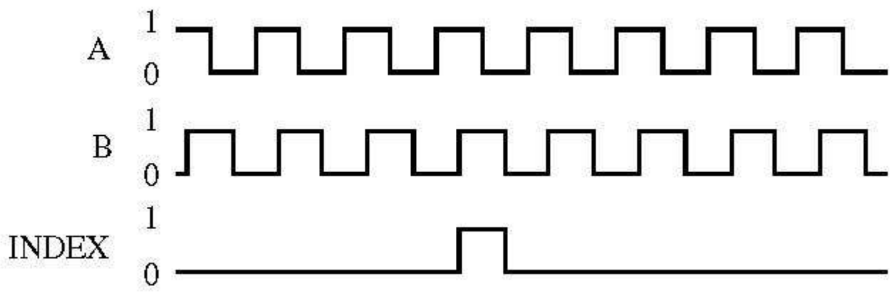
ROTARY ENCODERS 101

Rotary Encoders 101 February 2009

Rotary encoders fall into two major categories, **Incremental** and **Absolute**. Both encoders come in two basic construction designs, **Mechanical** and **Optical**.

Incremental Encoders are by far the simplest in design and use. They typically provide 3 main data lines: A and B lines are rotary pulses, while Z is an index pulse. These lines can also have compliments or inverted signals for noise immunity. Data lines A and B are phase shifted by 90 degrees. This phase shift allows for a controller to determine if the encoder is rotating in a clockwise (CW) or counter-clockwise (CCW) direction. The Z index pulse triggers once per revolution. The pulses which are provided must be counted by a controller to determine position. The Incremental Encoder does **NOT** actually “KNOW” its position.



Absolute Encoders are slightly more complex in design and use. They provide a position value as the shaft of the encoder is rotated. This value is transmitted to a controller via one of the many available output formats. These interfaces give the position value to the controller using codes to represent actual position. The Absolute Encoder “KNOWS” its actual position.

CONSTRUCTION

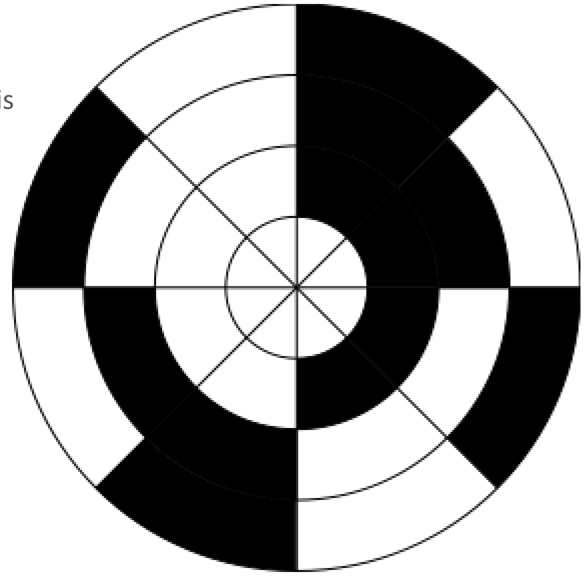
Mechanical encoders utilize a rotating metal disc containing concentric rings which have patterned openings. Typically a stationary row of sliding contacts is aligned with each ring. As the contacts wipe across the surface of the metal disc, contact is either made (closed) or not made (open). By design, the pattern gives a code of 1s (ON) and 0s (OFF) in a specific format (Binary, Gray or BCD).

Optical encoders utilize a rotating glass or plastic disc containing concentric rings which have patterns etched onto them. An LED is used to shoot light through a grid and the grid projects a pattern onto the rotating disc. A photo-diode is used on the other side of the rotating disc to read the pattern of light being passed through. The pattern on the grid, combined with the pattern on the rotating disc, gives a code of 1s (ON) and 0s (OFF) in a specific format (Binary, Gray or BCD).

STANDARD BINARY ENCODING

Binary code is the simplest of coding methods. It uses the standard binary numbering system of 1s and 0s.

This figure shows a disc with a 3 bit code. Where 0 is BLACK and 1 is WHITE. The code is increasing count in the CW direction. The disc is coded from outside ring (least significant bit) to inside ring (most significant bit).



