Selecting the Right Encoder for Your Application

Autotech offers one of the broadest lines of Encoders in the industry, from a tiny size 15 (housing diameter to be 1.5"), industry standard size 25 (2.5" dia), to explosion proof encoders and everything in between including built-in gear trains, along with wide variety of position sensing technologies, electrical character-istics and communication options. This section is written to provide a reference guide to selecting the right encoder for your application.

Basics:

Many industrial control systems need position and speed feedback. In the initial stages, the encoders consisted of potentiometers, brush encoders, magnetic encoders and rarely optical encoders and resolvers. Each device had certain limitations. The potentiometers and magnetic encoders had limited resolution. The brush encoders required frequent maintenance. The optical encoders used incandescent lamps, which were large in size and had limited life expectancy. The resolvers could offer better resolution and accuracy, but were very expensive due to the decoding electronics required. The recent technological developments have brought significant improvements in the initial models. Today optical encoders and resolvers are more commonly used in industry. And with the introduction of cost effective Smart-Encoders by Autotech, there will be a paradigm shift in the selection and use of encoders.

Types of Encoders:

Absolute and Incremental: The incremental encoder, when it rotates, generates pulses, 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 actual shaft position even if power fails and the shaft moves. Incremental encoders are less complex and have fewer outputs, 2 or 3, whereas Absolute encoders typically have 12 outputs, and are generally more 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 absolute. Absolute encoders are also available as multi-turn units with built-in gear trains suitable for linear applications where it takes several revolutions of the encoder shaft to complete one machine or process cycle.

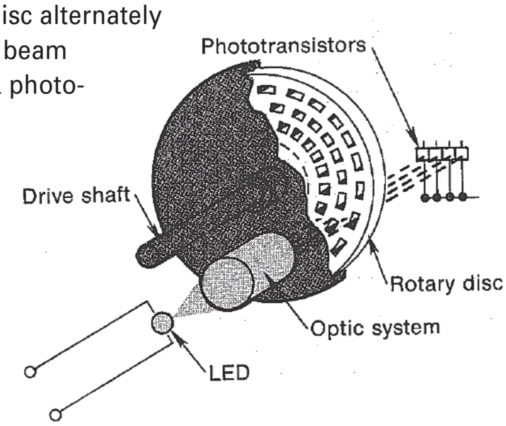
Choice of Optical or Resolver:

Optical Encoders

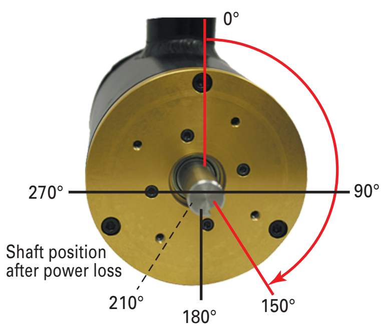
The Optical Encoders typically consist of a rotating and a stationary member. The rotor is usually a metal or glass disc mounted on its shaft. The disc has an optical pattern. The stator has an LED block and phototransistors arranged so that the LED light shines through the transparent sections of the rotor disc and received by phototransistors on the other side.

Incremental Optical Encoder

The incremental optical encoders uses a simple disc pattern. This slotted rotor disc alternately interrupts the light beam between the LED & photo-transistor and thus produces a pulse output. The number of pulses depends on the number of slots on the disc. The pulses are then fed to a counter, where they are counted to give position information.



The pulse rate indicates shaft speed. An additional phototransistor can also determine the direction of rotation. Some models also provide a marker pulse output, which is generated once every revolution at a fixed shaft position and can be used to mark a zero reference point. Many different pulse configurations are available, but the most commonly known is called the "quadrature", where two square wave pulses 90° apart from each other are generated.

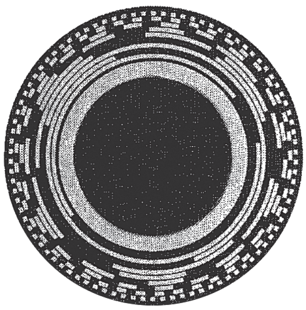


Asssuming 360 count resolution the encodershown has moved 150 counts clockwise. Incremental Encoder would have given 150pulses to be counted by an external device. If you lost power tothe encoder at this point and assuming the encoder moved another 60° before it came to a stop the external device would not know that the shaft position now is 210°, whereas if it was an absolute encoder that read shaft position and provided a unique value for this position, it will read 210° upon restoration of power. Optical encoders from other vendors can be either incremental or absolute whereas resolver encoders are typically absolute. Incremental Smart-Encoders are either optical or resolver based whereas absolute Smart-Encoders use resolvers only.

