Application Note

Position Sensing in Electronic Smart Locks Using Hall-Effect Sensors

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Position Sensing

ABSTRACT

There are two main uses for Hall-effect sensors in electronic smart locks; tamper detection and position sensing of the deadbolt. The position sensing can be implemented in different ways with Hall-effect sensors depending on the level of information needed by the system. This document covers the different approaches to position sensing for electronic smart locks.

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Trademarks

1 Hall-Effect Sensors in Smart Locks

Electronic smart locks have become a key part of a smart home and can be implemented in many different ways. One of the common key elements in a smart lock is understanding the position of the deadbolt. This can be used to reduce strain on the motor as well as provide information about the current state of the lock. If the lock is supposed to be fully closed but gets stuck part way, this can be reported to the user through notification that the door is not all the way closed. The position of the deadbolt can be implemented with a variety of technologies including optical switches, rotary encoders, mechanical switches, and Hall-effect sensors. In addition to being used to detect the position of the deadbolt, Hall-effect sensors can be used to determine if someone is attempting to tamper with the lock or gain access to the internal circuitry. Tamper detection provides an additional security feature to reduce the potential risk of someone breaking into a house through the smart lock.

1.1 Tamper Detection

There are a couple different ways that someone could tamper with a smart lock. One of these is to attempt to access the internals of the device by removing the outer shell to trick the device into opening. In this case, switches can be used to determine when the shell has been removed or bent out of position. This implementation is described in the *Limit Detection for Tamper and End-of-Travel Detection Using Hall-Effect Sensors* application brief. If the smart lock uses Hall-effect sensors to determine the position of the magnet, someone could try to trick the sensor by using a large magnet to trigger the sensor. One way of eliminating this risk is to have an additional sensor that alerts the main controller of the smart lock when a magnetic field stronger than the design accounts for is present in the system. The additional sensor implementation is also shown in the *Contactless, Hall-Effect Variable-Speed Trigger Reference Design With External Field Protection* design guide.

2 Methods for Hall-Effect Based Rotational Position Sensing

There are different ways of implementing position sensing in an electronic smart lock depending on the amount of resolution desired. Switched implementations can be used to give an absolute position of the deadbolt being completely open, completely closed, or somewhere in the middle depending on the position of the switch in the layout. Depending on how many states are desired, a varying number of switches can be used. Another method is to have a Hall sensor measure the angle of rotation for the motor or center shaft of the lock. Lastly, the motor can have encoding on the motor. Hall-effect sensors can be used to implement motor encoding as well. For more information on Hall sensor motor encoding, see the *Incremental Rotary Encoders* application brief.

2.1 Switch Implementation

One way to detect the position of a deadbolt using switches is by having a magnet rotate around the center shaft. From this, you can have Hall-effect switches placed to determine when the deadbolt is in the unlocked position and locked position. These switches can also be placed to determine if the lock is installed on a right-handed door or left-handed door.

