

## Optical and Resolver Encoders for Industrial Control Systems:

Applications, Types of Encoders, Specifying Guidelines, and Next Generation All-in-One Field Programmable Encoders.



WHITE PAPER

BY: EZAutomation

## Optical and Resolver Encoders for Industrial Control Systems:

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### APPLICATIONS:

Encoders are used in mechanical motion applications to determine the position, speed and direction. Many of industrial control systems today need to be able to get the position and speed feedback in rugged environments in order to operate. Such applications/industries include: metal stamping, can manufacturing, steel, tire, plating lines, drag lines, earth moving machinery, farm machinery, conveyors, oil drilling, packaging, dam/gate control, assembly, medical, dairy, food processing, semiconductor manufacturing, cranes, military, tank-turrets, textile, converting, printing, palletizing, ware-house control and numerous other industries.

AVG's Autotech Controls division introduced the first encoder product back in 1975 that became a standard on USI Clearing presses. The encoder was used to determine the angular position and speed of the ram in a typical press cycle. It employed a metal disc and shock mounted optics to be able to withstand the shock and vibration of the press at its pinch point. This product line became an automotive standard in the industry with thousands of these presses in operation worldwide with these products still in operation and going strong after more than 35 years.

Moving on from the automotive metal stamping presses, Autotech next addressed the need for a reliable encoder on the end conversion presses used in the 2-piece can manufacturing industry. Due to the vibration caused by these presses, an absolute encoder application was needed, and resulted in a resolver based encoder, providing an accuracy of better than 0.1 deg at 3000 rpm on can manufacturing lines throughout the world.

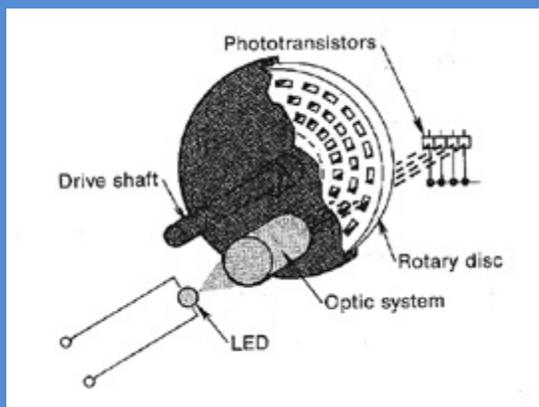
Today, optical encoders and resolvers are more commonly used as recent technological developments allow the prices to be cost effective in industrial control systems. With the introduction of the affordable EZEncoders™ by EZ Automation, there is a paradigm shift in the selection and use of encoders, especially with the advent of field programmability. This paper will explore how to select the right encoder based on its type, as well as the merits and applications for a field programmable Encoder and Resolver which are entirely programmable on the device itself, without the need of a computer or software.

## TYPES OF ENCODERS:

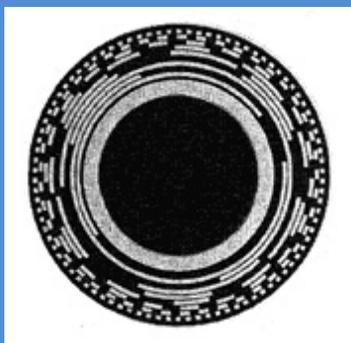
Industrial Encoders come in two types: absolute and incremental. An incremental encoder generates pulses as it rotates, which are counted to give position information relative to a known point, whereas an absolute encoder provides a unique value at each position and retains the actual shaft position, even if the shaft moves during a power failure. Incremental encoders are less complex and have fewer outputs than an absolute encoder, but as a result are usually less expensive. Incremental encoder applications typically require a reset input to zero out the count and start a fresh cycle whereas absolute encoders do not need a reset input as the output is always unique and therefore “absolute”.

### Optical Encoders:

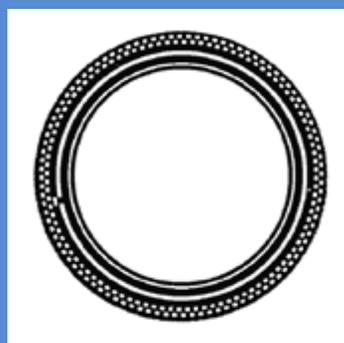
Optical Encoders typically use a simple disk pattern that are meant for industrial applications without extreme shock and vibrations constantly present. Optical Encoders typically consist of a rotating and a stationary member. The rotor is typically a metal or glass disc with an optical pattern mounted on its shaft. The stator has an LED block and phototransistors arranged so that the LED light shines through the transparent sections of the rotor disc and the light is received by phototransistors on the other side.



