Computer Aided Manufacturing

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Unit II

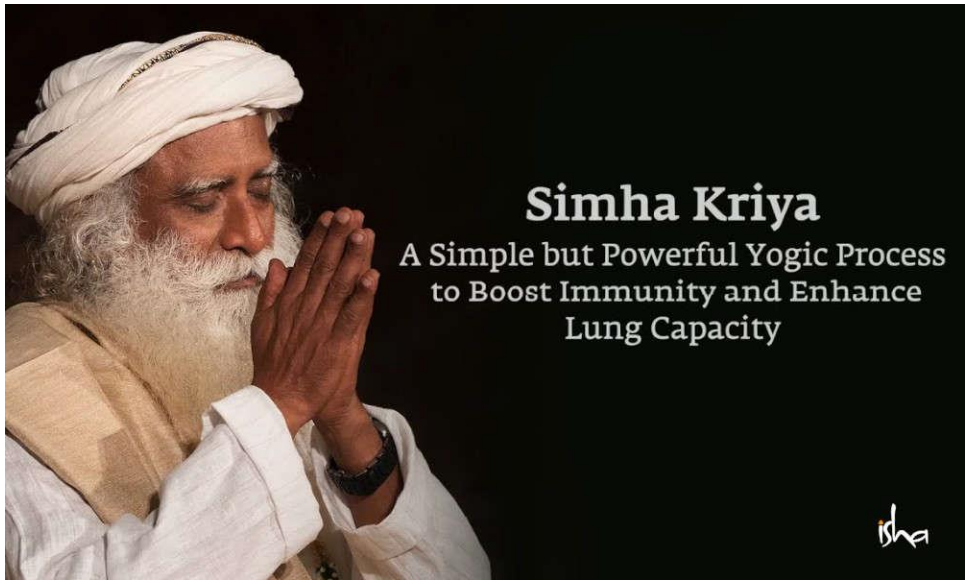
DRIVES AND CONTROL

Spindle and feed drives - Sensors - Position, Encoders, Proximity, Limit switch -Interfacing system -Microcontroller and PLC based -Introduction to Graphical User interface - Communication protocol -RS232, RS 485, USB, Ethernet - PLC -Ladder diagram -Peripherals -Timer, Counter, Encoder interface, Human Machine Interface

Prerequisites Knowledge

- Working principles of conventional Machines
- Basics of Electrical, Hydraulics and Pneumatics

Immunity Boosting Breathing

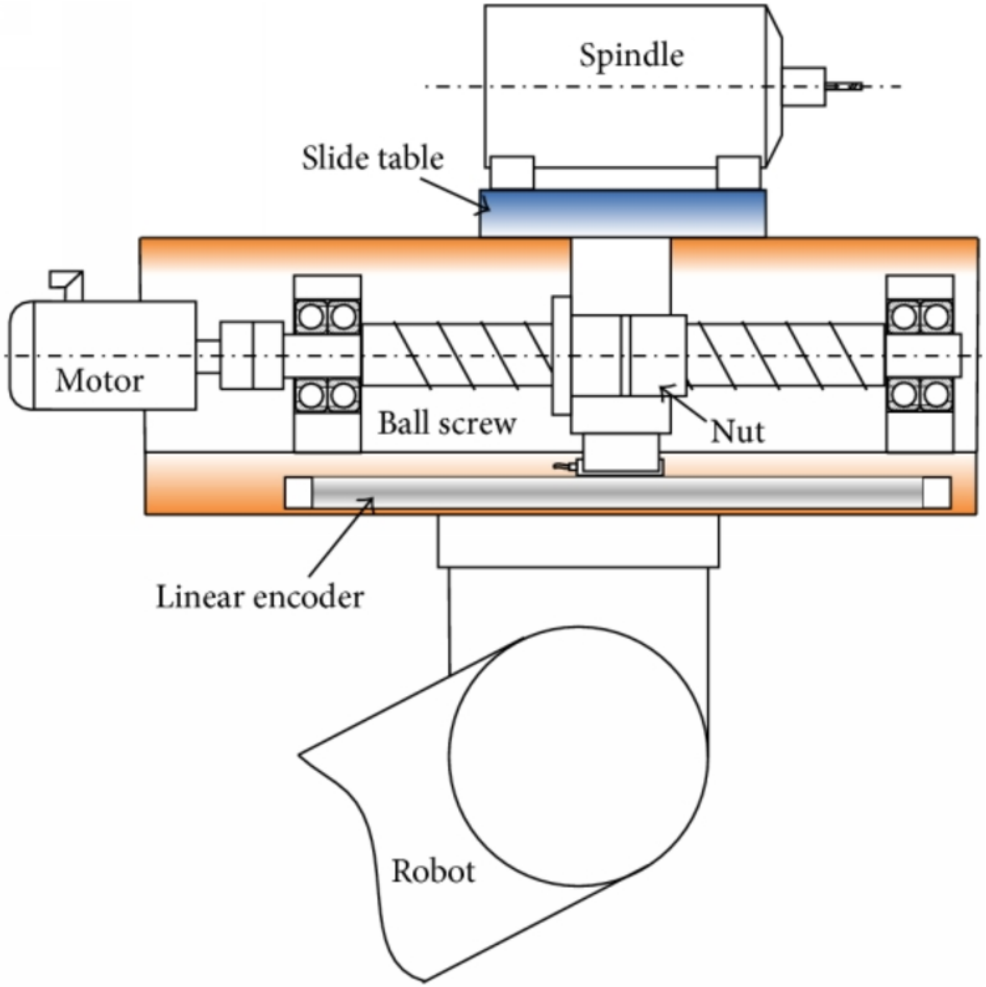


1 min

Recap and review of previous class

5 mins

Evocation



2 to 5 mins

General Objective (GO)

- Students will be able to understand the spindle and axis drives in Computer Numeric Control (CNC) machines and evaluate their suitability to achieve precision of machining.

2 mins

Specific Objectives

Students will be able to

- Recognize the type of drives used in CNC machines (R/F) (T)
- Explain the working concept of the drives used for spindles and feed in CNC machines. (U / C) (E)
- Attribute the requirements for spindle and axis drives used in CNC machines for smooth operation. (An / C) (E)
- Check the two drives suitable for axis movement in CNC machines based on precision machining of automobile steel part to fit and function at high speed rotation. (E / P) (E)

35 mins

Introduction to Drives

- Basic function of a CNC machine is to provide automatic and precise motion control to its elements such work table, tool spindle etc.
- Drives are used to provide such kinds of controlled motion to the elements of a CNC machine tool.
- A drive system consists of drive motors and ball lead-screws.
- The control unit sends the amplified control signals to actuate drive motors which in turn rotate the ball lead-screws to position the machine table or cause rotation of the spindle.
- In a CNC machine tool there are three major groups of elements
  - (a) Control and electronics
  - (b) Electric drives
  - (c) Mechanical elements (table, slide, tool holder, etc.)
- In addition, there can be hydraulic and pneumatic systems, which are integrated with the CNC machine tool.

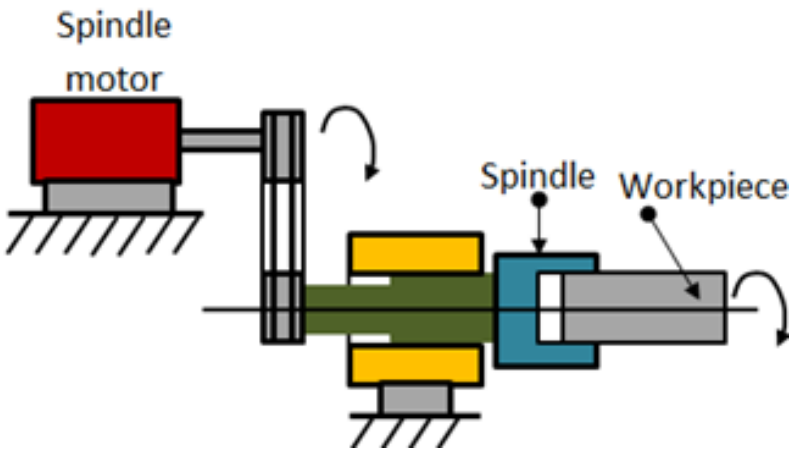
Drive System

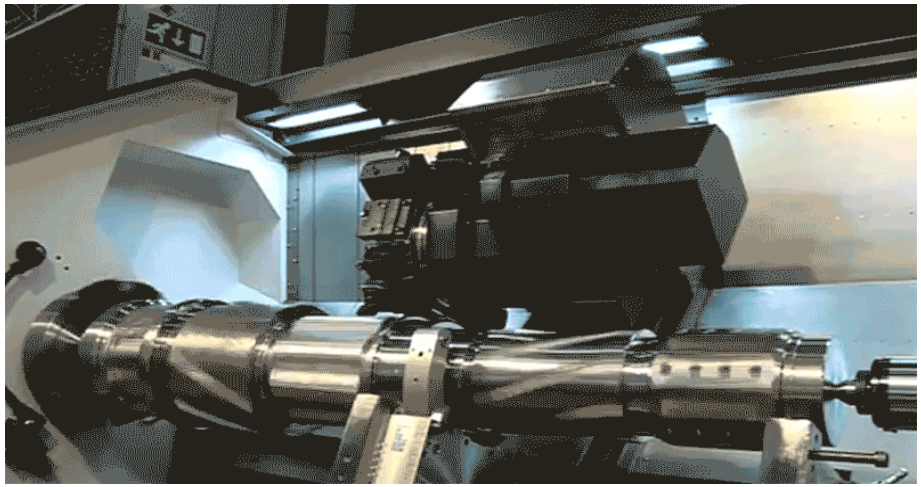
The primary function of the drive is to cause motion of the controlled machine tool member (spindle, slide, etc.) to conform as closely as possible to the motion commands issued by the CNC system.

- Drives are used to provide controlled motion to CNC elements
- A drive system consists of amplifier circuits, drive motors, and ball lead-screws.
- The MCU feeds the control signals (position and speed) of each axis to the amplifier circuits.
- The control signals are augmented to actuate drive motors which in turn rotate the ball lead-screws to position the machine table.

