Robotics Electrical Systems

Robotic Actuators

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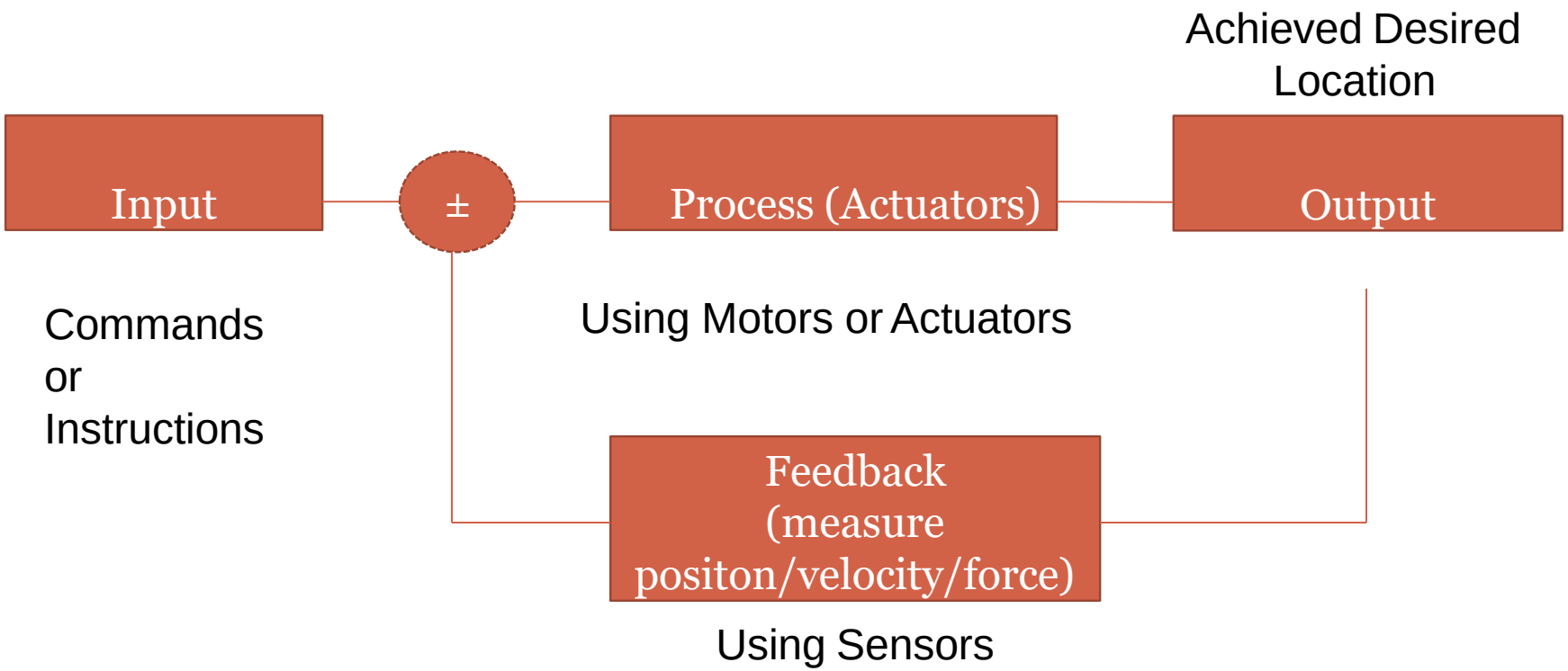
Robotics and Automation

Robotic Control System



Actuator

- Actuators are used to provide the motion of robotic joints to perform different tasks

- Motion can be produced linearly or rotationally

Classifications

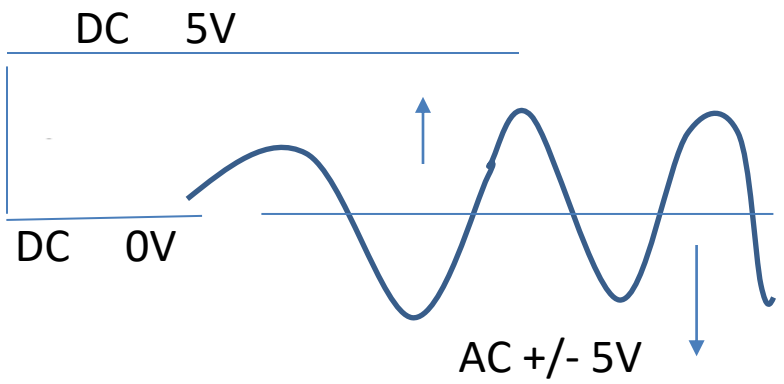
- Robotic actuators can be classified in the following categories

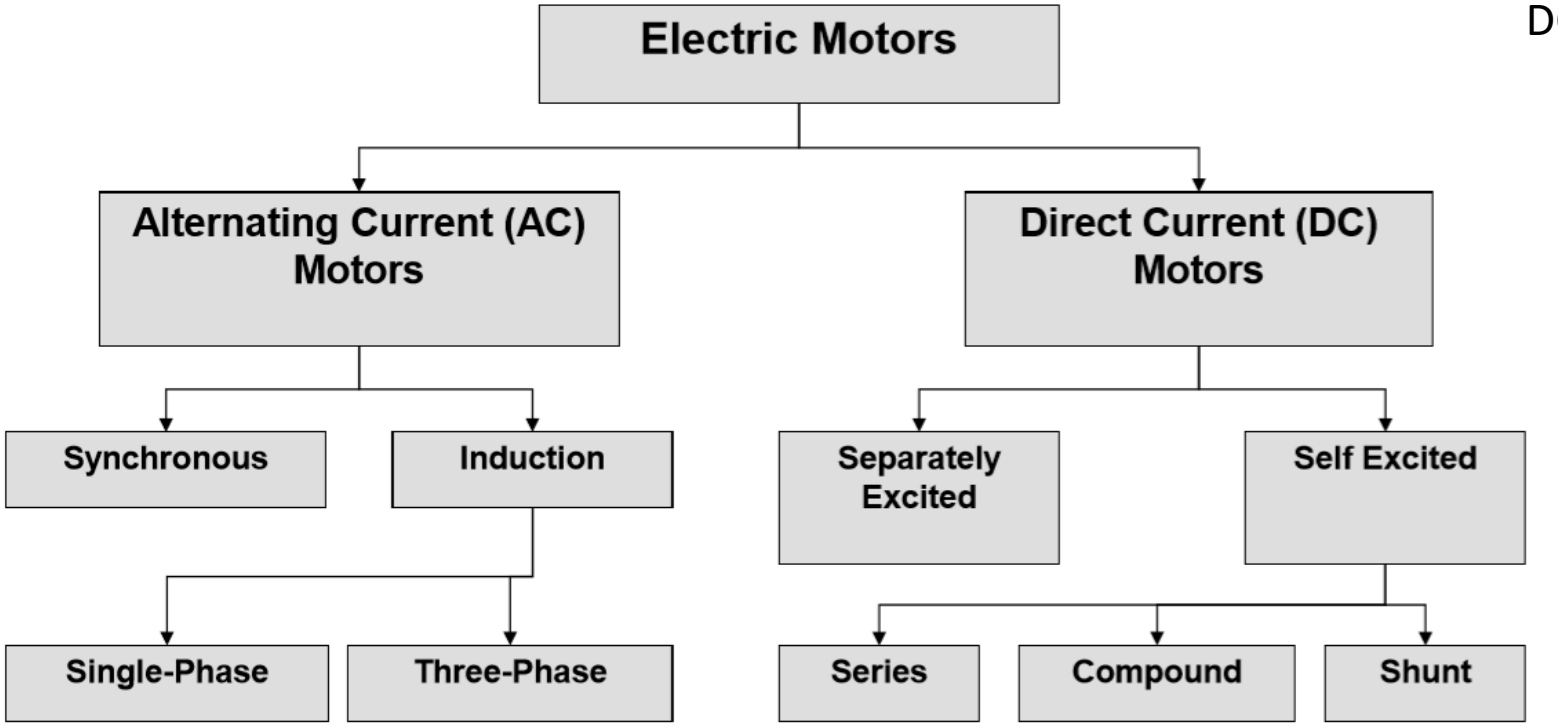
Electric Actuators (Electric Motors)

