THEORY ON WORKING OF DIFFERENT TYPES OF ENCODERS

SET-2

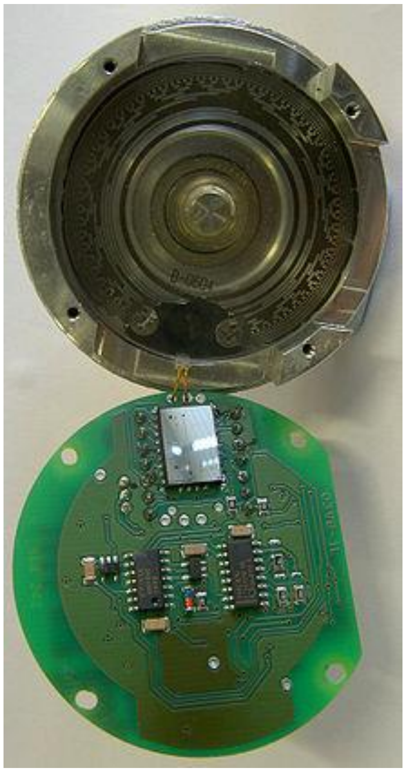

Figure 1. A Rotary Encoder

By

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An encoder is a device, circuit, transducer, software program, algorithm or person that converts information from one format or code to another, for the purposes of standardization, speed or compression.

Types of Encoders

- Rotary Encoder
- Incremental Encoder
- Quadrature Encoder
- Magnetic Encoder
- Absolute Position encoder
- Linear Encoder

Rotary Encoder

A rotary encoder is a type of position sensor which is used for determining the angular position of a rotating shaft. It generates an electrical signal, either analog or digital, according to the rotational movement.

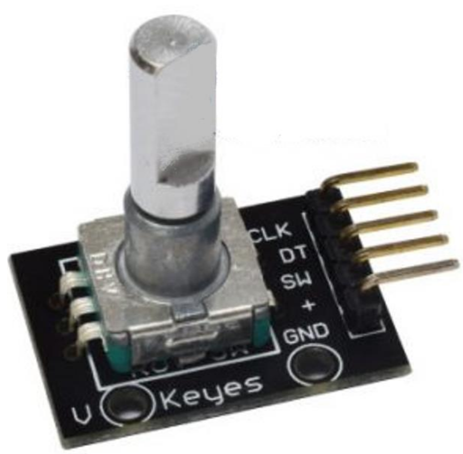

Figure 2. A Rotary Encoder

There are many different types of rotary encoders which are classified by either Output Signal or Sensing Technology. The particular rotary encoder that we will use in this tutorial is an incremental rotary encoder and it's the simplest position sensor to measure rotation.

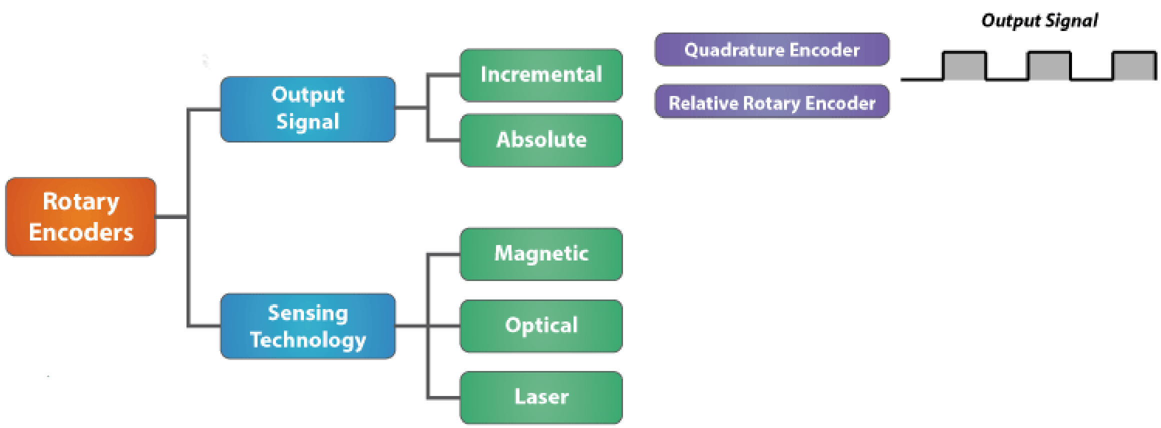

Figure 3. Processes involved in working of Rotary Encoder

This rotary encoder is also known as quadrature encoder or relative rotary encoder and its output is a series of square wave pulses.

