Application Brief

Limit Detection for Tamper and End-of-Travel Detection Using Hall-Effect Sensors

As advanced diagnostics are increasingly being included in various applications, it is often desired to detect when a unique or anomalous event occurs in a system. Example events to detect could include the detection of when a normally closed system is opened, detection of an actuator or control element reaching its end of travel, or even detection of a large external magnetic field. In all of these cases, a simple Hall-effect sensor can often solve this problem in a reliable and robust manner. This article discusses using Hall position sensors to implement a limit-detection function for use cases such as magnetic tamper detection, case tamper detection, and end-of-travel detection.

Magnetic tamper detection

External magnetic fields may affect magnetically-susceptible components in some systems. Example applications may include electricity meters, gas meters, door and window sensors, cordless power tools, and electronic smart locks. To deal with external magnetic fields tampering with the system, a Hall position sensor can be used to provide an alert to the system when the external magnetic field is beyond a predefined limit. This limit should be selected so that the Hall position sensor detects external magnetic fields before they are strong enough to significantly affect the operation of the system.

To detect strong magnetic fields from either the North or South poles of the magnet, an omnipolar Hall position sensor is often used. The omnipolar sensor will sense limits associated with both polarities of the magnet. In addition, three 1-dimensional Hall sensors arranged across three directions or one 3-dimensional Hall sensor can be used to detect strong magnets across all three dimensions. If only permanent magnets need to be detected, Hall switches are commonly used and the magnetic limit is set by the B_{OP} specification of the Hall switch. However, if an AC magnetic field must also be detected, linear Hall sensors can be used instead. If the system is powered from a battery, a duty cycle mode operation is also common, where the Hall position sensor alternates between active measurement mode and low-power sleep mode to reduce the average current consumption.

As an example, in electricity meters, a strong magnet can paralyze any current transformer current sensors or power supply transformers. As a result, strong magnets are commonly placed on electricity meters to steal electricity. The tampering magnet can be cylinder magnets as shown in Figure 1, or even bar magnets. To counteract magnetic tampering, meter manufacturers often use Hall position sensors to detect whenever external magnetic fields are beyond a predefined limit. In some cases, the meter deals with detected magnetic tampering by overcharging the customer as a precaution.

Figure 1. Magnetic Tampering in Electricity Meters

Case tamper detection

Certain applications implement secure enclosures or casings that are meant to be inaccessible by others. Example applications include electricity meters, gas meters, electronic point of sale (EPOS), set-top boxes (STB), ATMs, and enterprise servers. Often, intrusion attempts such as opening the enclosure or casing must be detected for these types of applications.

One method of implementing this case tamper detection feature is by placing a cylinder magnet on the case and placing a Hall switch directly underneath the magnet, as Figure 2 shows. When the case is closed, the Hall position sensor senses that the magnetic flux density is beyond the B_{OP} of the Hall switch. As the case is opened, the magnet will move with the case so that it is further away from the Hall sensor.

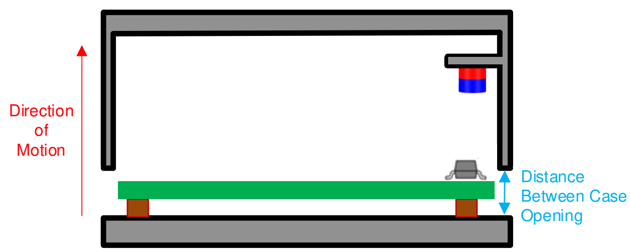

Figure 2. Case Tamper Detection Implementation

As the distance from the magnet and sensor increases, the sensed magnetic flux density decreases. Eventually, the magnet-to-sensor distance would reach a distance threshold that causes the sensed magnetic flux density to fall below the magnetic flux density limit, which would trigger the output state of the Hall position sensor to change and alert the system of the case opening. For this type of detection scheme, the magnetic flux density limit value is set by the B_{RP} specification of the Hall switch. The Hall position sensor should be selected so that its B_{RP} would equal the resulting magnetic flux density when the magnet-to-sensor distance is at the desired distance threshold. There is also some consideration that needs to be made to ensure that the magnetic flux density when the case is closed is far enough away from the magnetic flux density limit to prevent false trips.

Figure 3 shows the relationship between B_{OP}, B_{RP}, and the limit threshold for detecting the opening of the case. In this figure, the sensed magnetic flux density is constant until the case is opened.

