A blue rectangular box containing a close-up photograph of two industrial encoders. The encoders are metallic and have various ports and connectors. The background of the entire page is a light blue sky with soft, wispy clouds. In the lower half of the page, there is a pattern of white lines that look like a perspective grid or a series of converging lines, creating a sense of depth and movement.

# ENCODER APPLICATION HANDBOOK



**DANAHER**  
INDUSTRIAL CONTROLS

*A reference guide and tutorial on encoders for motion control:  
types, technologies, applications, and installations.*

## GENERAL

Encoders are sensors that generate digital signals in response to movement. Both shaft encoders, which respond to rotation, and linear encoders, which respond to motion in a line, are available. When used in conjunction with mechanical conversion devices, such as rack-and-pinion, measuring wheels, or spindles, shaft encoders can also be used to measure linear movement, speed, and position.

Encoders are available with a choice of outputs. *Incremental* encoders generate a series of pulses as they move. These pulses can be used to measure speed, or be fed to a counter to keep track of position. *Absolute* encoders generate multi-bit digital words that indicate actual position directly.

Encoders can be used in a wide variety of applications. They act as feedback transducers for motor-speed control, as sensors for measuring, cutting and positioning, and as input for speed and rate controls. Some examples are listed below

- Door control devices
- Robotics
- Lens grinding machines
- Plotters
- Testing machines
- Ultrasonic welding
- Converting machinery
- Assembly machines
- Labeling machines
- x/y indication
- Analysis devices
- Drilling machines
- Mixing machines
- Medical equipment

## SENSING TECHNOLOGY

Encoders can use either optical or magnetic sensing technology. Optical sensing provides high resolutions, high operating speeds, and reliable, long life operation in most industrial environments. Magnetic sensing, often used in such rugged applications as steel and paper mills, provides good resolution, high operating speeds, and maximum resistance to dust, moisture, and thermal and mechanical shock.

### Optical Encoders

Optical encoders use a glass disk with a pattern of lines deposited on it, a metal or plastic disk with slots (in a rotary encoder), or a glass or metal strip (in a linear encoder). Light from an LED shines through the disk or strip onto one or more photodetectors, which produce the encoder's output. An incremental encoder has one or more of these tracks, while an absolute encoder has as many tracks as it has output bits.



**Incremental Disk**



**Absolute Disk**



**Linear Scale**

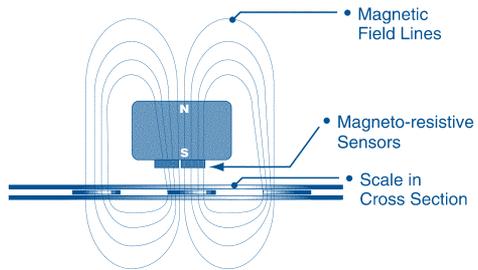
## Magnetic Encoders

Magnetic sensing technology is very resistant to dust, grease, moisture, and other contaminants common in industrial environments, and to shock and vibration. There are several types of magnetic sensors.

Variable reluctance sensors detect changes in the magnetic field caused by the presence or movement of a ferromagnetic object. The simplest variable-reluctance rotary sensor, often called a magnetic pick-up, consists of a coil wound around a permanent magnet. This generates a voltage pulse when a gear tooth moves past it. Rugged, reliable, and inexpensive, this sensor is used mostly to measure speed, as it does not work unless the target is moving past the sensor face at about 180 inches per second or faster.

Another type of sensor uses a permanent magnet and a Hall effect or magnetoresistive device to produce a change in either voltage or electrical resistance in the presence of ferromagnetic material, which can be in the form of a gear tooth (in a rotary encoder) or a metal band with slots (in a linear encoder). This type of sensor will work down to zero speed, and is available in both rotary and linear forms.

Another type of magnetic sensor uses a magnetoresistive device to detect the presence or absence of magnetized “stripes,” either on the rim of a drum or on a non-magnetic strip.

