SELECTING THE RIGHT MAGNETIC SWITCH OR LATCH FOR YOUR APPLICATION

By Allegro MicroSystems

INTRODUCTION

Allegro has a wide variety of Hall-effect and tunneling magneto-resistive (TMR) switches and latches that can be used in many different applications to include automotive, industrial, and consumer.

This application note is intended to provide a step-by-step process to help designers pick the right Allegro switch or latch part for their specific application. This application note details the different parameters that define Allegro switches and latches to help designers identify the most appropriate part for their needs.

The conclusion of this application note provides a summary of the selection process and a review of some of the common applications where Allegro switches and latches can be used.

SWITCH OR LATCH?

In magnetic position sensing, there are two main types of sensors—switches and latches. Switches are used in a wide range of applications to detect the open or closed state of white goods, medical devices, portable electronics, smart meters, and many other contactless open/closed position-sensing applications. These sensors typically indicate the closed state when a magnetic field is present and the open state when the magnetic field is removed.

A latch is a special variant of a switch with bipolar sensing properties. Latches are commonly used in brushless DC (BLDC) motors found in power tools, appliance pumps and fans, e-mobility platforms, industrial automation, and similar applications. Unlike a switch, a latch holds its output state until the magnetic field changes polarity.

Figure 1: Allegro Family of Switches and Latches

MAGNETIC SWITCH

When magnetic field exceeds the operating point threshold (B_{OP}), a switch turns on; when the same polarity field reduces to less than the release point threshold (B_{RP}), a switch turns off.

Switches can be either unipolar or omnipolar:

- A unipolar switch has a single magnetic polarity (unipolar south or unipolar north) for B_{OP} and B_{RP}.
- An omnipolar switch has B_{OP} and B_{RP} thresholds for both north and south polarity magnetic fields, so it can respond to magnetic fields of both polarities.

Output polarity can be either standard or inverted:

- Standard polarity makes the output go low when the applied magnetic field exceeds B_{OP}. This polarity is more common because, in the absence of an applied field, it avoids output current consumption.
- Inverted output polarity results in an output high state when the magnetic field exceeds B_{OP}.

For clarification, see Figure 2.

To select the best magnetic switch for a design:

- Determine what output polarity is optimal for the application; and
- Determine if the magnetic thresholds should be positive (unipolar south), negative (unipolar north), or both (omnipolar).

Because an omnipolar switch senses both south and north polarities, it provides an added benefit with respect to magnet placement: The magnet can be placed in the system with either the north pole or the south pole facing the sensor. However, to avoid unintentional switching from stray magnetic fields, some applications might benefit from a unipolar part.

