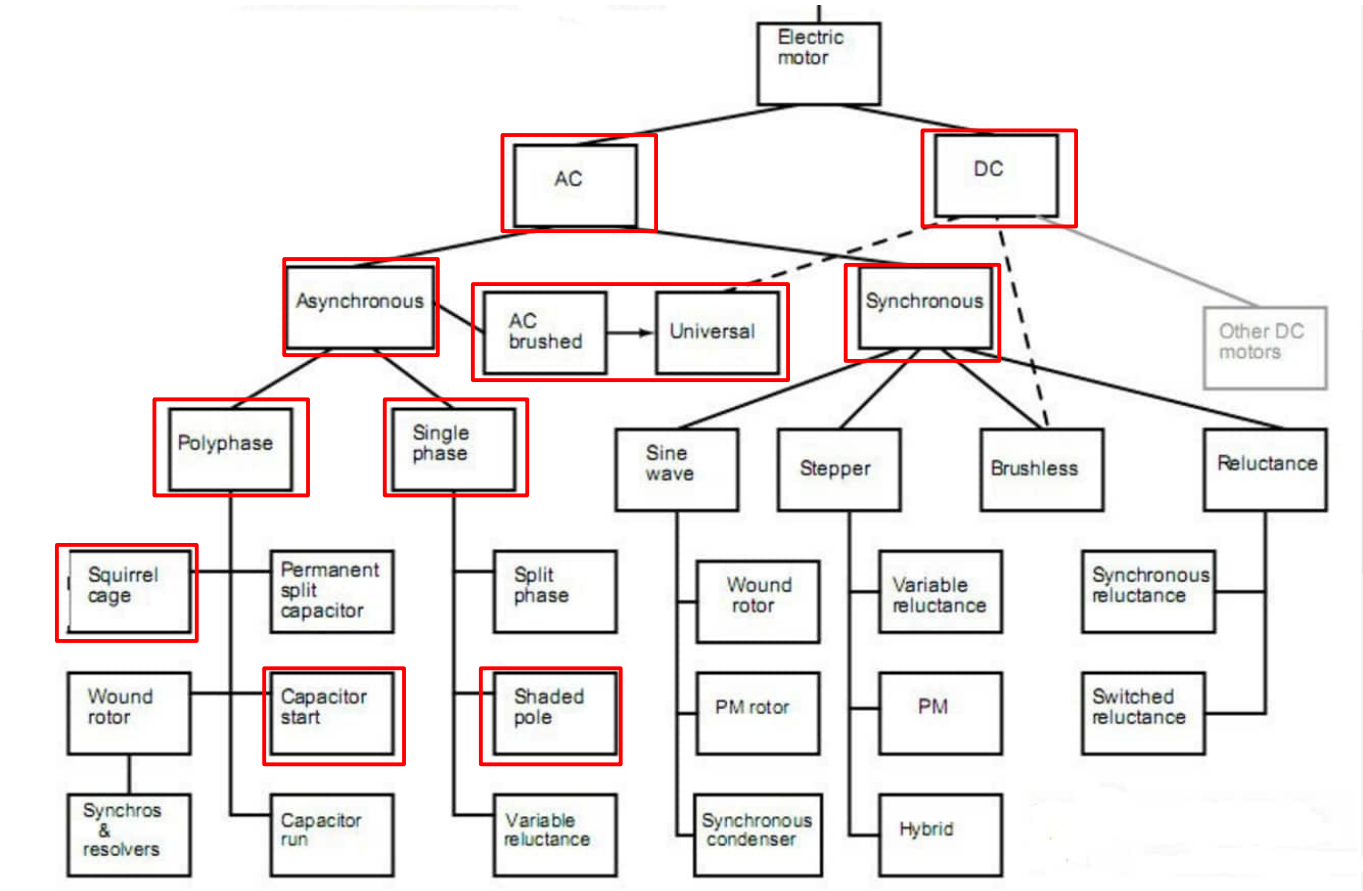
Jacobs University Bremen

Electric motors

Brushless DC and stepper motors

Automation
CO23-320203

Electric motor family



Synchronous vs asynchronous motors

- We have seen both:
  - A series/shunt universal motor has its rotor connected to the same circuit that the stator
    - The fields created by both are synchronised (by the commutator)
  - An induction motor has a stator which produces the field independently
    - By the very principle, it cannot move at the same speed as the circulating field of the stator