MSB		LSB	Decimal	Angular
0	0	0	0	0 to 45
0	0	1	1	45 to 90
0	1	0	2	90 to 135
0	1	1	3	135 to 180
1	0	0	4	180 to 225
1	0	1	5	225 to 270
1	1	0	6	270 to 315
1	1	1	7	315 to 360

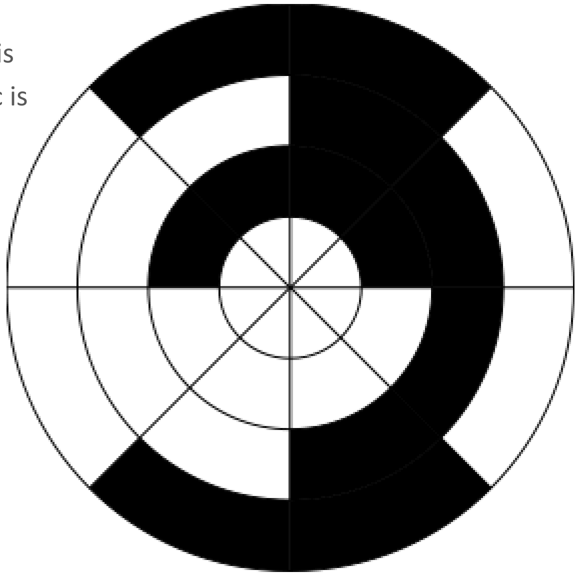
The issue with this style of coding is with the transition from one area to the next. Multiple bits are changing as the encoder is rotated. The physical change may not be happening at exactly the same time, what if bit 1 changes before bits 0 and 2? What if bit 2 changes before bit 0 and 1?

During the transition at 90 degrees, when EXACTLY does the code change from 001 to 010? Do the bits change at exactly the same time? The reality is with modern day technology the transition happens almost seamlessly, however this is still a potential issue.

GRAY CODE ENCODING

Gray code addresses the problem of transitioning from one sector to another. It uses the binary numbering system of 1's and 0's. However the sequence of organization does not follow standard binary counting conventions.

This figure shows a disc with a 3 bit code. Where 1 is BLACK and 0 is WHITE. The code is increasing count in the CCW direction. The disc is coded from outside ring (Least Significant Bit) to inside ring (Most Significant Bit).



MSB		LSB	Decimal	Angular
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0	0	1	1	45 to 90
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0	1	0	2	135 to 180
1	1	0	6	180 to 225
1	1	1	7	225 to 270
1	0	0	4	270 to 315
1	0	1	5	315 to 360

Gray Code eliminates the issue with multiple bits changing at the same time.
Only 1 bit ever changes state at any given transition.

BINARY CODED DECIMAL (BCD) ENCODING

Binary Coded Decimal (BCD) is essentially the same as Binary. BCD uses the standard binary numbering system of 1s and 0s, however, it is broken off into 4 bit groups. Each 4 bit group (nibble) represents its decimal equivalent as shown in the chart below. For double digit decimal numbers 8 bits (1 byte) would be used, triple digit numbers 12 bits, so on and so forth.

MSB			LSB	Decimal
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

3 5

0011 0101 = 35

9 9

1001 1001 = 99

ABSOLUTE ENCODER OUTPUT FORMATS

Communication between an encoder and control system can happen using one of many different formats. These formats can be divided into 3 Major Categories: **Point to Point**, **Fieldbus** and **Ethernet**.

Point to Point interfaces include Parallel, Serial Synchronous (SSI), Incremental Serial Interface (ISI), Analog, Asynchronous Serial Interface and others. The majority of these interfaces require a point to point connection from encoder to controller. Most of these interfaces use the above Encoding methods to transmit their data to the controller. Analog is unique in that it provides a varying signal to the controller, typically 4-20mA.

Fieldbus interfaces include ProfiBus, DeviceNet, CANOpen and others. These protocols use a BUS type topology which requires individual addressing of each unit or node on the BUS. The encoder data is read by the controller on the same line as other devices on the BUS. This output format requires a higher level of intelligence in the controller, but adds greater flexibility with less wiring.

EtherNet interfaces include ProfiNet, EtherCAT, PowerLink, and EtherNet/IP. These protocols use a Network topology which requires individual addressing of each device on the network. The encoder data is available on the network to be accessed by the controller. Ethernet interfaces utilize the newest communication technology. They are based off the standard office network protocol, refined to meet industrial requirements.

TR Electronic Center of Technical Excellence will work with you to develop the best solution for your Application.

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