In order to maintain a constant material removal rate, the spindle and the tool movements have to be coordinated such that the spindle has a constant power and the slide has a constant torque.

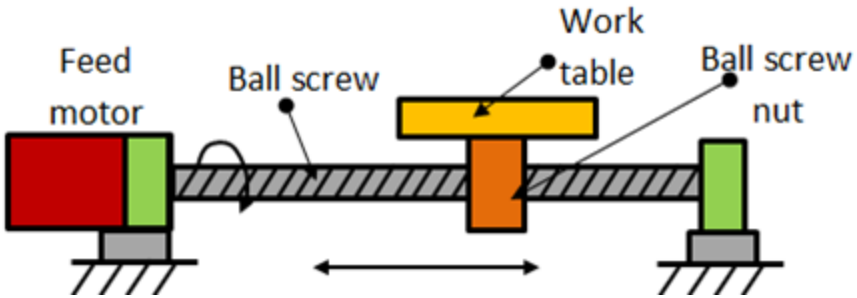
Spindle drive





The spindle drives are used to provide angular motion to the workpiece or a cutting tool. Figure shows the components of a spindle drive. These drives are essentially required to maintain the speed accurately within a power band which will enable machining of a variety of materials with variations in material hardness. The speed ranges can be from 10 to 20,000 rpm. The machine tools mostly employ DC spindle drives. But as of late, the AC drives are preferred to DC drives due to the advent of microprocessor-based AC frequency inverter. High overload capacity is also needed for unintended overloads on the spindle due to an inappropriate feed. It is desirous to have a compact drive with highly smooth operation.

Feed drive



These are used to drive the slide or a table. Figure shows various elements of a feed drive. The requirements of an ideal feed drive are as follows.

- The feed motor needs to operate with constant torque characteristics to overcome friction and working forces.
- The drive speed should be extremely variable with a speed range of about 1: 20000, which means it should have a maximum speed of around 2000 rpm and at a minimum speed of 0.1 rpm.
- The feed motor must run smoothly.
- The drive should have extremely small positioning resolution.
- Other requirements include high torque to weight ratio, low rotor inertia and quick response in case of contouring operation where several feed drives have to work simultaneously.

Variable speed DC drives are used as feed drives in CNC machine tools. However now-a-days AC feed drives are being used.

Spindle / Feed Motors used in CNC Machines

*In CNC, usually **AC, DC, servo and stepper electrical drives** are used. The various drives used in CNC machines can be classified as:*

a. Spindle drives to provide the main spindle power for cutting action
b. Feed drives to drive the axis

Spindle motors	*Feed motors*
DC shunt motor (separately excited)	DC Servomotor
Three phase ac induction motor	AC Servomotor
	Stepper motor

- **Spindle drives - (constant power)**
- **Feed drives – (constant torque)**

REQUIREMENT OF SPINDLE DRIVES

The requirements of a spindle drive motor are:

(a) High rotational accuracy
(b) Wide constant power band
(c) Excellent running smoothness
(d) Compactness
(e) Fast dynamic response
(f) Range of rated output from 3.7 kw — 50 kW
(g) Maximum speed up to 9000-20,000 rpm (high speed application)
(h) High overload capacity
(i) Large speed range.

TYPES OF SPINDLE DRIVES

DC SPINDLE DRIVES

Separately Excited Dc Shunt Motor

Controller

- Thyristor (Scr) Amplifier Or
- Microprocessor based Self-Tuned Thyristor Amplifier

Speed Control

- Armature And Field Control

AC SPINDLE DRIVES

Squirrel Cage Induction Motor

Controller

- Microprocessor based Pulse Width Modulated (Pwm) Inverter

Speed Control

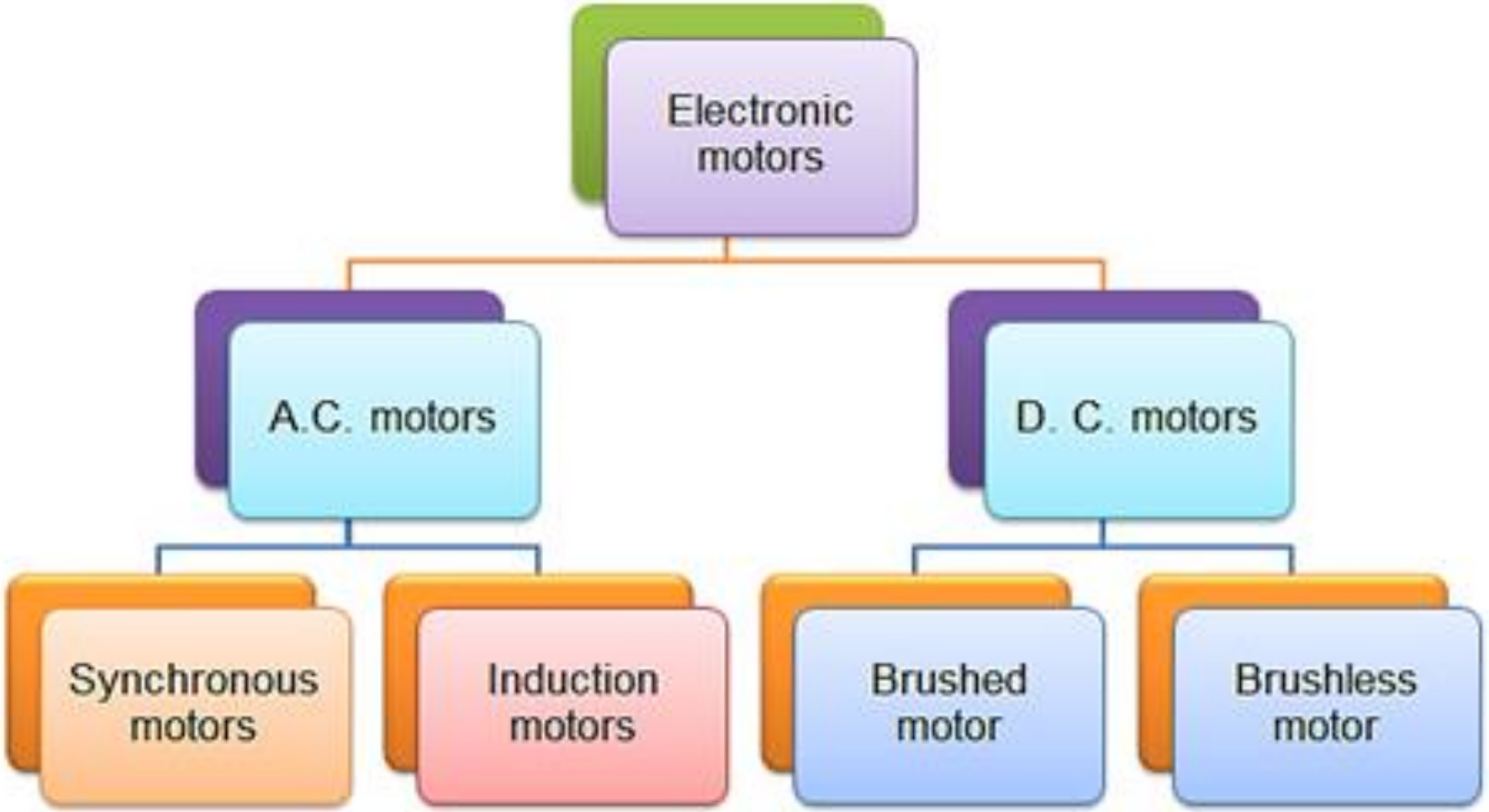
- Frequency, Vector Control

Power drives

Drives used in an automated system or in CNC system are of different types such as electrical, hydraulic or pneumatic.

- *Electrical drives* These are direct current (DC) or alternating current (AC) servo motors. They are small in size and are easy to control.
- *Hydraulic drives* These drives have large power to size ratio and provide stepless motion with great accuracy. But these are difficult to maintain and are bulky. Generally they employ petroleum based hydraulic oil which may have fire hazards at upper level of working temperatures. Also hydraulic elements need special treatment to protect them against corrosion.
- *Pneumatic drives* This drives use air as working medium which is available in abundant and is fire proof. They are simple in construction and are cheaper. However these drives generate low power, have less positioning accuracy and are noisy.

