Application Note

Door and Window Sensor Evaluation Platform Introduction and Performance Overview

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ABSTRACT

Magnetic field sensors and switches are one of the cornerstones of any residential or commercial security system. These devices are used in door and window sensors, as well as many other applications such as tamper detection. Reed switches are a common design in this end equipment, but the simplicity of the device does not come without pitfalls. This document introduces a magnetic field sensor and switch evaluation platform that can be used to showcase the performance of Hall-effect sensors over the reed switch in building security applications. This document provides an overview of a new platform that can be used to evaluate TI's Hall-effect sensors and switches against the commonly-used Reed switch.

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1 Introduction

Door and window sensors make up the backbone of any home security system and are specifically intended to monitor which doors and windows are opened and closed within a home or office. These devices are mostly battery operated and communicate with a main security system hub with information as to whether a door or window is open or closed. If an event occurs in which a door or window gets opened or breached when the alarm is on, the sensor sends an alert signal to the main control panel and immediately triggers the main alarm.

If the internal workings of the door or window sensor are examined, there is one device that is clearly integral to the functionality of this device, a ferromagnetic sensitive device. This can be a simple Reed switch or a Hall-effect sensor, but which is better for your design and why?

The subsequent sections of this article provide an overview of a door and window sensor evaluation platform focused on simultaneous comparison of performance and tamper susceptibility among the Reed switch, the DRV5032, and the TMAG5273. Additionally, tests and their respective results are outlined and compared for each device. To allow for a true comparison between the three sensors, each is co-located on the PCB.

2 Evaluation Platform Overview

The door and window sensor evaluation platform (Figure 2-1) is built upon the CC1312R platform which allows long-range communication with a building security panel throughout a residential or commercial space. Section 2.1 and Section 2.2 provide an overview of the main platform components and the features associated with this design.

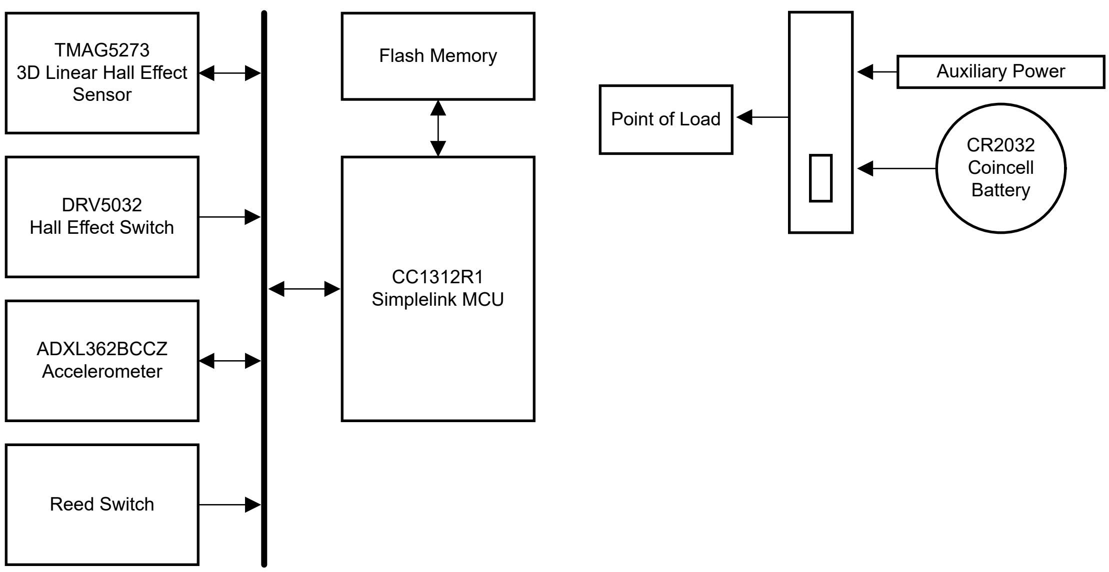

Figure 2-1. Block Diagram

2.1 Top-Side Board Overview

Figure 2-2 shows the top view of the door and window sensor evaluation platform.

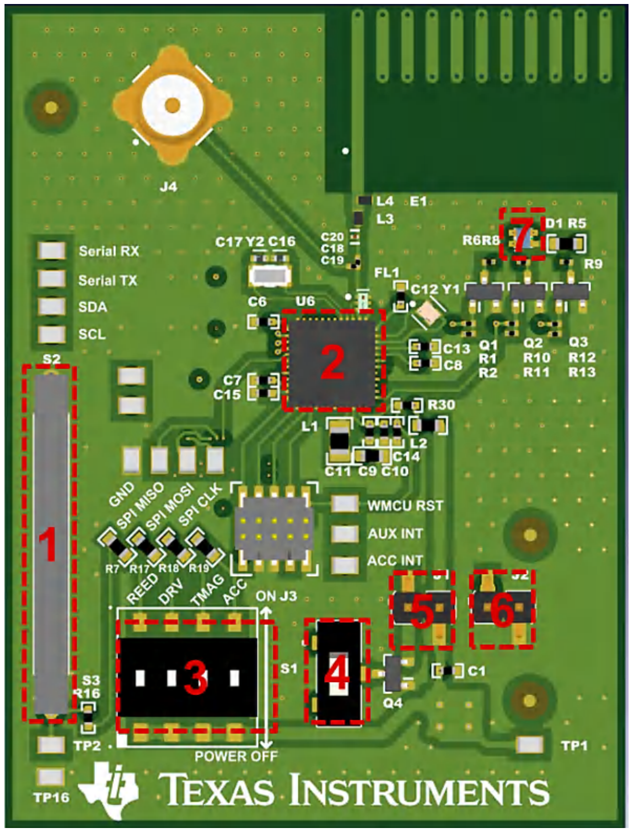

Figure 2-2. Door and Window Sensor Evaluation Platform Top View

The following list describes the labels in Figure 2-2.

