# Selecting the Appropriate Position Feedback Sensor for Factory Automation Valve Designs

WHITE PAPER

Precision Potentiometers

Non-Contacting
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Analog Non-Contacting Sensors

Digital Encoders

## INTRODUCTION

An integral part of automating factory equipment is the ability to read and monitor the real-time position of valves. Programmable Logic Controllers (PLCs) and Input/Output (I/O) modules are now being implemented in factory machinery to transmit valuable information on valve adjustment based on the actual position provided by the position feedback sensor. The valves can be actuated mechanically using hydraulics or with an electronic actuator. If an actuator is used then some type of linear or rotary position sensor measures the movement of the actuator.

The challenge for many factory automation system designers is the wide variety of rotary position feedback sensors currently available. Determining the best fitting rotary position sensor, specifically for valve position applications, is a function of fully understanding all of the sensor types and associated performance characteristics.

Developers typically use four general criteria categories to narrow the choice of sensor technology:

1. Contacting or non-contacting
2. Single-turn or multiturn capability
3. Analog or digital output
4. Communication protocol

This paper will discuss a variety of these choices while presenting the information as a high level guide for selecting the appropriate position feedback sensor for factory valve automation.

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# Selecting the Appropriate Position Feedback Sensor for Factory Automation Valve Designs

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## THE ROLE OF VALVES IN FACTORY AUTOMATION

The mature manufacturing market is driven by the need to constantly reduce costs and manage inventories. A portion of this effort is achieved through efficient power management that is mandated based on industry and government regulations. Automating the factory adds greater efficiency resulting in substantial cost savings and a competitive advantage. Overcoming the challenges of reliability, replacement and downtime requires the use of proper automation technology. Rugged position sensors are an optimal solution that can help maintain high reliability in harsh environments and avoid machinery downtime. Rotary position sensors contribute to longer life for factory equipment, helping to reduce the replacement costs throughout the system.

Valves have long been used to regulate, direct, or control the flow of fluids. Many industrial processes such as power generation, mining, food manufacturing and chemical manufacturing include valves and could benefit from the use of position sensors.

The main building blocks of a typical valve and position sensing system are illustrated in figure 1. The microprocessor control board is housed in anodized aluminum, sealed from fluid and dust ingression. This board interfaces with a motor and position indicator in the valve actuator assembly to control and measure the rotational position of a heavy duty stainless steel gear train. The gear train interfaces with the valve kit to open, close, or partially obstruct the fluid passageway.

