Encoders

Sensors and actuators

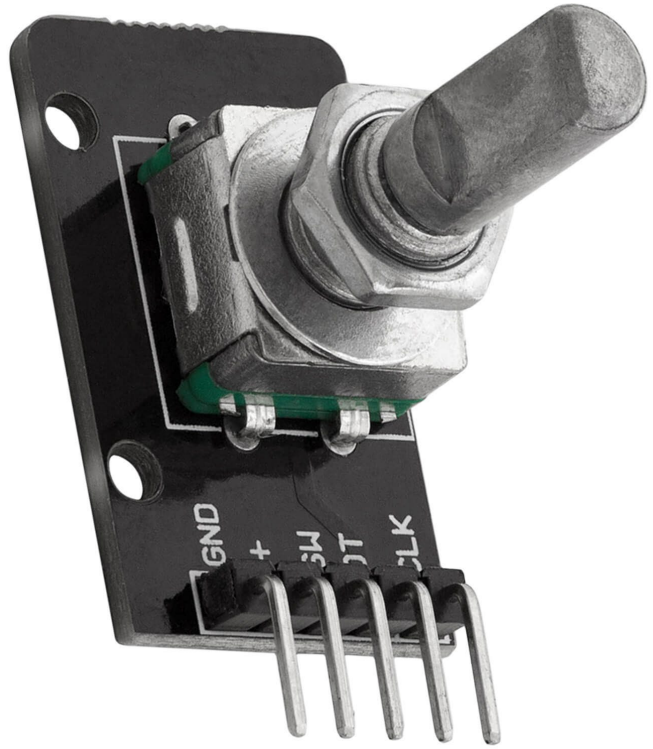
- Sensors are how a system would measure the environment around it
- Actuators are how a system interacts with the environment around it
- But what if we want to measure the actuators a system is using?

What is an encoder?

- An encoder is something which is attached to an actuator to measure an aspect of that actuator
- They can be either linear or rotational which link to the two types of actuators
- It is used to measure one of these 4 variables:
  - Position
  - Direction
  - Speed
  - Counts

What is an encoder

- Encoders take motion and convert it to an electrical signal which a controller can understand
- The controller will convert electrical signal to a useful value that can be used in a program



Types of encoders

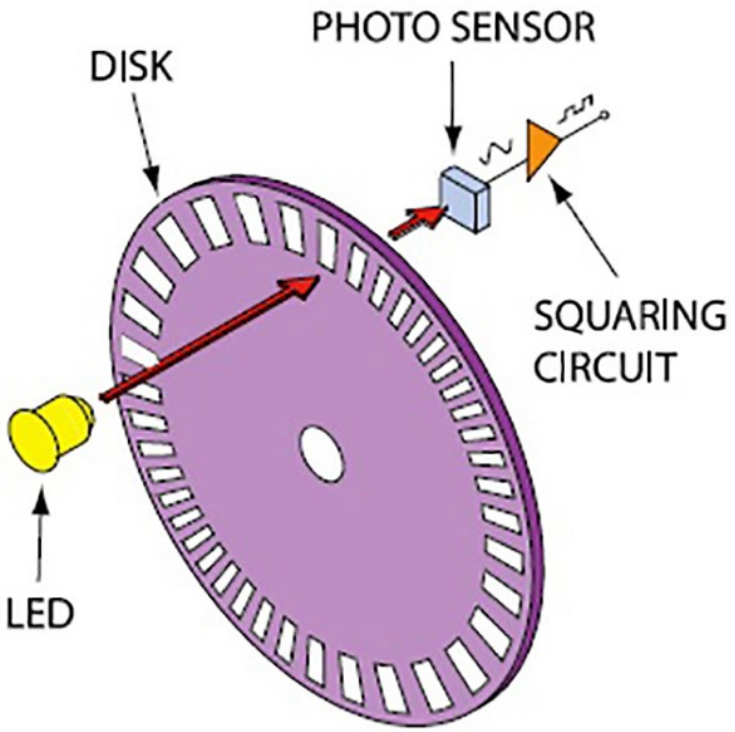
- There are 4 main encoder technologies:
  - Magnetic
  - Mechanical
  - Resistive
  - Optical
- There are 2 main types of encoders:
  - Absolute
  - Incremental

