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Making Switches Smarter with True Micropower Hall Effect Sensors

Khagendra Thapa, Business Unit Director

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Linear Hall effect sensors can bring valuable advantages to consumer technology and Internet of Things applications, but must achieve a significant reduction in power consumption in order to meet the expectations of equipment designers and end users

Introduction: Better Sensing Holds the Key to Progress

Improvements in sensing are critical to delivering the improved user experiences demanded of consumer devices such as smartphones, cameras and game controllers, and are also needed to realise the full potential of the Internet of Things (IoT). In consumer applications, smarter buttons with multi-function capability are needed to support sophisticated interactions and gesture-based controls. In the IoT, the ability to sense minute movements or positional differences allows controllers to make accurate inferences about the status of assets. In a security system for a smart building, for example, a basic sensor may be able to detect whether a window is closed, whereas a smarter sensor can inform the system whether the window is locked or unlocked.

Linear Hall effect sensors provide a means to achieve more sophisticated sensing compared to alternatives such as mechanical switches, which are often the incumbent technology in computer accessories like joysticks, or game controllers. Linear Hall effect sensors deliver a non-contact position sensing solution that is highly reliable and convenient to design in. Moreover, compared to other non-contact sensing devices such as optical sensors, the linear Hall effect device is not susceptible to errors that can be caused by obscuring of the optical windows by dust or other contaminants. Linear Hall effect sensors are already widely used in numerous industrial applications, for example for sensing the position of rotary valves.

The Hall Effect and Linear Sensors

The Hall effect refers to the measurable voltage developed across a conductor when a magnetic field acts on an electric current flowing in the conductive material. This voltage is proportional to the current flowing and the magnetic flux perpendicular to the conductor, as figure 1 illustrates. Hall effect sensor ICs integrate high-gain amplification and other signal-conditioning circuitry such as offset cancellation to generate an output that is representative of the magnetic flux detected, at voltages that are compatible with other logic or analog circuitry.

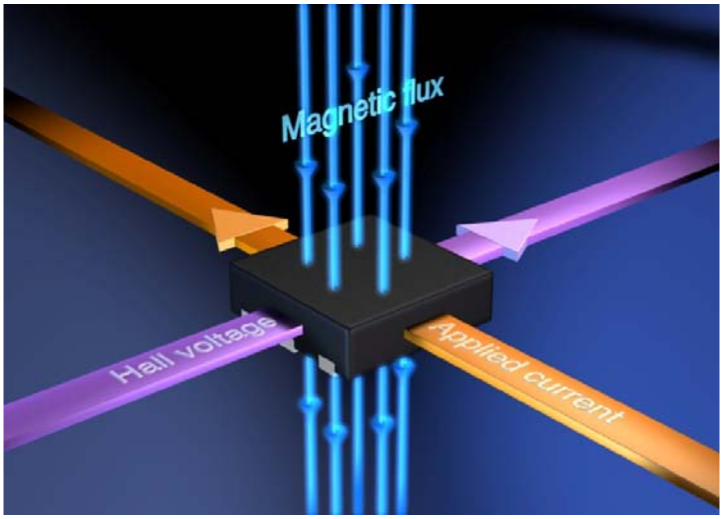

Figure 1. Sensing magnetic flux using a Hall effect sensor IC.

A wide variety of Hall effect devices are available: sensors with a digital output can be used as proximity switches in applications such as open/close detection for laptop PCs, by embedding a small magnet in the lid. A linear Hall effect sensor, on the other hand, is capable of generating an analog output proportional to the distance of a magnet from the sensor. This type of sensor can be used in a slide-by mechanism, to detect the position of a magnet moving past the sensor. For example, as the bar magnet moves past the sensor the output voltage varies as the flux density changes from zero when the magnet is far away to maximum negative flux due to the proximity of the magnet North pole, through zero when the magnet is centrally located over the sensor, and to maximum positive due to proximity of the South pole. As the magnet continues to move past, the sensor output moves towards zero.

The other main operating mode for a linear device is in head-on sensing, when the magnet is moved towards or away from the face of the sensor. In this case the magnetic flux, and hence the output voltage, changes from zero to a maximum level when the magnet is closest to the sensor. Figure 2 shows how the output voltage of a linear Hall effect sensor IC varies with magnetic field strength as the magnet is brought closer to the IC surface.