1. **Reed switch** – 1-A, single pole single throw (SPST), normally open, axial Reed switch tied to the power source and a GPIO pin of the main MCU.
2. **CC1312R SimpleLink™ MCU**
3. **Sensor enable dip switches** – On and Off slide switches which is used to provide power to each of the sensors onboard when placed in the *on* position. The *off* position removes all power for a particular sensor which is helpful in profiling power consumption of only the required sensors.
4. **Power source selection switch** – Selects between coin cell battery power source and the off-board power source.
5. **Main power current shunt** – jumper from power source that can be used to acquire current measurements.
6. **Off-board power connector** – Can be used to provide alternative power to the board in the case where a coin-cell battery is not present. Maximum voltage is 3.3 V from any source.
7. **RGB LED** – used for debug and detection status of the Reed switch and the DRV5032

On the top side of the evaluation platform there are several points of interest for testing. The main MCU is the CC1312R sub-1G wireless MCU. One of the benefits of using a SimpleLink platform aside from the long-range communication is the Sensor Controller Engine (SCE). This allows the main portion of the processor to remain in a low-power sleep mode, only waking up when the processor receives an alert from the SCE indicating activity. This significantly reduces system power consumption and can help increase battery life expectancy.

For the sensors, the Reed switch is placed on top due to the elongated tube that houses the switch itself. All other sensors are placed on the bottom of the board, in proximity to the Reed switch location. One nice feature this board has is the ability to fully remove power from any sensor that does not need to be active, thus removing any quiescent current associated with simply disabling the device and allowing for accurate system-level power consumption data. This is done with the four position slide switches located on the top of the board. A second switch is also located on the top side which allows the user to select the main power source from either the onboard battery or a secondary off-board power source.

Lastly, there is an RGB LED which can be used for debug, but the LED also gives feedback on magnetic field detection with respect to the Reed switch and the DRV5032. The following list summarizes the LED output for different events:

1. **Color Cycling through RGB:** system is setting up communication channels and implementing sensor register setup routine
2. **Green:** No magnetic field detected for either magnetic switch
3. **Red:** Magnetic field detected via Reed switch
4. **Blue:** Magnetic field detected via DRV5032
5. **Magenta:** Magnetic field detected with both Reed switch and DRV5032

This color scheme can be changed within the Sysconfig file for the Code Composer Studio™ (CCS) project, or disabled if an LED is not desired for evaluation (Detection indication is also given via serial console).

2.2 Bottom-Side Board Overview

Figure 2-3 shows the bottom view of the door and window sensor evaluation platform.

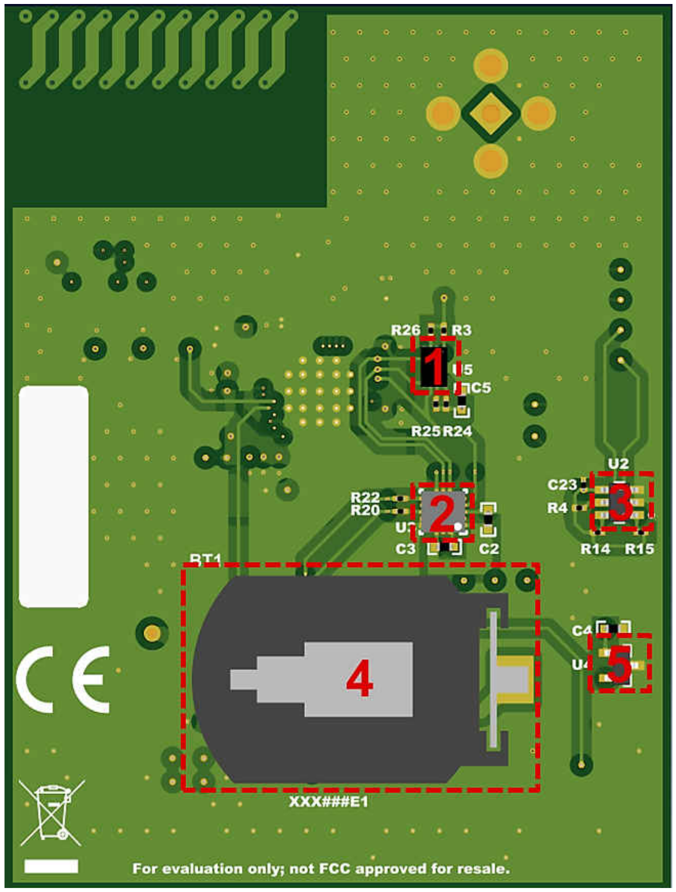

Figure 2-3. Door and Window Sensor Evaluation Platform Bottom View

The following list describes the labels in Figure 2-3.

1. **8Mb CMOS Flash memory**
2. **ADXL362 Accelerometer** – used for mounting position sensing as well as tamper detection. The accelerometer communicates with the MCU via SPI.
3. **TMAG5273** – 3D linear Hall-effect sensor for magnetic field detection and tamper detection. The device communicates with the MCU via I2C.
4. **Battery Holder** – battery holder for the CR2032 coin cell battery.
5. **DRV5032** – Hall-effect switch for magnetic field detection. Routed to a GPIO pin of the main MCU.

Most of the evaluation sensors are located on the bottom side of the board, in close proximity to the Reed switch on the top side for a more relevant comparison of performance. The DRV5032 and the TMAG5273 are located on the side next to each other, which also allows for an improved power performance combinational detection system where the TMAG5273 can be disabled, and woken up only when the DRV5032 detects a field presence. This can significantly reduce power by putting the linear Hall-effect sensor to sleep instead of continuously polling during periods of no activity. An accelerometer is also included to compliment the other sensors with respect to tampering, as well as providing a mounting profile for the placement of the board. This can be used to decipher what a normal approach of a magnetic field looks like, thus increasing the effectiveness of tamper detection of the system.

