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Actuators for IoT

Actuators – Introduction

- These are devices which translates the controller signal into change in a physical parameter

Input: control signal

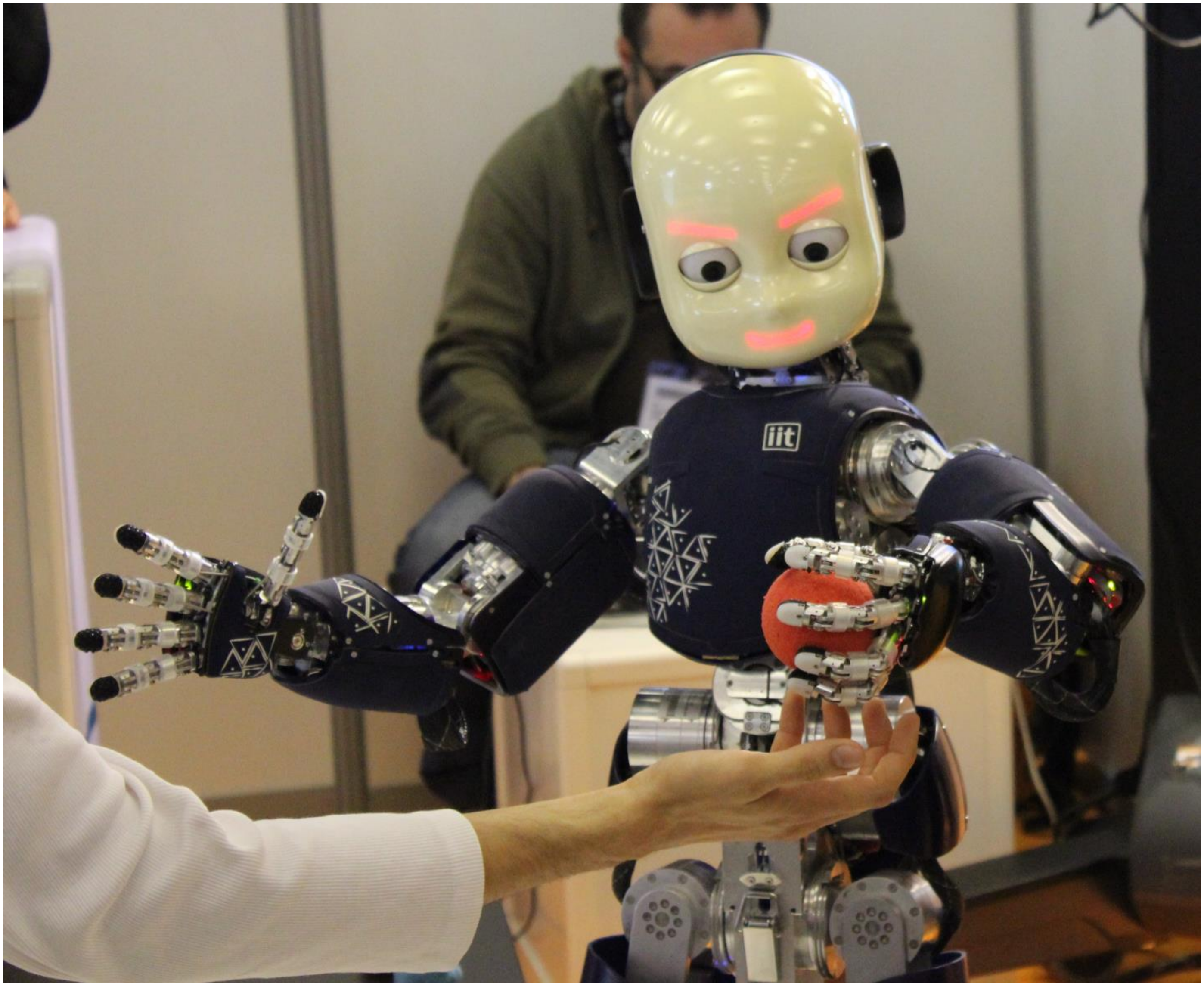
Actuator

Output: actuation

Main energy signal

Where do we see them around us !!!

Robotics / Toys



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Industrial setups

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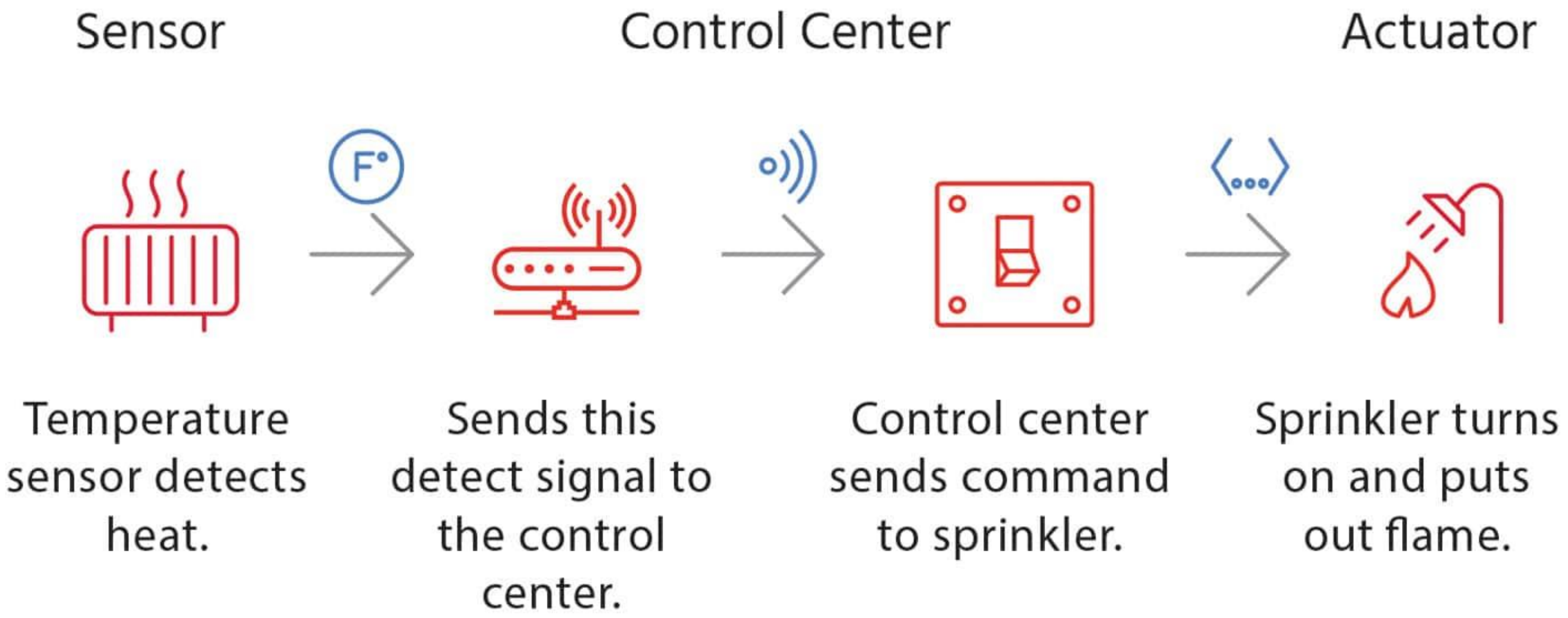
Internet of Things actuator applications



Actuators: Introduction

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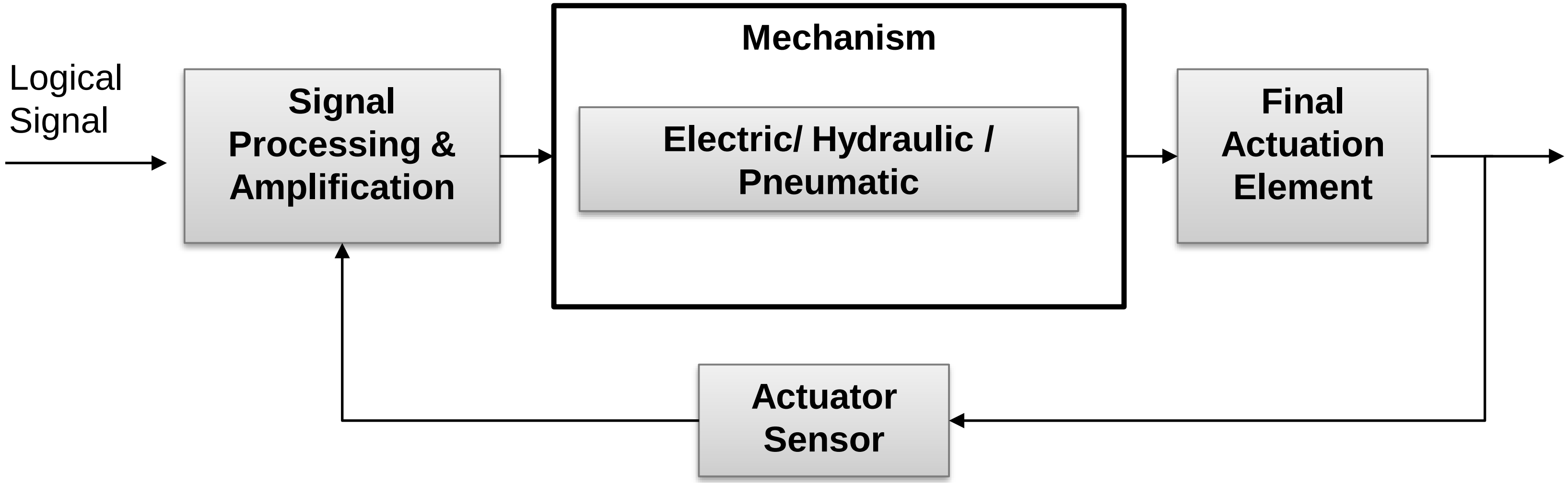
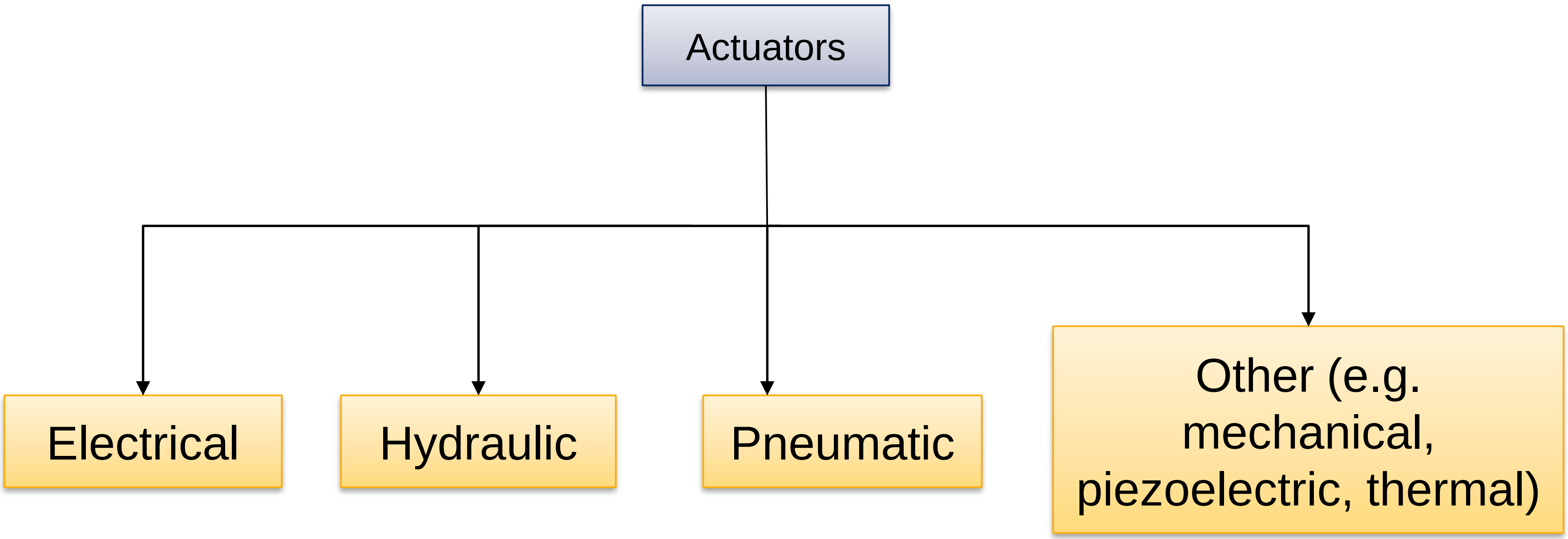
- Usually the output of the actuator is mechanical (e.g., change of position or velocity)
- Since it converts one physical quantity into an alternative form, it is also called as **transducer.**
- Usually, a low-level command signal activates the transducer. Therefore to drive the actuator, an amplifier is used to provide sufficient power.