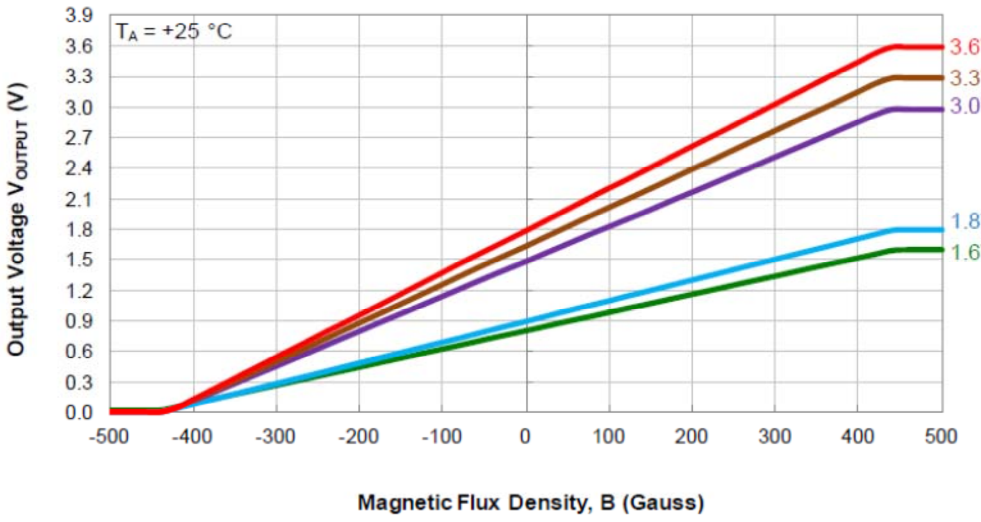

Figure 2. Transfer curve of a linear Hall effect device.

Power-Conscious Applications

Although the Hall effect was originally discovered in the 19th century, commercial Hall effect sensor ICs have been realised relatively recently with the integration of low-noise amplifiers and signal-processing circuitry capable of generating a usable output voltage. Subsequently Hall effect sensors, including linear devices, have become widely used for industrial proximity and position sensing tasks such as fluid level sensing and valve position control.

In consumer portables, linear Hall effect sensors offer the opportunity to introduce extra functionality that is difficult to achieve using a conventional mechanical switch, since the sensor can not only detect that a button has been pushed but can also determine the position of the button accurately. This allows multi-function buttons in devices such as camera phones or DSLRs, which feature half-press to auto-focus and full-press for shutter release. In the same way, using a linear Hall effect sensor allows the buttons of game controllers to control extra functions or to sense more complex player gestures.

On the other hand, these emerging applications place tougher demands on linear Hall effect sensors. In particular, ultra-low power consumption has become an absolute imperative to ensure advanced functionality without impairing battery life. IoT devices, for example, are usually required to operate autonomously for five, 10 or even 20 years powered by a small battery or energy-harvesting system. The handful of milliamps drawn by a conventional Hall effect sensor may be enough to prevent the designer achieving the required maintenance-free operating lifetime. As far as consumer electronic products are concerned, any noticeable reduction in battery life can potentially damage market appeal.

True Micropower Sensors

In many situations where a linear Hall effect sensor can be used for detecting button position, the sensor IC only needs to be fully operational for a brief period when position information is required. Introducing power management to the IC can help avoid unnecessary energy consumption when sensing is not required.

Some sensors, such as the Diodes AH8500 and AH8501, have an Enable pin that allows the host to control the operating mode. By default, an internal pull-down keeps the sensor in sleep mode drawing typical current of only 8.9µA. Driving the Enable pin high puts the device into active mode operating at a default sampling frequency of 6.25kHz and with current consumption of 1.16mA typical. Alternatively, a PWM signal can be used to set a custom sampling rate up to 7.14kHz.