Common electric motor ratings

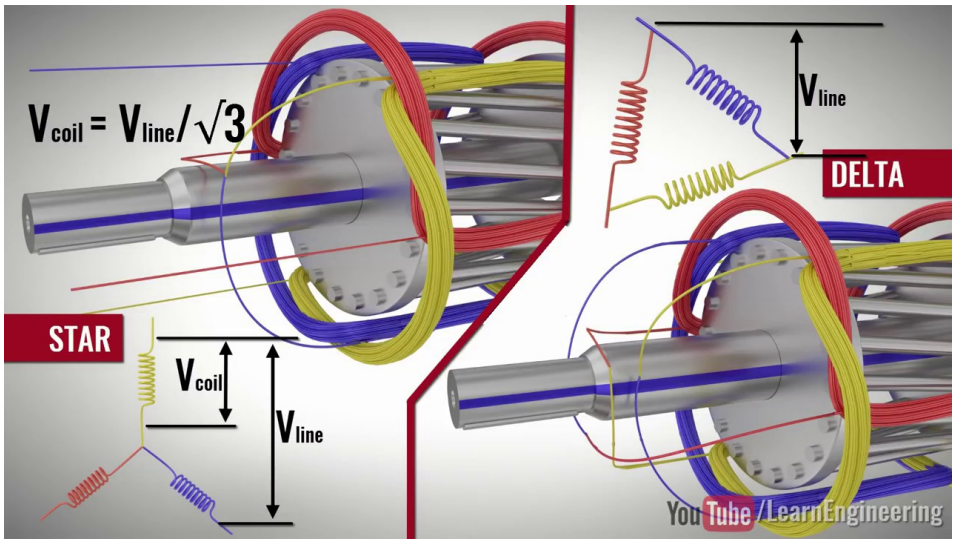
- **Rated Voltage**: The operating input voltage of the motor
- **Rated Power**: The output power (in watts [W] or horse power [HP = 745.7 W]) the motor is designed to deliver to the load for continuous operation
- **Rated Speed**: Speed (usually in rotations per minute [RPM]) for which the motor is designed to operate for continuous operation
- **Rated Load**: The load the motor is designed to carry for an continuous operation indefinitely. At “full-load” the motor is delivering the rated power to the rated load

Starting induction motors

- An electric motor is essentially a coil of copper wire
- The back EMF which reduces the current in the armatures is proportional to the rotational speed
- Before the speed builds up, the current and the power dissipation can be very high
- Especially for an induction motor where the line frequency dictates the rotation velocity of the stator magnetic field