HOW ROTARY ENCODER WORKS

Let's take a closer look at the encoder and see its working principle. Here's how the square wave pulses are generated: The encoder has a disk with evenly spaced contact zones that are connected to the common pin C and two other separate contact pins A and B, as illustrated below.

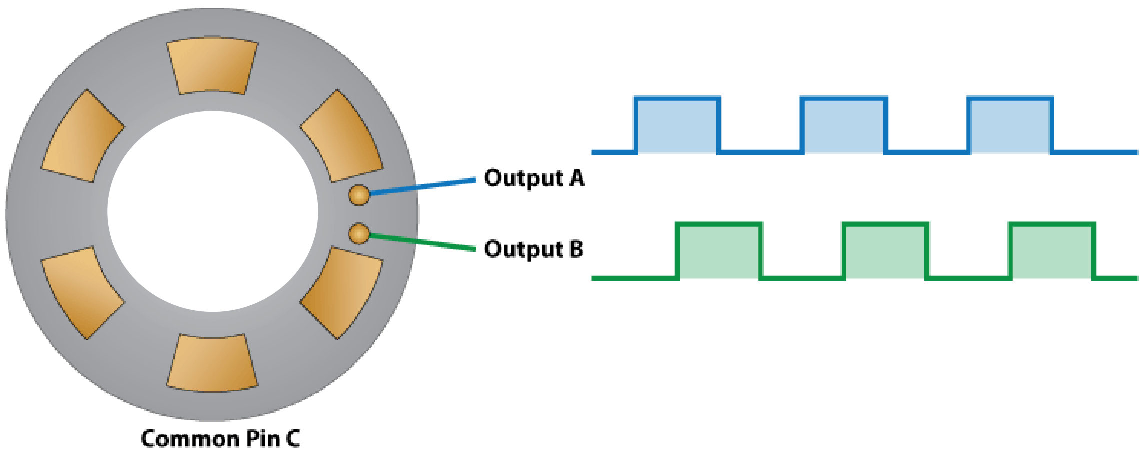

Figure 4. Working

When the disk will start rotating step by step, the pins A and B will start making contact with the common pin and the two square wave output signals will be generated accordingly.

Any of the two outputs can be used for determining the rotated position if we just count the pulses of the signal. However, if we want to determine the rotation direction as well, we need to consider both signals at the same time.

We can notice that the two output signals are displaced at 90 degrees out of phase from each other. If the encoder is rotating clockwise the output A will be ahead of output B.

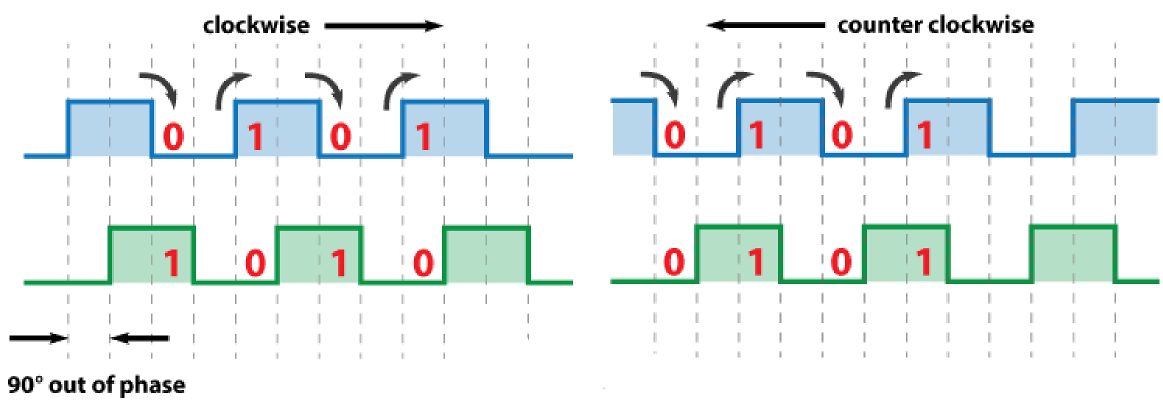

Figure 5. Output Signals

So, if we count the steps each time the signal changes, from High to Low or from Low to High, we can notice at that time the two output signals have opposite values. Vice versa, if the encoder is rotating counter clockwise, the output signals have equal values. So considering this, we can easily program our controller to read the encoder position and the rotation direction.

