Actuators

- Actuators are required to move joints, provide power and do work.
- Serial robot actuators must be of low weight
- – Actuators of distal links need to be moved by actuators near the base.
- Parallel robots – Often actuators are at the base.
- Actuators drive a joint through a *transmission device*

- Three commonly used types of actuators:
  - Hydraulic
  - Pneumatic
  - Electric motors

1

Actuators

- **HYDRAULIC ACTUATORS FOR ROBOTS**
  - Early industrial robots were driven by hydraulic actuators.
  - Pump supplies high-pressure fluid (typically oil) to a linear
  - cylinders, rotary vane actuator or a hydraulic motor at the joint
  - Large force capabilities.
  - Large power-weight ratio – The pump, electric motor driving the pump,
  - Control is by means of on/off solenoid valves or servo-valves controlled electronically.
  - The entire system consisting of Electric motor, pump, accumulator, cylinders etc. is bulky and often expensive –
  - Limited to 'big' robots.

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Actuators

- **PNEUMATIC ACTUATORS FOR ROBOTS**
  - Working fluid is air.
  - Air is supplied from a compressor to cylinders and flow of air is controlled by solenoid or servo controlled valves.
  - Less force and power capabilities.
  - Less expensive than hydraulic drives.
  - Chosen where electric drives are discouraged or for safety or environmental reasons such as in pharmaceutical and food packaging industries.
  - Closed-loop servo-controlled manipulators have been developed for many applications

3

Actuators

- **ELECTRIC ACTUATORS FOR ROBOTS**
  - Electric or electromagnetic actuators are widely used in robots.
  - Readily available in wide variety of shape, sizes, power and torque range.
  - Very easily mounted and/or connected with transmission elements such as gears, belts and timing chains.
  - Amenable to modern day digital control.
- **Main types of electric actuators:**
  - Stepper motors
  - Permanent magnet DC servo-motor
  - Brushless motors

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Comparison

Drive principle	Scope	Benefits	Disadvantages
Pneumatic	Passive Elements, Auxiliary devices	• Cheap • Low weight	•Compressibility of the air
Hydraulics	Manipulators with very high load capacity and very large working space	• High Dynamics • High-power • Weight ratio	•Necessary Directions: Pump, hoses, Servo Valves "Dirty" Maintenance Low efficiency Warming
Electric	Standard for Industrial robot	• High Dynamics • Very generally favorable opportunity • High performance Relationship • High Speed Ratio	• Necessary gear transmission • Warming

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Classification of actuators

Hydraulic Actuators

Hydraulic actuators use pressurised fluid.

- Linear actuators

Hydraulic cylinder produce translatory motion in joints.

1. Single acting
2. Double acting

- Rotary actuators

Hydraulic motors produce rotation motion joints.

1. Gear
2. Vane
3. Piston
4. Rack and pinion

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Classification of actuators

Pneumatic Actuators:
Pneumatic actuators use compressed air.
- Air cylinders

1. Air cylinders produce translatory motion in joints.
2. Single acting
3. Double acting

- Air motors

1. Air motors produce rotation motion joints.
2. Vane
3. Piston

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Classification of actuators

Electric Motors:
Electric Motors Produce rotational movement.
Translatory movement are produced by transmission devices.
1. Servomotor
- AC
- DC

2. Stepper motor
3. Direct drive motor

Shape Memory Metal Actuators
Magneto Restrictive Actuators

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Hydraulic system

Hydraulic systems comprise of the following:

1. A hydraulic power supply,
2. A servo valve for each axis of motion to effect power amplification,
3. A hydraulic actuator cylinder / motor for each axis of motion,
4. A sump (tank)

1. **Hydraulic power supply:-** The power source for hydraulic actuation system (cylinder/ Motor/ servo valves) wall is high pressure oil supplied by an oil pump.