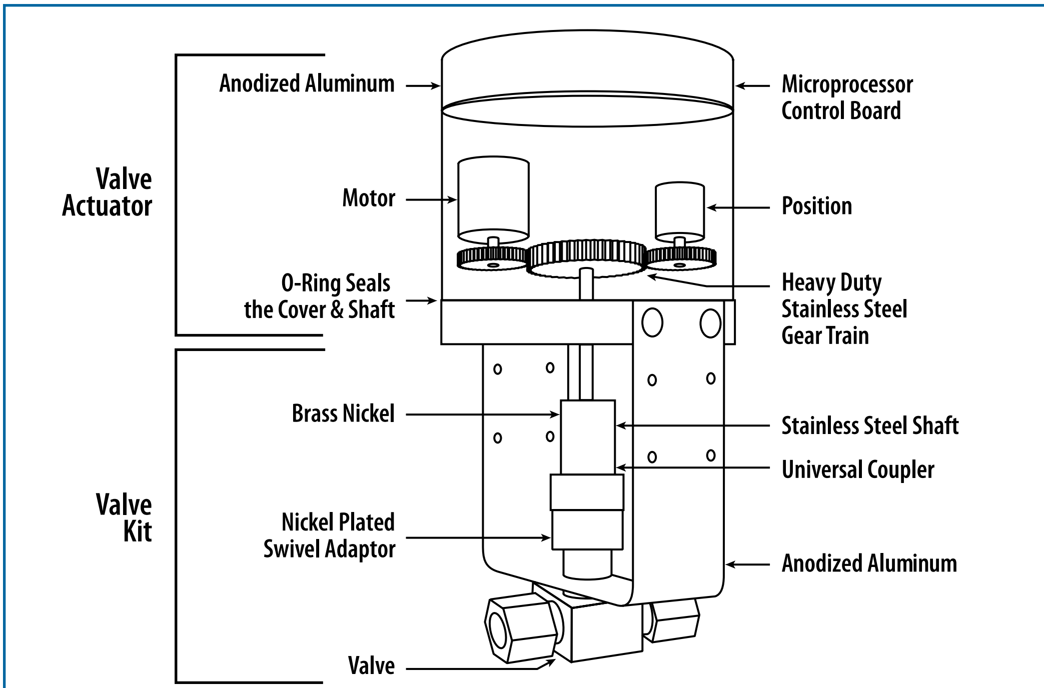


*Figure 1.* | *Typical Valve and Position Sensing System*

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## THE ROLE OF VALVES IN FACTORY AUTOMATION *(Continued)*

Several technologies are enabling advancements in automation. Retrofitting equipment with low voltage Alternating Current (AC) and Direct Current (DC) drives is a growing trend due to their energy efficient benefits. In addition, surge and circuit protection devices enable higher reliability for sensitive circuits such as Programmable Logic Controllers (PLCs) and Input/Output (I/O) ports needed for valve automation. It is essential that these devices conform to safety standards as well as surge and reliability testing to ensure conformance to widely-adopted industry standards. Furthermore, higher connectivity technology and the pervasive Internet are creating an increased demand for self-diagnostics, self-tuning and modern control processing optimization in factory automation systems.

## EVALUATING POSITION FEEDBACK SENSOR TECHNOLOGY OPTIONS

Designing position feedback sensors into a new or retrofit system can be a challenging and technical process, necessitating experienced field application engineering and product line support to help ensure that an optimal solution is reached.

### *Rotary Position Sensors*

Most simple designs can employ a rotary position sensor to translate a resistance or angular mechanical position to an electrical signal. Rotary position sensors are good solutions for applications that require frequent adjustment to control a variable such as speed or position. This type of position feedback sensor provides information to the microcontroller, enabling automated motor position control. A variety of rotary position sensor technologies are available. The three general criteria previously mentioned should be considered before selecting a specific device.

### *Contacting vs. Non-Contacting*

Contacting sensor technology includes a wiper and conductive element which provide a measure of resistance. Wirewound, conductive polymer and Bourns® Hybritron® technologies are the three primary types of contacting technologies relevant to sensors for valve position feedback applications. Wirewound elements offer good stability, excellent linearity, low noise, high power capabilities and good operational life over a wide range of resistance values up to 500 kΩ. The finite resolution steps caused by the wiper moving from turn to turn perpendicular to the coil of the wire is one of the main limitations of wirewound elements. As resistance values increase, smaller diameter wire with a higher number of turns is used, which improves the resolution. If an application is sensitive to discrete steps, then it is critical to select an element with resolution fine enough to meet requirements. Capacitance from turn to turn and also between the winding and the device can affect the performance of a wirewound element, especially when the element has a higher resistance.

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## EVALUATING POSITION FEEDBACK SENSOR TECHNOLOGY OPTIONS (*Continued*)

### *Contacting vs. Non-Contacting (Continued)*

Conductive polymer elements consist of thick film ink printed on elements generally available in a wide range of resistance values and tapers. Static and dynamic noise characteristics (contact resistance variation or output smoothness) and rotational life are improved measurably over wirewound elements and resolution is essentially infinite.

Bourns offers contacting sensors featuring Hybritron® technology. Hybritron® technology consists of a wirewound element with a conductive polymer coating, enabling smoother output and higher resolution than traditional wirewound technology. Bourns® Hybritron® elements combine the temperature coefficient and resistance stability of wirewound elements with the long operational life, high resolution and low noise of a conductive polymer element.

