

A GUIDE TO MAGNETIC POSITION SENSING FOR INDUSTRIAL VALVE APPLICATIONS

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INTRODUCTION

Accurate valve-position feedback is essential for safe and efficient automation in industrial processes. While closed-loop valve-control systems have historically used contact-based sensors like potentiometers and limit switches, and their wear-prone mechanisms present significant reliability challenges in harsh industrial environments. The mechanical wear of these legacy components makes them a common point of failure, which directly impacts system uptime and safety.

Noncontact magnetic-sensing technologies, such as Hall-effect and tunnel magnetoresistance (TMR), address these reliability issues by offering a fundamentally more-robust solution. A detailed comparison of these two technologies is presented in Appendix A: Allegro Magnetic Sensor Technology Overview. By eliminating mechanical contact, sensor integrated circuits (ICs) provide the wear-free position feedback that is fundamental for modern high-performance closed-loop systems (see Figure 1). They also provide numerous other operational advantages:

- **High Reliability and Long Service Life:** Eliminates mechanical wear and is inherently immune to contaminants like dust, oil, and moisture.

- **Flexible and Sealed Integration:** Senses through non-ferrous materials (e.g., plastic, aluminum), allowing the sensor electronics to be fully sealed and physically isolated from the environment.
- **High-Performance Operation:** Provides high-speed capability without mechanical inertia and with reliable performance over a wide temperature range (e.g., -40°C to 150°C).
- **Enhanced Safety and Diagnostics:** Includes on-chip fault detection (e.g., missing or misaligned magnet) for building functionally safe systems.

The purpose of this application note is to provide technical knowledge and design insights for the implementation of the Allegro portfolio of magnetic position sensor ICs, from simple switches to high-resolution angle sensors in linear and rotary valve applications. Following these guidelines enables the design of highly integrated, accurate, and maintenance-free systems that improve long-term reliability and reduce the total cost of ownership.

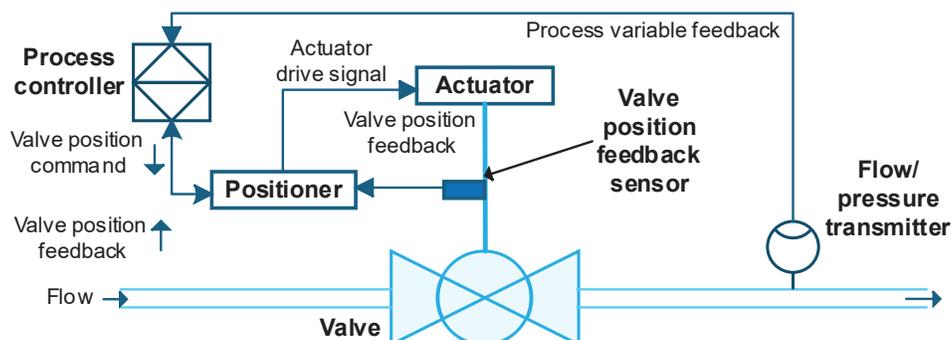


Figure 1: Typical Closed-Loop Valve Control with Position Feedback. The outer process loop uses a process controller to manage the overall flow or pressure, while a critical inner loop uses a position-feedback sensor to ensure the valve actuator has moved to the precise commanded position.

CLASSIFYING VALVE-SENSING APPLICATIONS

Industrial valve applications are fundamentally defined by two characteristics: their motion type and their operational mode.

Motion Type

Linear motion involves a straight-line movement of a stem, common in gate or globe valves, while rotational motion involves the turning of a shaft, characteristic of ball or butterfly valves (Figure 2a). These movements are typically driven by automated actuator types, such as pneumatic, electric, or hydraulic systems.

Operational Mode

Beyond motion, valves operate in either: an on/off mode, which requires simple binary feedback to confirm fully open or closed states; or a modulating mode, which demands continuous, precise position measurement for accurate flow control.

A framework for selection of the appropriate Allegro sensor technology based on these classifications is provided in the matrix in Figure 2b. For modulating applications that require continuous and precise position measurement, advanced linear and angle sensors provide the necessary proportional outputs. For binary on/off feedback in both linear and rotational valves, robust Hall and TMR switches are ideal for validating end-stop positions.