The main components of the hydraulic power supply are:

a. A pump(P), either gear pump vane pump for piston pump (radial or axial type) is used for supplying high-pressure oil.
b. An electric motor (M) for driving the pump usually three phase induction motor.
c. A fine filter for protecting the servo system for a dirt or chips.
d. A coarse filter for protecting the pump.
e. A check valve for eliminating a reverse flow from the accumulator to the pump.
f. A pressure regulating valve for controlling supply pressure to the servo system
g. An accumulator for storing hydraulic energy and smoothing the pulsating flow

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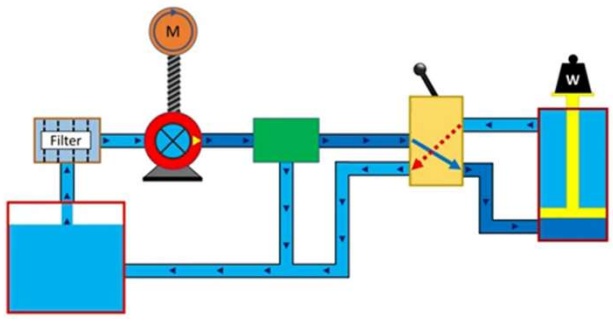
Hydraulic system



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Hydraulic system

2. Servo Valve:

i. The electro hydraulic servo valve controls the flow of high pressure oil to the hydraulic motor.

ii. That is, power amplification in a hydraulic system requires that an electrical signal processed in MCU be converted to appropriate hydraulic pressure.

3. Hydraulic Actuator:

i. The hydraulic actuator is either a hydraulic cylinder for linear motion or a rotary type motor for angular motion

ii. The hydraulic cylinder due to large quantity of high pressure oil which contains is limited for short throw applications, 0.6mm or less.

iii. The rotary hydraulic motor is used in large power servo systems and is preferred for longer travel and heavier workloads.

4. The Sump:

The used oil is returned to the sump. The oil is feedback to the hydraulic power supply and forms a source of the fluid for power supply.

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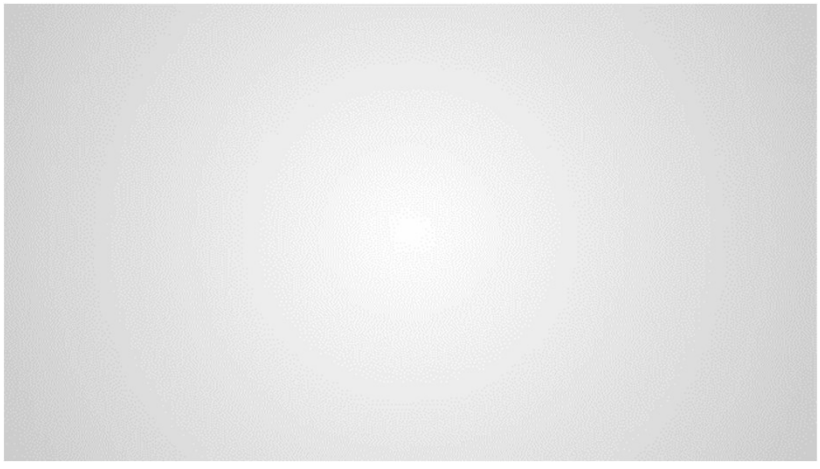
Hydraulic system



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Pneumatic system

Pneumatic actuation systems:

- They operate on the same principle as hydraulic systems except that pneumatic devices used compressed air as the power transmission medium.
- Pneumatic systems are generally comprised of the following components:
  1. A pneumatic power supply (air compressor)
  2. A servo valve for each axis of motion
  3. A pneumatic actuator (Pneumatic Cylinder / Pneumatic Motor) for each axis of motion.

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Pneumatic system

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Pneumatic system

1. **Pneumatic power supply:**
   a) The air compressor is the power source for pneumatic actuation systems.
   b) They may be either positive displacement: piston compressor or non positive displacement (dynamic) type: centrifugal compressor
   c) Air filter:- used to protect the server systems from dirt and foreign particles
   d) Dehydrator ;- To remove moisture from the air
   e) Lubrication :- Air is enriched with fine oil mist to provide lubrication
2. **Servo Valve:**
   i. With modifications, the four way proportional valve is used in pneumatic actuation systems.
   ii. In this case the flapper control has been replaced by a controller that moves the piston directly.

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Pneumatic system

3. **Pneumatic actuators:**
   i. Compressed air can be applied to both linear and rotary actuators.
   ii. Linear actuators in the form of double acting pneumatic cylinder are similar in construction and principle of operation, to their hydraulic components except that the cylinder piston arrangement makes possible only a limited traverse motion.
   iii. Rotary actuators in the form of pneumatic motors, consists of a rotary vane driver by applied air pressure and unlike its hydraulic counterpart the torque developed by the pneumatic motors is proportional to the supply pressure and independent of motor speed.