Classification: based on controlling phenomena



Electrical Actuators

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Converts electrical energy into mechanical energy

DC motor

DC motor rotating a propeller

Electrical actuators - Examples

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- Electric motor
  - DC / AC motor
  - Servo motor
  - Stepper motor
- Solenoid
- Relay
- Buzzers

.

Hydraulic Actuators

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- Hydraulic fluid amplifies the controller command signal
- These have a cylinder or fluid motor which uses **hydraulic power** to produce mechanical motion
- Mechanical motion may be in the form of linear or rotary motion
- The liquid motion is produced by a **pump** (which is typically an electric motor)

Hydraulic Power Transmission

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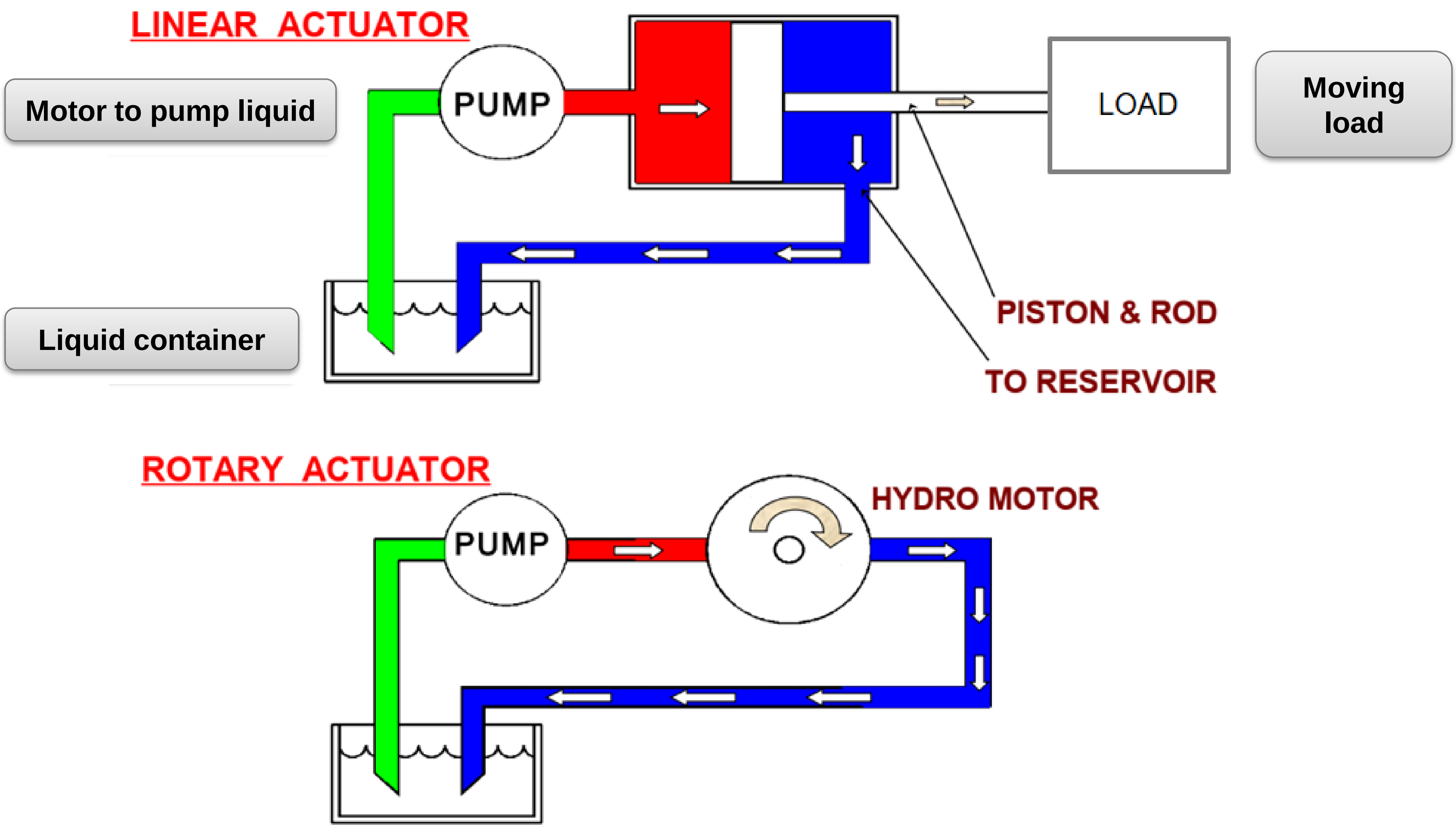

Hydraulic actuators

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Advantages:

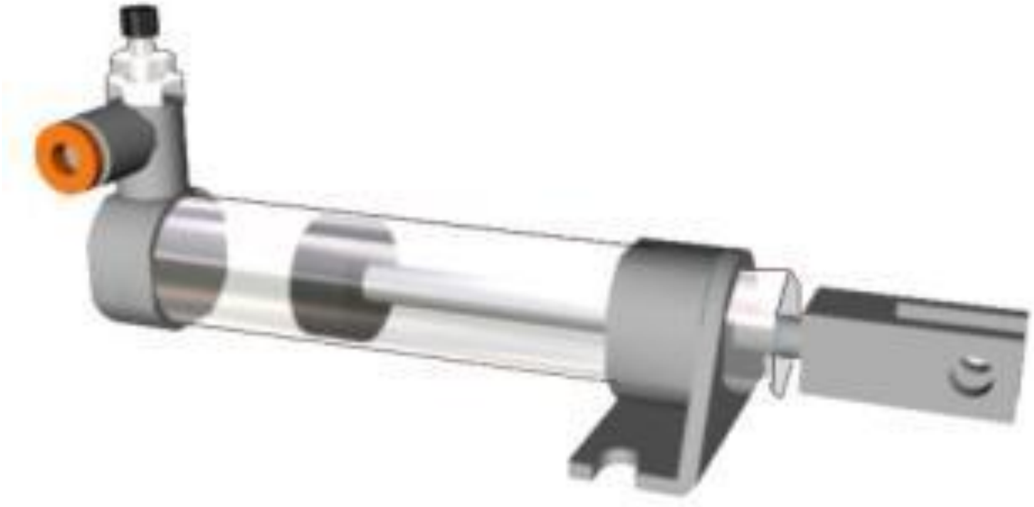
- Can cater to high loads
- Have simple design
- High speed

Disadvantages:

- High cost
- May have leakage issues
- Low resolution
- Temperature effects performance

Pneumatic actuators

- Compressed air provides driving force
- In these potential / kinetic energy of the stream of compressed gas used to move rod of piston etc.



Pneumatic actuators

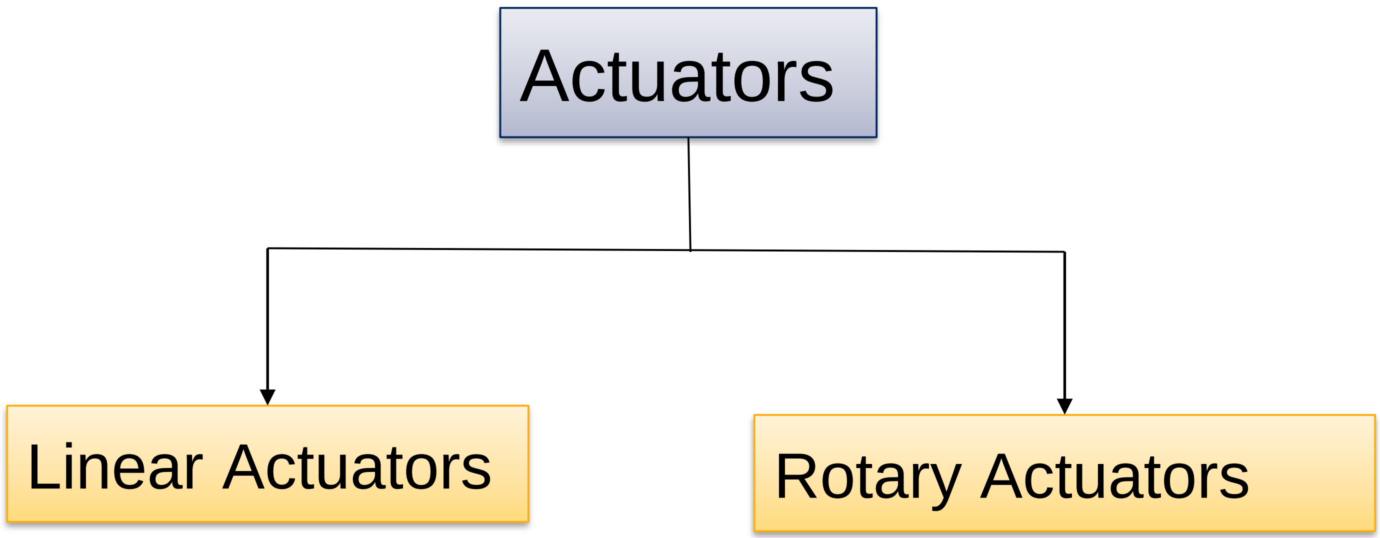
Advantages:

- Compressed air readily available
- Faster operation
- Cheaper than hydraulic systems
- Simple and Reliable

Disadvantages:

- Difficulties in performance at slow speed
- Compressibility of air

Classification: based on operation



Linear actuator

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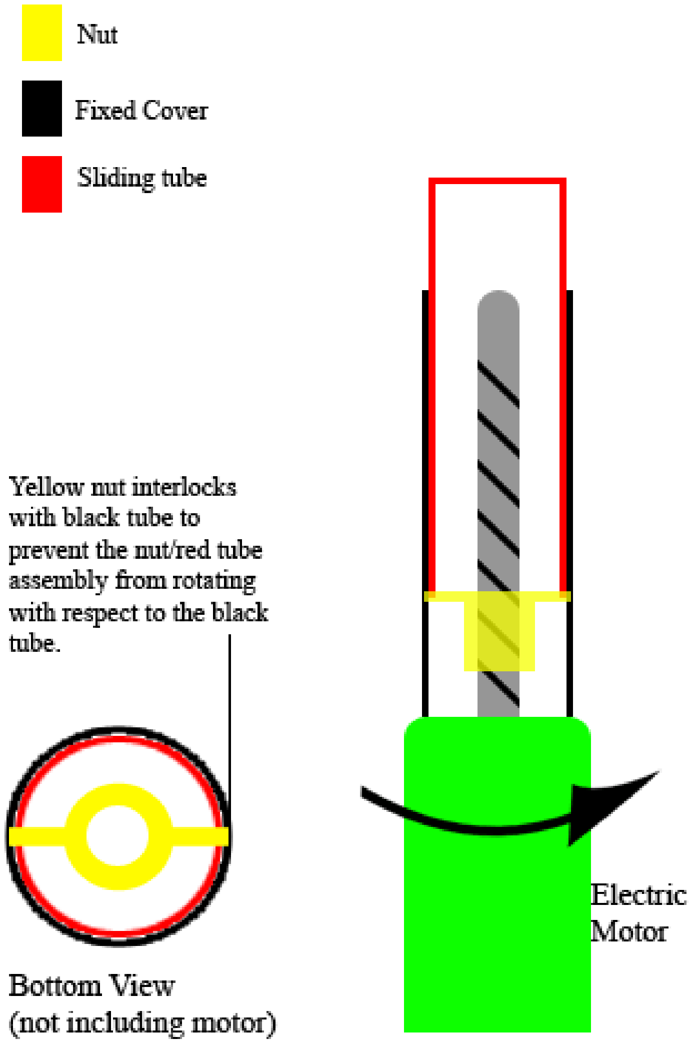
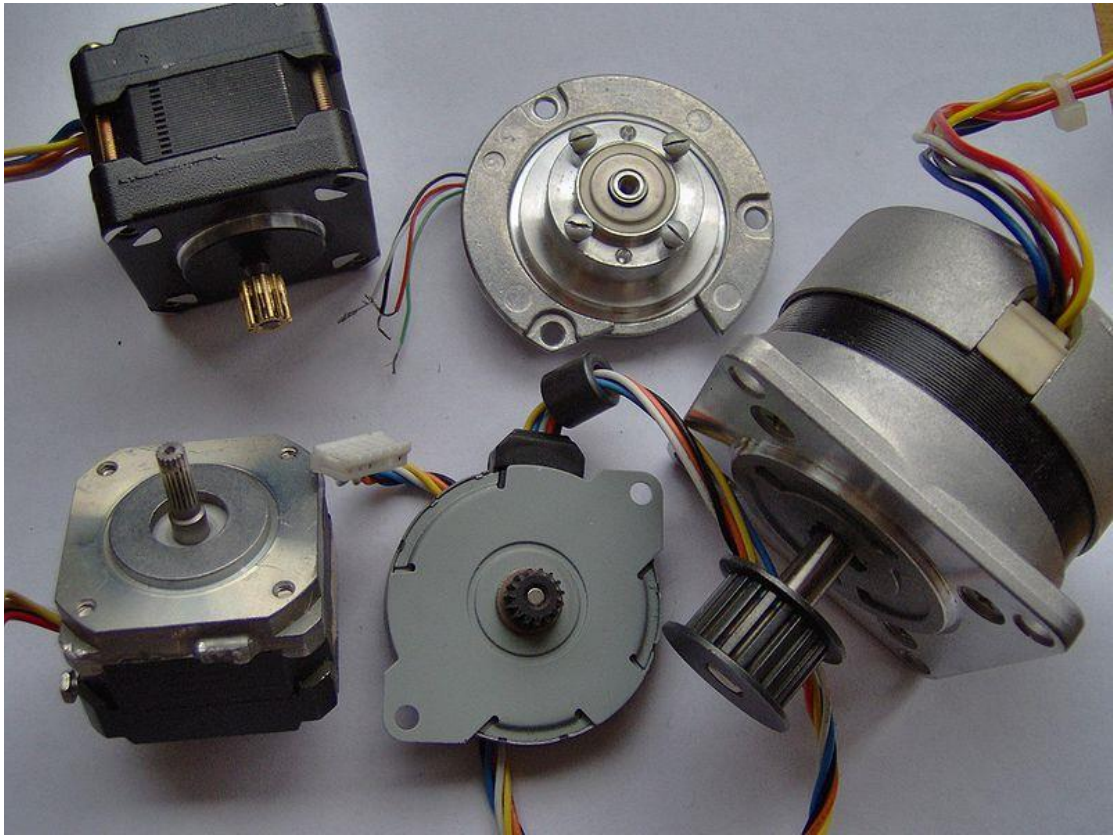
Linear actuators convert energy into straight line motions



Rotary actuator

Rotary actuators convert energy to provide rotary motion



Types of Actuators

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- Electric Linear
- Electric Rotary
- Fluid Power Linear
- Fluid Power Rotary
- Linear Chain Actuators
- Manual Linear
- Manual Rotary
- …… and many more combinations

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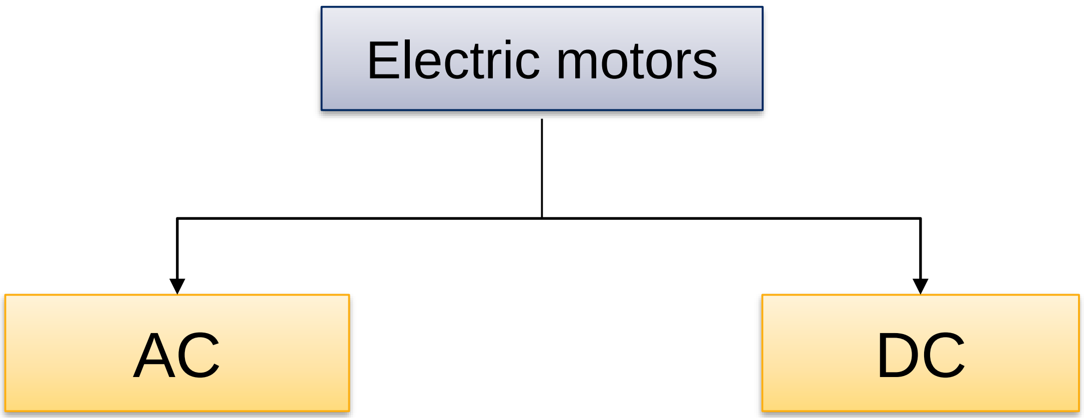
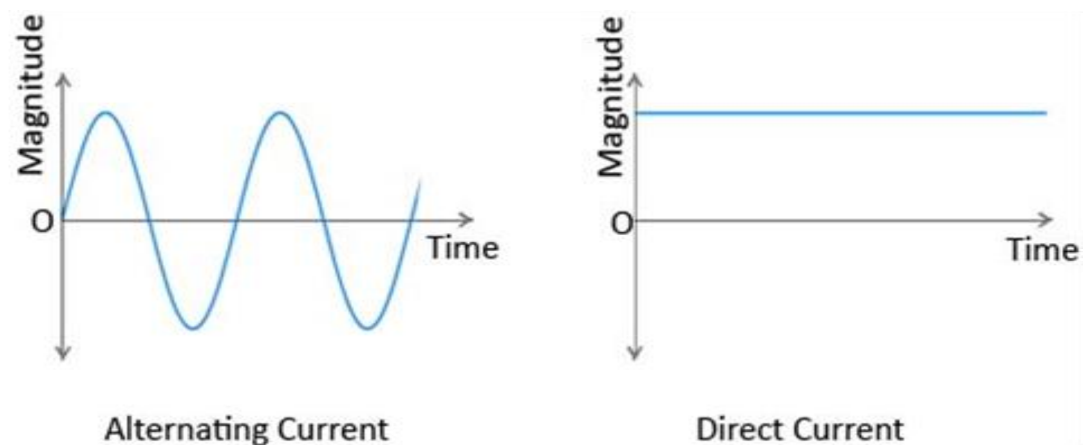
Electrical actuators: Electric motors (DC motor)


Electric motors
AC
DC


Magnitude
O
Time
Alternating Current
Magnitude
O
Time
Direct Current

Motor

1. Device converting electrical energy into mechanical energy (usually a torque).
2. Conversion → Generation of a magnetic field by means of a current flowing into one or more coils

Basic principle behind working

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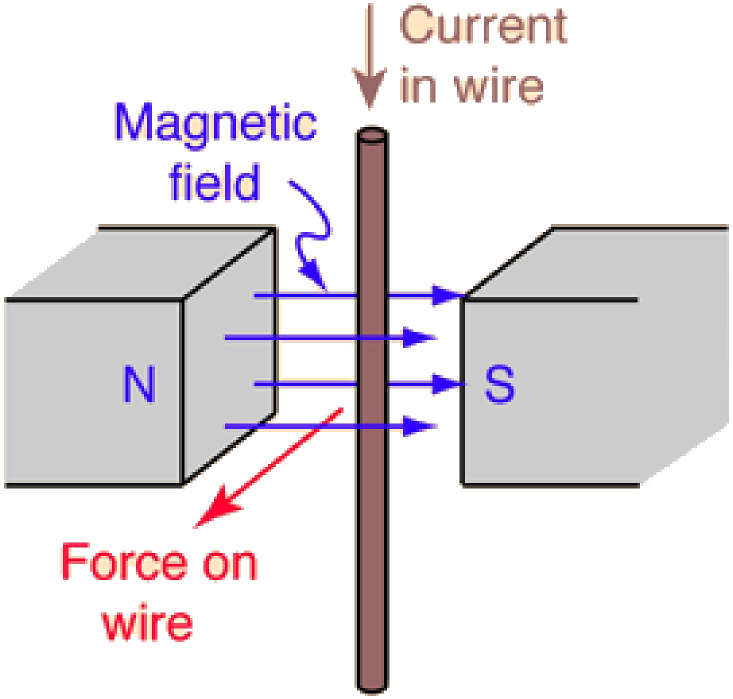
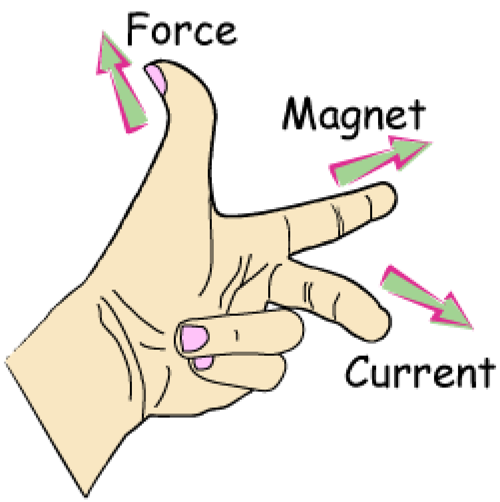
When a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force.

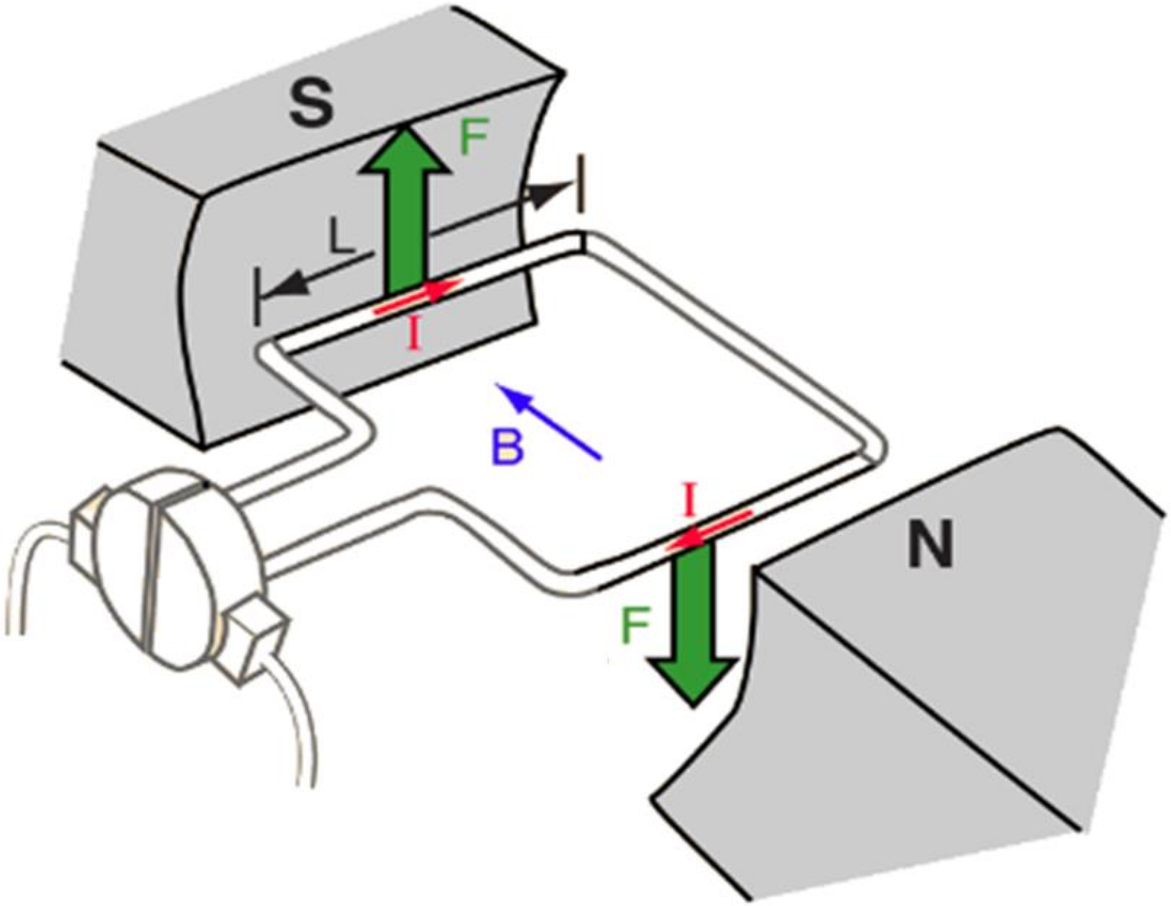




Fleming's Left hand rule

An inside view of motor to understand its working

Wire carrying electric current in a magnetic field



Motor – Speed Control (An Intuitive Idea)