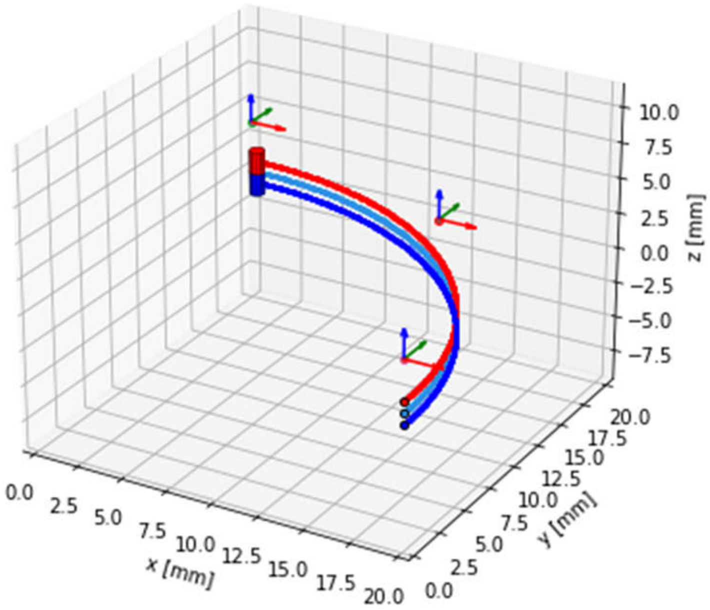

Figure 2-1. Hall-Effect Switch Implementation Example

In this example, there are three switches to determine the position of the deadbolt rotation as the magnet sweeps around the center shaft. The center switch can be used to determine when the deadbolt is completely open and the two end switches can be used to determine when the deadbolt is completely closed, one for a left-handed door installation and one for a right-handed door installation. This way, the lock can be installed on any door and still detect the position of the deadbolt. Figure 2-2 shows an example of the magnetic field of the magnet as the magnetic field moves along this path and the digital output of the switches. The Bz1, Bz2, and Bz3 lines are the magnetic field strengths at each sensor while the D1, D2, and D3 lines are the digital outputs based on the sensors Bop. The device hysteresis due to the smaller Brp of the device is not accounted for in this graph so this only shows when the switches can turn on in either direction.

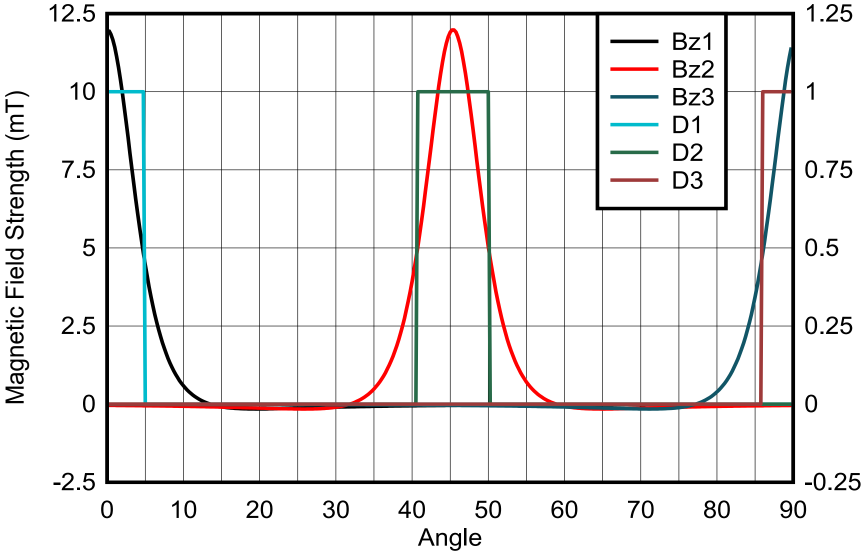

Figure 2-2. Hall-Effect Sensor 2mm Gap – One-Eighth-Inch Magnet

This simulation assumes the use of the DRV5032FB which has a typical magnetic threshold of 3mT. However, if an in-plane Hall-effect switch that senses magnetic fields parallel to the package marking surface is needed, the TMAG5233, TMAG5133, or TMAG5134 can be considered. The sensor is placed 2mm away from the end of the magnet which yields a 12mT peak in the sensed magnetic field. The mechanical tolerance of each switch can be adjusted by changing the distance between the magnet and sensor or by using a device with a different threshold. By increasing the distance, Figure 2-3 shows a tighter tolerance for when the switches detect the magnet.

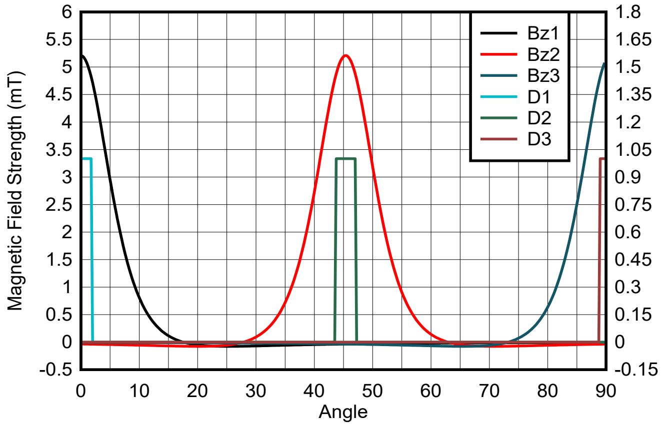

Figure 2-3. Hall-Effect Sensor 4mm Gap - One-Eighth Inch Magnet

While this implementation only uses three switches, adding switches or changing the placement can give more information about the position of the deadbolt. The magnet used for the above simulations is an N52 bar magnet with a 1/16th inch diameter and one-eighth inch thick. If a larger magnet is used, the magnetic field strength can be increased to allow the switches to turn on sooner for the rotational motion. For example, a similar bar magnet with a one-fourth inch thickness with a 2mm gap between the end of the magnet and the sensor yields the following.