Non-contacting technology provides a longer sensor life since the wear and tear associated with mechanical contact is eliminated. Optical and magnetic are both types of non-contacting technology that can be used for valve position feedback sensing.

Optical technology utilizes three main components for sensing: a light source, a code disk, and a detector. Non-contacting optical sensors can deliver a longer life span and are capable of higher resolution than sensors using contacting technology. Non-contacting optical technology can be used both in static and dynamic applications.

Magnetic technology utilizes two major components: magnet and sensor. Non-contacting magnetic encoders are capable of operating reliably in very high speed and high temperature applications. They are intended for use in dynamic and non-dynamic applications.

### *Single or Multiturn Capability*

Depending on the application, either a single-turn or multiturn sensor will be required to account for the full position range, or electrical rotation angle of the valve. This electrical rotation angle can vary from a few degrees to multiple revolutions, where 360 degrees represents a full revolution. Single-turn sensors may allow for continuous rotation, though provide an effective electrical angle that is just less than 360 degrees. In multiturn devices, however, the measurement corresponds to the position of the sensor over the full rotation angle. Several potentiometers offer essentially the same device in terms of packaging, construction, and standard features, with the difference in part number accounting for the number of turns or the mounting style for which the device was designed. Non-contacting technology may not have an upper limit to the number of rotations, and may provide measurements such as revolutions per minute (rpm) for values up to 10,000 rpm.



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## EVALUATING POSITION FEEDBACK SENSOR TECHNOLOGY OPTIONS (*Continued*)

### *Analog or Digital Output*

To determine the optimum sensor output, it is important to consider the sensor interface connection and the amount of available board space. An Analog-to-Digital (A/D) converter that already exists elsewhere on the microprocessor control circuit board will typically convert analog output so it can be used as digital input to the microprocessor. Other times, it is taken as direct input to an analog I/O circuit. If there is no A/D converter on the board, the output of a digital sensor can interface directly with the microcontroller, digital I/O board, or PLC, thus eliminating the need for an A/D conversion process. This approach can reduce memory overhead, wiring and wiring interconnects, and can provide a greater program speed for the microprocessor unit.

### *Communication Protocol*

Typically, potentiometric contacting sensors output a variable voltage, commonly known as an analog signal. This signal requires conversion for use in a digital system, whereas encoders produce an incremental quadrature or absolute output signals that can be directly integrated into digital systems. In today's highly computerized world, it is necessary to have flexibility with communication protocols in order to minimize circuitry and maintain maximum processing speed for a given system. Some of the more popular communication protocols are Synchronous Serial Interface (SSI), Serial Peripheral Interface (SPI), Controller Area Network (CAN), and Pulse-Width Modulation (PWM). These communication protocols are used in interrogation of the sensors to extract real-time data, to activate or deactivate the units, and to perform diagnostics. Each type of communication protocol has its advantages and disadvantages, and is normally selected based on the system requirements.

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## SELECTING A SENSOR

With the fundamentals of sensor technology understood, the capabilities and available customization of the components will distinguish the devices within each category.
Although contacting technology is still widely utilized, high-end valves are now being designed with non-contacting sensors for higher reliability and reduced maintenance. This technology is specifically for valves located in remote locations where system downtime is a major concern and the cost of frequent service is prohibitive. Systems that operate on 3.3 V or lower will require either a potentiometric solution or special interface electronics until newer and more energy efficient ASIC platforms are available. The output is primarily analog, though many designs are moving to digital with the rising popularity of various communication protocols for master-slave control, dual redundancy for high reliability, sleep mode for energy efficiency and other options designed for evolving microprocessor technology used in automation.

### *Precision Potentiometers*

Precision potentiometers are available for designs that can be accommodated with contacting analog components. These precision potentiometers provide accuracy, reliability and performance characteristics important to valve position sensing in factory automation applications. When selecting a position sensor, the first technology to evaluate is contacting analog technology as this selection provides the best option for high resolution and accuracy.

