TI Designs
Low-Power Touch Through Glass Reference Design
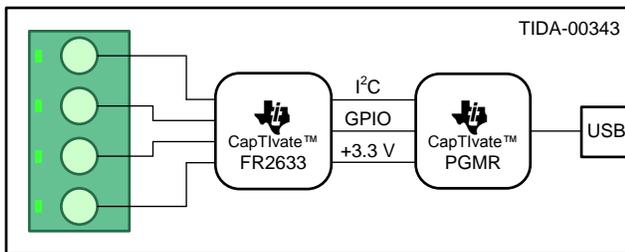
TEXAS INSTRUMENTS

Design Overview

The human machine interface (HMI) is an essential part of process plants because it is one of the major ways through which humans and machines interact. The TIDA-00343 reference design offers an HMI solution for harsh and hazardous area applications. In process plants, operators are required to interact with explosion-proof displays or controllers, which are housed in screw-on metallic enclosures with thick glass windows to display local readout and programming functions.

The TIDA-00343 TI Design, which uses CapTIvate™ innovative technology from TI, allows the operator to interact with a controller without requiring them to open the enclosure, which saves time by avoiding a work permit or plant shutdown.

Design Resources

TIDA-00343	Design Folder
MSP430FR2633	Product Folder
CapTIvate™	Tool Folder

TI E2E™ Community

ASK Our E2E Experts

Design Features

- Single and Multistep Button Press
- Four Robust Buttons Option Implemented
- Four LEDs as Feedback
- Variable Air Gap Between Buttons and Glass (1 mm to 2 mm)
- Touch Detection Through Thick Glass (8 mm to 12 mm)
- Work With Gloves and in Harsh Environment (Water, Oil, Dust, and So Forth)
- Temperature Range: –40°C to 85°C

Featured Applications

- HMI
- Process Control
- Field Transmitters
- Field Actuators

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1 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATION	DETAILS
Glass thickness	9.5 mm	See Section 3.2
Glass diameter	80 mm	See Section 3.2
Air gap	1 mm to 2 mm	See Section 3.3
Number of buttons	Four	See Section 3.3
Feedback	LED	—
Work with gloves	—	See Section 8.2
Harsh environment resistant	—	See Section 8
SNR	—	See Section 8
Crosstalk	—	See Section 8
Low power (≈10-Hz scan rate)	240 µA (average)	—
Temperature range	–40°C to 85°C	—

2 System Description

The TIDA-00343 design combines a button board with a TI CapTIvate™ integrated circuit (IC). The button board represents an operator interface and the CapTIvate IC processes the inputs given by an operator.

The complete system offers an HMI solution for harsh or difficult hazardous area applications in process plants that require operators to interact with an explosion-proof display or controller. Displays and controllers are housed in screw-on metallic enclosures with thick glass windows to display local readout and programming functions.

The CapTIvate technology in this TI Design allows the operator to interact with the controller without requiring them to open the enclosure, which saves time by avoiding a work permit or plant shutdown.

The CapTIvate technology provides high-resolution capacitive-touch sensing, which allows plant operators to touch buttons through the thick glass window while offering high reliability and noise immunity at the lowest power (see Figure 1).

Figure 1. Touch Through-Glass Application

3   System Design Theory

This section focuses on the design theory of the electrode board. For more information on CapTIvate technology, consult the following *CapTIvate™ Technology Guide*.

3.1   *Mechanical Design*

Designing the electrode board requires attention to a few key mechanical details. Note that the board is to be housed in a screw-on metallic enclosure (see Section 3.2), which can be removed by unscrewing the unit. To prevent any interference with the electronics when the user removes the enclosure, the electrode board must not be in direct contact with the glass window. The distance between the window glass and the electrode board can vary depending on the application.

The typical placement of the electrode board is in the lower part of the glass window to leave space for a liquid-crystal display (LCD) on the upper part of the glass window for a local readout of the sensor parameters.

3.2   *Explosion-Proof Enclosure*

The TIDA-00343 design uses an explosion-proof enclosure made of stainless steel with a 9.5-mm thick glass window. Figure 2 shows the mechanical specifications of this enclosure.
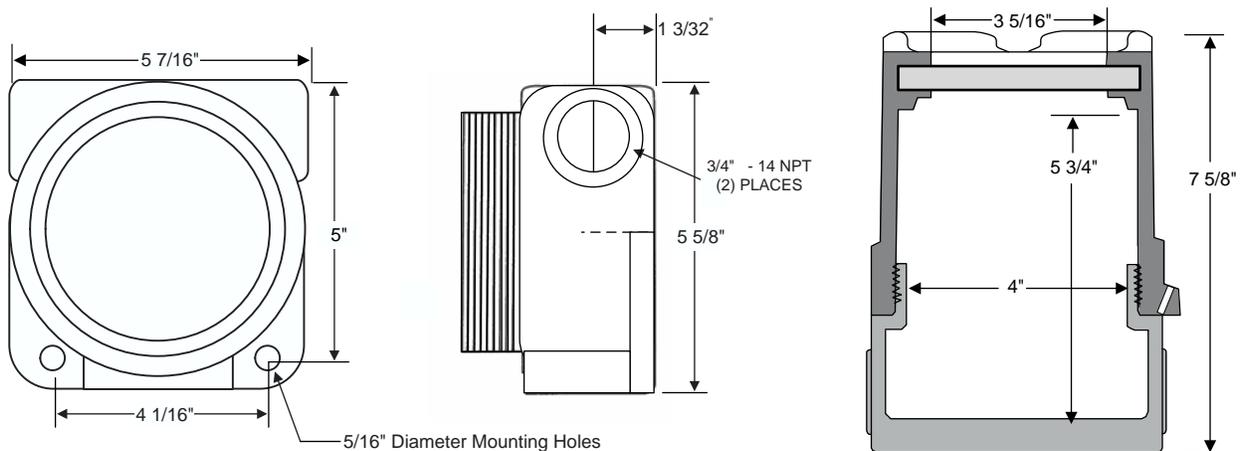
Figure 2. Explosion-Proof Enclosure (XIHLDGCX From Adalet)

The enclosure is big enough to contain the electronics and has a hole on the bottom side that allows the user to wire the USB cable, which is used to connect to the PC and acquire data from the sensors.

The enclosure must be grounded. If the enclosure is floating, a touch on it may couple together all of the buttons and cause a false detection.

However, the buttons closer to the enclosure or any conductive surface that is tied at a fixed potential are less sensitive than the other buttons because the grounded enclosure pulls in the electric field, which limits the field above the glass in the desired area of interaction.

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3.3 Electrode Design

The diameter and shape of the electrodes are defined by a tradeoff between obtaining the maximum sensitivity (Equation 1) and the mechanical constraints of the application (see Figure 3).