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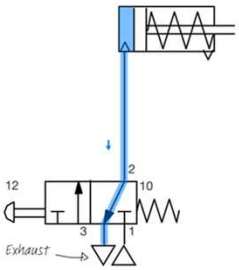
Pneumatic system

NORGREN

IMI

NORGREN



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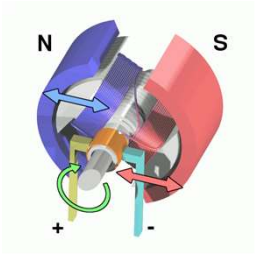
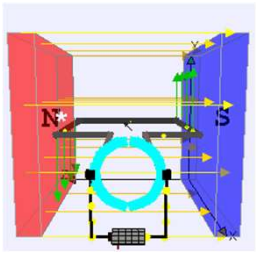
Electrical system

DC motor

Permanent magnets are used to generate the stator magnetic field by supplying directly the electrical current into the armature winding of the rotor through brushes and commutators.

- **Shunt Motor** In the shunt wound motor, a stator field winding is connected in parallel with the armature winding.
- **Series wound motor** In the series wound motor, the stator winding (electromagnet) is connected in series with the armature winding.
- **Compound wound motor** In the compound wound motor, two stator windings are connected—one in series and the other in parallel with the armature winding.
- **BLDC motor** In brushless d.c. motors, electronic commutation in matching with the rotor and the stator magnetic fields is made replacing the conventional brush-commutation system.





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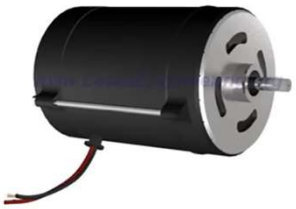
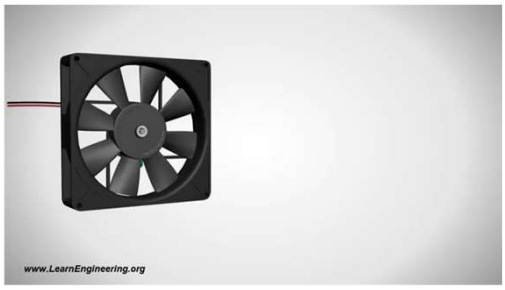
DC motor





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Difference between AC and DC

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Electrical system

AC-Motor (alternating current)

- Synchronous motor

1. - Exchange of usual Keramikoxid-magnet by the permanent magnet (Somarium-cobalt, neodymium-ferrite-boronic) with higher power density.
2. - The advanced power semiconductor technology (IGBT Insulated Gate - Bipolar Transistor) has improved the dynamics and controllability.
3. - Power up to 10-20 kW, speed 3000 min^{-1}.

- Asynchronous motor

1. - More robust than synchronous motor
2. - Higher power density as a synchronous motor
3. - By the excitation of the magnetic field, these motors can in large area at the constant output power and at the nominal rotational speeds.
4. - This provides significant advantage over the synchronous motor.
5. - Power to 80 kW, speed up to 10000 min^{-1}.

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Synchronous motor and Asynchronous motor

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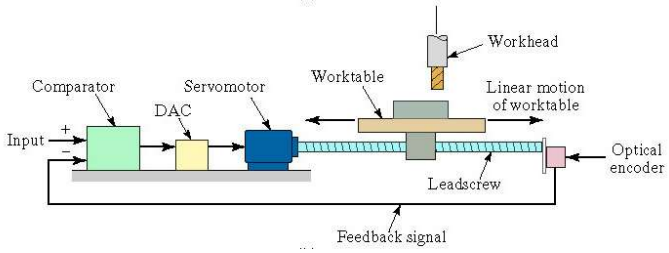
Servo Motor

What is a Servo Motor?

A servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration.

- It consists of a suitable motor coupled to a sensor for position feedback.
- If you want to rotate and object at some specific angles or distance, then you use servo motor.
- It is just made up of simple motor which run through servo mechanism. It can be DC or AC
- We can get a very high torque servo motor in a small and light weight packages. Due to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine etc.