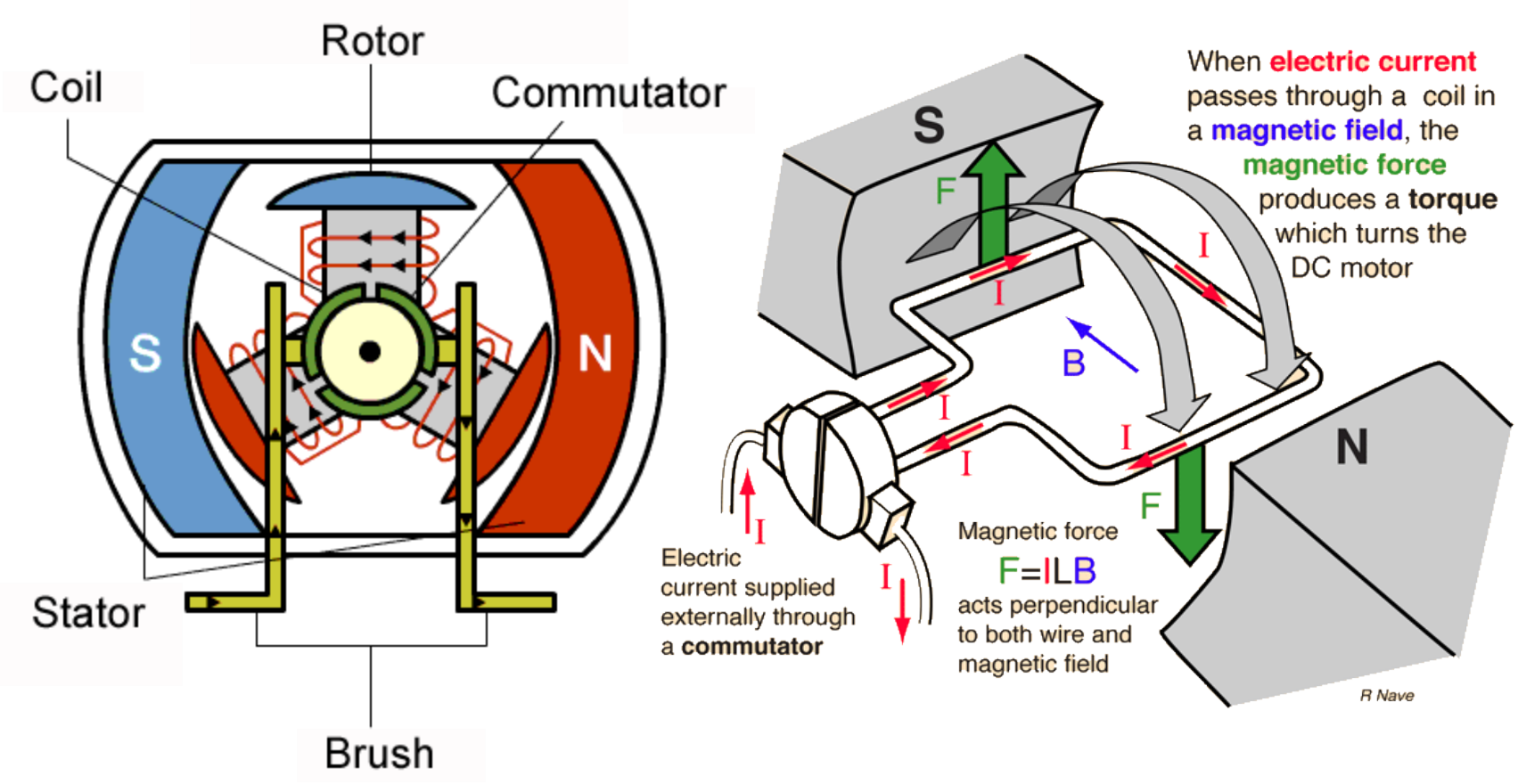
Electrical Motors

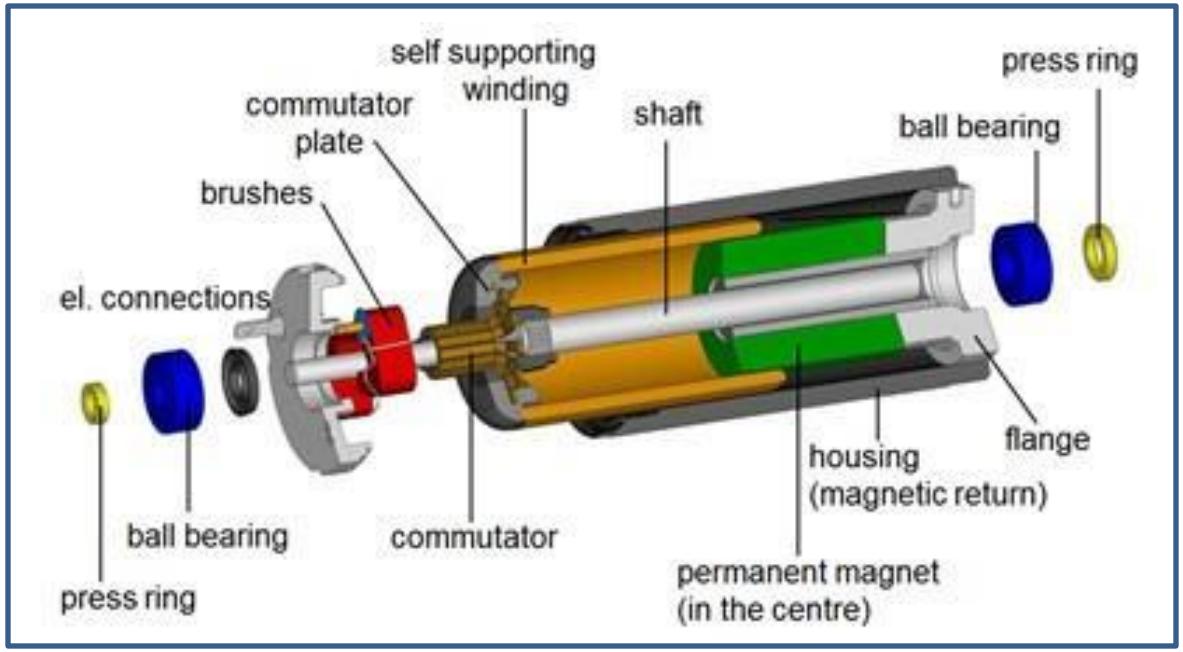


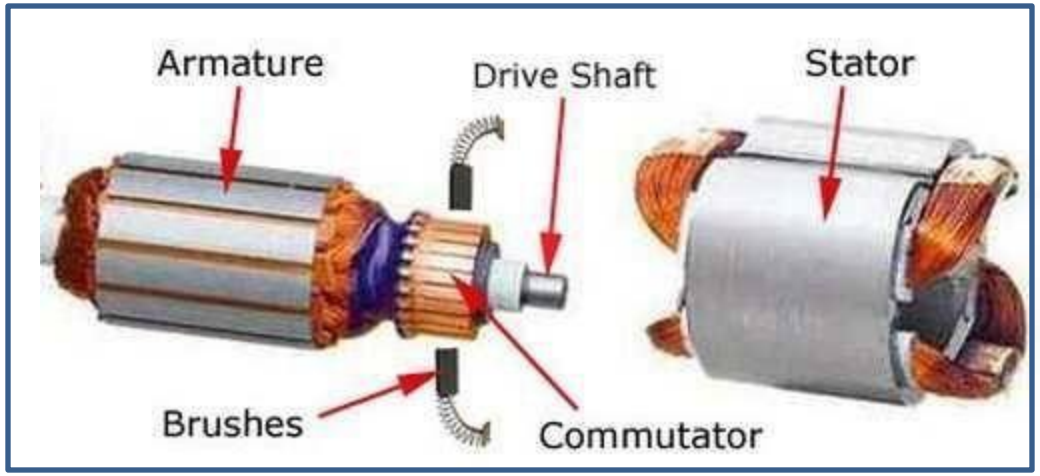
DC Motors

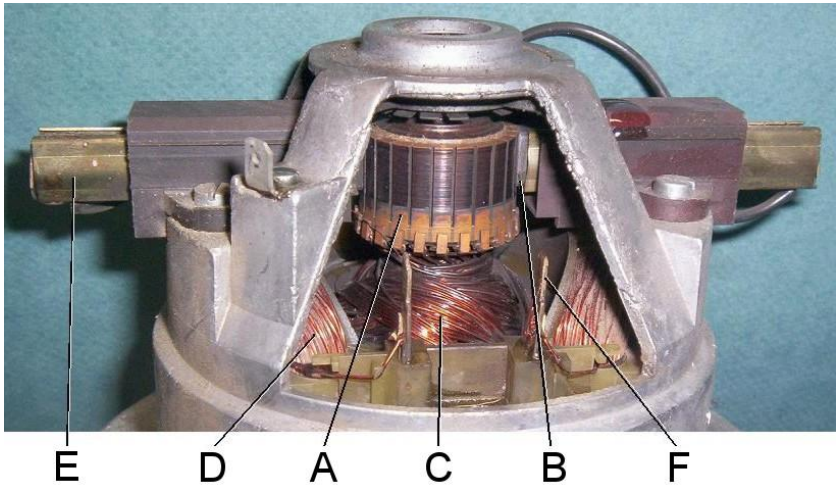
- A DC motor is a device that converts direct current (electrical energy) into rotation of an element (mechanical energy). These motors can further be classified into brushed DC motor and brushless DC motors.

Brush type DC motor









Parts: *(A)* commutator, *(B)* brush, *(C)* rotor (armature) windings, *(D)* stator *(F)* (field) windings, *(E)*brush guides

