

Inductive Touch - Configuring LDC2114 Touch-Button Sensitivity

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ABSTRACT

Erroneous or unintended button presses can result in a frustrating user experience in a human machine interface (HMI). Capacitive touch buttons trigger anytime a grounded object is brought close to the button; this can often cause false or erroneous button presses. One advantage mechanical buttons have over capacitive touch buttons is that a certain amount of force must be applied on the buttons for them to trigger. Button activation force for mechanical buttons is tuned by tightly controlling mechanical tolerances and precisely machining the moving parts, which is complex and expensive to achieve. Inductive touch buttons implemented using the LDC211x devices can be configured to precise amounts of button activation force without the need for tight mechanical tolerances or moving parts. This application note provides instructions on how to configure the GAINn register configuration in the LDC211x devices for configuring the button activation force.

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1 Inductive Touch Buttons - The Working Principles

The three main components of the inductive touch button technology are the inductive sensor, target surface, and an inductance-to-digital converter. As shown in Figure 1 when a force is applied on the target surface, the material deflects slightly, reducing the distance between the inductive sensor and the target surface (D_{TARGET}). This change in D_{TARGET} changes the inductance of the sensor ($\Delta \text{Sensor Inductance} \propto \Delta D_{\text{TARGET}}$), which is measured by the inductance-to-digital converter. When the force is removed the surface returns to its original unstressed shape.

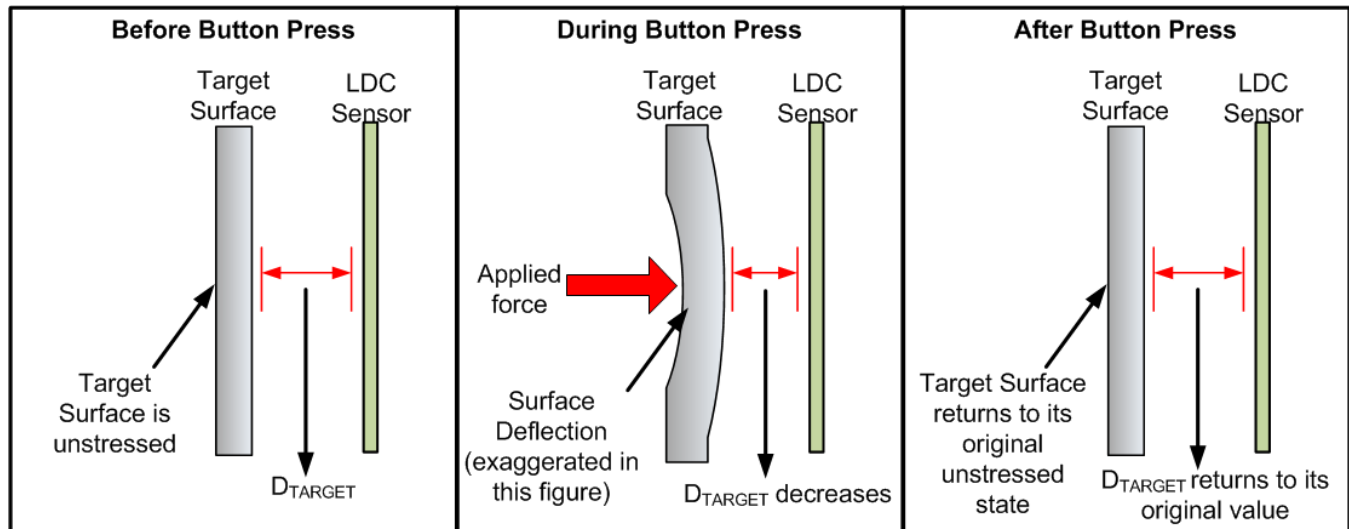


Figure 1. Inductive Touch Components

The primary factors that contribute to the sensitivity ⁽¹⁾ of an inductive touch button are:

1.1 Target Distance (D_{TARGET}) and Sensor Size

Inductive sensing relies on the interaction of EM fields generated by the inductive sensor and the eddy currents ⁽²⁾ being induced on the conductive surface. The amount of eddy currents induced on the target surface decreases with an increase in D_{TARGET} as the target conductive surface now captures a smaller portion of the electromagnetic field generated by the inductive sensor. In turn, the physical size of electromagnetic field lines generated by an inductive sensing coil is directly proportional to the diameter of the sensor. Figure 2 shows how to set D_{TARGET} as a percentage of the coil diameter for inductive touch.