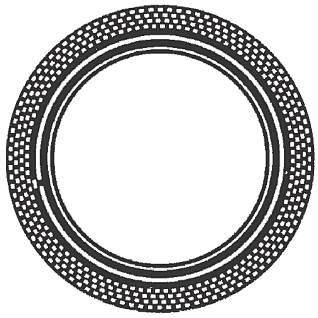
Encoder - Basics

Absolute Optical Encoders

As you can see from the picture of the disc used in an absolute optical encoder, it is much more complex than the simple disc used in incremental encoders. Since the absolute encoder needs to encode a unique value for the shaft position, the number of tracks on the disc and corresponding phototransistors depend on the resolution sought and number of bits used. For example, for a 12 bit absolute encoder with resolution of 4096, you need 12 tracks on the disc. Depending upon the shaft position, the phototransistor output is modulated in a gray-code pattern, which can be converted internally to binary or BCD. The size, complexity and cost of absolute optical encoders increases exponentially with resolution, as the pattern gets increasingly complex with increased number of bits.



Optical disc for Absolute Encoder

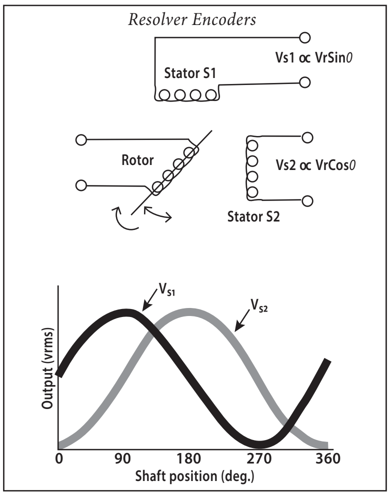


Optical disc for Incremental Encoder

Resolver Encoders

Resolvers, invented during World War II for military applications are by far the most rugged position transducers available. Resolver is essentially a rotary transformer, having one rotor winding and two stator windings. The stator windings are located 90° apart. Either rotor or stator winding can be used as primary. Typically, the rotor winding is 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.



(Figure 2)

See figure 2. The two induced stator voltages are a measure of the shaft angle and are converted to a digital signal in resolver-to-digital decoder.

Ratiometric Tracking Converter

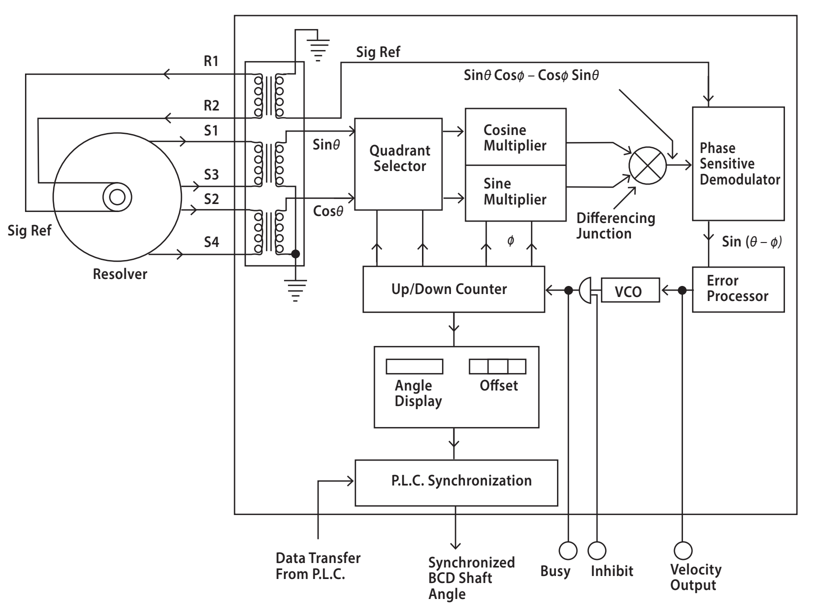
(A typical block diagram for a Ratiometric Tracking Converter is shown in figure 3.)