Starting induction motors

- Start – delta: electrical arrangement of the coils

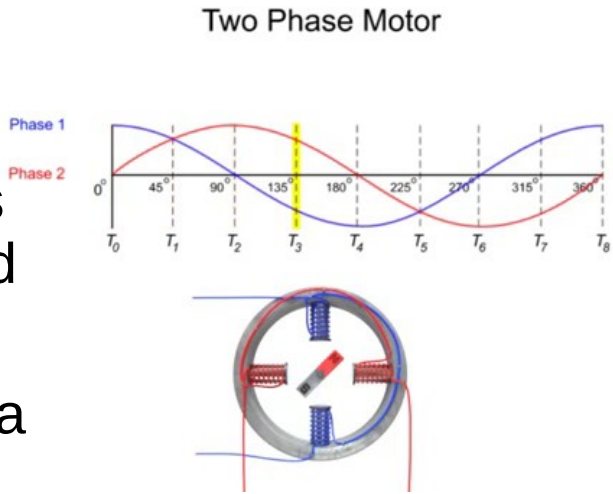


Understanding STAR-DELTA Starter !
https://www.youtube.com/watch?v=km8MSWm39Z0

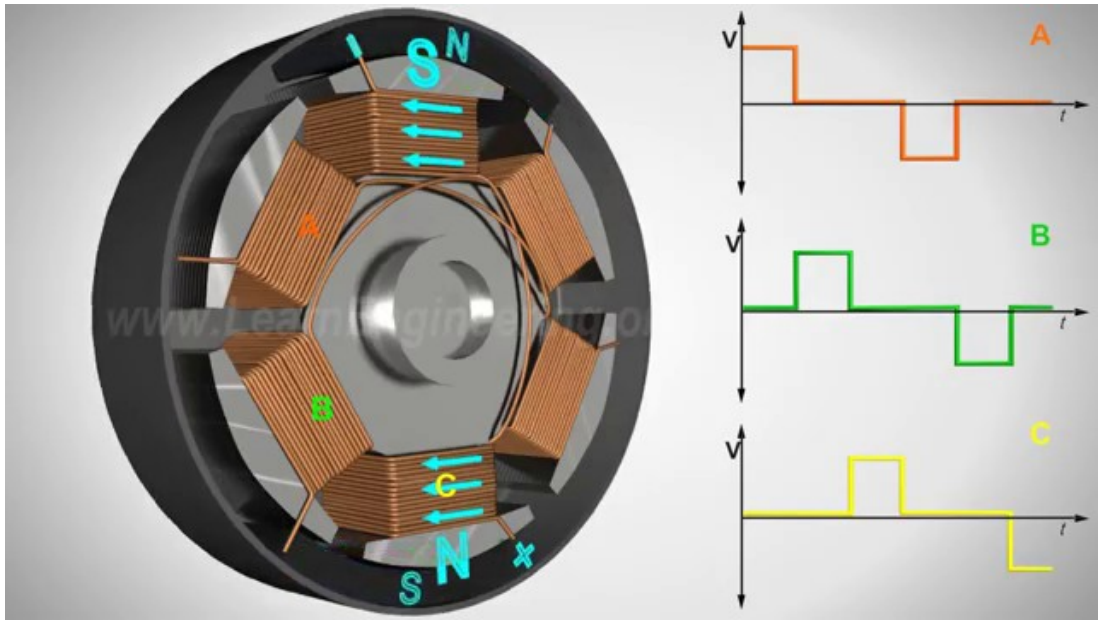
- An alternative to reducing input voltage or complicated motor control circuits like ESC or VFD (discussed later)

Brushless DC Motor

- We have already seen the basic construction!
  - But the input to the stator's electromagnets was a fixed frequency AC current
  - In BLDM, we assume that a set of sinusoids of appropriate frequency and amplitude will be created by a special circuit – the ESC



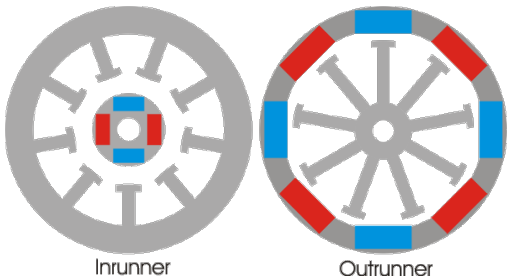
Brushless DC Motor

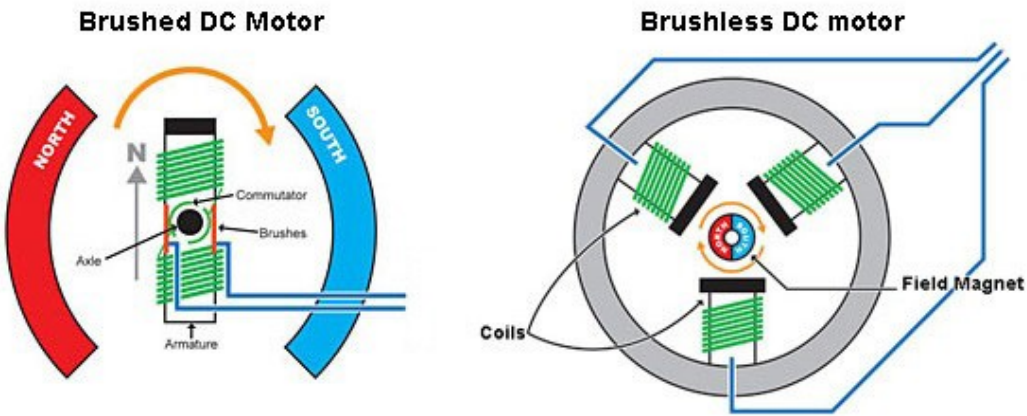


"Brushless DC Motor, How it works ?"
https://www.youtube.com/watch?v=bCEiOnuODac

Brushless DC Motor

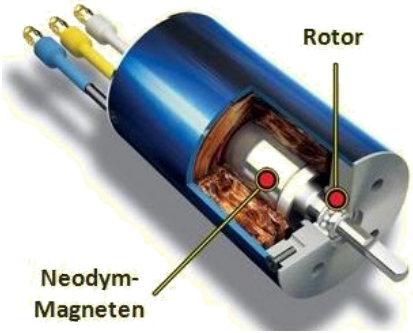
- The basic principle is an inversion of the basic DC motor type: a rotating electric armature surrounded by the permanent magnet
  - We make the magnet rotate!