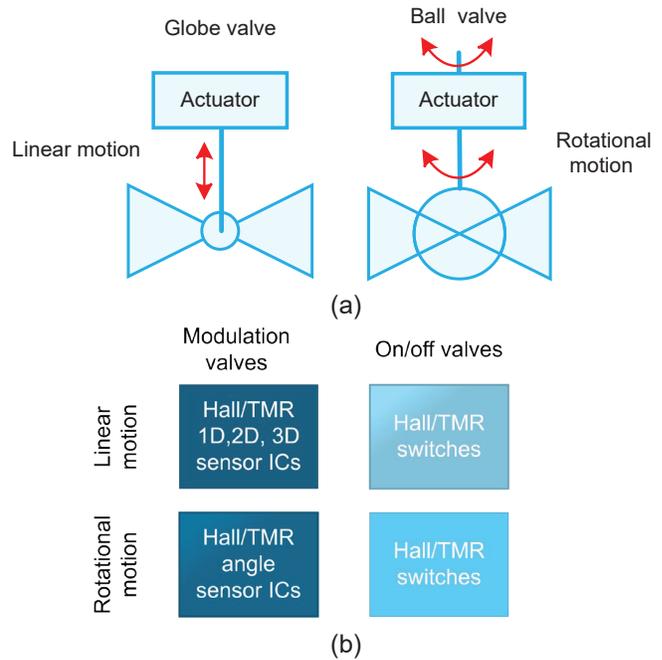


Figure 2: Valve Application Framework. (a) Representative valve movements, showing the linear motion of globe/gate valves and the rotational motion of ball/butterfly valves. (b) The corresponding Allegro sensor selection matrix, which guides the choice of sensor technology based on the motion of the valve and the operational mode.

POSITION SENSING FOR LINEAR VALVES

Modulating Linear Valves: Continuous Position Tracking

Position sensing for modulating linear valves, such as gate or globe types, is achieved by pairing a permanent magnet with a stationary Allegro sensor. This can be implemented in several ways: a magnet can be affixed to the moving valve stem with the sensor mounted in parallel; both can be integrated within the actuator housing for a sealed and protected solution; or, as shown in Figure 3a, the sensor can be mounted on the actuator yoke to detect a magnet on the valve stem. The sensor measures the magnetic field, generating a proportional voltage output that corresponds to the valve position. The magnetic field components (B_x , B_y , B_z) are versus travel relative to the 50% open position, where the magnet is centered on the sensor, is plotted in Figure 3b. Positive displacement from this point opens the valve toward 100%, while negative displacement closes it. A simple approach uses a one-dimensional (1D) linear sensor to measure the magnetic field along a single axis, such as a Hall-effect device (e.g., A31010^[1]) for perpendicular (B_z) sensing or a TMR sensor (e.g., CT100^[2]) for in-plane (B_x) sensing. However, the limited linear range of this magnetic field (as shown in as Figure 3b) restricts this method to short-stroke applications (typically less than 10 mm) and designs that require high mechanical precision.

A more-robust method for linear valve-position sensing involves use of a three-dimensional (3D) sensor to calculate the angle between the axial (B_x) and radial (B_z) magnetic fields. This angle is proportional to stem travel and provides a significantly wider linear range, as shown in Figure 4. While this angle can be converted to an analog or digital output, its linearity can become compromised by mechanical and magnetic nonidealities. To resolve this, advanced Allegro 3D sensors^[3] like the A31315^[4] integrate on-chip linearization, which corrects for these nonlinearities to ensure high accuracy across the entire range of travel. The principles behind these advanced correction techniques are discussed in detail in the Allegro application note [Linearization Parameter Calculation for Allegro AAS33001 and AAS33051 Angle Sensor ICs \(AN296161\)](#)^[5]. To illustrate the benefits of applying linearization, the raw, nonlinearized output is directly compared to the corrected, linearized output in Figure 4. If detection of longer valve stem travels is required, multiple 3D sensors can be used in a cascaded arrangement to achieve long strokes, as described in the Allegro application notes [Slide-By Sensing for Long-Stroke Applications \(AN296115\)](#)^[6] and [Analysis of Hall-Effect System with Two Linear Sensor ICs for 30 mm Displacement \(AN296097\)](#).^[7]