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Servo motor

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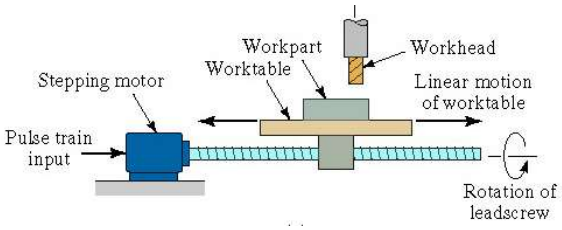
Stepper motor

- In most applications stepper motors are used without feedback.
- This is because a unless a step is missed stepper motors steps a known angle each time it is moved.
- Thus its angular position is always known and no feedback is necessary.
- Unlike AC or DC motors, stepper motor will not rotate when connected to power.
- Stepper motors rotate only when magnetic field is rotated through the different windings.
- Even when not powered, stepper motors have a residual torque called defend torque.
- It requires an external torque to turn a stepper motor.



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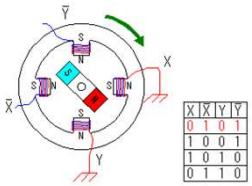
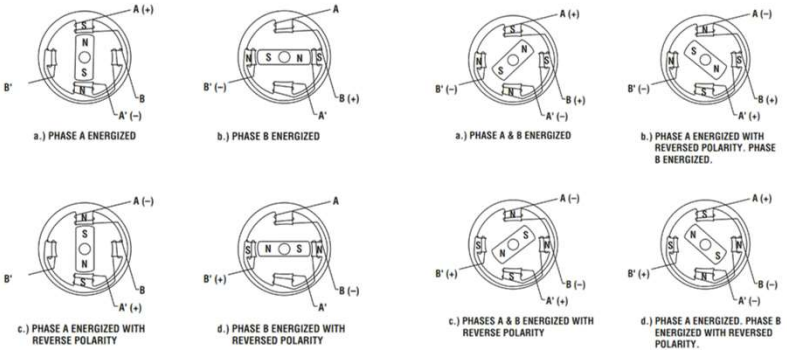
Stepper motor

- Basic principle of operation of a stepper motor as the coils in the stator are turned on and off the rotor will rotate to align itself with the magnetic field





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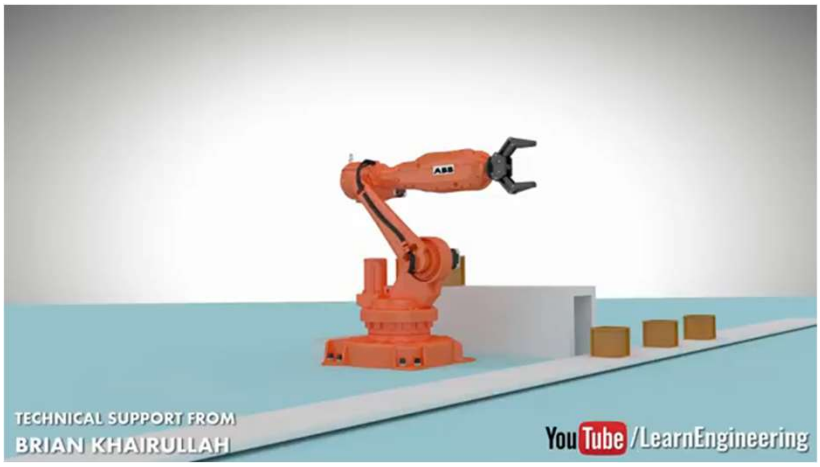
Stepper motor



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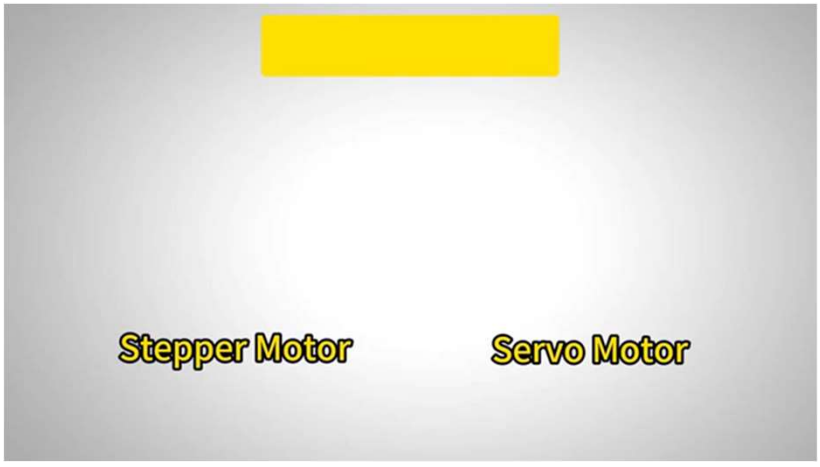
Stepper motor Vs Servo motor



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Numericals

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