Incremental vs Absolute Encoders

Feature	Incremental Encoder	Absolute Encoder
Output Signal	Pulses	Unique position code
Position Tracking	Relative	Absolute
Power Loss Behaviour	Position lost	Position retained
Resolution	Pulses per revolution	Unique positions per revolution
Cost	Lower	Higher
Applications	Speed and relative motion sensing	Precise position tracking

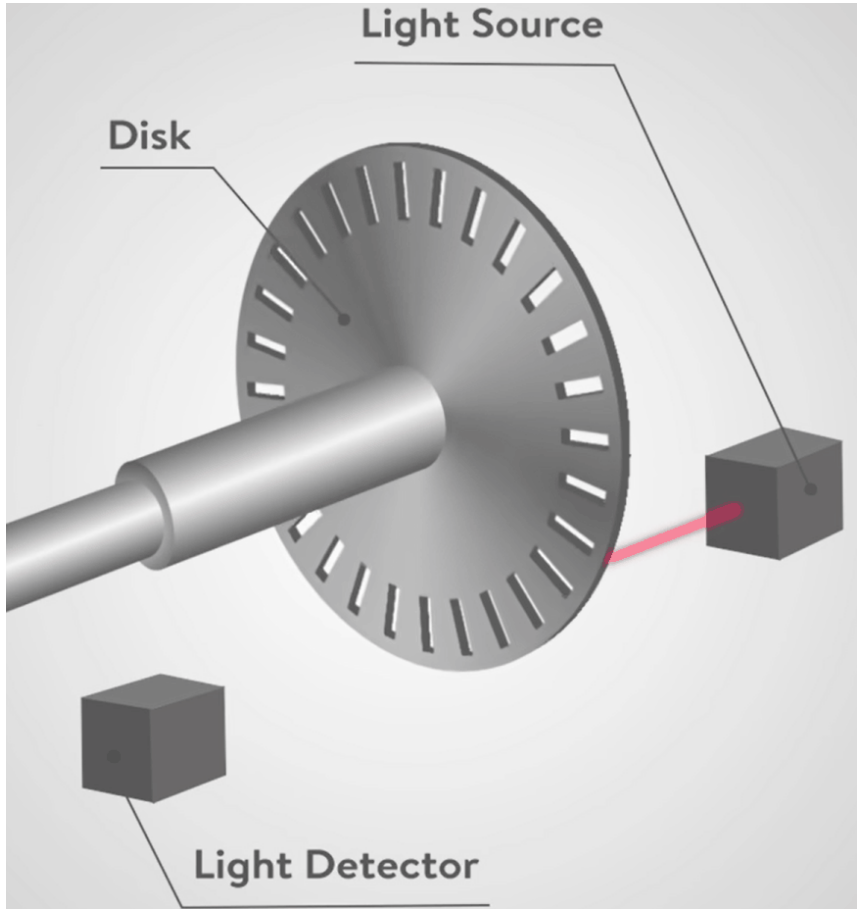
Optical Encoders

- Optical encoders are the most common type of encoder technology
- They work by shining a beam of light at a light detector.
- Between the light detector and light source is a disk that spins with many holes in it