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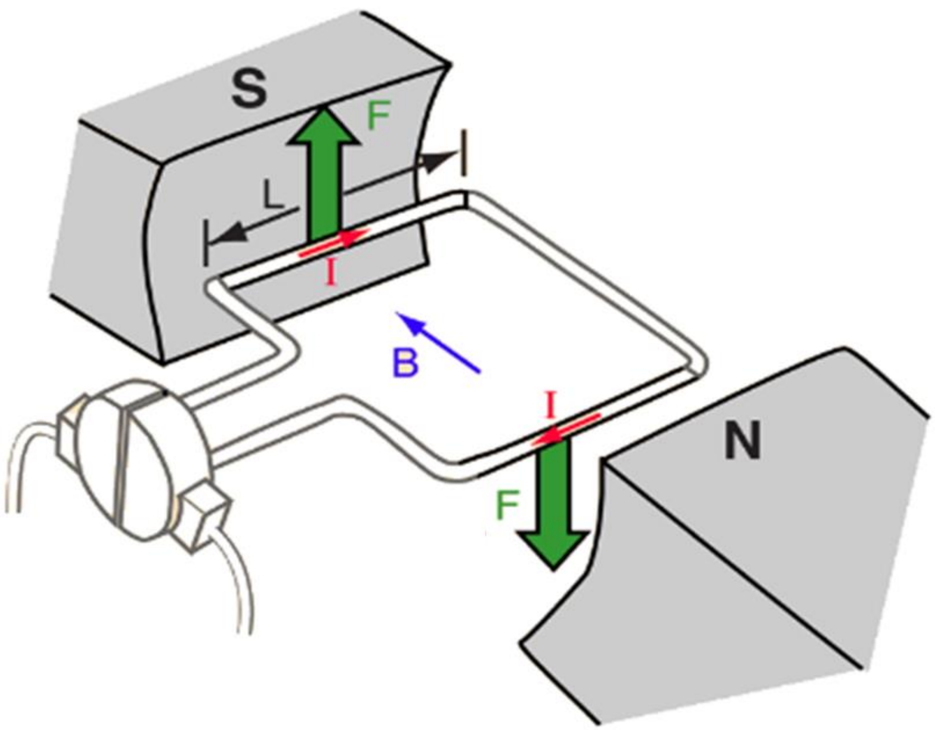
- The torque is proportional to the current (I) and the magnetic field (B)
- How to further increase torque: by having multiple turns of wire



Animation showing working of DC motor

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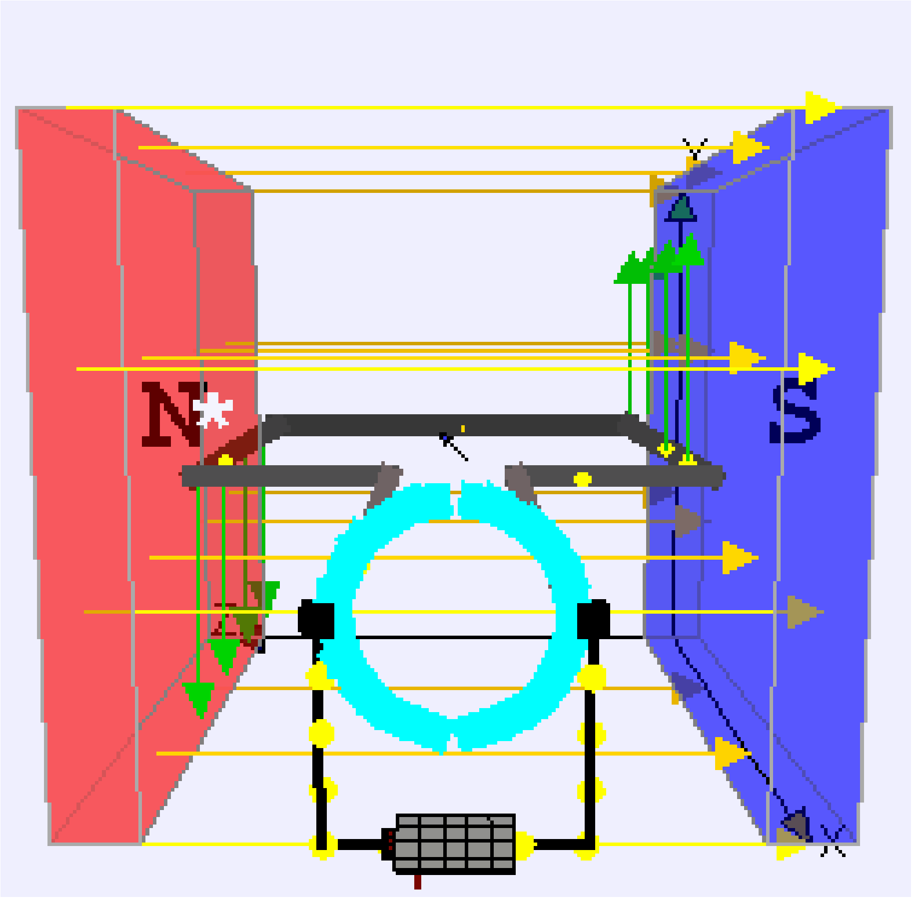
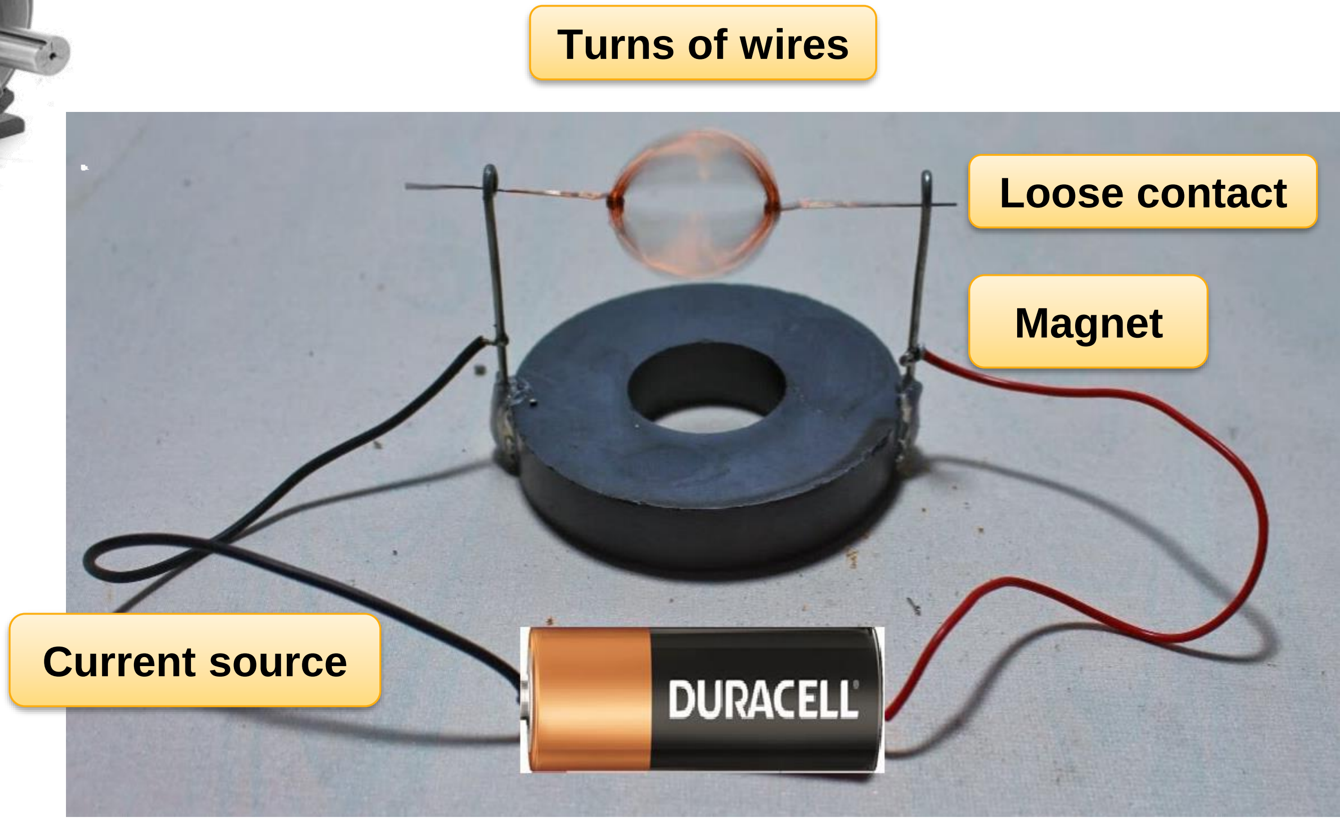
- Permanent magnet
- Armature (with multiple windings)
- Commutator (light blue)
- Current source (current shown by yellow over the black wire).
- Carbon brushes to supply current through commutator



DC motor: Can even be made at home



Making a magnet using current.