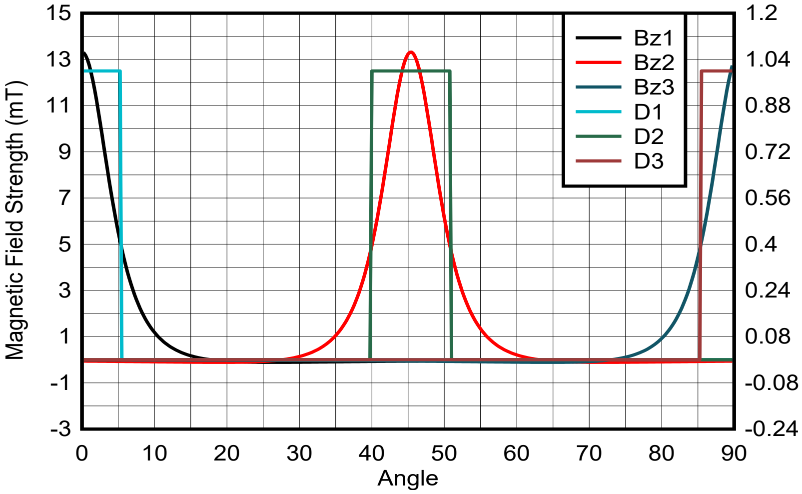

Figure 2-4. Hall-Effect Sensor 2mm Gap - One-Forth Inch Magnet

The new peak magnetic field is roughly 13.3 mT. This increase is not very large but also gives a wider angle range of when the sensor output is triggered. Selecting a magnet for this application can rely heavily on the space available in the system but factors like desired tolerance need to be considered and compared to the magnet threshold of the sensor.

Using a Hall switch is a low power and low-cost implementation. The previously mentioned DRV5032FB can operate on less than 1μA to preserve battery life in this application. Alternatives to this design are the TMAG5233, TMAG5133, or TMAG5134 which are in-plane Hall-effect switches. These switches have an omnipolar magnetic response that enables the device to respond to both north and south magnetic poles that are horizontal to the package marking surface. The TMAG5233 is available in an industry standard SOT-23 package and comes in 5Hz and 40Hz duty cycle options. The TMAG5133 is available in an industry standard X1LGA package. The TMAG5134 is available in both an industry standard X1LGA and SOT-23 package.

Hall sensors also provide additional product lifetime when compared to reed switches. For more details on a comparison between reed switches and Hall sensors, see the *Reed Switch Replacement with TI's Hall-effect and Linear 3D Hall-effect Sensors* application note.

2.2 Rotational Sensing With 3D Hall-Effect Sensors

In a system that needs a higher resolution of the rotational angle, a single 3D Hall sensor can be used to detect the angle of the magnet. Since this device only requires one device, the best placement for the sensor is directly on top of the magnet so the rotation only happens on the Z axis of the sensor.

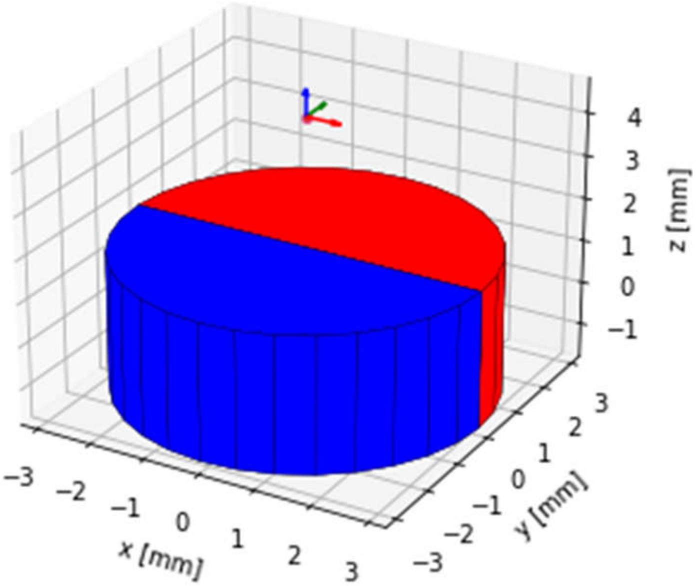

Figure 2-5. 3D Hall-Effect Sensor Placement Example

The sensor and the magnet are perfectly aligned so only the X and Y portions of the magnetic field are varying while the magnet rotates.