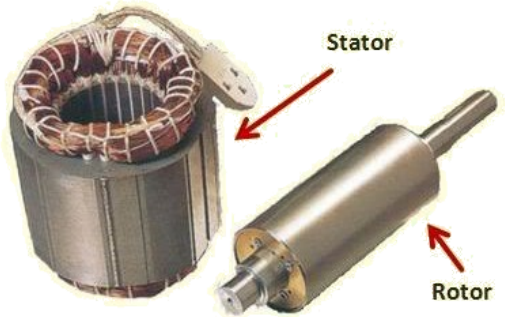


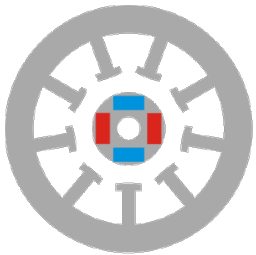


Brushless DC Motor

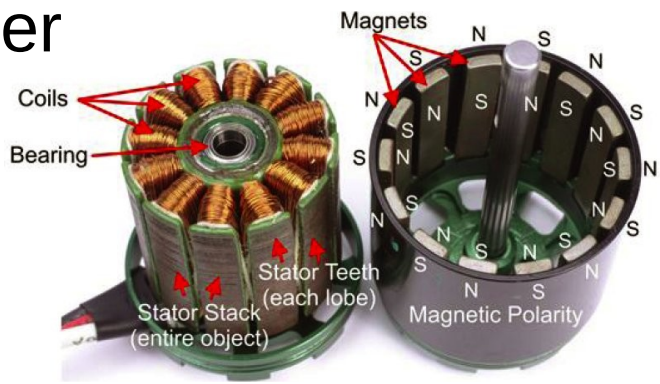
- Inrunner

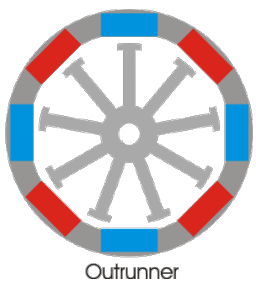






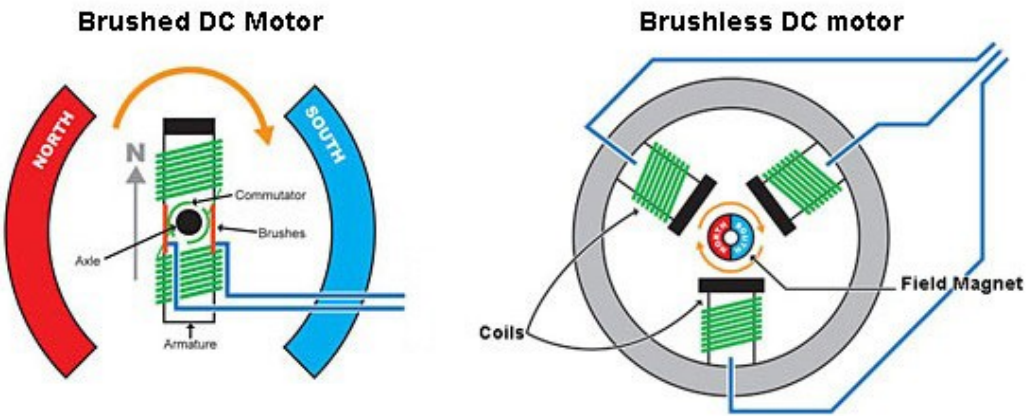
- Outrunner





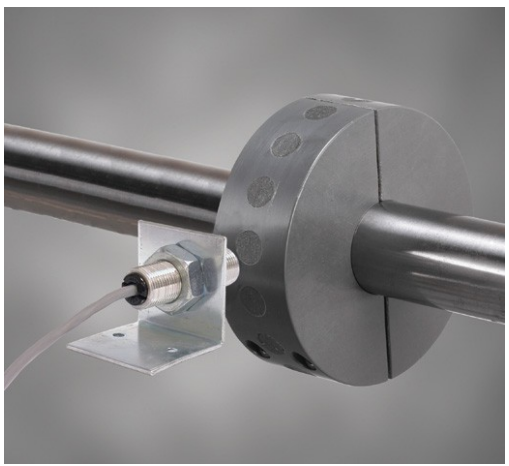
Brushless DC Motor

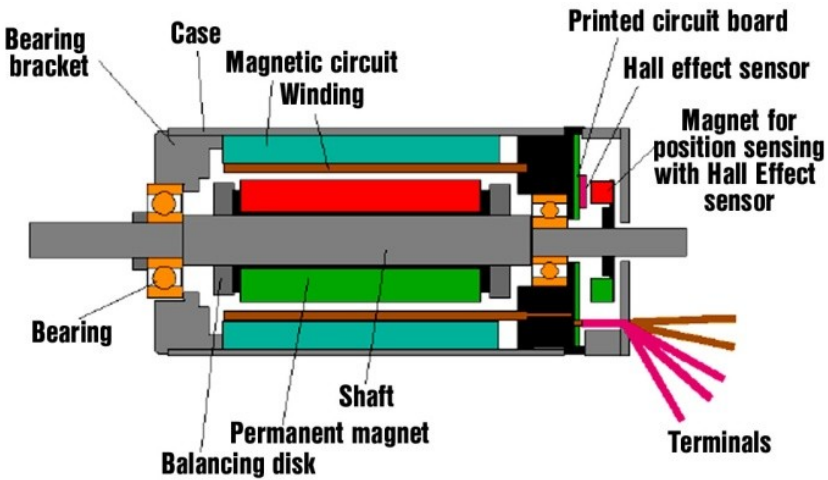
- Since no sliding contacts (brushes) are present, these motors are more reliable and need less maintenance.
- The big question: how do we vary the current to synchronize it with the rotation of the rotor?
  - Remember, we don't have a commutator anymore!