Figure 2-4 shows a summary of different event detection modes that can be realized with this evaluation platform.

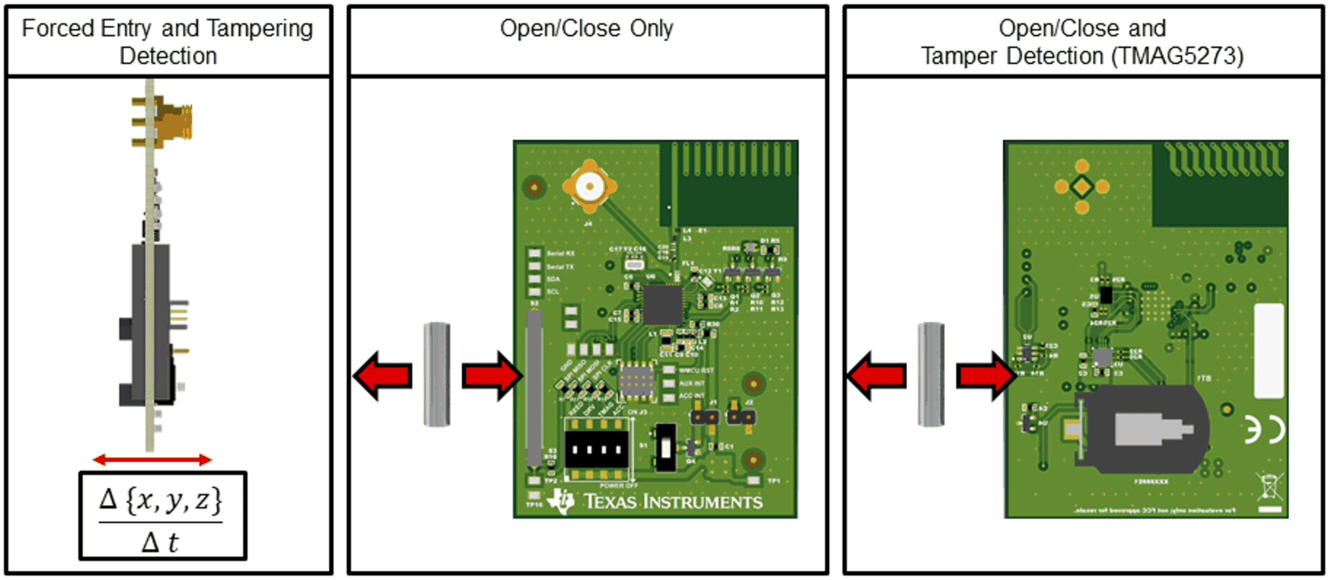

Figure 2-4. Event Detection Modes

3 Testing and Results

3.1 Testing Setup Overview

This board gives the added benefit of being able to not only evaluate all sensors simultaneously, but also allows the user to observe incoming data via the universal asynchronous receiver-transmitter (UART) console. This ability allows continuous data acquisition which can then be imported into a spreadsheet tool for further analysis.

Figure 3-1 shows the testing process for the evaluation platform. Upon start-up, all sensor communications and registers are setup automatically before initiating serial printing of sensor data. Accelerometer and TMAG5273 data are streamed to the console based on a predetermined update cadence while the DRV5032 and Reed switch status is only given in the event of magnetic field detection. The DRV5032 is meant to serve as an ultra-low power switch to start TMAG5273 data, so the testing excludes the field detection of the DRV5032. See the *Reed Switch Replacement with TI's Hall-effect and Linear 3D Hall-effect Sensors* application note for more data on the detection field of the DRV5032.

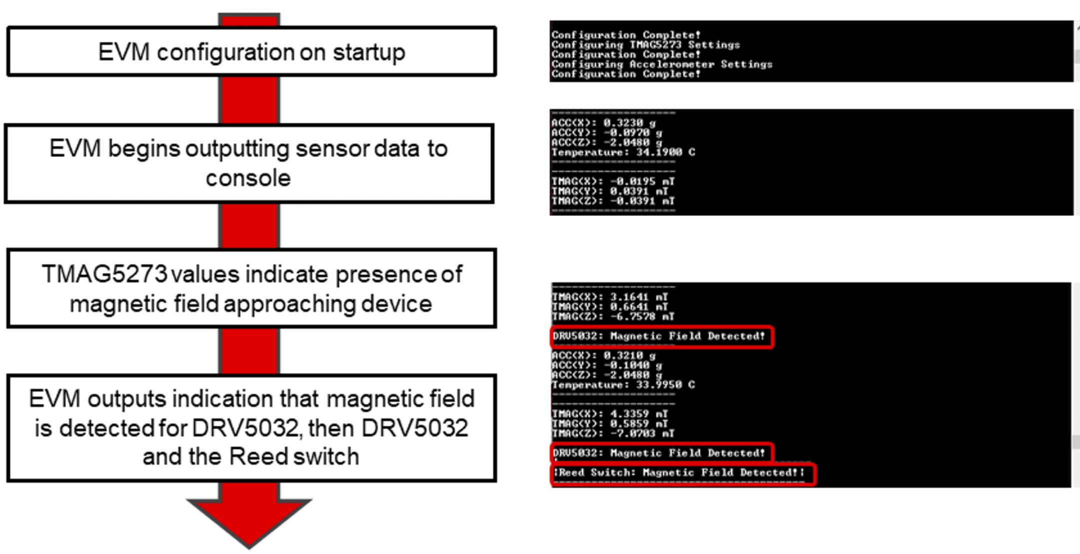

Figure 3-1. Data Acquisition Process

The testing done in this document is based on 2 different magnets. The first is a cylindrical magnet and the second is a rectangular magnet. The purpose of using 2 magnets is to show the influence of magnet shape and magnetization direction on the sensing field of the Reed switch and TMAG5273.

