Magnetic Sensors in IoT Devices

Tim Resker, Business Development Manager, Coto Technology

Recent advances in wireless technology have resulted in low cost, low power, SoC's (System on a Chip) supporting a multitude of wireless protocols such as Bluetooth, Zigbee, Z-Wave and ANT+. With these SoC's, developers can design devices around the home, the business, the factory and the environment – as well as devices on or implanted in human and animal bodies – that can sense surroundings and communicate through the internet. Such devices are commonly known as IoT (Internet of Things) devices. Three types of magnetic sensors commonly used in such IoT devices are TMR (tunneling magnetoresistive) sensors, bare reed switches and Hall sensors. Device designers should understand their options when making a determination of which magnetic sensor to choose for their designs.

Magnetic sensors play an important role in IoT devices, so let's look at some examples. Proximity sensing is very common use for magnetic sensors. The classic example of that would be the window and door sensors commonly found in home security systems (Fig.1) The sensor mounts on the door or window jamb or casing and a magnetic is mounted on the door or window sash in close proximity to the sensor. When the door or window opens, the sensor detects the absence of the magnetic field and wirelessly communicates the status to the security system base station.

Magnetic sensors can also be used for counting rotations in wheels and meters. In a factory setting, a flow meter (Fig. 2) measuring flow of a liquid often utilizes a magnetic sensor to sense rotations of an impeller. On a bicycle, a magnetic sensor counts rotations of the wheel and crank shaft. Magnetic sensors can also be used to measure fluid level using a magnetic float and a series of sensors that can sense the float as it moves with the fluid level. All of these applications utilize a magnetic sensor on a fixed surface working in conjunction with a magnet on a nearby surface that moves relative to the sensor.

Often IoT devices require a mode selection dial or bezel that allows the user to manually select the appropriate mode or level setting. The traditional means of implementation is to use electromechanical contacts that open and close as the dial is rotated. However, electrical engineers have discovered over time that electromechanical contacts are prone to failure and can be replaced with a contactless design using magnetic sensors at each mode position and a magnet that rotates to activate the sensors.

Finally, an increasingly common magnetic sensor application is to trigger a "power on" function. Particularly for hermetically sealed, small battery operated, IoT devices, designers need a way to keep the device in a "power off" or "sleep" mode until it is ready to be deployed by the user. A good example of this would be a wearable continuous glucose meter used to measure and communicate body glucose levels to the patient, doctor and insulin pump (Fig.3). Mechanical switches and battery "tabs" can keep a device powered down but, unfortunately, they also leave the electronics of the device vulnerable to harsh environments. A preferable method is to use a magnetic sensor inside the sealed device coupled with a small magnet outside the device, usually embedded in the protective packaging of the device. This way, when the device is removed from the packaging, (and simultaneously away from the magnet's field) the sensor output changes and a circuit "turns on" the device. Not only does this method conserve battery power; it also provides an "instant on" or "out of the box experience" for the user.

Important considerations in all of these magnetic sensor functions include power consumption, sensitivity, output response options, size, reliability and cost. There are several common magnetic sensor options – each with its strengths and weaknesses with respect to IoT devices.

The simplest magnetic sensor, which also has been around the longest, is the venerable bare reed switch. A reed switch is an electro-mechanical device comprised of two ferrous metal "reeds" each attached to leads and encapsulated within a glass tube. A magnetic field pulls the two reeds together closing a circuit. Reed switches are commonly used in various IoT devices, most notably window and door sensors used in security systems, meters and implantable medical devices. The biggest advantage to reed switches is that they are passive devices that consume zero power. Reed switches also have the advantage of being simple and cheap with a limited range of sensitivity. However, reed switches have several significant limitations. One of the limitations of reed switches is size. The most common reed switch is 10mm in length - acceptable for some IoT devices, but not for many wearable and implantable devices that require a sensor size less than the 1mm square range. Smaller reed switches are available, (down to 5mm length) but they are very expensive and difficult to obtain. Reed switches can also have poor reliability due to their mechanical nature and inherent fragility of their glass tube design. Overmolded reed switches improve reliability by protecting the glass tube and the seals around the leads exiting the tube, but this adds to the cost – as well as the size.

Another magnetic sensor type that has stood the test of time is the Hall effect sensor. The Hall effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current. Being a solid state, CMOS technology, Hall effect sensors are small, reliable and low cost. The biggest disadvantage of Hall sensors is their current consumption. Most Hall effect sensors exceed several microAmps of current which is problematic for many battery operated IoT devices.

The last class of magnetic sensors is the magnetoresistive (MR) sensor. Based on the principle that a conductor's resistance will change in the presence of a magnetic field, different MR technologies have been developed as the basis for MR sensors. While all of these sensors offer the benefits of a solid state IC, small size, low cost and reliability, the tunneling magnetoresistive (TMR) sensors provide the combination of highest sensitivity and lowest power. With power consumption as low as sub-200nA, TMR sensors represent a paradigm shift for battery operated IoT devices requiring a magnetic sensor function. Additionally, TMR sensors are the most sensitive of all the MR sensors and are equivalent to the sensitivity of the most sensitive reed switch. A highly-sensitive sensor enables the use of smaller, cheaper magnets or longer activation distances.

	Reed Switch	Hall Effect Sensor	TMR Sensor
			
Technology	Mechanical	Electronic	Spintronic
Power Consumption (µA)	0	5~5000	0.1~1
Switching Frequency	Low	High	>300KHz
Reliability	Medium	High (Solid State)	High (Solid State)
Sensitivity (mV/V/Oe)	Medium	0.01	10
Size	Large	Small	Tiny
Noise Immunity	High	Low	High
Cost	Medium	Low	Low

Table 1: A comparison of notable features of Reed Switch, Hall Effect and TMR Sensors.

Table 1 summarizes the relative strengths and weaknesses of the reed switch, the Hall sensor and the TMR sensor. Across power consumption, switching frequency, reliability, sensitivity, size, noise immunity and cost, the TMR Sensor comes out on top over the other magnetic sensing technologies.

Once the best sensor technology for your needs is chosen there are still decisions to be made about which sensor output, sensor polarity response, sensing frequency and magnetic sensitivity is right for your application. And then there is the challenge of designing your magnetic subsystem. (determination of orientation of the sensor, placement of the magnet, and size and type of magnet to meet operating requirements and limit cost). Most electrical and mechanical product design engineers do not have the experience, knowledge, or tools to properly design and validate the magnetic sensing design. In this case, these IoT device designers should choose magnetic sensor suppliers who offer specialized application engineering support, knowledge and tools to help with the magnetic sensing design process.

The "Internet of Things" may be an industry buzzword, but it is a very real trend that is touching many different applications throughout our world. While magnetic sensors provide the technology to support life-changing devices within the IoT world, device designers must understand the benefits of the different types in order to choose the right solution for their design.

www.cotorelay.com