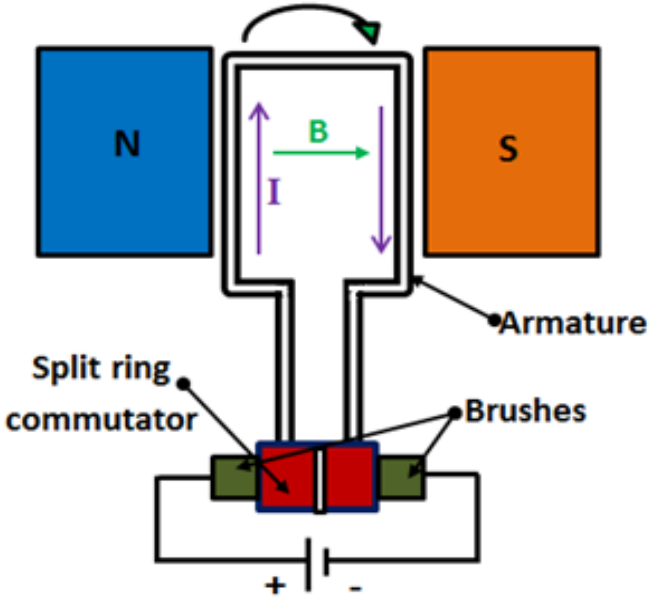
Brush type DC motor

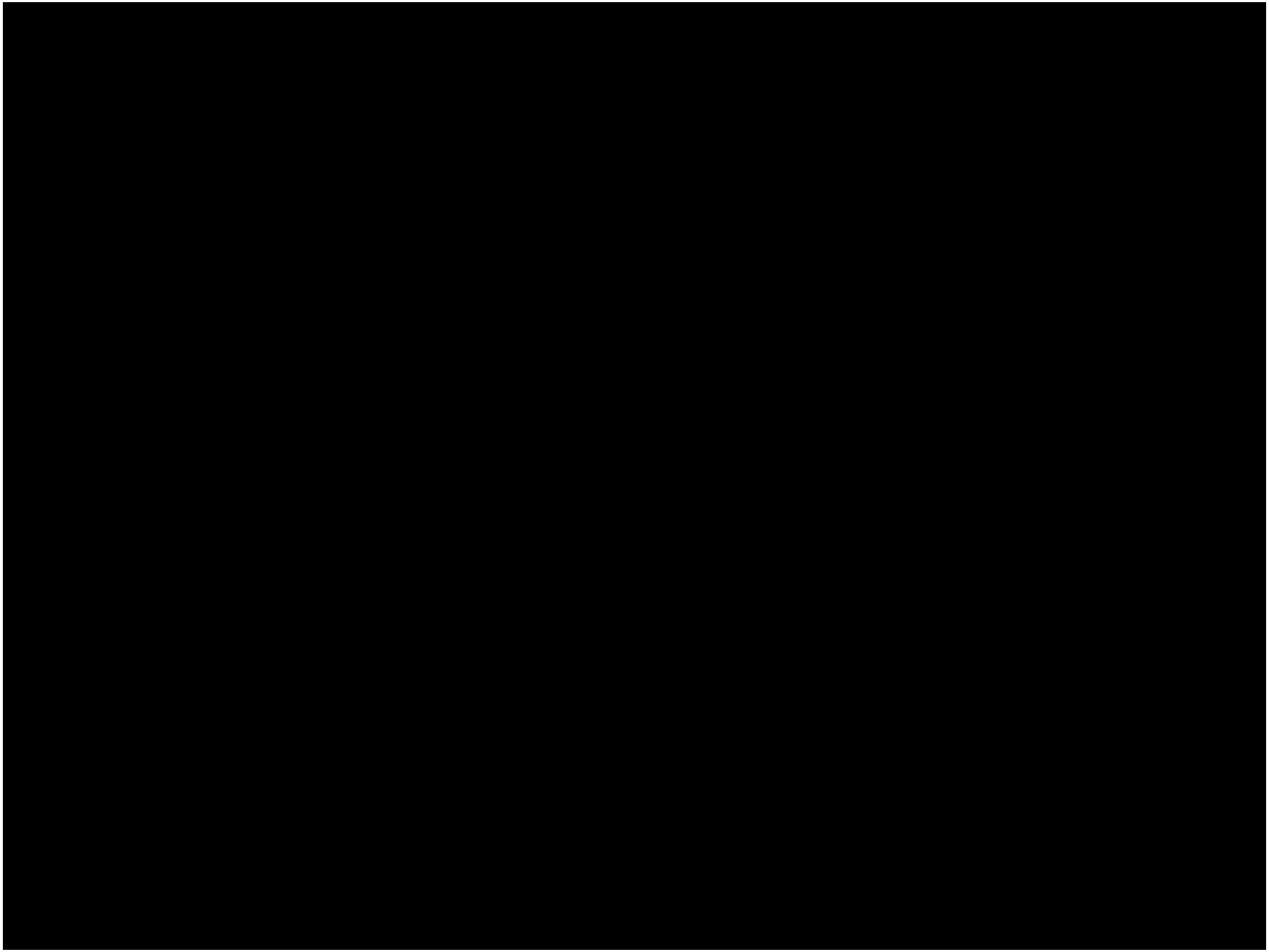
Advantages of brushed DC motor **:**

•The design of the brushed DC motor is quite simple
•Controlling the speed of a Brush DC Motor is easy
•Very cost effective

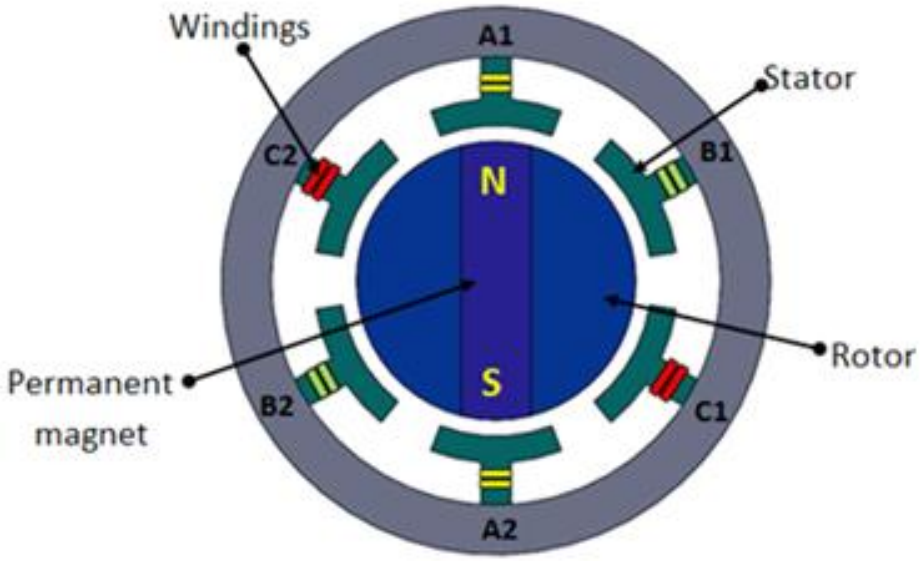
Disadvantages of brushed DC motor **:**

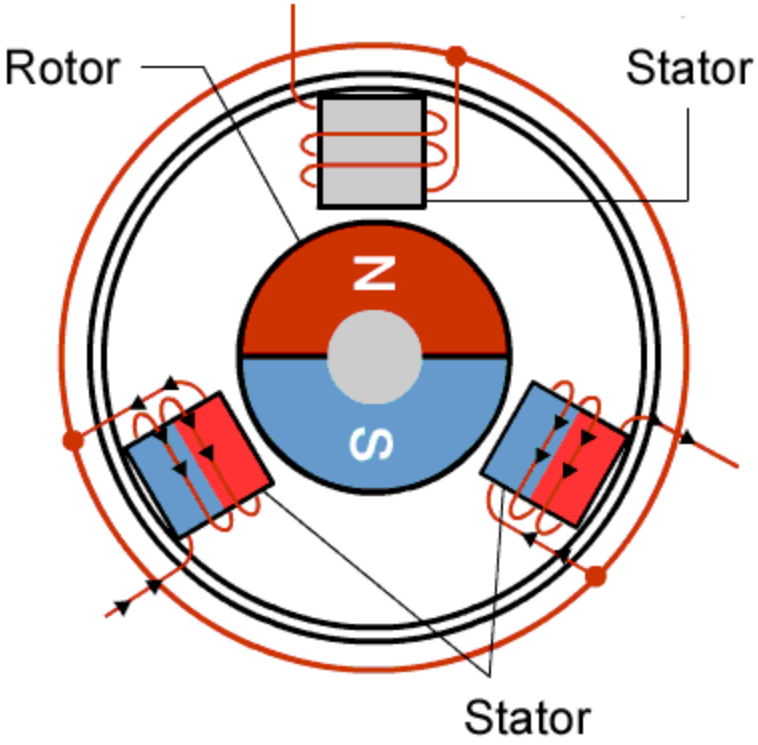
•High maintenance
•Performance decreases with dust particles
•Less reliable in control at lower speeds
The brushes wear off with usage





Brushless DC motor

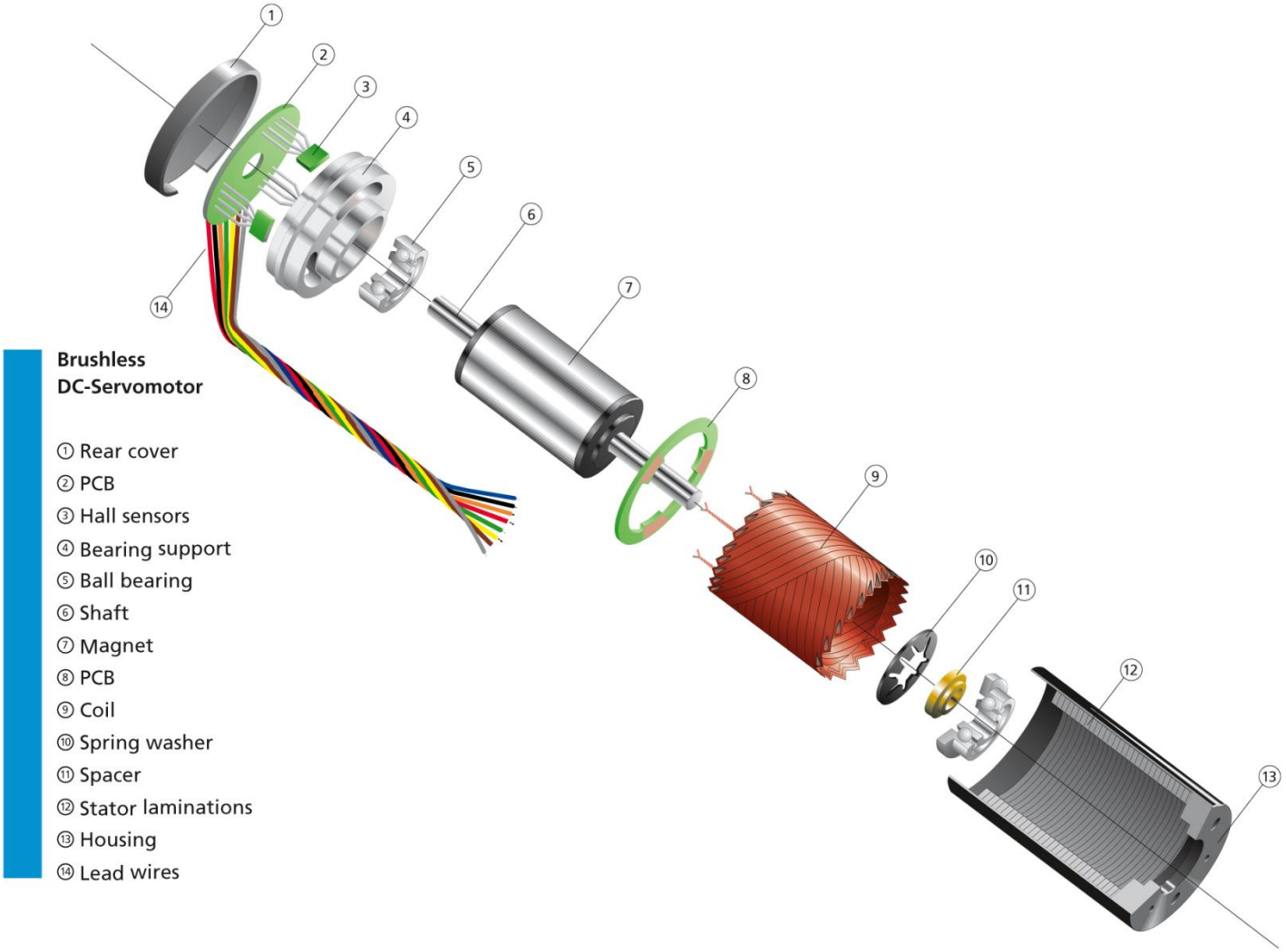




A brushless DC motor has a rotor with permanent magnets and a stator with windings. The rotor can be of ceramic permanent magnet type. The brushes and commutator are eliminated and the windings are connected to the control electronics. The control electronics replace the commutator and brushes and energize the stator sequentially. Here the conductor is fixed and the magnet moves.

