ANALOG DEVICES

AN-925
APPLICATION NOTE

One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Sensors for the AD7147 and AD7148 CapTouch Controllers

by Susan Pratt

INTRODUCTION

This application note introduces the capacitive sensors used with the AD7147 and AD7148 CapTouch™ controllers.

The AD7147 and AD7148 are capacitive-to-digital converters (CDCs) for single electrode sensors. The AD7147 is a thirteen capacitive input device, while the AD7148 is an eight input device. The AD7147 and AD7148 are designed for use with capacitance sensors implementing functions such as buttons, scroll bars, and wheels.

The AD7147/AD7148 provide on-chip calibration logic to compensate for changes in the ambient environment. The calibration sequence is performed automatically and at continuous intervals when the sensors are not touched. This ensures that there are no false or nonregistering touches on the external sensors due to a changing environment.

The AD7147 has an SPI-compatible serial interface; the AD7147-1 model and the AD7148 have an I²C®-compatible serial interface. The AD7147-1 and the AD7148 devices have an interrupt output, while the AD7147 models have a general-purpose input/output (GPIO). A V_{DRIVE} pin sets the voltage level for the serial interface independently from V_{CC}.

The AD7147 is available in a 24-lead, 4 mm × 4 mm LFCSP. The AD7148 is available in a 16-lead, 4 mm × 4 mm LFCSP. The devices operate from a 2.6 V to 3.6 V supply.

SENSOR TYPES, SIZES, AND CONNECTIONS

Table 1 shows a list of sensor types for the device, the recommended minimum, typical, and maximum sensor sizes, and the number of input pins on the AD7147/AD7148 required for each sensor type.

The total area of the sensor, rather than the exact dimensions, is of highest importance. A sensor with a large area provides a large electrical field with which the user can interact and, therefore, provides the greatest response when activated.

Each sensor needs to connect physically to one of the AD7147/AD7148 CIN input pins. The number of inputs required depends on the type of sensor. Once the connection is established, the AD7147/AD7148 sequencer must be configured so that the sensors are connected through to the CDC when the part is converting.

Table 1. Sensor Sizes and Input Connection Pins

Sensor Type	Minimum Size	Typical Size	Maximum Size	Number of CIN Input Pins
Button	3 mm diameter	8 mm diameter	--	1
Slider	25 mm × 4 mm	40 mm × 10 mm	60 mm × 20 mm	5 to 8, dependent on slider length
Wheel	16 mm diameter	30 mm diameter	50 mm diameter	8
Matrix Keypad	1 row × 1 column	12 keys, 3 rows × 4 columns	36 keys, 6 rows × 6 columns	1 input per column plus 1 input per row

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SENSORS

BUTTONS

Figure 1 shows some typical designs for a button sensor. The button can be any size (the minimum size is 3 mm in diameter). Each button sensor is connected to one CIN input of the AD7147/AD7148. Buttons can be circular, oval, square, or irregularly shaped.

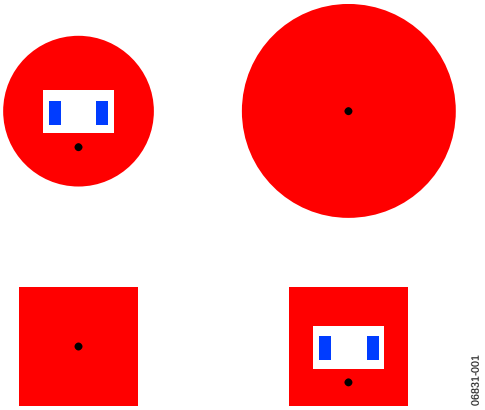

Figure 1. Button Layouts

Some of the button sensors in Figure 1 have a cutout area in the middle of the sensor with pads for a component. This layout can be used for applications with LEDs on the printed circuit board (PCB), with the LED mounted on the back side of the board. Light from the LED can be directed through the cutout area of the button allowing the button to be programmed to light up when activated. The maximum size of the cutout in the button depends on the size of the buttons. Table 2 provides examples of maximum button cutout sizes.

