Find Your Fit: Custom Magnetic Sensor Selection and Design Guide, Part II

October 9, 2015 By: Gwenn Gmeinder, Littelfuse

Review

Part I of this article discussed the importance of conducting a thorough review of the environmental, mechanical, electrical and magnetic parameters when specifying a custom sensor. As mentioned, the design engineer should consider the full magnetic circuit, including the sensor and the magnetic actuator.
The first article also discussed the importance of maintaining clear, direct communication before assembling the project plan. The engineer should work with the original equipment manufacturer (OEM) and customer team to conduct a thorough review of the application parameters, requirements and constraints. When all key factors are known, the engineer can recommend a magnetic circuit design with a robust sensing technology.

Part II will explain how to select magnetic sensing technologies for digital and analog applications. It will define and describe the benefits of reed and Hall effect sensors while providing examples of microprocessor-controlled applications that utilize these sensors. Using the design principles and recommendations discussed, the article concludes with details of a custom magnetic sensing solution for a high-precision outdoor application.

Digital Sensors for High-Reliability Applications

Most users require digital output for their magnetic sensing applications because they want to verify that an object is in its proper position. The following digital sensors deliver exceptional reliability for custom magnetic sensing applications:

Reed Switch

- Definition: This is an electrical switch that does not require power to operate like an integrated circuit. The contacts are hermetically sealed within a glass tube with precious metal contact material.
- Benefits: The switch is highly reliable because it is unaffected by moisture or other environmental factors. Therefore, the contacts will not oxidize and will continue operating for millions of cycles with logic-level loads.
- Applications: Reed switches are very popular for battery-powered applications. They are used in automotive safety products such as seatbelt buckle clamping/closure detection sensors and crash sensors for collision detection. Because reed sensors can switch ac or dc loads, they are a popular choice for digital on/off applications such as door closure detection for the security and household appliance markets.

For example, a refrigerator door uses a reed switch for door closure detection. The magnet is mounted to the door and the reed sensor is attached to the fixed frame hidden behind the external wall of the refrigerator. When the door is open, the magnetic field cannot be sensed by the reed sensor, causing the LED bulb to turn on. When the door closes, the sensor detects the proper magnetic field and the LED turns off. In this application, a microcontroller within the appliance obtains the signal from the reed sensor and then the control unit activates or deactivates the LED.

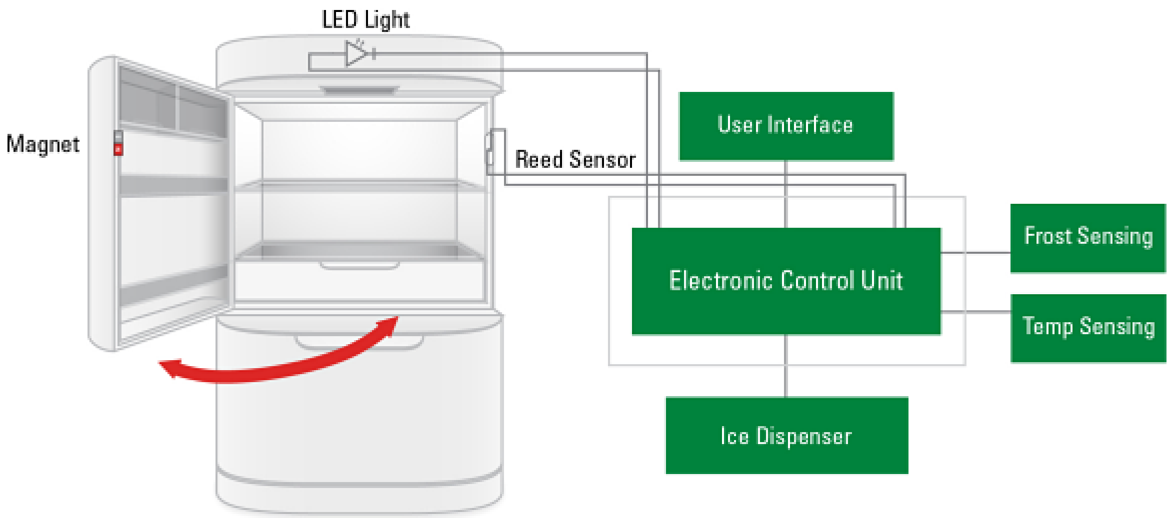

Fig. 1: Reed sensor used in a refrigerator door.