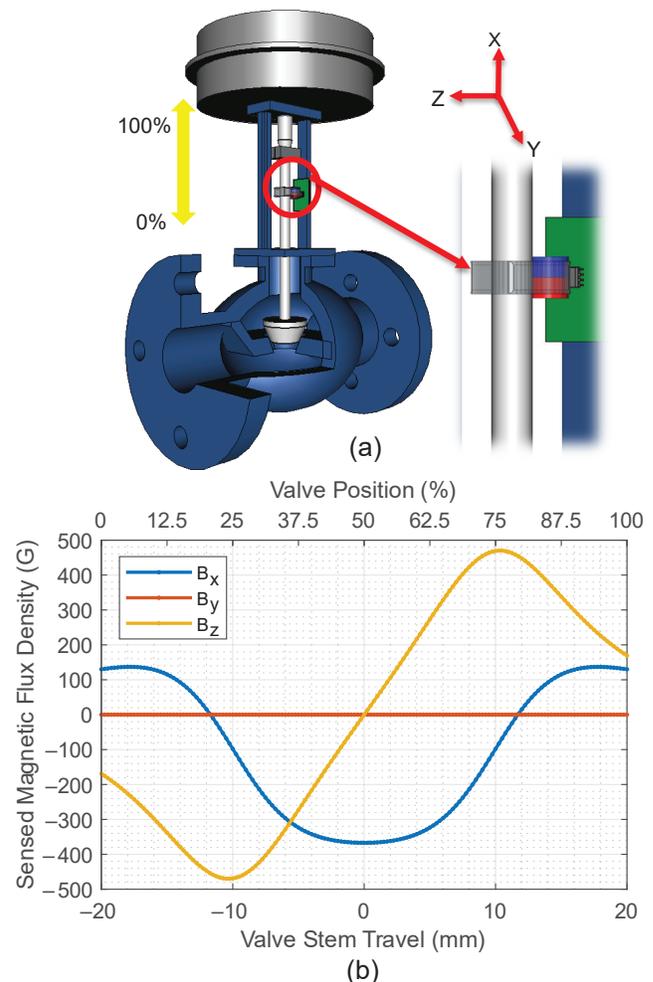


Figure 3: Linear Valve Sensing Principle. (a) A typical magnet and sensor arrangement for a globe valve. (b) The corresponding magnetic field components (B_x , B_y , B_z) versus valve stem travel.

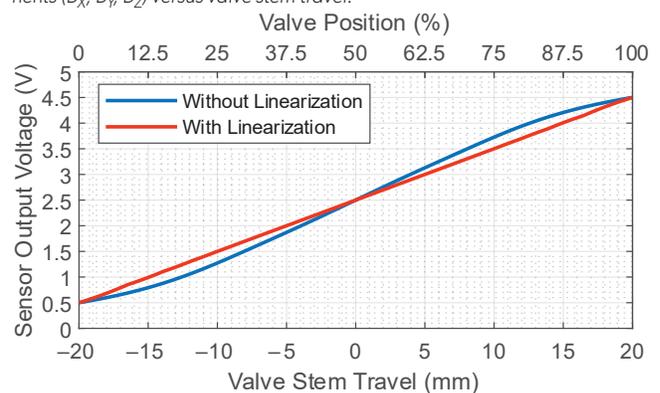


Figure 4: Benefit of On-Chip Linearization for Modulating Valves. Comparison of the raw, nonlinearized sensor output versus the corrected, highly linear voltage output achieved with Allegro on-chip linearization, ensuring accuracy across the full stroke.

