Using Rotary Position Sensors for Accurate, Long-Term Measurement in Electronic Linear Actuators

APPLICATION NOTE


Precision Potentiometers


Analog Non-Contacting Sensors


Digital Non-Contacting Sensors


Non-Contacting
Hall Effect Sensors

BACKGROUND

Linear actuators are employed in virtually every type of electro-mechanical device requiring linear motion. These pervasive designs are integral to all types of industrial automation equipment, machine tools, robotics, medical imaging and diagnostic devices, solar equipment, automotive parts, computer peripherals such as disk drives and printers and test and inspection applications. Typically, they are designed to be used in conjunction with motors, valves, pumps, switches and dampers.

An integral part of actuated equipment is the ability to determine and monitor the real-time position of the actuator rod. An ideal solution to handle this vital function is to implement rotary position sensors that measure parameters such as movement and the position of the actuator. The output of these sensors is an electronic signal, and this is processed by the system. Electronic linear actuators are now more frequently chosen over hydraulic or pneumatic actuators due to the ease of interface with computing or processing units. With Programmable Logic Controllers (PLCs) and Input/Output (I/O) modules tied closely to the system, the electronic linear actuator sensor provides information that allows for a faster and more accurate adjustment than achievable with a mechanical system. When compared to other types of actuators, electronic linear actuators generally are cleaner, more cost-effective, involve fewer parts and require less maintenance. These advantages, however, are dependent on the quality and capability of parts in the system as well as the sensor that is designed into the system.

Equipment can be idle for long periods of time and may be located in remote areas or harsh environments. It is critical for rotary position sensors to perform reliably at startup in spite of such environmental factors. The lifecycle of the sensor can be a limiting factor in the maintenance cycle of the system due to the expense of downtime, technician labor, and possible sensor replacement. Therefore, a rotary position sensor must meet the specifications of an application including side load capability, mounting style, electrical angle to cover actuator stroke length, rotational life and programmability. Bourns offers a variety of rotary position feedback sensors to meet these strict application requirements and help contribute to reliable, long deployment system operation. This paper will discuss a variety of rotary position feedback sensors including digital, contacting analog, and non-contacting analog, and may act as a high-level guide to selecting the right sensor for a given linear actuator design.

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ACTUATORS IN INDUSTRIAL APPLICATIONS

An actuator is an electromechanical device that incorporates a motor driven by electric current. Its mechanical position is adjusted by translating rotary motion into linear motion. Two examples of electronic linear actuators are shown in figure 1.

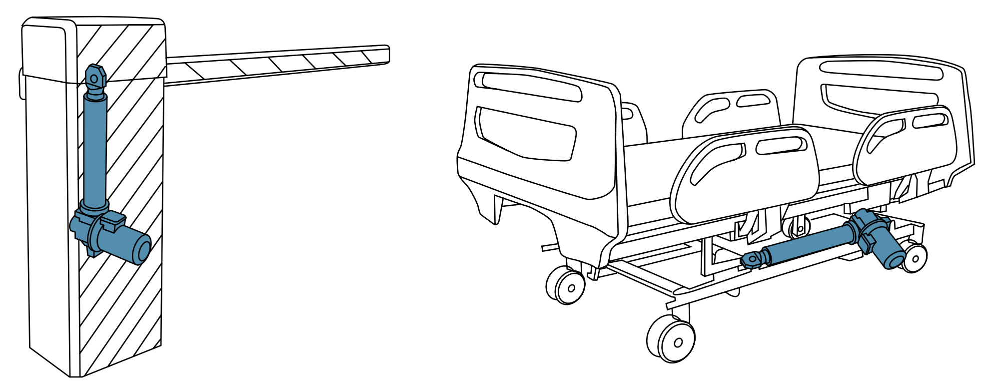

Figure 1. | *Electronic Linear Actuators are used to Adjust the Mechanical Position of an Object in a Security Barrier (left) and Automatic Hospital Bed (right)*

The actuator assembly contains a mechanically linked feedback sensor to relay the angular position and changes in direction. The position sensor can be connected to the drive through a gearing system. As the motor extends or retracts the actuator, the gearing system rotates the shaft of the position sensor providing an electrical output to be processed by a control circuit. Figure 2 illustrates a block diagram with the main components in an electronic linear actuator. Electronic linear actuators do not require pumps, hoses or valves compared to that of a hydraulic system, so the entire system is lighter, quieter, more reliable and easier to install.