Optical Encoders

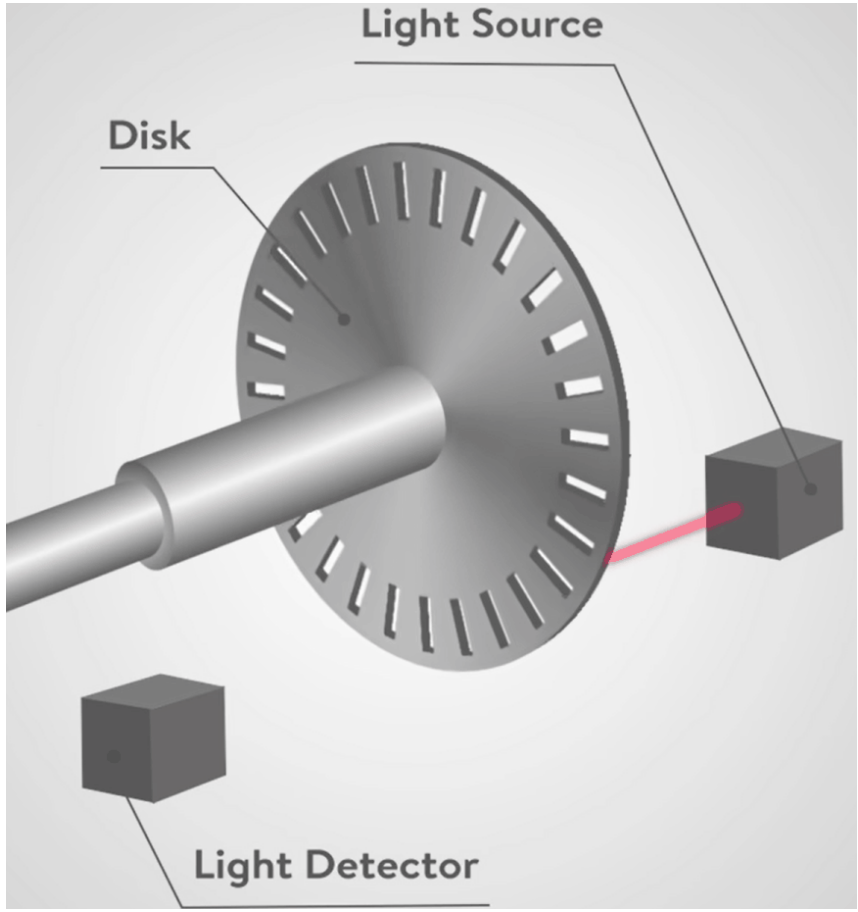
- As the disk rotates the light gets let through in pulses based on the pattern on the disk
- This light pattern is then converted to an electrical signal and sent to the controller
- The number of holes on the disk determines what the encoder is used for



Optical Encoders

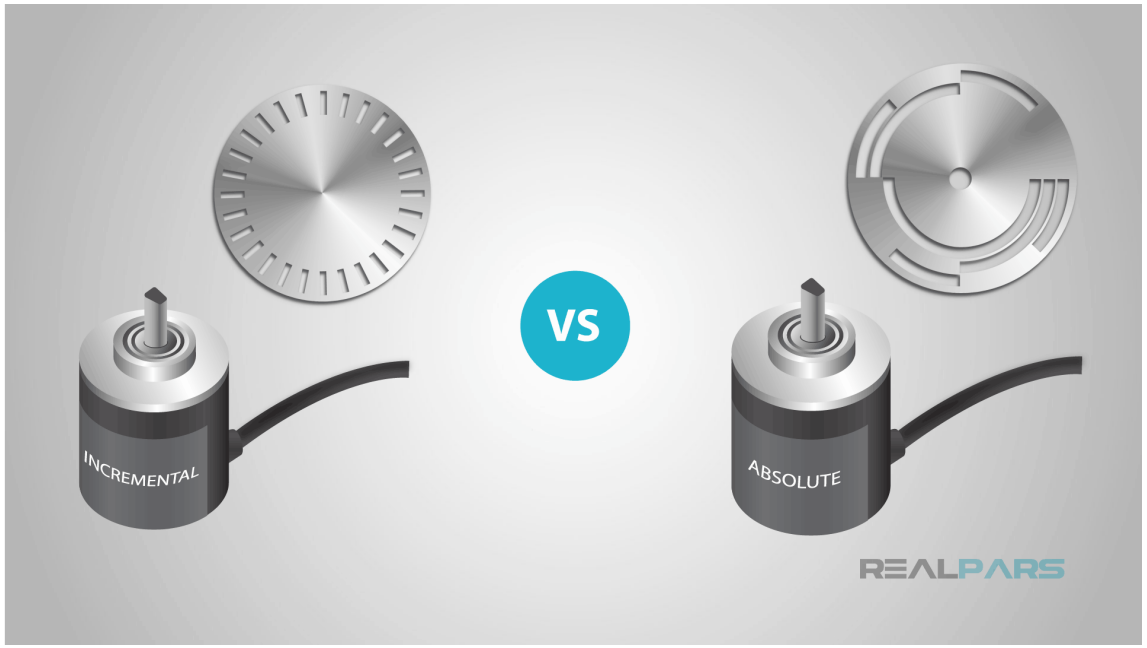
- The number of holes in the disk can also be known as the resolution of the encoder, it determines how many distinct positional steps the encoder can detect within one full revolution of the disk.

