Incremental Encoders

The incremental encoder creates a series of square waves. The number of square waves can be made to correspond to the mechanical increment required. For example, to divide a shaft revolution into 1000 parts, an encoder could be selected to supply 1000 square wave cycles per revolution. By using a counter to count those cycles we could tell how far the shaft rotated. 100 counts would equal 36 degrees, 150 counts 54 degrees, etc. The number of cycles per revolution is limited by physical line spacing and quality of light transmission.

We provide incremental resolutions up to 288,000 counts per turn through a combination of direct read on the code disc and various multiplication techniques (see count multiplication on next page).

Generally, incremental encoders provide more resolution at a lower cost than their absolute encoder cousins. They also have a simpler interface because they have fewer output lines. Typically, an incremental encoder would have 4 lines: 2 quadrature (A & B) signals, and power and ground lines.

A 12 bit absolute encoder, by contrast, would require 12 output wires plus a power and ground line.

Any Questions?

Call 1-800-ENCODER and ask for “Applications Assistance”
Absolute Encoders

An absolute encoder provides a “whole word” output with a unique code pattern representing each position. This code is derived from independent tracks on the encoder disc corresponding to individual photodetectors. The output from these detectors would then be HI or LO depending on the code disc pattern for that particular position.

Absolute encoders are used in applications where a device is inactive for long periods of time or moves at a slow rate, such as flood gate control, telescopes, cranes, valves, etc.

8 Bit Absolute Disc

Count Multiplication

Incremental encoders are often supplied with two channels (A & B) that are offset from one another by 1/4 of a cycle (90 degrees). This type of signal is referred to as quadrature and allows the user to determine not only the speed of rotation but its direction as well. By examining the phase relationship between the A and B channels, one can determine if the encoder is turning clockwise (B leads A) or counterclockwise (A leads B).

Many counter and controller manufacturers include a quadrature detection circuit as part of their electronics. This allows the use of a two-channel quadrature input without further conditioning.

With quadrature detection we have the ability to derive 1X, 2X or 4X the basic code disc resolution. 10,000 counts per turn can be generated from a 2500 cycle, two-channel encoder by detecting the Up and Down transitions on both the A and B channels. With a quality disc and properly phased encoder, this 4X signal will be accurate to better than 1/2 count.

Another type of count multiplication, interpolation, can be used to electronically subdivide the base resolution. Interpolation is achieved through the use of internal electronics and results in improved resolution. This interpolated signal can be further multiplied through the quadrature detection method mentioned above. Interpolative multipliers of 2, 4, 5, 10 and 20 are readily available. More detail is available on pages 34 and 35.
Typical Applications

Measuring Wheel

Purpose
To measure distance travelled for a cut-to-length operation

Parameters
- Speed of Travel: 25 feet per minute
- Measuring Wheel Circumference: 12 inches
- Desired Resolution: 0.005 inches
- Uni-directional measurement only
- Manufacturing plant environment, very dusty
- 50 foot electrical cable run to controller
- Integrate to programmable controller
- 12V power supply available
- Resolution Required: $12/0.005 = 2400$ cycles per turn
- Output Frequency: $25 \text{ rpm} \times 2400/60 = 1000\text{Hz}$

Encoder Specifications
- Heavy Duty: H25
- Square flange mount: D
- Shaft Seal: SS
- Cycles per Turn: 2400
- Channels: A
- Output IC: 4469 (operates from 5-15 Volts)
- Termination: SM16 (7 pin, side exit)

Model Number
H25D-SS-2400-A-4469-SM16

Linear Position with N/C Display

Purpose
To encode the position of a work table through a ball screw

Parameters
- Rotational Speed: 500 RPM
- Pitch: 1/4
- Total travel: 20 inches
- Desired resolution: 0.0005 inches
- 20 foot cable run to counter
- Oil mist environment
- Overtravel protection required
- 5V power supply available
- Resolution required = Pitch/resolution = $(0.25/0.0005) = 500$ cycles per turn
- Output Frequency = $500 \times 500 / 60 = 4167 \text{ Hz}$

Encoder Specifications
- Heavy Duty: H20
- Square flange mount: D
- Pilot (to accept seal): B
- Shaft Diameter: 25 (0.25” nominal)
- Shaft Seal: SS (protection from oil mist)
- Cycles per Turn: 500
- Channels: AB
- Index: Z (generates home pulse with microswitch at end of travel)
- Output IC: 7272 (operates from 5-24 Volts)
- Termination: SM16 (7 pin, side exit)
- Input Voltage: 5-24V