The current supplied to the stator is based on the position of rotor. It is switched in sequence using transistors. The position of the rotor is sensed by Hall effect sensors. Thus a continuous rotation is obtained.

Brushless DC motor



Advantages of brushless DC motor **:**

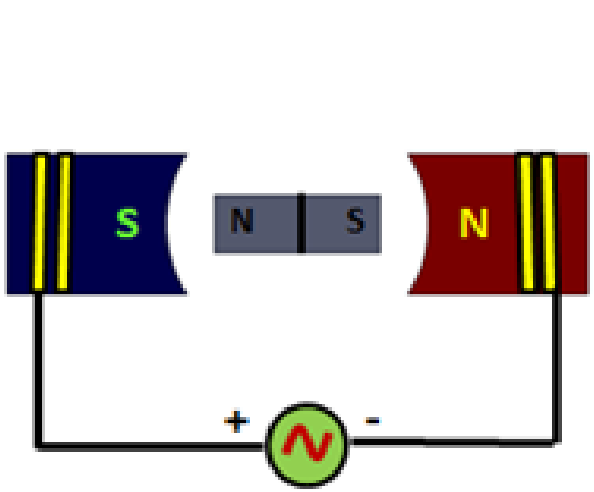
•More precise due to computer control
•More efficient
•No sparking due to absence of brushes
•Less electrical noise
•No brushes to wear out
•Electromagnets are situated on the stator hence easy to cool
•Motor can operate at speeds above 10,000 rpm under loaded and unloaded conditions
•Responsiveness and quick acceleration due to low rotor inertia

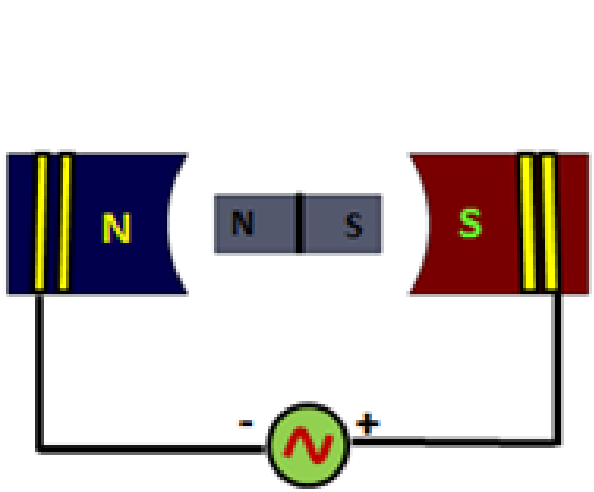
Disadvantages of brushless DC motor **:**

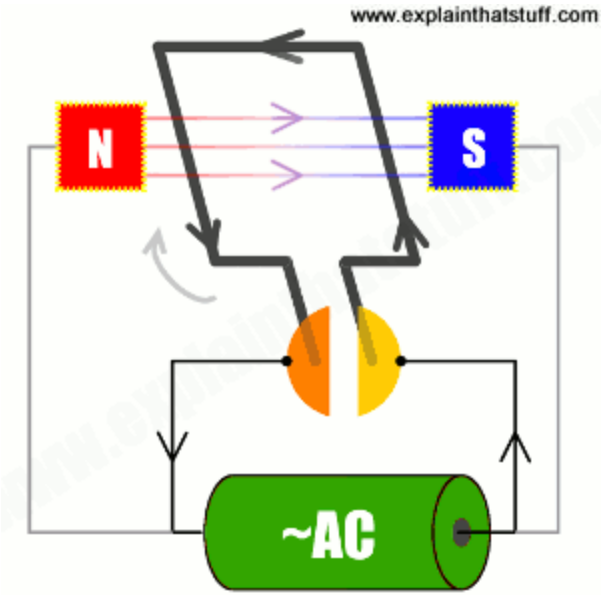
•Higher initial cost
•Complex due to presence of computer controller
Brushless DC motor also requires additional system wiring in order to power the electronic commutation circuitry

AC motors

AC motors convert AC current into the rotation of a mechanical element (mechanical energy). As in the case of DC motor, a current is passed through the coil, generating a torque on the coil. Typical components include a stator and a rotor. The armature of rotor is a magnet unlike DC motors and the stator is formed by electromagnets similar to DC motors. The main limitation of AC motors over DC motors is that speed is more difficult to control in AC motors. To overcome this limitation, AC motors are equipped with variable frequency drives but the improved speed control comes together with a reduced power quality.

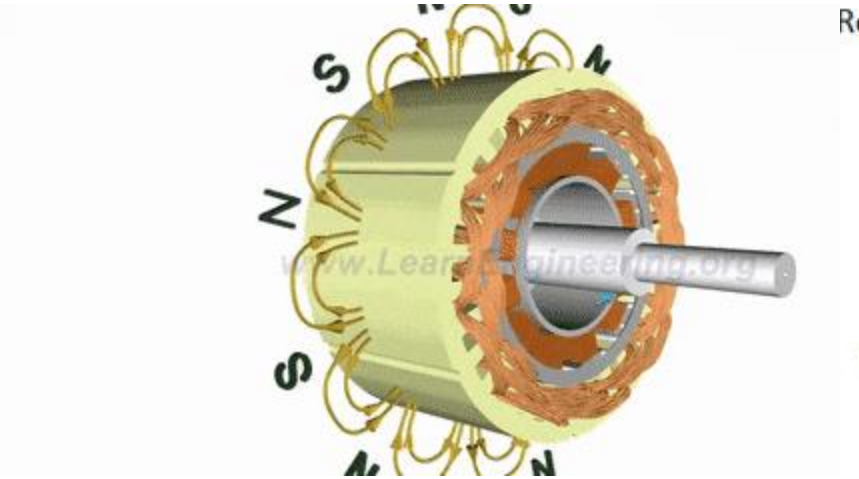


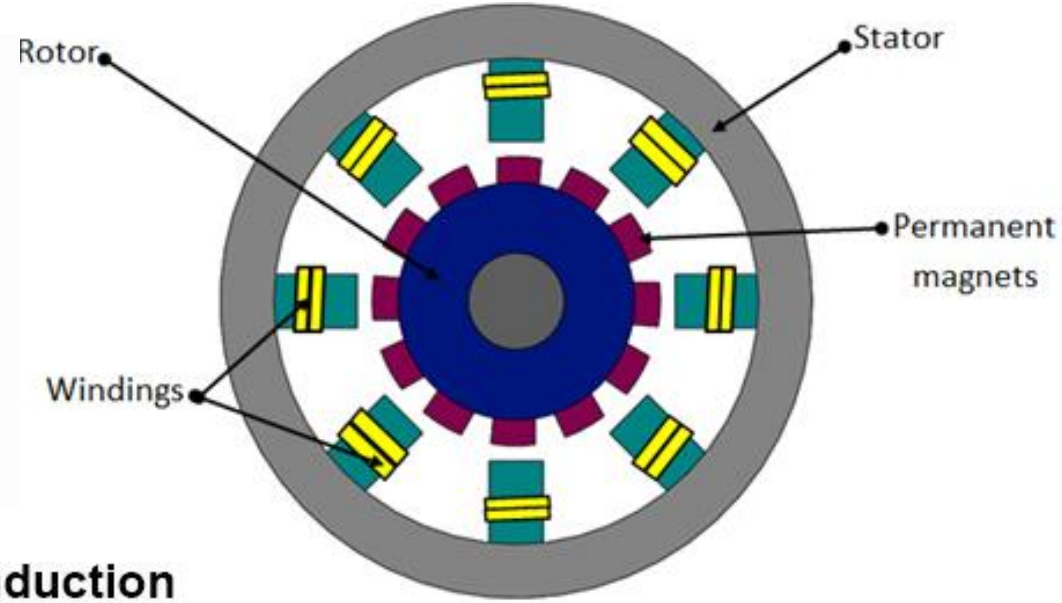




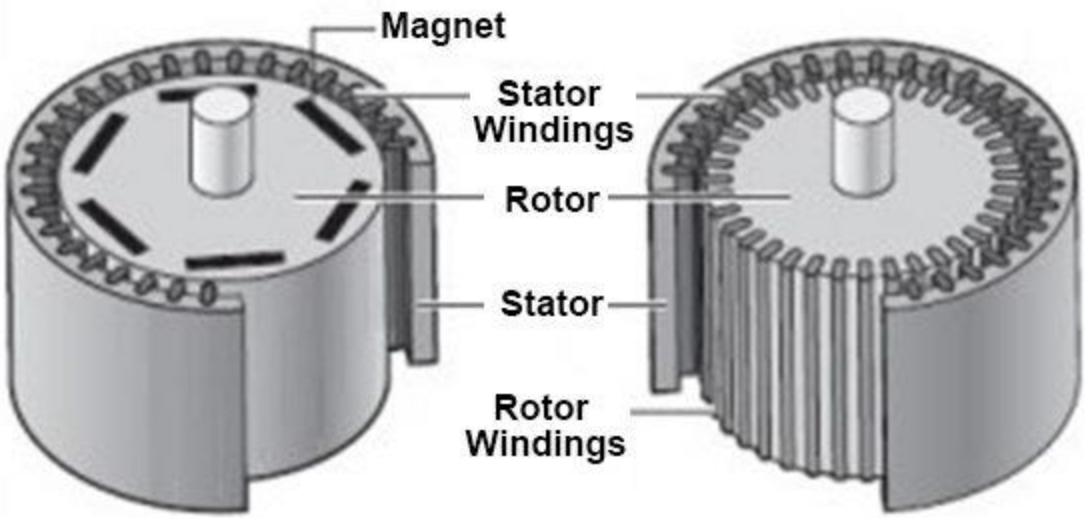
AC motors can be classified into synchronous motors and induction motors