- So a disk with 100 holes will have 100 individual steps it measures in a full turn allowing you to be a lot more accurate when controlling a motor

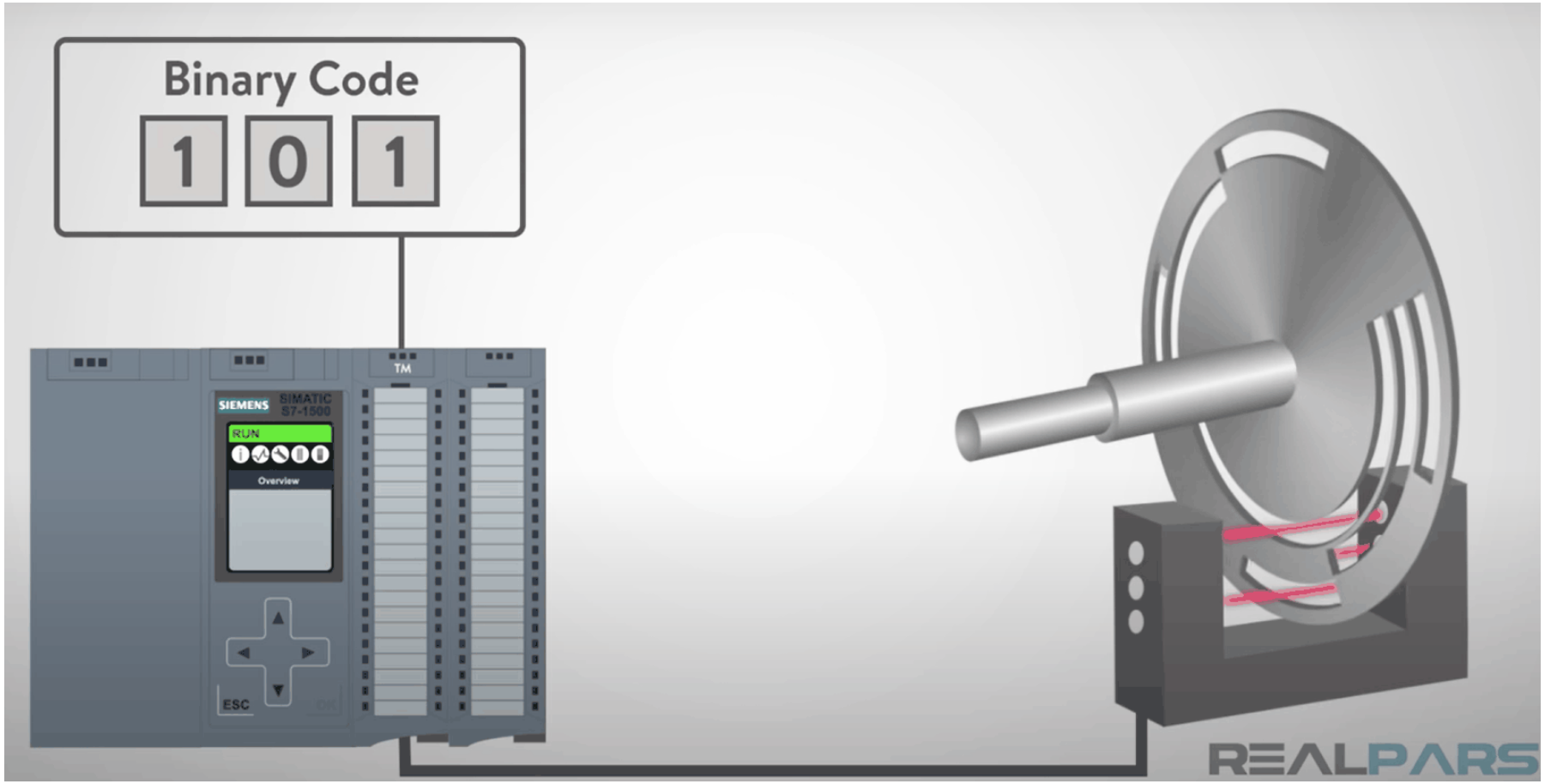


Optical Encoders

- Incremental optical encoders have 1 light source and sensor with one ring of holes to determine movement of the system
- Absolute optical encoders have arrays of light sources and sensors which read out a binary code based on which is on or off