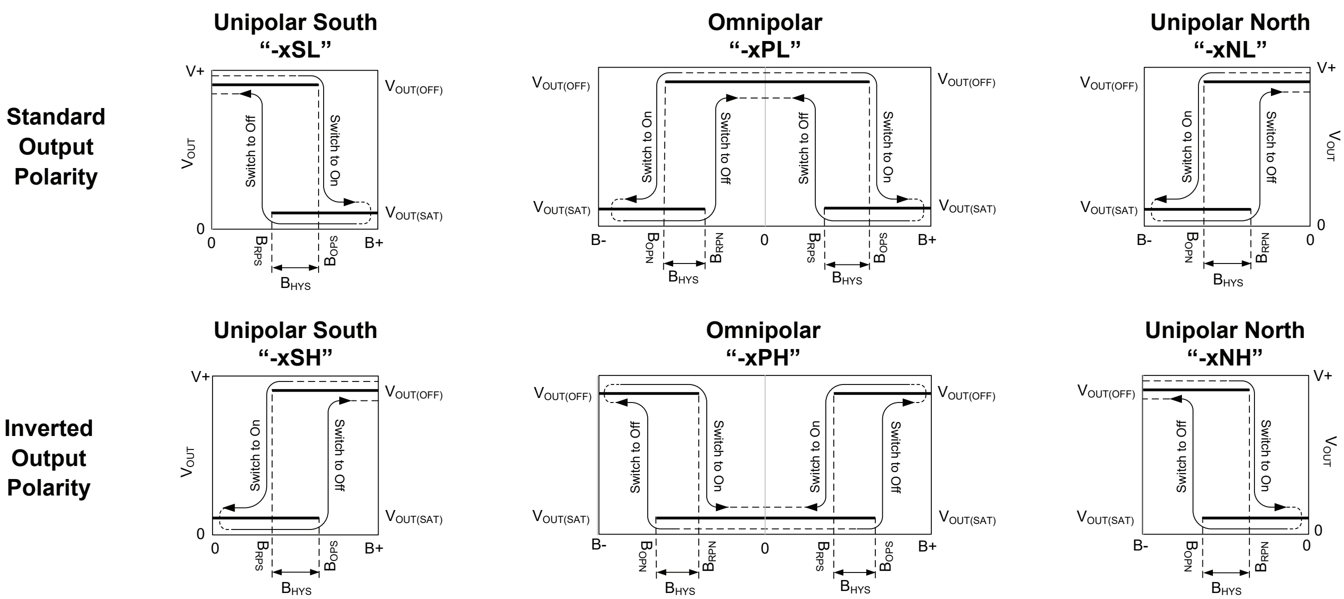

Figure 2: Hall Switch Output State vs. Magnetic Field

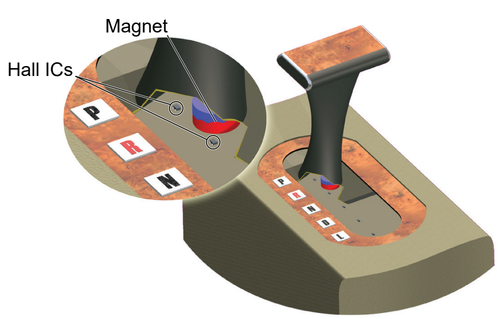

Figure 3: Application Using a Unipolar Switch: ICs Switch as the Magnet (Red and Blue Cylinder) Moves Past Them During Gear-Shifting

MAGNETIC LATCH

A latch is a special form of switch circuit where the B_{OP} and B_{RP} thresholds respond to different polarities; this means that an opposing magnetic field is required to change the output state of the device. Therefore, if the B_{OP} threshold is for a positive magnetic field, the B_{RP} threshold is negative.

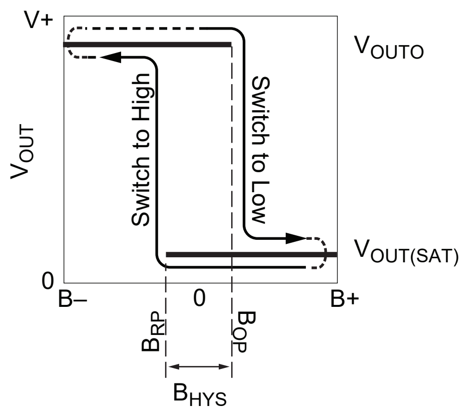

Figure 4: Hall Latch Output State vs. Magnetic Field

For latches, the output polarity can be selected based on the desired behavior when the applied magnetic field exceeds B_{OP}:

- Standard polarity makes the output go low (Vsat).
- Inverted polarity makes the output go high .

For clarification, see Figure 4.