For both devices, the magnet is brought incrementally closer to the device and the distance of detection is recorded. The approach-point is incremented in the Y, Z plane and recorded for the X axis. For the TMAG5273, the output for each axis is linear so at each increment, magnitude values are given for each axis, whereas the Reed switch is a binary indication of field presence.

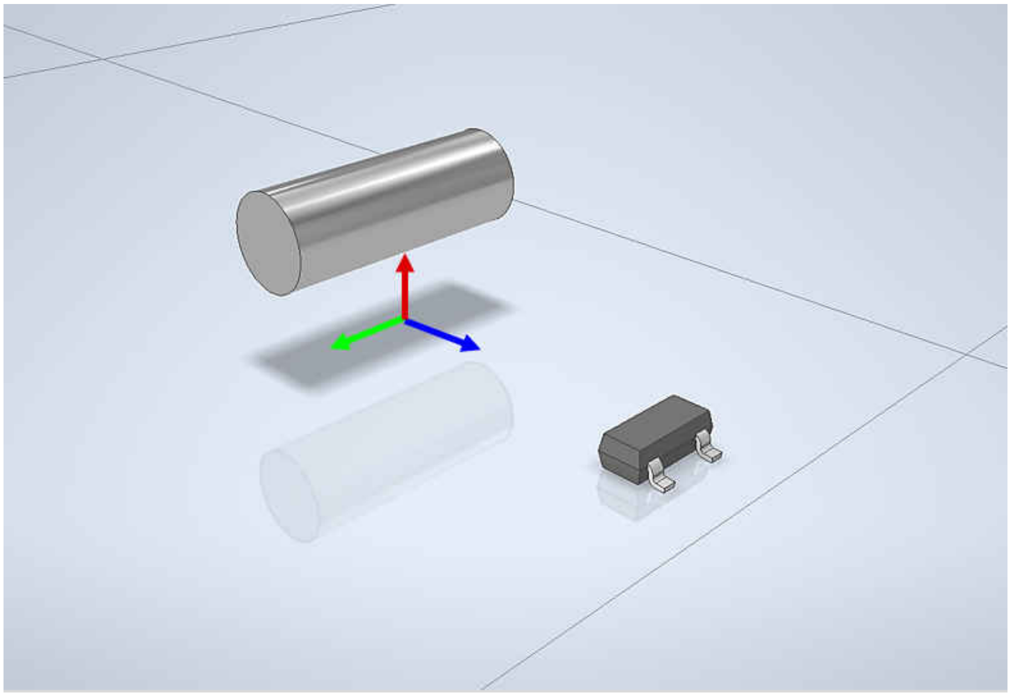

Figure 3-2. Magnet Approach Test Example

The software used in conjunction with the evaluation hardware is relatively simplistic in the sense that, for performance data collection, most of the processes are automatic, so the user can start evaluating right out of the box. There are several start-up routines that run once the board is powered up, namely establishing communications with the sensors and initializing registers with the necessary values for operation.

From this point, the main function runs through each of the sensor routines for collecting data. Due to the binary nature of both the Reed switch as well as the DRV5032, detection for these devices is indicated visually via the RGB LED schemes mentioned in the previous section, where no detection is indicated by a green LED, red is the Reed switch, and blue is the DRV5032. The TMAG5273 and accelerometer data are sent to the UART console and logged for later analysis. The update rate can be changed in the firmware based on desired report frequency, and thus can be used to control the responsiveness and granular resolution of sensor events.

