Encoders

YORK COLLEGE & UNIVERSITY CENTRE

Sensors and actuators

- Last lesson we went over sensors and actuators
- We learnt that sensors are how a system would measure the environment around it
- We learnt that 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

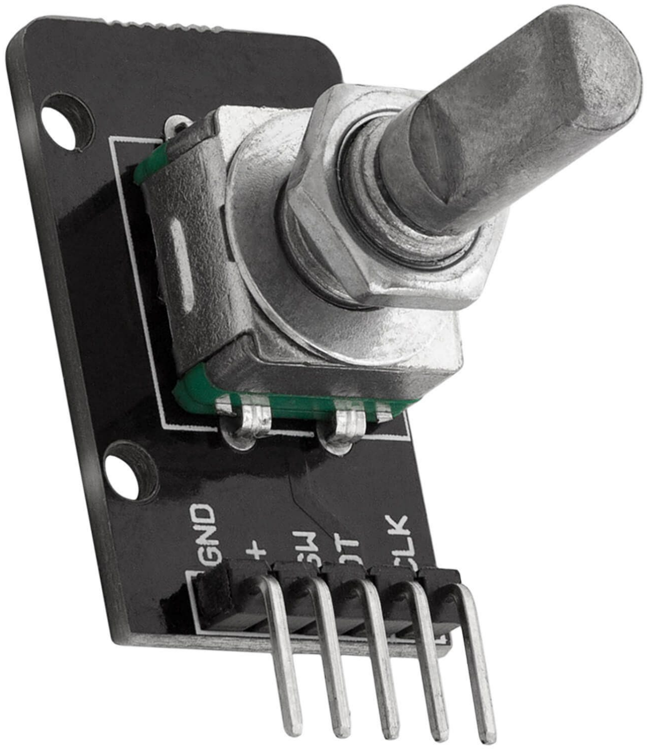
- They can be either linear or rotational which link to the two types of actuators

- 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

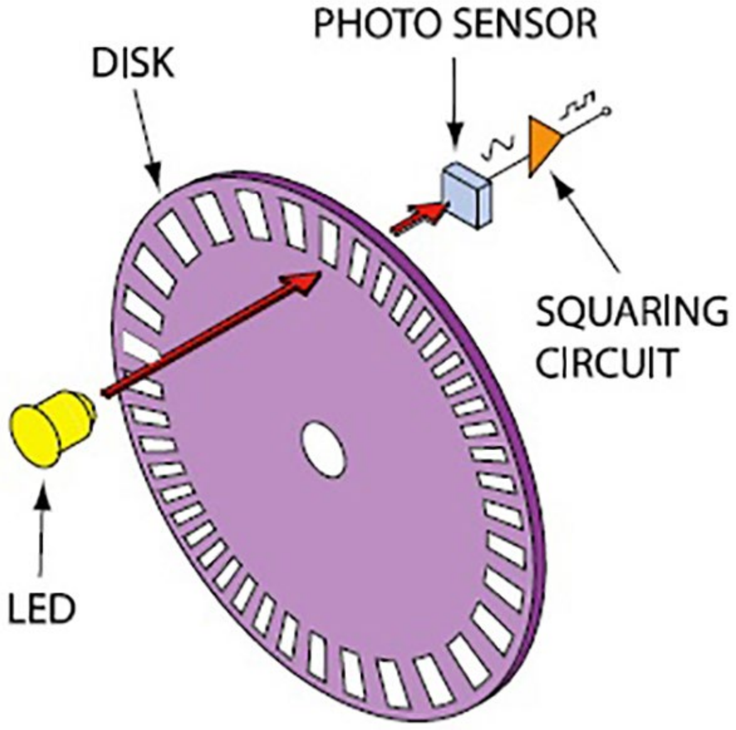
Incremental encoders	**Absolute encoders**
Produce pulses as the actuator moves indicating relative motion (how far or fast it has moved)	Every position has its own unique digital code allowing you to track the exact position of the actuator
The position is calculated by counting pulses from a reference point. This reference point is lost upon power down and thus must be set on startup	Provide the exact position immediately upon power-up, without needing a reference or homing process due to the unique code.
Resolution is defined by the number of pulses per revolution (PPR) or per unit of motion.	Resolution is defined by the number of unique positions or codes per revolution (or movement).
Often cheaper	Often more expensive

