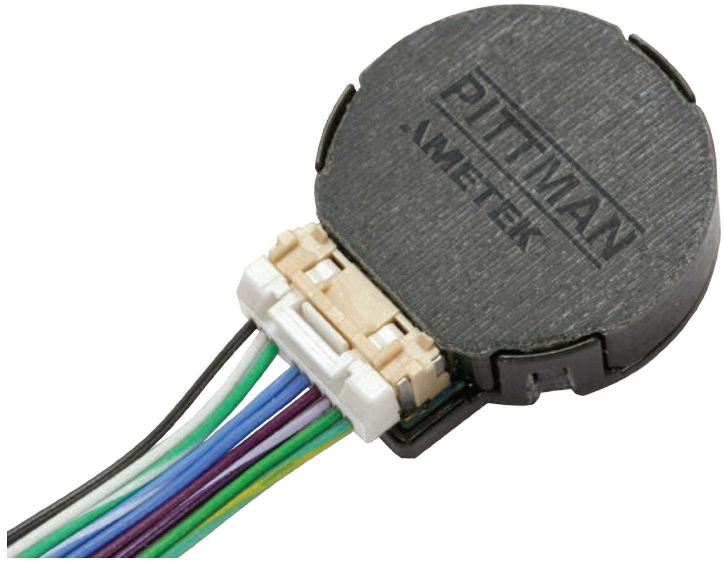
Incremental Encoder Signals

Incremental encoders are used on servo motors as feedback devices to determine position and direction. Motor controllers can also use the position information from the encoder to calculate velocity for speed control.

The incremental encoder is a critical component that provides important data necessary for the automatic control of a variety of motion systems, from autonomous vehicles to vending machines.



Incremental Encoder Operation

A two-channel incremental encoder consists of two output signals typically denoted as channels A and B. They are called quadrature signals because there is 90 electrical degrees of phase displacement between the two signals. See Figure 1.

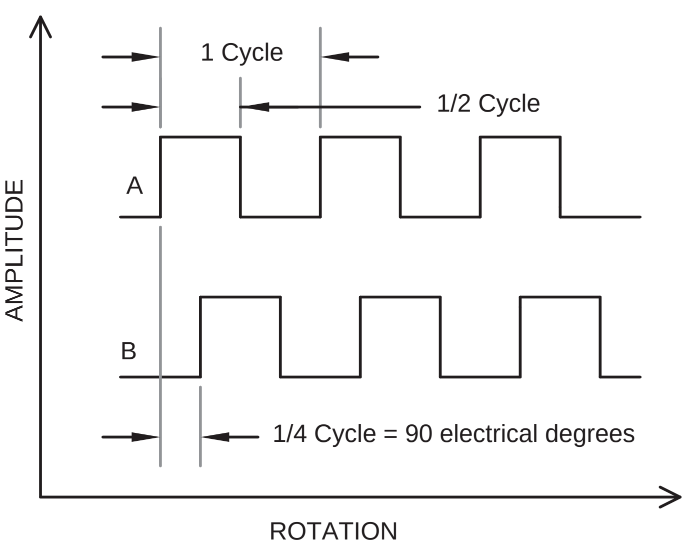


Figure 1: Two-channel incremental encoder waveform.

Designers can use this phase relationship to determine direction. In one direction of rotation, signal channel A transitions from low to high before channel B, that is, channel A leads channel B. In the opposite direction, channel B leads channel A. The direction of rotation for servo motors with encoders is observed by facing the shaft extension at the motor mounting end. See Figure 2.

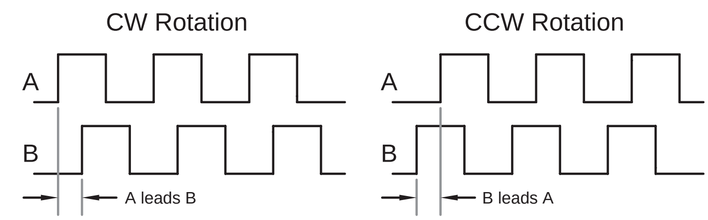


Figure 2: Encoder waveforms indicating a change in direction.

Channel A and B signals are also used to determine position. When counting in quadrature, an electronic counter will count each signal transition, low to high and high to low, of both channels. This produces four counts for each electrical cycle. Thus, the counts per revolution are four times the encoder's base resolution given in cycles per revolution which is sometimes referred to as number of lines for an optical encoder. See Figure 3.

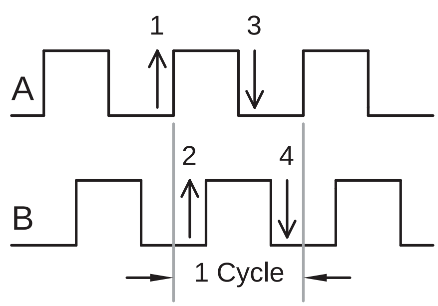


Figure 3: Quadrature counting of encoder signals.