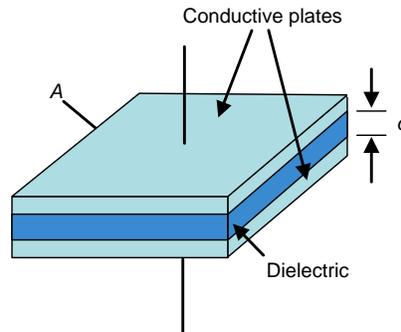$$C = \epsilon_r \times \epsilon_0 \times \frac{A}{d}$$

(1)

Figure 3. Parallel Plate Capacitor

The area of the button must be as big as possible or at least the same size of the average finger press for a higher sensitivity. The button diameter of the TIDA-00343 is equal to 10 mm, which is a bit smaller than the average finger press of an operator and is limited by the mechanical constraints of the application.

This application typically requires the use of a glass window with a diameter that spans from 4 cm up to 12 cm and contains three to six buttons, which are placed behind the glass on the lower section. In this setup, the space for each button is approximately 1 cm to 2 cm without accounting for the minimum distance required between the buttons, which is fundamental to avoiding crosstalk, and the space occupied by the microcontroller (MCU), light-emitting diode (LED), and passives in the printed circuit board (PCB).

A medium-sized enclosure has an 8-cm glass window diameter and a four-button application. To account for the application requirements of this design, the TIDA-00343 has four buttons with 10-mm diameters.

Section 3.1 explains the importance of placing the buttons a certain distance from the metallic enclosure. Additionally, the buttons must be placed as far as possible from each other to avoid crosstalk, which increases as the air gap between the glass and buttons increase. Note that the dielectric of this application is not negligible (see Figure 4).
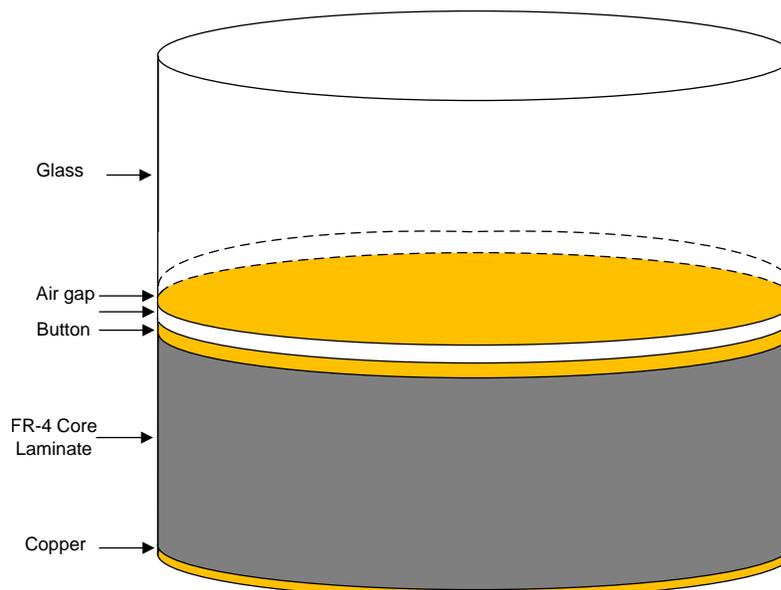

Figure 4. Application Stackup

Every 1 mm of air gap is equivalent to 7 mm to 8 mm of glass (see Table 2). So with a glass thickness of 10 mm, the actual stackup consists of approximately 25 mm to 30 mm of glass. This ratio of material affects the sensitivity of the buttons, too.

Table 2. Dielectric Material

MATERIAL	DIELECTRIC CONSTANT (Er)
Air	1.0
FR-4	4.8
Glass	7.6 to 8.0
Gorilla and regular glass	7.2 to 7.6
Polycarbonate	2.9 to 3.0
Acrylic	2.8
ABS	2.4 to 4.1

Figure 5 shows the configuration of the buttons.

All the measurements are in mm
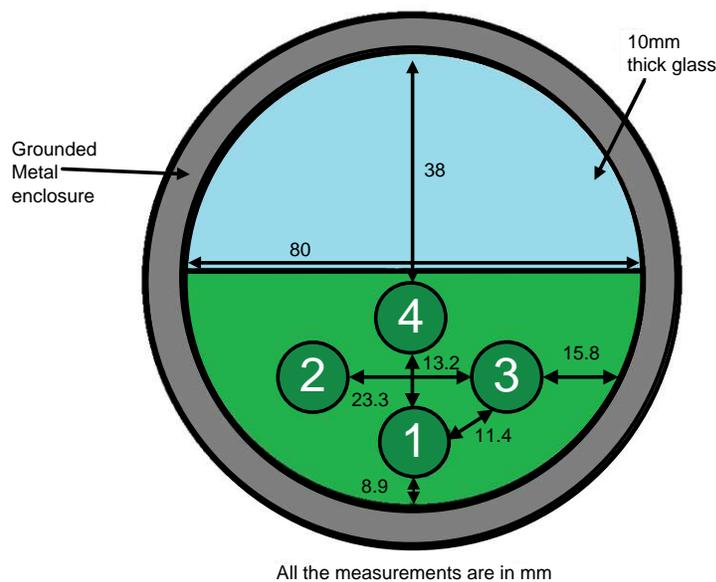
Figure 5. Button Configuration

This configuration allows the user to test how the crosstalk varies among the buttons and how the metal enclosure influences the different buttons.

The TIDA-00464 design utilizes buttons known as self-capacitance buttons.

3.4 Self-Capacitive Buttons

A self-capacitive button sensor is a single electrode. Self-capacitive buttons are simple to lay out and each button is assigned to only one pin on the MCU (see Figure 6). Self-capacitive buttons provide greater sensitivity as compared to a mutual capacitive button, but are more influenced by parasitic capacitances to ground.
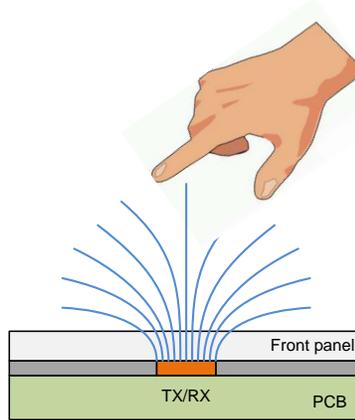
Figure 6. Example Diagram—Self-Capacitive Button Design

Table 3 shows the basic specifications of self-capacitive buttons.

Table 3. Self-Capacitive Button Properties

PARAMETER	GUIDANCE
Radiation pattern	Between electrode and ground
Size	Equivalent to interaction
Shape	Various: typically round or square
Spacing	0.5 × overlay minimum thickness

3.4.1 Self-Capacitive Button Shapes

The electrode shape is typically rectangular or round with common sizes of 10 mm and 12 mm. Ultimately, the size depends on the required touch area. A good design practice is to keep the size of the button as small as possible, which minimizes the capacitance and helps with the following:

- Reduce susceptibility to noise
- Improve sensitivity
- Lower power operation as a result of smaller capacitance and reduced electrode scan time

Figure 7 shows an example of a silkscreen-button outline pattern.