Pneumatic Actuator

Hydraulic Actuator

Type Of Electric Motors

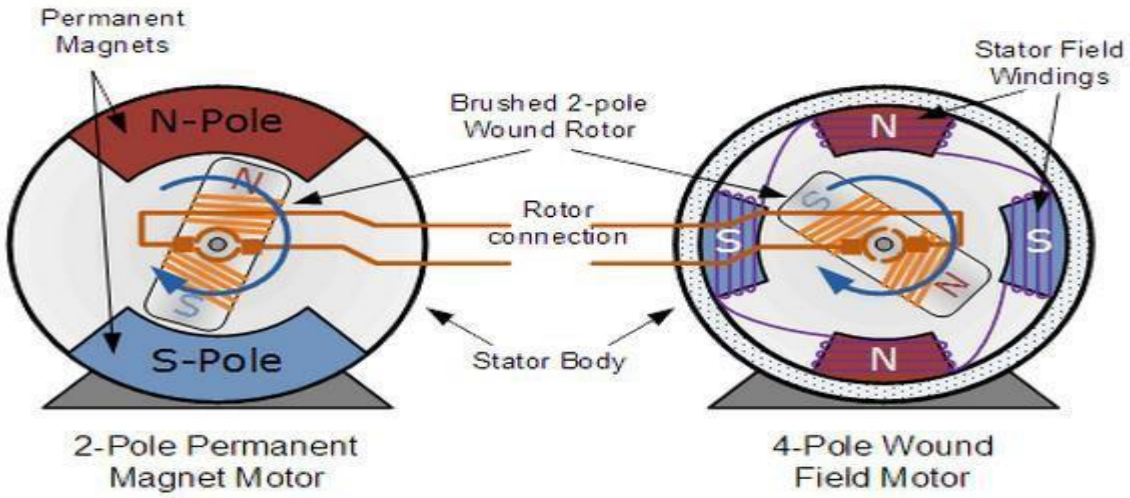




DC MOTOR

DC Motor converts electrical energy to mechanical energy to produce power. It works of Direct current.

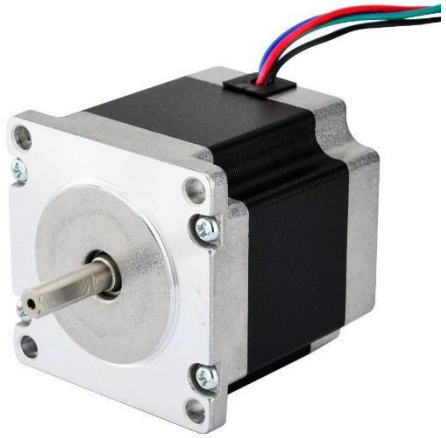
A DC motor consist basically of two parts, the stationary body of the motor called the “Stator” and the inner part which rotates producing the movement called the “Rotor”. For D.C. machines the rotor is commonly termed the “Armature”.

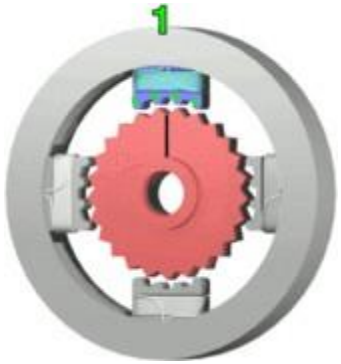


Stepper Motor

- Stepper motors run in steps by counting the number of steps the motion of the motor can be controlled.

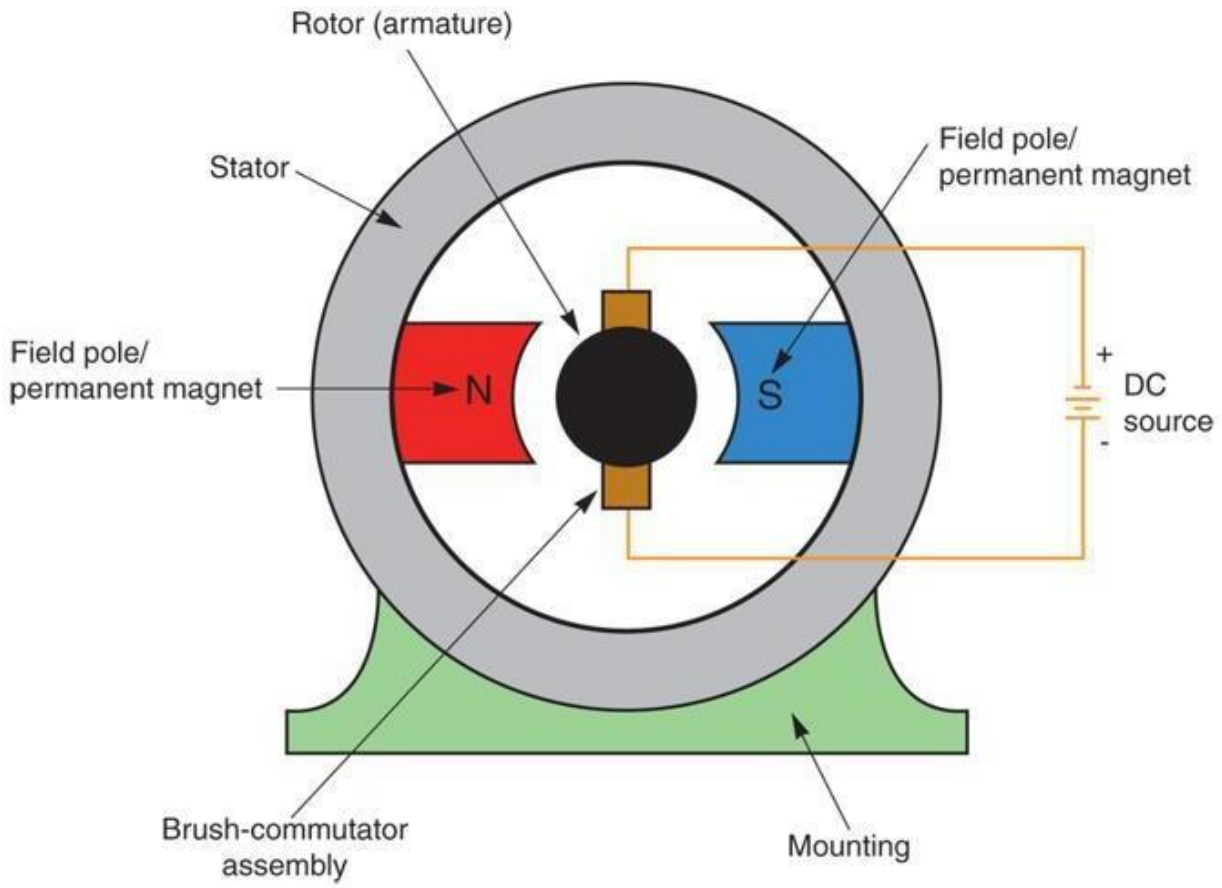
- Each step corresponds to the pulse. Each pulse generate the constant amount of rotation