Optical Encoders



Advantages/Disadvantages of Optical Encoders

Advantages

High precision and resolution

Low wear, long lifespan

Works at high speeds

Can detect position and direction

Less noise than analogue

Supports incremental & absolute data

Disadvantages

Expensive to make

Sensitive to dust and dirt

Fragile to shock/handling

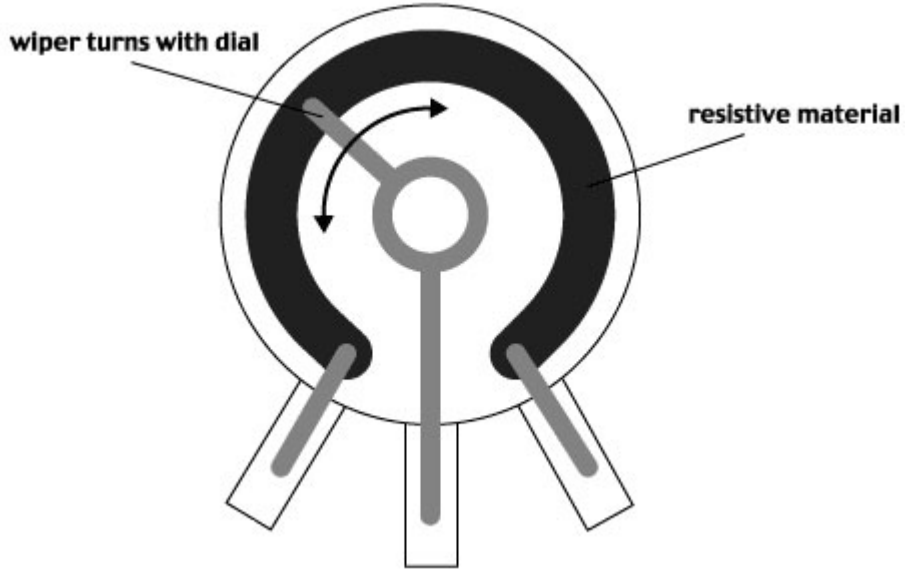
Poor performance in extreme temps

Bulkier than other types

Needs constant power

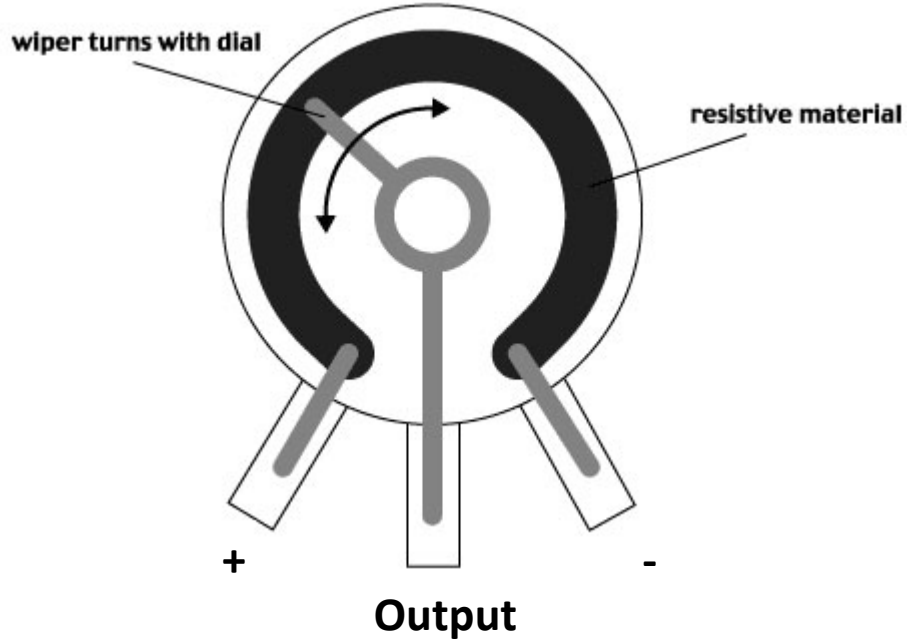
Resistive Encoder

- A resistive encoder works by varying resistance based on the location of the shaft
- A resistive controller has a set range, it can't turn infinitely, this range is typically less than 1 full rotation (usually 270^{o} or less)
- Resistive encoders also come in linear format which works on the same principles but with a head moving up and down rather than a shaft rotating