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

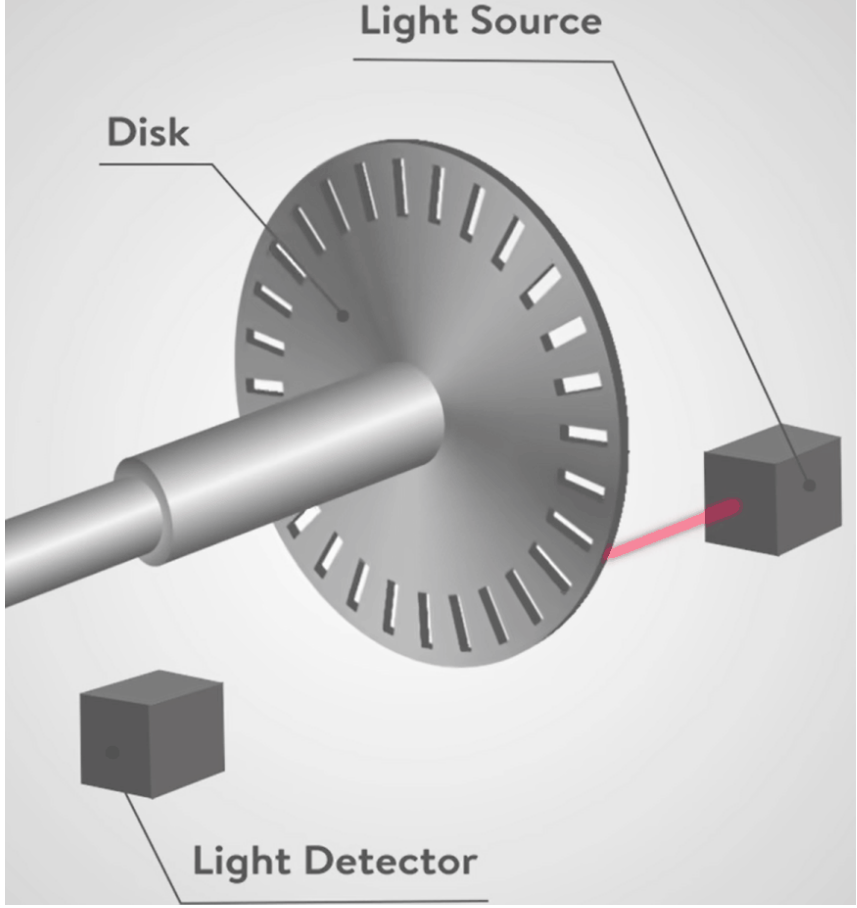


Optical Encoders

- 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

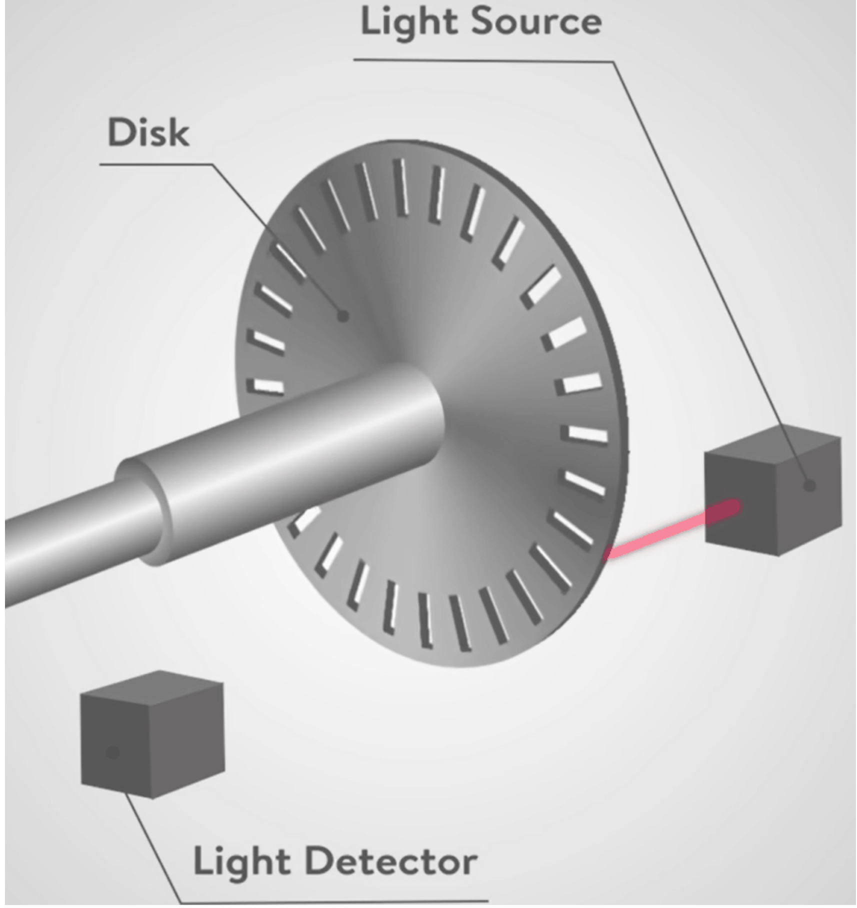
- The number of holes on the disk determines what the encoder is used for