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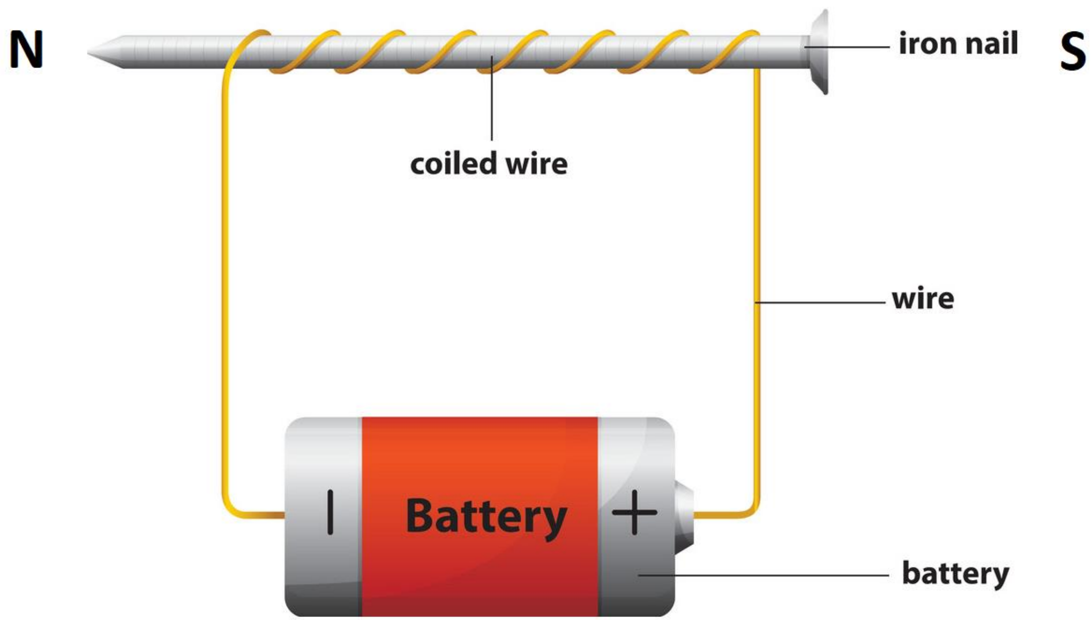
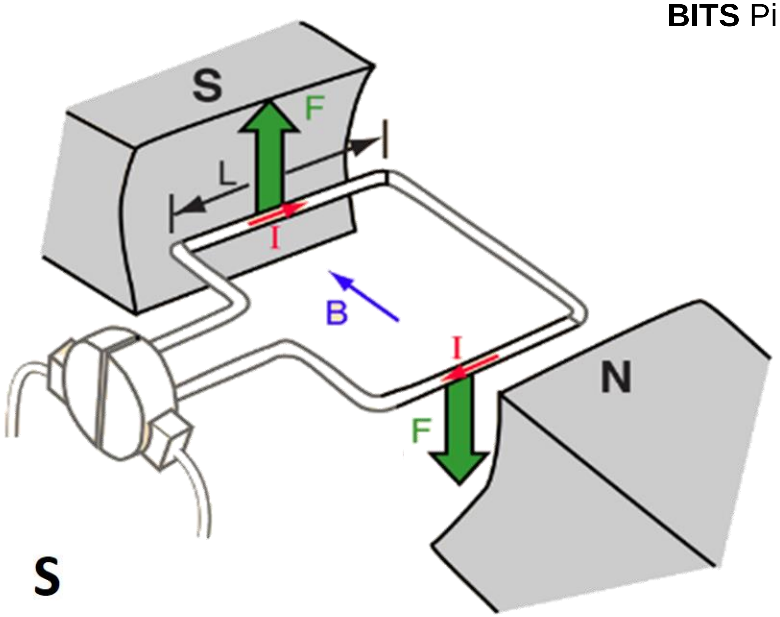
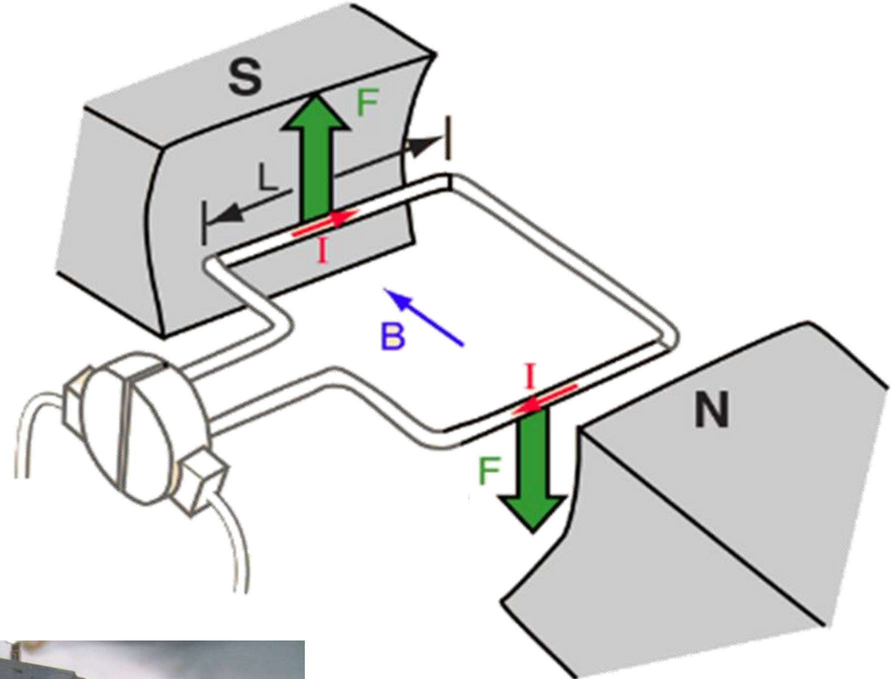
Nail becomes an electromagnet

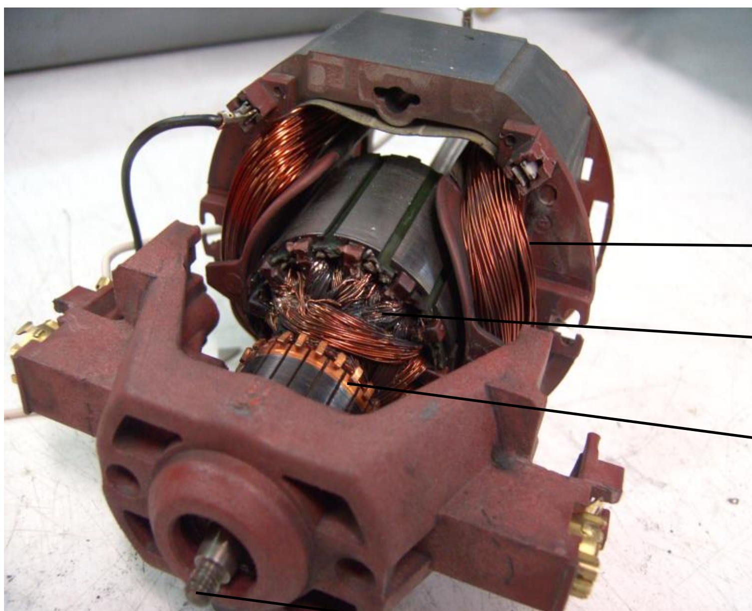




Magnetic field is proportional to the current

Magnetic strength ∝ current





Stator windings (electromagnet)

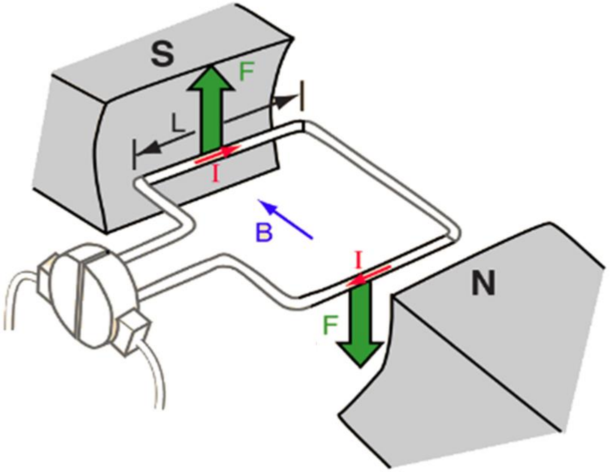
Rotor windings (the current carrying wires within the electric field)

Commutator rings

Load

Speed Control – An Intuitive Idea

Torque ∝ current



Applications of DC motor

1. Lathe machines
2. Grinders
3. Drilling machine
4. Compressors

Other applications

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Electrical actuators: Servo motors

Servo motor: Definition

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A servomotor is classified as a **rotary actuator**. It enables precise control of angular position, velocity & acceleration.

Servo motor for hobby kits

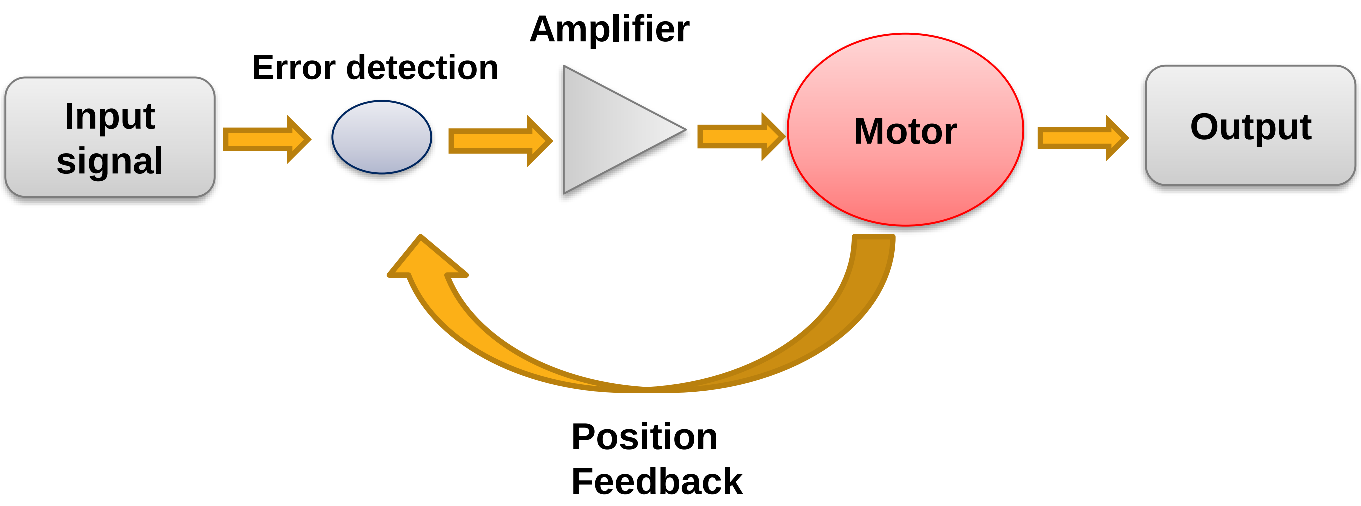
Steering for robot vehicle

By John Nagle, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=10268729

Servo motor : Industrial application

Block diagram

Servomotor comprises of a suitable motor which is coupled to a sensor to get position feedback.



Types of servo motor

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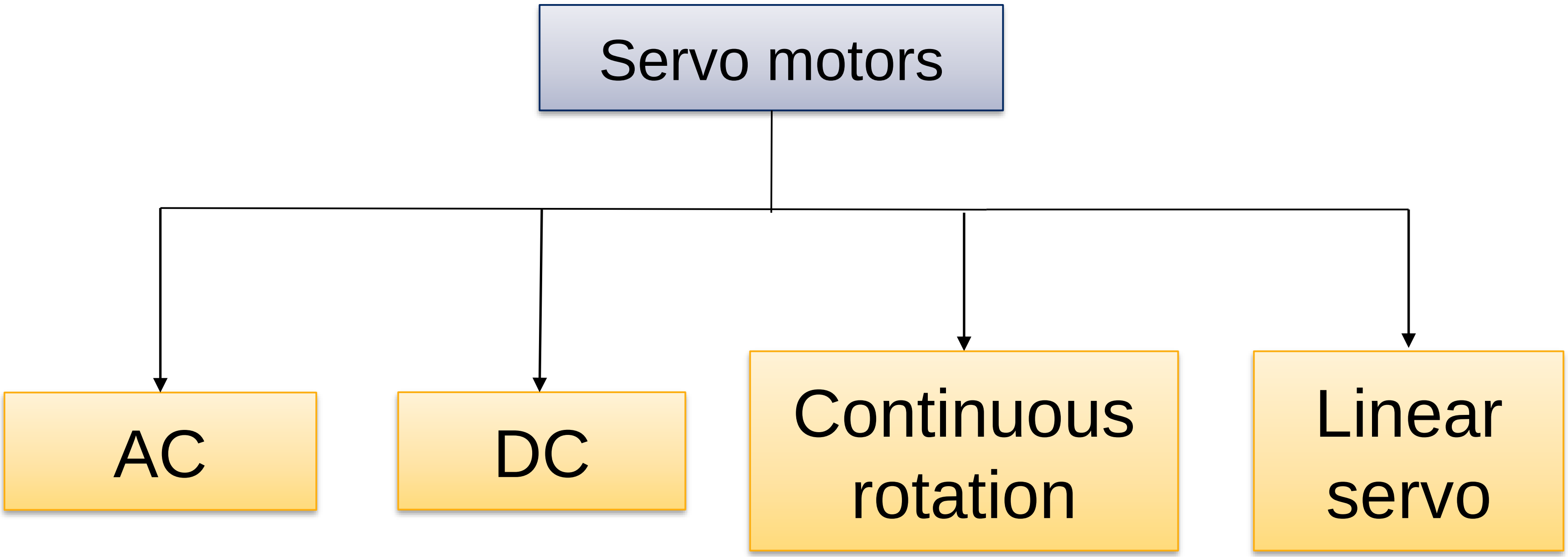