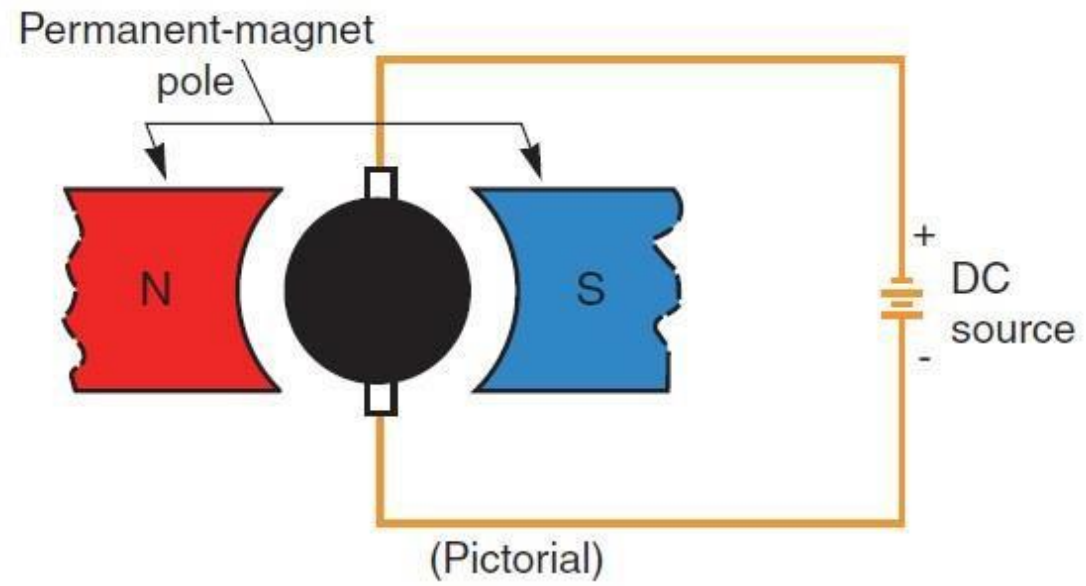


Wikipedia

DC Motor –Permanent Magnet

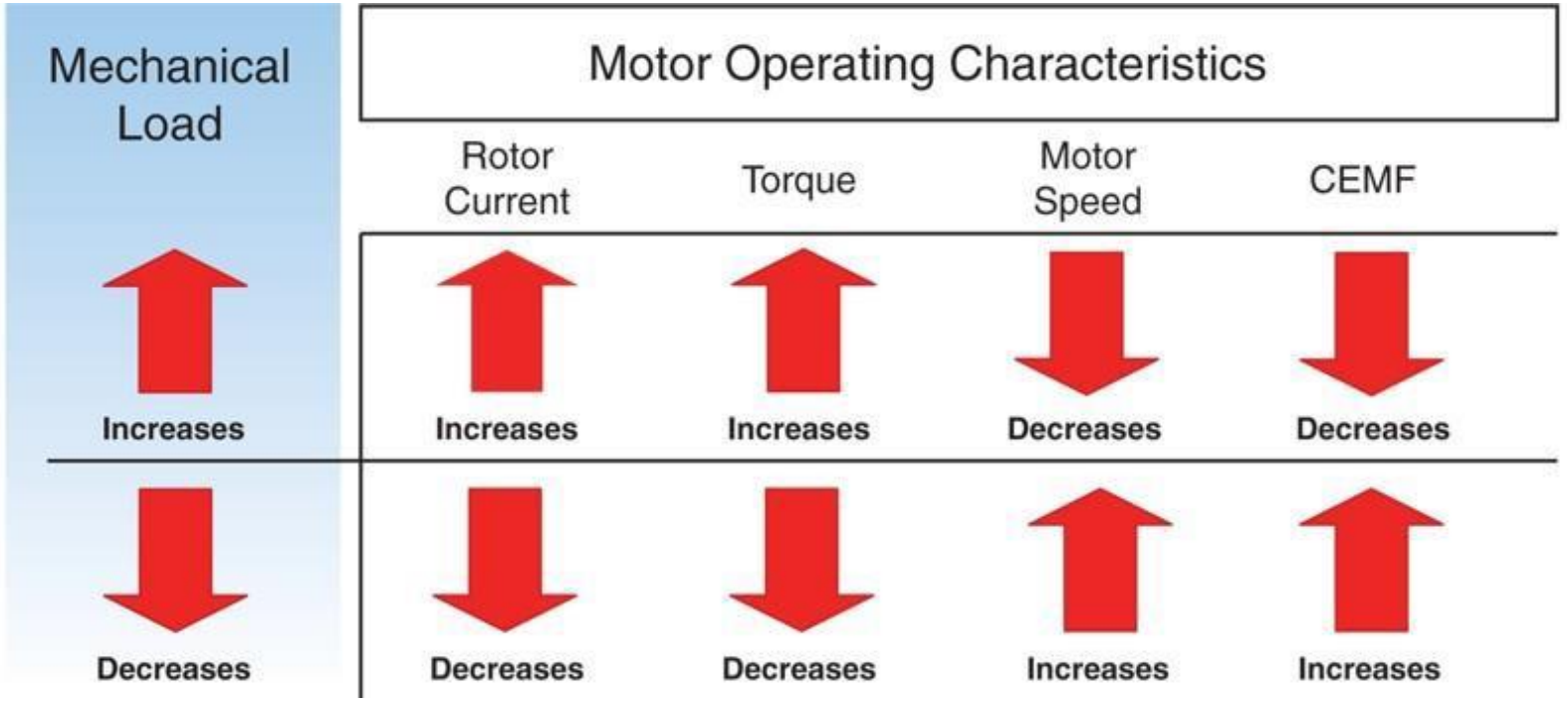


Permanent-Magnet DC Motor



Permanent-magnet dc motor

DC Motor Characteristics



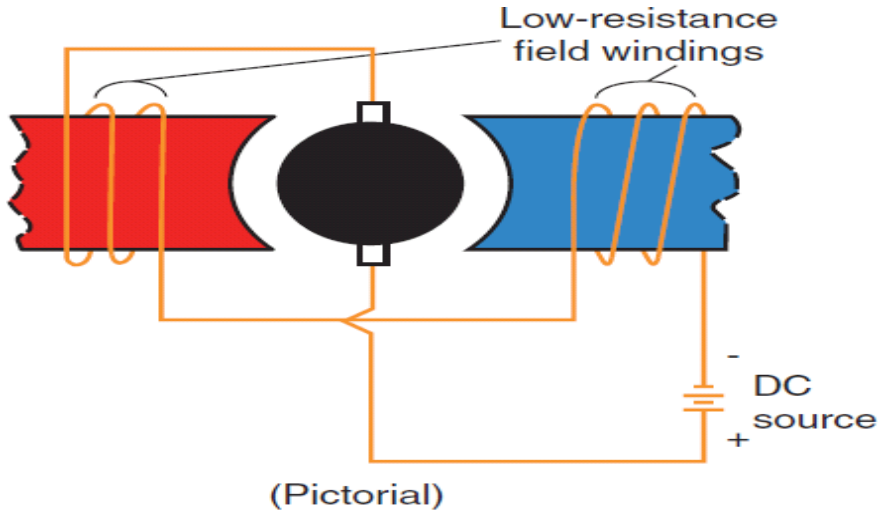
Series-wound DC Motor

Field winding has low resistance and connected in series with the armature, only one path to current flow in the field and the rotor.

Change in load cause change in current through the field, load increase causes, increase in current that create stronger magnetic field.

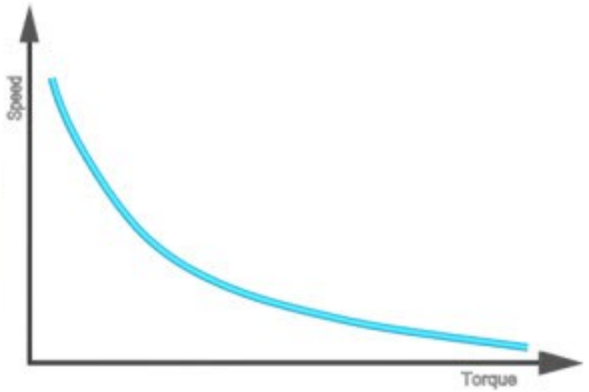
Produce high torque but at low speed

It can be operated with ac power



(Pictorial)

Series-wound dc motor



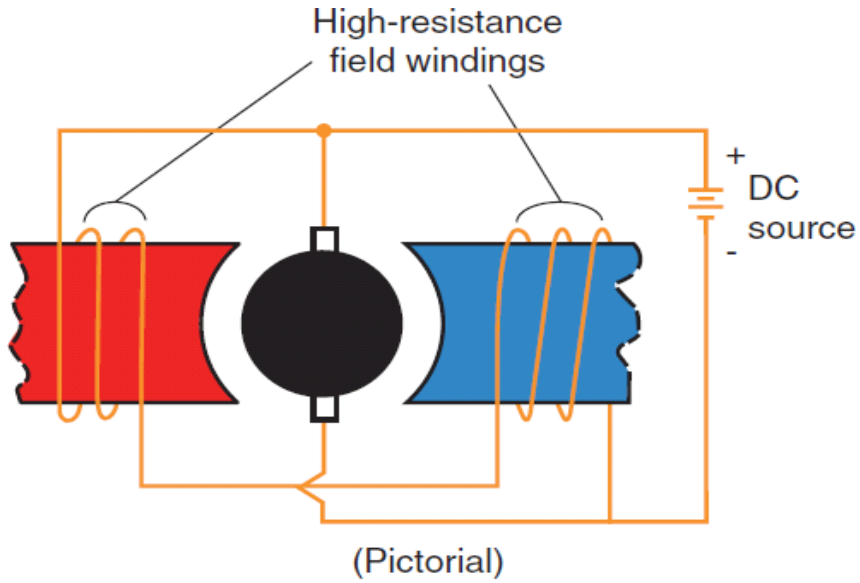
Shunt-Wound DC Motor

Field winding have relatively high resistance and connected in parallel with the armature and Small amount of current flow in the field.

