ANALOG DEVICES

AN-830
APPLICATION NOTE

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Factors Affecting Sensor Response

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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 gives the user an interface with greater sensitivity and control than standard mechanical input technologies.

Analog Devices' capacitance sensing solution has three components: the AD7142 capacitive-to-digital converter IC, sensors on the PCB, and software to communicate with the AD7142. The solution consists of an excitation source connected to a transmitter, which generates a capacitive field to a receiver. The capacitive field lines measured at the receiver are translated into the digital domain by a Σ-Δ analog-to-digital converter. The total capacitance measured at the receiver decreases when a grounded object, such as a finger, comes close to the induced capacitive field. The excitation source and Σ-Δ CDC are implemented on the AD7142, while the transmitter and receiver are constructed on the sensor PCB.

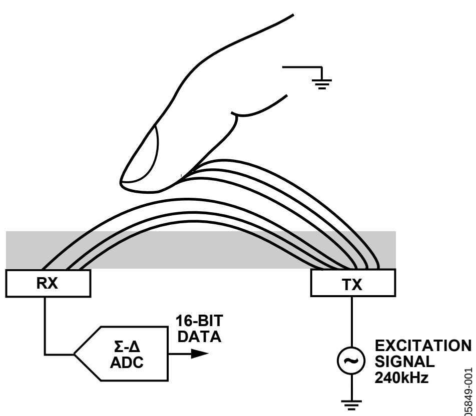

Figure 1. Capacitance Sensing

The sensor PCB is glued to the underside of the case or covering of the finished product. The capacitive field lines extend above the sensor PCB for about 4 mm. The field also extends above any covering material over the sensor PCB. One advantage of this sensor arrangement is that the user is never in contact with the sensor PCB itself, so there is no wear on the sensor.

The case or covering material housing consumer products such as MP3 players, digital still cameras, and handsets, is made from a variety of materials. Materials such as plastic or glass are suitable covering materials for use with capacitance sensing; metal cannot be used.

The response of the capacitance sensor depends on three factors:

- The size and type of the sensor element
- The size of the object touching the sensor
- The thickness and type of the covering material

Each of these factors affects the magnitude of change measured by the CDC when the sensor is touched. If the change in CDC output is very small, then it becomes difficult to differentiate between the sensor-touched and the sensor-not-touched conditions. This application note details how each of these factors affects the sensor response and can be used as a guideline when deciding the size and form of the sensor configuration, as well as the covering plastic specification.

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REVISION HISTORY

12/05—Revision 0: Initial Version

FACTORS AFFECTING SENSOR RESPONSE

SENSOR ELEMENT

The size of the sensor element determines the size of the capacitive field induced between the transmitter and receiver. A smaller sensor element has a smaller field to interfere with than a larger sensor element. If the sensor element is too small, there is not a sufficient change in capacitance measured by the CDC when the sensor is touched.

The type of sensor element is also important. For a button sensor, only on/off or touch/no touch information is required. A button can tolerate some loss of sensor response, as long as it is possible to determine if the button is touched or not. A slider sensor, however, must output position data relating to the length of the slider. A reduction in sensor response for a slider reduces the number of CDC codes that are used to describe a full traverse of the slider, thus affecting the resolution and accuracy of the slider sensor position data.

OBJECT TOUCHING THE SENSOR

For all applications, the object touching the sensor is a finger or hand, which is naturally grounded. However, the size of the object touching the sensor is not constant; finger size can vary from person to person, or indeed the same person can use different fingers at different times to activate the sensors. Consumer devices need to be designed for a range of finger sizes, from small to large, to ensure that everyone can operate the device successfully.

Any grounded object can activate Analog Devices' sensors. For this application note, a grounded metal probe was used to simulate a finger during the data gathering experiments. Three probes of different sizes were used to simulate different finger sizes: 5 mm, 10 mm, and 15 mm diameter probes.

