

White Paper 2000

Important Considerations when selecting Digital Encoder Outputs

An encoder is an electro-mechanical device that translates mechanical motion into electrical signals. There are two major types of encoders, linear encoders and rotary encoders. Linear encoders have a read head and track. The read head will slide along the track with a predetermined scale. This will produce an output for distance traveled typically in pulses per inch (PPI). A rotary encoder converts the angular movement of a rotational device and will have an output for rotation about the fixed axis typically in pulses per revolution (PPR). Figure 1 shows two typical motion feedback systems where rotary encoders are used.

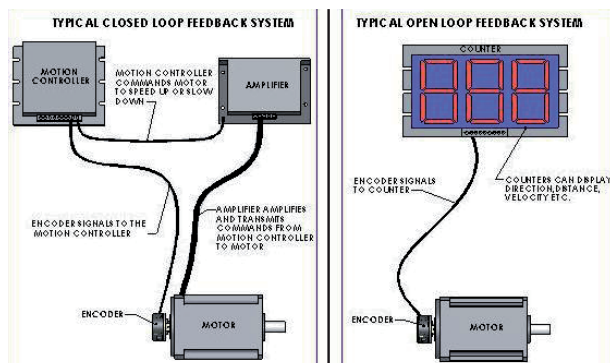


Figure 1. Two types of feedback systems. Closed loop feedback is where the encoder signals control the motor without any user inputs. Open loop feedback is where the encoder signal runs to a display and the user adjusts the motor to fit a desired output.

Within linear or rotary encoders there are two basic types of electrical output formats; incremental or absolute. Absolute encoders have a unique digitally coded output or address for every distinct position of the encoder. Incremental encoders will output a count or pulse at periodic predetermined intervals. Rotary incremental encoders are the most commonly used encoder. We will focus on rotary incremental encoders for this discussion.

There are two important considerations when selecting the outputs of an encoder. The first is the number of output channels. The second is the electrical output characteristics of the encoder channels. In order to make this determination it is very important to understand the requirements of the receiving device. Receiving devices may consist of PLC's, motion controllers, high speed counters, or any other device designed to accept encoder inputs. Some receiving devices have selectable inputs which will provide more flexibility in selecting the appropriate encoder.

Rotary incremental encoders have three basic choices for the number of channels: single channel (figure 2), two channels in quadrature often referred to as a quadrature encoder (figure 3), and quadrature with an index channel (figure 4). A single channel has a single "A" channel that will output a set number of pulses per revolution. The single channel encoder

will give feedback that can determine rate, velocity, or acceleration. A single channel encoder cannot give directional feedback and is therefore limited from many bidirectional applications.

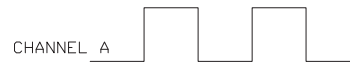


Figure 2. Single channel encoder output.

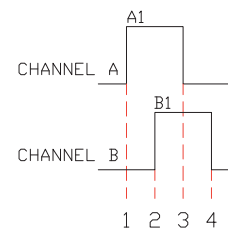


Figure 3. Quadrature encoder and quadrature counting.

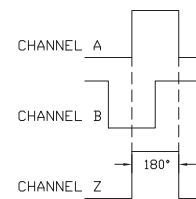


Figure 4. Quadrature encoder with an index channel.

A quadrature encoder has two channels typically referred to as channel A and channel B. Each channel of the quadrature encoder will have the same number of pulses per revolution offset by 90° electrical. A standard British Encoder Products Company (BEPC) encoder will have channel "A" lead channel "B" for clockwise shaft rotation. This quadrature relationship provides directional information to the receiving device. Many receiving devices also have the capability of using a quadrature encoder's signals to perform edge counting to increase the resolution 2 or 4 times, sometimes called quadrature counting. This can increase the effective system resolution by up to 4 times.

The index or "Z" channel of an encoder happens once per revolution of the encoder. The index is also sometimes called a reference, marker or homing pulse. One common function of the index is as a home position locator. Every time the index is triggered the receiving device knows where the encoder is within its rotation. The index is normally 180° electrical and gated to either channel A or channel B. In addition to standard gating, BEPC encoders have other gating options that a customer can order based on the customer's special needs.