Incremental Optical Encoders use a simple disc pattern, alternatively interrupting the light beam between the LEDs and the phototransistors, producing a pulse output. The number of pulses depends on the number of slots on the disc. These pulses are then fed to a counter which provides position information. Pulse rate determines shaft speed, and an additional phototransistor can also be used to determine the direction of the rotation. Some models also provide a marker/index pulse output which is generated once every revolution at a fixed shaft position, and is useful to mark a zero reference point. The most common pulse configuration is called the “quadrature”, where two square wave pulses 90 degrees apart from each other are generated.

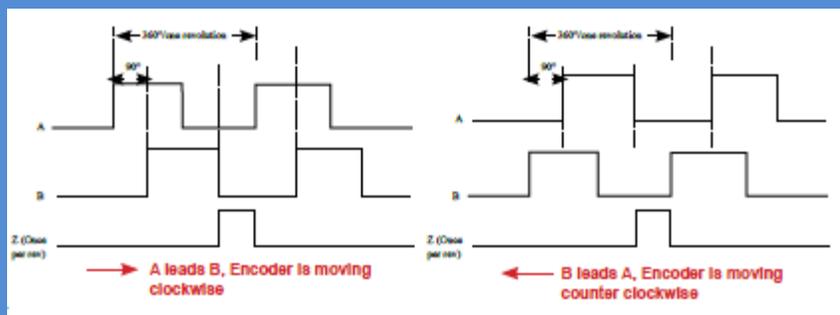


Optical Disc for Absolute Encoder



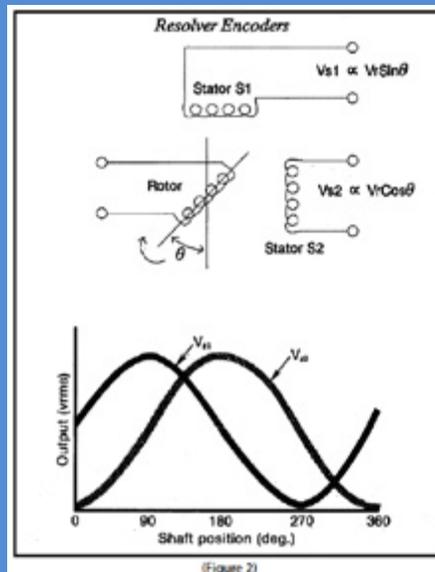
Optical Disc for Incremental Encoder

With a typical Incremental Encoder, there are two channels called A and B, which are electrical outputs from the encoder, phase shifted by 90 degrees, allowing the encoder to be able to determine the direction of rotation. If A leads B (that is A transition occurs before B), the counter can determine which direction the encoder is moving, either clockwise or counterclockwise. If B begins to lead A, it means the encoder has changed direction. A third channel called Z (for Zero/index) is an optional signal which provides a pulse once per revolution that can be used to synchronize zero value in the counter.