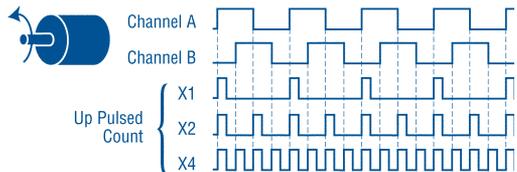


**Inductive Principle**

## ABSOLUTE VS. INCREMENTAL CODING

### Incremental Coding

Incremental encoders provide a specific number of equally spaced pulses per revolution (PPR) or per inch or millimeter of linear motion. A single channel output is used



for applications where sensing the direction of movement is not important. Where direction sensing is required, quadrature output is used, with two channels 90 electrical degrees out of phase; circuitry determines direction of movement based on the phase relationship between them. This is useful for processes that can reverse, or must maintain net position when standing still or mechanically oscillating. For example, machine vibration while stopped could cause a unidirectional encoder to produce a stream of pulses that would be erroneously counted as motion. The controller would not be fooled when quadrature counting is used.

When more resolution is needed, it's possible for the counter to count the leading and trailing edges of the pulse train from one channel, which doubles ( $\times 2$ ) the number of pulses counted for one rotation or inch of motion. Counting both leading and trailing edges of both channels will give  $4\times$  resolution.

An incremental encoder's output indicates motion. To determine position, its pulses must be accumulated by a counter. The count is subject to loss during a power interruption or corruption by electrical transients. When starting up, the equipment must be driven to a reference or home position to initialize the position counters.

Some incremental encoders also produce another signal known as the "marker," "index," or "Z channel." This signal, produced once per revolution of a shaft encoder or at precisely-known points on a linear scale, is often used to locate a specific position, especially during a homing sequence.

## Absolute Coding

An absolute encoder generates digital words that represent the encoder's actual position, as well as its speed and direction of motion. If power is lost, its output will be correct whenever power is restored. It is not necessary to move to a reference position as with incremental type encoders. Electrical transients can only produce transient data errors, usually too brief to effect the dynamics of a control system.

An absolute encoder's resolution is defined as the number of bits in its output word. This output can be in straight binary or in gray code, which produces only a single-bit change at each step to reduce errors.

The difference between incremental and absolute encoders is analogous to the difference between a stop watch and a clock.

A stop watch measures the incremental time that elapses between its start and stop, much as an incremental encoder will provide a known number of pulses relative to an amount of movement. If you knew the actual time when you started the watch, you can tell what time it is later by adding the elapsed time value from the stop watch. For position control, adding incremental pulses to a known starting position will measure the current position.

When an absolute encoder is used, the actual position will constantly be transmitted, just as a clock will tell you the current time.

## Single vs. Multi-Turn

In a single-turn encoder, the output codes are repeated for every revolution of the encoder's shaft. There is no data provided to indicate if the encoder had made one revolution—or 1000 revolutions. With multi-turn absolute encoders, the output is unique for each shaft position, through every rotation, up to 4096 revolutions.

## RESOLUTION AND ACCURACY

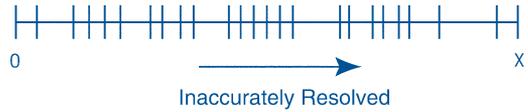
**Resolution** is the number of measuring segments or units in one revolution of an encoder shaft or one inch or mm of a linear scale. Shaft encoders are available with resolutions up to 10,000 pulses per revolution (PPR) directly, and 40,000 PPR by edge-detection of the A and B channels, while linear encoders are available with resolutions measured in microns. The bottom line is, the selected encoder must have resolution equal to or better than that required by the application. But resolution is not the whole story.

Accuracy and resolution are different, and it is possible to have one without the other. This figure shows a distance X divided into 24 increments or "bits." If X represents 360° of shaft rotation, then one revolution has been resolved into 24 parts.

While there are 24 bits of resolution, the 24 parts are not uniform. This transducer could not be used to measure position, velocity or acceleration with any accuracy.

On the other hand, in this figure the distance X is divided into 24 *equal* parts. Each increment represents exactly 1/24 of a revolution.

This transducer operates with accuracy as well as resolution. Accuracy, however, can be independent of resolution. A transducer may have a resolution of only two parts per revolution, yet its accuracy could be  $\pm 6$  arc seconds.