Figure 7. Silkscreen-Button Outline Pattern

The goal of the button area is to provide a sufficient signal when the user touches the overlay above the button electrode. Typically, a nonconductive decal or ink is used to identify the touch area above the electrode. The relationship between the decal and the electrode can be varied so that contact with the outer edge of the decal registers a touch. Conversely, the electrode can also be small to ensure that the button only activates after touching the center of the decal. The following Figure 8 and Figure 9 show how the effective touch area is a function of the electrode size and the size of the finger making contact.
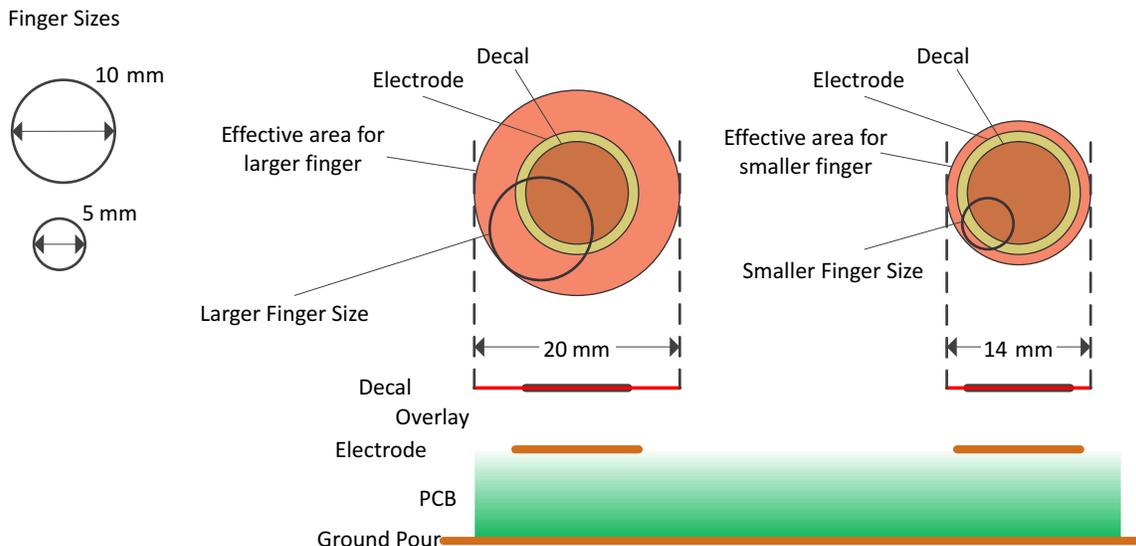
Figure 8. Effective Area Example for Electrodes Larger Than Decal
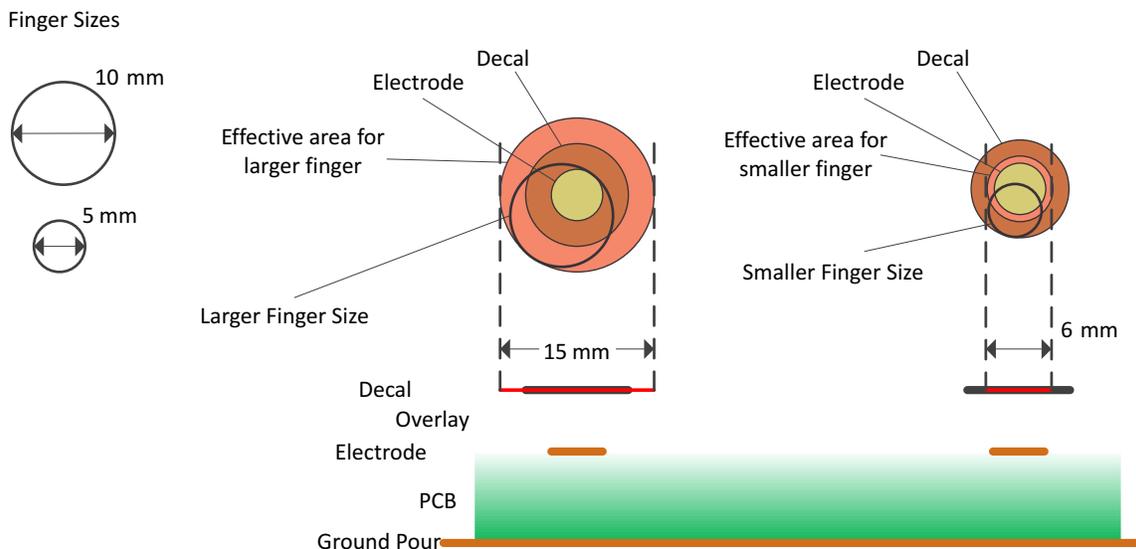
Figure 9. Effective Area Example for Electrode Smaller Than Decal

One common mistake is to make the electrode the same shape as the icons printed (in nonconductive ink) on the overlay. As Figure 10 shows, this action can lead to electrodes with odd shapes that create discontinuities and reduce surface area.
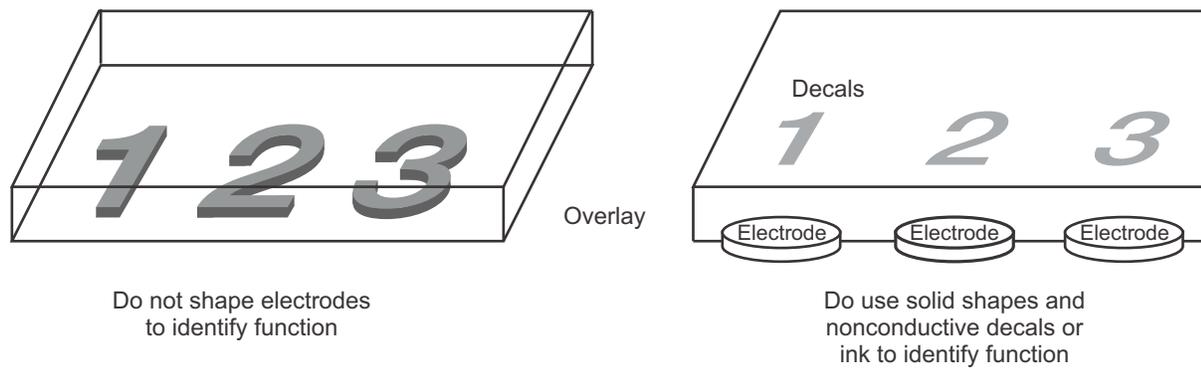
Figure 10. Button Shape Examples—Dos and Don'ts

As the distance of the overlay increases, the effective area decreases; therefore, it is important to keep the button electrode diameter at least three times the laminate thickness.