Model Number
H20DB-25-SS-500-ABZ-7272-SM16-24V
Belt or Conveyor

**Purpose**
To determine relative position, direction and speed of travel in a bi-directional conveyor belt

**Parameters**
- Conveyor Speed: 100 feet per minute maximum
- Desired resolution: 0.002 inches
- Diameter of Conveyor belt drum: 4 inches
- Manufacturing plant: Dust and dirt
- 100 foot cable run to controller
- Programmable controller with high speed counter module requiring 12 volt differential line drivers.
- 12 Volt power supply
  - Drum speed = \((12 \text{ in/ft})(\text{feet/min})/(\pi \times \text{Diam}) = (12 \times 100)/(\pi \times 4) = 95.5\text{ RPM}\)
  - Resolution required = \((4 \times \pi)/(0.002) = 6283\) cycles per turn
  - Use the T5 interpolate feature:
    - \(6283/5=1256.6\) base resolution, use 1257
  - Frequency output = \(6285 \times 95.5 / 60 = 10,004\) Hz

**Encoder Specifications**
- Heavy Duty: H25
- Square flange mount: D
- Shaft Seal: SS
- Cycles per Turn: 6285-T5
- Channels: AB
- Complements: C (for differential line driver)
- Output IC: 4469 (operates from 5-15 Volts)
- Termination: SM18 (10 pin, side mount)

**Model Number**
H25D-SS-6285-T5-ABC-4469-SM18

Linear Actuator

**Purpose**
To encode the position and velocity of a rack and pinion

**Parameters**
- 40 Tooth 1/20 pitch = 2 inches per turn
- 20 inch stroke
- Maximum linear velocity = 10 inches per second
- 0.0002 inch resolution
- Oil spray
- 10 foot cable length
- 24 Volt power supply
  - Resolution required = 2 inches per turn/0.0002 inches = 10,000 cycles per turn
  - Use 2500 base cycles per turn with T4 interpolate for 10,000 cycles per turn
  - Maximum frequency output = 10,000 cycles per turn X 10 inches/sec X 1 turn/2 inches = 50,000 Hz

**Encoder Specifications**
- Heavy Duty: H25
- Square flange mount: D
- Shaft Seal: SS (protection from oil mist)
- Cycles per Turn: 10,000-T4
- Channels: AB
- Output IC: 7272 (operates 5-24 Volts)
- Termination: SCS120 (side exit with cable seal, 120 inches long—uses shielded/jacketed cable)

**Model Number**
H25D-SS-10,000-T4-AB-7272-SCS120
Encoder Quality

Industrial Encoders are available for use over a wide range of environmental conditions. A large variety of designs allows the user to customize an encoder to his requirements. This also allows the specifying engineer to select only the options needed without incurring unnecessary additional costs.

There are a number of factors that must be considered to ensure reliable, consistent encoder operation in industrial applications.

In particular, the encoder must have a high degree of mechanical and electrical stability. In order to achieve this stability the encoder must have a solid foundation. The encoder disc, shaft and bearings must be of the highest quality to assure the ultimate accuracy of the device.

The encoder disc interrupts the light as the encoder shaft is rotated, and it is the code pattern etched on the disc which is primarily responsible for the accuracy of the electrical signal generated by the encoder. Should the disc pattern be inaccurate, the resulting signal will reflect that inaccuracy.

BEI has been a world leader in the development of sophisticated, accurate divided circle machines. These machines are capable of accuracies in the sub arc second range. Originally intended for the military and aerospace industries, this quality is automatically incorporated into the industrial products.

The shaft and bearings maintain accurate rotation of the disc and help to eliminate such errors as wobble and eccentricity which would be translated into position errors. The encoder disc must be carefully mounted to avoid eccentricity as the pattern is read. Such eccentricity can cause inaccuracies in the encoder output that will not be apparent to the user during electrical testing but will cause false position information.

In order to eliminate eccentricity errors, BEI has developed electronic centering fixtures capable of centering accuracies up to 40 millionths of an inch.