[1] <https://www.allegromicro.com/en/products/sense/linear-and-angular-position/linear-sensors-1d/a31010>
 [2] <https://www.allegromicro.com/en/products/sense/linear-and-angular-position/linear-sensors-1d/ct100>
 [3] <https://www.allegromicro.com/en/products/sense/linear-and-angular-position/multi-axis-linear-and-angle-sensors-3d>
 [4] <https://www.allegromicro.com/en/products/sense/linear-and-angular-position/multi-axis-linear-and-angle-sensors-3d/a31315>
 [5] <https://www.allegromicro.com/en/insights-and-innovations/technical-documents/hall-effect-sensor-ic-publications/an296161-linearization-aas330x1>
 [6] <https://www.allegromicro.com/-/media/files/application-notes/an296115-slide-by-sensing-for-long-stroke-applications.pdf>
 [7] <https://www.allegromicro.com/-/media/files/application-notes/an296097-hall-effect-system-with-two-linear-sensor-ics.pdf>

On/Off Linear Valves: Endpoint Detection

To reliably detect the end of travel for on/off linear valves, two unipolar magnetic switches^[8] are placed at the fully open and closed positions, as shown in Figure 5a. A magnet on the moving part of the valve, such as the valve stem, activates the corresponding switch, providing a digital signal (see Figure 5b). Use of a unipolar switch, such as the high-voltage APS11203^[9] for direct connection to industrial supplies or the low-power TMR CT8111,^[10] ensures secure operation by responding only to a specific magnetic pole (e.g., a north pole). This makes correct magnet orientation critical during assembly but prevents false activations from stray fields, guaranteeing a highly reliable system.

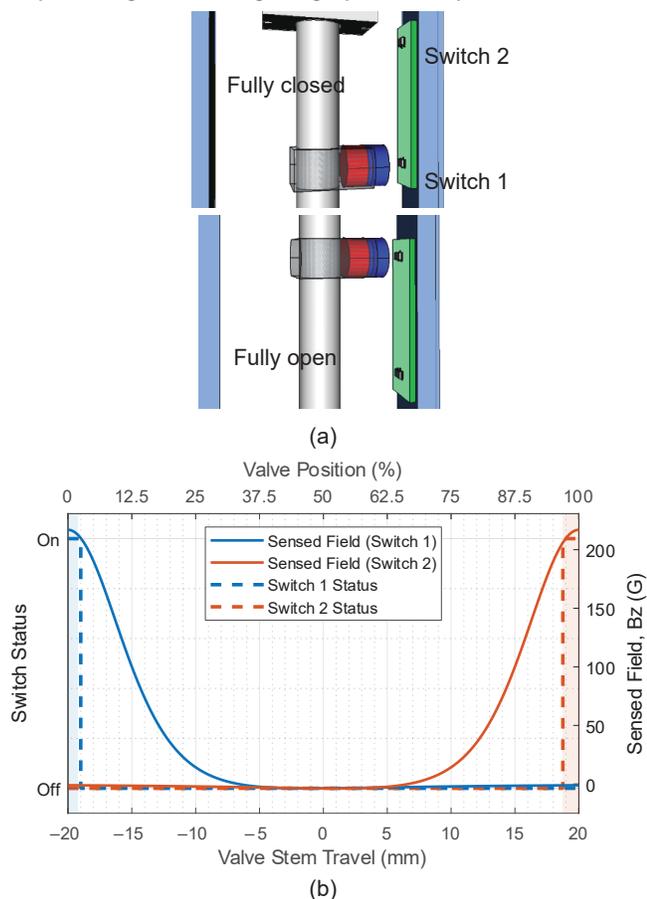


Figure 5: On/Off Linear Valve Endpoint Confirmation. (a) A typical arrangement showing two unipolar Hall-effect switches placed at the fully open and closed positions. (b) The corresponding plot shows how each switch provides a definitive digital ON signal as the sensed field exceeds the magnetic operating point (B_{Op}) threshold.

POSITION SENSING FOR ROTARY VALVES

Modulating Rotary Valves: High-Accuracy Angle Sensing

For modulating rotary valves, such as ball and butterfly types, which typically operate with a 90-degree rotational movement, a permanent magnet is attached to a rotating element. This can be implemented in several ways: the magnet can be placed directly on the valve stem; for a more practical and protected setup, it can be on the output shaft of the actuator, as shown in Figure 6a where a magnet is mounted on top of the shaft with the sensor placed above it; or for the most compact and robust solution, it can be fully integrated within the actuator housing. In each configuration, an adjacent Allegro angle sensor^[11] using either Hall-effect technology with built-in linearization (e.g., A31315^[4]) or advanced stray-field immune Hall technology (e.g., A33023^[12]) detects the changing direction of the magnetic field as the magnet rotates. This enables highly accurate and continuous 0-degree to 360-degree angular position sensing, which is then mapped to the 90-degree travel of the quarter-turn valve, to provide precise position feedback, such as pulse-width modulation (PWM) output, as shown in Figure 6b. This is discussed in the Allegro application notes *Using the A1335 in a Short-Stroke Application* (AN296166)^[13] and *Short-Stroke Rotary Application of the A31315* (AN296204).^[14]