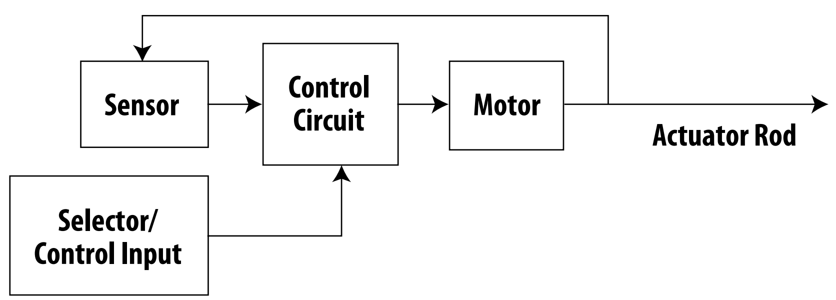

Figure 2. | *The Control Circuit in an Actuated System uses Inputs from a Sensor and Selector/Control Input to Drive the Motor that is Connected to the Actuator Rod*

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ACTUATORS IN INDUSTRIAL APPLICATIONS *(Continued)*

In many cases, industrial applications use electronic linear actuators to automate equipment, thereby improving efficiency, minimizing maintenance and reducing costs. Table 1 provides a comprehensive list of applications that use electronic linear actuators. In an operational loop, standard voltages of 12, 24, or 36 VDC or 115, 230, or 400 VAC power are typical power requirements for linear actuators. The electronic linear actuator moves along a single axis and should maintain its positioning accuracy regardless of the force, speed and number of repetitions or direction changes. The size of the actuator will depend on factors including the load, duty cycle, stroke length and retract length.

Packaging and Handling	Factory Automation	Clean Energy
Pick and place, palletizing	Robots and manipulators	Solar tracking of solar cell panels
Label printing and scanning	Printing and scanning	Adjustment of windmill turbine houses
Carton packing and filling	Welding, soldering, and drilling	Opening and closing of windmill hatches
		Parking brakes in windmills
Machine Tools	**Medical and Health**	**Aerospace and Defense**
Loading and unloading of machined parts	Nuclear medicine, oncology	Ground vehicles and sea systems
Positioning of machining tools	CT, MRI, imaging	Missiles and guided munitions
Operating doors, hatches, safety features	Dental chairs	Maintenance, overhaul, and repair
Other safety features	Patient lifts	Cabin seat positioning
	Wheelchairs and mobility vehicles	
Mobile Off-Highway	**Material Handling**	
Construction, road maintenance	Overhead crane systems	Automatic/manual lift and transport aids
Farm, forestry, turf, lawn, and garden	Conveyor systems	Pick and place equipment
Railways	Production line equipment	
Recreational		

Table 1. | *Actuators are used in a Variety of Industries and Applications*

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THE BASICS OF SENSOR OPERATION

At a fundamental level, a rotary position sensor translates an angular mechanical position to an electrical signal. Position feedback sensors provide information to the control circuit, making automated motor position control possible. Designing the position feedback sensors into a new or retrofit system can be easier if the sensor technology is well understood.

Contacting and Non-Contacting Technology

Contacting sensors use a wiper and resistive element to provide a measure of resistance. Wirewound, conductive polymer and Bourns® Hybritron® elements are three types of contacting technology. Wirewound elements offer good stability, excellent linearity, low noise, high-power capabilities and good operational life. Capacitance from turn-to-turn and also between the winding and the device can affect the performance of a wirewound element in a system, especially at higher resistance values. The resolution (angular distance between steps) of a wirewound element is limited by the number of finite steps over the range of its total electrical angle. Short stroke lengths or long stroke lengths with coarse movement increments can take advantage of wirewound technology. Wirewound technology also offers the best power ratings and stability in temperature extremes. If the electronic linear actuator stroke length is long and the motion control increments are small, then wirewound technology may not be capable of providing adequate resolution.

Bourns offers a hybrid element known as the Hybritron® element that features a wirewound element coated with a conductive polymer resistive ink resulting in smoother output and better resolution than a traditional wirewound. The Bourns® Hybritron® element provides the wirewound benefits of operating temperature stability along with the long operational life, high resolution and low noise of a conductive polymer element. Since many actuators are located in harsh environments and are coupled with heat dissipation from continuous operation, temperature range and stability are important factors in selecting the appropriate technology.