Digital Hall Effect Sensor

- Definition: This semiconductor-based sensor varies the output voltage relative to a change in the magnetic field. These sensors combine a Hall effect sensing element with circuitry to provide a digital on/off output signal that corresponds to a change in the magnetic field without using any moving parts. The Hall effect unit is limited to applications with low DC voltage and current. Unlike a reed switch, a Hall effect device contains active circuitry, so it draws a small amount of current at all times.
- Benefits: Digital Hall effect sensors offer high reliability and can be programmed to activate at a given magnetic field tolerance for precise sensing requirements.
- Applications: These sensors are very popular for high-speed sensing applications such as washing machines. In this application, a rotating 16-pole ring magnet activates the Hall effect chip with each passing red (north pole) segment and deactivates it with each passing white (south pole) segment, resulting in a very accurate speed signal. Digital Hall effect sensors are especially useful in automotive safety applications such as seatbelt buckle clamping detection and transmission gear-tooth speed sensing.

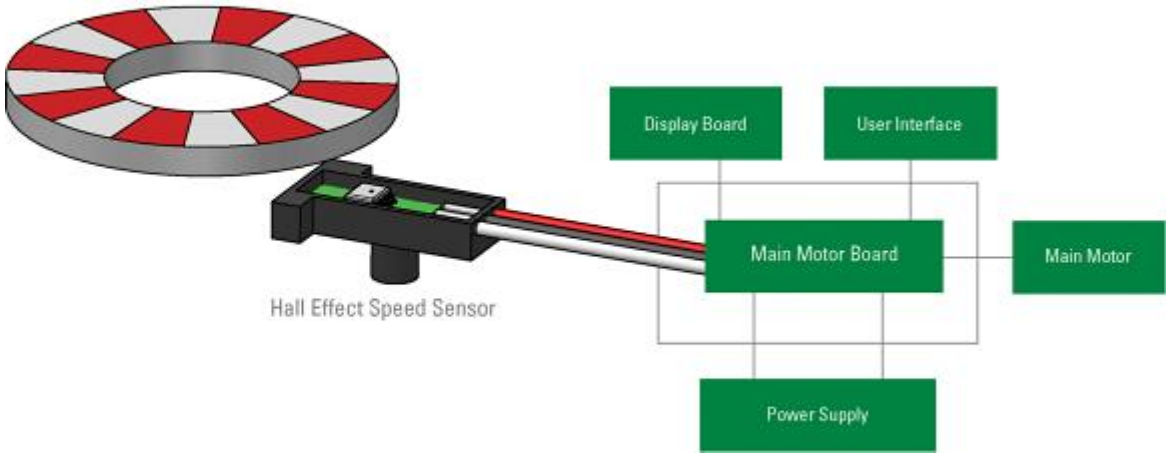

Fig. 2: Diagram of a Hall effect speed sensing application.

Analog/Ratiometric Sensors for Added Stability and Accuracy

Analog sensing applications allow the end user to obtain instantaneous feedback on the magnet's position. The analog Hall effect sensor has a high-accuracy, high-resolution ratiometric output signal.

Previously, analog Hall effect sensors measured the flux density of the magnets and were greatly influenced by the temperature value of the application. Since analog Hall effect technology has advanced in recent years, the Hall effect chip now measures the angle of the flux field instead of the traditional amplitude, making it much less sensitive to temperature changes. This improvement allows the sensor to deliver a more stable analog output across a large temperature range.