Table 2. Button Cutout Sizes

Button Diameter	Maximum Cutout Size
5 mm	2 mm × 1.6 mm
6 mm	2.8 mm × 1.2 mm
8 mm	4 mm × 2 mm

Typical Button Sensor Response

The response from the sensor is the difference in the CDC output value between sensor touched and sensor not touched conditions. The response from the sensor depends on several factors: sensor area, size of the user's finger, and thickness and permittivity of the material that covers the sensor. The AN-830 application note provides more details on the factors affecting sensor response.

Figure 2 and Figure 3 show typical responses from button sensors of various diameters. For the 4 mm diameter button, the CDC output code changes by approximately 800 codes when the sensor is activated. For the 8 mm button, the CDC output changes by approximately 4000 codes. All buttons were covered with 2 mm of plastic material during testing.

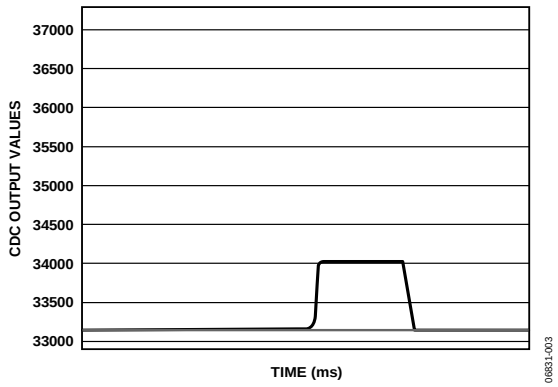

Figure 2. 4 mm Diameter Button Response

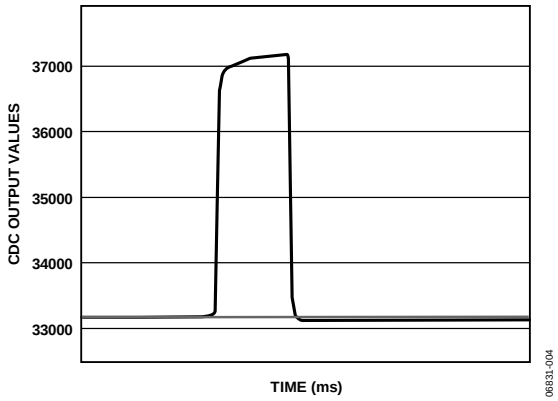

Figure 3. 8 mm Diameter Button Response

MATRIX KEYPAD

The AD7147/AD7148 can be used to implement a matrix keypad. The AD7147 can implement up to 36 keys. The AD7148 can implement up to 16 keys. The keys are arranged in rows and columns, similar to a standard matrix keypad. Each row and column of the keypad requires an input to the AD7147/ AD7148. The keys are constructed with one-half of the keys connected to the column input line, and the other half connected to the row input line. Figure 4 shows a matrix key, with connections to two CIN inputs, one for the row and the other for the column.

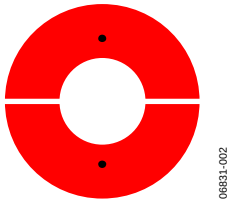

Figure 4. Matrix Keypad Button

When the user activates any key on the keypad, status bits in the status registers are set. The host can read back data from the AD7147/AD7148 to determine which key is pressed. The decoding is the same as that required for conventional mechanical matrix keypads. The active key is at the location where both its row and column status bits are set.

SLIDER

Figure 5 shows the layout for a slider sensor. A slider can be designed with varying widths (from 5 mm to 12 mm) and varying lengths (from 10 mm to 60 mm). The layout of the slider can be straight, in either a vertical or a horizontal position.