COVERING MATERIAL

The properties of the material covering the sensor must be looked at closely. The capacitive field extends about 4 mm to 5 mm above the sensor PCB. This field must extend above any covering material in order for the sensor to work. The material must not absorb too much of the capacitive field. Some types of plastic are more conductive than others, and so more of the capacitive field gets through. Table 1 shows the dissipation factor for a variety of plastic polymers. The dissipation factor is a measure of how lossy the material is. The lower the dissipation factor, the more of the capacitive field passes through the material.

Table 1.

Polymer Material	Dissipation Factor (x 10^{-3})	
	@50 Hz	@1 MHz
LDPE	0.15	0.08
HDPE	0.24	.20
PP	0.4	0.5
PVC-plasticized	80	120
PS	0.1 to 0.4	0.05 to 0.4
ABS	3 to 8	2 to15
PMMA	40 to 60	4 to 40
POM	5	5
PTFE	0.2	0.2
PCTFE	1	20
PC	0.7	10
PET	2	20
PI	2	5
PUR-linear	120	70
PUR-thermoset	50	50
PUR-thermoplas	30	60
CAB	6	21
Silicone	5 to 13	7

Glass is also a suitable covering material. However, metal cannot be used as a covering material

For this application note, the sensor PCBs were covered in ABS that ranged in thickness from 0.5 mm to 4 mm.

BUTTON SENSOR

A button sensor is the simplest sensor element to implement. The button can be circular, square, or a custom shape. A button sensor can be any size, from 5 mm × 5 mm square upwards. Figure 2 shows a typical button sensor design.

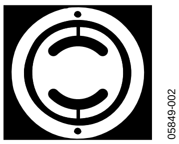

Figure 2. Button Sensor

BUTTON SENSOR RESPONSE

A10 mm × 10 mm square button sensor was used to gather typical button sensor response data. To simulate a user's finger, grounded metal probes of various sizes were used to activate the button. The sensor PCB was placed under plastic varying from 0.5 mm thick to 4 mm thick. The sensor response is defined as the change in CDC output code between the sensor-touched condition and sensor-not-touched condition.

The measured output from the CDC is shown in Figure 3. The data shows clearly that the response from the sensor decreases with respect to increasing plastic thickness. The response from the button sensor becomes insufficient when the CDC output falls below 500 codes. At this point, it becomes difficult to differentiate between a true sensor activation and noise in the CDC codes. A 10 mm button can be successfully used with up to 4 mm plastic on top. For smaller sensors, the response is less than that of larger sensors. For a 5mm button, the sensor response could fall to about 500 codes. For 5 mm buttons, it is recommended that the covering plastic be 2 mm or less to ensure proper sensor operation.

Also noteworthy is the effect the probe size has on the sensor response. A small probe can only decrease the measured capacitance at the receiver by a small amount. This trend holds for finger size also—the smaller the finger, the smaller the response from the sensor.

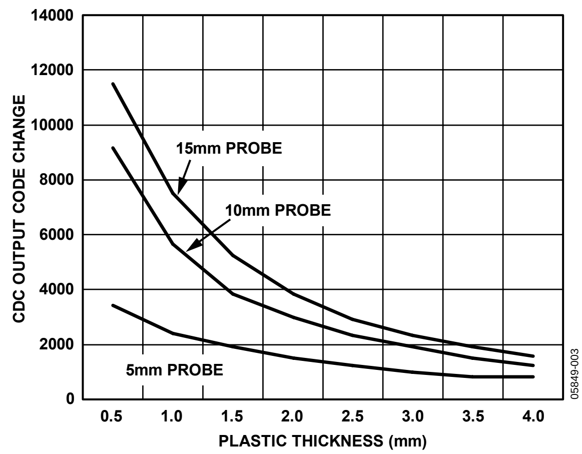

Figure 3. Button Sensor Response

SLIDER SENSOR

A slider sensor element is useful for scrolling through menus, or lists of data, quickly and easily. Slider sensors should be greater than 25 mm in length and greater than 5 mm in width to give sufficient response to implement scrolling functions. The maximum length recommended is about 45 mm. Figure 4 shows a typical slider sensor design.