Allegro magnetic sensors, such as the A33023,^[12] can achieve a specified angle error of $\pm 0.5^\circ$ to $\pm 1^\circ$ over temperature with proper system design. For applications that require higher accuracy and resolution, Allegro inductive sensors^[15] are the recommended alternative.

[8] <https://www.allegromicro.com/en/products/sense/switches-and-latches/switches>
 [9] <https://www.allegromicro.com/en/products/sense/switches-and-latches/switches/aps11203>
 [10] <https://www.allegromicro.com/en/products/sense/switches-and-latches/switches/ct811-2-3>
 [11] <https://www.allegromicro.com/en/products/sense/linear-and-angular-position>
 [12] <https://www.allegromicro.com/en/products/sense/linear-and-angular-position/motor-position-sensors-2d/a33023>
 [13] https://www.allegromicro.com/-/media/files/application-notes/an296166_a1335-short-stroke.pdf
 [14] https://www.allegromicro.com/-/media/files/application-notes/an296204-a31315-short-stroke-rotary.pdf?sc_lang=en
 [15] <https://www.allegromicro.com/en/products/sense/inductive-position-sensors>

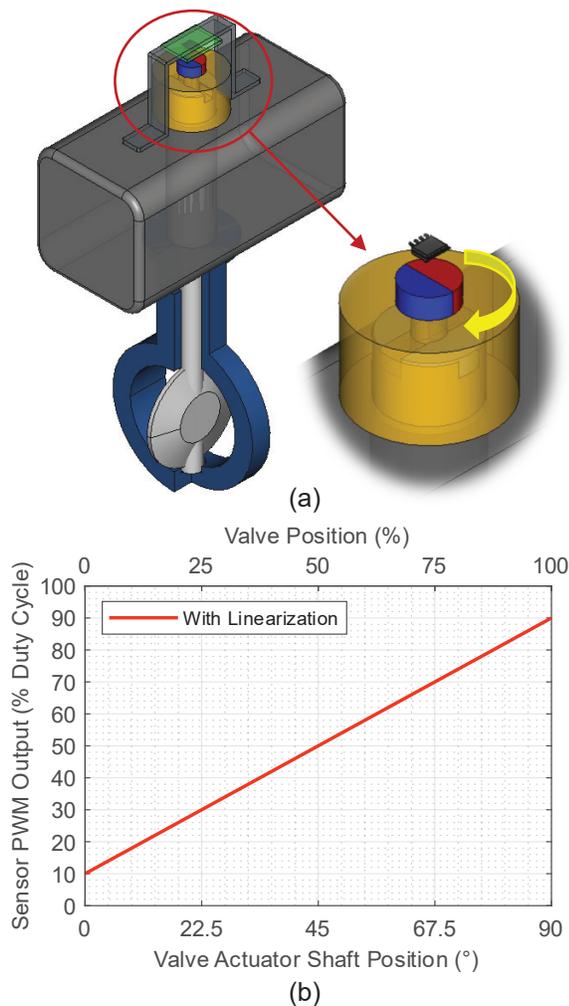


Figure 6: Modulating Rotary Valve Sensing. (a) A common end-of-shaft magnet and sensor placement on a rotary actuator. (b) The sensor raw angle measurement is linearized and mapped to the 0° to 90° travel of the valve, providing a precise PWM output.