## System Effects on Accuracy and Repeatability

**System Accuracy:** An encoder's performance is typically stated as resolution, rather than accuracy of measurement. The encoder may be able to resolve movement into precise bits very accurately, but the accuracy of each bit is limited by the quality of the machine motion being monitored. For example, if there are deflections of machine elements under load, or if there is a drive screw with 0.1 inch of play, using a 1000 count-per-turn encoder with an output reading to 0.001 inch will not improve the 0.1 inch tolerance on the measurement. The encoder only reports position; it cannot improve on the basic accuracy of the shaft motion from which the position is sensed.

*Note: Given a particular machine design, some errors in measuring motion such as mechanical backlash and errors in leadscrews or gearing systems, can be electronically compensated by some of the more advanced motion controllers.*

**System Repeatability:** Repeatability is the tolerance to which the controlled machine element can be repeatedly positioned to the same point in its travel. Repeatability is generally less than system resolution, but somewhat better than system accuracy. 10,000 pulses per turn can be generated from a 2500 cycle, two-channel encoder. Typically with a Dynapar encoder, this 4 $\times$  signal will be accurate to better than  $\pm 1$  count.

## ENCODER COMMUNICATIONS

The output of an incremental encoder is a stream of pulses on one or two channels, while the output of an absolute encoder is a multi-bit word. This can be transmitted in either parallel or serial form.

### Parallel Output

Parallel output makes all output bits available simultaneously. It may be provided as straight binary or transformed into gray code. Gray code produces only a single-bit change at each step, which can reduce errors. The table on page 6 shows an example of conversion between straight binary and gray code.

Some parallel-output encoders also can accept inputs from the outside—output latching commands, for example, and direction sense setting.

The advantage of parallel output is that it's fast: all the data is available in real time, all the time. Disadvantages include bulky (and expensive) cables and limited cable length. Most encoders come with cables a meter or two long, but a parallel output using differential output and shielded cabling can be extended to 100 m using a thicker cable, at a reduction in speed. Open-collector (sinking or sourcing) outputs can go roughly a third that far.

### Serial Output

The alternative to parallel output is to encode it and send it in serial form. There are several dedicated serial buses available, as well as standard industrial buses. Tradeoffs among these include bandwidth, update rate, hardware requirements, wire count, proprietary vs nonproprietary nature, and availability. The table below summarizes the major differences.

Decimal	Gray Code	Binary
0	0000	0000
1	0001	0001
2	0011	0010
3	0010	0011
4	0110	0100
5	0111	0101
6	0101	0110
7	0100	0111
8	1100	1000
9	1101	1001
10	1111	1010
11	1110	1011
12	1010	1100
13	1011	1101
14	1001	1110
15	1000	1111

Dedicated Serial Interfaces				
	HIPERFACE®	SSI + Sine/ Cos	EnDat®	BiSS
Open Protocol	No	No (License available)	No	Yes
Connection	RS-485: Bus or Point-to-Point Analog: Point-to-Point	Point-to-Point	Point-to-Point	Bus or Point-to-Point
Analog Signals Required	Yes	Yes	No	No
Transmission Mode (Digital)	Bidirectional, asynchronous	Unidirectional, synchronous	Bidirectional, synchronous	Bidirectional, synchronous
Digital Data Transmission Rate	38.4 kBaud	1.5 MHz	4 MHz	10 MHz
Cable Length Compensation	No	No	Yes	Yes
Protocol Length Adjustable	No	No	Yes	Yes
No. of Wires	8	6-8	6 to 12	6
Hardware Compatible				
Alarm/Warning Bit	No	Definable	Yes	Definable

### SSI® (Synchronous Serial Interface)

Synchronous Serial Interface is an all-digital point-to-point interface popular in Europe. It provides unidirectional communication at speeds up to 1.5 MHz and uses a four-wire cable (plus two wires for power).

Some encoders also provide a 1 V p-p sin/cos output for real-time control, since the on-demand absolute encoder data can come in too slowly for many control loops.

Data rate depends on both resolution and cable length, as shown.