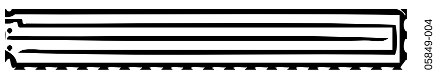

Figure 4. Slider sensor

SLIDER SENSOR RESPONSE

The slider has two responses that can be measured: the activation response (is the slider touched?) and the position data output or scrolling movement response. The data gathered for this application note used a slider of 12 mm in width and 28 mm in length. To simulate a user's finger, grounded metal probes of various sizes were used to touch the slider. The sensor PCB was placed under plastic of thickness varying from 0.5 mm thick to 4 mm thick. Both the slider activation and slider position response were measured, with the slider response being defined as the change in CDC codes between the sensor touched and sensor not touched conditions.

Figure 5 shows data gathered from the slider to measure the activation level. The data clearly shows that the thicker the plastic, the smaller the response from the sensor. The activation measurement tells us when the slider has been touched. In this way, the slider's functionality is similar to a button's on/off functionality and can tolerate some degree of reduction in the sensor response.

Figure 6 shows the response of the slider while scrolling. Again, the same trends are clear: the best response from the sensor is achieved using thin covering plastic and a large probe. The scrolling or position data response from the slider is not tolerant to reductions in sensor response. If the sensor response is good, the difference in codes for the slider is 14000; this means that there is a large code change while scrolling the length of the slider. When the sensor response falls, there is a much smaller change in code while scrolling the length of the slider. This translates into less resolution or accuracy in the scroller position data.

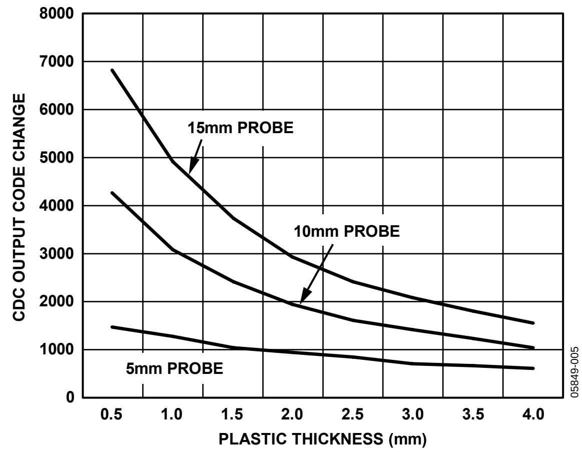

Figure 5. Slider Sensor Activation Response

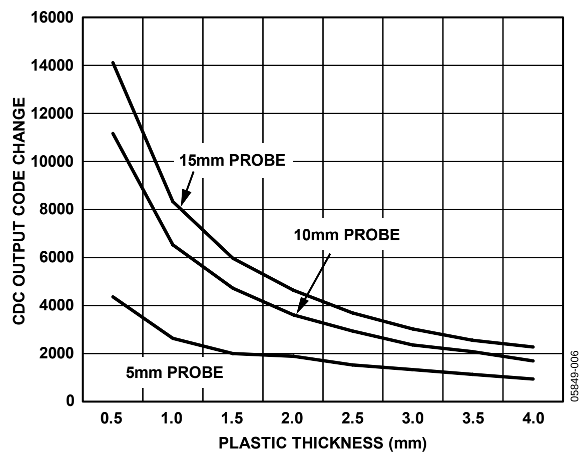

Figure 6. Slider Sensor Position Data Response

RECOMMENDATIONS

To achieve the best response from any sensor element, here are a number of recommendations.

- The covering plastic should have a maximum thickness of 2 mm. This is a general guideline, based on measurements taken with ABS. Other materials may tolerate thickness above or below this. Because sensor size and finger size also affect the sensor response, it may be possible to alter the design to operate at plastic thicknesses above 2 mm.
- Sensor elements should be as big as the design allows. When designing the sensor elements, they should always meet the minimum size requirements set for that sensor type.
- Thought should be given to the target market to ensure that the sensor responds well to the upper and lower distributions of finger size in that market. If designing a toy, then the sensor should be designed to operate best using a child's average finger size.

For further information on Analog Devices' capacitance sensing, go to www.analog.com.

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