Servo feedback: how does it work

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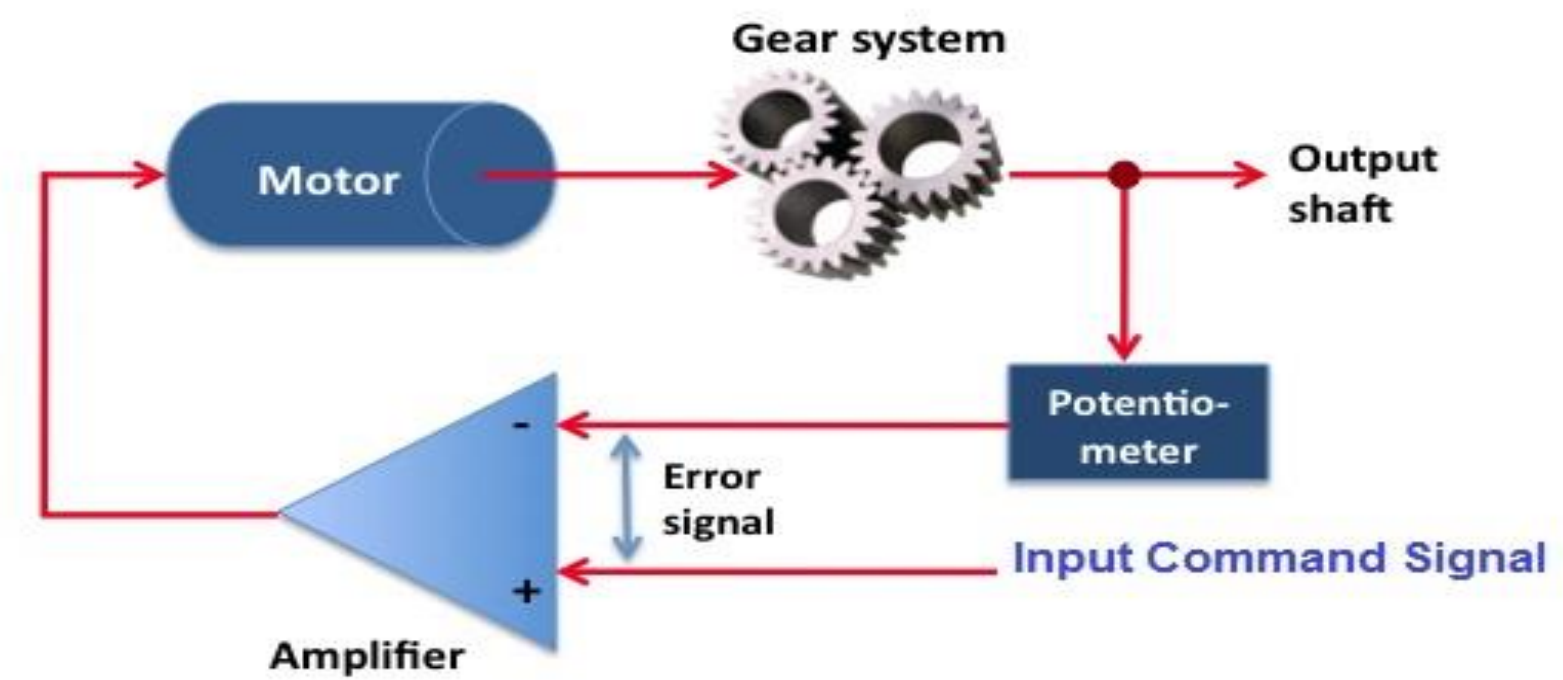
A servomotor has a closed-loop servo-mechanism that uses **position feedback to control its motion** and final position.

The **input command signal** (either analogue or digital) indicates the position commanded for the output shaft.



Servo rating

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- Servo motors are typically rated in **kg/cm** (kilogram per centimeter).

- kg/cm rating tells us **how much weight it is capable of lifting at a particular distance**. For example:

6kg/cm Servo motor: capable of lifting a load of 6kg suspended at a distance of 1cm from the motor shaft. As the distance increases the weight carrying capacity decreases.

- Typical hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm.

Servo motor mechanism

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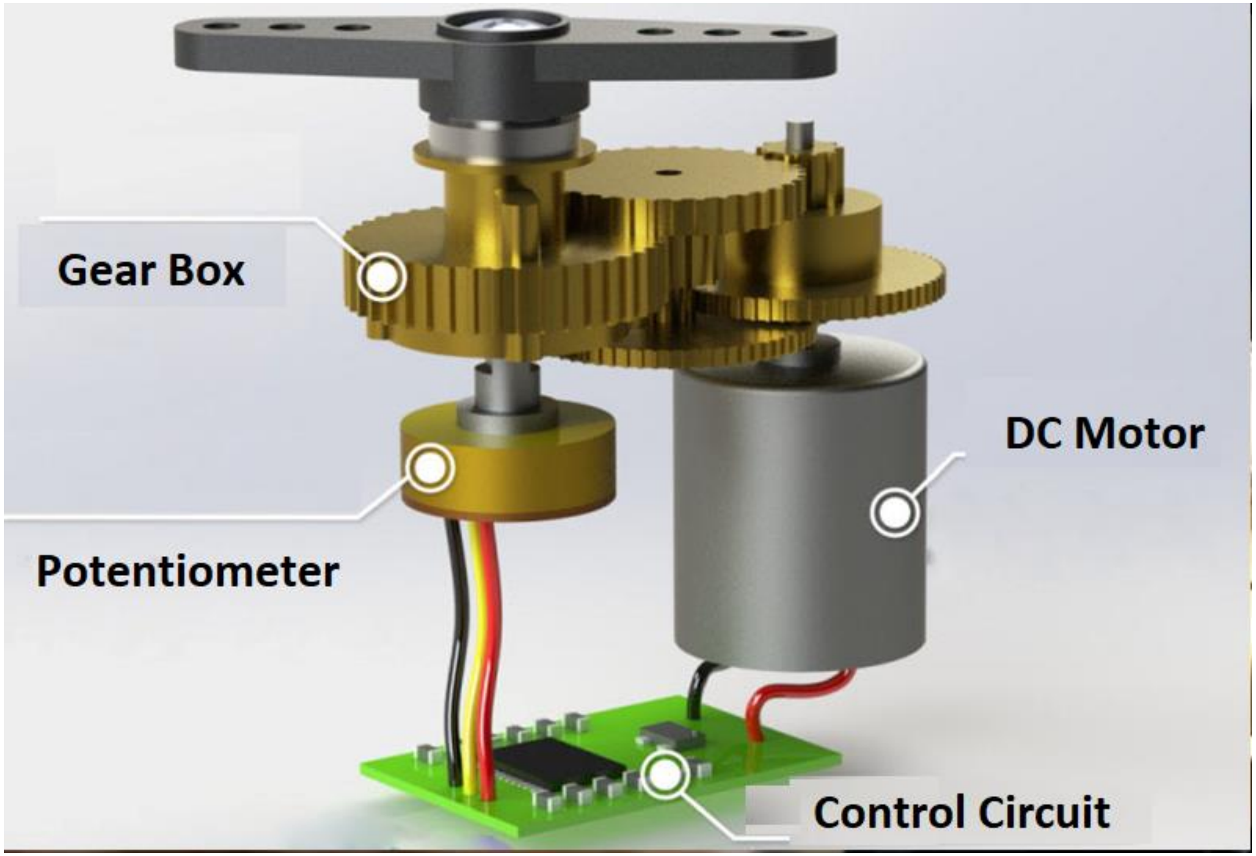
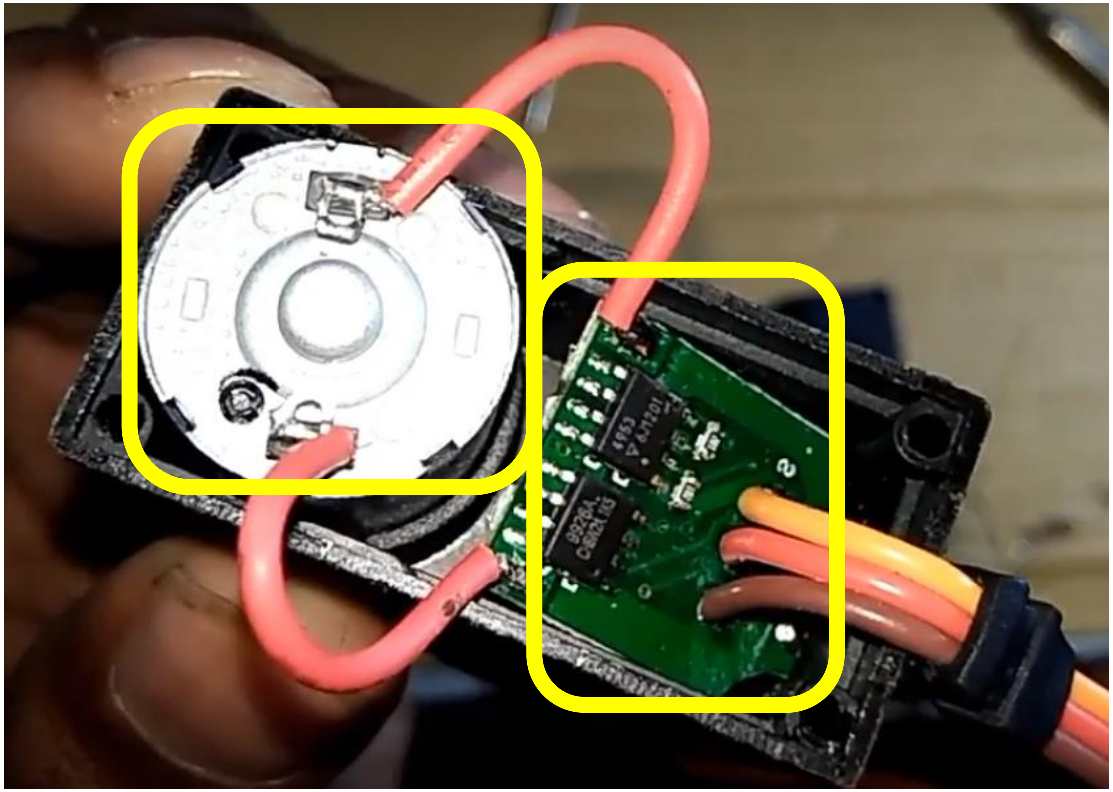
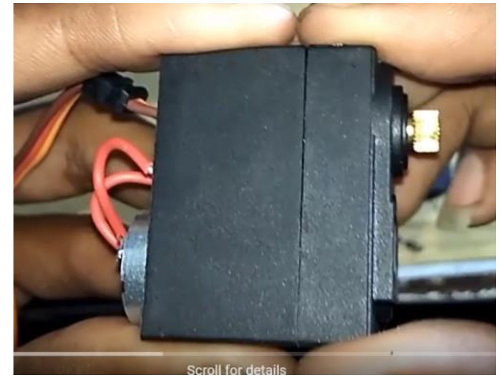
A servo comprises a controlling circuit, a motor, gear assembly and a potentiometer