4 Block Diagram
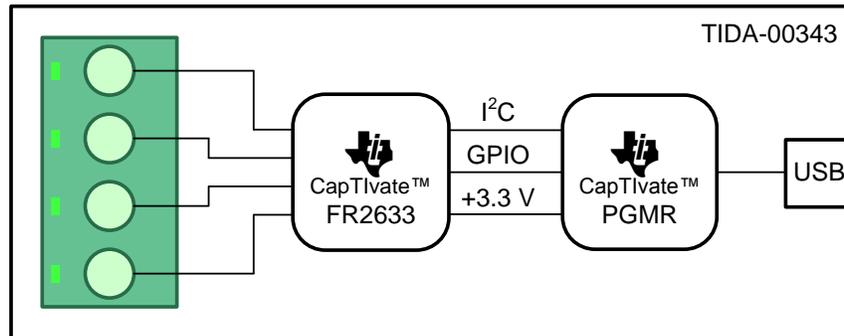
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Figure 11. TIDA-00343 Block Diagram

4.1 Highlighted Products

The key part of the TIDA-00343 system design is the MSP430FR2633 MCU, which allows capacitive sensing by pressing a button. The touch of this button registers, even through layers, such as a screen of thick glass. The implementation of CapTIvate technology enables the capacitive touch sensing capabilities of the MSP430FR2633 MCU.

4.1.1 MSP430FR2633

- Embedded microcontroller
  - 16-bit RISC architecture
  - Clock supports frequencies up to 16 MHz
  - Wide supply voltage range from 1.8 V to 3.6 V [1]
- Optimized ultra-low-power modes
  - Active mode: 126 µA/MHz (typical)
  - Standby
  - LPM3.5 real-time clock (RTC) counter with 32768-Hz crystal: 770 nA (typical)
  - Shutdown (LPM4.5): 15 nA (Typical)
- Low-power ferroelectric RAM (FRAM)
  - Up to 15.5KB of nonvolatile memory
  - Built-in error correction code (ECC)
  - Configurable write protection
  - Unified memory of program, constants, and storage
  - 10^{15} write cycle endurance
  - Radiation resistant and nonmagnetic
  - High FRAM-to-SRAM ratio, up to 4:1

- Intelligent digital peripherals
  - Four 16-bit timers
    - Two timers with three capture/compare registers each (Timer_A3)
    - Two timers with two capture/compare registers each (Timer_A2)
  - One 16-bit counter-only RTC
  - 16-bit cyclic redundancy check (CRC)
- Enhanced serial communications
  - Two enhanced universal serial communication interfaces (eUSCI_A) support UART, IrDA, and SPI
  - One eUSCI (eUSCI_B) supports SPI and I²C
- High-performance analog
  - 8-channel 10-bit analog-to-digital converter (ADC)
    - Internal 1.5-V reference
- Clock system (CS)
  - On-chip 32-kHz RC oscillator (REFO)
  - On-chip 16-MHz digitally controlled oscillator (DCO) with frequency-locked loop (FLL)
    - ±1% accuracy with on-chip reference at room temperature
  - On-chip very low-frequency 10-kHz oscillator (VLO)
  - On-chip high-frequency modulation oscillator (MODOSC)
  - External 32-kHz crystal oscillator (LFXT)

[1] Minimum supply voltage is restricted by SVS levels

- – Programmable MCLK prescalar of 1 to 128
- – SMCLK derived from MCLK with programmable prescalar of 1, 2, 4, or 8
- General input/output and pin functionality
  - – 16 interrupt pins (P1 and P2) can wake MCU from low-power modes
- Development tools and software
  - – Free professional development environments

- Family
- Package options
  - – 24-Pin: VQFN (RGE)
  - – 24-Pin: DSBGA (YQW)
- For complete module descriptions, see the *MSP430FR4xx and MSP430FR2xx Family User's Guide* (SLAU445)

The TI MSP family of low-power microcontrollers consists of several devices that feature different sets of peripherals targeted for various applications. The architecture, combined with extensive low-power modes, is optimized to achieve extended battery life in portable measurement applications. The MCU features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows the MCU to wake up from low-power modes to active mode typically in less than 10 µs.

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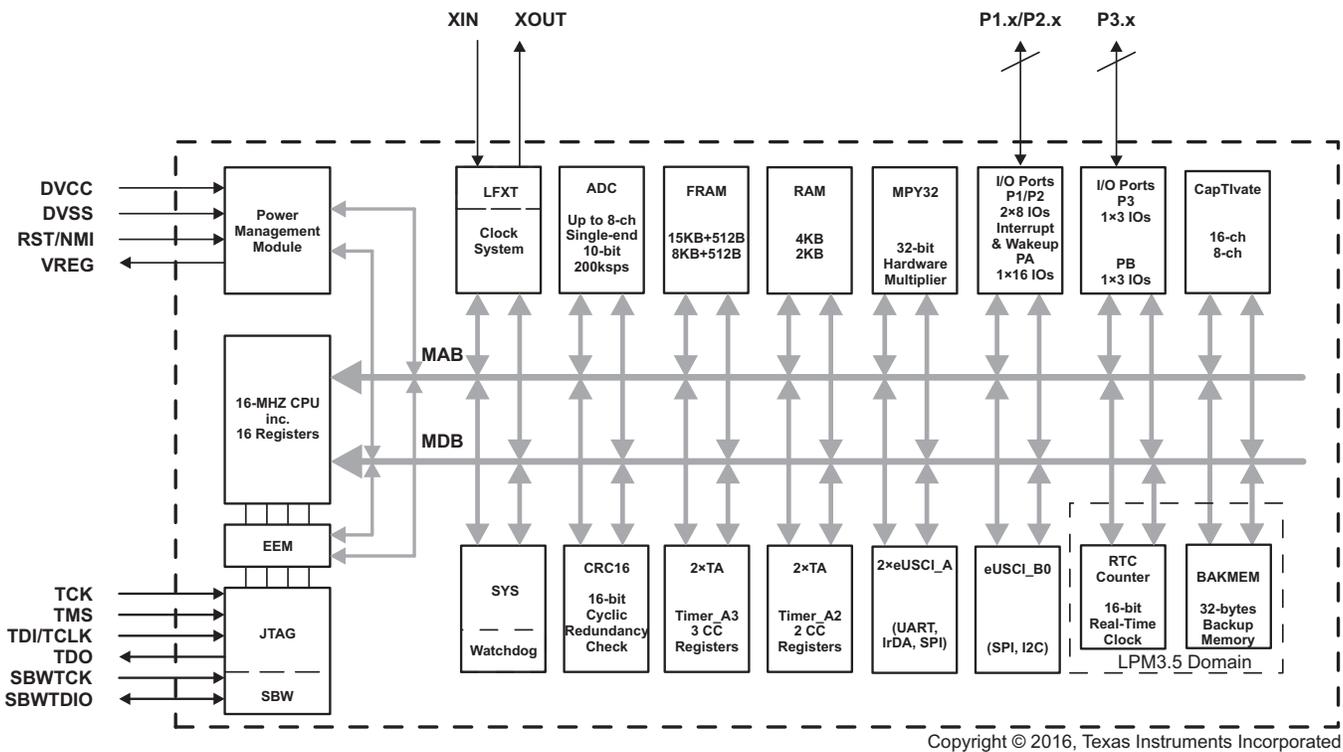
Figure 12. Functional Block Diagram

5   Getting Started Hardware

Implement the following steps to set up the hardware:

1. Connect the CapTIvate-FR2633 PCB to the CapTIvate-PGMR PCB. For more information about the CapTIvate-FR2633 PCB and CapTIvate-PGMR PCB, visit the *Hardware* section of the *CapTIvate™ Technology Guide*.