A three-channel incremental encoder consists of the channel A and B output signals and a reference output signal denoted as the Index. The Index signal produces a single pulse per revolution at a unique position. The Index pulse may be gated or ungated. The ungated Index pulse edges are not necessarily coincident with channel A and B signals. The gated Index pulse will be coincident with a high or low state of either or both channels. A gated Index pulse coincident with /A & /B is typical. See Figure 4.

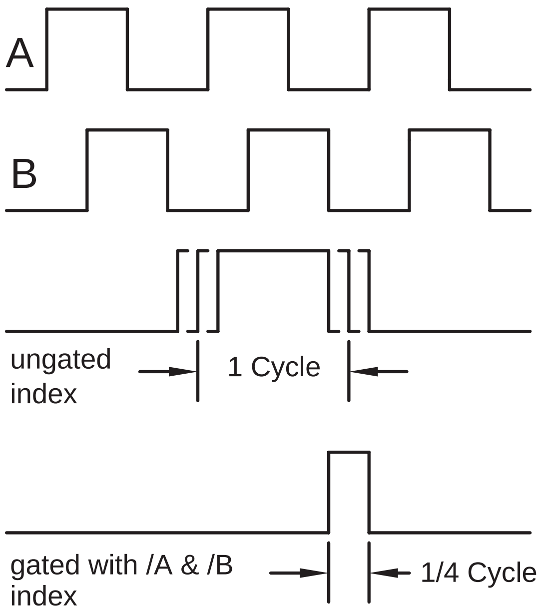


Figure 4: Three-channel incremental encoder waveform with a comparison of ungated and gated forms of index signals.

The Index signal is typically used to identify a center position, home position, reset point or zero reference. It is often used in combination with some type of proximity sensor which provides a course home position. The next occurring index pulse is used to zero the position count.

All three encoder outputs, channels A and B and Index, may be supplied as single ended or differential signals. A single ended output is referenced to the common signal (GND) of the encoder power supply. As such it requires only one wire per output in addition to the power supply leads as shown in Figure 5. Single ended encoder outputs are typically TTL compatible. They should be used with short lead lengths to minimize signal degradation and electrical noise problems. The single ended output encoder, when used within its limitations, can be a cost effective solution for OEM's.

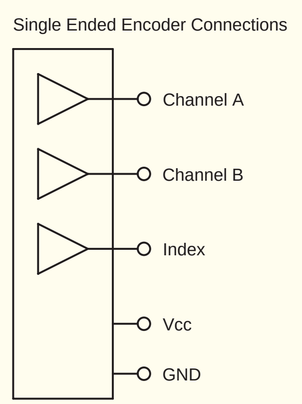


Figure 5: Connector pin-out for a three-channel encoder with single ended outputs.

Differential line driver encoder outputs are more immune to electrical noise than single ended signals and can travel over long cable lengths. These outputs are complementary signal pairs, when one signal is high; the other signal is low as shown in Figure 6. Each differential output requires two wires; typically twisted pairs are used for increased noise immunity. Differential line drivers have low impedance which makes them noise immune. They should be connected to high impedance differential line receivers for common mode noise rejection. The complementary outputs are processed by the differential line receiver circuit so that the required signal can be reconstituted without noise or distortion as shown in Figure 7. These benefits have an associated incremental cost for the differential line driver circuits and the additional wiring required.

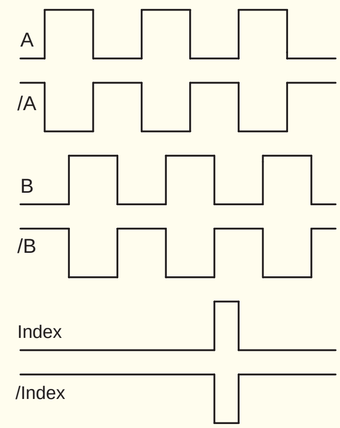


Figure 6: Differential line driver encoder waveform.

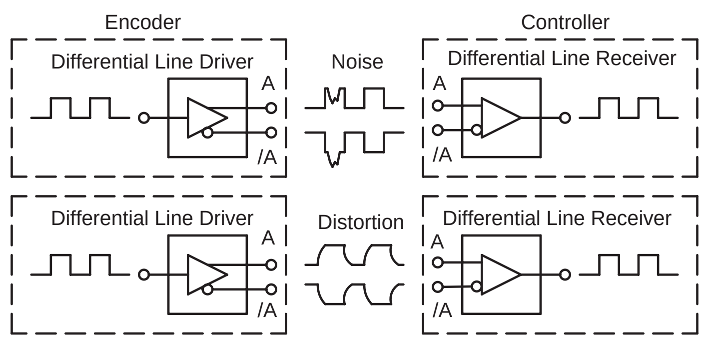


Figure 7: Differential line driver signal conditioning.

This technical article was prepared by the engineering team at Haydon Kerk Pittman Motion Solutions, a leader in motion technologies. Complex custom and ready-to-ship standard lead screw assemblies are made at USA facilities with a full range of onsite capabilities including designing, engineering and manufacturing.