MEE303 Sensor Systems

W05
Displacement Sensing

Digital displacement Sensing

A digital transducer is a measuring device that produces a digital output. A transducer whose output is a pulse signal may be considered in this category since the pulses can be counted and presented in the digital form

Shaft encoders are digital transducers that are used for measuring angular displacements and angular velocities. They generate a coded (digital) reading of a measurement can be termed as an encoder

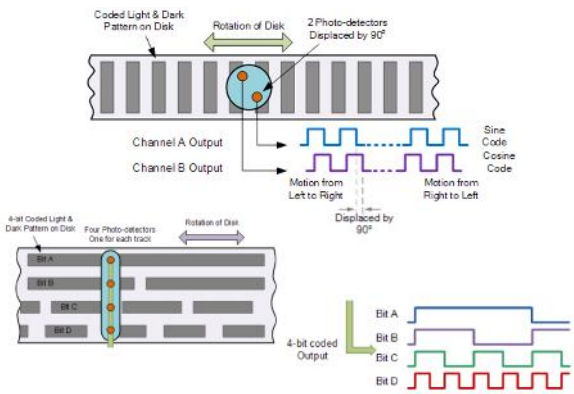
According to the method of interpretation

Incremental encoders *absolute encoder*

Output of an incremental encoder is a pulse signal, which is generated when the transducer disk rotates as a result of the motion that is measured

- with respect to some reference point
- by counting the pulses

absolute encoders need at least as many signal pick-off sensors as there are tracks, whereas incremental encoders need just one pick-off sensor to detect the magnitude of rotation.



An absolute encoder (or, whole-word encoder) has many pulse tracks on its transducer disk. When the disk of an absolute encoder rotates, several pulse trains,equal in number to the tracks on the disk, are generated simultaneously

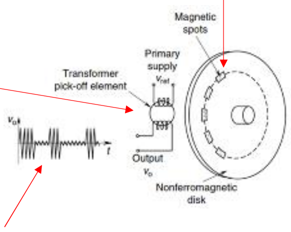
The pulse windows on the tracks can be organized into some pattern (code) so that the generated binary number at a particular instant corresponds to the specific angular position of the encoder disk at that time

Digital displacement Sensing

Magnetic encoders

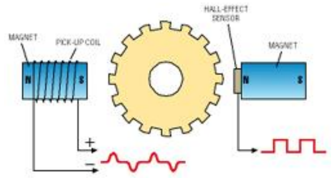
Magnetic encoders have high-strength magnetic regions imprinted on the encoder disk.

The signal pick-off device is a microtransformer, which has primary and secondary windings on a circular ferromagnetic core



a pulse peak corresponds to a nonmagnetic area and a pulse valley corresponds to a magnetic area for each track

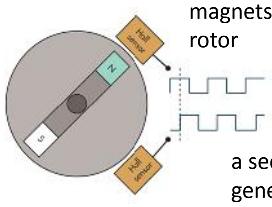
If a permanent magnet and hall effect used in given manner a better pulse can be obtained



A high-frequency (typically 100 kHz) primary voltage induces a voltage in the secondary winding of the sensing element at the same frequency, operating as a transformer

When magnetic spots come accross transformer, they attract major amount of the magnetic flux. Therefore, the primary secondary winding coupling become weak.

Absolute Magnetic Encoder



magnets placed around the edge of a rotor

and a single sensor. Such a device would produce a sine wave output

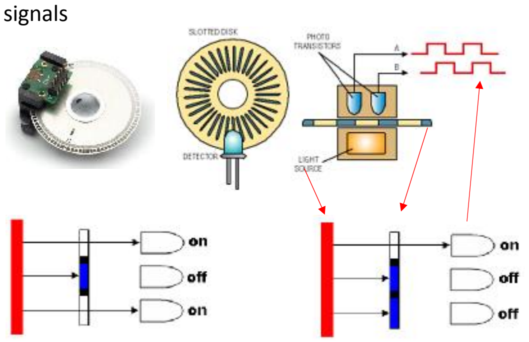
a second sensor, set 90° apart, generating a cosine output,

it becomes possible to not only detect the direction of rotation but also to interpolate the absolute position of the shaft

Digital displacement Sensing

Optical encoders

Optical encoders encompass a variety of devices, all of which use light as the means to transform movement into electrical signals



The sensor element of such a measuring device is the encoder disk, which is coupled to the rotating object (directly or through a gear mechanism).

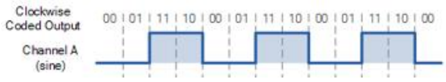
The transducer stage is the conversion of disk motion (analog) into the pulse signals, which can be coded into a digital word

Optical encoders consist of

- a light source (LEDs or IR LEDs),
- an optical setuop using a lens to make the beams parallel,
- Photodetector(s) (Either Photodiodes or Phototransistors) d
- a code disk (One or more “tracks” with slits to allow light to pass through).

A parallel beam of light is projected to all tracks from one side of the disk.

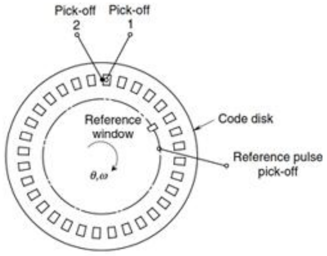
the light from the source is interrupted by the opaque regions of the track, the output signal from the photosensor is a series of voltage pulses.



Digital displacement Sensing

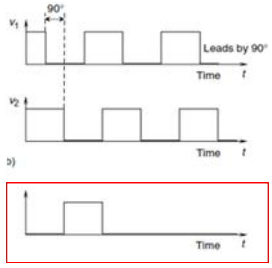
Incremental Optical Encoders

The disk has a single circular track with identical and equally spaced transparent windows. The area of the opaque region between adjacent windows is equal to the window area.