2. Connect the electrode board to the CapTIvate-FR2633 board through wires. The following Table 4 shows the corresponding connections:

**Table 4. Electrode Board to CapTIvate™-FR2633
Connections**

CONNECTOR ELECTRODE BOARD (J1)	CONNECTOR CapTIvate™-FR2633 (J10)
B1	C1
B2	C5
B3	C9
B4	C13
L1	A12
L2	A13
L3	A14
L4	A15
GND	A1
GND	Enclosure

3. Use plastic spacers to elevate the board from the floor up to the glass. The length of the spacers depends on the used enclosure.

4. Use screws, nuts, spacers, or bumpers to establish a defined air gap between the glass window and the board.

5. Place the board inside the enclosure with the electrode board facing the glass window, as Figure 14 shows.

6. Connect the CapTIvate-PGMR PCB to the PC through a micro-USB cable.

6   Getting Started Firmware

Follow these steps to get started with the firmware (for more information, refer to the *Design Center GUI* section of the *CapTIvate™ Technology Guide*):

1. Download the CapTIvate™ Design Center tool.

2. Double-click on the desktop shortcut *CapTIvateDesignCenter* to start the tool.

3. In the *File* menu, navigate to the *File → Project New* menu to create a new project.

4. Place a button group (keypad) sensor in the design area.

    (a) Select the button group by clicking on the sensor icon. Place the new object by clicking on the design canvas.

5. Display the sensor properties to configure it to be a self-capacitance button group with four elements.

    (a) Double-click on the button group object in the design area to display its properties.

    (b) Configure the sensor to have four elements and close the properties dialog by clicking the *ok* button.

6. Place the MSP430 controller.

    (a) Select the MSP430 by clicking on the MCU icon. Place the new object by clicking on the design canvas.

7. Connect the sensors to the MSP430 capacitive touch input/output (I/O) ports.

    (a) Double-click on the MSP430 controller object in the design area to display its properties.

    (b) Configure the MSP430 controller as *MSP430FR2633IRHB* (32-pin QFN package).

    (c) Select the *Auto-Assign* button to automatically assign all the sensor ports to the appropriate ports on the MSP430.

    (d) Under the *Compile Time Options* heading, check the box for *Enable Noise Immunity*: This option enables 4-frequency scanning and jitter filtering.

8. Generate the source code.

    (a) Select the *Generate Code* button on the *MSP430 Controller properties* dialog.

    (b) In the *Settings* pop-up window for the *Select configuration*, check the radio button for *Create new project* and then click the *OK* button to create a new full project.

    (c) In the *Settings* pop-up window for the *Output Directory*, click the *OK* button to keep the default location for the generated code.

9. Load and run the MSP430FR26xx/25xx generated firmware project using the Code Composer Studio™ (CCS) software from Texas Instruments or IAR.

Figure 13 shows how the CapTIvate Design Center project appears after properly loading:
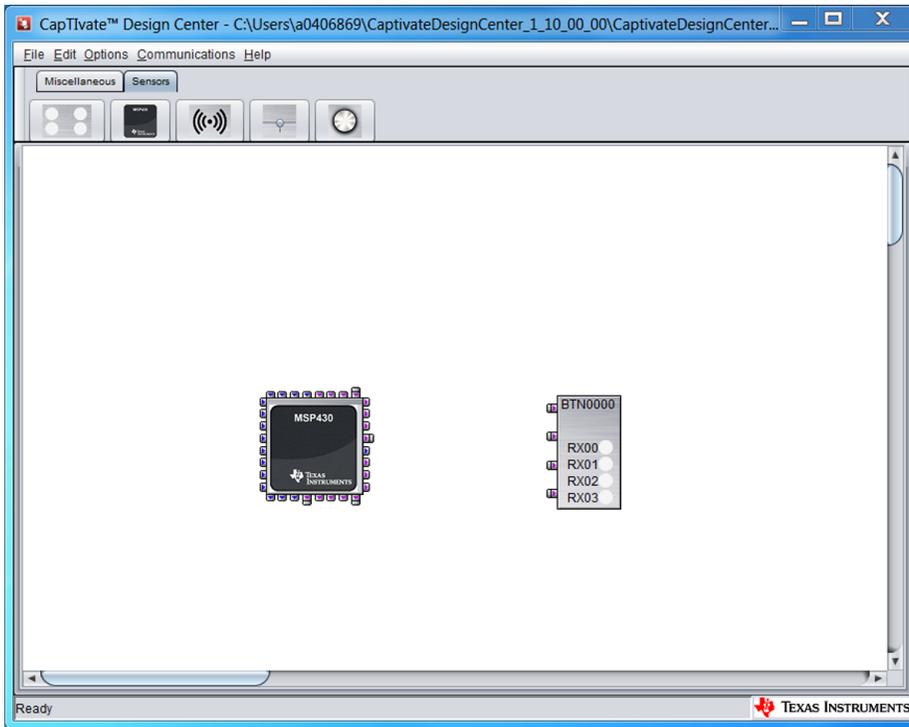
Figure 13. TIDA-00343 Project Screenshot

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7　Test Setup

The electrode board, CapTIvate-FR2633 PCB, and CapTIvate-PGMR PCB must be connected as outlined in Section 5 and then contained in an explosive-proof enclosure. A USB wire is the only object that is allowed to protrude from the enclosure and this USB must be connected to a laptop, which uses the CapTIvate Design Center tool to acquire the sensor data. Figure 14 shows an image of the final test setup.

Figure 14. Test Setup

Adjusting the conversion gain and the conversion count is an important step that the user can control in the CapTIvate Design Center . Adjust these properties by opening the *ButtonGroupSensor* properties with a double-click on the button group icon and then navigating to the *Conversion_Control* tab.

The conversion gain and conversion count are the fundamental parameters used to establish the performance of the sensor. These parameters determine the resolution, sensitivity, and required conversion time.

The TIDA-00343 design has a conversion gain count equal to 1400 and a conversion gain equal to 200. Increasing the strength of the infinite impulse response (IIR) filter to improve the signal-to-noise ratio (SNR) is also possible. This property is controlled by the *Count Filter Beta* parameter located in the *Tuning* tab for each sensor. The TIDA-00343 design has a count filter beta set to 3.