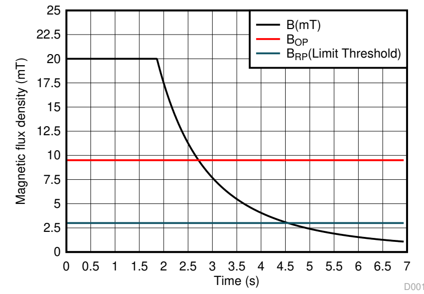

Figure 3. Magnetic Flux Density for Case Tamper Detection

End-of-travel detection

Hall position sensors can also be used to detect an end-of-travel event for a moving component within a system. Diagnosing when a moving component has moved beyond its intended range of movement is a typical use-case for end-of-travel detection. Example applications for this include the sliding door modules, window modules, roof motor modules, and wiper modules in cars. In this scenario, an axially magnetized cylinder magnet can be placed on the moving component so that it moves with it. For this application, the direction of motion would be opposite to the direction of motion in Figure 2 since the magnet will be approaching the sensor instead of moving away from it. A Hall switch can then be used to detect whenever the component and magnet are close enough to the Hall switch. As the magnet gets closer to the switch, the sensed magnetic flux density increases until it increases beyond the magnetic limit. This magnetic limit is set by B_{OP} of the Hall switch. Once the sensed magnetic flux density exceeds the B_{OP}, the state of the Hall switch changes and the system is alerted of this end-of-travel event. The Hall position sensor should be selected so that its B_{OP} would equal the resulting magnetic flux density when the magnet-to-sensor distance is at the desired distance threshold. Figure 4 shows the relationship between B_{OP} and the limit threshold for the scenario where the end-of-travel state has been detected.

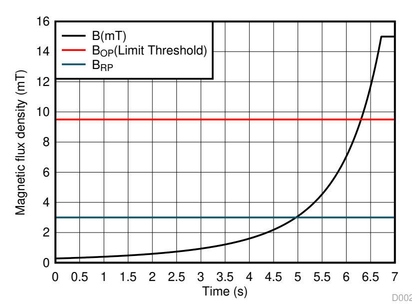

Figure 4. Magnetic Flux Density for End-of-Travel Detection

Selecting the right part for limit detection

Hall switches for limit detection are often selected based on the following specifications:

- **B_{OP} and B_{RP}:** The B_{OP} or B_{RP} determine the implemented limit, as described in the previous sections. The necessary values of these specs depend on the strength and size of the magnet as well as its distance from the sensor. A tighter hysteresis between B_{OP} and B_{RP} enables detecting smaller distance openings for case tamper detection.
- **Current consumption**: If the application runs off a battery, the current consumption should be minimized to maximize the lifetime of the battery.
- **Response time:** Quick response times require a fast sampling rate.
- **Operating voltage range:** Different systems have different available supply voltages. If the available supply voltages of a system are all outside of the operating voltage range of the Hall position sensor, an additional voltage regulator device will be needed to generate a voltage rail for powering the Hall position sensor.
- **Open-drain vs push-pull output:** Open-drain outputs are selected when it is desired to have the logic high output voltage to be at a different voltage than the VCC voltage of the Hall position sensor or if it is necessary to implement a logical AND of different open-drain outputs without additional circuitry. Compared to open drain outputs, push-pull outputs have lower current consumption and do not require a pullup resistor.
- **Omnipolar vs. Unipolar:** Omnipolar Hall sensors detect both the North and South poles of a magnet while unipolar only detects one.

The DRV5032 is offered in multiple versions, making this device ideal for limit detection. The various B_{OP} and B_{RP} threshold variants of the DRV5032 enable multiple options for the magnetic flux density limit. In addition, the device has open-drain output, push-pull output, omnipolar, and unipolar device variants. Also, the device has a low average current consumption and can be powered from low voltages, which maximizes the lifetime of any battery that powers it.

If it is necessary to sense in three directions, such as for electricity meter magnetic tamper detection, a 3D linear Hall position sensor can also be used. Some 3D linear Hall devices like the TMAG5170 and TMAG5273 include a feature where a limit can be configured by the user for each axis so that the Hall sensor can provide an interrupt when the sensed magnetic flux density of any axis is beyond its set limit.

Alternate Device Recommendations

For high-speed end of travel applications, a fast response time is needed, which can be achieved with the DRV5021, DRV5023, or DRV5033 Hall switches. The TMAG5124 can also be used for remotely detecting an end of travel event. Table 1 has links that provide more details on the specifications of these alternate devices:

Table 1. Alternate Device Recommendations

Device	Characteristic
DRV5021	Low voltage, high bandwidth unipolar switch
DRV5023	High voltage, high bandwidth unipolar switch
DRV5033	High voltage, high bandwidth omnipolar switch
TMAG5124	Two-wire (current output), high-voltage switch