Incremental Encoder

An incremental encoder provides a specified amount of pulses in one rotation of the encoder. The output can be a single line of pulses (an "A" channel) or two lines of pulses (an "A" and "B" channel) that are offset to determine rotation. This phasing between the two signals is called quadrature. Learn more about quadrature encoder output here.

The typical assembly of an incremental encoder consists of a spindle assembly, PCB, and cover. The PCB contains a sensor array that creates just two primary signals for position and speed.

Optionally, additional signals can be provided:

An index or 'Z' channel can be provided as one pulse per revolution signal for homing and pulse count verification on the A and/or B channels. This index can be gated to either A or B in their various states. It can also be un-gated and vary in width.

Commutation (U, V, W) channels can also be provided on some encoders. These signals are aligned to the commutation windings found on servo motors. They also ensure that the drive or amplifier for those motors apply current to each winding in the correct sequence and at the correct level.

INCREMENTAL ENCODER ALTERNATIVES

Resolvers

Resolvers are electro-mechanical precursors to encoders, based on technology going back to World War II. An electrical current creates a magnetic field along a central winding. There are two windings that are perpendicular to each other. One winding is fixed in place, and the other moves as the object moves. The changes in the strength and location of the two interacting magnetic fields allow the resolver to determine the motion of the object.

The simplicity of the resolver design makes it reliable in even extreme conditions, from cold and hot temperature ranges to radiation exposure, and even mechanical interference from vibration and shock. However, the forgiving nature of resolvers for both origin and application assembly comes at the expense of their ability to work in complex application designs because it cannot produce data with enough accuracy. Unlike incremental encoders, resolvers only output analog data, which can require specialized electronics to connect with.

Absolute Encoder

Absolute encoders work in situations where accuracy for both speed and position, fail tolerance, and interoperability matters more than system simplicity. The absolute encoder has the ability to "know where it is" in reference to its position in case of system power-down and restart if the encoder were to move during a power-down.

The absolute encoder itself understands the positioning information – it doesn’t need to rely on outside electronics to provide a baseline index for the encoder position. Especially when compared to resolvers and incremental encoders, the obvious strength of absolute encoders is how their positioning accuracy affects the overall application performance, so it is typically the encoder of choice for higher precision applications such as CNC, medical and robotics

Quadrature Encoder

The code disk inside a quadrature encoder contains two tracks usually denoted Channel A and Channel B. These tracks or channels are coded ninety electrical degrees out of phase, as indicated in the image below, and this is the key design element that will provide the quadrature encoder its functionality. In applications where direction sensing is required, a controller can determine direction of movement based on the phase relationship between Channels A and B. As illustrated in the figure below, when the quadrature encoder is rotating in a clockwise direction its signal will show Channel A leading

Channel B, and the reverse will happen when the quadrature encoder rotates counter clockwise.

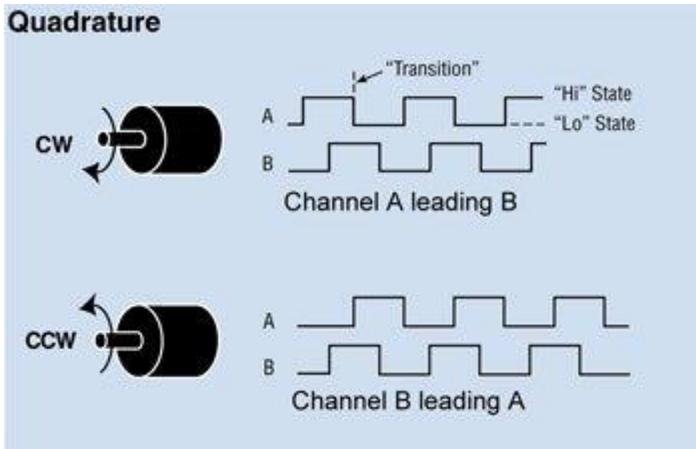

Figure 6.Output Signals

Apart from direction, position can also be monitored with a quadrature encoder by producing another signal known as the "marker", "index" or "Z channel". This Z signal, produced once per complete revolution of the quadrature encoder, is often used to locate a specific position during a 360° revolution.