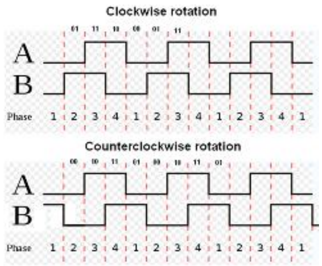
Two photodiode sensors (pick-offs 1 and 2) are positioned facing the track at a quarter-pitch (half the window length) apart.

The forms of pick offs output signals (v1 and v2), after passing them through pulse-shaping circuitry (idealized),



An additional track with a lone window and associated sensor is also usually available. This track generates a reference pulse (index pulse) per revolution of the disk

The quarter-pitch offset in sensor location is used to determine the direction of rotation of the disk

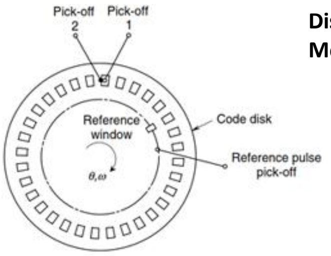


If rising edge in V1 occurs when v2 is high cw rotation

If falling edge in V1 occurs when v2 is high ccw rotation

Digital displacement Sensing

Incremental Optical Encoders



the range of the encoder is +/- θ_{max}

Displacement Measurement $\theta = \frac{n}{M}\theta_{max}$ $M = 2^{r-1}$ count is stored as digital data of r bits

Digital resolution

$$\Delta\theta = \frac{\theta_{max}}{M} = \frac{\theta_{max}}{2^{r-1}}$$ Typically, $\theta_{max} = \pm 180^\circ$ or 360°. Then,

$$\Delta\theta_d = \frac{180^\circ}{2^{r-1}} = \frac{360^\circ}{2^r}$$

$$\Delta\theta = \frac{\theta_{max} - \theta_{min}}{(2^{r-1} - 1)}$$

physical resolution

- Incremental Optical Encoder

$$Resolution = \frac{360^\circ}{n}$$

n = Number of Windows on Code Disk per Channel

If we read the rising edge of Channel A **and** Channel B,

$$Resolution = \frac{360^\circ}{2n}$$

If we read the falling edge of Channel A **and** Channel B,

$$Resolution = \frac{360^\circ}{2n}$$

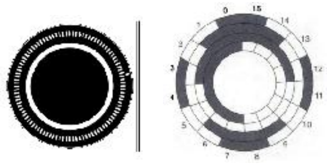
If we read the rising edge **and** the falling edge of Channel A **and** Channel B,

$$Resolution = \frac{360^\circ}{4n}$$

Digital displacement Sensing

Absolute Optical Encoders

An absolute encoder directly generates a coded digital word to represent each discrete angular position (sector) of its code disk.



n pick-off sensors

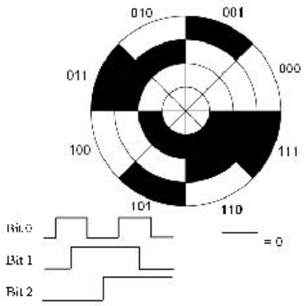
n bit Word buffer

This is accomplished by producing a set of pulse signals (data channels) equal in number to the word size (number of bits) of the reading

As the disk rotates, the bank of pick-off sensors generates pulse signals, which are sent to n parallel data channels (or pins).

The code disk may have direct binary coding or a graycode coding on it

Direct Binary Encoding



Angle	Binary	Dec
0-45	000	0
45-90	001	1
90-135	010	2
135-180	011	3
180-225	100	4
225-270	101	5
270-315	110	6
315-360	111	7

There is a data interpretation problem associated with the direct binary code in absolute encoders:

For direct binary encoding, an angle shift results in multiple bit changes.

Example: 1 => 2   001   (start at 1)
000   (turn off bit 0)
010   (turn on bit 1)

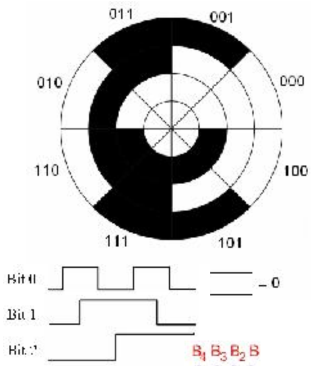
Digital displacement Sensing

Absolute Optical Encoders

Gray Coding: In the case of gray code, each adjacent transition involves only one bit switching.

The resolution of an absolute encoder is limited by the word size of the output data

$$\Delta\theta = \frac{360^\circ}{2^n}$$



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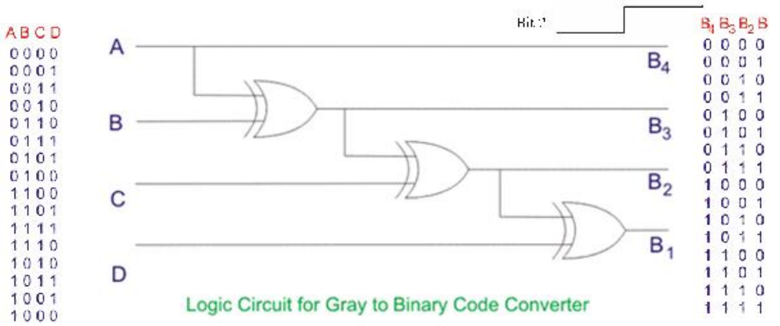

Logic Circuit for Gray to Binary Code Converter