Consider two types of Hall effect sensors that can be selected for custom analog sensing applications:

Rotary Hall Effect Sensor

- Definition: This semiconductor-based sensor varies the output voltage relative to a change in the magnetic field. It combines a Hall effect sensing element with circuitry to provide an analog output signal that corresponds to the change in a rotating magnetic field without involving any moving parts. This sensor offers two output options: analog or pulse-width modulation (PWM). The device is programmable so that the engineer can associate a specific output voltage or PWM to a precise degree of rotation. Multiple programming points are available up to 360º of rotation. Each programming point represents a voltage or PWM output value that corresponds to a given angle of the magnetic field. This results in a ratiometric output signal relative to the degree of rotation.
- Benefits: Unlike a mechanical rotary or resistive film rotary device, the rotary Hall effect sensor does not experience mechanical wear or changing resistance values. In addition, it is very stable over normal operating temperatures up to +105°C. Units are accurate from 0 to 360º rotation with 0.5 V to 4.5 Vdc output or 10% to 90% duty cycle for PWM.
- Applications: Rotary Hall effect sensors are becoming very popular for replacing the resistive film or potentiometer mechanical devices. They are used in automotive and off-highway applications such as detecting

the EGR valve position on engines. These sensors may also be used for detecting the dial position in appliance and white goods applications.

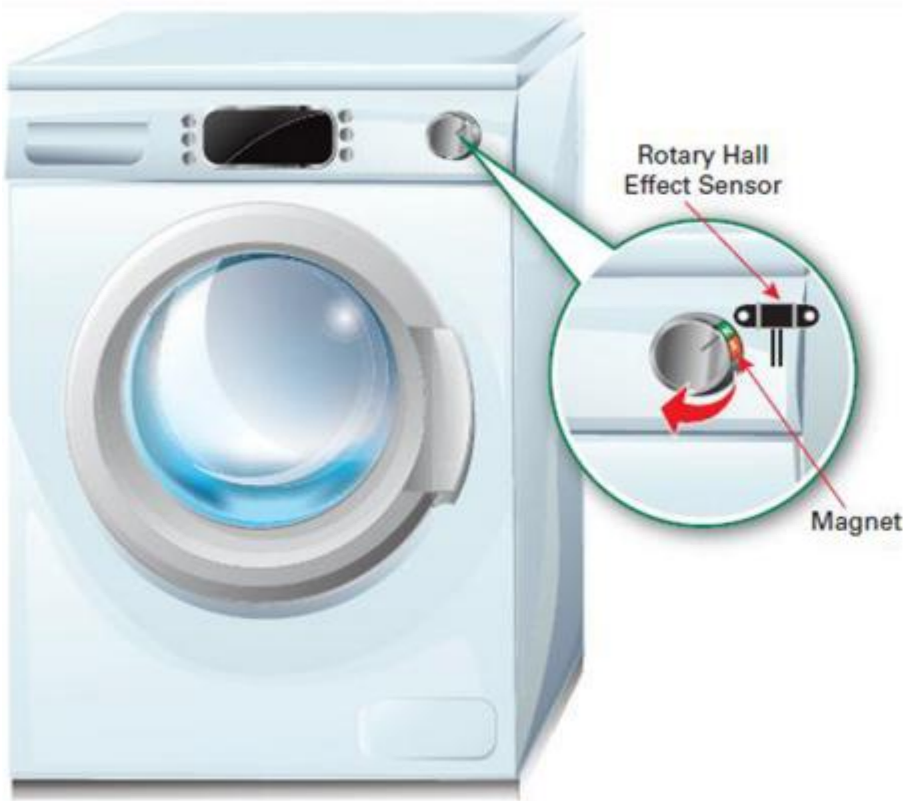

Fig. 3: Rotary Hall effect sensor used in a washing machine.