WHEN TO USE QUADRATURE ENCODERS?

Quadrature encoders are used in bidirectional position sensing and length measuring applications. However, in some unidirectional start-stop applications, it is important to have bidirectional information (Channel A & B) even if reverse rotation of the shaft is not anticipated. An error in count could occur with a single-channel encoder due to machine vibration inherent in the system. For example, an error in count may occur with a single-channel encoder in a start/stop application if it mechanically stops rotating when the output waveform is in transition. As subsequent mechanical shaft vibration forces the output back and forth across the edge the counter will up-count with each transition, even though the system is virtually stopped. By utilizing a quadrature encoder, the counter monitors the transition in its relationship to the state of the opposite channel and can generate reliable position information.

ACHIEVING HIGHER RESOLUTION WITH QUADRATURE ENCODERS

When more resolution is needed, it is possible for the counter to count the leading and trailing edges of the quadrature encoder's pulse train from one channel, which doubles (x2) the number of pulses per revolution. Counting both leading and trailing edges of both channels of a quadrature encoder will quadruple (x4) the number of pulses per revolution. As a result, 10,000 pulses per turn can be generated from a 2,500 PPR quadrature encoder**.**

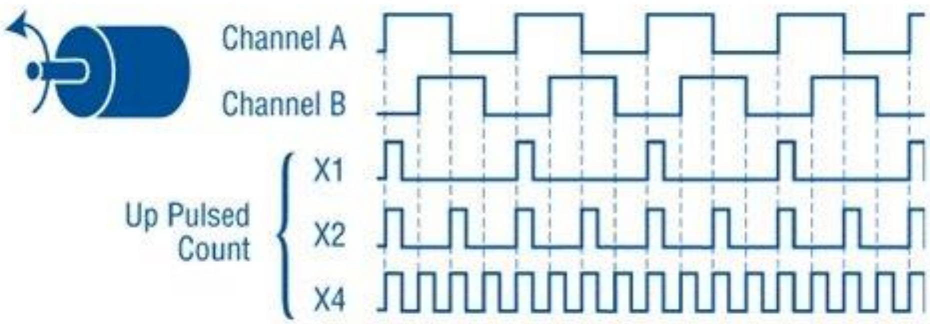

Figure 7. Output Signals

Magnetic Encoder

An optical encoder uses light (optics) to identify unique positions for the encoder. A magnetic encoder uses the same principle to determine a position as an optical encoder, but it does it using magnetic fields rather than light.

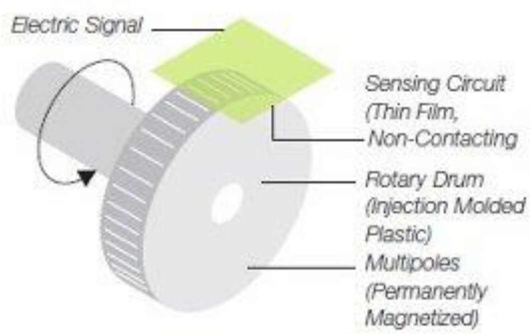

Figure 8. Magnetic Encoder

With a magnetic encoder, a large magnetized wheel spins over a plate of magneto-resistive sensors. Just as the disk spins over the mask to let light through in predictable patterns, the wheel causes predictable responses in the sensor, based on the strength of the magnetic field. The magnetic response is fed through a signal conditioning electrical circuit.

The number of magnetized pole pairs on the wheel pole, the number of sensors, and the type of electrical circuit all work together to determine the resolution of the magnetic encoder.

The key to using magnetism as the element to produce a signal is that it is unaffected by very demanding environments – including dust, moisture, and extreme temperatures, and shock.