**Resolver Encoders:**

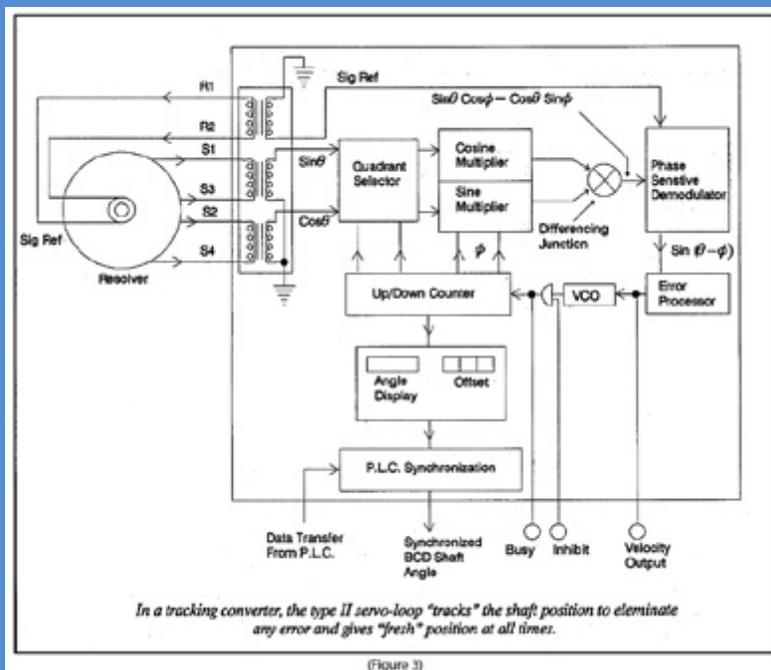
Resolver based encoders are generally required in harsher environments with heavy shock and vibrations such as in press manufacturing. Resolvers are essentially rotary transformers with one rotor winding and two stator windings. They were invented during World War II for military applications and are considered very rugged. The stator windings are located 90 degrees apart and either rotor or stator winding can be used as the primary, with the rotor winding typically driven by a reference voltage at a frequency ranging from 400 Hz to several KHz. As the shaft rotates, the output voltages of the stator windings vary as the sine and cosine of the shaft angle, and these two voltages are a measure of the shaft angle and are converted to a digital signal in the resolver-to-digital decoder.



A Ratiometric Tracking Converter features a Type II servo-loop that comprises of a sine/cosine multiplier and an error amplifier together with phase sensitive demodulator, error processor, voltage controlled oscillator (VCO) and an up/down counter. The information produced by this type of converter is always “fresh”, being continually updated and always available at the output. The basis of determining the shaft angle in a ratiometric converter is the ratio between the two stator signals:

$$\frac{V_{s1}}{V_{s2}} = \frac{V_r \sin \theta}{V_r \cos \theta} = \tan \theta; \therefore \theta = \tan^{-1} = \frac{(V_{s1})}{(V_{s2})}$$

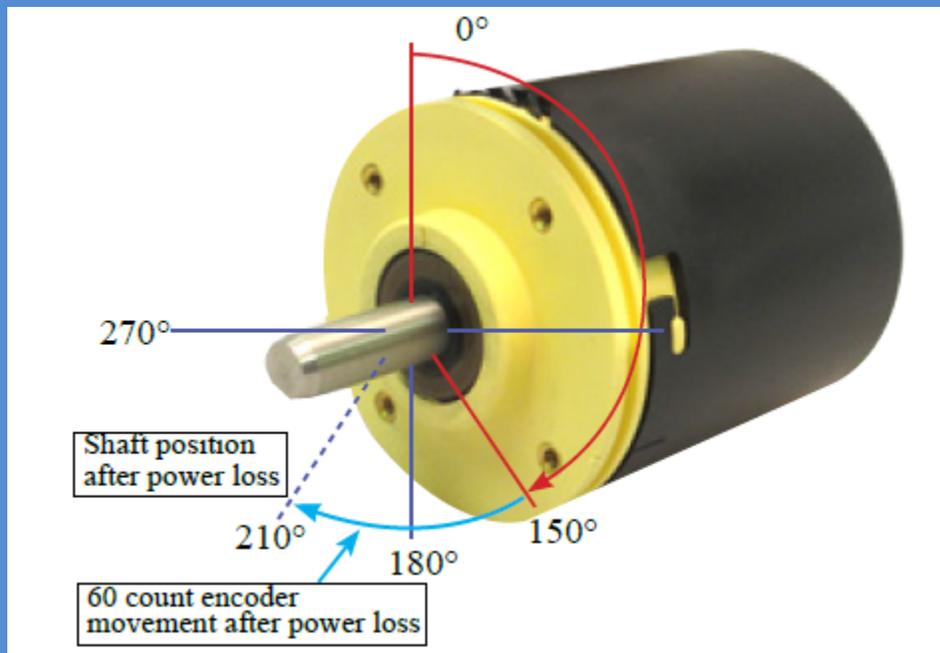
From that relationship, it can be noted that the angle is no longer a function of the induced rotor voltage  $V_r$ , but rather the ratio of  $V_{s1}$  and  $V_{s2}$ . Therefore, the variations in the rotor voltage  $V_r$ , frequency and temperature, are no longer factors in a ratiometric converter, resulting in a highly accurate and repeatable resolver-to-digital converter.