Rotation encoders – Hall sensor

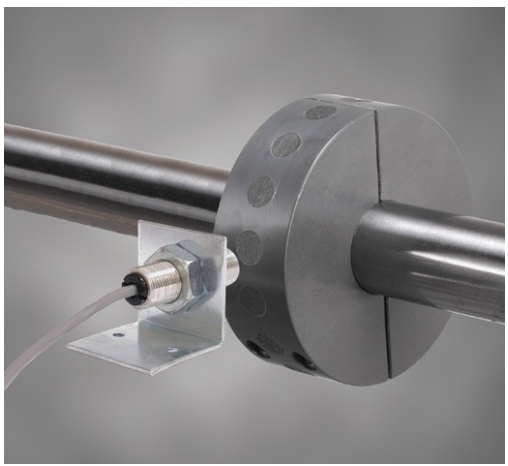
- The position of the shaft which dictates what should be the orientation of the stator field to create the highest torque on the motor (if desired) can be measured by a hall sensor
- In a basic design, it's more suitable for measuring velocity

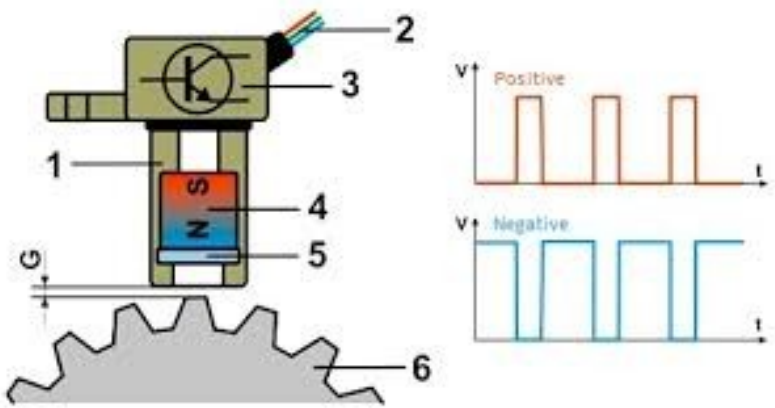




Rotation encoders – Hall sensor

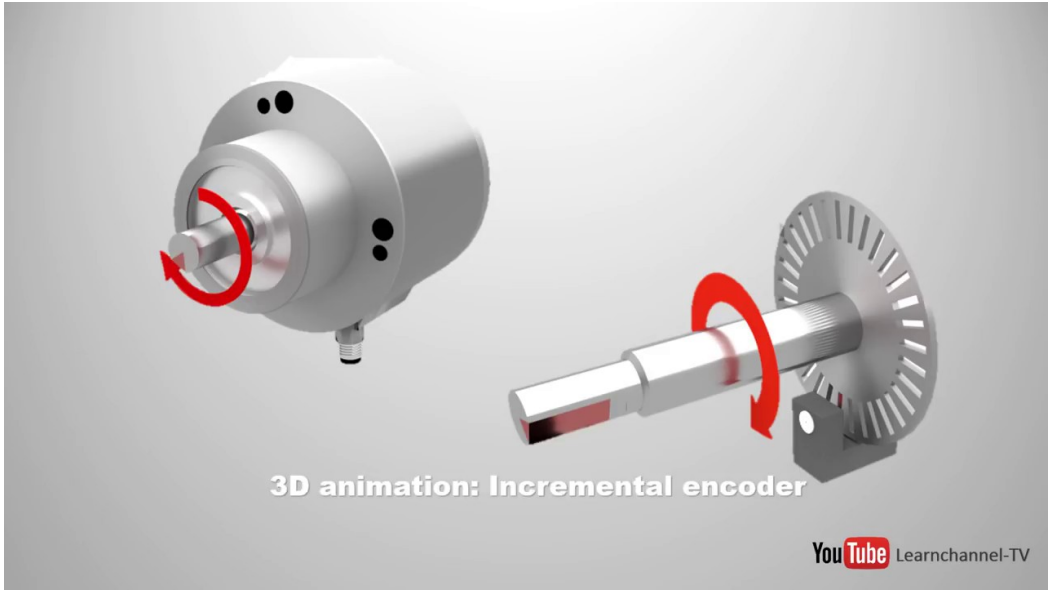
- Incremental sensing by counting the peaks
  - To know what angle the shaft has travelled
  - To know how many “teeth” per second pass in front of the sensor