Optical Encoders

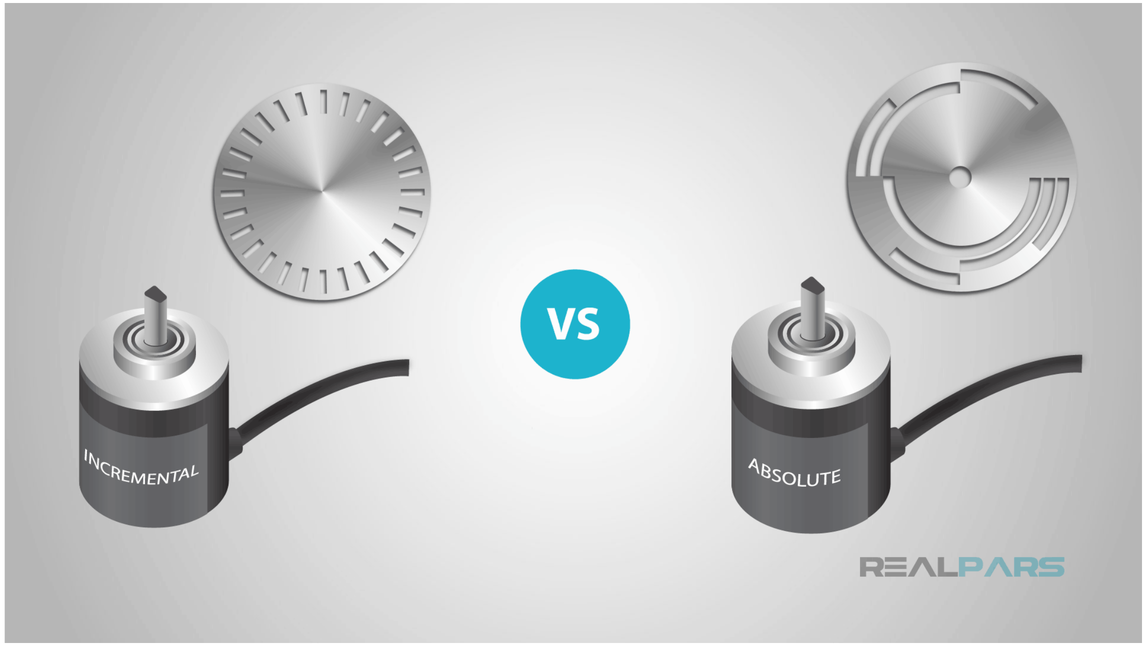
- The number of holes in the disk can also be known as the resolution of the encoder, it determines how many distinct positional steps the encoder can detect within one full revolution of the disk.