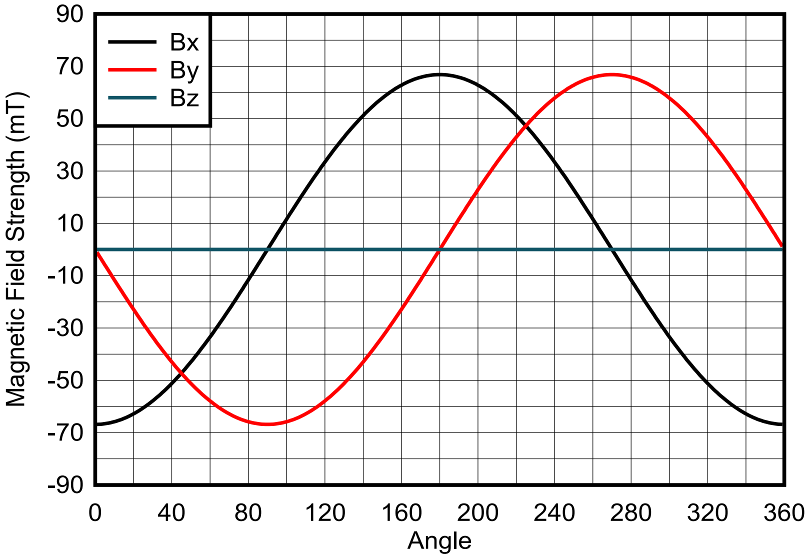

Figure 2-6. 3D Hall Sensor Rotation Example

As shown in Figure 2-6, only two of the magnetic field axis are needed to determine the angle of the magnet so the third axis is free to implement tamper detection or to gather additional information on the device status. To determine the angle of the magnet, the data can be processed with an MCU. However, devices like the TMAG5273 and TMAG5170 have an integrated CORDIC algorithm that reports the angle as a register value so no additional calculations are needed from the MCU. If there is a shift or offset in the magnet and sensor alignment, then the Z axis of the magnetic field will change. If the magnet is still aligned with the axis of rotation but no longer aligned with the sensor, then the Z axis starts to change in a sinusoidal pattern.

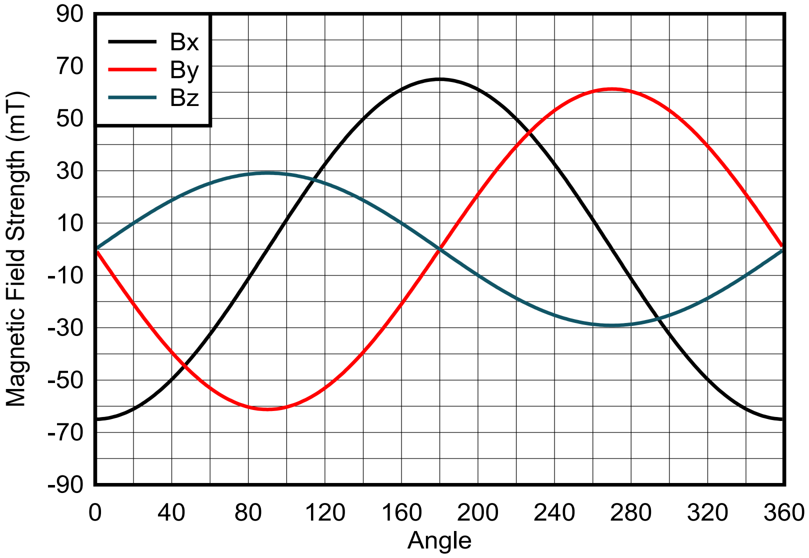

Figure 2-7. Hall Sensor Offset From Axis of Rotation

Having the Z axis magnetic field vary like this indicates that the magnet is still rotating about its center, but the magnet is no longer aligned with the sensor. Another offset that can occur is having the magnet no longer on the axis of rotation. As long as the sensor is still in line with the axis of rotation, this causes the Z axis magnetic field to become a constant.