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Some rotary incremental encoders have additional auxiliary channels for motor commutation. Encoder commutation channels can replace Hall Effect sensors in a brushless DC motor for motor control and timing. The pole count of the encoder commutation tracks needs to match the motor pole count. Encoder commutation for DC motors is more accurate and repeatable than using Hall Effect sensors. The typical encoder commutation accuracy is $\pm 1^\circ$ mechanical. The higher accuracy commutation outputs will allow the motor to run more efficiently.

After selecting the correct number of channels for an encoder, the next task is selecting the electrical output type of the encoder channels. There are multiple output types to choose from, each with its own advantages and disadvantages. The four most common output types are differential line driver, push-pull, open collector, and pull-up.

The first output type is differential line driver, which is called out as "HV" in the BEPC Encoder part number. With differential signals, there will be two connections for each channel (figure 5). It provides differential output, or complementary signals for noise immunity. Noise immunity is obtained by what is called "common mode rejection". Common mode rejection occurs when noise is present on a differential pair and the differential receiver cancels the noise. Differential line driver is the preferred output type for longer encoder cable lengths because of the inherent noise immunity. Differential line driver is the preferred output type for longer encoder cable lengths because of the inherent noise immunity. Differential line driver also meets RS-422 standards when operated at 5 VCC. An encoder should have differential line drive outputs when the receiving device is set up to receive differential signals. Some of BEPC encoders also have a 5 VCC regulated differential line driver output "L5". This will take a higher input voltage and regulate the output to 5 VCC.

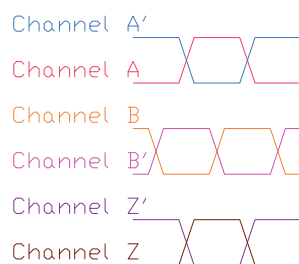


Figure 5. Differential outputs.

The second output type is push-pull or "PP". Push-pull is sometimes referred to as a "totem-pole" type of output circuit. This is a combination of sinking and sourcing outputs. When the output is in logic state high, current will source to the receiving device load. When the output is in logic state low, current will sink from the load. Push-pull does not have the noise immunity that is inherent in a differential line driver. When the output is high, the noise that is on the DC power supply (ripple, voltage, spikes, etc.) may show up on the output of the encoder. A push-pull output type can replace a PNP transistor output in some applications. Some EPC Encoders have a 5 volt regulated output "LP". With a LP output type, an encoder will have a 5 volt signal when the supply voltage to the encoder is higher than 5 volts.

The third output type is NPN open collector. NPN open collector is a current sinking output type and requires a pull-up resistor external to the encoder. Typically, the pull-up resistor is built into the receiving device. Open collector is useful for doing what is called level shifting. Level shifting occurs when the encoder is pulled up externally to a different voltage level. For example, the encoder can be powered with 5 volts, and the output can be pulled up to a 24 VCC level. British Encoder Products Company also offers an open collector differential output on some encoder models. This is an open collector output with the complimentary channels similar to a line driver. NPN open collector is not the same as a PNP output. A PNP output requires a pull down resistor and is a current sourcing type output. PNP outputs are seldom used in encoders.

The fourth output type we will discuss is pull-up. It is the same as the open collector, but, as the name implies, it contains the pull-up resistor internal to the encoder. This is useful for customers that do not need the level shifting capabilities of an open collector and do not want to add external pull-up resistors to the feedback system. Common values for the internal pull-up resistor in an BEPC encoder are between 1.5k and 2.2k.

Choosing the correct number of channels and the correct output type for an encoder can be the determining factor in whether or not a feedback system will function properly. This is one of the most common problems customers have when selecting encoders. Remember it is the receiving device that determine the correct configuration of the encoder's outputs. If the encoder configuration is in question, call British Encoder Products Company's technical service for assistance.