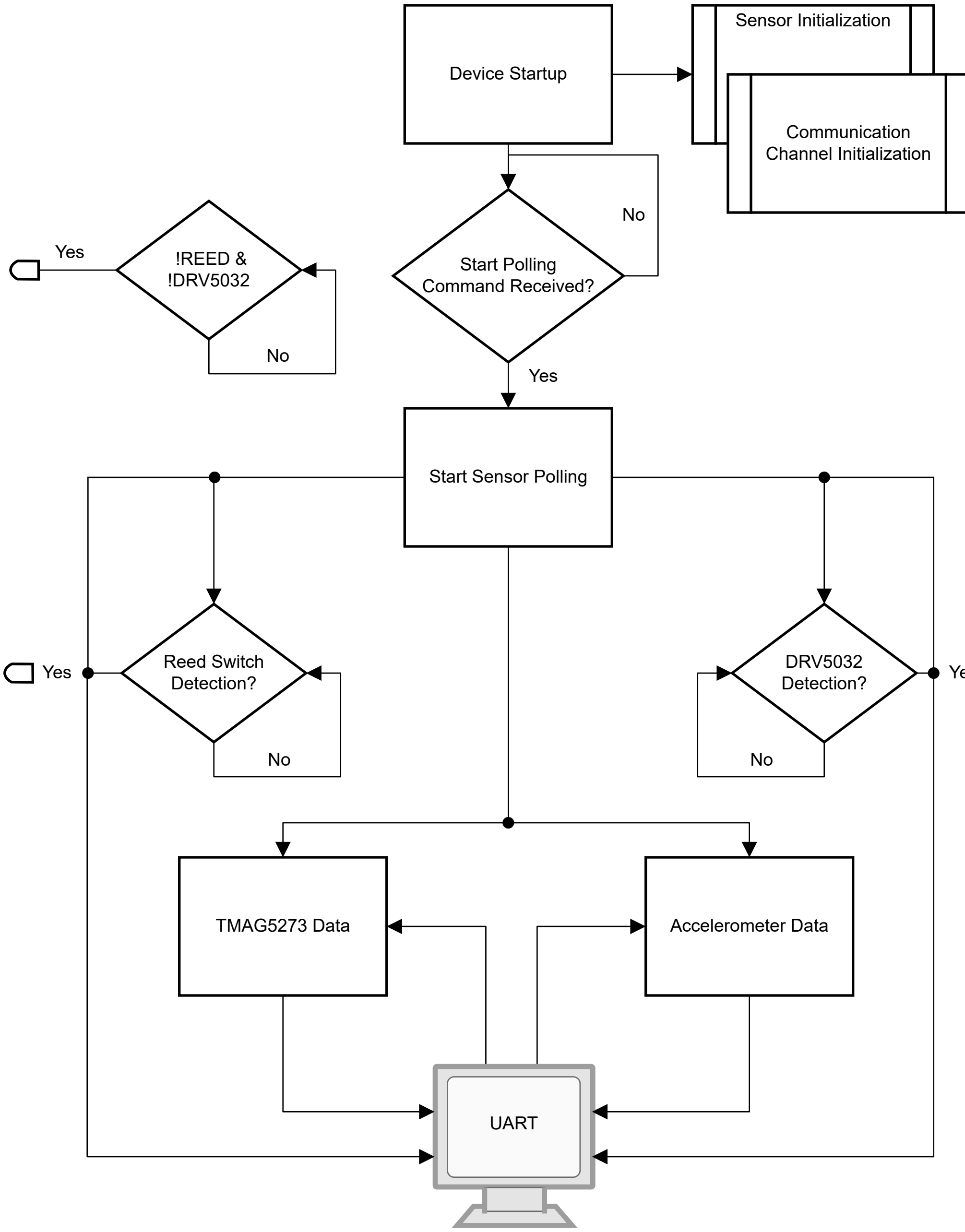

Figure 3-3. Software Flowchart

The door and window sensor evaluation platform also features the ability to wirelessly collect data via the serial bridge console commands, but these additional features are outside the scope of this article. The wireless portion of the design is covered in more detail in a followup article. Section 3.2 shows the results of the testing for the TMAG5273, the Reed switch, and the accelerometer.

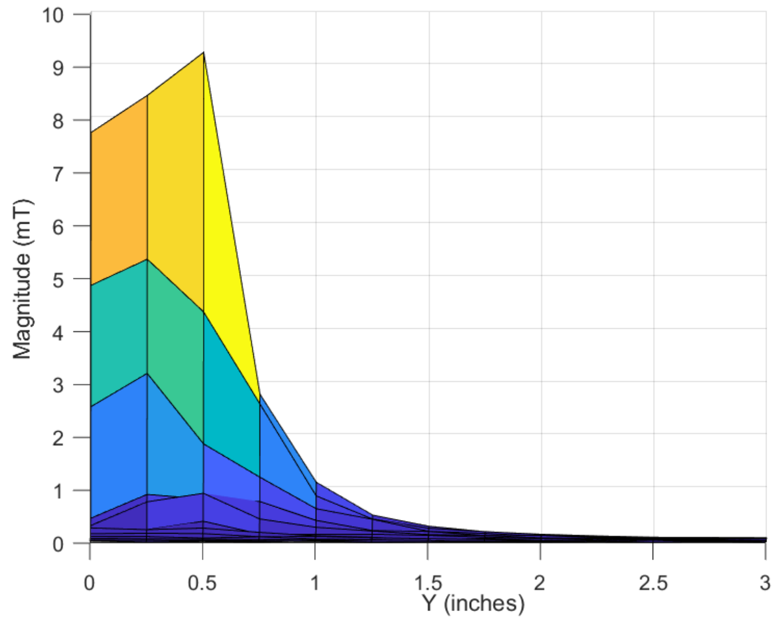

Figure 3-4. TMAG5273 Magnet 1 Detection Field (2D)

Figure 3-4 shows the detection field of the TMAG5273 where the Z axis is magnitude in mT and the Y axis represents the nodal points used to collect data (data collected every half inch). As can be deciphered from the plot, the detection begins to appear at approximately 2 inches and increases as the magnet is brought closer to the device, peaking at 0.5 inches from the IC. The magnetic flux sensed by the TMAG5273 peaks at approximately 9.2 mT. Figure 3-5 shows a 3D view of the magnetic flux as the magnet is brought closer to the IC.

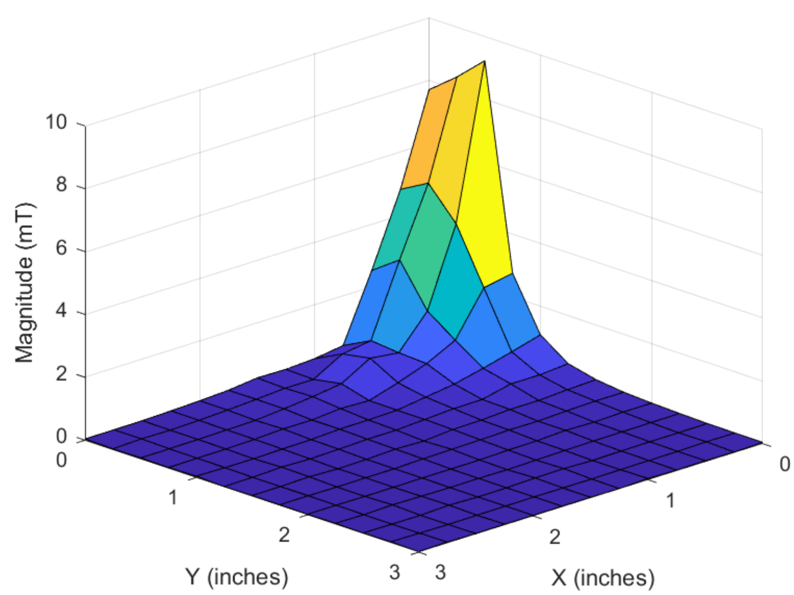

Figure 3-5. TMAG5273 Magnet 1 Detection Field (3D)

Figure 3-6 shows the detection field for the Reed switch. The detection distance with the first magnet is maximum at the center at approximately 0.7 inches, with two lobes on either side of the center peak. The darker shaded red areas indicate detection overlap in the Z axis. This overlap is displayed more clearly in the 3D figure in Figure 3-7.