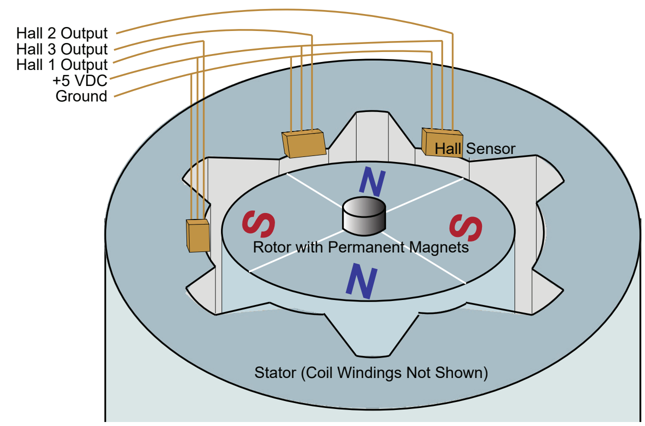

Figure 5: Typical Latch Application for a BLDC Motor, Using Three Hall Latch Sensors for Motor-Coil Commutation

WHAT SENSING PLANE?

Allegro switches and latches can sense on the X, Y, or Z planes (see Figure 6).

Most Allegro parts sense on the Z axis (perpendicular to the part) using a standard planar Hall sensor. Planar sensing is the most common configuration used within the industry and is the easiest to design. Z-axis sensing serves most applications well. However, certain applications and PCB designs require the sensing axis to be in the X or Y plane (same plane as the part). For X- or Y-axis sensing, a vertical Hall transducer (VHT) can be used. Switch and latch solutions that employ an Allegro XtremeSense, ultra-low-power tunneling magneto-resistive (TMR) transducer naturally sense magnetic fields in the X and Y planes because this is their default sensing configuration.

To sense more than one axis at a time, additional options for two-dimensional (2D) and three-dimensional (3D) sensing employ multiple transducers.

The final decision about the sensing plane(s) depends on the application, the magnetics, and the location of the sensor in the PCB design.

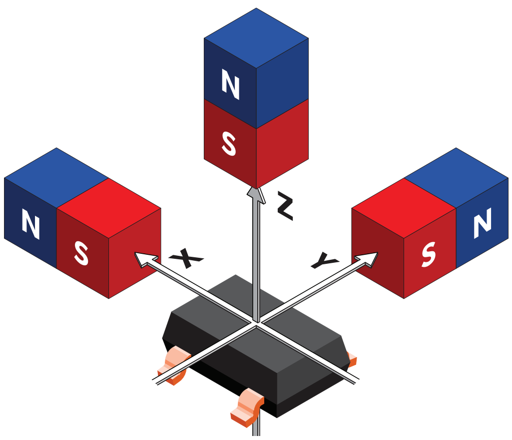

Figure 6: Sensing Planes of Allegro Switches and Latches

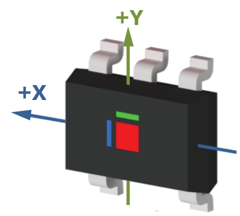

Figure 7: Example of Device with Two Vertical Hall Plates for X and Y Sensing (Green and Blue Rectangles) and One Planar Hall Plate for Z Sensing (Red Square)

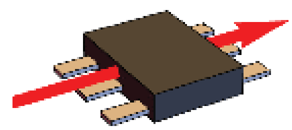

Figure 8: X or Y Plane Sensing with XtremeSense Switch or Latch Using a TMR Sensor

WHAT MAGNETIC SWITCH POINT?

Allegro Hall sensors have a wide variety of magnetic switch-points ranging from 10 G to 600 G (1 mT to 60 mT).

In the case of latches that are used inside DC motors for commutation purposes, the magnetic field at the sensor takes a form similar to a sine wave. Because this waveform crosses a 0 Gauss level, a sensor with a lower switch point provides better coverage for the wide range of weak or strong magnet types that might be used. The weaker the magnet, the lower the strength of the magnetic field generated and the lower the switch point threshold required for the application. Regardless, to serve the wide range of potential applications and magnet types, Allegro offers latches with both high and low switch points.