## SPECIFYING ENCODERS:

### 1. Incremental or Absolute:

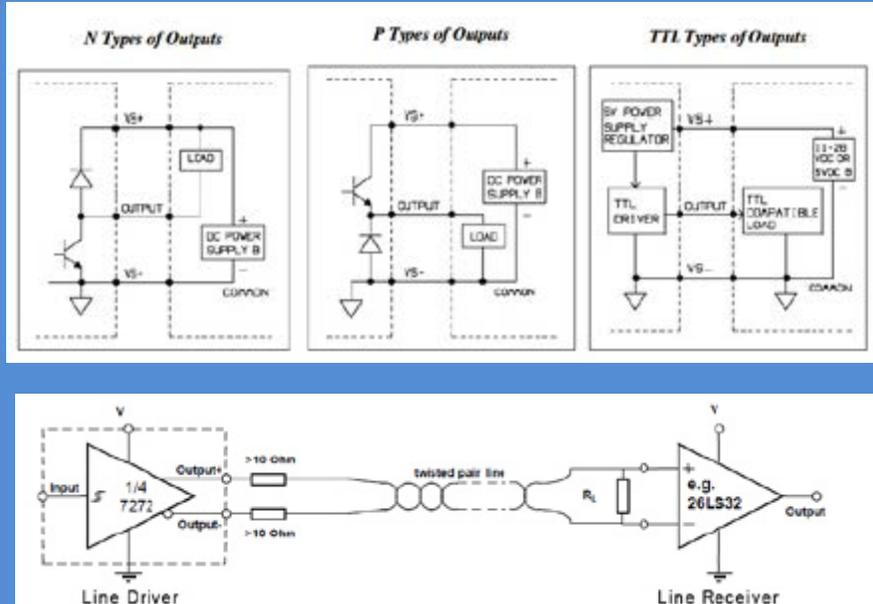
The first parameter one needs to consider when selecting an encoder is whether the position of the encoder is critical at all stages of the operation. Can you afford to lose position in case of power failure? That is the defining question to answer when deciding between an incremental or absolute encoder. If the answer is no, then you must use an absolute encoder. As discussed before, an incremental encoder simply generates pulses proportional to the position, whereas an absolute encoder generates a unique code for each position. After a power outage, with an absolute encoder, the machine operation will pick up from where it had left off even if the encoder shaft had moved during the power down. This is important to keep in mind as an encoder shaft will coast to a stop when power is lost, and not come to an immediate stop. With an incremental encoder, the pulse count is lost upon power loss and the machine will need to be returned to "home" position in order to start operation again. In addition, an incremental encoder is generally more susceptible to electrical noise. Whereas absolute encoders may give you a false output under noisy conditions, the true position is restored when noise is gone. With an incremental encoder, false counts due to noise remain until reset or re-synched. Absolute encoders are more expensive than their incremental counterparts, so a price/feature trade-off may be worth considering.



Application Example: Assuming a 360 count resolution, the encoder shown above has moved 150 counts clockwise. An Incremental Encoder would have given 150 pulses to be counted by an external device. If you lose power to the encoder at this point and assuming the encoder moved another 60 degrees before it came to a stop, the external device would not know that the shaft position is now 210 degrees. However, if it was an absolute encoder that read shaft position and provided a unique value for this position, it will read 210 degrees upon restoration of power.

## 2. Power Supply and Output Signals (NPN, PNP, TTL, or universal "ET7272 line driver")

The power supply for both Optical and Resolver Encoders used in the industrial environment is typically 12 or 24 VDC. The outputs can be either single ended N type (current sinking) with pull up resistors, P type (current sourcing) with pull down resistors, T type for standard TTL totem pole or differential line driver for greater noise immunity and longer cable lengths between the encoder and the interface device. One of the more common output drivers used in today's encoders is a semiconductor chip called "ET7272" which can be used as single ended or differential output. ET7272 outputs are short circuit proof and have an automatic thermal shut down.



3. Mechanical Configuration (Diameter of Housing, Shaft Size / Max Shaft Load, Environmental Rating)

Another key factor pertains to the mechanical configuration options of the encoder. Package selection is based upon the application need as far as mechanical stress on the encoder shaft and housing, and the environment in which the encoder shall be operating. Industry standard sizes of encoders are Size 15 (1.5" housing diameter with 1/4" shaft), Size 25 (2.5" housing diameter with 3/8" shaft), and Size 40 (4.0" housing diameter with 5/8" shaft). The encoder can also be either a Flange mount or Servo mount unit. Note that the Flange mount NEMA 4/IP65 Size 25 or 2.5" diameter encoder with 3/8" shaft, is the workhorse of the industry due to its ideal size and mechanical strength.