Rotation encoders – absolute encoder

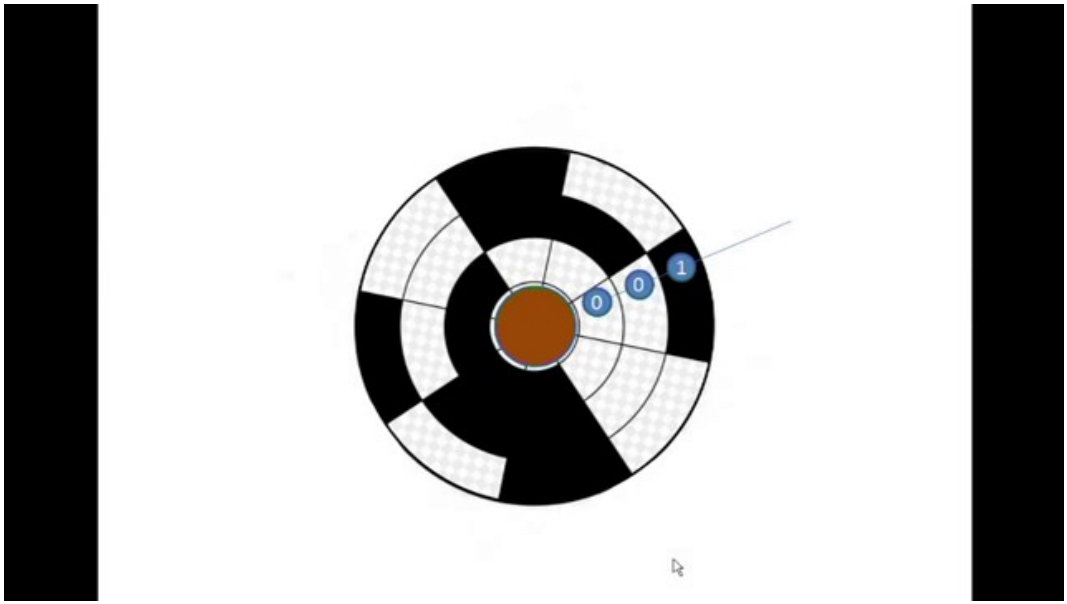
- The counting and direction sensing principle:



"Incremental Encoder (Shaft Encoder)- how it works "
https://www.youtube.com/watch?v=J4dIxnCuIpI

Rotation encoders – absolute encoder

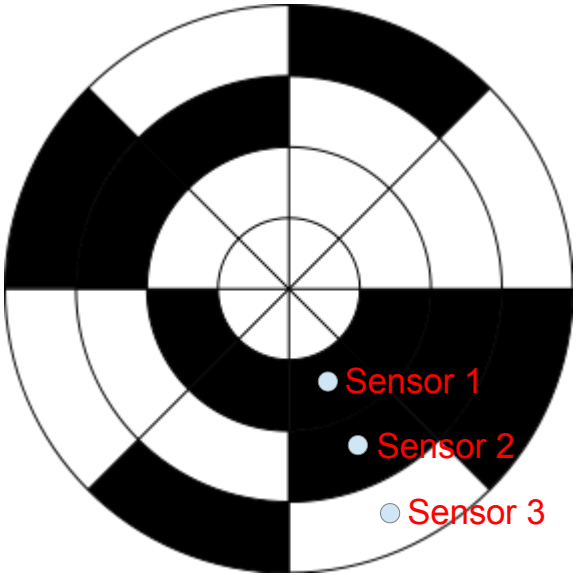
- The counting and direction sensing principle:



"Binary and Gray Shaft Encoders"
https://www.youtube.com/watch?v=cdeNxFkTwR0

Rotation encoders – absolute encoder

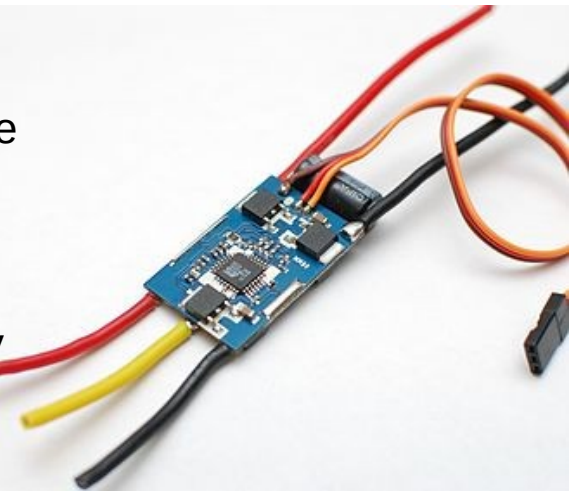
- An absolute encoder produces a binary integer (e.g. bx101110) at every moment
- The idea: to update the least significant bit (LSB) with the small rotations and MSB with big
- What is the resolution of this encoder? - check how often (every x°) the LSB switches
- Many advantages of this sensor over incremental sensing with hardware/software counting
  - Instant absolute position
  - No guesswork required after a power-failure



Arrangement for a 3-bit absolute encoding scheme

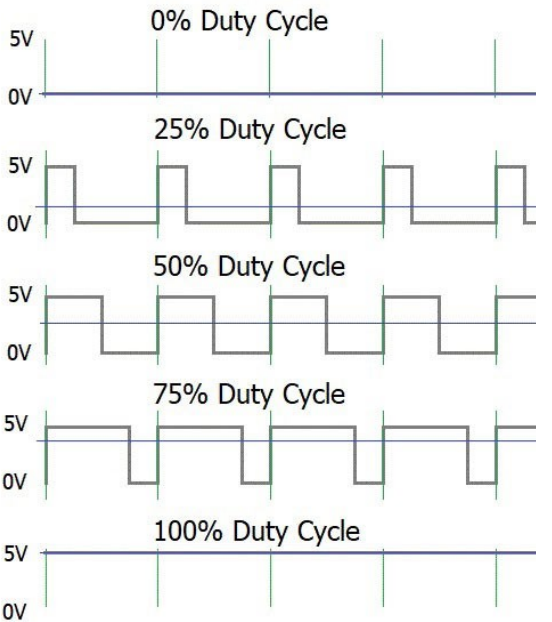
Motors control circuits

- Electronic speed control, or ESC is a circuit that controls and regulates the speed of an electric motor
  - The input signal defines the level of power to be applied to the motor
  - Brushless ESCs create a three phase AC input waveform for a motor; a simple ESC for a DC motor could just amplify the input signal
  - Technology: rapid switching of power transistors – an inexpensive technology which helped popularise the brushless motors



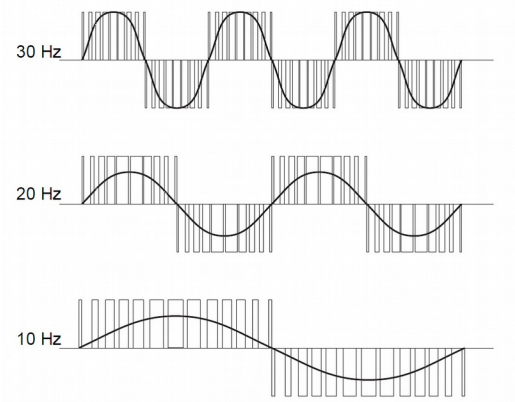
Pulse width modulation

- Pulse width modulation, or PWM, is a way to reduce power sent to a device (a DC motor, an LED diode, etc.) without having to modify the voltage source level