For switches, the optimal switch-point threshold depends highly on the specifics of the end application. For example, for a turn-on switch (such as for a washing machine door) the operating magnetic field must be less than the strength of the field generated when the door closes, but not so low that false triggers result from other magnetic fields that might be present in the environment. Also, the hysteresis between the operating (B_{OP}) and release (B_{RP}) thresholds should be high enough to prevent false triggering due to noise or spurious signals. For example, without proper hysteresis, the mechanical movement of the door of a washing machine (and its magnet) during its typical operation could generate a false door-open signal.

If an application requires adjustment or calibration of the magnetic threshold during production or operation, Allegro offers parts with programmable magnetic thresholds. This allows customers to adjust the magnetic operate and release set points of the switch or latch, as needed.

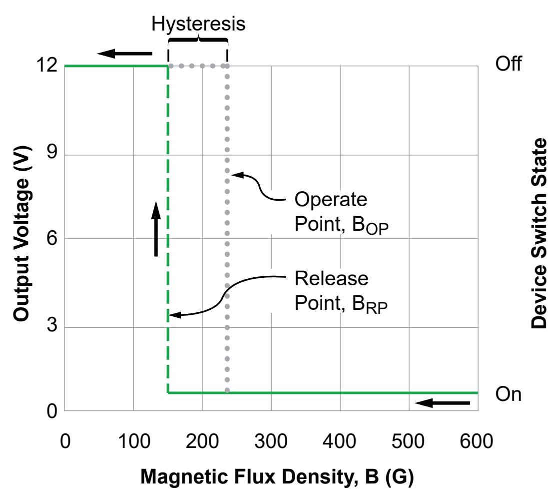

Figure 9: Description of B_{OP}, B_{RP} and H_Y

TWO-WIRE OR THREE-WIRE OUTPUT?

Allegro switches and latches are designed for either three-wire or two-wire operation:

- Three-wire parts require three wires to be properly connected (VCC, GND, and OUT). These parts typically employ an open-drain output with a pull-up resistor. Most applications prefer this topology.
- Two-wire parts require connections to VCC and GND only. Applications that benefit from a reduced wire count might prefer this topology. For a two-wire part, the supply current is modulated to reflect the on or off status of the switch based on the strength of the magnetic field detected by the sensor. Therefore, in a two-wire device, the switch-state data is embedded within the IC supply current (I_{CC}).

The clear benefit of two-wire parts is the ability to eliminate one connecting wire, and the longer the wires need to run between the switch to the central processor (ECU, etc.), the bigger the cost benefit.

The disadvantage of two-wire parts is a higher solution current consumption that can be as much as five times greater than the current consumption of the IC itself.

Three-wire (also called open-drain) parts are more common because they are simpler, less expensive, and lower-power consumption than two-wire parts. However, for some specific applications the benefit of saving one wire compensates for these disadvantages.

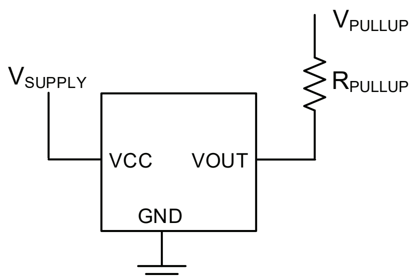

Figure 10: Three-Wire Interface Circuit

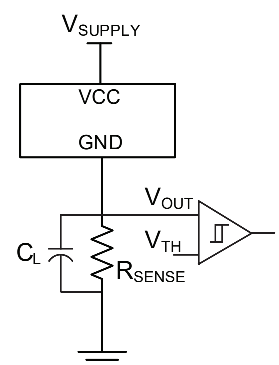

Figure 11: Two-Wire Interface Circuit

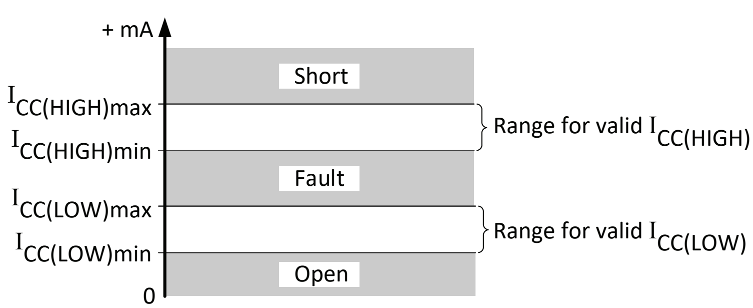

Figure 12: Two-Wire Digital Levels

LOW VOLTAGE OR HIGH VOLTAGE?