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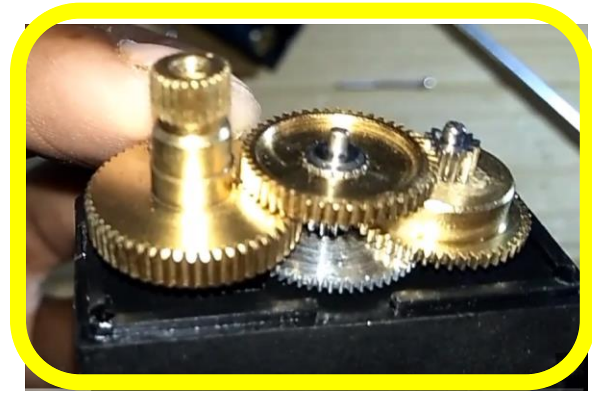

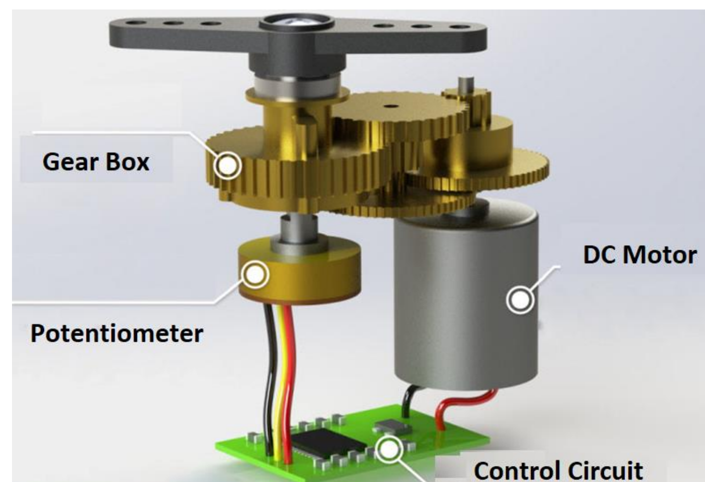

Working Principle

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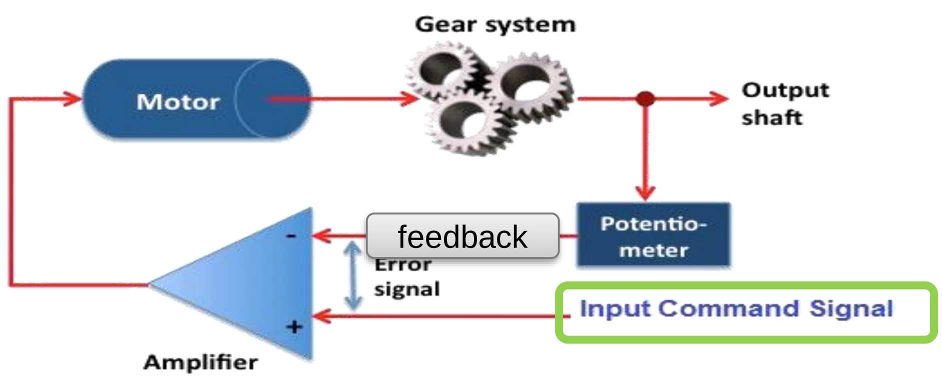
DC motor: this is the main component which does the task of rotating based on the input signal.

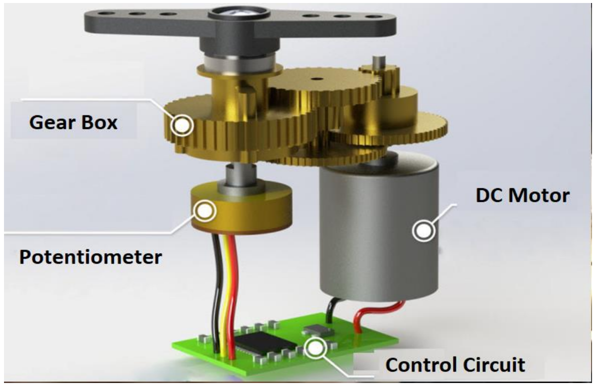
Gear assembly : It is used to reduce RPM (rotations per minute) and increase torque.

Assume that at initial position of motor shaft, the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. In that case error signal = input signal. The motor moves and so the gear system.

Potentiometer: As the gears move, the potentiometer position changes and the voltage changes which is given as feedback to the control circuit.

Control circuit: This circuit compares the feedback and the input signal and based on that generates an error signal so that the servo can get to the desired state (rotation).





More precise control

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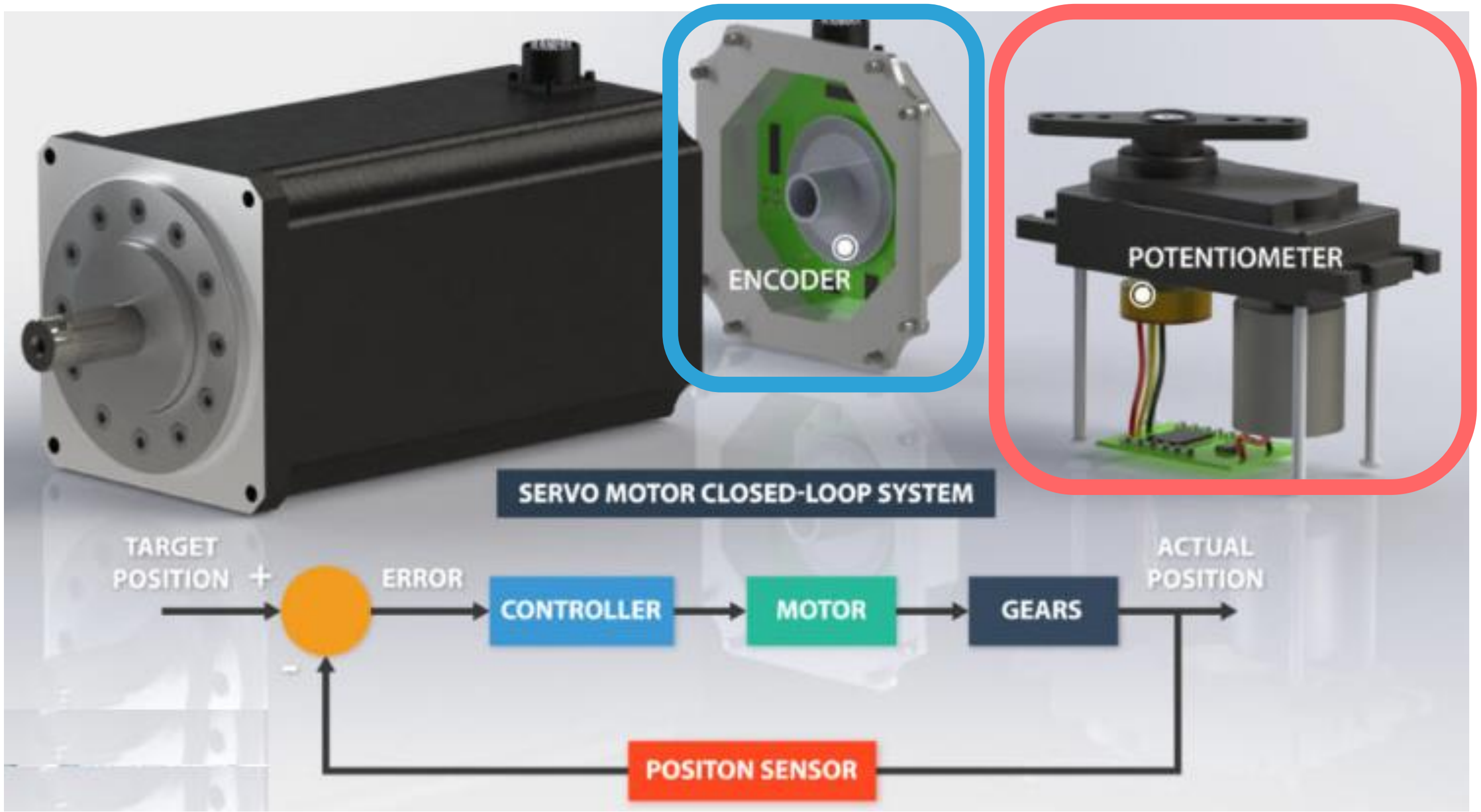
More accurate position control using encoders which precisely determine the angular motion




Packing Machines
Cutting Machines
Punching Machines
Robots
Electronic Manufacturing
Textile Machinery
Printing Machines
CNC Machines
High Precision
Highly Cost-effective
High Speed
Compact Size
Quick Response
EL5 Series
Servo Systems

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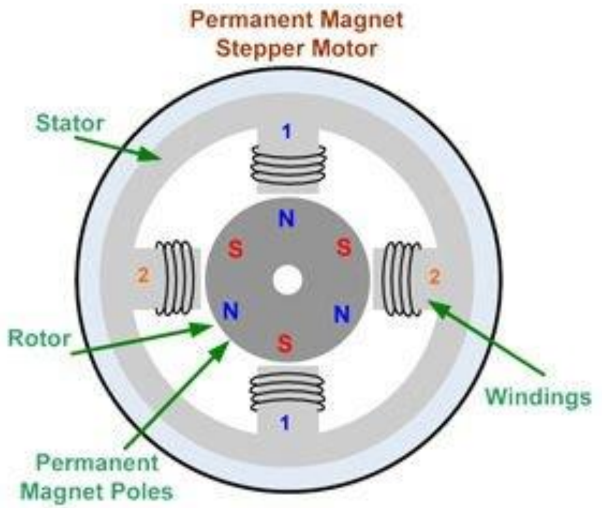
Electrical Actuators: Stepper – Motor

EEE F411: Internet of Things (Dr. Vinay Chamola, BITS-Pilani)

Stepper Motor

➢ A stepper Motor is essentially a synchronous Motor. It does not have any brushes, it does not rotate continuously, but in the form of **discrete steps** or pulses. Hence it is a called stepper motor

➢ The principle used in stepper motor is Electro-Magnetism. It comprises of a **permanent magnet rotor** and a **stator made of electromagnets.**



Stepper Motor

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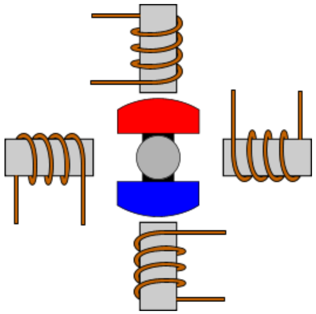
- Since they can move in discrete steps, they are used in **robotics and industrial automation.** Stepper motors are used widely in **IC Fabrication plants, x-y plotters and CNC** (Computer Numeric Control) machines.

- **When no input current is given to the motor, it holds its position firmly** (it does not rotate). These motors can rotate without limits in both direction depending on the input polarity. They are easy to use and cheap.