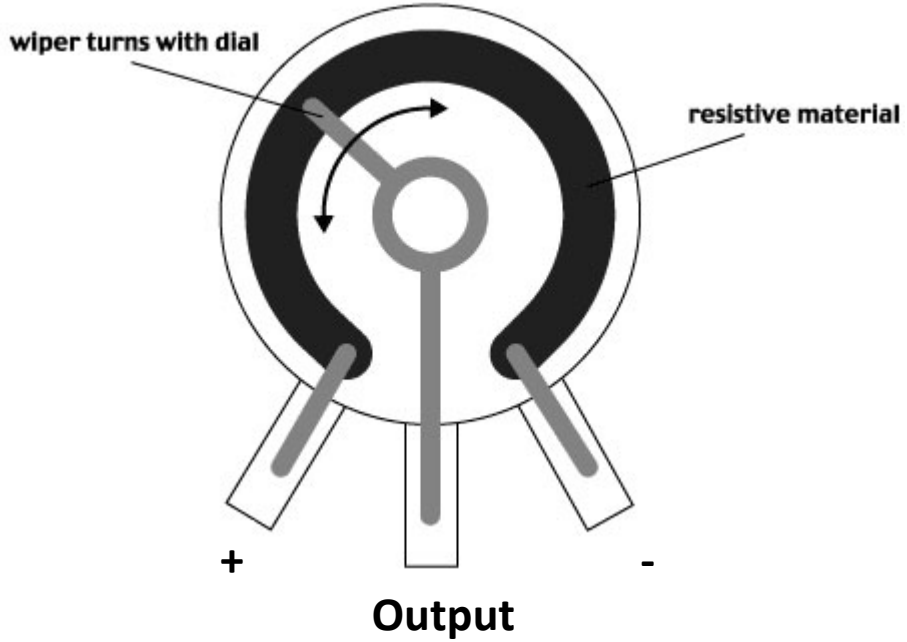
Resistive Encoder

- Inside a resistive encoder a wiper contacts a resistive track (typically carbon), as the actuator moves it moves this wiper along the track increasing and decreasing resistance
- As the resistance increases and decreases so does voltage due to ohm's law
- This voltage can then be read by a controller to determine where the encoder is on the track



Resistive Encoder

- Resistive encoders are always absolute as they correspond to a location along the track



Advantages/Disadvantages of Resistive Encoders

Advantages

Cheap

Easy to use

Continuous analogue output

Good for fixed ranges (e.g., volume)