When selecting an optical encoder for the industrial environment, the following areas may be considered:

Heavy Loads

In applications utilizing gears or drive belts, excessive radial (side) loading on the shaft can shorten bearing life. Therefore, encoders should be specified in accordance with the anticipated side loading. Typical maximum loads for industrial encoders are 5, 40, and 100 lbs. Ultra heavy duty encoders are available to withstand heavier loads as well as shocks of up to 200g’s.

Corrosive or Washdown

Aluminum encoder housings with a chemical film coating (ex.: Iridite or Alodine) finish are sufficient for most applications. However, if the encoder is intended for operation in a corrosive environment, a hard anodize finish with a dichromate seal should be considered. For food or medical grade applications where a washdown may occur, an electroless nickel coating may be required.

Temperature Extremes

The temperature specification of the selected encoder must be consistent with the application. 0-70 degrees Celsius is the standard operating temperature on BEI’s industrial encoders. Extended temperature testing from -40 to +105 degrees Celsius is available.
Hazardous Environments

Your application may require a special certification, such as explosion proof. Testing for this certification determines that if certain flammable gases infiltrate the encoder housing and are ignited by the internal electronics, the resulting flame or explosion is not able to escape from the housing and ignite the surrounding atmosphere. Specially designed encoders are available that meet the appropriate specification (NEMA Class 1, Group D, Division 1, and NEMA Class 2, Group E, F, & G, Division 1). Intrinsically safe encoders are also available (see pages 46-47).

Electrically Noisy Environments

The increasing use of controllers and microprocessors has resulted in industrial environments that are rich in a variety of electrical signals that can create Electromagnetic Interference (EMI). Some protection can be afforded by the use of shielded cable, especially in conjunction with the use of twisted pair conductors. When this type of cable is used with an encoder and its complements and a differential line receiver, a significant improvement in noise immunity can be realized.

SPECIAL NOTES

Installation

Even with the appropriate package, shaft, bearings, and disc, the user must exercise care to avoid undue shock and abuse. In particular, the bearings or code disc can be damaged if the encoder is dropped or a pulley is hammered on the shaft. The typical shock and vibration specification for an industrial encoder is a 50g shock for 11 msec, as well as a vibration of 20g’s from 2 to 2000 Hz.

Mechanical Protection

To adequately protect the optical and electronic components from exposure to the environment, encoder case thickness should be consistent with the severity of expected abuse. In applications where the housing may be struck by tools or debris, a cast housing or protective shroud should be considered.

Wet or Dirty Environments

If your application requires operation in a liquid or dusty environment, the encoder must be selected accordingly. Adequate sealing is a “must” to ensure against contamination from liquids or dust, particularly through the shaft/bearing assembly. Contaminants that infiltrate the shaft bearing can rapidly degrade encoder performance; they may also work their way to the encoder interior where they can disrupt the optical components or damage the circuit board. A shaft seal is recommended in general, and must be used in applications where liquids are present. If liquid exposure is expected, the user should request a leak test.
Without a shaft seal, the bearings and optical path would be subject to contamination due to dust, dirt and moisture in the environment.

**Inside tip:** A lubricated rotating lip seal provides the best overall environmental protection over the life of the encoder.

Shafts transmit the rotational movement of the device to be monitored into the encoder either directly (hollow-shaft style encoders) or through a flexible coupling (Shafted style of encoders).

**Inside tip:** Look for corrosion resistant shafts and a low TIR (Total Indicated Runout), generally 0.001" or less.

The optics assembly, in conjunction with the electronics, generates a variable amplitude analog signal from the rotation of the code disc and translates it into a digital pulse stream for use by a controller or counter.

**Inside tip:** Electronically centered discs are accurate to better than ±1/40th of a cycle.
Bearings

Bearings, along with the shaft (or shaft tube in the case of a hollow-shaft style of encoder) combine to provide a stable rotational platform which carries the code disc.

**Inside tip:** The most accurate encoders use dual preloaded bearing assemblies.

Covers / Connectors

Covers provide mechanical protection for the internal components of the encoder and seal it against dust and moisture intrusion. Connectors carry the signal through the cover of the encoder body while maintaining environmental protection.

**Inside tip:** All points of entry, including cover screw holes, should be O-ring sealed for the best environmental protection.

Environmental & Operational Specifications

The environmental and operational specifications establish the environment under which the manufacturer feels it is prudent to operate the encoder.

**Inside tip:** Check bearing and temperature ratings carefully. There is no specification standard in the encoder community for these items and if they are critical to your application, you will want to be sure of what you are getting.