Change in load does not cause change in current through the field and have little effect on the speed

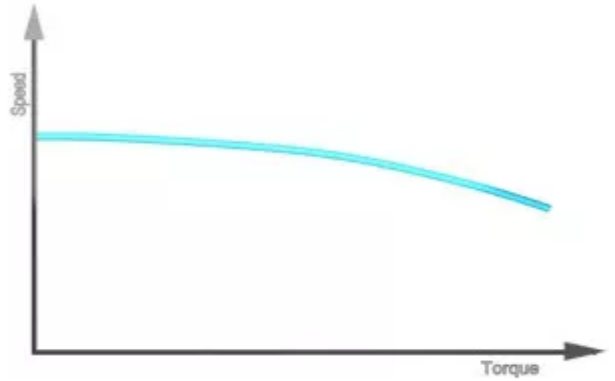
Has low starting torque but constant speed in case of high torque

The field resistance can be changed by additional series variable resistance (Rheostat) to change the rotor speed

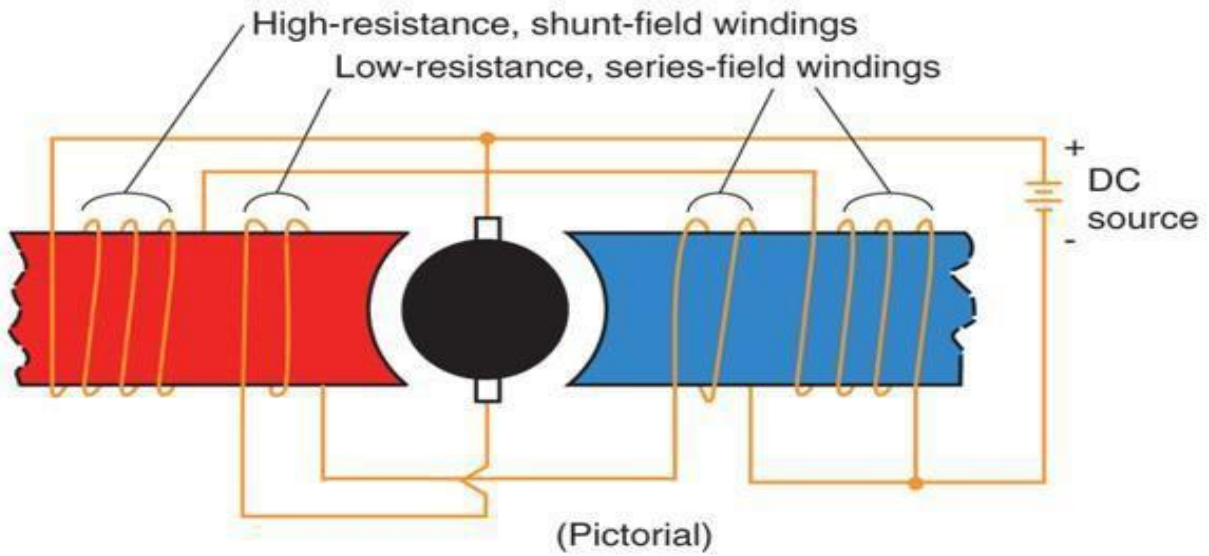


(Pictorial)

Shunt-wound dc motor



Compound-Wound DC Motor



Two sets of field winding

One is in series with armature and other is in parallel

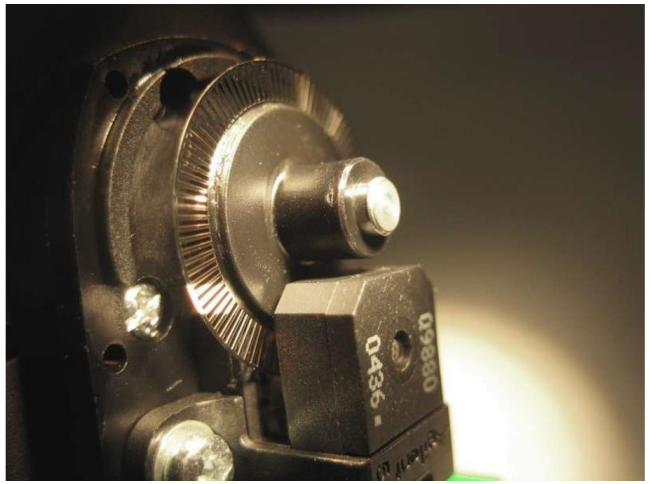
High torque because of series field winding and good speed regulation because of shunt field winding

Servo Motors

- Servo motors are feedback motors. A feedback sensor is installed inside the casing of the motor to control and monitor the speed of the motor.

- Servo motors are simple DC motors with feedback sensor (potentiometer or encoder) connect to the rotor with gears and the control circuit.

Mitsubishi motor

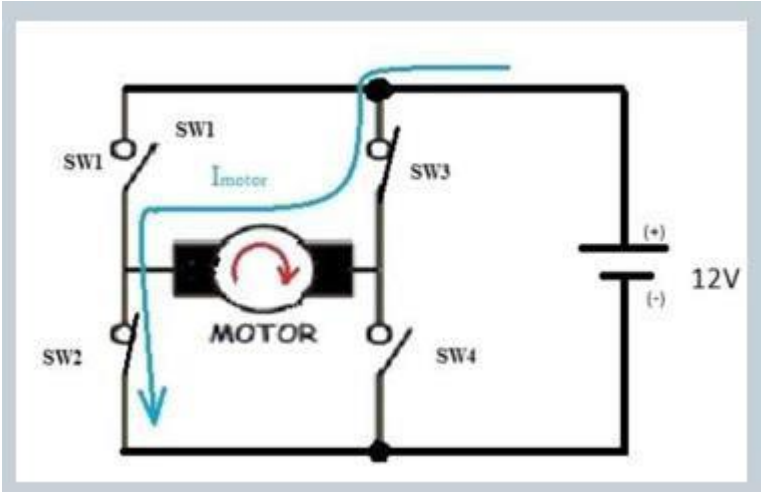


Motor Controls

- Direction Control
- Speed Control

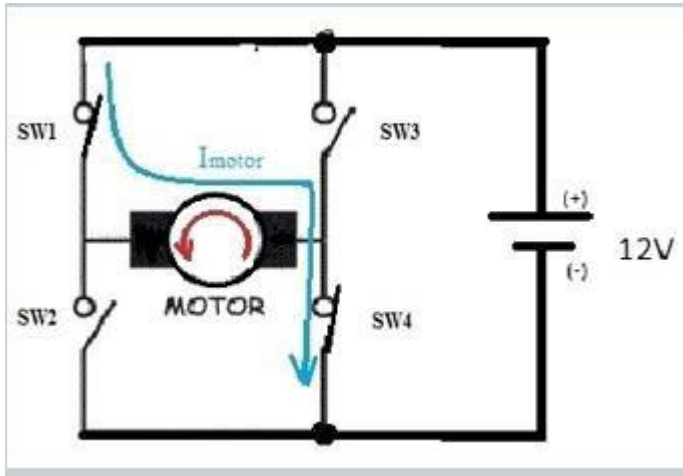
Direction Control of DC Motor (Switching Method)

SW3=SW2= ON (Connect the Circuit)
SW1=SW4= OFF (Disconnect the Circuit)



Clockwise Rotation

SW3=SW2= ON (Connect the Circuit)
SW1=SW4= OFF (Disconnect the Circuit)