Disadvantages

Parts wear out over time

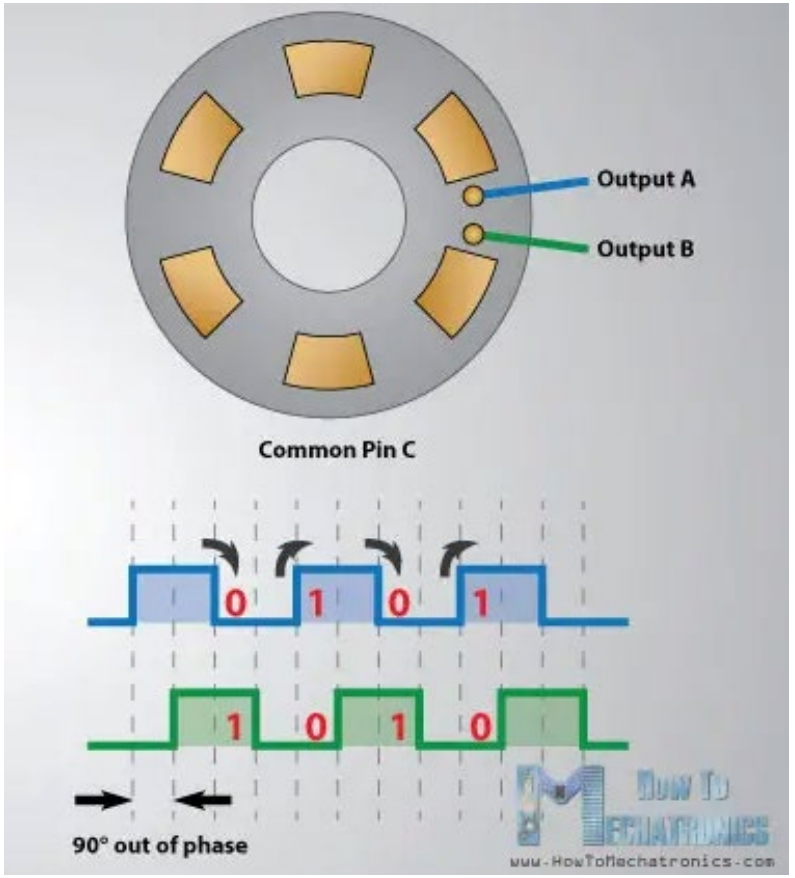
Limited range

Low precision

Noisy due to analogue output

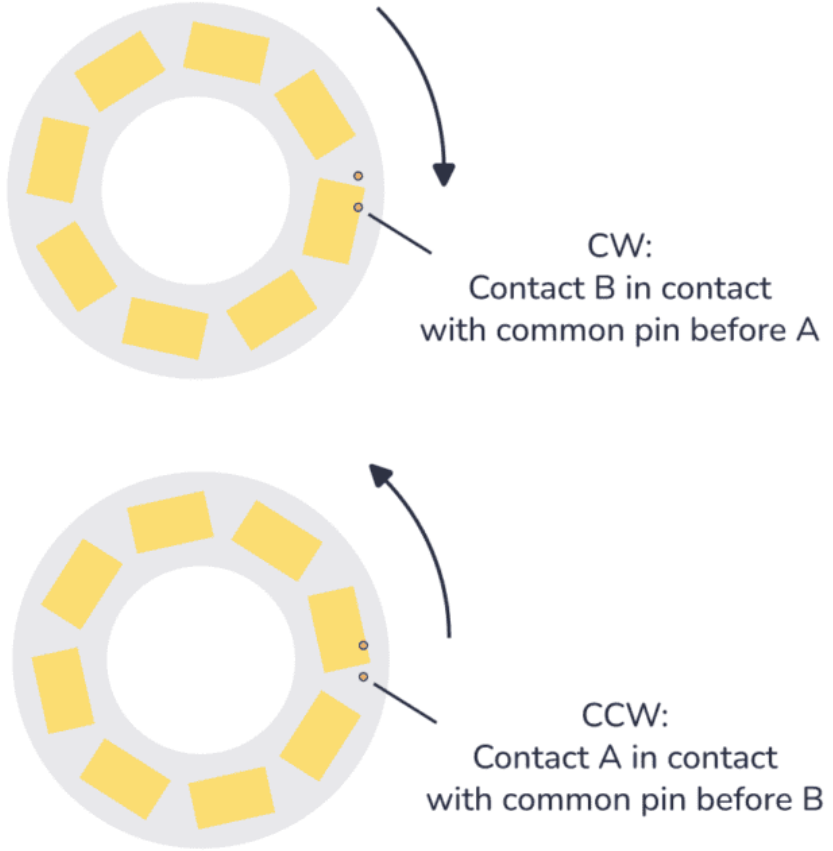
Mechanical Encoder

- Mechanical encoders work very similarly to resistive encoders with brushes running over a moving disk
- When the brushes contact a pad on the encoder, they give an output which can be read by a controller
- This is because the pads are half of a circuit and when the brushes hit the pad it completes the circuit giving an output



Mechanical Encoder

- Mechanical encoders can give you direction by checking which of the two brushes contacts the pad first. Whichever one does is the direction the disk is moving
- Mechanical encoders also come in linear format using the same ideas but in a line.
- The pads either provide a digital pulse (incremental) which can be read by the microcontroller or a unique binary pattern (absolute)