Cable Length	Data Rate
50 m	400 kHz
100 m	300 kHz
200 m	200 kHz
400 m	100 kHz

### **EnDat®**

EnDat (Encoder Data) is a proprietary protocol developed by Heidenhain. Like SSI, it is synchronous, with clock signals fed to the encoder by the controller. EnDat can carry more information than SSI, because it provides for internal memory in the encoder that can be read and written to by the controller. This data can include encoder diagnostics, identification, and alarm status. In addition, the controller can set the encoder's zero reference point, which aids in equipment setup. As with SSI, EnDat encoders transmit absolute position data on demand. Depending on version EnDat can include an analog 1 V p-p sin/cos output that electronics in the controller interpolate to derive incremental data for real-time control. EnDat uses a six- to twelve-conductor cable up to 150 m long,

### **HIPERFACE®**

HIPERFACE is a proprietary protocol developed by Max Stegmann GmbH. It uses an eight-wire cable (two for data, two for power and four for 1Vp-p sin/cos) and has two channels: One carries 1 V p-p sin/cos incremental data, while the other is a bidirectional RS-485 link. Absolute position data is transmitted via the RS-485 link at power-up, and the system is incremental after that.

HIPERFACE can access the encoder's memory area for manufacturer's data, status, alarm information, and so on. In addition, the controller can write to certain memory areas, and can set the absolute zero position.

### **BiSS**

BiSS (**B**idirectional **S**ynchronous **S**erial interface), is an open protocol and is the newest of the encoder interfaces. It takes a somewhat different path: BiSS sends full absolute position data whenever the controller polls the encoder, rather than just at startup. It allows easy recovery from momentary data dropouts during operation. Since it is an all-digital system, it eliminates the cost of A/D converters needed in drive systems that connect to encoders using some proprietary protocols. It is hardware-compatible with SSI, requiring only software changes.

BiSS uses four data lines, one pair carrying data from the encoder and one carrying clock data to it, plus two power conductors.

BiSS can address internal registers in the encoder that can be read by and written to by the master with data about the encoder itself (identification, device data, resolution, etc.). It can also carry other digital data (temperature, acceleration, etc.) and transmit it to the master on demand, without interfering with real-time operation.

BiSS, like HIPERFACE, can be connected either point-to-point or via a bus.

## Industrial Bus Interfaces

Three general-purpose industrial buses are commonly used with encoders.

### DeviceNet™

Based on the Controller Area Network (CAN), this system's basic trunkline-dropline topology provides separate twisted-pair wires for both signal and power distribution, enabling 24 VDC devices to be powered directly from the bus. End-to-end network distance varies with data rate and cable size.

### Profibus

This open communication standard developed by the European Community (European Common Standard EC50170), comes in two variations: FMS, which is used for upper level cell-to-cell communication, and Profibus DP, which is optimized for data transfer with local field devices like valves, drives and encoders. There are specific device profiles defined, including one for encoders. DP is good for applications that require high speed transmission of fairly large amounts of information (512 bits of input data and 512 bits of output data over 32 nodes in 1 ms).

### Interbus®

Designed by Phoenix Contact in the mid '80s, Interbus is the longest-standing open industrial network. A true token ring topology, Interbus is actually divided into two buses. The remote bus is an RS-485 transmission medium with length capabilities up to 13 km. The local or peripheral bus enables connection of up to eight devices within a 10 m range.

Bus Network Comparison			
	DeviceNet	Profibus	Interbus
<b>Topology</b>	Linear (trunkline/dropline)	Linear (trunkline/dropline)	Closed Loop
<b>Communication System</b>	Master/Slave	Multimaster (Producer/Consumer)	Master/Slave
<b>Data Exchange</b>	Polled, Change of State, Cyclic	Polled	Polled
<b>Max. Length</b>	500 m	1200 m (w/repeaters)	13 km
<b>Max. Nodes</b>	64	126	512
<b>Data Packet</b>	0-8 bytes	244 bytes	Flexible
<b>Transmission Speed</b>	125 Kbps @ 500 m 250 Kbps @ 250 m 500 Kbps @ 100 m	9.6 Kbps to 12 Mbps	500 Kbps
<b>Transmission Media</b>	2-wire twisted pair with 2-wire bus power cable w/drain wire	2-wire twisted pair w/shield	Local: 3-pair twisted w/drain Remote: 5-pair twisted w/drain

## APPLICATIONS

### Linear/Straight-Line Measuring with Shaft Encoders

Through mechanical means, usually racks and pinions or leadscrews, rotary encoders can measure straight-line or linear motion. Calibrating the number of pulses per unit of measure involves selecting the proper transducer and may include a separate calibration step.