- 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

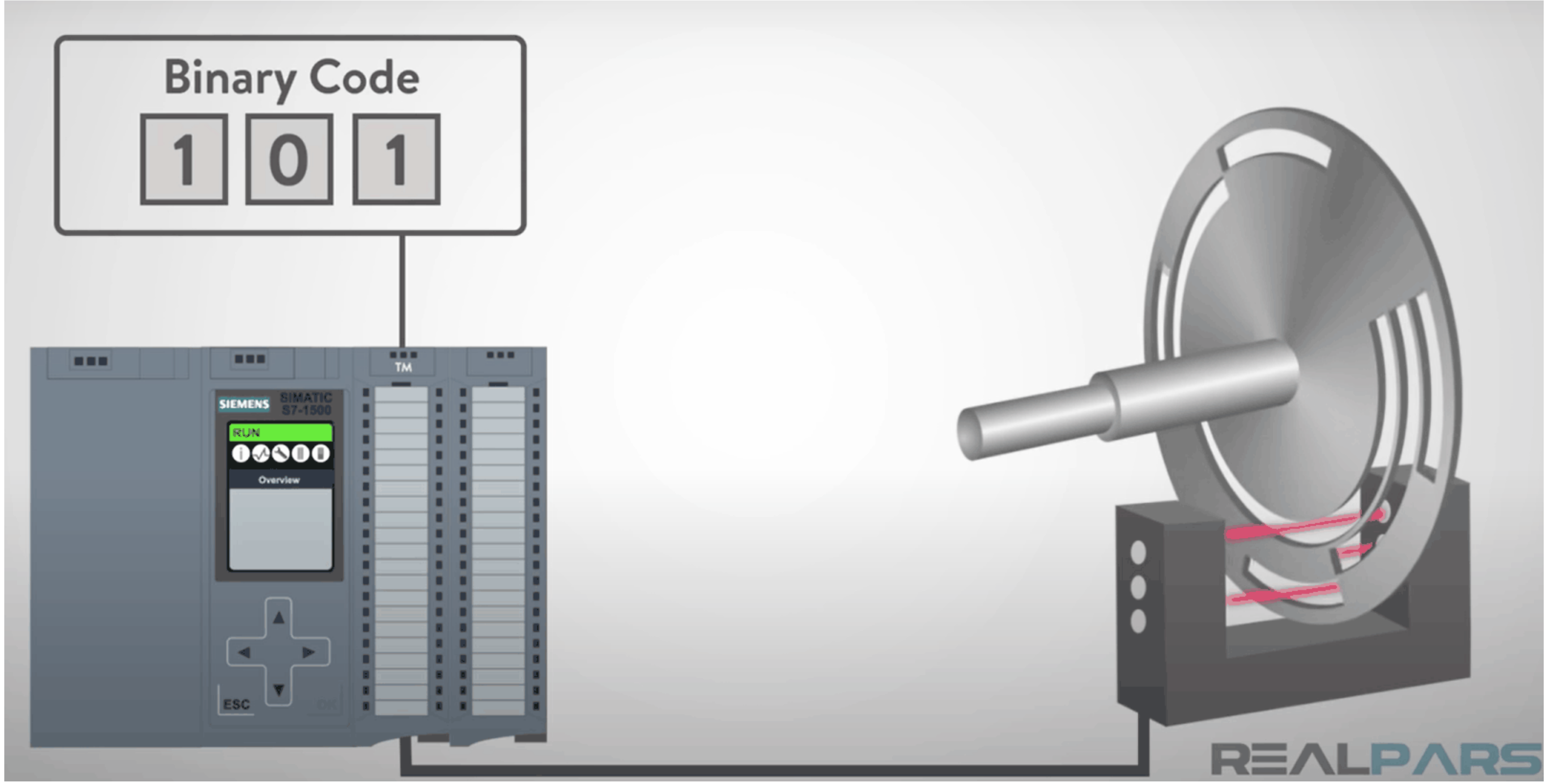


Optical Encoders

- 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

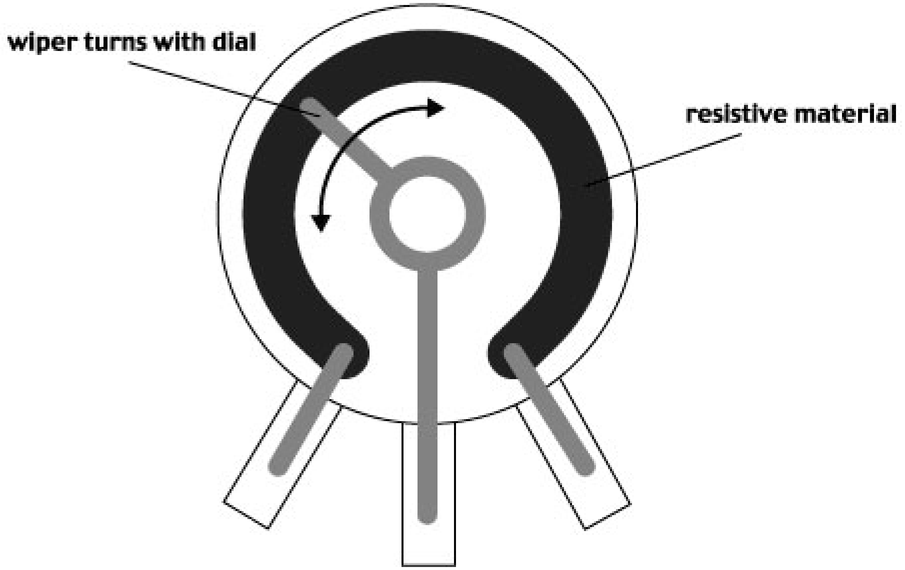


Advantages/Disadvantages of Optical Encoders

Advantages	**Disadvantages**
Very high precision and resolution (up to 1000s of pulses per revolution)	Usually more expensive due to precise manufacturing techniques
No physical contact between disk and optical components meaning low wear and long lifespan	Dust, dirt, or oil can obstruct the light path and cause errors or failure.
They can operate at very high speeds making them ideal for complex machinery	The optical disk and sensor are delicate and can be damaged by physical shock or rough handling.
Quadrature optical encoders can determine both the position and direction of rotation.	Optical components may not perform well in extreme temperatures.
Less prone to noise than analogue encoders making it ideal for noisy scenarios	Optical encoders tend to be larger than magnetic or capacitive encoders
Can provide both incremental and absolute position data, depending on the design.	Requires constant power source to power the light source