Conductive polymer elements, also known as thick film technology, are another option to consider. These elements are typically ceramic or thermoplastic substrates with a conductive polymer resistive ink silk-screened on the surface. The element is typically paired with a multifinger wiper that produces the output. Conductive polymer elements offer essentially infinite resolution, making them a viable option for actuators with long stroke lengths or very fine motion increments. This element type offers measurable improvement over the wirewound element in terms of static and dynamic noise characteristics (CRV or output smoothness) and rotational life.

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THE BASICS OF SENSOR OPERATION *(Continued)*

Another factor that drives the technology decision is operational life with special consideration to the operating environment, and the cost of maintaining or replacing a sensor in remote locations. Since mechanical contact is eliminated in non-contacting technology, optical and magnetic encoders can provide a longer sensor operational life. Optical encoders contain a light source, code disk and detector to provide measurements with higher resolution than contacting technology. This is an option when fine measurements, long stroke lengths and long operational life are required. Magnetic encoders are also constructed with two major components: the magnet and the sensor. Magnetic encoders are capable of operating in extreme temperatures, whereas, optical encoders should be operated in a more controlled environment. The quick response time of the sensor enables certain non-contacting encoders to capture data at up to 10,000 revolutions per minute, a definite advantage over contacting technology. Magnetic encoders may require shielding when operating in high magnetic field environments, whereas optical encoders are not affected by high magnetic fields.

Single and Multiturn Configurations

An actuator's stroke length will be translated into an electrical angle based on the number of revolutions required for the rotary sensor to cover its full range of motion. This can vary from a few degrees to multiple revolutions, where 360 degrees represents a full revolution. Overall stroke length will help to determine whether a single-turn or multiturn sensor will be needed. Single-turn sensors may allow for continuous rotation if there are no mechanical stops, though they provide an effective electrical angle that is typically just less than 360 degrees. When this range is exceeded by long stroke lengths, for example, then a multiturn sensor is required to provide an output corresponding to an electrical angle greater than 360 degrees.

Analog and Digital Output

Analog has been the primary output signal for sensors, though many designs are moving to digital to take advantage of interface protocols and options introduced by microprocessors. The output of a digital sensor can interface directly with the microcontroller, digital I/O board, or Programmable Logic Controller (PLC), thus eliminating the need for an Analog to Digital (A/D) conversion process. This approach can minimize board space used, memory overhead and wiring interconnects, and it can increase the program speed of the microprocessor unit. Many times, signal conversion is necessary so the sensor output can match the input type required by the control circuit. If an A/D converter exists elsewhere on the microprocessor control circuit board, it can be used to convert a sensor's analog output to a digital signal. The choice of output is affected by the interface to which the sensor is connected, the availability of an A/D converter, and the amount of board space remaining in the actuator assembly. Some sensors can be programmed and configured to provide other communication protocols. 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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FOCUS ON SENSOR SPECIFICATIONS

Given the fundamentals of sensor technology, it is the capability and available customization of the components that distinguish the parts within each category. Several potentiometers offer essentially the same device in terms of packaging, construction, and standard features, with the part number differentiating the rotational life, number of turns or the mounting style for the device's design. In working through the sensor selection process, the designer can start with the simplest contacting design and add complexity until specifications are met, keeping in mind that contacting sensors are the most cost-effective solution should there be budgetary constraints.

Precision Potentiometers

The first technology to examine is contacting analog technology. Precision potentiometers provide the accuracy and reliability necessary for many electronic linear actuator systems. Single-turn potentiometers such as the Bourns® Model 6537, 6538, 6539 and 6639 are designed for accurate control applications over an extended temperature range. These potentiometers have essentially infinite resolution over an electrical angle of 340 degrees and offer 0.1 % standard output smoothness. The Bourns® Model 6537 and 6538 are servo mounted and can be customized with non-standard features. The main difference between the two models is the extended life that the Model 6538 provides. The Bourns® Model 6539 and 6639 are high quality single gang potentiometers with rugged construction. Both have an exceptional rotational life and provide a cost-effective solution for applications with space constraints. The Bourns® Model 6538 is bushing mounted and the Bourns® Model 6638 is servo mounted with continuous and mechanical stop options available.