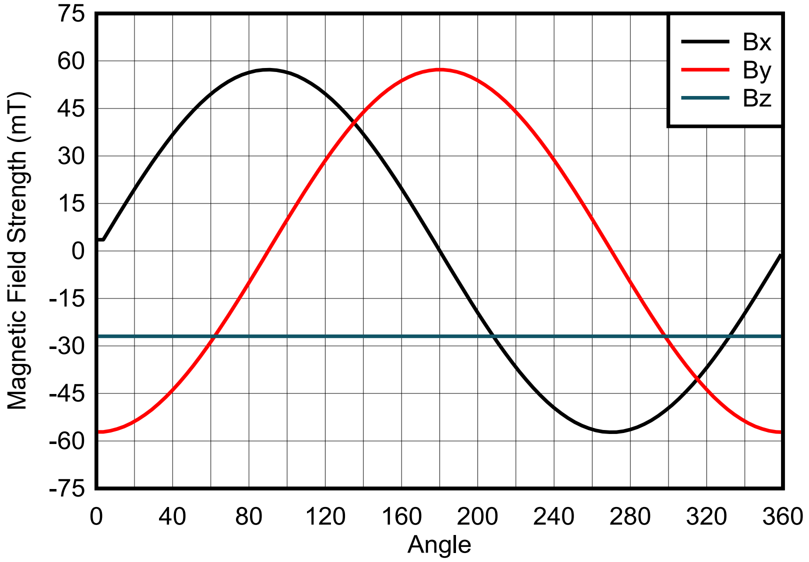

Figure 2-8. Magnet Offset From Axis of Rotation

Knowing the expected results from these two different offset types, the Z axis of the magnetic field can be used for predictive maintenance of the system. If these offsets appear while the product is in use, it means that something has shifted and may need to be realigned. The offset in the Z axis could also be used to determine if an external magnet is being applied to the system. If this is the case, there could also be an impact to the expected data of the X and Y magnetic field axis.

Many times, the magnet for this implementation cannot be placed directly on the center shaft or motor. In that case, a gear can be used to offset the magnet rotation and change the resolution of the magnet angle to the deadbolt position. By using a gear ratio that allows the magnet to spin more than the center shaft, a larger angle variation will occur for the motion of the deadbolt. This can be used to gain increased resolution on the position of the deadbolt if desired. An example of this is shown in Figure 2-9.