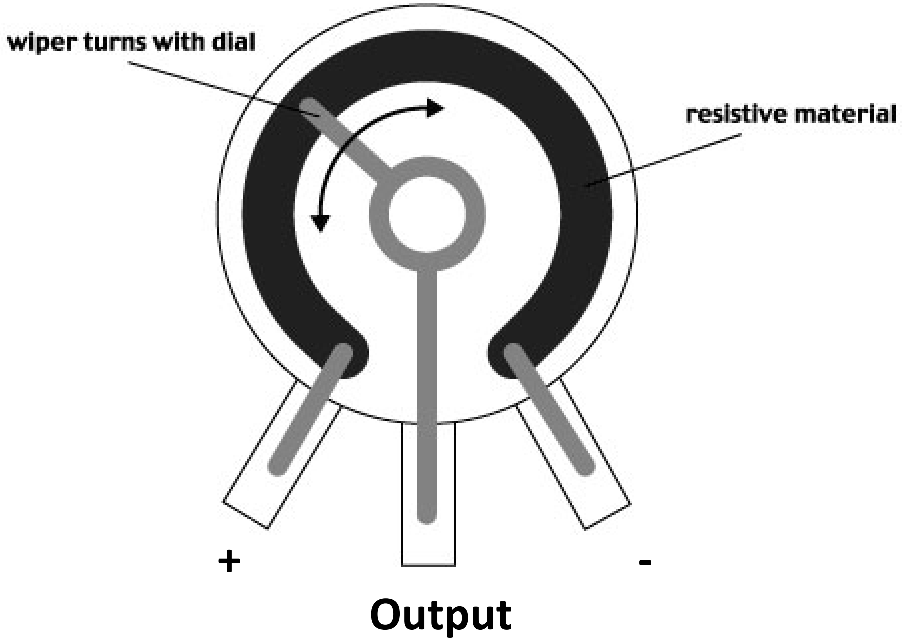
Resistive Encoder

- 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



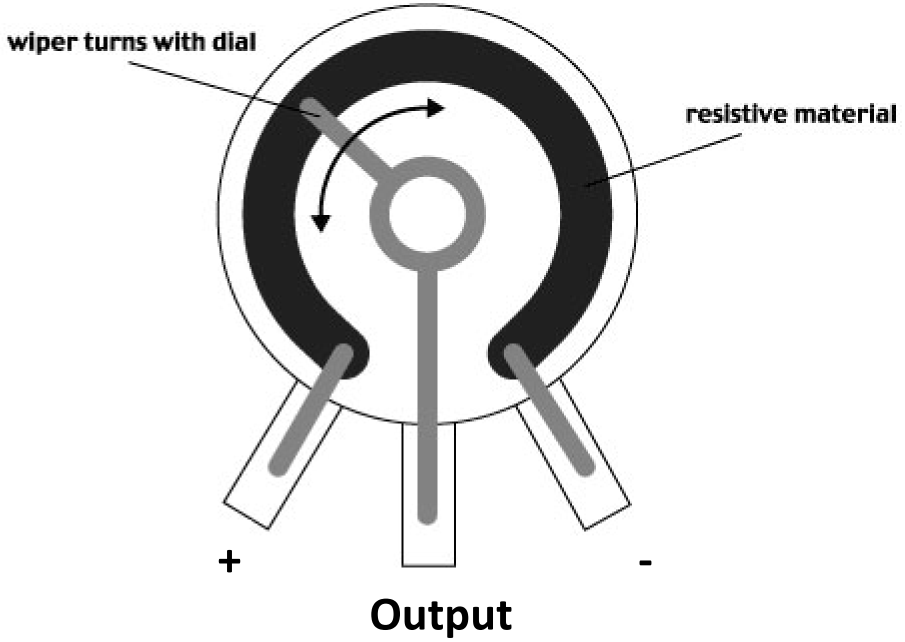
Resistive Encoder

- 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

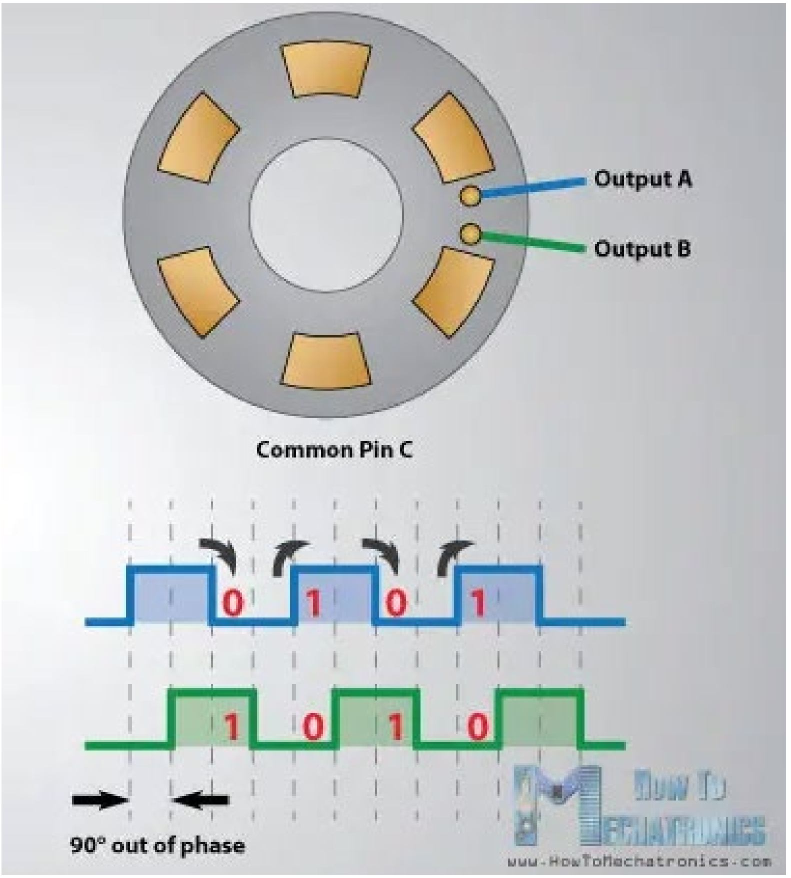


Advantages/Disadvantages of Resistive Encoders

Advantages	Disadvantages
Often very cheap compared to other encoder types	Due to the wiper needing to constantly contact the resistive track there is a high likelihood of parts degrading and breaking over time
Very simple to implement in multiple scenarios	The encoder only has a limited range making it not ideal for use in motors
Provides a continuous analogue output.	Limited precision due to the nature of resistance
Due to its limited range its ideal for something which has a set range already e.g. volume	Due to the output being analogue it is very susceptible to noise from other components