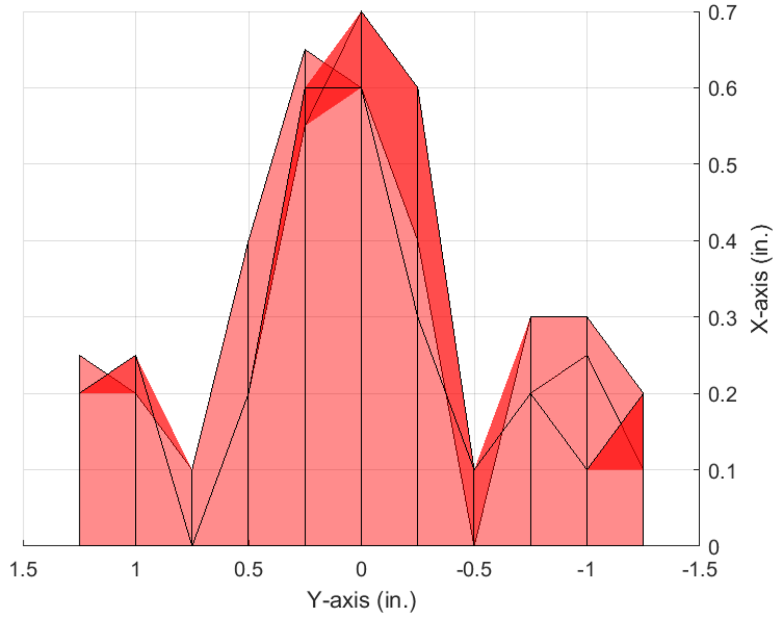

Figure 3-6. Reed Switch Magnet 1 Detection Field (2D Top Down)

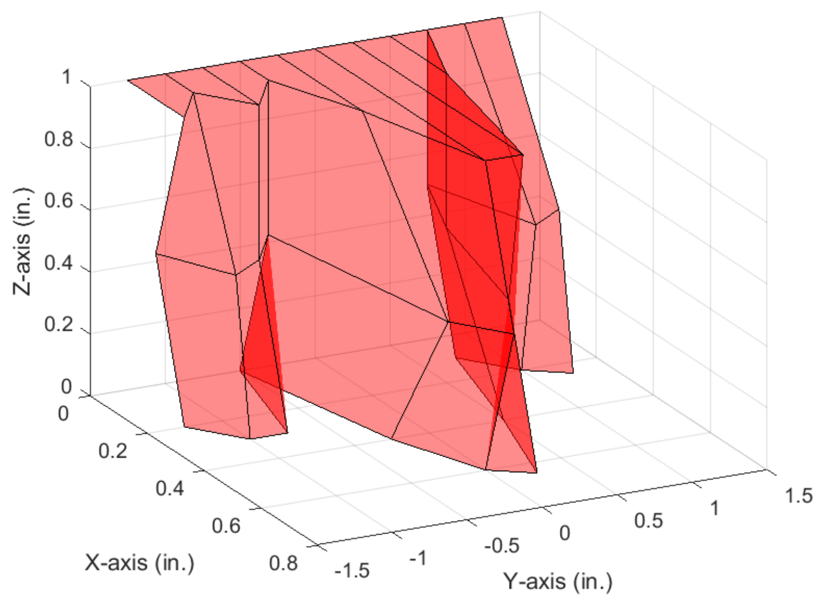

Figure 3-7. Reed Switch Magnet 1 Detection Field (3D)

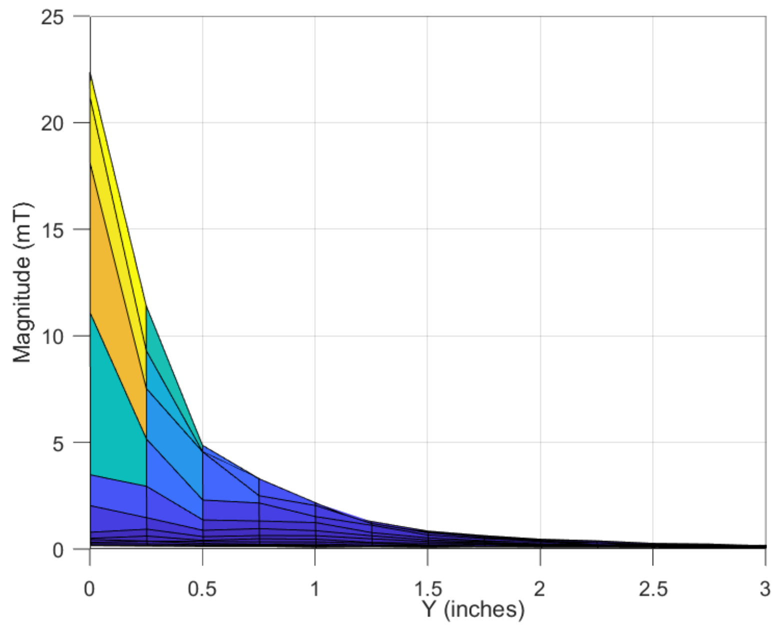

Figure 3-8. TMAG5273 Magnet 2 Detection Field (2D)

The same testing procedure is done with a second magnet, a rectangular magnet roughly 2 in × 0.75 in × 0.5 in. For this magnet, the detection distance is slightly farther from the IC at 2.5 inches. Due to the increased magnet strength of the second magnet, the magnitude increases to almost 25 mT at the peak, and due to the shape and magnetization of the magnet used, the peak is now at the IC instead of slightly in front. Figure 3-9 shows a 3D view of the magnetic flux as the magnet is brought closer to the IC.

