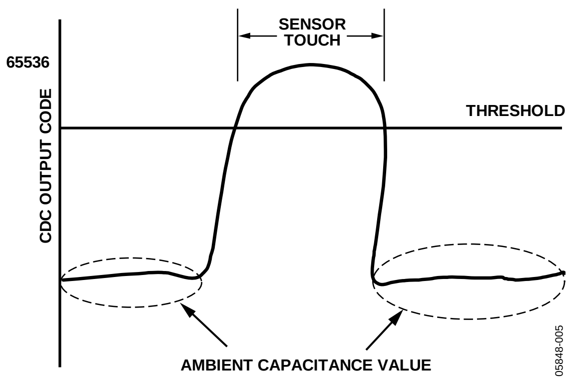

Figure 5. Sensor Activation

The same principle of thresholds is used to determine if other types of sensors, such as sliders or joy pads, are being touched.

ENVIRONMENTAL COMPENSATION

Changes in the background capacitance level are generally much smaller than the changes that occur when a sensor is touched. However, if the change in measured capacitance due to the environment is great enough to cross the threshold, the sensor registers as being touched, when in fact, it was not.

In Figure 6, Button 2 threshold is fixed at 51000. When the measured value from Button 2 falls below this threshold, this registers as a sensor activation. At low humidity values, the measured value is well above the threshold, an indication the button is not touched. However, as the humidity increases, the value measured from Button 2 decreases and crosses the threshold at humidity values above 70%. Once the threshold is crossed, a button press is registered, which in this case is a false activation. Consider a real-world application in which a you are listening to an MP3 player. When you leave an air-conditioned building to go outside on a humid summer day, the MP3 player could start rewinding a tune midsong. Button 1 is also affected by the humidity in the same manner.

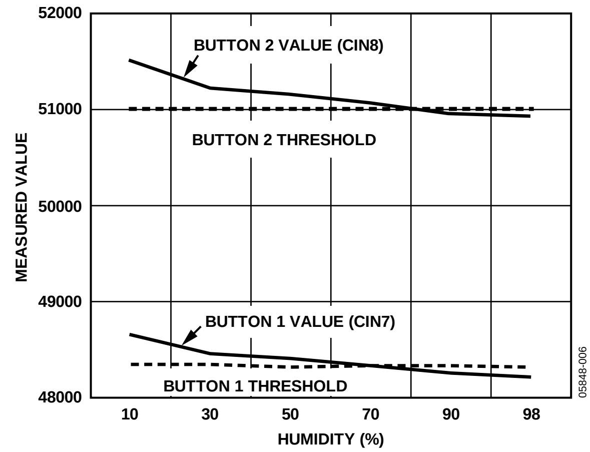

Figure 6. Button Sensors with Fixed Thresholds

The measured capacitance from a sensor may also increase due to environmental changes. In this case, the sensor may never register as being activated, as the capacitance value may never fall below the threshold even when the sensor is pressed.

Analog Device's complete capacitance solution takes the changing environment into account by actively adapting the threshold values with the changing environment. This ensures that the sensors operate correctly in all environments and prevents false touches or failure to register a valid touch. This compensation is part of the digital logic on board the AD7142, and is performed by the part automatically at regular intervals. Figure 7 shows how the environmental compensation algorithm changes the threshold levels with changing humidity and thus ensures that the measured values from the button sensors do not fall below the threshold value to register a false touch.

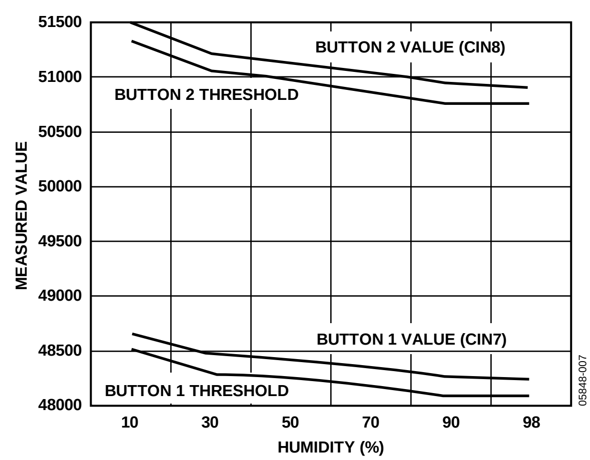

Figure 7. Button Sensors with Adaptive Sensors

Similarly, the threshold values for other sensor types are adjusted for changing temperature and humidity by the compensation algorithm. For the slider sensor, shown in Figure 8, the sensor is registered as being active when the activation level exceeds either the higher or lower threshold level. An increase or decrease in ambient temperature could potentially activate the sensor. However, the adaptive thresholds ensure that no false touches are registered.

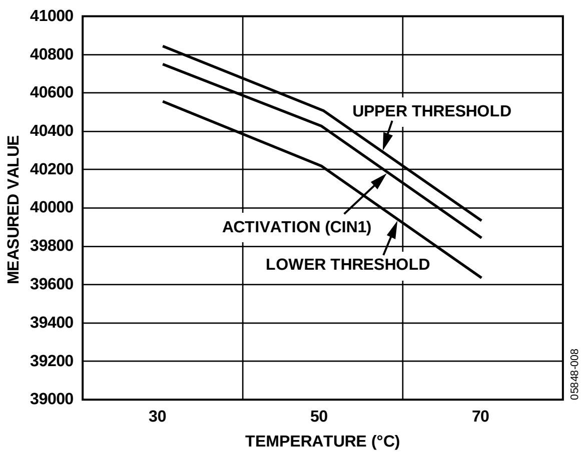

Figure 8. Slider Sensor with Adaptive Thresholds at Constant 50% Humidity

Figure 9 shows how the thresholds governing operation of the joy pad adapt to changing humidity. The joy pad registers a touch if the CIN4 measured value exceeds with the left or right thresholds, or if the CIN6 measured value exceeds either the up or down thresholds. Again, the environmental compensation algorithm ensures that the threshold values track the environmental changes and ensures correct operation of the sensor.

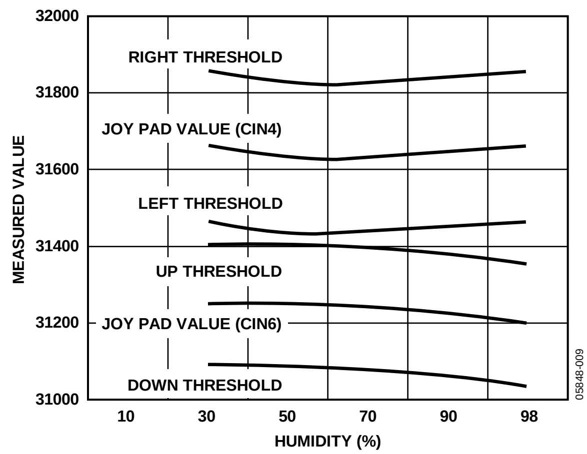

Figure 9. Joy Pad Sensor + Thresholds at Constant 30°C.

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