The following tests were performed:

- Touch
- Touch with gloves
- False touch

In each test, 1000 samples were taken while pressing a button (touch) and 1000 samples were taken without performing any action (untouched). The sampling was followed by a calculation of the SNR and crosstalk among the buttons.

The diagram in Figure 15 can be used to show the results if considering a normal distribution for the touch event and untouched event:
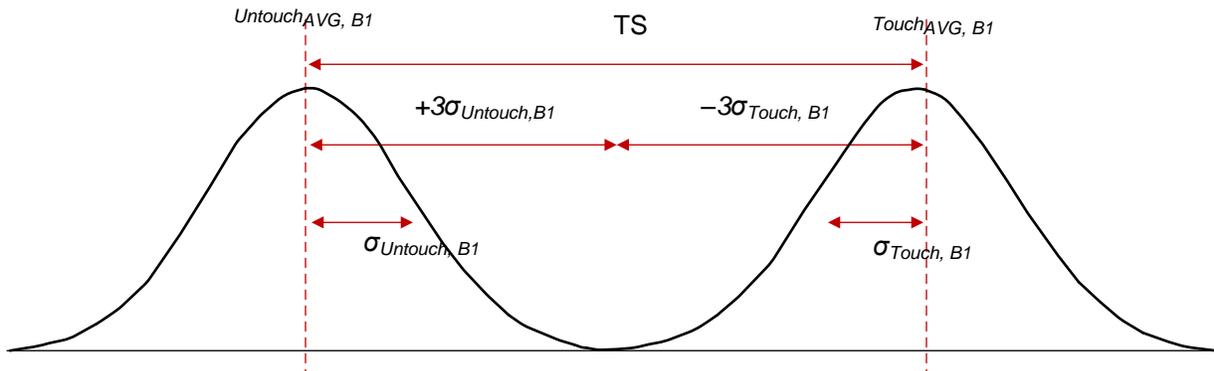
Figure 15. Event Distribution (SNR) With Touch and Untouched

Touched$_{AVG\_B1}$ is the average of 1000 sample while pressing button 1 (see Equation 2).

$$Touched_{AVG\_B1} = \frac{\sum_{n=0}^{Sample\ Size} Touched_{B1}[n]}{Sample\ Size} \tag{2}$$

Untouched$_{AVG\_B1}$ is the average of 1000 samples without any button presses (see Equation 3).

$$Untouched_{AVG\_B1} = \frac{\sum_{n=0}^{Sample\ Size} Untouched_{B1}[n]}{Sample\ Size} \tag{3}$$

Table 5 shows the SNR and the probability of a false event as a function of the number of σ.

Table 5. SNR and Probability of False Event in Function of Number of σ

zσ	SNR	PROBABILITY OF FALSE EVENT
1σ	0 dB	31.73%
2σ	6 dB	4.55%
3σ	9.5 dB	0.27%
4σ	12 dB	60 ppm
5σ	14 dB	0.57 ppm

To achieve a 0.27% probability of a false event, the user must ensure that the value for the Touched$_{AVG\_B1}$ is calculated as follows in Equation 4:

$$T_{AVG\_B1} - 3\sigma_{Touch\_B1} > U_{AVG\_B1} + 3\sigma_{Untouch\_B1} \tag{4}$$

where:

$$\sigma_{Touch\_B1} = \sqrt{\left(\frac{\sum_{n=0}^{Sample\ Size} \left(Touched_{B1}[n] - Touched_{AVG\_B1} \right)^2}{Sample\ Size} \right)} \tag{5}$$

$$\sigma_{Untouch\_B1} = \sqrt{\left(\frac{\sum_{n=0}^{Sample\ Size} \left(Untouched_{B1}[n] - Untouched_{AVG\_B1} \right)^2}{Sample\ Size} \right)} \tag{6}$$

The calculations from Equation 4 can be further simplified in Equation 7:

$$T_{AVG\_B1} - U_{AVG\_B1} > 3 \left(\sigma_{Untouch\_B1} + \sigma_{Touch\_B1} \right) \rightarrow \frac{T_{AVG\_B1} - U_{AVG\_B1}}{\sigma_{Untouch\_B1} + \sigma_{Touch\_B1}} > 3 \tag{7}$$

Define the touch strength (TS) in Equation 8 using the previous calculations from Equation 7:

$$\text{Touch Strength} \left(TS \right) = Untouched_{AVG\_B1} - Touched_{AVG\_B1} \tag{8}$$

Calculate the SNR in dB in Equation 9:

$$SNR \left(dB \right) = 20 \times \log \left(\frac{\text{Touch Strength} \left(TS \right)}{\sigma_{Untouch\_B1} + \sigma_{Touch\_B1}} \right) > 9.5 \text{ dB} \tag{9}$$

To ensure that the probability of a button being touched is equal to 99.73%, the SNR must be greater than 9.5 dB (see Table 5).

The method for calculating the crosstalk is similar to that of the SNR; however, this method considers the average of 1000 samples of a button while touching a nearby button (see Figure 16).
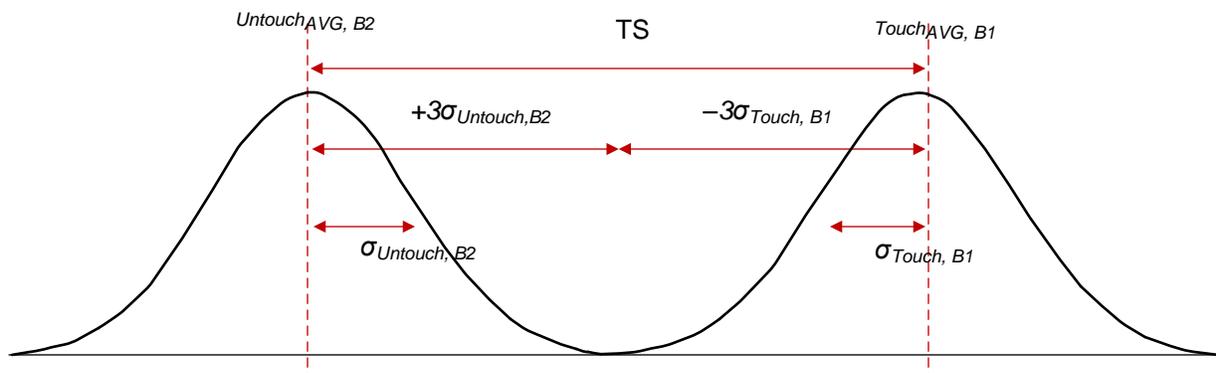
Figure 16. Event Distribution (Crosstalk) With Touch and Untouched

In Figure 16, $Touch_{AVG\_B1}$ is equal to the average of 1000 samples while button 1 is pressed and $Untouch_{AVG\_B2}$ is equal to the average of 1000 samples of button 2 while button 1 is pressed.