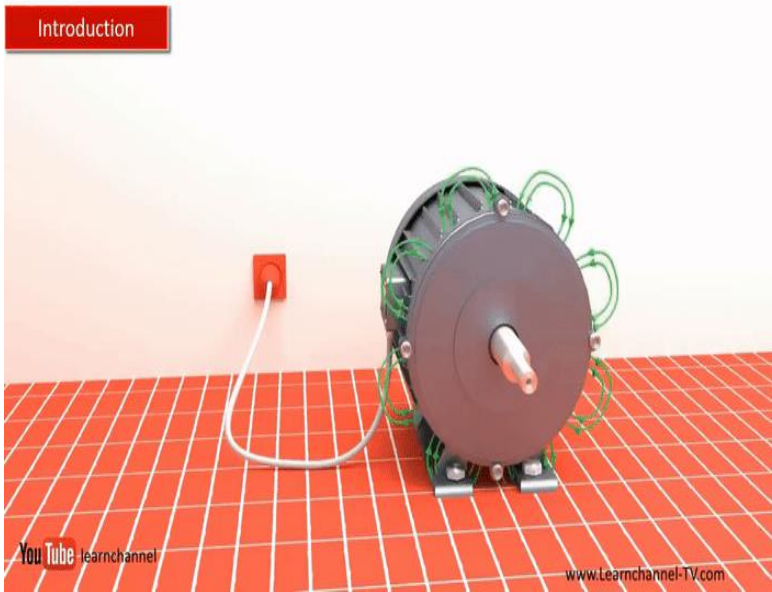
Synchronous motor



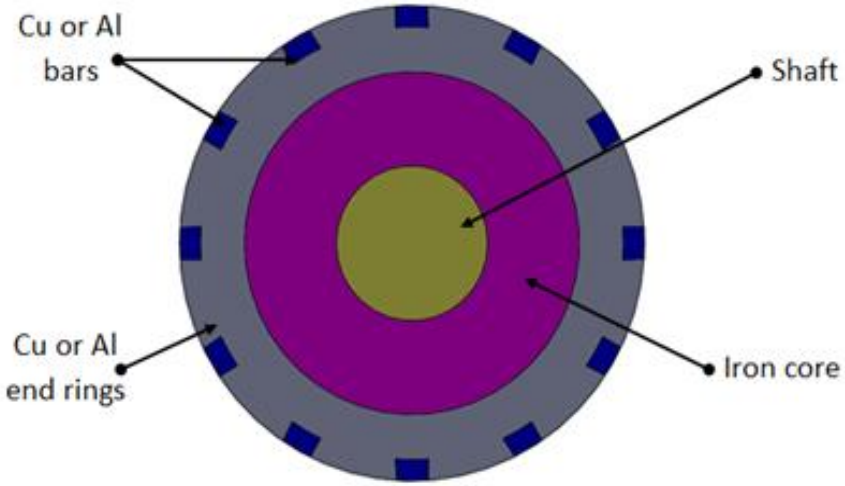


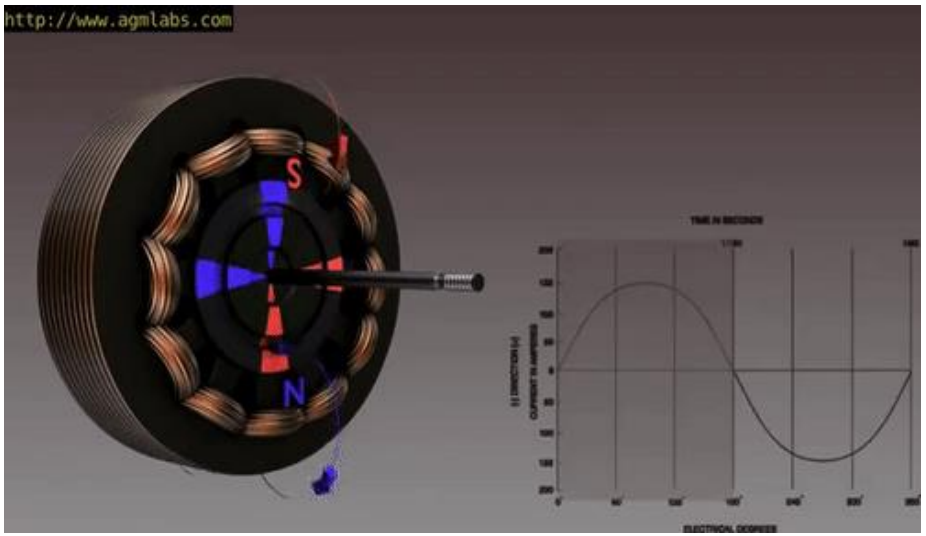
Permanent Magnet **Induction**

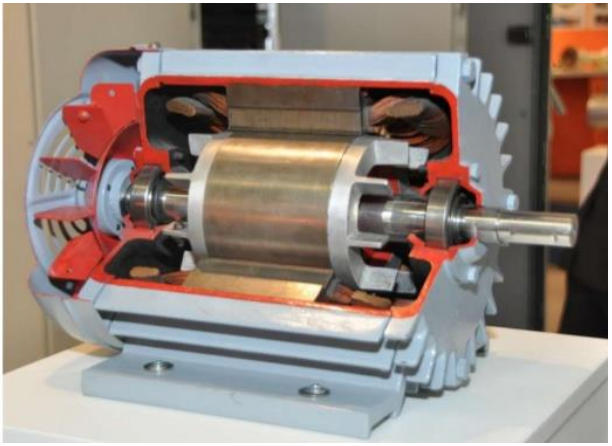


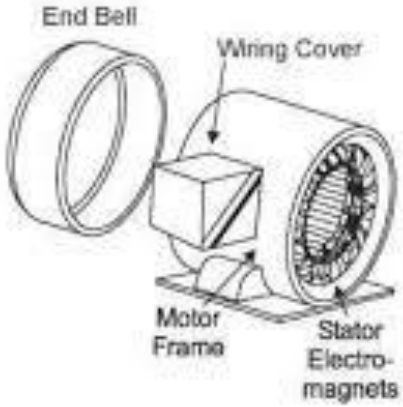


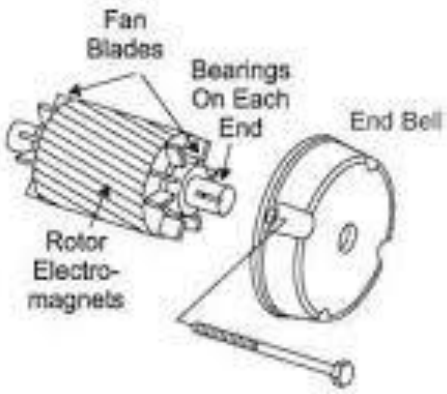
Induction motor











Advantages of AC induction motors

•It has a simple design, low initial cost, rugged construction almost unbreakable

•The operation is simple with less maintenance (as there are no brushes)

•The efficiency of these motors is very high, as there are no frictional losses, with reasonably good power factor

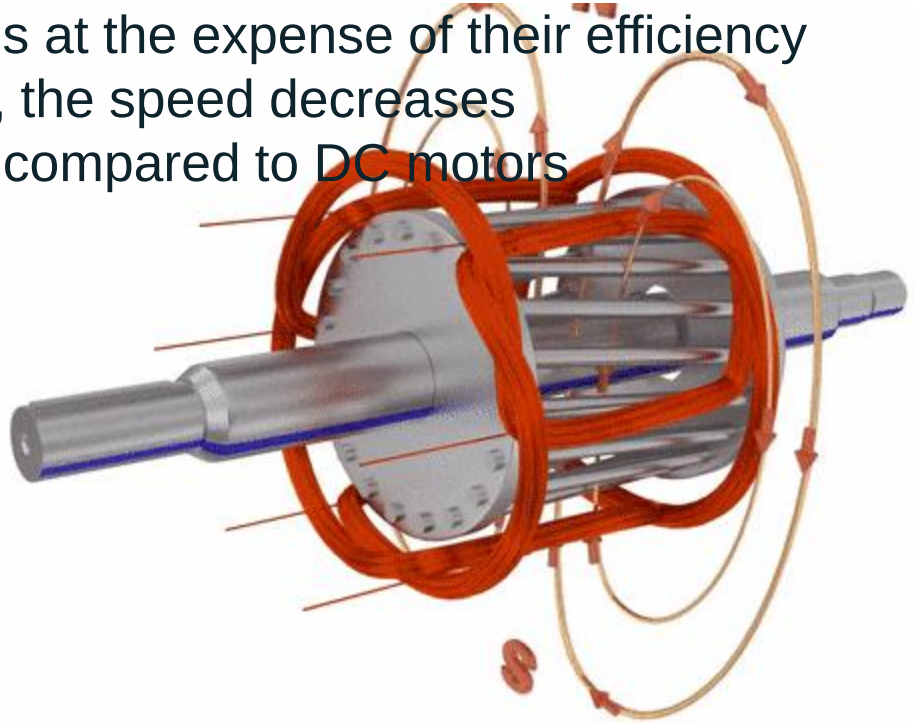
•The control gear for the starting purpose of these motors is minimum and thus simple and reliable operation