### Measuring Length with Leadscrews

The relationship between resolution, lead screw pitch, and PPR is shown below.

$$\text{Resolution} = \frac{\text{Lead}}{\text{PPR}} = \frac{1}{\text{PPR} \times \text{Pitch}}$$

$$\text{PPR} = \frac{\text{Lead}}{\text{Resolution}} = \frac{1}{\text{Resolution} \times \text{Pitch}}$$

The table below shows some examples. Note that the PPR of an encoder can be doubled or quadrupled by counting the rising and falling edges of one or both output channels, so a 1000 PPR encoder with a 4× multiplication will act like a 4000 PPR encoder.

Encoder PPRs and Servo Resolutions for Typical Leadscrew Applications			
Servo Resolution	Encoder PPR and Logic Multiplier		
	0.5-in. Lead (2 pitch)	0.25-in. Lead (4 pitch)	0.2-in. Lead (5 pitch)
0.0001 in.	1250 × 4	625 × 4	500 × 4
0.00005 in.	2500 × 4	1250 × 4	1000 × 4
0.0005 in.	250 × 4	250 × 2	200 × 2
0.00025 in.	500 × 4	250 × 4	200 × 4
0.0002 in.	625 × 4	625 × 2	500 × 2
0.001 mm	3175 × 4 (special)	3175 × 2	1270 × 4
0.002 mm	3175 × 2	3175 × 1	635 × 4
0.01 mm	635 × 2	635 × 1	508 × 1
0.005 mm	635 × 4	635 × 2	508 × 2

### Examples:

1. An incremental encoder is required on a milling machine to provide a digital readout display. The display must read directly in ten thousandths of an inch. The travel is regulated by a 10-pitch precision leadscrew, which moves the bed 1/10th inch for every revolution of the leadscrew. Using the formulas,

$$\text{PPR} = \frac{1}{\text{Resolution} \times \text{Pitch}} = \frac{1}{0.0001 \times 10}$$

Alternatively,

$$\text{PPR} = \frac{\text{Lead}}{\text{Resolution}} = \frac{0.1}{0.0001} = 1000$$

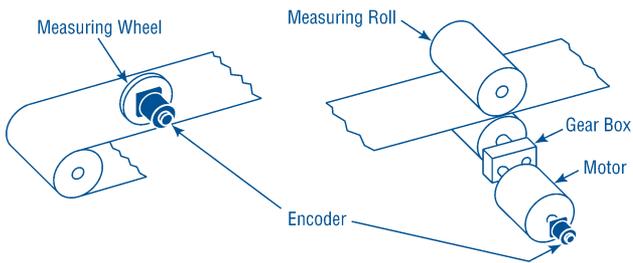
So the encoder must have 1000 PPR, whichever way we calculate it. If we like, we could also use a 500 PPR encoder with a 2× logic multiplier.

- To measure 10 inches of travel to 0.01 inch resolution: Total count = 1000; Resolution = 0.01 inch. If the encoder makes one full turn over the total travel, a 1000 PPR encoder can satisfy this requirement. At full travel, the encoder and counter will read 9.99, which is within the stated tolerance of 0.01 inch.

## Measuring Length with Wheels and Rolls

An encoder can also measure linear distance using a measuring wheel or roll. The table below gives the calibration constant, K, that must be set on the counter or tach readout in order to give the display resolution desired.