Housing	Size 25 2.5" dia.	Size 15 1.5" dia.
Max. Starting Torque @ 25 deg. C (oz. in.)	5 (360.04)	0.07 (5.04)
Moment of Inertia (oz* in^2)	4 x 10 <sup>4</sup>	2 x 10 <sup>4</sup>
Max Slew Speed (RPM)	5000	5000
Shaft Size	3/8"	1/4"
Max. Shaft Loading Axial and Radial	80 lb.	10 lb.
Bearing Life at Max. Mfr. Spec. (Rev.)	1 x 10 <sup>9</sup>	1 x 10 <sup>9</sup>
Shock	100 g for 11ms	100 g for 11ms
Vibration	20 g to 2000 Hz	20 g to 2000 Hz
Enclosure	NEMA 4/IP 65	NEMA 12/IP 54

EZEncoder™ Mechanical Specifications

4. Resolution of Encoder (Counts / Revolution: 100, 180, 250, 360, 500, 720, 1024, 2048, 4096 etc..)

The Resolution also described as PPR of an encoder is important when determining the amount of accuracy required. The resolution of an encoder refers to the number of counts provided in exactly one complete revolution of 360 degrees. The higher the resolution, the more number of segments counted per one complete cycle, hence the higher degree of accuracy. Traditional encoders are ordered with specific resolutions based on the degree of accuracy needed for the application. However, next generation encoders offer field programmability where one encoder can be used for various application design requirements.

NEXT GENERATION FIELD PROGRAMMABLE ENCODERS:

The EZEncoder™ P Series encoders are revolutionizing the way either Incremental or Absolute encoders are used in the field. Rather than having to select a fixed resolution encoder based on anticipated Pulses Per Revolution requirements, the Programmable Incremental and Absolute encoders allow a user to program any resolution from 10 to 1024 PPR (Pulses Per Revolution) for incremental and 10 to 4096 Counts/rev for absolute, while the encoder is installed and connected on the machine. With the use of two buttons on the face of the encoder, adjustments can be made on the fly, with no requirement for a Personal Computer, Programming Cable, installed Software, or worrying about having the right connectors available. Programmable parameters include the Resolution (PPR), Direction (Clockwise or Counter Clockwise), Zero Position, Output Format for Absolute (Grey Code, Binary, BCD), and can be password protected so no false settings can be configured.

EZEncoder™ P Series Programmable encoders come equipped with the ET7272 Line Drive Outputs, which allow them to be connected up to 100 feet away from the controller due to the superb line drive capability of the ET7272. It is also short circuit proof with thermal protection. The 3/8" Stainless Steel shaft with an 80lb Axial/Radial load rating, lengthy lifespan ( $1 \times 10^9$  revolutions) and Nema 4/IP65 Engineered Shatter-proof plastic housing, make this the most economical size 25 Encoder, while still providing total Field Programmability.

The Programmable Absolute Resolver models provide additional immunity to extreme shock, vibration and chemical fumes. This is primarily due to the absence of a code disc that could break due to excessive shock and vibration.



In addition to the ease of use and programmability in the field, the LED Display on the front of the Encoder provides immediate feedback to the user with the current position and speed (RPM) of the shaft during operation. As a side note, besides having one encoder fit all applications, the EZEncoders™ of Size 25 are also designed to be drop-in replacements for traditional BEI, Dynapar, Rockwell and EPC encoders.

#### About EZAUTOMATION:

EZAutomation, a division of the AVG Group, is a manufacturer of industrial automation products including, HMI/Operator Interface Panels, Programmable Logic Controllers (PLCs), Power Supplies, Sensors, Industrial PCs, Programmable Encoders, all-in-one HMI-PLC combo units, Proximity Sensors, Encoders and much more. AVG Automation, and its three divisions, Autotech Controls, Uticor Technologies and EZAutomation, have been in business serving the automation industry since 1968. AVG is proud to be one of the only remaining few automation suppliers that continues to manufacture in the United States!

For more information please visit [www.ezautomation.net](http://www.ezautomation.net) or call 1-877-774-EASY (3279)