Disadvantages of AC induction motors

•The speed control of these motors is at the expense of their efficiency

•As the load on the motor increases, the speed decreases

•The starting torque is inferior when compared to DC motors



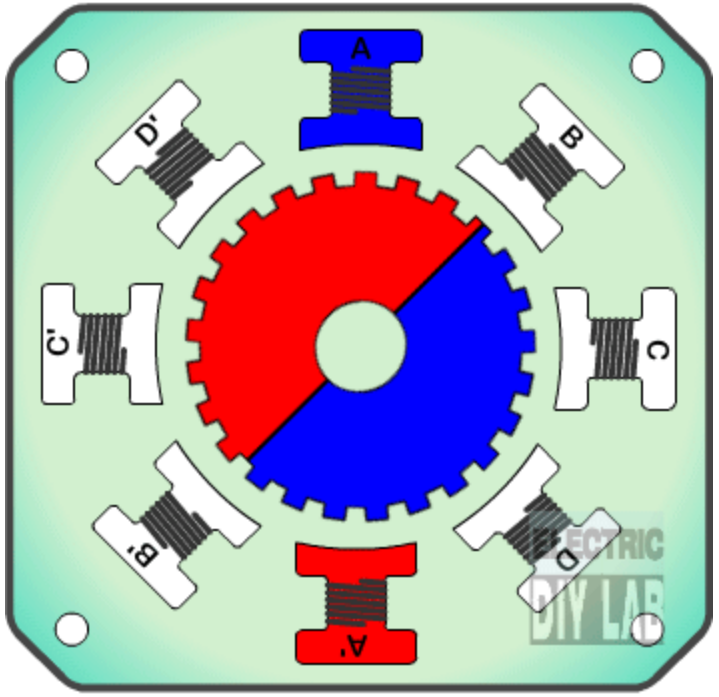
Feed Drives

Stepper motor

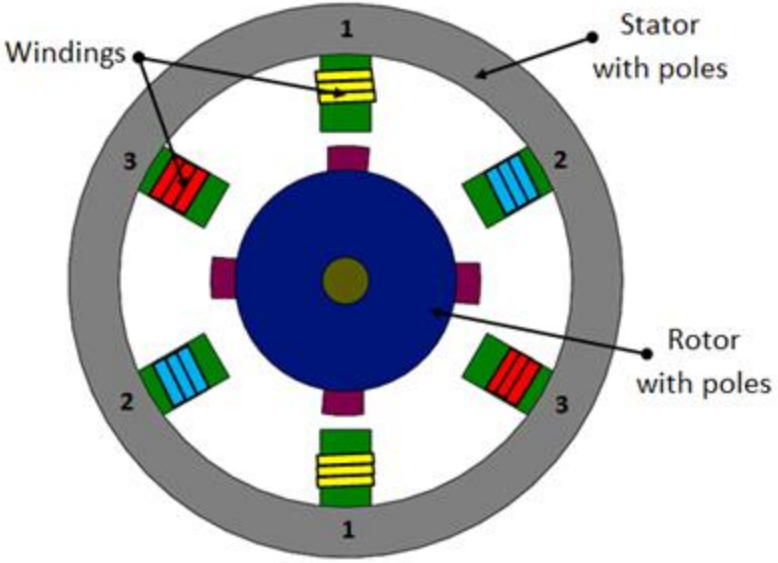
A stepper motor is a pulse-driven motor that changes the angular position of the rotor in steps. Due to this nature of a stepper motor, it is widely used in low cost, open loop position control systems.

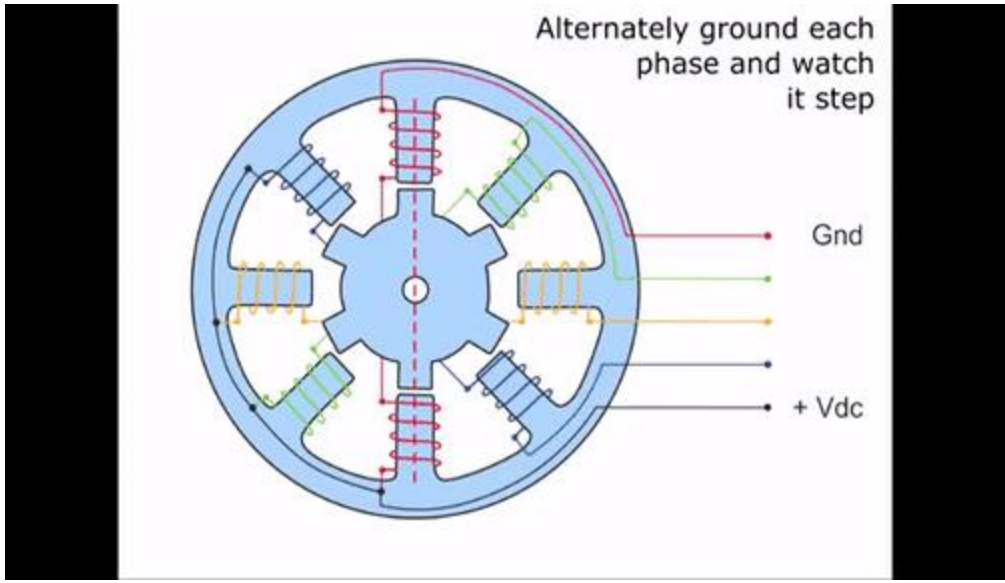
Types of stepper motors:

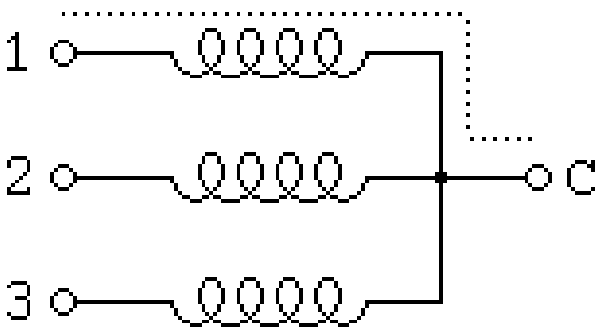
- Permanent Magnet
  - Employ permanent magnet
  - Low speed, relatively high torque
- Variable Reluctance
  - Does not have permanent magnet
  - Low torque