Equation 10 shows how to calculate the crosstalk:

$$Crosstalk_{B1\_B2} \left(dB \right) = 20 \times \log \left(\frac{\text{Touch Strength} \left(TS \right)}{\sigma_{Untouch\_B2} + \sigma_{Touch\_B1}} \right) > 9.5 \text{ dB} \tag{10}$$

To ensure that the probability of an unintentional button touch is equal to 0.27%, the crosstalk must be greater than 9.5 dB (see Figure 16). Refer to Equation 5, Equation 6, and Equation 8 for calculating the touch strength, $\sigma_{Untouch\_B2}$, and $\sigma_{Untouch\_B1}$.

The air gap between the glass window and the buttons varies in each test from 1 mm to 2 mm and no air gap. Decrease the proximity and touch threshold in the *Tuning* tab of the *ButtonGroupSensor* properties as the air gap increases.

8   Test Data

8.1   *Touch*

This test measures the SNR and crosstalk for each button while using a human finger to press the button. The following Table 6 and Figure 17 show how the SNR decreases as the air gap increases.

Table 6. Touch—SNR

AIR GAP (mm)	SNR (dB)			
	B1	**B2**	**B3**	**B4**
0	34	36	33	33
1	21	22	25	21
2	15	13	17	16
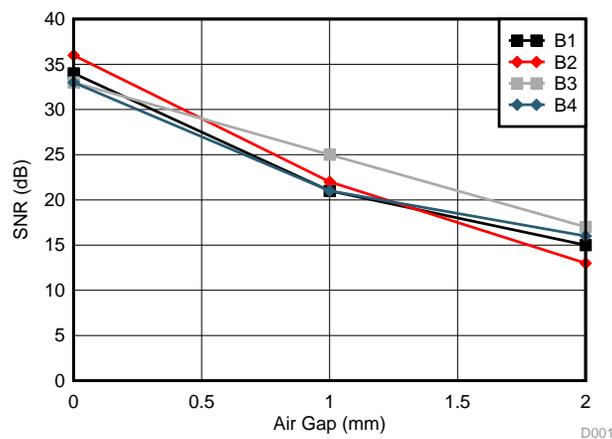
Figure 17. Touch—SNR

The SNR is still greater than 9.5 dB at a 2-mm air gap for all the buttons, which ensures that the application is robust. The crosstalk has a similar behavior to that of the SNR: the crosstalk decreases as the air gap increases. Table 7 shows the obtained results:

Table 7. Touch—Crosstalk

AIR GAP (mm)	CROSSTALK (dB)				
	UNTOUCHED BUTTONS	**B1**	**B2**	**B3**	**B4**
0	B1	—	22	23	27
	B2	20	—	24	25
	B3	23	24	—	26
	B4	22	22	21	—
1	B1	—	20	20	17
	B2	15	—	21	16
	B3	19	21	—	18
	B4	18	18	20	—
2	B1	—	15	13	15
	B2	13	—	17	14
	B3	14	18	—	16
	B4	11	13	14	—

The crosstalk is measured for each button pressed. The best crosstalk results are obtained between button 3 and button 2 because they have the most distance between each other with respect to the other buttons (see Figure 5).

Figure 18 shows the crosstalk results:
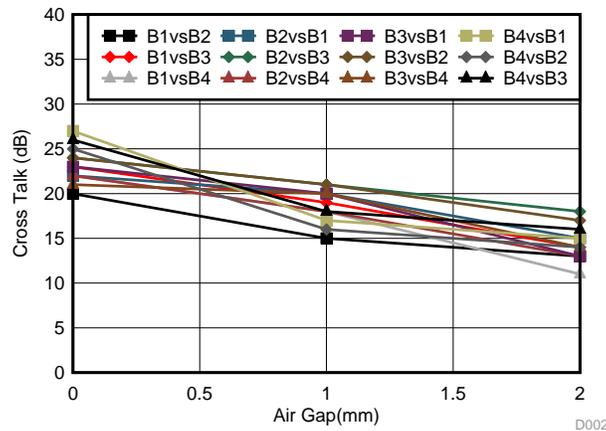
Figure 18. Touch—Crosstalk

8.2 Touch With Gloves

This test measures the SNR and crosstalk for each button while a human finger wearing a thick glove is used to press the button (see Figure 19).

Figure 19. Example Firefighting Glove

This test shows a significant decrease in the measured SNR and crosstalk in comparison to the test results without a glove, which is a result of the thick fabric of the glove and its resistance to harsh environments.

However, the SNR values are still greater than 9.5 dB, even at 2 mm (see Table 8), which indicates that the TIDA-00343 device is still capable of recognizing a button press while a user is wearing a thick pair of gloves (see Figure 20).

Table 8. Touch With Gloves—SNR

AIR GAP (mm)	SNR (dB)			
	B1	B2	B3	B4
0	24	23	25	23
1	16	17	19	17
2	12	14	15	13
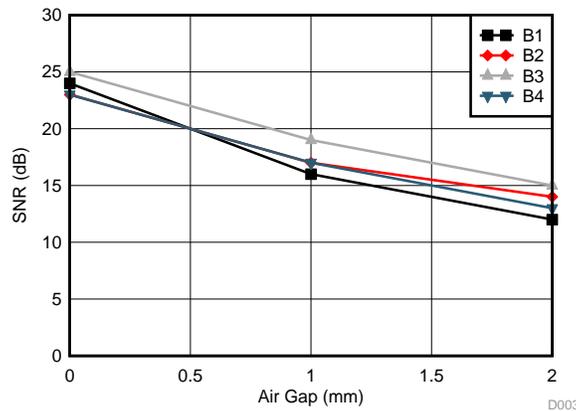
Figure 20. Touch With Gloves—SNR

Table 9 shows the crosstalk values. Some of the resulting crosstalk values are less than 9.5 dB when measuring at the 2-mm air gap. These results indicate that a touch of the button while wearing gloves can influence nearby buttons.

However, the results can be improved by implementing a data processing algorithm. One such example is to increase the sample rate, which also effectively increases the sample averaging (see Figure 21).

Table 9. Touch With Gloves—Crosstalk

AIR GAP (mm)	CROSSTALK (dB)				
	UNTOUCHED BUTTONS	B1	B2	B3	B4
0	B1	—	22	21	19
	B2	19	—	23	20
	B3	21	24	—	20
	B4	22	23	23	—
1	B1	—	14	13	12
	B2	10	—	15	11
	B3	13	15	—	14
	B4	13	11	14	—
2	B1	—	9	9	9
	B2	3	—	12	8
	B3	9	13	—	9
	B4	5	7	7	—
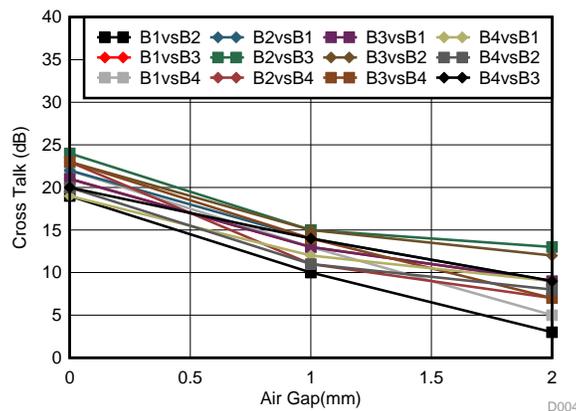
Figure 21. Touch With Gloves—Crosstalk