Low voltage switches and latches are generally defined as parts that operate with a supply voltage (V_{CC}) as low as 1.65 V up to as high as 5.5 V. High-voltage switches and latches are defined as those parts that can operate from a supply voltage up to 24 V or 26 V (typically from 2.8 V to 3 V). The end application defines whether a high or low supply operating voltage is needed.

Low-voltage parts are typically connected to a low-voltage rail generated by an external regulator or directly to a low-voltage battery in battery-powered applications. Low-voltage switches and latches are commonly used when low power consumption is needed for applications like smart meters, wearable medical devices, remote internet-of-things (IoT) sensors, and mobile devices.

High-voltage switches and latches typically incorporate an internal regulator that allows these parts to be connected directly to the car battery bus, or other high-voltage rail, without the need for an external regulator. High-voltage switches and latches are widely used in the automotive industry and in high-torque motor-control applications.

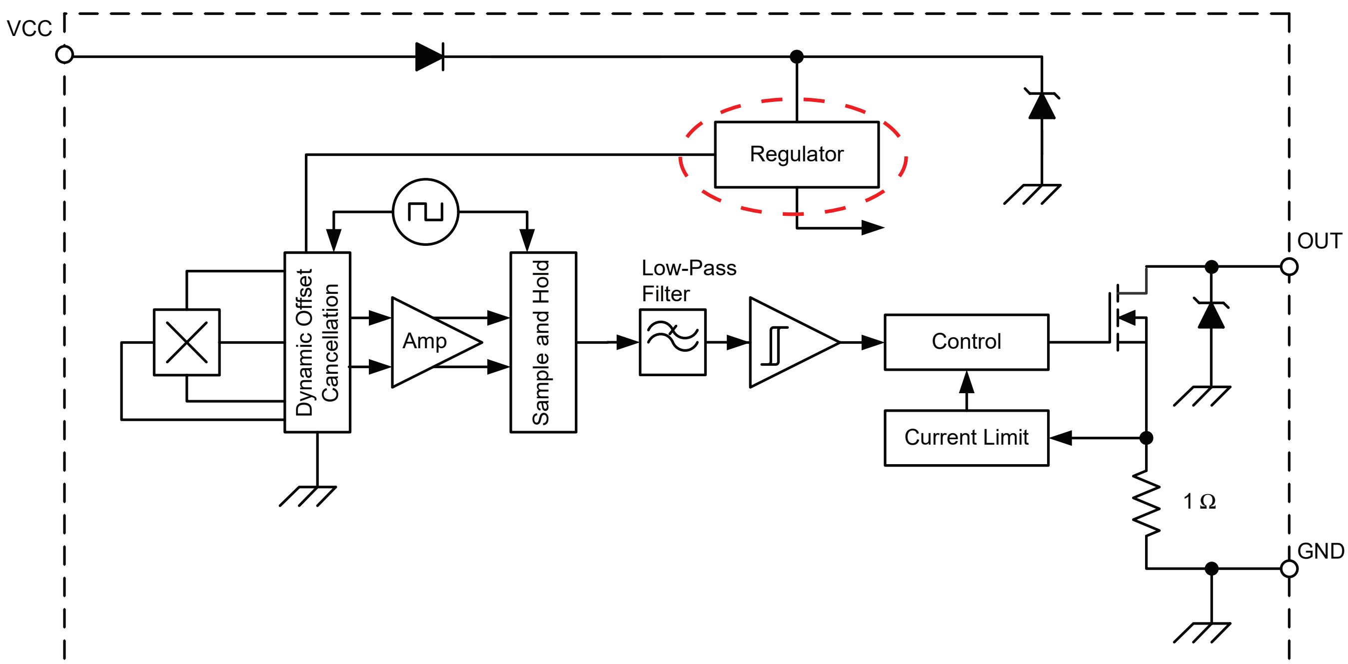

Figure 13: High-Voltage Latch with Internal Regulator

IS POWER ON TIME IMPORTANT?

