Technical Article

The Hall effect: How an in-plane switch increases sensitivity and lowers design cost

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Devices with smart magnetic position sensors – door and window sensors, electronic smart locks (shown in Figure 1), laptops, earbuds, tablets, smartphones, and water and gas meters – all depend on smaller, more power-efficient switches. Magnetic switches often need to detect magnetic fields parallel or horizontal to the printed circuit board (PCB), a type of sensing orientation called in-plane.

Figure 1. Electronic locks rely on magnetic sensor switches

The most popular in-plane magnetic switches are anisotropic magnetoresistive (AMR), tunnel magnetoresistive (TMR) and reed switches. AMR and TMR work by changing resistivity based on the angle and magnitude of the magnetic field. Reed switches comprise two pieces of ferromagnetic metal encapsulated in a glass tube. The pieces come in contact when channeling a sufficiently strong magnetic field between them.

Although AMR, TMR and reed switches are the incumbent solutions in the market, there are disadvantages. Because reed switches are enclosed in a glass tube or another hermetically sealed enclosure, the package is large and expensive, and susceptible to torque when placed next to a magnet (see Figure 2). The enclosures can also easily break between 100,000 and 1 million switch cycles, which makes the technology less durable and reliable. And reed switches are unable to detect magnetic fields with a high level of accuracy.

Another challenge when designing with reed switches is that they can experience debounce, which is the result of an elastic collision where the two reeds separate after coming into contact. The debounce extends the signal settling time, and can affect transmission integrity if not handled.

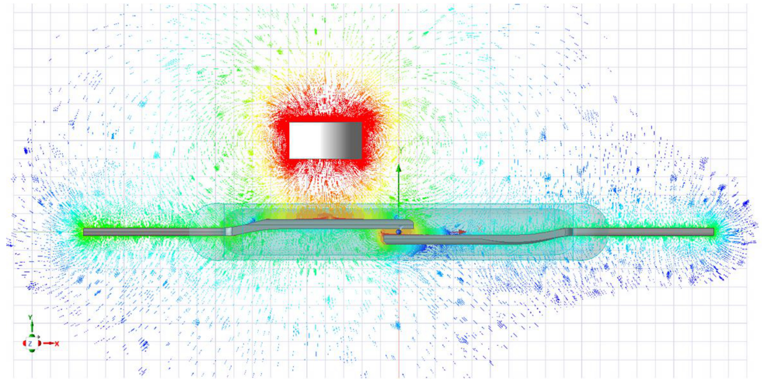

Figure 2. Simulated response of a reed switch showing concentrated magnetic flux density between the tips of the two reeds

AMR and TMR sensors are expensive to manufacture given their complex stack of metal layers. Creating these metal layers necessitates specialized deposition equipment that is not easy to acquire and can lead to supply limitations; the layers also have to be magnetized.

A new era of magnetic sensing

There is growing demand for Hall-effect technology because it offers similar sensitivity and power consumption to the popular switch types while being scalable and more economical. Hall-effect switches work by monitoring the voltage change based on the magnitude of the magnetic field.

TI's TMAG5134 in-plane Hall-effect switch (Figure 3) has an integrated magnetic concentrator, which comprises two metal plates positioned over the sensing element. The concentrator focuses the magnetic field across the sensing element, amplifying the magnetic field and enabling detection of magnetic fields that are too weak to effectively measure with Hall-effect sensors alone. The TMAG5134's ability to detect magnetic fields as weak as 1mT enables the use of small magnets, reducing system-level costs.

The performance generated by the TMAG5134's integrated magnetic concentrator and the manufacturing cost of Hall-effect technology makes it a fair competitor to AMR, TMR and reed switches, with significantly reduced system costs.

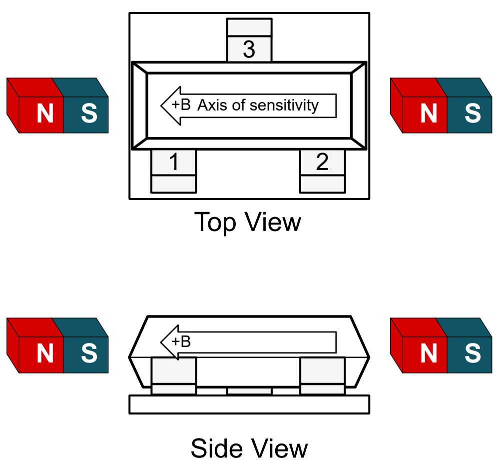

Figure 3. In-plane position design of the TMAG5134 Hall-effect switch

The integrated magnetic concentrator reduces power consumption compared to standard Hall-effect sensors because it amplifies the signal, eliminating the need to bias the sensor with as much current. The TMAG5134 can consume as little as 0.6μA of power.

In addition, the TMAG5134's in-plane sensing orientation gives you more flexibility when designing your system if you're detecting magnetic fields parallel or horizontal to the PCB. It's possible to resolve this challenge by using a Hall-effect switch in a transistor outline (TO)-92 package, but that consumes more board space. Since the TMAG5134 is a Hall-effect switch, it senses magnetic fields contactlessly, reducing wear and tear and increasing reliability and resiliency compared to mechanical switches.

TI has a magnetic simulation tool called the Texas Instruments Magnetic Sense Simulator (TIMSS), with which you can simulate the magnetic field and sensor output based on sensor magnet placement. TIMSS decreases system and full product design revisions and enables quick experiments with different system tolerances. You can select the TMAG5134 in TIMSS and get a 3D visualization of the magnetic field and device output that you'd see in your system.

Design engineers often need to consider cost, power and operating threshold when choosing the right technology (see Table 1).

Table 1. The TMAG5134 Hall-effect switch compared to other in-plane sensing technologies

Parameter	TMAG5134	AMR switch	TMR switch	Reed switch
Sensing direction	In-plane (X-axis)	In-plane (X-axis)	In-plane (X-axis)	In-plane (X-axis)
Cost	Low	High	High	High
Current consumption	As low as 0.6µA	<0.1µA	<0.05µA	0
Typical operating threshold (Bop)	As low as 1mT	Approximately 3mT	As low as 0.3mT	<5mT

Smarter sensing applications

The functionality of in-plane Hall-effect switches such as the TMAG5134 includes these examples:

1. In smart home systems including door and window sensors and electronic smart locks:
2. Detecting when users have opened or closed a door or window.
3. Monitoring deadbolt position to determine the state of a door.
4. Extending battery life.
5. In consumer electronics such as notebooks, tablets and earbuds:
    a. Detecting when users have opened or closed a notebook lid or tablet cover, or detecting when users have folded a notebook 360 degrees. In notebooks and tablets, the screen turns on or off based on its open and close state.
    b. Determining when users have opened or closed an earbuds charging case lid, or inserted or removed earbuds from the case. Either action determines the charging status of the earbuds.
6. In energy infrastructures:
    a. Detecting the swiping of a magnet in water and gas meters to put the meter into diagnostics mode.
    b. Detecting the placement of an external magnet on the meter to disrupt meter measurement.

Conclusion

In-plane Hall-effect switches such as the TMAG5134 are shaping the future of magnetic position sensing. In the future, devices such as the TMAG5134 could be a good fit for products such as augmented or virtual reality headsets and smart glasses. The combination of good performance and low cost makes TMAG5134 in-plane Hall-effect switches an attractive choice.

Additional resources

- Get started with the Hall-effect breakout adapter evaluation module.
- Quickly evaluate your Hall-effect switch design with the TMAG5134EVM.
- Watch our TI Precision Labs series of videos on magnetic sensors.

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