### Examples:



**TYPE 1**

**TYPE 2**

Length	Application	
Display Resolution	Type 1 Measuring Wheel	Type 2 Measuring Roll
1 Foot	$K = \frac{C}{12N}$	$K = \frac{0.2618D}{GN}$
1 Inch	$K = \frac{C}{N}$	$K = \frac{3.1416D}{GN}$
0.1 Inch	$K = \frac{10C}{N}$	$K = \frac{31.416D}{GN}$
0.01 Inch	$K = \frac{100C}{N}$	$K = \frac{314.6D}{GN}$
1 Meter	$K = \frac{M}{N}$	$K = \frac{0.079796D}{GN}$
1 Decimeter	$K = \frac{10M}{N}$	$K = \frac{0.797966D}{GN}$
1 Centimeter	$K = \frac{100M}{N}$	$K = \frac{7.97966D}{GN}$
1 Millimeter	$K = \frac{1000M}{N}$	$K = \frac{79.796D}{GN}$
0.1 Millimeter	$K = \frac{10,000M}{N}$	$K = \frac{797.966D}{GN}$

**Example:** In a Type 2 application we wish to display feet to the nearest 1 foot. From the table above:

$$K = \frac{0.2618D}{GN}$$

If  $G = 2.6$ ,  $N = 1$ ,  $D = 9.15$ ,

$$K = \frac{0.2618 \times 9.15}{2.6 \times 1} = 0.92133$$

### Ratio Calibration

In some cases, the desired display is the ratio of two inputs, A and B. This table shows how to calculate the calibration factor, K, for the A and B inputs to the counter to give the desired display resolution.

Ratio Display Resolution	Application	
	Type 1	Type 2
.001	$K = \frac{5C}{N}$	$K = \frac{15.708D}{GN}$
.0001	$K = \frac{50C}{N}$	$K = \frac{157.08D}{GN}$

WHERE:

G = Gear Ratio (increases rpm of encoder in relation to rpm of roll)

N = Encoder pulses per revolution

D = Roll diameter in inches

C = Measuring wheel circumference in inches

**Example:** Assume that both inputs are Type 2 and you want a 0.001-in. display resolution.

$$K = \frac{15.708D}{GN}$$

$$D = 17.0 \text{ in.}$$

$$N = 12$$

$$G = 3.5$$

**Input B**

$$K = \frac{15.708D}{GN}$$

$$D = 19.2 \text{ in.}$$

$$N = 12$$

$$G = 2.8$$

Then:

$$K_A = \frac{15.708 \times 17.0}{12 \times 3.5} = 6.3580$$

$$K_B = \frac{15.708 \times 19.2}{12 \times 2.8} = 8.9760$$

### Establishing Reference Position

#### Reference Pulse

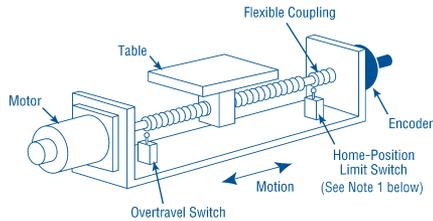
An incremental encoder's reference pulse (sometimes called a Marker or Index Pulse) occurs at a precisely-known point in a 360° revolution of a shaft encoder or along a linear scale. A unique position can be identified by using the reference-

pulse output only, or by logically relating the reference pulse to the A and B data channels. Thus it is most frequently used in positioning and motion control applications as an electronic starting point of known position from which counting or position tracking begins.

In long travel or multiple turns of the encoder, the reference pulse is sometimes used by the control to initiate an electronic check on the total count received from the encoder. For example, each time a reference pulse is received by the control, the total count received from channels A and B should be an even multiple of the encoder's pulses per revolution.

### Ballscrew Position Table Example

In motion control encoder applications, a PLC, CNC, or motion controller will usually command a sequence of moves with each axis of a positioning system to bring the table to the same starting position before beginning a task. The following is a typical automatic referencing and backlash compensation sequence for establishing a home position through the use of an encoder marker pulse.



1. If the Home Switch is open (indicating a position on the positive side of home) when the command is received, the axis is accelerated in the negative direction at the JOG ACCELERATION rate and moved at the FAST JOG VELOCITY until the Home Switch closes.