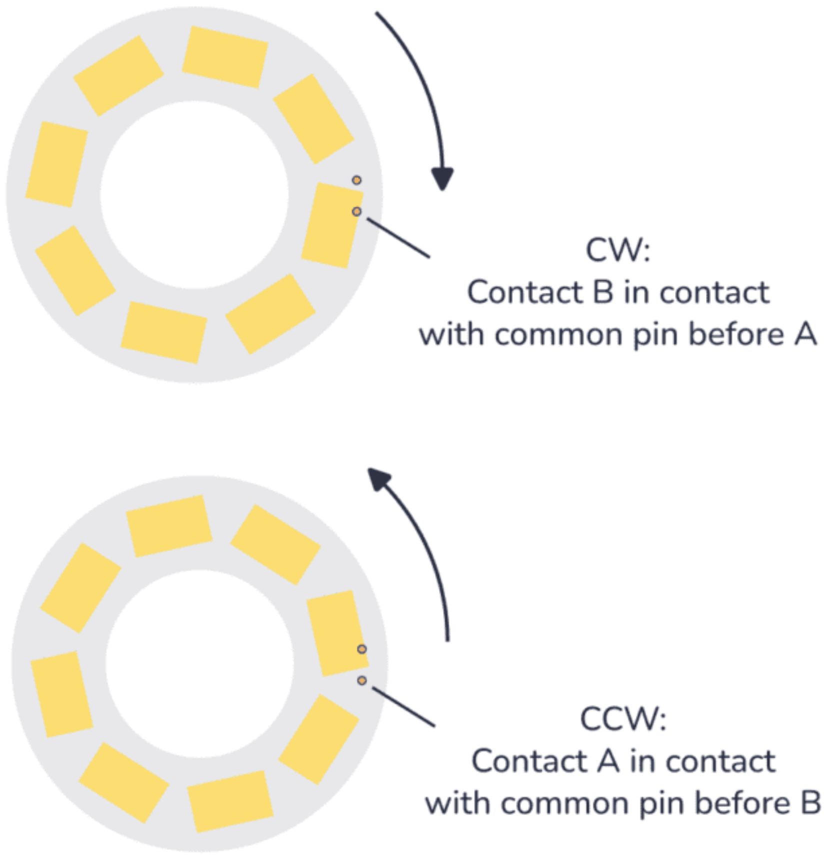
Mechanical Encoder

- 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

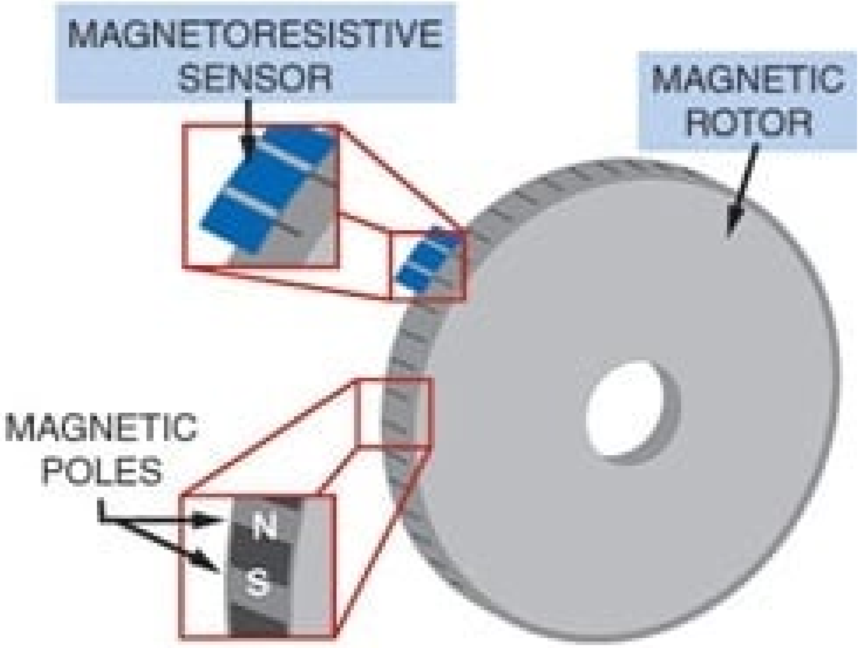
Advantages	Disadvantages
Often very cheap compared to other encoder types	The physical contact between the brushes and the disk leads to wear over time, reducing the lifespan of the encoder.
Very simple to implement in multiple scenarios	Mechanical encoders typically have lower resolution due to the physical size and spacing of the contacts.
Mechanical encoders do not require complex electronics, simplifying the overall system.	They are not suitable for high-speed applications
Mechanical encoders can be robust in extreme environments, such as areas with dirt or dust.	The switching of contacts can produce electrical noise or "bouncing," which needs to be debounced electronically or via software.
	The contact points may degrade over time due to corrosion

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)

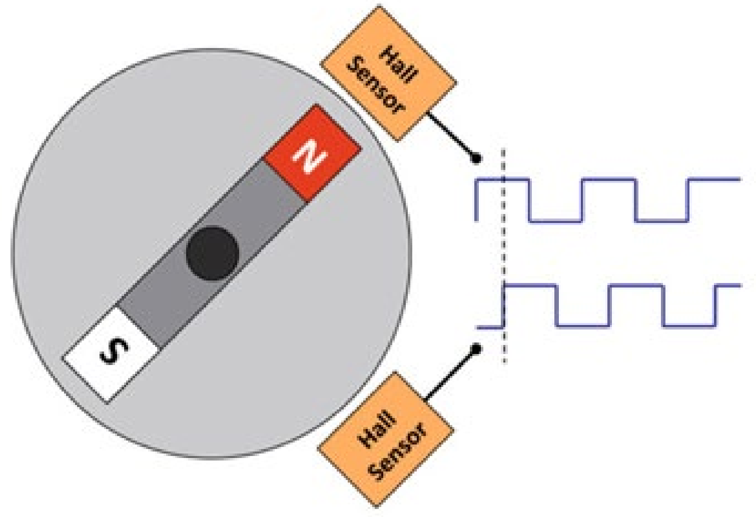
- The sensors measure the strength and orientation of the magnetic field and generate an output signal.



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	Disadvantages
Magnetic encoders are highly resistant to dirt, dust, oil, moisture, and vibrations, making them suitable for harsh industrial environments.	Magnetic encoders typically have lower resolution compared to optical encoders, although modern designs are improving this.
They perform well in extreme temperatures, typically ranging from -40°C to 125°C or more.	Strong external magnetic interference can affect performance, though shielding can mitigate this issue.
Magnetic encoders can be very small, making them ideal for compact systems.	Magnetic encoders may experience slight inaccuracies due to non-uniform magnetic fields or mechanical misalignment.
With no physical contact between the sensor and the magnet, they have a longer lifespan.	
Usually less expensive than high-resolution optical encoders for similar performance	
Can operate at high speeds without signal degradation.	

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

Questions