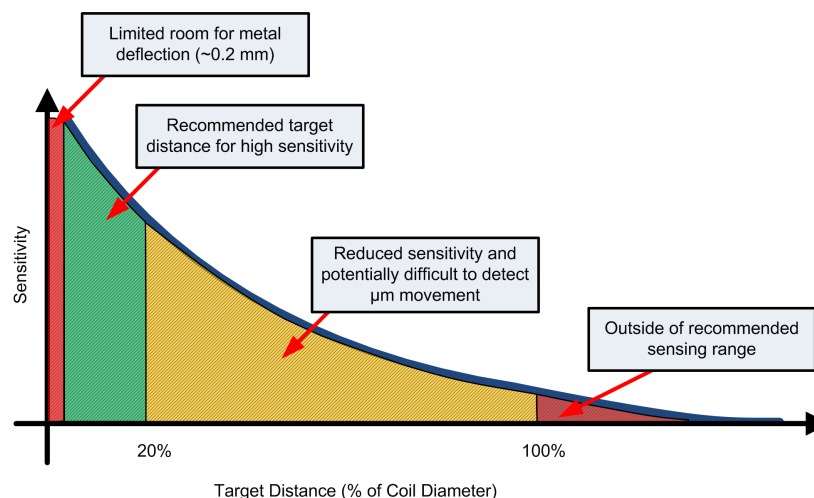


Figure 2. Button Sensitivity as a Function of D_{TARGET}

⁽¹⁾ Button sensitivity is defined in terms of force that needs to be applied on the target conductive surface to trigger a response.

⁽²⁾ Refer to [SNOA957](#) and [SNOA930](#) for more information about eddy currents and LDC sensor design.

1.2 Target Material

A material with higher electrical conductivity (σ) is a better target for inductive sensing technologies. The amount of eddy currents generated on the target surface are directly related to σ of the target material making higher conductivity materials such as copper or aluminum optimum targets for inductive touch buttons. Figure 3 shows the normalized inductance response plotted against D_{TARGET} as a percentage of the coil diameter for different target materials. Copper and aluminum exhibit larger shifts in inductance with target movement resulting in a higher measurement resolution.

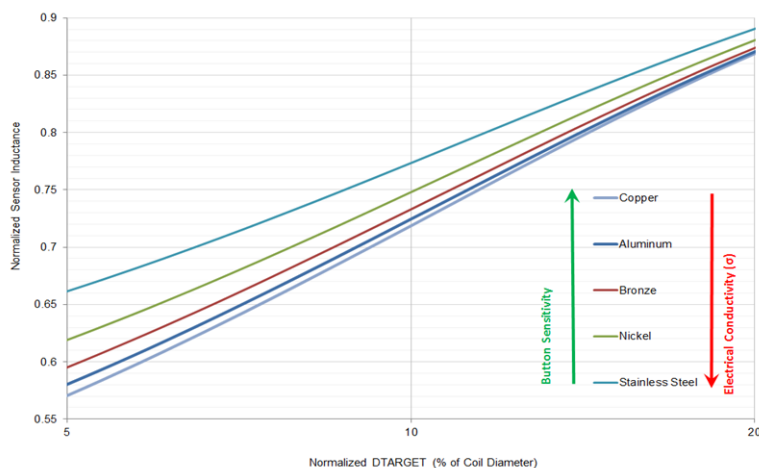


Figure 3. Button Sensitivity as a function of the Electrical Conductivity of Target

Because inductive sensing works on the principle of eddy currents, which are a surface phenomenon, a very thin layer of a conductive material (for example, 0.08 mm of copper) can be added to non-conductive surfaces like plastic or glass to implement an inductive touch interface.