On/Off Rotary Valves: Endpoint Detection

For on/off rotating valves, position feedback is achieved in a similar manner to linear on/off applications, employing two magnetic switches to detect the fully open and closed endpoints. A small cylindrical magnet is attached perpendicular to the axis of rotation, as illustrated in Figure 7. When the valve reaches its fully open or closed state, the magnet is brought into proximity with the corresponding switch, activating it and providing a definitive digital signal. Use of unipolar Hall-effect switches, such as the [APS11202](#),^[16] ensures secure operation because the switch only triggers when the correct magnetic pole is presented, which prevents false activations from stray fields.

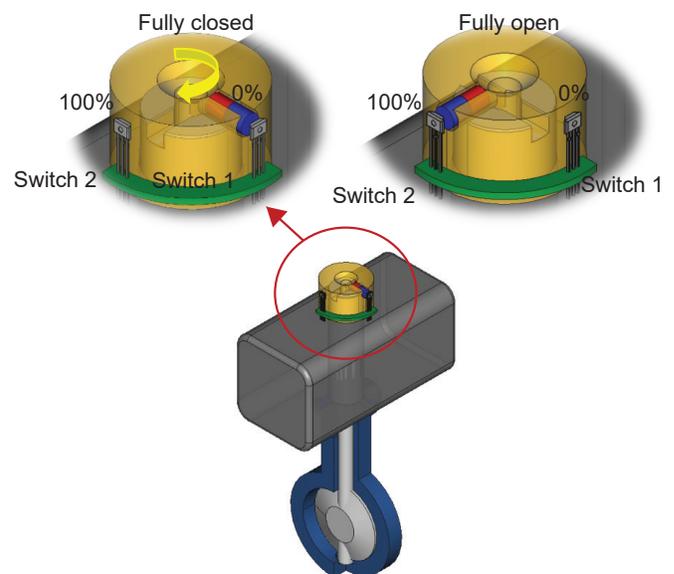


Figure 7: On/Off Rotary Valve Endpoint Confirmation. A magnet mounted perpendicular to the rotation axis activates a corresponding unipolar switch at the fully open and fully closed positions.

[16] <https://www.allegromicro.com/en/products/sense/switches-and-latches/switches/aps11202>

SYSTEM DESIGN AND INTEGRATION CONSIDERATIONS

Mechanical Design and Integration

A robust and accurate sensing system requires treating the magnet, sensor, and mechanical assembly as a single, cohesive system. This section provides guidelines about the key design considerations for this mechanical environment.

Magnet Selection: The selection of the magnet is a key part of the system design process. The magnet should be chosen based on factors like material (e.g., neodymium for high strength, ferrite for cost-effectiveness), geometry (e.g., diametrically magnetized discs for angle sensing), and sufficient magnetic flux density for the air gap required by the application.

Mechanical Design and Integration: To ensure repeatable performance, consistent air gap and precise alignment between the active area of the sensor and the magnet are paramount. This often necessitates custom brackets or precision-machined fixtures. A variety of IC packages are available to facilitate easy mounting and to reduce mechanical stress.

Performance Over Temperature: The overall system must be robust to temperature variations. The sensors undergo a factory calibration process to compensate for their own thermal characteristics, ensuring a stable and accurate output across wide operating ranges (e.g., -40°C to 150°C). While the sensor itself is designed to be robust over temperature, drift of the external magnet also affects system accuracy. For the best performance, designers should either select a magnet with low thermal drift or use an advanced Allegro sensor that can be programmed to compensate for this effect.

Electrical Design and System Interfacing

Power and Signal Integrity: Proper electrical integration is critical for sensor performance. Allegro position sensors are designed to operate at common supply voltages (V_{CC}), such as regulated 3.3 V and 5 V, or over a wide input range for direct connection to industrial or automotive supplies. To ensure stable operation, this supply must be decoupled using a bypass capacitor placed as close as practicable to the V_{CC} and GND pins to minimize noise. Additional passive components, such as resistor-capacitor (RC) filters on output lines, might also be necessary for signal integrity. The device datasheet is the authoritative source for the complete application circuit, including all component values, as shown for the A31315^[4] in Figure 8.