Advantages/Disadvantages of Mechanical Encoders

Advantages

Cheap

Simple to use

No complex electronics

Works in dirty environments

Robust

Disadvantages

Wears out over time

Low resolution

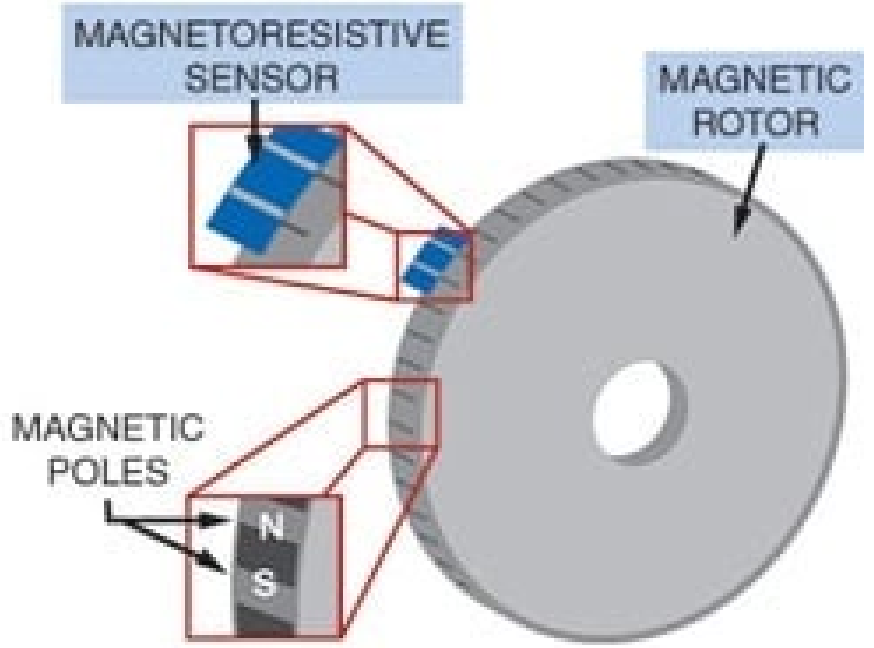
Not good for high speed

Contact noise/bouncing

Contacts can corrode

Magnetic Encoder

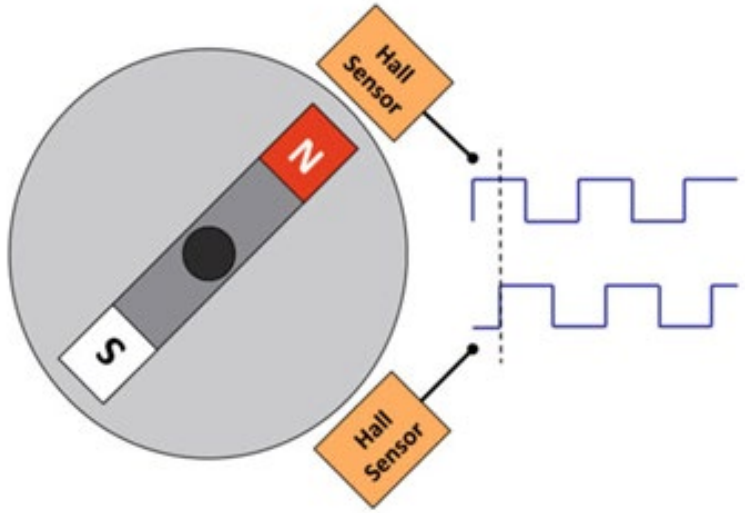
- A magnetic encoder uses a magnet or series of magnets attached to an actuator
- A sensor (such as Hall-effect or magneto resistive sensors) detect changes in the magnetic field due to the moving magnet(s)
- The sensors measure the strength and orientation of the magnetic field and generate an output signal.



Magnetic Encoder

- An incremental magnetic encoder generates pulses based on the movement of the magnet which is then interpreted by the controller

- An absolute magnetic encoder generates a unique code for every rotation/position based on a magnetic field map



Advantages/Disadvantages of Mechanical Encoders

Advantages

Resistant to dirt, dust, and harsh conditions

Works in extreme temperatures

Very small/compact

No physical contact → long life

Cheaper than high-res optical

High-speed operation

Disadvantages

Lower resolution than optical

Affected by magnetic interference

Can have slight inaccuracies

Calculating Position

- You don’t have to do anything to find the position of the absolute as it is already a position value
- To find the position distance/rotation of an incremental encoder you use the equation:
  - Position = increments moved * complete movement/resolution
- So, say we have moved 40 increments from the start position, we have a complete rotation of 360^{o} as its rotational and a resolution of 100 we can work out the position as:
- 40*360/100=144 so we have moved 144^{o} in the clockwise direction

Calculating Velocity/Speed

- For both incremental and absolute encoders finding the velocity is simple:
- Velocity = Change in position/change in time
- (change in time is seconds, change in position is either degrees or meters)
- So, say for an angular incremental encoder we want to find the velocity and we take 2 readings, at 0 seconds it's at 10^{o} and at 6 seconds it's at 90^{o}
- We can do (90-10)/(6-0) which is 80/6 which is 13.33 °/s