Linear Hall Effect Sensor

- Definition: Linear Hall effect sensors are similar to the rotary Hall effect sensors except that they measure the linear movement of a magnetic field rather than the rotation. The Hall effect sensor is programmable for a set output voltage that is ratiometric for a given travel distance. The output options are the same as the rotary Hall effect. The sensor measures the linear movement and relative flux angle of a magnetic actuator up to 30 mm of travel distance with a single Hall effect chip. This results in a ratiometric output signal relative to the precise movement of the sensor.
- Benefits: The sensor and actuator can be placed in their final mounting area within the application, which would now include all magnetic influences from the nearby surroundings, prior to programming the output voltage or PWM value to correspond to the relative magnetic field value of the actuation magnet. This allows the engineer to optimize the application's output since any shunting, mechanical tolerances or stack-up tolerances of the magnetic field will be included within the programming environment.
- Applications: Linear Hall effect sensors are often used as level sensors for monitoring fluid levels. In this application the sensor detects the location of the moving float, which has a magnet attached to it. Linear sensors are also beneficial in more complex designs such as automotive transmission gear shifting.

Expertise Applied: Custom Sensing Solution for High-Precision Outdoor Application

Employing the design guidelines and best practices discussed so far, some design engineers recently designed a custom magnetic sensing solution for a demanding outdoor application.

The Problem

Initially, the customer wanted a normally closed standard reed sensor that could be mounted in an outdoor environment located in any type of climate. After extensive communication between the customer and the design engineering teams, it was determined that a standard reed sensor would be unable to address the harsh outdoor conditions.

The Requirements

The customer needed a custom sensing solution that would address the following requirements:

- The unit had to include a normally closed contact reed switch and be sealed against dripping water and meet the IP65 rating.
- The wire harness would be exposed to sunlight and had to be outdoor rated for ultraviolet (UV) light.
- Although the temperature range seemed benign at -40°C to +105°C, it included humidity cycling and a special setup for a water drip test under thermal cycling conditions.
- The customer required a very tight activation distance tolerance over the full temperature range of the application.

The Solution

Following additional discussions and sample evaluations, the engineering team developed a robust, custom design that incorporated the following elements:

- The team used a UV-rated cable for connecting two of the reed sensors into a Y joint. The joint was tied into a harness and an associated connector that was connected to the customer control box.
- To meet the IP65 rating, each reed sensor had a sealed interface connected to the cable, special potting material, an over-molded Y joint and an overmolded connector leading to the harness wire of the control box. In addition, the team performed a special cleaning process to the harness and capsules so that the overmolding of the connector and potting material within the sensors could meet the challenging IP65 rating requirements and withstand the water drip test during the thermal cycling test.
- The activation distance tolerance and special alignment for the sensor and actuator required the team to use custom injection-molded capsules for both the sensors and actuators.

The reed switch was chosen over other technology options for several reasons:

- It was a normally closed switch. Other sensing technologies such as Hall effect or magnetoresistive (MR) would require current consumption at all times, even in nonactivate mode. The customer needed a simple switch that would not require mechanical operation in its challenging environment.
- Reed switches are unaffected by dirt and moisture because of their hermetically sealed contacts. Also, they are known for performing well in tough climates such as those found in automobile safety applications.
- In addition to the above reasons, the competitive price and high reliability made the custom reed switch the optimal choice.

Conclusion

This two-part article explained the best strategies for designing magnetic circuits that require custom sensors. Before beginning any design project, the engineers must communicate clearly with the customer and support team to fully understand the unique constraints and parameters involved.

Noncontact sensing solutions such as reed and Hall effect sensors are in demand for complex microprocessor-controlled applications because they offer highly effective, custom-design solutions. Digital applications may utilize custom reed switches or Hall effects sensors for exceptional reliability. Rotary and linear Hall effect sensors offer stability and accuracy in custom analog applications. Designing a magnetic circuit that incorporates all known parameters and a robust magnetic sensor will result in a highly efficient and reliable sensing application.

About the Author

Gwenn Gmeinder is the North American Business Development Manager for sensor products within the Electronic Business Unit at Littelfuse. For over 30 years, he has worked with sensor technologies at several companies. Gmeinder joined Hamlin in 1978 as a product design engineer and began managing its global business development in 2007. He has held his current position within the company - now part of Littelfuse - since June 2013. Gmeinder earned his BS in industrial technology from the University of Wisconsin-Stout. He can be reached at GGmeinder@Littelfuse.com.