Power on time (POT) is defined as the amount of time it takes a switch or latch to show a valid output once the supply voltage (V_{CC}) exceeds the minimum V_{CC} for the part (V_{CCMIN}). For some applications, a short-duration POT is critical.

If a very-short-duration POT is required for an application, a continuous-time part (such as the Allegro A110x or A120x family) can be selected. These continuous-time parts do not use dynamic offset cancellation, so POT is much shorter—typically 4 µs or less. For continuous-time parts, offset is removed by trimming as opposed to chopper stabilization circuits.

If a very-short-duration POT is not required (which is typical for most applications), an Allegro part that uses dynamic offset cancellation is recommended. Dynamic offset cancellation eliminates the need for offset trimming, so it is less susceptible to offsets from mechanical stress or drift over temperature. Most Allegro switches and latches use some form of dynamic offset cancellation. These parts typically have a maximum POT of approximately 25 µs.

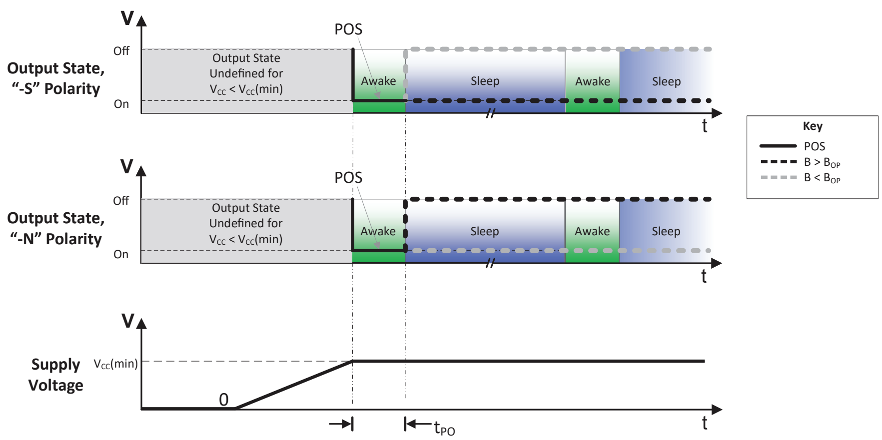

Figure 14: Defining Power On Time (POT) for a Switch

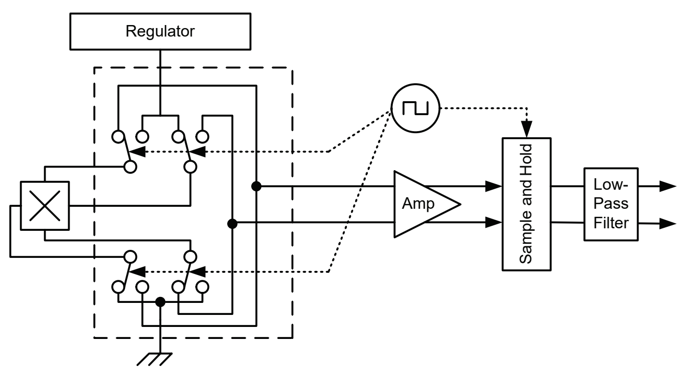

Figure 15: Chopper Stabilization Circuit

IS POWER CONSUMPTION IMPORTANT?