*Note that a mechanical home-position limit switch is usually not repeatably accurate enough for this application. The encoder reference or marker pulse has much greater repeat accuracy and is therefore a better reference point to establish a starting point for subsequent measurements. The home limit switch is used to signal the control that the next marker pulse signal received is "Home" in multi-turn encoder applications.*

2. The axis is stopped at the JOG ACCELERATION rate.
3. The axis is accelerated in the positive direction at the JOG ACCELERATION rate and moved at the FAST JOG VELOCITY until the Home Switch opens.
4. The axis is accelerated in the negative direction at the JOG ACCELERATION rate and moved at the SLOW JOG VELOCITY until the Home Switch closes and an encoder marker pulse is sensed by the control (in that order).
5. The axis is stopped at the JOG ACCELERATION rate.

### Transducer Operating Speed

All transducers have inherent mechanical and electronic speed limitations, and exceeding them may result in incorrect data or premature failure. The maximum operating speed for a given application will be the maximum electronic operating speed of the encoder and the electronics to which it is connected, or the encoder's maximum mechanical RPM specification, whichever is less.

## GENERAL WIRING AND INSTALLATION GUIDELINES

The most frequent problems encountered in transmitting an encoder's signal(s) to the receiving electronics are signal distortion and electrical noise. Either can result in gain or loss of encoder counts. Many problems can be avoided with good wiring and installation practices. The following descriptions and recommendations are presented as general guidelines and practices for field-installed equipment.

### Protecting Signals from Radiated and Conducted Noise

Take reasonable care when connecting and routing power and signal wiring on a machine or system. Radiated noise from nearby relays (relay coils should have surge suppressors), transformers, other electronic drives, etc. may be induced into the signal lines causing undesired signal pulses. Likewise, the encoder may induce noise into sensitive equipment lines adjacent to it.

Route machine power and signal lines separately. Signal lines should be shielded, twisted and routed in separate conduits or harnesses spaced at least 12 inches from power leads. Power leads are defined here as transformer primary and secondary leads, motor armature leads and any 120 VAC or above control wiring for relays, fans, thermal protectors, etc.

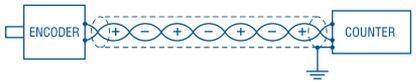
Maintain continuity of wires and shields from the encoder through to the controller, avoiding the use of terminals in a junction box. This helps to minimize radiated and induced noise problems and ground loops.

In addition, operation may be influenced by transients in the encoder power supply. Typically, encoder power should be regulated to within  $\pm 5\%$ , and it should be free of induced transients.

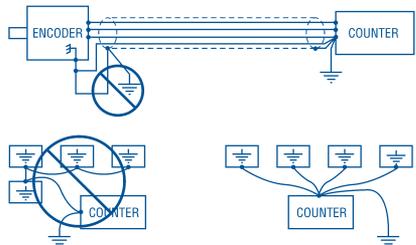
The encoder case must also be grounded to insure proper and reliable operation. Dynapar encoders usually have provisions for a case ground connection through the connector/cable if a ground cannot be secured through the mounting bracket/machine ground. **DO NOT** ground the encoder case through both the machine and the cable wiring. Use high quality shielded wire only and connect the shield only at the instrument end, as shown.



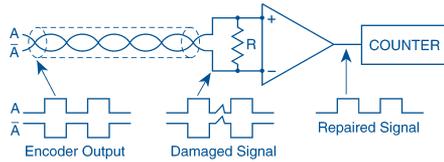
For more protection against electrical noise, specify an encoder with complementary output signals and connect with twisted-pair shielded wire—induced currents will self-cancel, as shown.



In industrial environments, high current fluxes are created by motors, remote control switches and magnetic fields. This can result in varying electrical potentials at different ground points. To avoid problems, ground the shield, together with all other parts of the system requiring grounding, from a single point at the instrument end, as shown.



Signal distortion can be eliminated by complementary encoder signals (line drivers), used with differential receivers (line receivers or comparators) at the instrument end, as shown here.

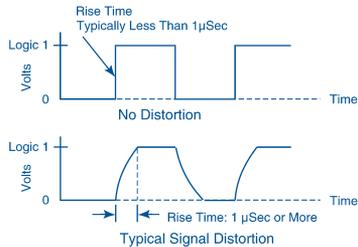


Grounding requirements, conventions and definitions are contained in the National Electrical Code. Local codes will usually dictate the particular rules and regulations that are to be followed concerning system safety grounds.