1.3 Target Thickness

Deflection produced in the target surface for a given amount of force is inversely proportional to Young's modulus and thickness of the material. A given amount of force produces a larger deflection in a thinner or less stiff (lower Young's modulus) material than a thicker or stiffer (higher Young's modulus) one. Figure 4 shows how deflection decreases with respect to target thickness for different materials for a fixed button size.

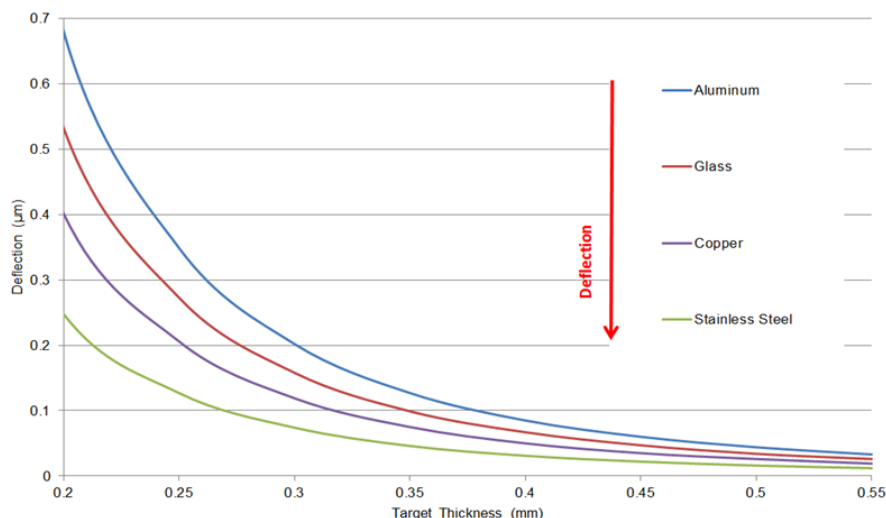


Figure 4. Deflection Decreases for More Rigid Materials

2 LDC2114/LDC2112 Gain Settings

[Section 1](#) highlights that inductive touch button sensitivity can be affected by a few different factors. Some of these factors relate to the mechanical design and construction of the button enclosure and are sometimes complex to control or change in an existing design.

The LDC2114 and LDC2112 devices address the need to control the sensitivity of inductive touch buttons through an easy-to-use register setting. Button sensitivity can be precisely tuned by adjusting the GAINn registers (0x0E, 0x10, 0x12, and 0x13) in these LDC devices.

The GAINn register field scales the normalized 12-bit DATAn output value. A higher GAINn value results in a higher DATAn value for a given amount of force applied to the target conductive surface. The 6-bit GAINn setting can be used to set the gain factor to values between 1 and 232. Each incremental GAINn value increases the gain factor by an average of 9% which provides enough granularity to precisely control the button sensitivity.

NOTE: The GAINn setting does not affect the amount of deflection experienced by the button surface for a given amount of force nor does it affect the amount of inductance shift experienced by the inductive sensor.

[Figure 5](#) shows how the button threshold can be configured to different amount of button activation force by simply tuning the GAINn register settings:

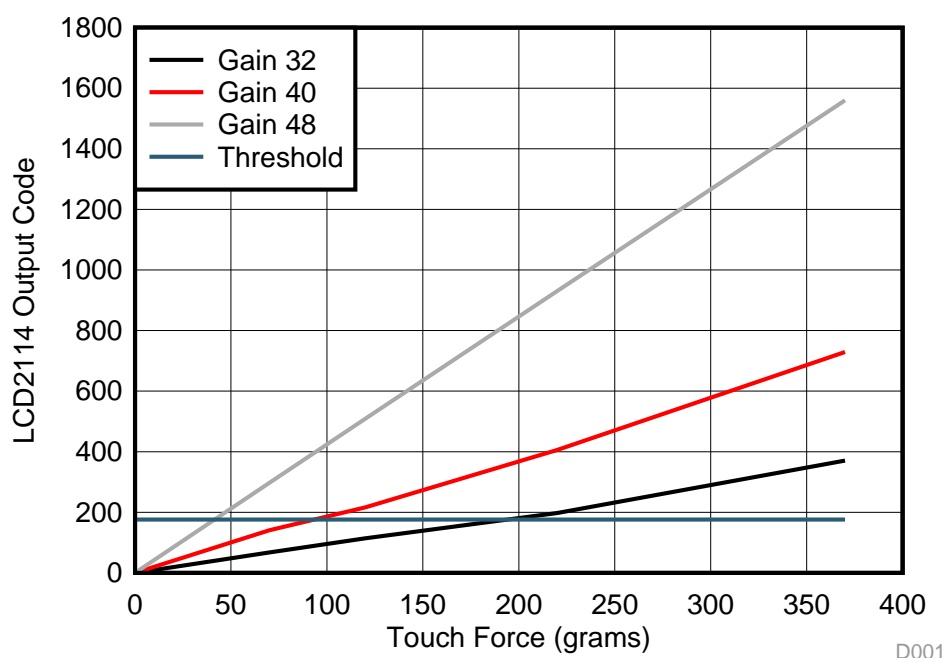


Figure 5. Gain and Button Threshold

It is important to remember that the GAINn setting does not have a significant impact on the noise observed on the DATAn output. This is a result of the extremely low noise architecture of the LDC2114 and LDC2112 devices. [Figure 6](#) shows SNR for a given amount of force across a range of gain factors:

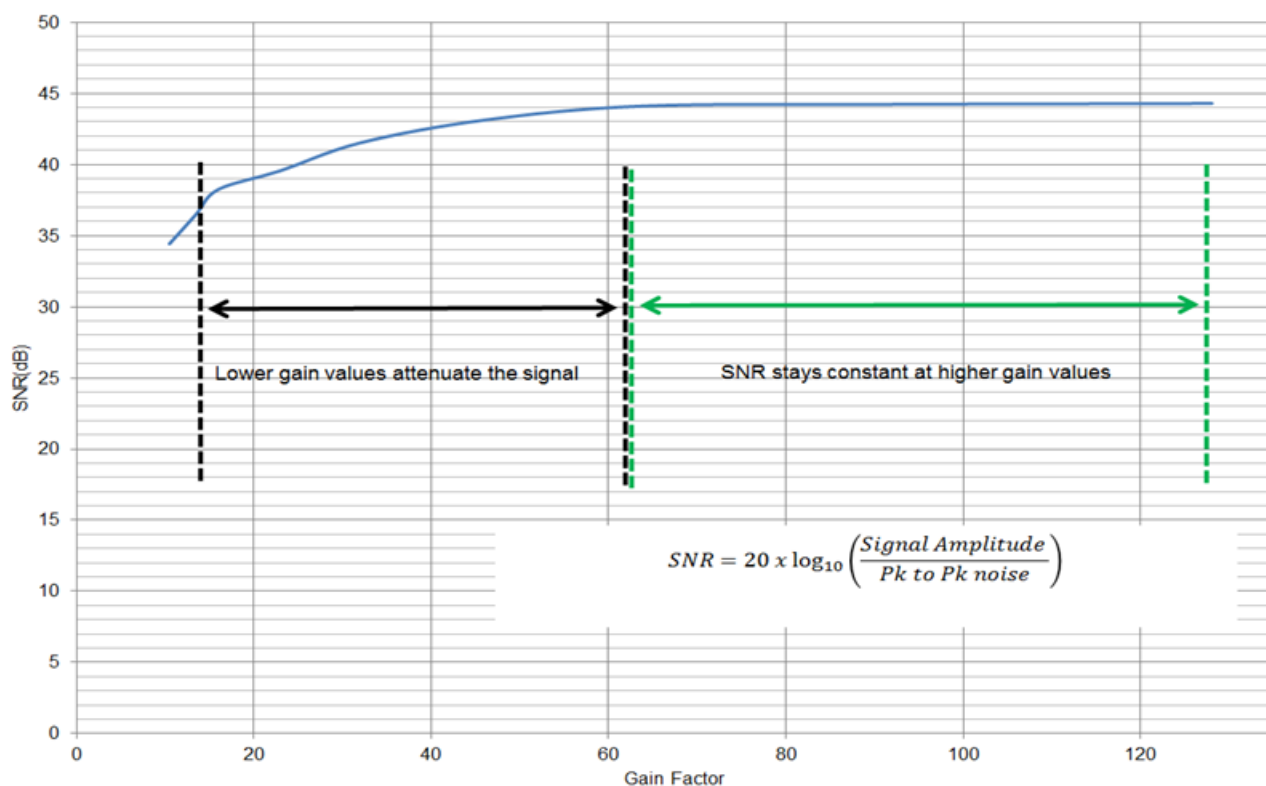


Figure 6. SNR (dB) vs Gain Factor

3 Threshold Configuration Process

Tuning button sensitivity requires a correctly configured LDC2114/LDC2112. The configuration process ⁽³⁾ prior to tuning the button activation force should include the following:

- Selecting the correct power mode (LPWRB pin)
- Choosing the appropriate scan rate (NP_SCAN_RATE, LP_SCAN_RATE)
- Setting the correct sensor configuration (SENSORn_CONFIG)
- Configuring the counter-scale value (CNTSC)

A quick way to check whether the LDC2114 is configured correctly is by probing the INx pins; the waveforms should resemble those shown in :

⁽³⁾ Detailed instructions for configuring the LDC2114/LDC2112 have been provided in the [LDC2114](#) data sheet.

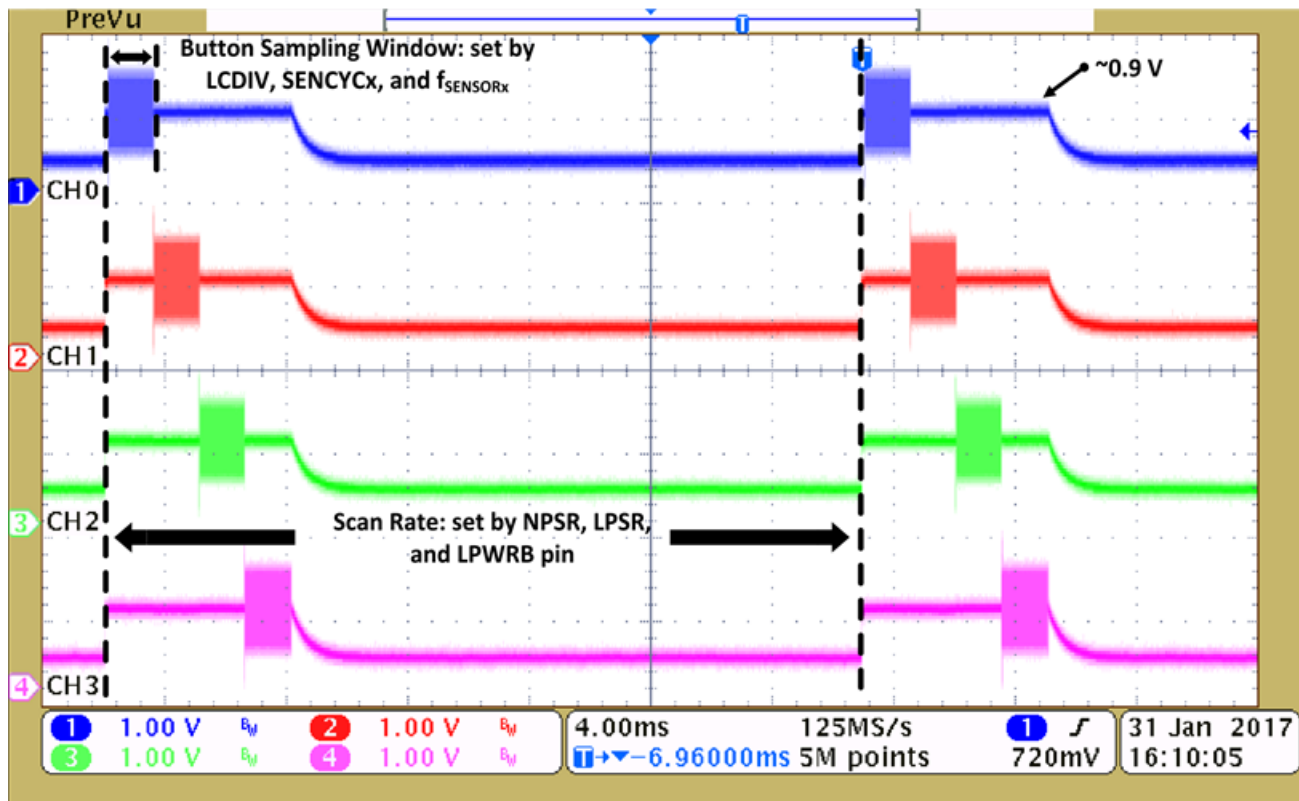


Figure 7. INx Waveforms

An error-free STATUS (Register 0x00) and correct sensor frequency, sampling window, and scan rate are good indications of a correctly configured LDC2114/LDC2112. Once the LDC2114/LDC2112 has been verified to have been configured correctly the gain can be adjusted for each individual button by following these steps:

1. Perform an I2C read transaction to determine the currently programmed GAINn (Registers 0x0E, 0x10, 0x12, and 0x13) and HYST (Register 0x18) values.
2. Correlate the GAINn register values to the gain factor by using Table 1 in the LDC2114 data sheet. This currently programmed GAINn factor will be referred to as GAINnFACTOR_{OLD} from here on.
3. Apply the desired amount of activation force on the button being calibrated and perform I2C read transactions to capture the STATUS (address 0x00) and DATAn value for the corresponding button. Using the captured DATAn value the new GAINn factor value can be calculated using Equation 1:

$$\text{GAINnFACTOR}_{\text{NEW}} = \frac{\text{SWITCHING_THRESHOLD} \times \text{GAINnFACTOR}_{\text{OLD}}}{\text{DATAn}} \quad (1)$$

The SWITCHING_{THRESHOLD} can be calculated using Equation 2:

$$\text{SWITCHING}_{\text{THRESHOLD}} = 128 + (4 \times \text{HYST})$$

where

- HYST is the value stored in register 0x18, which by default is 8

The GAINnFACTOR_{NEW} needs to be now correlated back to the closest GAINn decimal value using Table 1 in the LDC2114 data sheet and programmed into the corresponding GAINn register.

If the above process was followed correctly the button should now be calibrated to the desired button activation force. As an additional quality check, one can program the LDC2114/LDC2112 with the calculated gain factor, apply the desired button activation force, and verify if the button turns on. [Section 4](#) walks through an example of the threshold configuration process for an inductive touch button interface.

4 Example Application

This example configures one of the buttons on inductive touch-cell-phone reference design (TIDA-03041) to trigger at 100 g of force. [Figure 8](#) shows the cell-phone reference design, which employs two inductive touch buttons on each of the two side walls.