The circuit features a Type II servo-loop that comprises of sine/cosine multiplier and an error amplifier together with phase sensitive demodulator, error processor, voltage controlled oscillator (VCO) and an up/down counter. Since the VCO is controlled by an error integrator, the greater the lag between the actual shaft angle and the digital angle in the counter, faster will the counter be called upon to "catch-up" or "track" and eliminate the error. The information produced by this type of converter is always "fresh", being continually updated and always available at the output. As an added bonus, additional outputs, such as, an analog output proportional to the shaft RPM to eliminate external tachometers and a busy signal pulse for incremental pulse applications, are also available. The basis of determining the shaft angle in a ratiometric converter is the ratio between the two stator signals:

From this relationship it can be noted that the angle is no longer a function of the induced rotor voltage Vr, but rather the ratio of VS1 and VS2. Therefore, variations in the rotor voltage Vr, frequency and temperature are no longer factors in a ratiometric converter. This results in a highly accurate and repeatable resolver-to-digital converter.

$$\frac{V_{S1}}{V_{S2}} = \frac{V_r \sin\theta}{V_r \cos\theta} = \tan\theta;\ \therefore\ \theta = \tan^{-1} \times \frac{(V_{S1})}{(V_{S2})}$$

Resolver encoders from Autotech are available both as Incremental as well as Absolute outputs.



In a tracking converter, the type II servo-loop "tracks" the shaft position to eliminate any error and gives "fresh" position at all times.

(Figure 3)

Encoder Selection

Housing	Size 40 4.0" dia	Size 40 explosion-proof 4.0" dia.	Size 40 4.0" dia
Max. Starting Torque @ 25 °C (oz. in.)	8 (576.1)	8 (576.1)	5 (360.04)
Moment of Inertia (oz*in^2)	6.4×10^{-4}	6.4×10^{-4}	4×10^{-4}
Max. Slew Speed (RPM)	5000	5000	5000
Shaft Size	5/8"	5/8"	3/8"
Max. Shaft Loading Axial and Radial:	120 lb.	120 lb.	80 lb.
Bearing Life at Max. Mfr. Spec. (Rev.)	2×10^9	2×10^9	2×10^9
Shock		150g for 11 ms	100g for 11 ms
Vibration		20g to 2000 Hz	20g to 2000 Hz
Enclosure	NEMA 4/IP 66	NEMA 4X (Div 1, Class 1, Groups B, C and D)	NEMA 4/IP 66

Factors to be considered for Selection of Encoders

Incremental vs. Absolute

Can you afford to lose position in case of power failure? If the answer is no, then you must use an absolute encoder. 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 power down which is very typical as the encoder shaft will coast to a stop when power is lost. In an incremental encoder the pulses generated are counted in a counter and at power loss it will lose the count and consequently you will have to home the machine before you can start the operation. Typical application examples for Incremental Encoders are “Cut to Length”, Conveyor Control, Augur Control, metering equipment, and machines that use lead screws for motion control such as a milling machine. Upon power down, you have to re-sync the controlled apparatus. Absolute Encoders are used when the machine/process has to know the true position all the time and re-sync is not allowed, such as a Press or Assembly machine or a Dam control or an Oil Valve control. Also, an incremental encoder is generally more susceptible to electrical noise. Whereas absolute encoder may give you a false output under noisy conditions, the true position is restored when noise is gone. On the other hand, if you can false counts with noise when using an incremental encoder, the bad count would remain there until reset or re-synced. The absolute encoders are more expensive than the incremental encoders, therefore, a price/feature trade-off may be worth considering.

Optical Encoder vs. Resolver

This decision is primarily based on the operating environment. The environmental integrity of a brushless resolver is unchallenged. Being simple rotary transformers, the resolvers can take much more abuse than optical encoders and exhibit no significant wear or aging. Especially, if the operating temperature is below freezing or above 150 °F, there is no other choice, but to go for resolvers. Operating temperature range of resolvers is typically between -67 °F to +248 °F. In extremely hostile environment such as continuous mechanical shock and vibrations, humidity, oil mist, coolants and solvents, resolver is the best choice.

Mechanical ratings

Choice of encoder size and NEMA rating also depends on the operating environment. where as size 25 is the work force of the industry due to its ideal size and mechanical strength, NEMA 4 size 15 from Autotech with 50 pound load strength would be ideal where space is a constraint. Size 40, water submersible and explosion proof encoders are self explanatory. Please also note that built-in gear trains are available in only size 40 encoders.

Electrical ratings:

We recommend 24VDC power and 7272 outputs for highest reliabilty and immunity to electrical noise.

Single-Turn vs. Multi-Turn

In a single-turn encoder, the encoder shaft makes one revolution for one complete cycle of machine operation, where as in a multi-turn application, the encoder shaft makes more than one revolutions to complete one machine cycle. Absolute multi-turn encoders and resolvers are available with various built-in gear ratios.

Built-in vs. Remote Decoder

In resolver based encoders Autotech offers a choice of built-in decoder inside the encoder housing or remote decoder. In outdoor applications where temperature could be extreme as well as applications where the encoder is located far away (up to 2500 ft) from the control panel, remote decoder is the best choice.