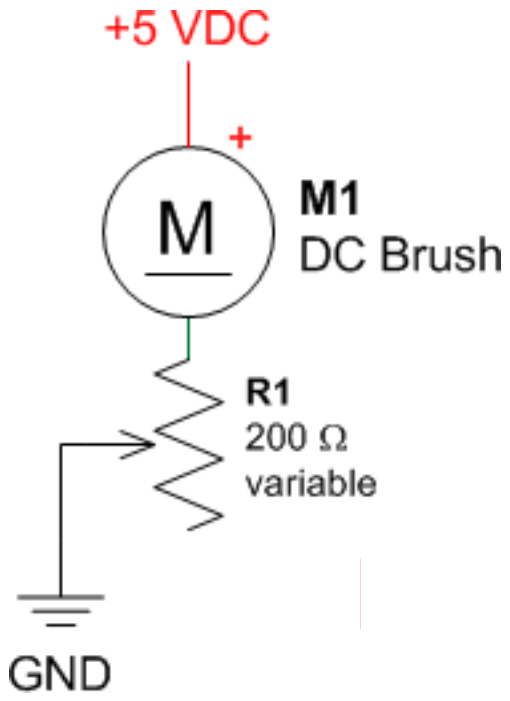
Anti Clockwise Rotation

Speed Control Using Variable Resistance

- Large resistance in series of motor
- Variable resistance can control the speed

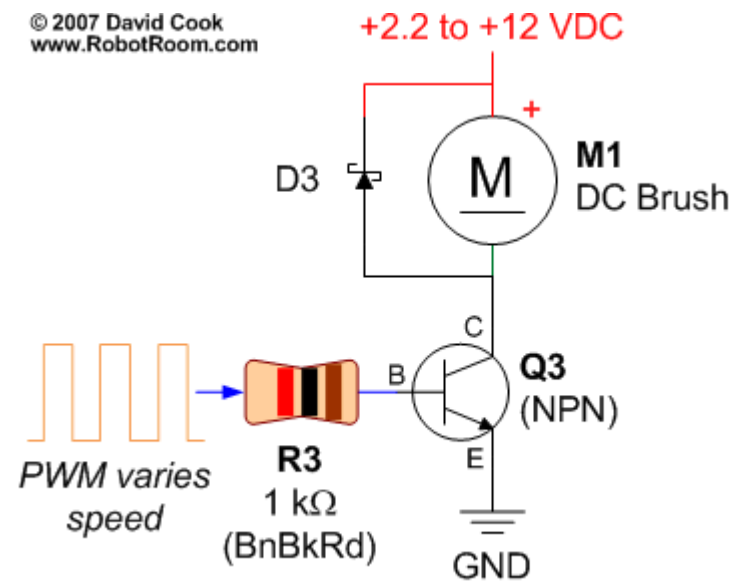
Disadvantages

- Limited load capability
- High power required
- Generate lot of heat hot
- Difficult to start at high resistance



Pulse-width Modulation

- By replacing the potentiometer with a transistor, the speed of the motor can be controlled by the duty cycle of the square wave.



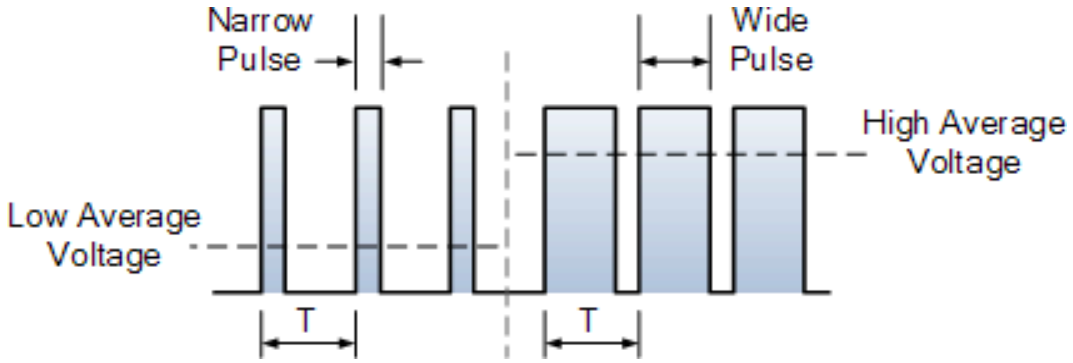
Schematic of a pulse-width modulator (PWM) controlling the speed of a motor.

Pulse Width Modulation

- One simple and easy way to control the speed of a motor is to regulate the amount of **voltage** across its terminals and this can be achieved using "**Pulse Width Modulation**" or PWM.
- Simply PWM is the process of switching power ON and OFF to a device in pulses at a specific frequency.
- Same approach used in commercial light dimmers, DC motor speed controller, CPU fan speed controllers and etc.

Pulse Width Modulation

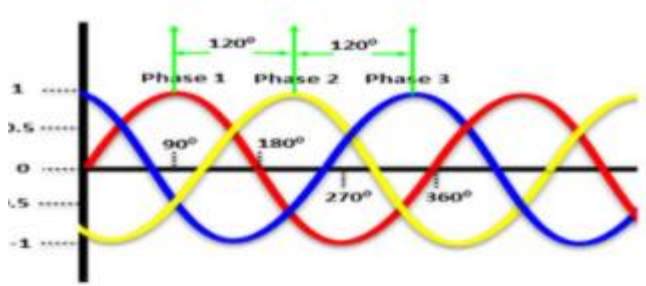
- P WM speed control works by driving the motor with a series of “ON-OFF” pulses and varying the duty cycle, the fraction of time that the output voltage is “ON” compared to when it is “OFF”, of the pulses while keeping the frequency constant.
- By changing or modulating the timing of these pulses the speed of the motor can be controlled, ie, the longer the pulse is “ON”, the faster the motor will rotate and likewise, the shorter the pulse is “ON” the slower the motor will rotate.



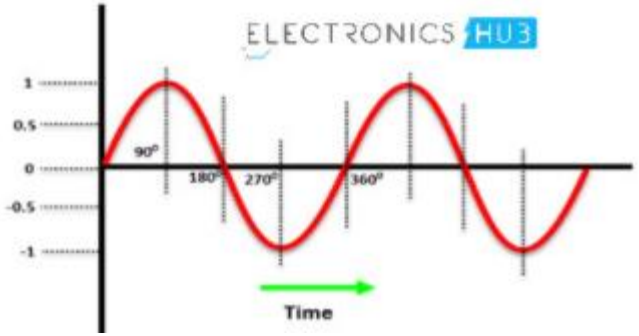
AC Motors

- Universal Motor – Single Phase - Series Wound DC Motor
- Induction Motor – Single Phase and Three Phase
- Synchronous Motor