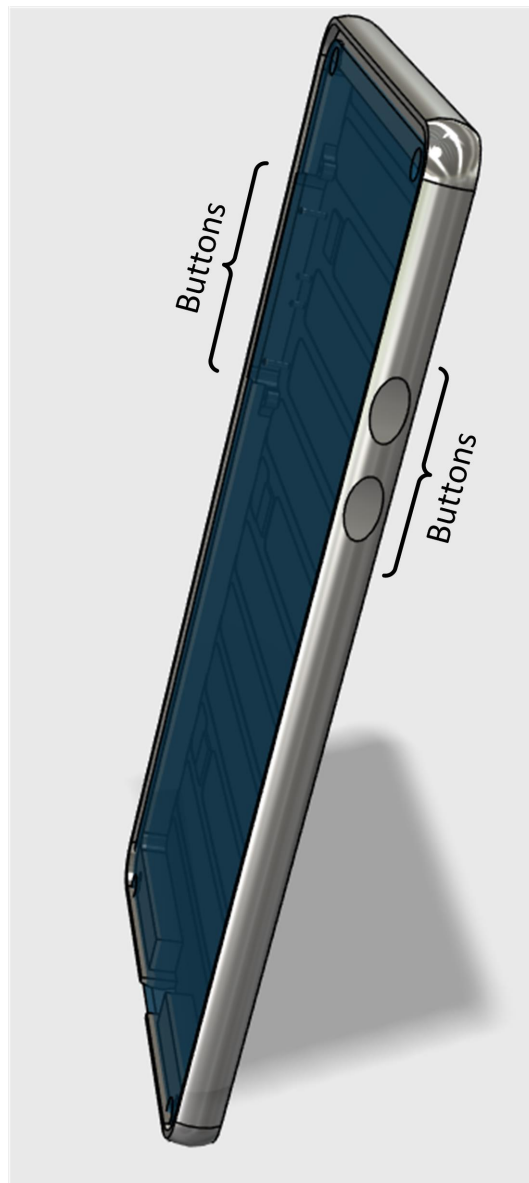


Figure 8. TIDA-03041

Each individual button region is 8 mm long and 6 mm tall and is constructed out of 0.4-mm thick aluminum. The inductive sensor is a flexible printed circuit board with an 8-mm long and 2.6-mm tall coil region. The sensor is separated from the cell phone side wall by an approximately 0.15-mm air gap ($D_{\text{TARGET}} = 0.15 \text{ mm}$). For more details regarding the sensor coil, the mechanical construction, or LDC2114 specific register configuration, refer to TI Design TIDA-03041 [LDC2114 Inductive Touch Buttons for Mobile Devices Design Guide](#).

This example configures the button that corresponds to the sensor that is connected to channel 0 on the LDC2114. The following steps to configure the button activation force assume all the settings (power mode, scan rate, sampling window, and sensor configuration) except GAIN0 for the LDC2114 onboard TIDA-03041 have been configured correctly:

1. Perform an I2C read transaction to read back currently programmed GAIN0 (address 0x0E) value for the selected channel.
2. Let's assume the I2C transaction in step 1 returned the value 0x28 (default) for the GAIN0 register. A GAIN value of 0x28 corresponds to a gain factor of 11.5 according to Table 1 in the LDC2114 datasheet. This gain factor value (11.5) is the GAINnFACTOROLD term in [Equation 1](#).
3. Apply 100 g of force on the button surface.
4. Perform an I2C read transaction to read back the STATUS (address 0x00) register to lock the current conversion results.
5. Perform an I2C read transaction to read back DATA0 registers (address 0x02 and 0x03) from the LDC2114 device.
6. Let's assume the 12-bit 2's complement DATA0 value read back from registers 0x02 and 0x03 is 0x3C. A two's complement conversion of this hexadecimal value results in the decimal value 60.
7. Perform an I2C read back of register 0x18 to determine the currently programmed HYST value.
8. Let's assume the HYST register read back to have returned the value 0x08 (default) and, using [Equation 2](#), calculate the switching threshold:

$$\text{SWITCHING}_{\text{THRESHOLD}} = 128 + (4 \times \text{HYST})$$

$$\text{SWITCHING}_{\text{THRESHOLD}} = 128 + (4 \times 8) = 160$$

9. Use [Equation 1](#) to calculate the GAINnFACTORNEW term for channel 0:

$$\text{GAINnFACTOR}_{\text{NEW}} = \frac{\text{SWITCHING}_{\text{THRESHOLD}} \times \text{GAINnFACTOR}_{\text{OLD}}}{\text{DATA}_n}$$

$$\text{GAINnFACTOR}_{\text{NEW}} = \frac{160 \times 11.5}{60} = \sim 31$$

The GAINnFACTORNEW can now be correlated to a GAIN value of 40 using Table 1 in the LDC2114 datasheet (GAINnFACTORNEW was rounded up to 32 to match the closest gain factor in the table).

10. Perform an I2C write transaction to set the STATUS register to the value 0x01 in order to put the LDC2114 device in configuration mode.
11. Perform an I2C write transaction to update GAIN0 (address 0x0E) to the value 40.
12. Perform an I2C write transaction to set the STATUS register to the value 0x00 to put the LDC2114 device in active mode.

After the completion of step 12 the button is programmed to trigger to an activation force of 100 g. This can be verified by applying 100 g of force on the button and ensuring that OUT0 toggles, which indicates a button press.

5 Summary

Inductive touch buttons implemented using the LDC2114/LDC2112 can be tuned to precise amounts of button activation force with relative ease. The process to tune the button activation force requires a correctly configured LDC2114/LDC2112 and an adjustment of the gain configuration. This document went over the steps required to tune an inductive touch button to a precise amount of force.

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