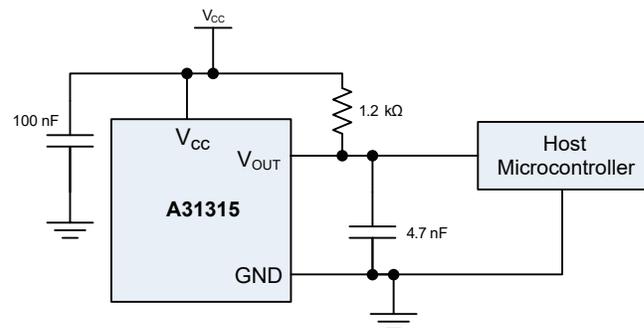


Figure 8: A31315 Typical Application Circuit for Digital Output Modes (SENT/PWM)

Stray Field Immunity: Industrial environments contain sources of stray magnetic fields from motors or high current conductors. Many Allegro sensors mitigate these effects by using differential sensing techniques that inherently reject common-mode fields. For the most demanding applications, advanced sensors like the Allegro A33023^[12] incorporate sophisticated on-chip algorithms that actively compensate for stray fields, enabling accurate position sensing without the need for costly magnetic shielding.

Output Protocols and Industrial Interfacing: A wide variety of output protocols are available, including on/off, analog, PWM, and digital interfaces like SPI, I²C, and SENT. When the magnetic position sensor is an integral part of an actuator, positioner, or valve controller, interfacing is typically straightforward because the main printed circuit board (PCB) is designed to provide the necessary power and to directly read the native output of the sensor. However, for standalone modules interfacing with standard industrial automation systems (e.g., a PLC), additional steps are required. A simple low-dropout regulator (LDO) is commonly used to step down the 24 V power rail of the system to the V_{CC} of the sensor. The native output of the sensor can then be converted to industrial standards. For example, a signal-conditioning IC can translate an analog or PWM signal into a 4 to 20 mA current loop, while a small microcontroller can act as a bridge to protocols like IO-Link or HART. For detailed guidance about how to select the best native protocol, refer to the Allegro application note [Output Protocols for Angle and Linear Position Sensors \(AN296191\)](#).^[17]

[17] https://www.allegromicro.com/-/media/files/application-notes/an296191-ast-output-protocols.pdf?sc_lang=en

CONCLUSION

This application note has demonstrated that noncontact magnetic sensors (Hall-effect and TMR) offer a robust and reliable alternative to wear-prone mechanical sensors for industrial valve-position feedback. For on/off applications, unipolar switches provide definitive endpoint detection. For modulating valves, 3D angle sensors with on-chip linearization and two-point programming deliver high-accuracy continuous position tracking scaled to the specific stroke length. Successful implementation requires a system-level approach, that includes key mechanical design considerations (magnet selection, alignment) and electrical interfacing (power decoupling, stray field immunity, conversion to industrial protocols, such as 4 to 20 mA or IO-Link). The principles outlined in this document provides the foundation for successful design. For application-specific questions, refer to the relevant resources on the [Allegro website](https://www.allegromicro.com/en/)^[18] or in the product datasheet, or contact [Allegro technical support](https://www.allegromicro.com/en/about-allegro/contact-us/technical-assistance)^[19] for further assistance.

[18] <https://www.allegromicro.com/en/>

[19] <https://www.allegromicro.com/en/about-allegro/contact-us/technical-assistance>

APPENDIX A: ALLEGRO MAGNETIC SENSOR TECHNOLOGY OVERVIEW

Hall-Effect Sensors

Allegro Hall-effect sensors operate by generating a voltage across a conductor when exposed to a perpendicular magnetic field. This Hall voltage is proportional to magnetic field strength and is detected by on-chip elements. While this out-of-plane (Z-axis) field sensing is the primary method, Allegro’s advanced sensors also incorporate technology to detect in-plane (X- and Y-axis) fields, enabling high-accuracy 2D and 3D position sensing. Hall sensors feature robust, noncontact magnetic-field detection from permanent magnets, electromagnets, or biased ferromagnetic components. Integrated signal processing delivers switch/latch outputs for ON/OFF sensing, or enhanced continuous outputs (analog, PWM, digital SPI/I²C/SENT) for precise linear or angular position feedback, as described in the Allegro application note [Hall-Effect IC Application Guide \(AN27701\)](#). [20]