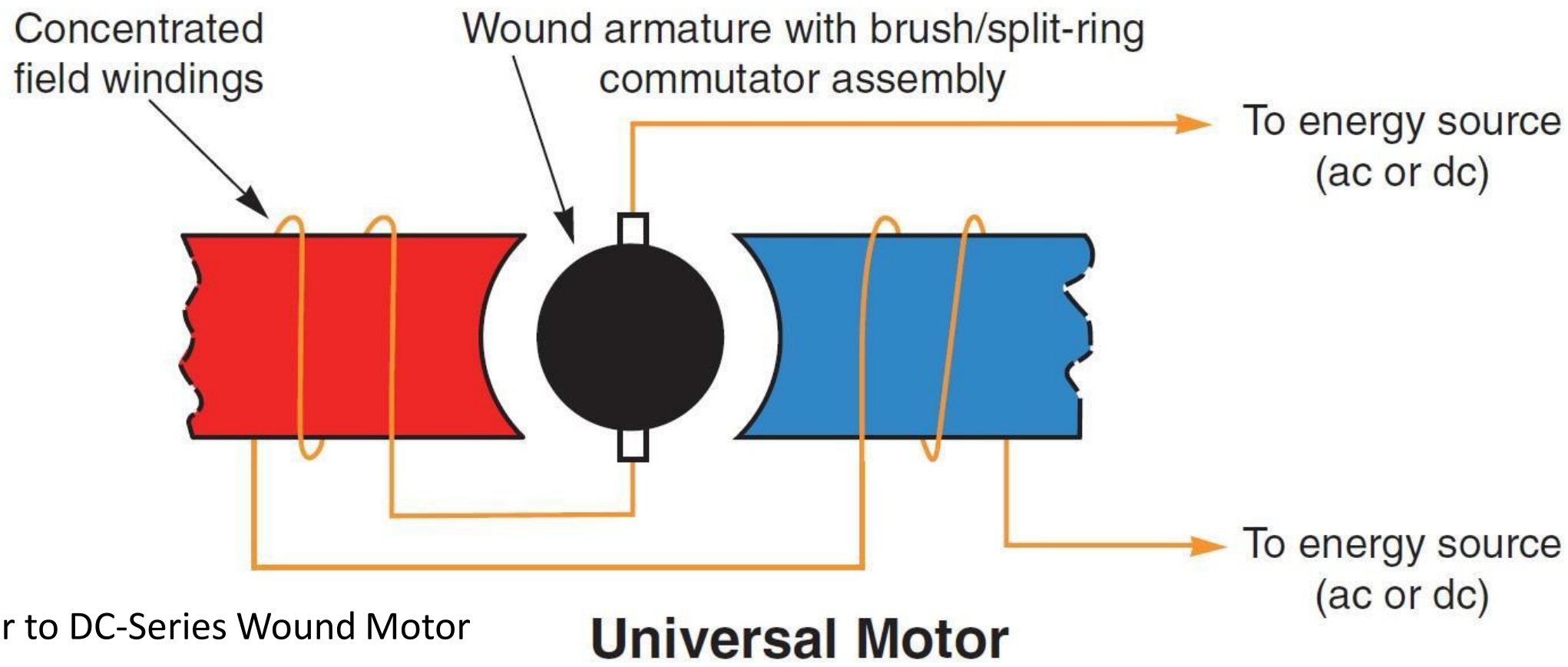
Three Phase



Single Phase



Single Phase AC Motor



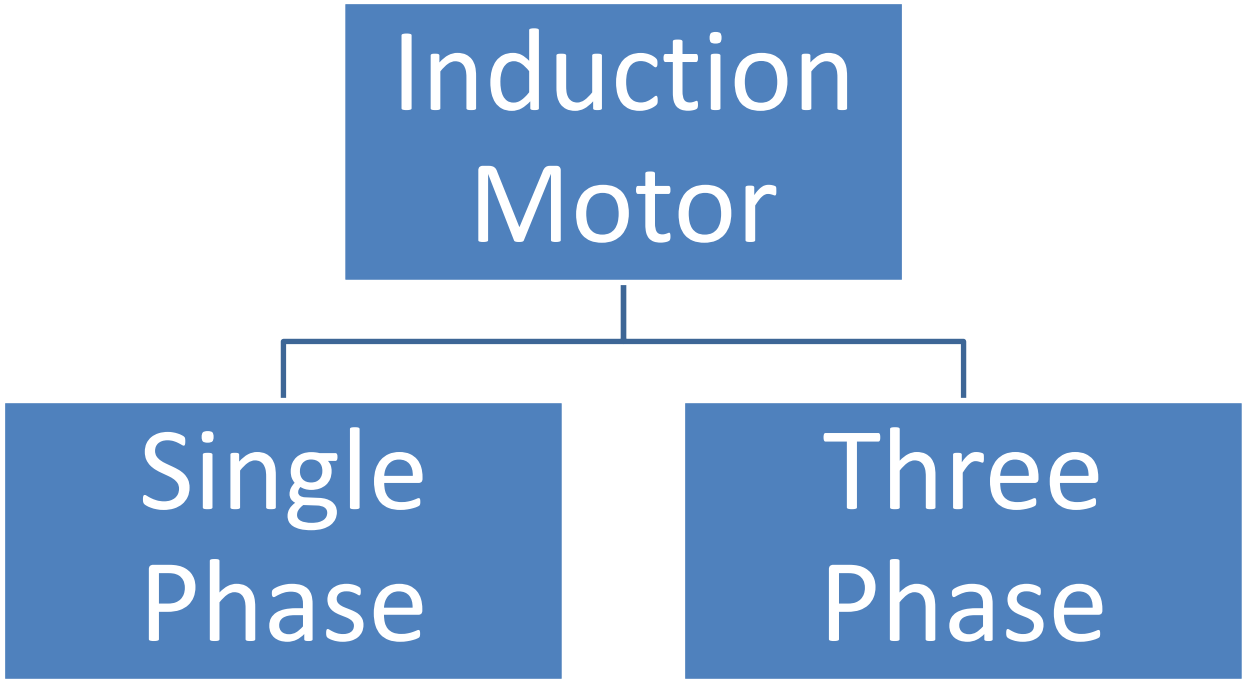
Similar to DC-Series Wound Motor

Induction Motor – AC supply

Not giving the current to the rotor

Rotor rotates due to Magnetic field of the stator

Because of AC supply We have rotating magnetic field

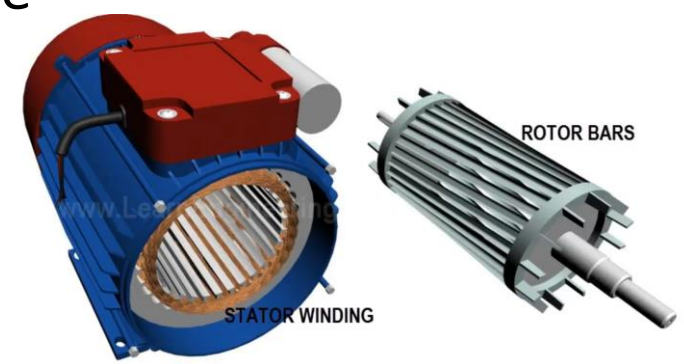


Single Phase Induction Motor

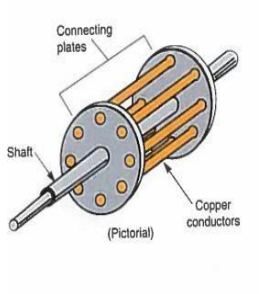
Has solid rotor, called squirrel cage rotor, copper conductors are soldered to connecting plates

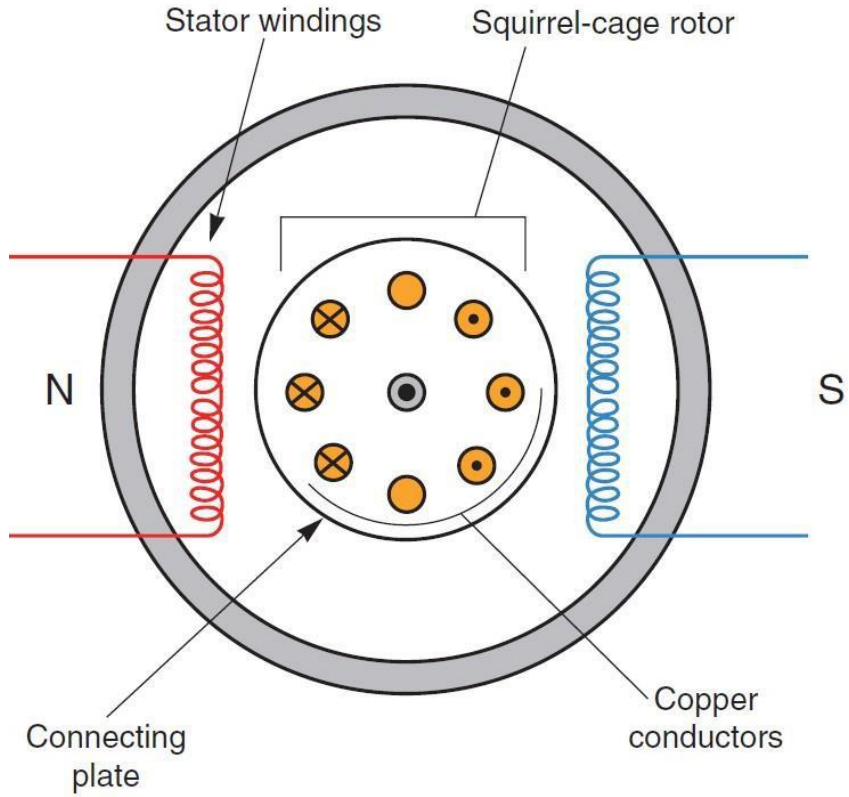
Flow of current in stator winding induces the rotor

The stator polarity changes in step with the applied ac frequency. This develop rotating magnetic field around the stator that cause to rotate the rotor