A slider can be constructed using between five and eight discrete sensor segments depending on the sensor length, with each segment connected to a CIN input pin on the AD7147/AD7148. Discrete sliders are used for applications that require linear, repeatable output position locations and consist of discrete sensors elements arranged in a strip, one after the other.

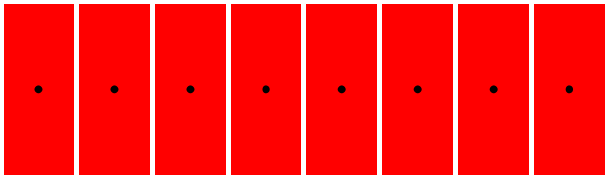

Figure 5. Discrete Slider Sensor Layout

These discrete sensing segments operate like buttons. Each sensing segment is arranged in close proximity to the next sensor; thus, when a user moves a finger along the slider, more than one sensor segment is activated at a time. This slider can produce up to 128 output positions. Each segment of the slider requires one CIN input connection to the AD7147/AD7148.

To achieve 128 output positions using only eight sensor segments, there is some interpolation using the CDC results from each sensor. The CDC results from each segment are weighted and added together to form a normal distribution curve. The mean of this normal distribution provides the output position from the slider.

Analog Devices, Inc. provides the software algorithm to achieve this linearization. It is provided as C code and is available to download from the AD7147 and AD7148 product pages. In the **RESOURCES & TOOLS** section of the product pages, choose the **TOOLS, SOFTWARE & SIMULATION MODELS** box. Click on the **Software Modules** link to access the sample code. Downloading and opening the software implies acceptance of the Analog Devices software license agreement. This code requires 7391 bytes of program code and 481 bytes of RAM in the host processor to run successfully. Code size increases to 7948 bytes of program code and 496 bytes of data memory using a software serial interface implementation.

SCROLL WHEEL

The scroll wheel is a special type of discrete slider. Each of the discrete segments in the slider is arranged into a circular shape, as shown in Figure 6. The scroll wheel can provide as many as 128 output positions.

To achieve 128 output positions using only eight sensor segments, there is some interpolation using the CDC results from each sensor. The CDC results from each segment are weighted and added together to form a normal distribution curve. The mean of this normal distribution gives the output position from the scroll wheel.

The software algorithm used to achieve this linearization is provided as C code is available to download from the AD7147 and AD7148 product pages. In the **RESOURCES & TOOLS** section of the product pages, choose the **TOOLS, SOFTWARE & SIMULATION MODELS** box. Click on the **Software Modules** link to access the sample code. Downloading and opening the software implies acceptance of the Analog Devices software license agreement. This code requires 8467 bytes of program code and 468 bytes of RAM in the host processor to run successfully.

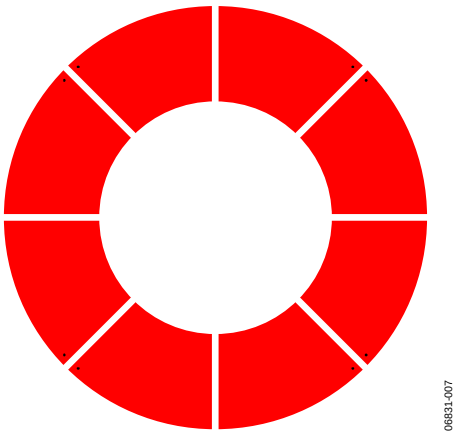

Figure 6. Scroll Wheel Sensor Layout

SENSOR LIBRARY

A sensor library is available to download from the AD7147 and AD7148 product pages. In the **RESOURCES & TOOLS** section of the product pages, choose the **EVALUATION BOARDS & DEVELOPMENT KITS** box. Click on the **Evaluation Boards/Tools** link to access the sensor library.

The sensor library is available in two formats: as a Mentor Graphics PADS 2005 library and as .dxf files. Sensors can be picked and placed from the libraries and used either directly in a layout or as the basis for a custom sensor design.

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