If an application requires low power consumption—for example, battery-powered devices, such as cellphones, drones, remote IoT sensors, and wearable medical devices—a switch or latch with low power consumption is essential. These parts also need to be capable of operating directly from the battery or other low-voltage rail. For these applications, Allegro offers a wide variety of parts that can operate from supply voltages as low as 1.65 V with very low power consumption.

Low-voltage micropower parts reduce their power consumption through duty cycling, only turning on (awake) for a short period of time (approximately 60 µs maximum) to measure the applied magnetic field. The ratio of the on and off (sleep) times for a micropower switch or latch can vary from part to part. For devices that need to operate at the absolute lowest power levels, sleep periods are much longer and can range from 1.5 ms up to 200 ms. By extending the time between active awake periods, micropower switches like the Allegro APS11753 can reach continuous current consumption levels at less than 5 µA.

However, a drawback to long sleep periods is that, because these changes cannot be detected while the IC is in sleep mode, the switch or latch requires more time to respond to any change in the external magnetic field. For high-speed applications, where the magnetic field changes rapidly, a micropower device with a long sleep period might not have sufficient bandwidth to properly detect magnetic field changes. However, this is not problematic for lower-bandwidth applications, such as lid open/closed detection in battery-powered notebook computers and portable electronics.

Push-pull outputs are another common feature of ultra-low-power and low-voltage switches and latches. In contrast to a single open-drain field-effect transistor (FET) and external pull-up resistor, push-pull outputs use two transistors that switch on and off to pull down or pull up the output. While push-pull outputs consume much less power than open-drain configurations, push-pull outputs cannot deliver high-output drive currents. Therefore, output drive requirements need to be analyzed carefully. Compared to open-drain outputs that can deliver up to 25 mA of drive current and also provide different on and off output voltages depending on the applied output voltage, push-pull outputs are generally limited to approximately 1 mA; however, this is more than enough for most high-impedance digital input/output (I/O) interfaces.

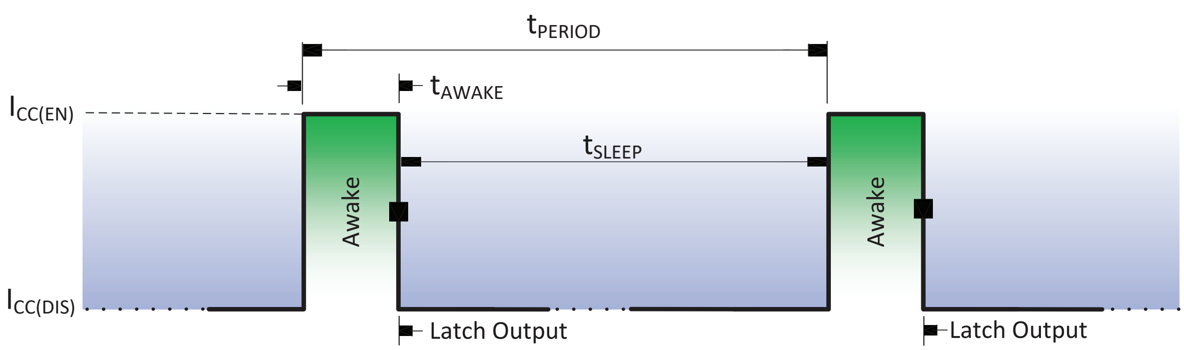

Figure 16: Micropower Operation

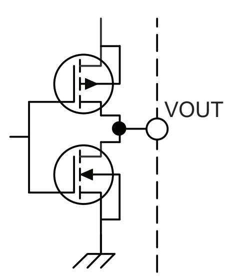

Figure 17: Push-Pull Output Configuration

Allegro XtremeSense TMR switch and latch products (CT811x, CT812x, CT813x) detect the magnetic field by use of a tunneling magnetoresistive (TMR) transducer in place of a Hall plate. Compared to a Hall sensor, a TMR transducer offers greater sensitivity and higher bandwidth performance, which allows these devices to achieve sub-µW power consumption levels.