3D view of Squirrel-cage rotor





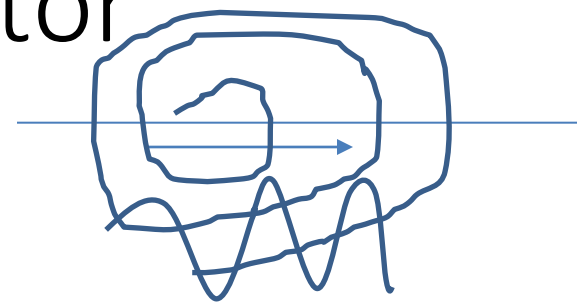
Single-phase Induction Motor

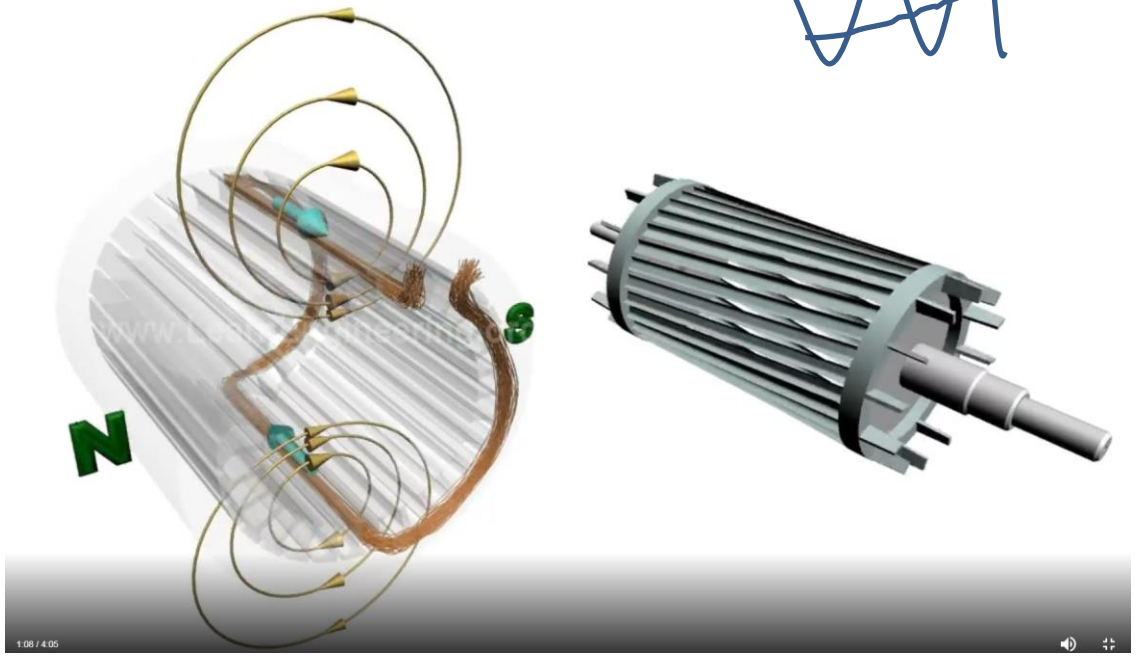
Single Phase Induction Motor

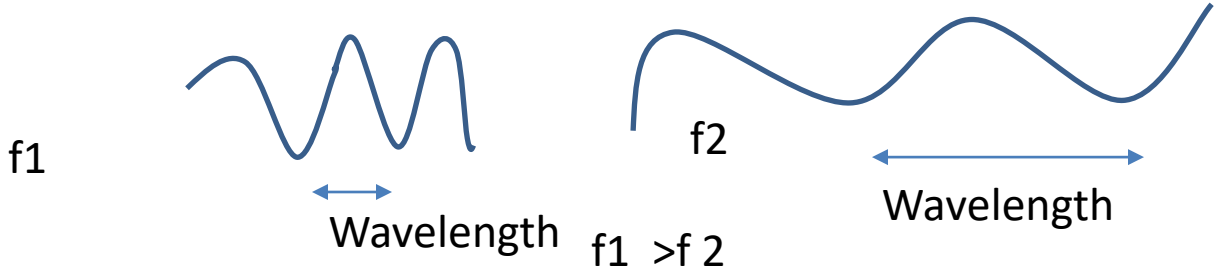
The speed of the rotating magnetic is also known as synchronous speed and it is developed by frequency of ac voltage and the number of poles in stator winding

The rotor becomes polarized and rotates in step with synchronous speed. However, due to inertia, the rotor must be set into motion by some auxiliary starting method.

The rotor speed is less than the synchronous speed in order to develop the torque. The difference between the synchronous speed and the rotor speed is called slip.

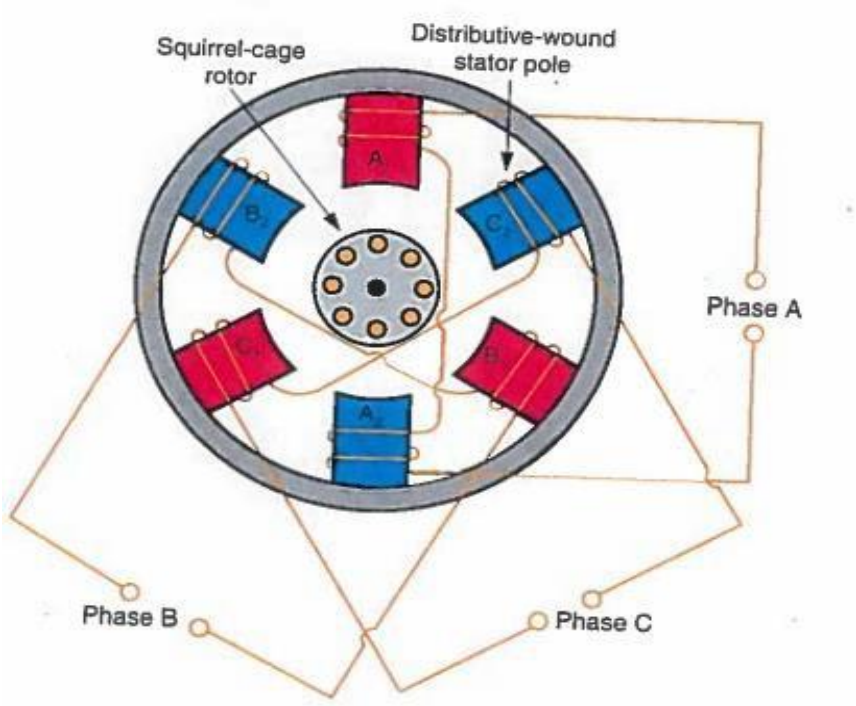






Three-phase Induction Motor

Three Phase Induction motor has 03 phases A, B and C. Phase A connected to winding A1 and A2, which are located 180° apart. Similarly, Phase B is connected to B1 and B2 and Phase C is connected to C1 and C2.



In case of 03 phase induction, the power of magnetic flux high and it overcome the inertial resistance of the rotor. Therefore, no additional method is required to initially start the rotor.

More powerful
Strong RMF (Rotating magnetic Field)
No startup circuit – or Auxiliary circuit
Difference between RMF and rotor speed, known as slip
Actual speed of rotor is unknow

Synchronous motor

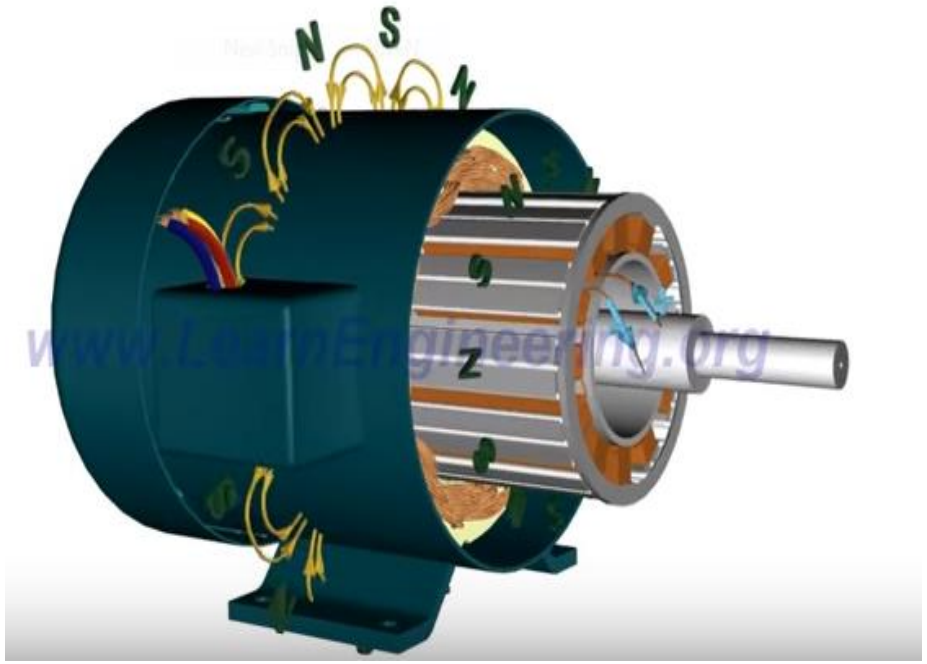
Synchronous motors are special motor. It has both input DC as well as AC