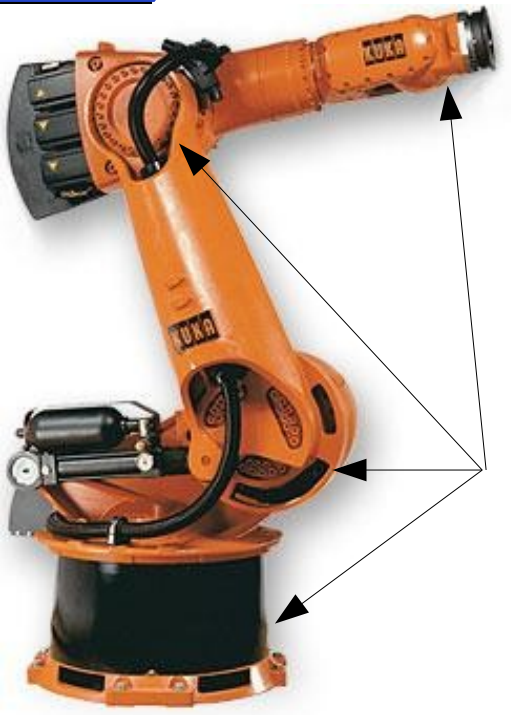
Motors control circuits

- Variable-frequency drive, or VFD, is very similar in idea to ESC but is typically supplied with a fixed frequency AC power and can modify this frequency and power level at the output
- Most of the global electric power is consummed by induction motors. VFDs improve efficiency by allowing to generate the precise power needed



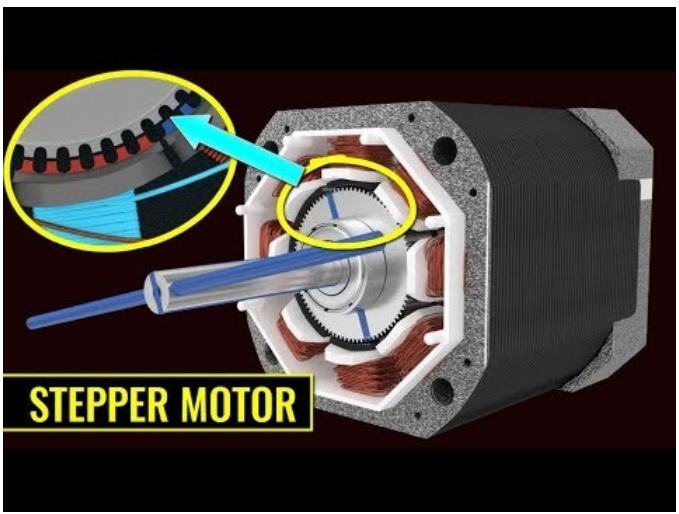
Stepper motors and servos

- Up until now we thought of electric motors as of devices to produce angular rotation and torque
- With a simple mechanical arrangement, they can provide linear motion, too!
- In automated systems, one often needs a precise angular orientation
- Stepper motors and servos are designed to deliver this capacity



Stepper motors

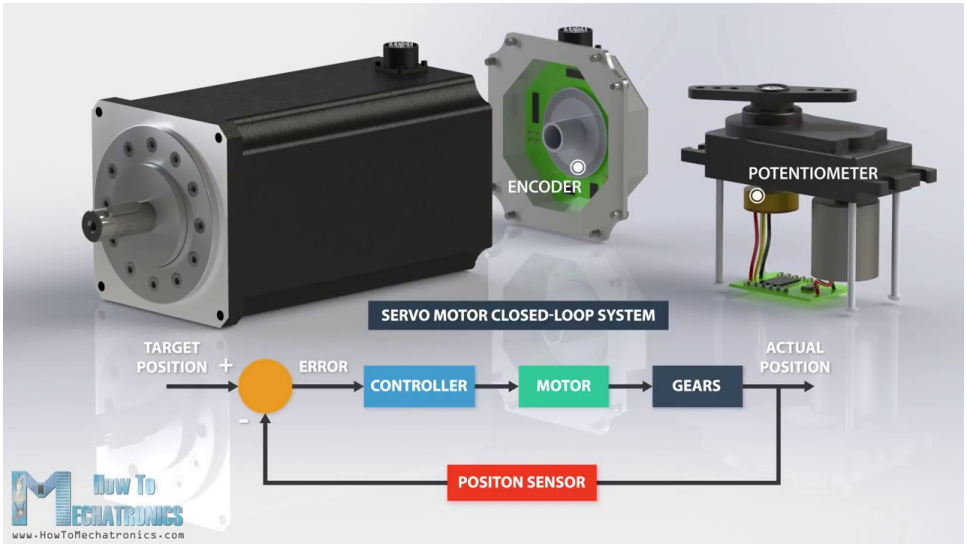
- Stepper motor is a inrunner DC motor that relies on a specific arrangement of the rotor magnets to
  - Increase static holding power
  - Give fine movement control



"How does a Stepper Motor work ?" https://www.youtube.com/watch?v=eyqwLiowZiU

Servo motors

- Servos use position encoder, a feedback loop and, very often, a system of gears



"How Servo Motors Work & How To Control Servos using Arduino"
https://www.youtube.com/watch?v=LXURLvga8bQ