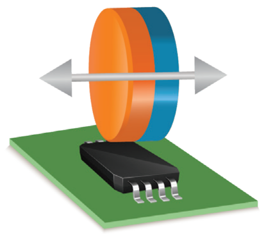

Figure 18: XtremeSense TMR Switch or Latch Position Sensor

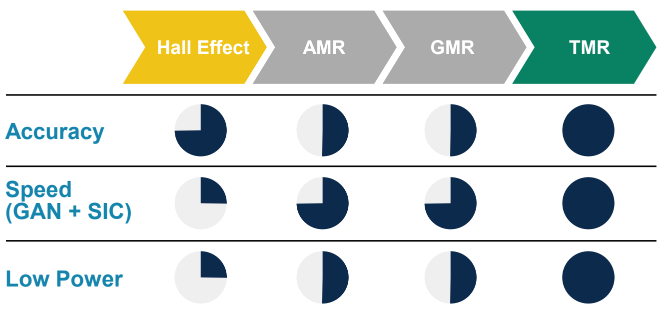

Figure 19: TMR Sensors Offer Higher Bandwidth and Greater Sensitivity

IS ASIL RATING A NEED?

Some automotive applications require switches and latches to be rated at the Automotive Safety Integrity Level (ASIL). ASIL is a risk classification scheme defined by ISO 26262. Allegro has a wide variety of switches and latches across its portfolio that are ASIL rated and are thus well suited to automotive applications. These include three-wire and two-wire configurations with X-, Y-, or Z-axis sensing, such as the Allegro APS12450, APS11800, and A113x families.

IS ESD IMPORTANT?

Compared to other applications, automotive high-voltage applications typically require the capability to withstand higher levels of electrostatic discharge (ESD) according to the human body model (HBM). Conversely, low-voltage applications typically have less stringent ESD requirements. Allegro HBM ESD ratings for high-voltage switches and latches are typically in the range of 4 kV to 6 kV. However, Allegro also offers some parts with ESD-withstand capability in excess of 12 kV.

QUICK SELECTION GUIDE

A selection of Allegro devices that represent the different options discussed in this application not is shown in Table 1. For detailed information about all available Allegro parts and datasheets, visit:
https://www.allegromicro.com/en/products/sense/switches-and-latches

Table 1: Selection of Allegro Switch and Latch Devices

Part Number	Switch or Latch?	Two-Wire or Three-Wire?	Low Voltage or High Voltage?	Micro-power?	Sensing Plane?	Switch Point? (Gauss)	Power On Time? (µs)	ASIL Rated?
APS11753	Switch	Three-Wire	Low Voltage	Yes	Z	15 to 400	100 (max)	No
APS12753	Latch	Three-Wire	Low Voltage	Yes	Z	10 to 400	100 (max)	No
APS115X	Switch	Two-Wire	High Voltage	No	Z	50 to 80	25 (max)	No
APS11800	Switch	Two-Wire	High Voltage	No	Z	50 to 80	70 (max)	Yes (B)
APS12450	Latch	Three-Wire	High Voltage	No	Z	22 to 150	150 (max)	Yes (B)
A1266	Latch	Three-Wire	Low Voltage	Yes	X + Y + Z	25	300 (typ)	No
A1260	Latch	Three-Wire	High Voltage	No	X or Y	25	25 (max)	No
APS11700	Switch	Three-Wire	High Voltage	Yes	Z	40 to 280	350 (max)	No
APS11760	Switch	Three-Wire	High Voltage	Yes	X or Y	40 to 280	350 (max)	No
A121x	Latch	Three-Wire	High Voltage	No	Z	78 to 220	4 (max)	No
CT811x	Switch	Three-Wire	Low Voltage	Yes (TMR)	X	15 and 30	75 (max)	No

Revision History

Number	Date	Description	Responsibility
–	January 8, 2025	Initial release	P. Bolsinger, T. Williams

INNOVATION WITH PURPOSE

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