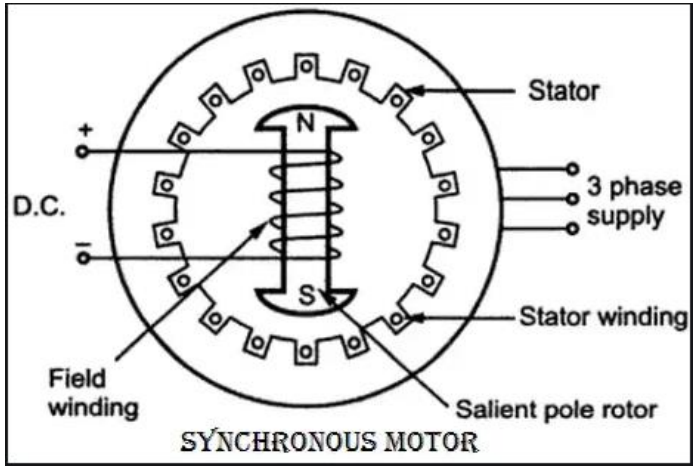
Direct current (DC) is applied to the wound rotor to produce the electromagnetic field.

Three phase AC power is applied to the stator, which also has windings.

A basic three-phase synchronous motor has no starting torque, external means need to start the motor

Synchronous motor rotates at the same speed as the revolving stator field, therefore there is no slip.





Control of an AC Motor

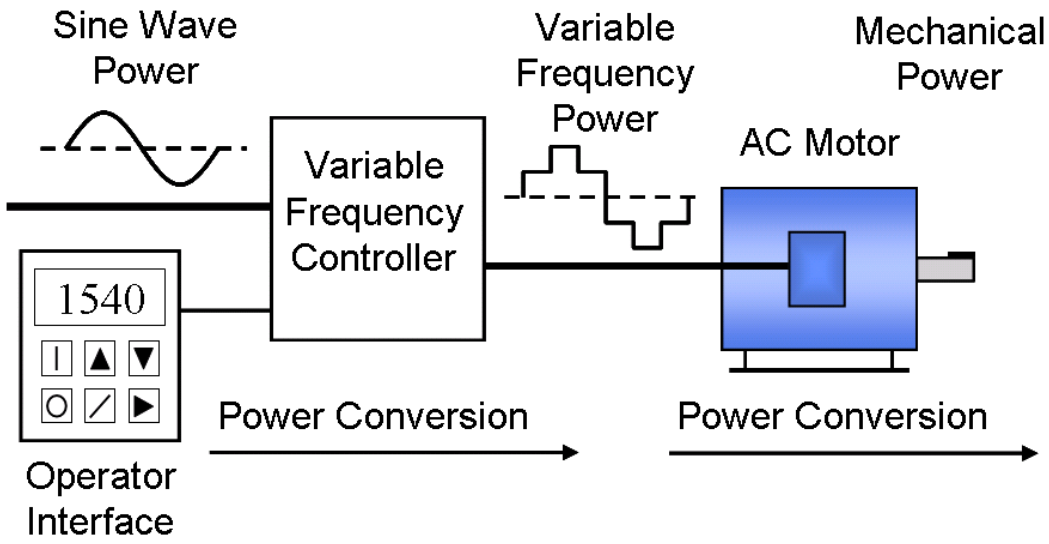
AC Motor can be controlled through the frequency.

Higher input frequency increases the rotor speed and lower input frequency decrease the rotor speed.

$$N_{rotor} \; \alpha \; f_{input}$$

VFD (Variable Frequency Drive) is used to control the speed of an AC Motor.

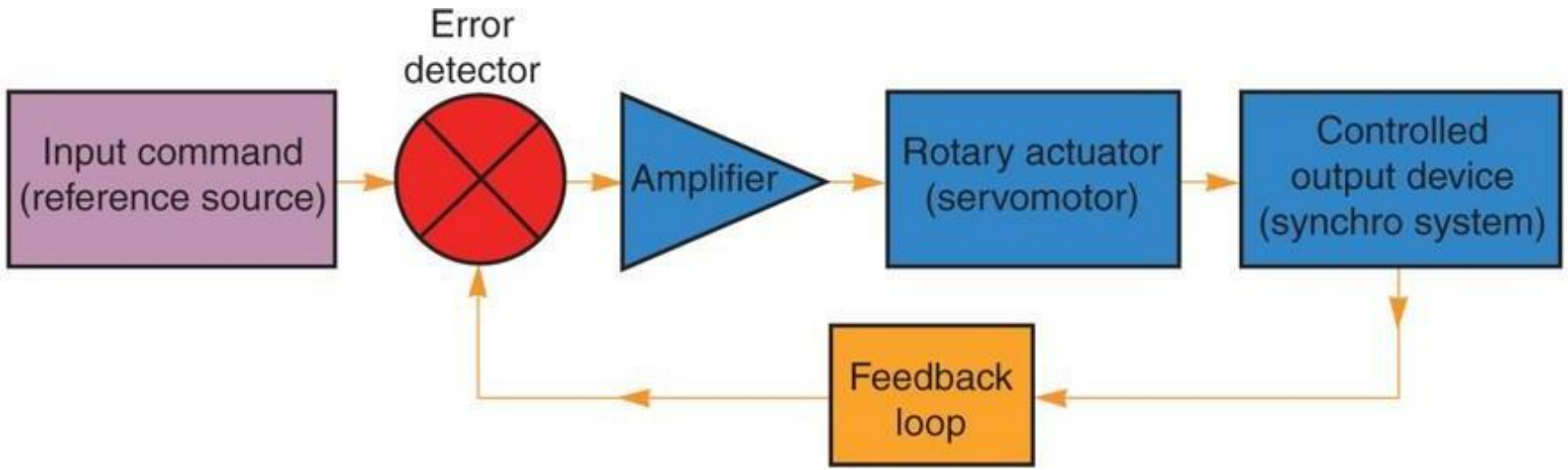
DC ----- PWM
AC --------VFD



Source: https://en.wikipedia.org/wiki/Variable-frequency_drive#/media/File:VFD_System.png

Servo motor

Servo-Motor System



DC Servo Motor

- Brushes are within the motor
  - Brushes wear and need replacement
  - Preventive maintenance recommended

- Current moves through coils which sequences by the brushes and the commutator

- Control is much simpler than AC
  - Field or current armature magnitudes are the only requirements for motor control
  - A duty-cycle-controlled PWM operates motor speed

- Torque is controlled independently by a control flux, which allows the torque to maintain consistency while in operation.

- Inertia may reach a higher level in some situations

AC SERVO MOTOR

- Brushes are not within the motor
  - Less maintenance

- A feedback system controls and alerts the engine to the location of the rotor to initiate the sequence of current through the coils.

- Feedback alignment is used within most AC servo motors to function properly with a controller or amplifier.

- Inertia is lower on rotors.

- Sophisticated control system
  - Stator current magnitudes, frequencies, and their phases require a coordinated control process.
  - Closed-loop communication system located with the controller/amplifier
  - Motor speed operates by a sinusoidal PWM, where the speed control is in the frequency of the PWM

- Higher RPM with the ability to reach 6000 RPM on many servo motors

DC Servo Motor / AC Servo Motor

DC Servo Motor

- Brushes are within the motor
  - Brushes wear and need replacement
- Current moves through coils which sequences by the brushes and the commutator
- Control is much simpler than AC
  - A duty-cycle-controlled PWM operates motor speed
- Torque is controlled independently by a control flux, which allows the torque to maintain consistency while in operation.
- Inertia may reach a higher level in some situations

AC Servo Motor

- Brushes are not within the motor
  - Less maintenance
- A feedback system controls and alerts the engine to the location of the rotor to initiate the sequence of current through the coils.
- Sophisticated control system
  - Motor speed operates by Variable Frequency Drive System (VFD)
- Higher RPM with the ability to reach 6000 RPM on many servo motors