Single-turn potentiometers such as Bourns® Model 6537, 6538, 6539 and 6639 are designed for applications requiring accurate control over an extended temperature range. These potentiometers have essentially infinite resolution over an electrical angle of 340 degrees. The Bourns® Model 6537 and 6538 precision potentiometers feature 1 % linearity and 0.1 % standard output smoothness. The rear terminals are molded in and the device can be customized with non-standard features. The main difference between these models is the extended life available in Bourns® Model 6538. The Bourns® Model 6539 and 6639 are single gang potentiometers constructed to be rugged and high quality for general purpose applications. Both have an exceptional rotational life and provide a high quality, cost-effective option for applications with space constraints. The Bourns® Model 6538 is bushing mount, whereas the Model 6638 is servo mount with continuous and mechanical stop options.

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## SELECTING A SENSOR (*Continued*)

### *Precision Potentiometers (Continued)*

If a multiturn device is required, then the Bourns® Model 3549, 3548, and 3547 provide the same level of accuracy and reliability over a larger range of rotation. Available with wirewound or Bourns® Hybritron® construction, these potentiometers offer high rotational life and a variety of options including an anti-rotation lug, bushing or servo mount configurations, single or dual gang selections, and a bronze bushing with stainless steel shaft option for use under a side load. The Bourns® Model 3590 is another option for an application requiring a single gang, bushing mounted sensor. It uses wirewound technology and is available with a plastic or metal shaft and bushings. Options include an anti-rotation pin and a full body seal. These potentiometers differ in the number of turns and linearity options, as shown in table 1.

*Table 1.* | *Turns-Count and Linearity Options for Multiturn Precision Potentiometers*

| Bourns® Potentiometer | Number of Turns | Linearity |
|---|---|---|
| 3547 | 3 | 0.2 % or 0.25 % |
| 3548 | 5 | 0.15 % or 0.25 % |
| 3549 | 10 | 0.1 % or 0.2 % |
| 3590 | 10 | 0.25 % |

Once the number of turns has been decided, the element type can be selected, taking environment and current levels into consideration. Wirewound potentiometers offer greater moisture resistance, temperature stability, power dissipation, and wiper current capacity over Hybritron® technology and conductive polymer. Hybritron® technology is not recommended for applications requiring high wiper current (greater than 50 mA), though its combined benefits enhance performance in designs with low to moderate wiper current.



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## SELECTING A SENSOR (*Continued*)

### *Analog Non-Contacting Sensors*

If the contacting option does not meet the rotational life requirement of the application, a non-contacting technology may provide a better solution. This is especially true for applications demanding long deployment life, which can be met by the performance characteristics of non-contacting technology. Magnetic technology provides an optimum solution to industrial applications exposed to vibration, shock, temperature extremes, and the ingress of dust or fluid.

The Bourns® Model AMS22 is a family of non-contacting single-turn sensors which provide high reliability for a broad range of applications. Bourns® Models AMS22S, AMS22U and AMS22B Series use Hall Effect magnetic technology to sense rotary position. The robust design of the AMS22 series is suited for pneumatic control, valve position feedback, and actuator motor position feedback. It is highly repeatable and is programmable at the factory for zero position. Servo, bushing and dual ball bearing servo mount options make it viable for many application designs.

Multiturn non-contacting sensors are available in the Bourns® Model AMM20B Series. A wiperless design allows for different engagement mechanisms such as a customized shaft, motor control, or mechanical arm position locator. The slope of the signal is programmable, and it is available with 3, 5 or 10-turn options.

Both products can be factory programmed to provide the proper communication protocol required by the specific system, i.e., PWM, SPI, SSI or other protocol. Programming flexibility provides a single solution for multiple systems.