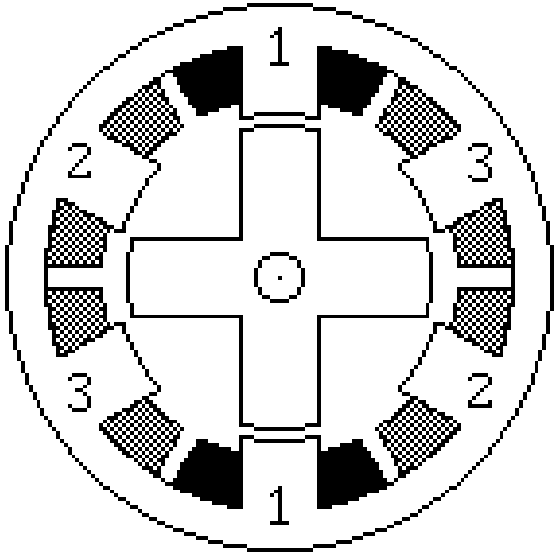


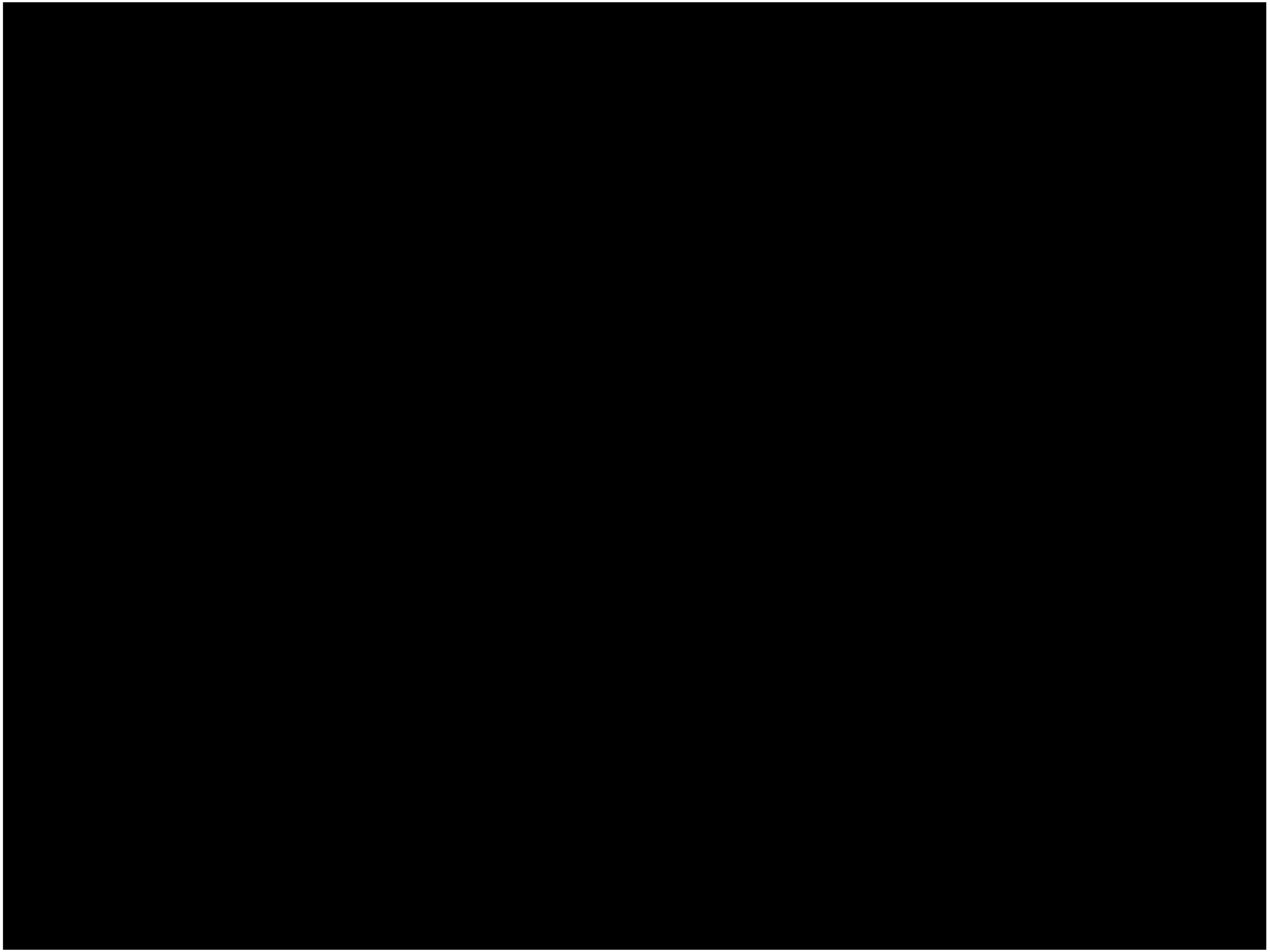
Variable Reluctance Motor





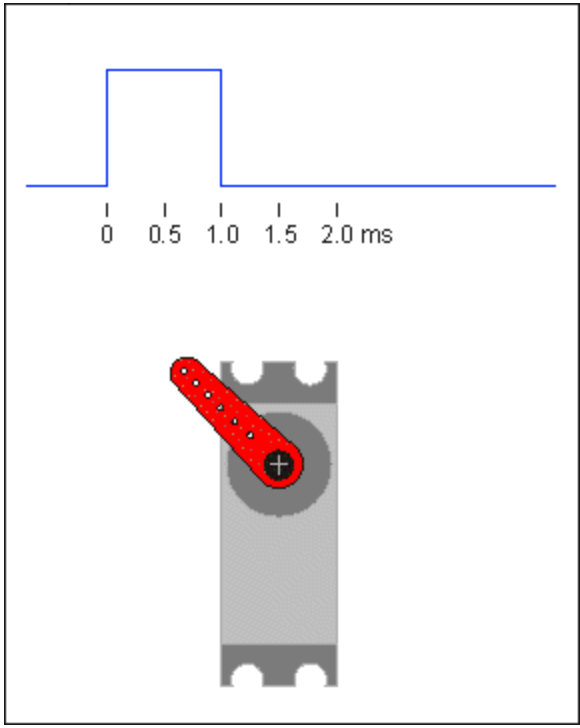






Servomotors

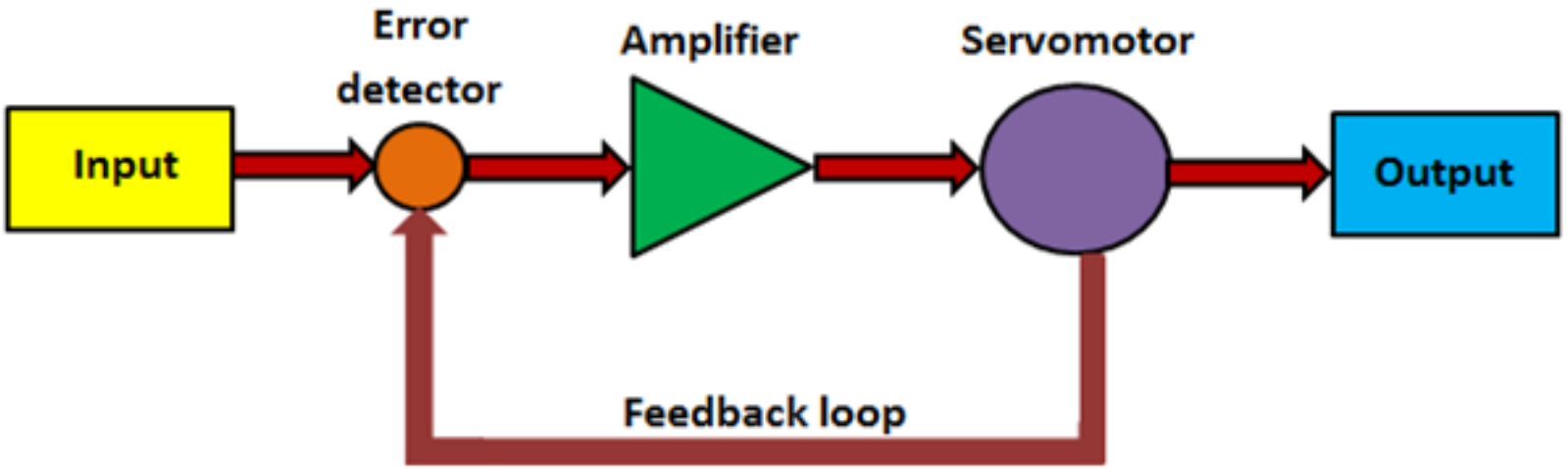
- Servomotors are special electromechanical devices **that produce precise degrees of rotation.**
- A servomotor **is a DC or AC or brushless DC motor combined with a position sensing device.**
- Servomotors are also called **control motors as they are involved** in controlling a mechanical system.
- If the motor as controlled device, **associated with** servomechanism is **DC motor, then it is commonly known DC Servo Motor.**
- **Servomotor is a special type of motor which is automatically operated up to certain limit for a given command with help of error-sensing feedback to correct the performance.**



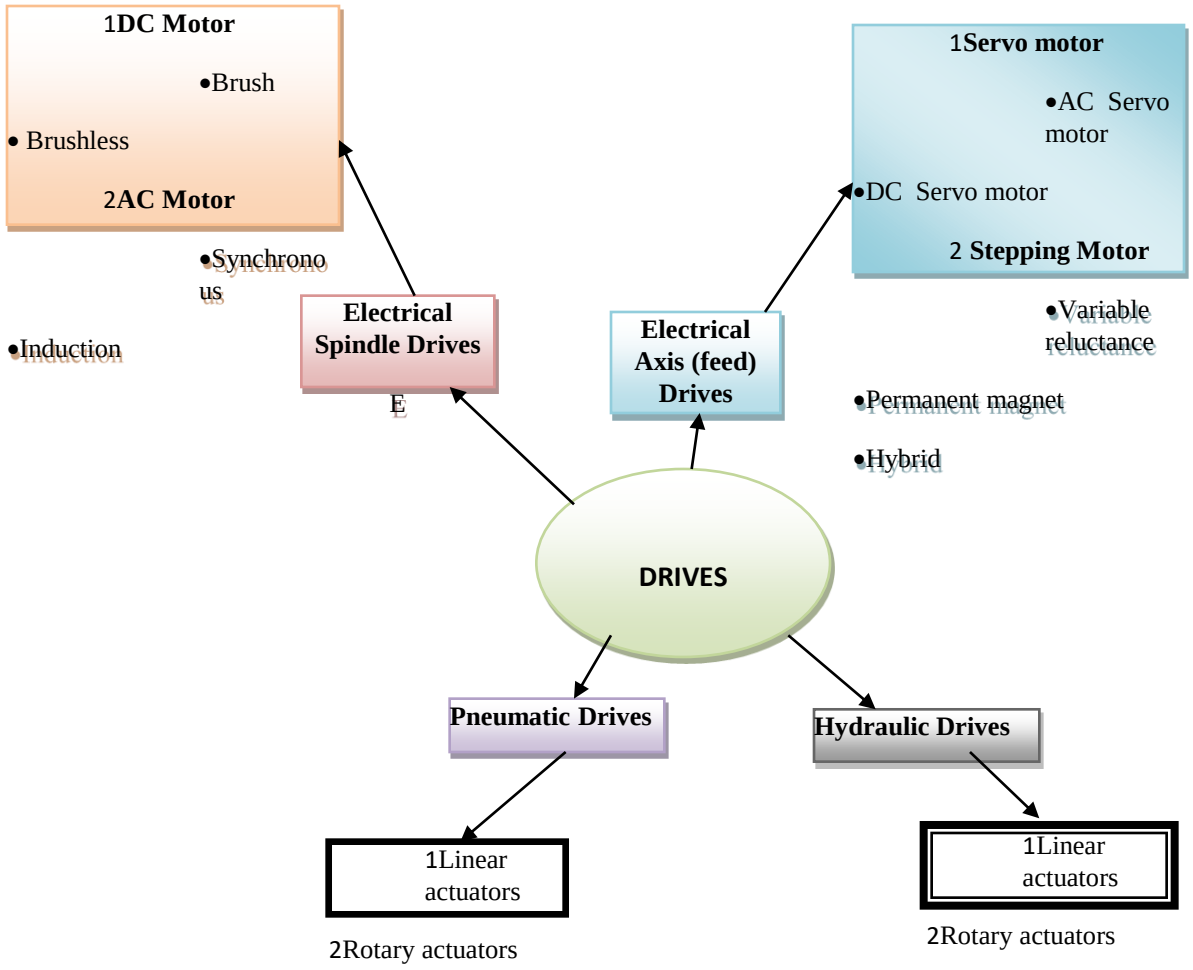
Servo motors

Components:

- Consists of three basic components
  - **a controlled device (motor and driver circuit)**
  - **a output sensor**
  - **a feedback system.**
- Controlled by a feedback signal instead of variable input signal.
- Reference signal (input or command signal) is compared with sensor signal, and a third signal (error) produced.
- This third signal (error) acts as an input signal of controlled device.
- Primary task of a servomechanism is **to maintain the output of a system at the desired value in the presence of disturbances.**


Error
detector
Amplifier
Servomotor
Input
Output
Feedback loop

Concept Map


1DC Motor
•Brush
• Brushless
2AC Motor
•Synchronous
•Induction
Electrical Spindle Drives
E
1Servo motor
•AC Servo motor
•DC Servo motor
2 Stepping Motor
•Variable reluctance
•Permanent magnet
•Hybrid
Electrical Axis (feed) Drives
DRIVES
Pneumatic Drives
Hydraulic Drives
1Linear actuators
2Rotary actuators
1Linear actuators
2Rotary actuators

Discussion

10 mins