## Signal Distortion

The majority of signal transmission problems involve electrical noise. Severity of the problem increases with transmission distance. Good shielding practice, as described previously, should be observed.

The primary cause of signal distortion is cable length, or more specifically, cable capacitance.

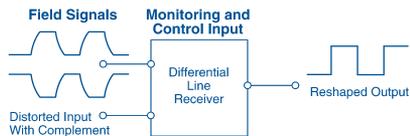


Generally, the receiving electronics will respond to an input signal that is either logical “0” or logical “1”. The region between logical 0 and logical 1 is undefined, and the transition through this region must be very rapid (less than about 1 microsecond). As the leading edge of the waveform is distorted, the transition time increases. At some point, the receiver becomes unstable and encoder counts may be gained or lost.

To minimize distortion, low capacitance cable (typically less than 40 picofarads per foot) should be used. The longer the cable, the greater the potential for signal distortion. Beyond some cable length, the signal must be “reshaped” before it can be used reliably.

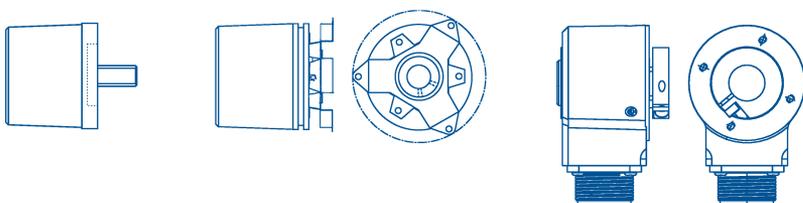
Squarewave distortion is not usually significant for cable lengths less than about 50 feet (capacitance up to about 1000 picofarads). Encoders supplied with differential line drivers are recommended for applications with cable length requirements of hundreds of feet.

Greater assurance of signal integrity is best achieved when an encoder with line driver outputs is used in conjunction with a line receiver.



## MECHANICAL INSTALLATION

Encoders are available in (below, l to r) shaft, hub shaft, and hollow shaft configurations.



The method of coupling the encoder to the machine is important because of possible errors or stresses which can be introduced. Take care not to exceed the rated shaft loading, both radial and axial.

Common causes of difficulty are end thrust, misalignment, and belt or gear thrust. Backlash or modulation in the coupling can cause errors in position indication. The smallest misalignment can result in high radial loads, which lead to premature bearing failure. To prevent this, use a flexible coupling that compensates for the misalignment between the shaft of the encoder and the machine. Generally, the greater the misalignment, the quicker the coupling will fail. When selecting the coupling determine how long it will last under operating misalignment, and the effect of this misalignment on shafts and bearings. This will yield better results than just choosing a coupling solely on the basis of how much misalignment it will take. A coupling will last indefinitely if there is no misalignment.

Encoders usually require a precision instrument coupling to prevent errors caused by backlash and to prevent damage to shaft and bearings. **Specifically, do not use fingered motor couplings with rubber spacers.**

### Timing Belts

Use Series XL timing belts. Reliable long-life encoder performance is achievable provided the belt is installed in accordance with the manufacturer's instructions.

**Belt Tension:** The belt's positive grip eliminates the need for high initial tension. A properly tensioned belt will last longer, cause less wear on encoder bearings, and operate more quietly.

### General Guidelines

Encoders are used to provide precise measurements of motion.

- Never hammer the end of the shaft.
- Avoid hammering the encoder case when mechanical fits are tight.
- Do not subject the encoder to radial or axial shaft stress.
- Do not use a rigid coupling or makeshift mounting techniques.

Encoders provide quality measurements and longer life when common sense, care, and accurate alignments are achieved at the time of installation.



## About Danaher Controls

Danaher Controls designs, manufactures and markets a wide variety of encoders, counters, motion controls and timing products worldwide, including Dynapar, Northstar, and Hengstler brand encoders, Veeder-Root brand counters, Partlow-West controllers and recorders, and Eagle Signal brand timers. For more information, contact your nearest Danaher Controls distributor or Danaher Controls at 1675 Delany Road, Gurnee, IL 60031.

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