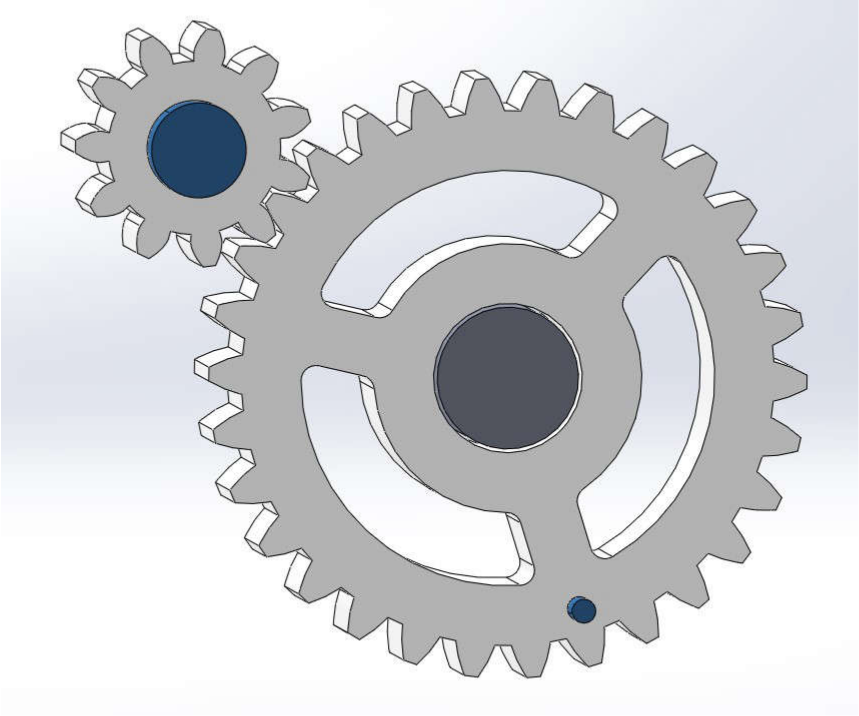

Figure 2-9. Magnet on Gear Example

This example has the offset gear that rotates a magnet directly above a linear Hall sensor as well as a magnet that moves along the outer edge of the larger gear. The smaller magnet moves in an arced path that works with the switch implementation previously discussed. This is just one way to implement these magnets for this application. Since the magnet is the main care about, the method of mechanical motion can be changed or adjusted as needed to fit the application.

3 Summary

Using Hall-effect sensors to determine the position of a deadbolt in an electronic smart lock can be done in two main ways. A switched implementation provides a lower power consumption per device while the 3D Hall sensor provides additional information on the position of the deadbolt. The tolerances of the design can also be varied as needed by selecting different magnets or sensors.

Table 3-1. Recommended Devices

Device	Characteristics	Design Considerations
DRV5032	Ultra-low-power digital switch Hall-effect sensor available in SOT-23, X2SON, and TO-92 packages. Both omnipolar and unipolar options available.	Great for low power applications. This device can operate on as little as 1.65V with typical current consumption below 1uA. DU and FD variants in X2SON have dual unipolar functionality.
TMAG5233	In-plane Hall-effect switch (vertical sensor) available in industry-standard SOT-23 package.	Has an omnipolar magnetic response that reacts to both north and south magnetic poles parallel to the package marking surface.
TMAG5133	In-plane digital Hall-effect switch (vertical sensor) available in industry-standard X1LGA package.	Has an omnipolar magnetic response that reacts to both north and south magnetic poles parallel to the package marking surface.
TMAG5134	In-plane digital Hall-effect switch (vertical sensor) available in industry-standard X1LGA and SOT-23 package.	Has an omnipolar magnetic response that reacts to both north and south magnetic poles parallel to the package marking surface.
TMAG5170	High-precision linear 3D Hall-effect position sensor available in SOT-23, X2SON, and TO-92 packages. Both omnipolar and unipolar options available.	Measures magnetic field strength on all 3 axes and reports data over SPI. This device offers high precision and self-diagnostic features beneficial for system monitoring.
TMAG5273	Low power linear 3D Hall-effect position sensor with I2C interface available in 6 pin SOT-23 package.	Measures magnetic field strength on all 3 axes and reports data over I2C interface. This device can operate on as little as 1.7V. Configurable power mode options allow for system performance and current consumption optimization.
TMAG3001	Lower power linear 3D linear and angle Hall-effect sensor with I2C interface and wake up detection in YBG package.	Measures magnetic field on X, Y, and Z axes and reports data over I2C interface. Great for low power applications. This device can operate on as little as 1.65V. Configurable power mode options allow for system performance and current consumption optimization.

4 References

1. Texas Instruments, *Limit Detection for Tamper and End-of-Travel Detection Using Hall-Effect Sensors*, application brief.
2. Texas Instruments, *Contactless, Hall-Effect Variable-Speed Trigger Reference Design With External Field Protection*, design guide.
3. Texas Instruments, *Incremental Rotary Encoders*, application brief.
4. Texas Instruments, *Reed Switch Replacement with TI's Hall-effect and Linear 3D Hall-effect Sensors*, application note.

5 Revision History

Changes from Revision A (September 2024) to Revision B (July 2025) **Page**

- Added TMAG5133 throughout document.......... 1
- Added *TMAG5134* 2
- Added *TMAG5134* to the Recommended Devices table 9

Changes from Revision * (June 2022) to Revision A (September 2024) **Page**

- Updated the numbering format for tables, figures, and cross-references throughout the document 1
- Added *However, if an in-plane Hall-effect switch that senses magnetic fields parallel to the package marking surface is needed, the TMAG5233 can be considered* sentence.......... 2
- Added *Recommended Devices* table.......... 9

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