TMR Sensors

Tunneling magnetoresistance (TMR) sensors use thin-film stacks of ferromagnetic layers separated by an insulating barrier. Due to this layered construction, TMR technology is inherently sensitive to in-plane magnetic fields that are parallel to the surface of the chip. The resistance across the stack varies depending on how this in-plane field aligns the magnetization vectors, enabling highly sensitive, low-noise magnetic detection. TMR bridges and ICs offer binary switching options, or high-resolution continuous outputs optimized for fine control and compact packaging. For more information, refer to the Allegro application note [From Hall Effect to TMR \(AN117\)](#). [21]

Notes

Practical Robustness Highlights for Hall Sensors: Hall sensors excel where stray magnetic fields (from motors, solenoids) and mechanical tolerances are challenging. Their wide dynamic range and well-established reliability make design-in straightforward.

Power Comment for TMR Angle/Linear: Allegro TMR angle and linear ICs typically operate in the low mA range, comparable to Hall linear/angle ICs. Their higher sensitivity means good signal quality can be maintained with duty-cycled (low average current) operation, especially in energy-sensitive or battery-powered designs.

Table 1: Comparison Table Allegro Hall vs. TMR Sensors

Parameter	Hall Sensors	TMR Sensors
Sensitivity	Good with standard magnets/gaps	Higher; enables smaller magnets, larger gaps
Resolution	Robust; suitable for typical motion	Finer, lower noise
Dynamic Range	Wide; handles strong fields/electromagnetic interference (EMI) well	Narrower; magnet/gap needs planning
Power Consumption	Very low (mA)	Very low (µA)
Technology Maturity	Decades-proven, broad portfolio	Newer, rapid adoption

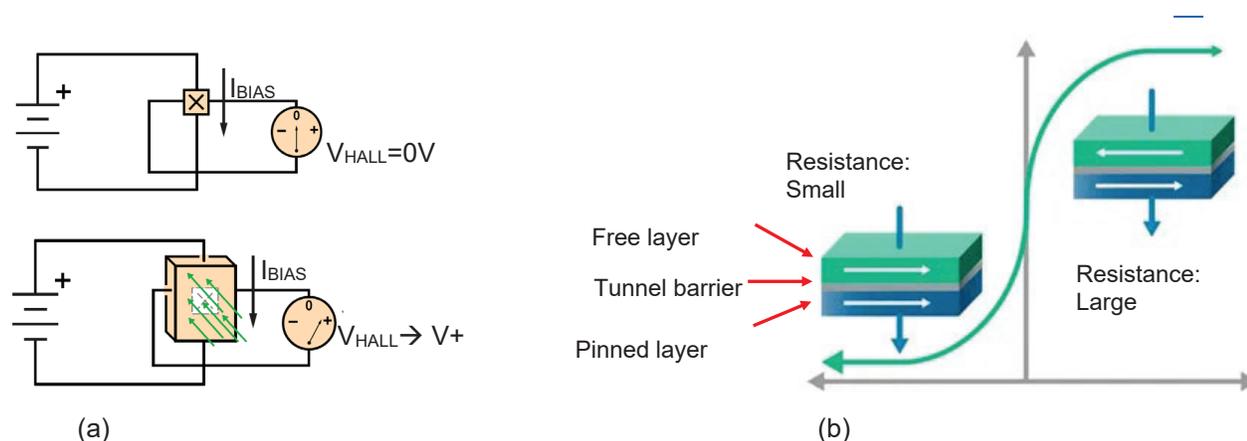


Figure 9: Hall-Effect and TMR Sensing Principles. (a) A Hall-effect sensor generates a voltage proportional to the magnetic field. (b) A TMR sensor has resistance that changes based on the alignment of its magnetic layers.

[20] <https://www.allegromicro.com/-/media/files/application-notes/an27701-hall-effect-ic-application-guide.pdf>
 [21] https://www.allegromicro.com/-/media/files/application-notes/an117-from-hall-effect-to-tmr.pdf?sc_lang=en&hash=E7F1996AF665DE056837C60E3444DEDF

Revision History

Number	Date	Description	Responsibility
-	January 13, 2026	Initial release	Y. Abadi

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