If a multiturn device is required, then Bourns® Model 3549, 3548, and 3547 provide the same level of accuracy and reliability over 3-, 5-, and 10-turns, respectively. Available with wirewound or Hybritron® technology, these precision potentiometers offer high rotational life and a variety of options including an anti-rotation lug, bushing or servo mount and side load capability. Once the number of turns has been chosen, the element type can be selected, taking environment and current levels into consideration. Wirewound elements offer better performance in terms of moisture resistance, temperature coefficient, power dissipation, and wiper current capacity than conductive plastic and Hybritron® elements. Although their combined benefits enhance performance in designs with low to moderate wiper current, Hybritron® elements are not recommended if the actuator system requires high wiper current.

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FOCUS ON SENSOR SPECIFICATIONS *(Continued)*

Analog Non-Contacting Sensors

If an actuator demands a sensor with a long rotational life, then analog non-contacting technology may be a better choice than contacting technology. In addition to a long lifespan, magnetic technology provides high resistance to vibration, shock, and the ingress of dust or fluid, allowing it to perform well in industrial applications. The Bourns® Model AMS22 Series is a robust, magnetic, single-turn sensor with proven reliability and repeatability. It is programmable at the factory for zero position. The servo mount option is indicated by Bourns® Model AMS22U and a bushing mount by Bourns® Model AMS22B. If a multiturn non-contacting sensor is required, the bushing mount Bourns® Model AMM20B is available with 3-, 5- and 10-turn options. The slope of the signal is programmable. Since there is a great variety of stroke lengths in actuators, having a single product that can be programmed for different stroke lengths is a major advantage of these Bourns® sensors. In addition, this family of products can be modified to meet most popular communication protocols.

Digital Non-Contacting Sensors

If a direct digital signal to a microcontroller is necessary, then the Bourns® Model EN rotary encoder provides an ideal solution with numerous resolution options. The Model EN encoder uses optical technology to provide both magnitude and direction information. Here, one sensor provides two components to a signal. This is a great choice for an actuator that moves back and forth or changes direction often. The Model EN encoder has a quadrature output that is compatible with Transistor-Transistor Logic (TTL) and Complementary Metal Oxide Semiconductor Logic (CMOS) interfaces, and debouncing is not required. The compact size and digital accuracy of this component makes it versatile. A useful life up to 200 million rotations makes it a good choice for extended service applications.

Non-Contacting Hall Effect Sensors

The most sophisticated sensing option is the Bourns® Model EMS22, a highly versatile non-contacting Hall Effect rotary position sensor with four available output signal types: Pulse-Width Modulation (PWM), direction/step, quadrature, and absolute. A PWM signal provides excellent noise immunity in challenging settings. The direction/step option is used for incremental counting. Quadrature signals provide both direction and magnitude, similar to the Bourns® Model EN encoder. An absolute output is not affected by power interruption since each position corresponds to a pre-set unique code, making it ideal for applications that do not have a constant, reliable power source and for systems that require exact actuator positioning. Absolute measurements are formatted similar to serial communication and this option is well-suited for high-speed rotation in fast-moving actuator applications. The rotational lifetime of the Bourns® Model EMS22 rotary position sensor is approximately 50 times greater than Bourns' contacting technology.

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ENABLING RELIABLE, LONG LIFE SYSTEMS

Electronic linear actuators provide the benefits of fewer parts, lower maintenance, and a direct interface to a computerized system. Using Bourns® sensors complements these advantages with benefits at the component level. Given the wide range of Bourns® rotary position sensors available, a designer can evaluate from the simplest to the most complex sensors to find one or more suitable products to meet or exceed design specifications. Whether contacting or non-contacting, single or multiturn, analog or digital, the standard and optional features of Bourns® sensor technology provide options for most actuator applications. Bourns® contacting sensors provide cost-effective, precise, and reliable measurements. Non-contacting technology offers a longer rotational life, increased resolution, and high repeatability. Sensor technology includes rugged and sealed packaging to endure the harsh environments presented in a factory setting. Bourns® components are RoHS compliant* and can be manufactured to meet IP standards up to IP 68.

Bourns has been a leader in potentiometer technology since its inception. This proven expertise enables the company to offer robust solutions for new and retrofit designs. Integrating a Bourns® rotary position feedback sensor in an electronic actuator assembly allows for accurate, long-term, reliable measurement and control in the harshest of settings.

ADDITIONAL RESOURCES

For more information on Bourns® Sensors and Controls, visit Bourns online at:

www.bourns.com

*RoHS Directive 2002/95/EC Jan. 27, 2003 including annex and RoHS Recast 2001/65/EU June 8, 2011

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