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## SELECTING A SENSOR (*Continued*)

### *Digital Encoders*

With the increasing use of microcontrollers, valve designs are moving to digital communications. These designs are well-served by Bourns® Model EN Rotary Optical Encoders. The Bourns® Model EN Encoder uses optical technology, and is available with numerous resolution options. The incremental quadrature output signal provides both magnitude and direction of adjustment. The compact size and accuracy of this component along with several mounting options make it versatile for a wide range of applications. The custom ASIC in the Model EN contains debounce filters, eliminating the need for external debounce components, and produces a signal compatible with Transistor-Transistor Logic (TTL) and Complementary Metal Oxide Semiconductor (CMOS) logic circuits. A useful life of up to 200 million rotations makes it a good choice for exceptional performance in extended service applications located in clean and controlled environments.

### *Non-Contacting Hall Effect Sensors*

The most sophisticated option for valve position sensing is a non-contacting Hall Effect rotary position sensor. The Bourns® Model EMS Series Magnetic Encoder has the versatility to interact with many types of systems with its four available output signal types. Bourns® Model EMS22P with Pulse-Wave Modulation (PWM) output provides excellent signal noise immunity in challenging settings. Bourns® Model EMS22D with direction/step output is used for incremental counting in applications such as flow measurement, however, it is not widely used in valve position feedback sensing. Bourns® Model EMS22Q with quadrature output provides direction and magnitude, similar to the Bourns® Model EN, for use in valve feedback sensing. Bourns® Model EMS22A with absolute output uses SSI serial communication, making it ideal for high-speed rotation applications requiring exact positions. This product is not affected by power interruption since each position conforms to a preprogrammed unique code. The rotational life of the Bourns® Model EMS rotary position sensor is approximately 50 times greater than contacting technology, and is sealed to meet Ingress Protection (IP) standard IP 65, providing an optimal and robust solution for industrial settings and environments with a high particle presence. The Bourns® Model H-832-4 Engineering Design Kit is available to enable testing all four options in a specific design.

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## THE RIGHT SENSOR FOR THE JOB

Given the wide range of rotary position sensors available for valve automation applications, the primary design consideration for factory valve automation should be the most reliable solution suited to the environment where the valve will be located. Contacting technology can provide high precision and reliability, whereas non-contacting technology provides a longer deployment life under conditions such as temperature extremes, vibration, shock and the ingress of fluid, dust and other particles.

The second design consideration is the type of adjustment required to fully open, close or monitor the valve operation. A fine adjustment would require a multiturn rotary position sensor, whereas a coarse adjustment could possibly use a single-turn rotary position sensor.

The third design consideration is integration of the position feedback sensor into the system and the required communication protocol. Although a contacting analog output sensor may be an adequate and more simplistic approach to a design, a digital output reduces the complexity of the signal conversion in digital systems, providing direct input to a microcontroller while offering flexibility in communication protocol.

Finally, the cost of the rotary position sensor should be considered for compliance to budgetary constraints. Contacting technology provides a cost-effective solution, whereas more expensive non-contacting solutions offer additional digital communication that can be advantageous for self-diagnostics and enhanced energy efficiency, options that can be important in systems where the valve is located in areas with prohibitive access.

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## CONCLUSION

Regardless of the type of technology chosen, Bourns® components are RoHS compliant* and most models can be manufactured to meet IP standards up to IP 68 for exceptional performance under the harshest environmental conditions.

As the application requirements and sensor technology become more clearly defined and understood, the position feedback sensor solution to be considered can be narrowed until the necessary features are available in one sensor. Whether contacting or non-contacting, single or multiturn, analog or digital, the standard and optional features of Bourns' sensor technology provide a solution for most valve position feedback applications.

Bourns has been a leader in contacting potentiometer technology since its inception and the addition of non-contacting rotary feedback sensor technology offers an expanded portfolio of products. Bourns' expertise and technical support can assist designers in the selection of standard models, or in the creation of robust custom solutions for new and retrofit valve position feedback designs. Including a Bourns® rotary position feedback sensor in a valve assembly allows for accurate, long-term, reliable valve control in the harshest of factory settings.

## ADDITIONAL RESOURCES

For more information about Bourns' complete line of sensors and controls, please visit:

**www.bourns.com**



* RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2011/65/EU June 8, 2011.



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