By providing an Enable pin, these devices are suitable for a variety of IoT applications, such as smart building security or entry-control systems, where a signal is available to activate the sensor. On the other hand, consumer devices such as cameras, mobiles and game terminals may not be able to anticipate when the user is likely to push a button and hence will not be able to drive the Enable pin high. Nevertheless, the user expects instantaneous response. For this type of application, the AH8502 and AH8503 operate by default in micropower mode drawing only 13µA typical at a default sampling rate of 24Hz. When activity is detected, the sensor can be operated in turbo mode, and increases the sampling rate if needed. A Control pin is provided, which allows the system to adjust the sampling rate up to the maximum of 7.14kHz drawing a current of 1.16mA.

Enhanced power management, such as shutting down analog circuitry and the ADC when idle, and applying patent-pending power-saving techniques between cycles, allows these devices to draw significantly lower current in normal, sleep and micropower modes compared to alternative low-power linear Hall effect sensors.

The devices integrate signal-conditioning circuitry including an 8-bit ADC and DAC as shown in figure 3, and hence generate an analog output with 8-bit resolution suitable for a wide range of IoT and consumer applications.

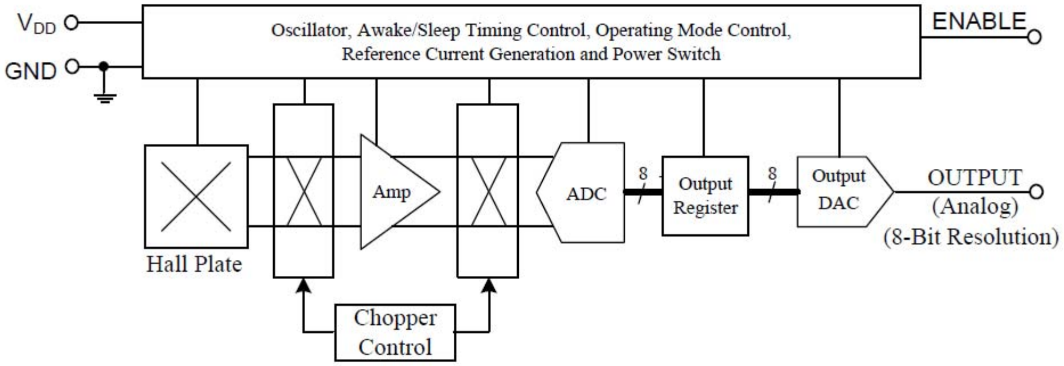

Figure 3. Integrated signal conditioning provides 8-bit analog resolution.

For applications where high accuracy is required, The AH8501 (with Enable pin) and AH8503 available with the option of a trimmed output that ensures accuracy sensitivity is within ±3%. Combined with very low temperature coefficient of ±3%, this ensures the maximum sensitivity variation is within ±6%. This is significantly better than the sensitivity accuracy of closely priced alternatives, and compares favorably with the most expensive linear Hall effect sensors on the market today. The non-trimmed AH8500 (with Enable pin) and

AH8502 have sensitivity accuracy within ±15%, and provide the flexibility to perform calibration on the production line.

It is typical for linear Hall effect sensors to integrate ESD protection on I/Os, but the level of protection provided is usually only up to 1kV or 2kV. By providing enhanced protection, capable of withstanding up to 6kV, the AH850x family benefits from greater immunity to hazards encountered on the factory floor during production or when in the hands of end users.

Enhanced ESD protection alleviates the need for external protection components, which delivers advantages such as lower bill of materials costs and savings in PCB real-estate. Enhanced protection also allows these devices to be used in domestic appliances such as coffee machines as well as industrial applications, in addition to consumer mobiles.

Conclusion

Since the first commercial ICs entered the market, Hall effect sensors have quickly become popular, particularly in industrial applications requiring high reliability, non-contact position or proximity detection.

The emergence of the IoT, and continuous demands coming from consumer electronics markets for improved user experiences, are two major trends that now present significant extra opportunities for Hall effect sensors, and in particular linear sensors capable of supporting sophisticated features such as multi-function buttons. Relatively high power consumption, even in some micropower sensors, has restricted the use of these devices, but the latest generations of true micropower linear Hall effect sensors now enable sophisticated position sensing at acceptably low power consumption. High accuracy, enhanced integrated ESD protection and operational flexibility deliver a further boost to the usability of these advanced devices.