MAGNETIC ENCODER APPLICATIONS

A magnetic encoder is designed to output reliable digital feedback in the most demanding and harshest of application environments. Applications for this technology usually require broad temperature specs, high shock and vibration resistance, robust sealing, and contaminant protection all while focusing on output signal reliability, easy installation, and downtime reduction. Popular applications for magnetic encoders include position and velocity feedback in Steel, Pulp, Paper, & Lumber mills.

Absolute Position Encoder

Absolute encoders have an encoder disc which has marks or slots on a power-transmission shaft and a stationary pickup. The disc records a unique code for each shaft position. Each position corresponds to a unique code, and even movements that occur while there is no power are recorded into accurate position values once the encoder is turned on again.

There are two types of absolute encoders: single-turn and multi-turn encoders. Single-turn encoders measure displacement in one turn or across 360 deg. from a starting position. The output is repeated for every revolution. Multi-turn encoders measure in the same fashion as single-turn, but also track the number of total revolutions of the shaft using a unique word for each position and number of revolutions.

Absolute rotary encoders are preferred when safety is a concern because they position themselves when the machine is powered on. Single-turn are useful for short travel situations. Multiple-turn are better for more complex or longer positioning situations. The latter record position data electronically, typically in binary format. Being resistant to electrical noise is another advantage. However, absolute rotary encoders typically cost more than incremental encoders.

ABSOLUTE ROTARY ENCODER ADVANTAGES

- Remembers its position after a power outage and offers continuous position monitoring
- Typically have speed, scaling, preset, and fieldbus functions
- Allow you to determine the exact position of a machine and control over the storage of electronic data
- Multiple interface options: Analog, Ethernet, Fieldbus, Parallel, Serial
- Single-turn and Multi-turn revolution options available
- Optical a magnetic measuring principle
- Absolute encoders have a resolution of up to 16 bits, or 65,536 pulses per revolution (PPR).

Linear Encoder

A linear encoder is a sensor, transducer or readhead paired with a scale that encodes position. The sensor reads the scale in order to convert the encoded position into an analog or digital signal, which can then be decoded into position by a digital readout (DRO) or motion controller.

The encoder can be either incremental or absolute. Motion can be determined by change in position over time. Linear encoder technologies include optical, magnetic, inductive, capacitive and eddy current. Optical technologies include shadow, self-imaging and interferometric. Linear encoders are used in metrology instruments, motion systems and high precision machining tools ranging from digital calipers and coordinate measuring machines to stages, CNC Mills, manufacturing gantry tables and semiconductor steppers.

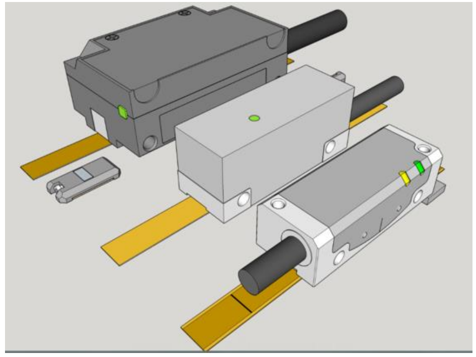

Figure 9. Typical Encoders

PRINCIPLE

Optical

Optical linear encoders dominate the high-resolution market and may employ shuttering, diffraction or holographic principles. Optical encoders are the most accurate of the standard styles of encoders, and the most commonly used in industrial automation applications. When specifying an optical encoder, it’s important that the encoder has extra protection built in to prevent contamination from dust, vibration and other conditions common to industrial environments. Typical incremental scale periods vary from hundreds of micrometers down to sub-micrometer. Interpolation can provide resolutions as fine as a nanometre.

Magnetic

Magnetic linear encoders[1] employ either active (magnetized) or passive (variable reluctance) scales and position may be sensed using sense-coils, Hall effect or magnetoresistive readheads. With coarser scale periods than optical encoders (typically a few hundred micrometers to several millimeters) resolutions in the order of a micrometer are the norm.

Capacitive

Capacitive linear encoders work by sensing the capacitance between a reader and scale. Typical applications are digital calipers. One of the disadvantages is the sensitivity to uneven dirt, which can locally change the relative permittivity.