8.3 *False Touch*

This test measures the SNR of the two buttons that are the closest to the false touch position and is performed by touching the point between two buttons, as Figure 22 shows.
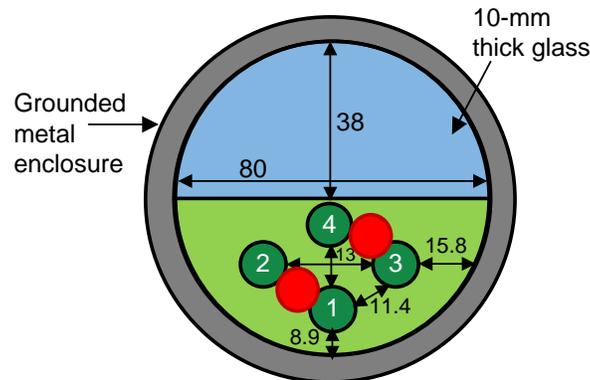
Figure 22. False Touch Example

Table 10 shows the results of the false touch test:

Table 10. False Touch—SNR

AIR GAP (mm)	SNR (dB)				
	B1–B2	B2–B4	B4–B3	B3–B1	B3–B2
0	24–25	25–21	25–25	26–24	25–21
1	16–18	19–18	18–19	16–16	17–17
2	7–7	9–9	10–9	7–10	10–10

In the false touch example, the measured SNR on button 1 and button 2 is 16 dB and 18 dB, respectively, when measuring with a 1-mm air gap. These values show that the SNR of button 1 and button 2 is lower during a false-touch event in comparison to the values in Table 6 during a normal button touch event. The minimum SNR difference between a false and true event is 3 dB. This difference is enough to set a proper threshold to exclude the false touch event from the true event. Another way to address false touch events is to exclude them from the true events when the SNR of the two buttons is simultaneously high.

The same false touch test has been performed while wearing the firefighter glove, for which Table 11 shows the results.

Table 11. False Touch With Gloves—SNR

AIR GAP (mm)	SNR (dB)				
	B1–B2	B2–B4	B4–B3	B3–B1	B3–B2
0	17–18	16–17	18–21	19–17	19–16
1	11–10	13–13	13–16	15–12	12–13
2	0–7	7–7	3–6	0–5	2–7

9   Design Files

9.1   *Schematics*

To download the schematics, see the design files at TIDA-00343.

9.2   *Bill of Materials*

To download the bill of materials (BOM), see the design files at TIDA-00343.

9.3   *Layout Guidelines*

9.3.1   PCB Layout Recommendations

The use of a hatched ground plane on the bottom side reduces the parasitic capacitance associated with both trace and electrode capacitance, reducing the susceptibility of the traces to capacitive touch events (see Figure 23).
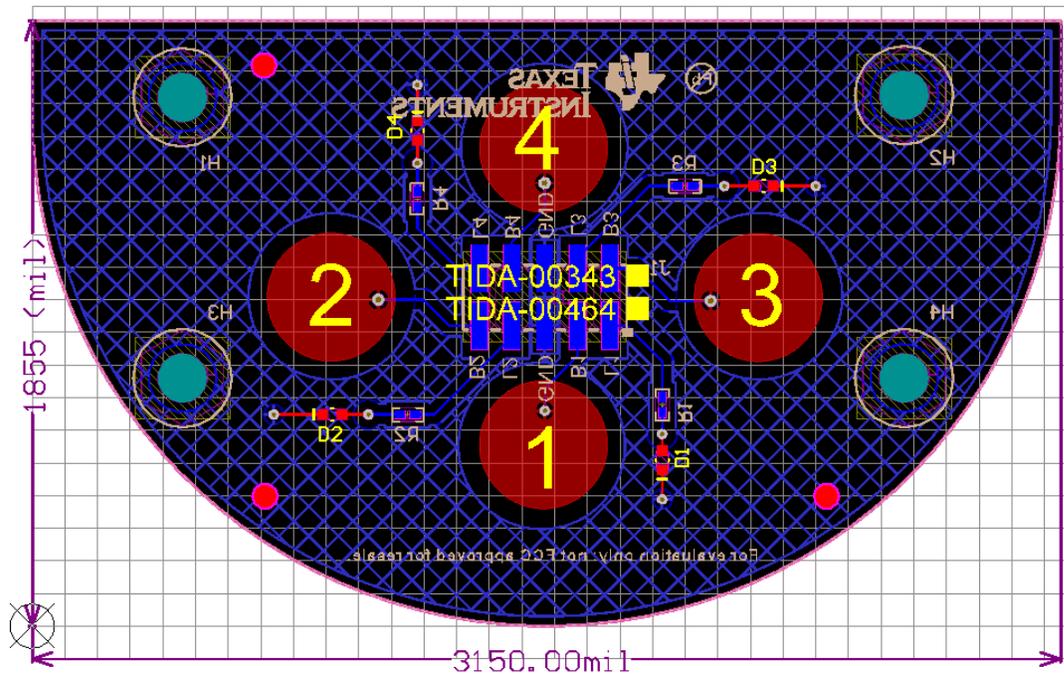
Figure 23. TIDA-00343 Layout

TI recommends to keep the traces as short as possible. Increasing the distance of the trace increases the parasitic capacitance associated with the trace. Increasing the trace length can also increase susceptibility to noise.

Refer to the *Best Practices* section of the *CapTIvate™ Technology Guide* to browse other recommendations for an optimized layout.

9.4   *Layout Prints*

To download the layer plots, see the design files at TIDA-00343.

9.5   *Altium Project*

To download the Altium project files, see the design files at TIDA-00343.

9.6 *Gerber Files*

To download the Gerber files, see the design files at TIDA-00343.

9.7 *Assembly Drawings*

To download the assembly drawings, see the design files at TIDA-00343.

10 Software Files

To download the software files, see the design files at TIDA-00343.

11 References

1. Texas Instruments, *CapTIvate™ Technology Guide*, Software Guide v1.10.00.00 (http://software-dl.ti.com/msp430/msp430_public_sw/mcu/msp430/CapTIvate_Design_Center/latest/exports/docs/users_guide/html/)

12 About the Author

GIOVANNI CAMPANELLA is an Industrial Systems Engineer with the Field Transmitter Team in the Factory Automation and Control organization. He earned his bachelor's degree in electronic and telecommunication engineering at the University of Bologna and his master's degree in electronic engineering at the Polytechnic of Turin in Italy. His design experience covers sensors and analog signal chain (with a focus on fluxgate and analytics sensing technologies) and mixed-signal control of DC brushed servo drives.

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