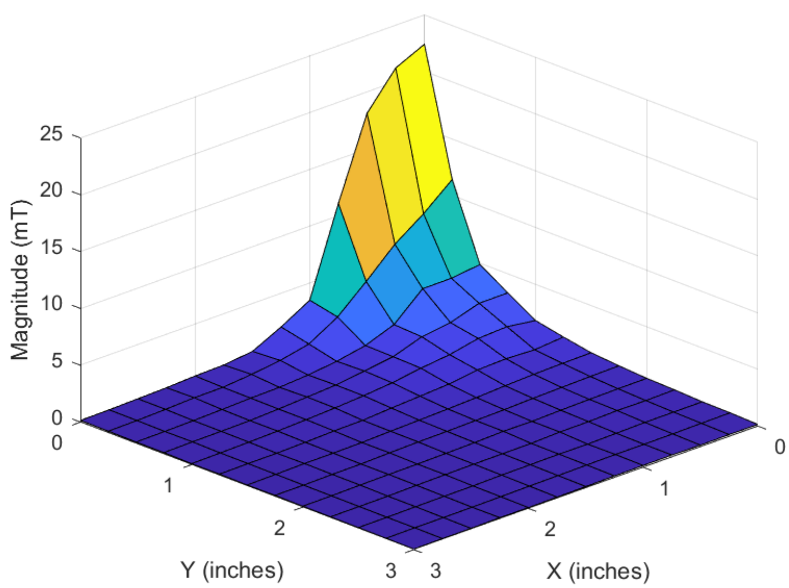

Figure 3-9. TMAG5273 Magnet 2 Detection Field (3D)

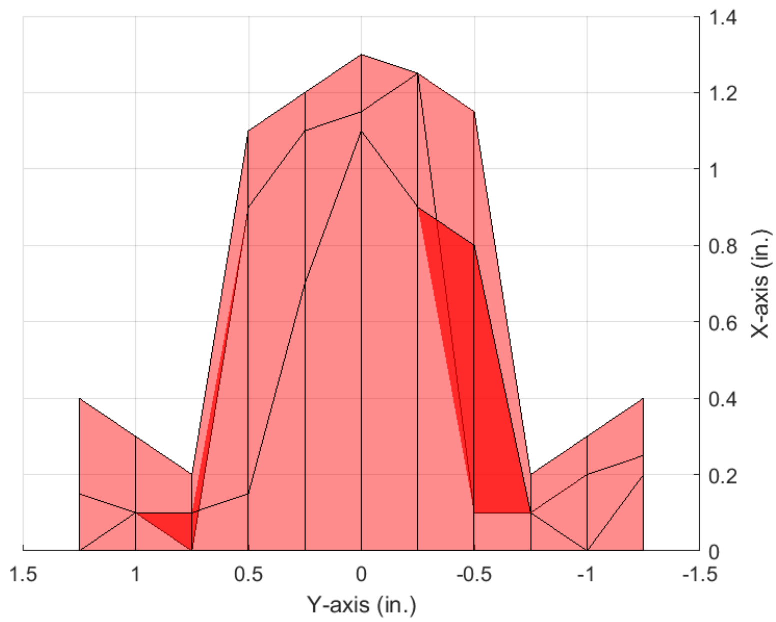

Figure 3-10. Reed Switch Magnet 2 Detection Field (2D Top Down)

The same test is done again with the Reed switch to map out the detection range of the device. As in the first Reed switch test, there are two lobes on either side of the main peak, located on the center axis of the Reed switch. Due to the stronger magnetic field, the detection distance is almost doubled at approximately 1.3 in from the switch. An offset view is also shown in Figure 3-11 to add to the visual understanding to Figure 3-10.

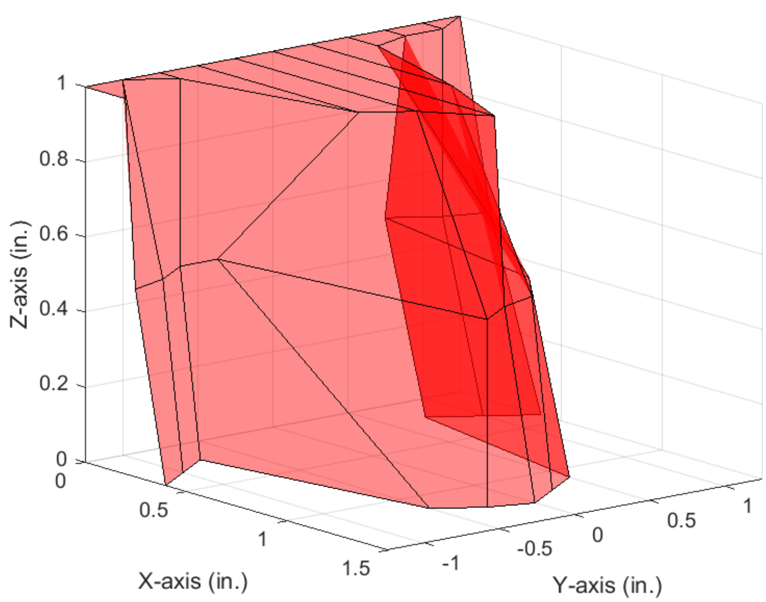

Figure 3-11. Reed Switch Magnet 2 Detection Field (3D)

3.2 Accelerometer Event Testing Results

A third set of tests are also done to show the different event signatures associated with the onboard accelerometer. This can be leveraged in conjunction with a Hall-effect switch or Hall-effect sensor like the TMAG5273 for increased event detection modes and indication of brute force entry attempts on a particular door or window.

Figure 3-12 shows the accelerometer output of the X, Y, and Z axes for a door opening event. From the data, observe that the X direction is positioned vertically and the disturbance is captured on the Z axis.

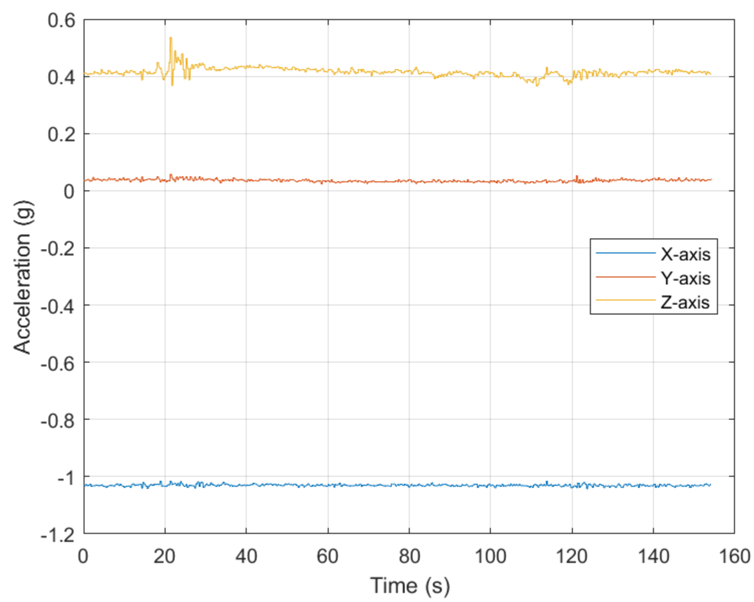

Figure 3-12. Accelerometer Door Open Event

Doing the same test for a closed door event, observe that there is more movement sensed as well as event indication which is now also shown on the X and Y axes, see Figure 3-13. This is due to the sharp deceleration once the door is fully closed.

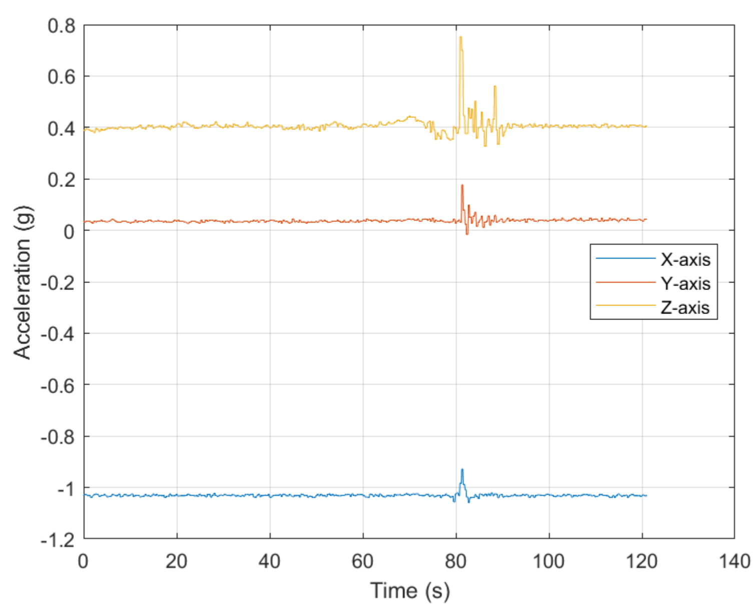

Figure 3-13. Accelerometer Door Close Event

Finally, the sensor is tested for the ability to detect brute force attempted entry. Figure 3-14 shows the event signature of attempting to open a closed door forcefully. As shown, there is a much larger disturbance detected on the Z axis (pointing outward parallel to the door) than in the previous test due to the larger vibration associated with the entry attempt. There are also minor movements picked up by the X and Y axes, but the Z axis data is sufficient in detecting a forceful entry attempt, in this case.

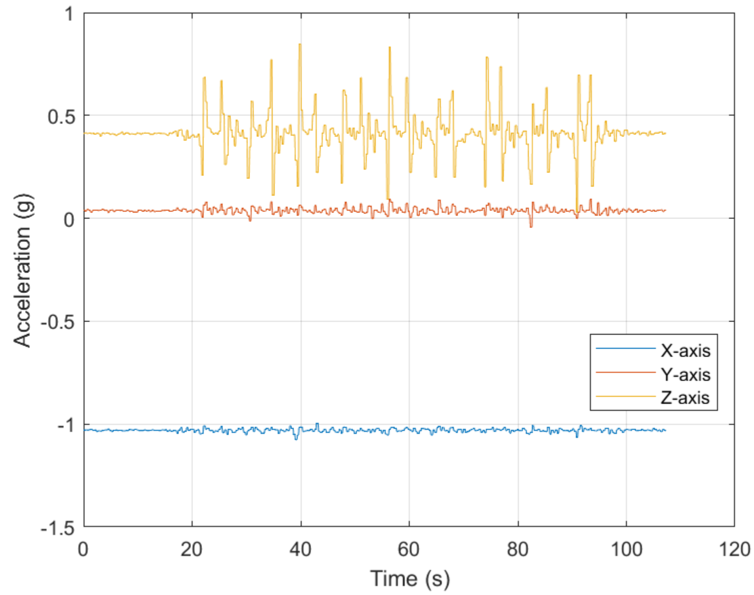

Figure 3-14. Accelerometer Brute Force Entry Attempt

4 Summary

In summary, the door and window sensor evaluation platform can be leveraged to evaluate and compare TI's DRV5032 Hall-effect switch, the 3D linear output Hall-effect sensor, and a radial glass tube Reed switch simultaneously to show positives and negatives of each. The TMAG5273 has a larger detection range for both magnets used in the testing and offers greater detection modes of operation while greatly reducing susceptibility to tampering attempts that can otherwise go undetected with a typical Reed switch door and window sensor. Due to the low power requirements of door and window sensors, a combination design of an ultra-low power DRV5032 as a first-pass detection switch, along with the TMAG5273 for secondary event detection and tamper detection, provides a much more robust answer for door and window sensor applications than the typical Reed switch design. More advanced door and window sensors can also leverage accelerometer data for brute force break-in attempt detection as well as provide sensor mounting position indication which can be leveraged to indicate which direction a magnetic field needs to approach during normal operation versus during a tampering attempt.

5 References

1. Texas Instruments, *Reed Switch Replacement with TI's Hall-Effect and Linear 3D Hall-Effect Sensors* application note