Stepper Motor

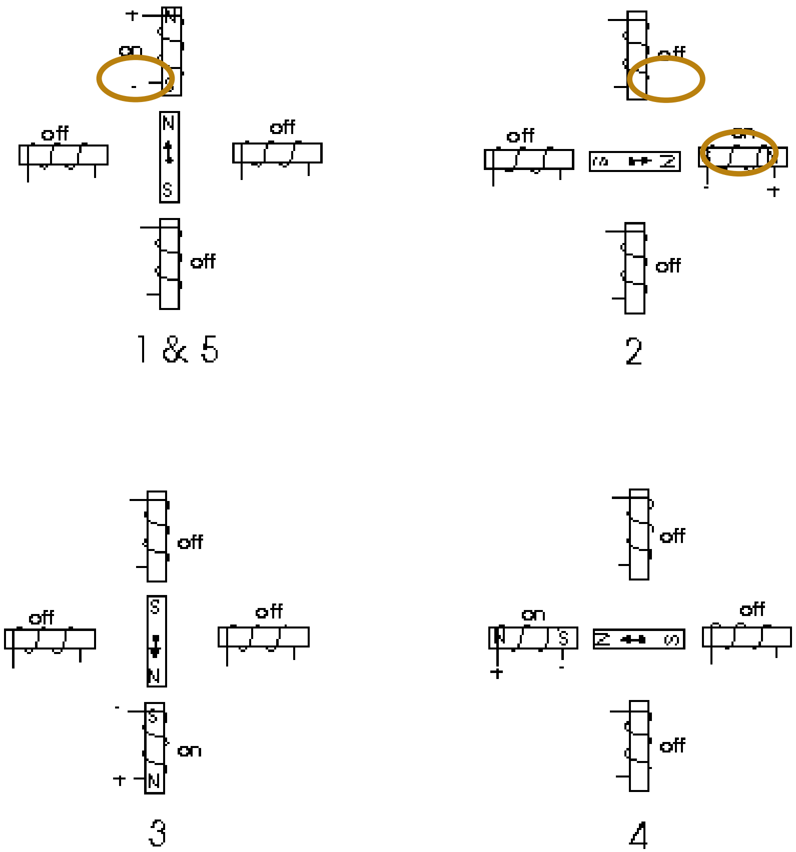
BITS Pilani

- The stator has four coils fixed at 90º angle with each other. The type of stepper motor is determined by the way in which the coils are arranged and connected.
- These coils are not connected to each other.
- This particular motor has a rotation step of 90 degrees in a cyclic order, the coils are activated one by one.
- The order in which the coils are activated is determines the direction in which the shaft rotates.

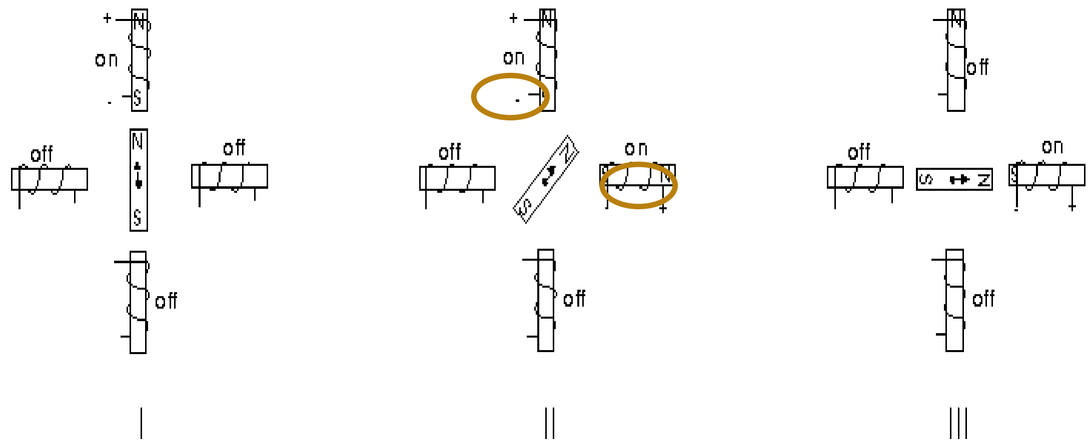


Stepper Motor

1. Brushless, synchronous electric motor
2. Can divide a full rotation into an expansive number of steps



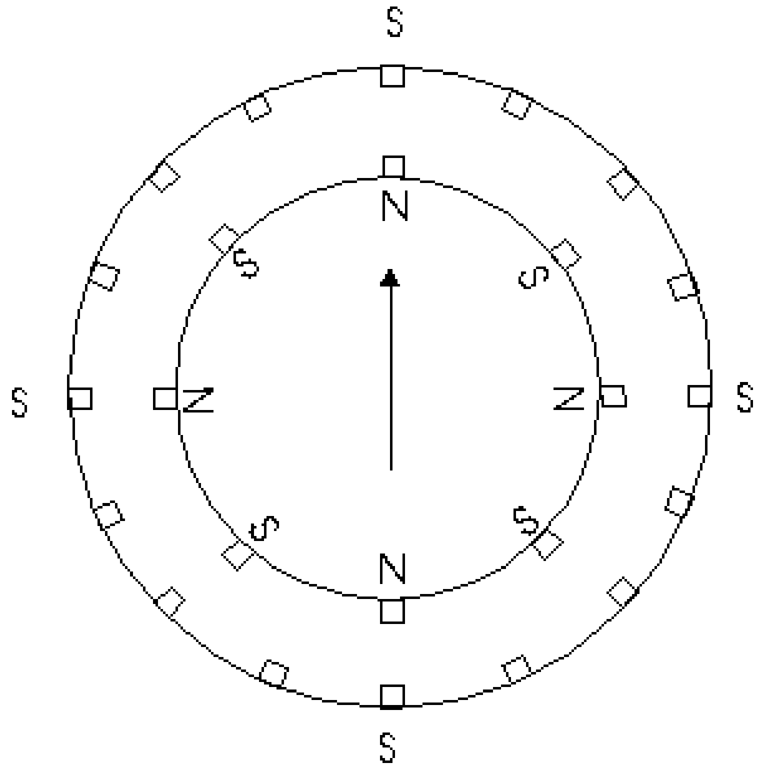
4 pole stepper motor with rotor magnet in the middle



Increased resolution mechanism in 4 pole stepper motor

Image courtesy: https://www.imagesco.com/articles/picstepper/02.html

Many pole stepper motor



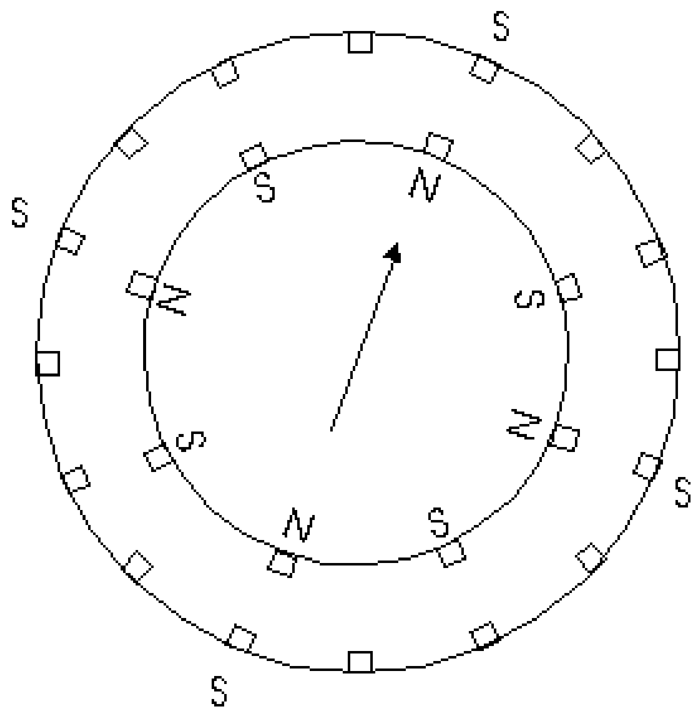


Image courtesy: https://www.imagesco.com/articles/picstepper/02.html

Stepper Motor

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➢ It can be incrementally driven one step at a time, either forward or backward.

➢ Stepper motor is characterized by:
- **Number of steps per revolution** (e.g. 100 steps per revolution = 3.6° per step)
- **Maximum No of steps/second** ("stepping rate" = max speed)

Driving a stepper motor

- *full-step mode:* 4 step switching sequence is required
- *half-step mode (higher resolution):* 8 step switching sequence is required
- The final motion appears very smooth if the stepping sequence is very fast.

Stepper motor applications

Electrical actuators: Relays

What is a Relay?

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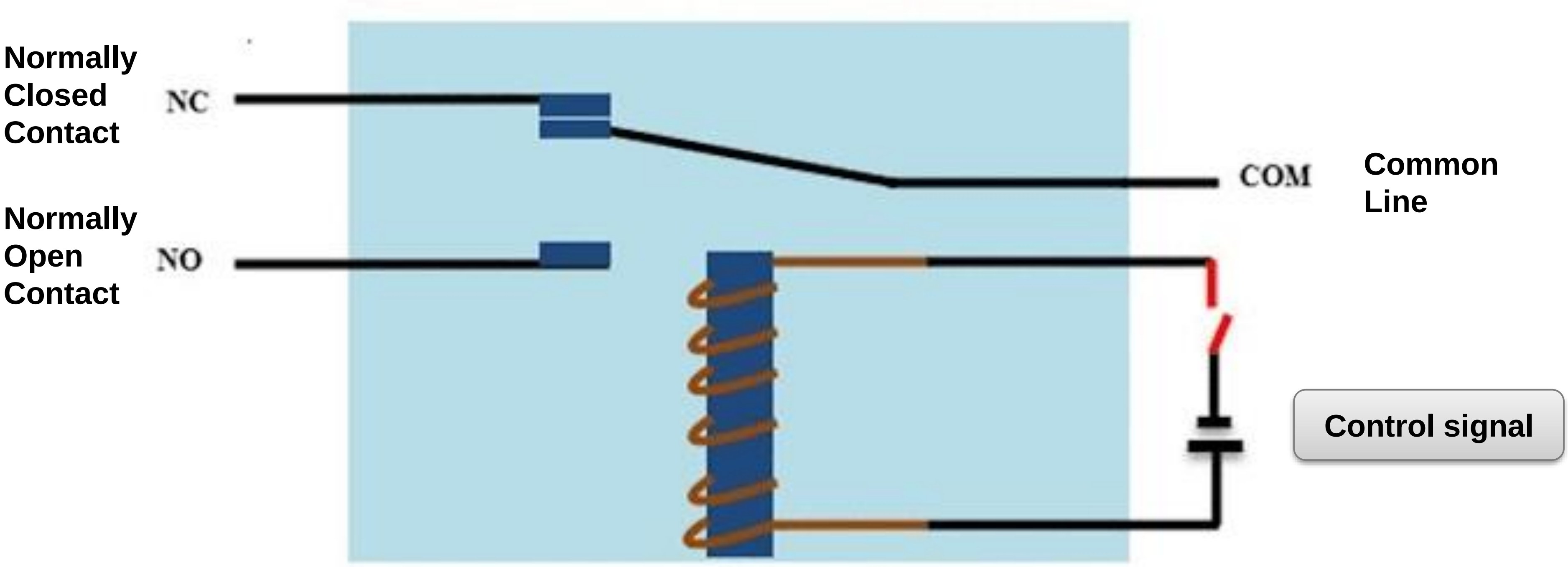
A relay is just a switch which is operated electrically. It usually uses an **electromagnet** to perform the switching operation.

When the **electromagnet is de-energised**, current flows through the common line and through the NC contact. When the **electromagnet is energised**, the magnetic contact moves from NC to NO contact and current flows from the common line though the NO contact.



Why do we need Relays?

Relays are used where it is necessary to **control a circuit by a separate low-power signal**, or where several circuits must be controlled by one signal.

Example Application: You want the AC in a house to switch on when the temperature increases beyond 30 degrees Celsius.

How to go about it:

- Use a **temperature sensor** and connect it to a microcontroller which is configured such that it outputs current only when the temperature increases beyond 30 degrees.

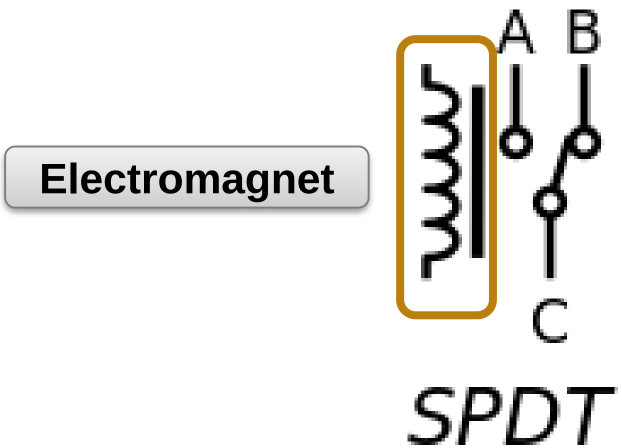
- **Connect the microcontroller to a relay** which can be fitted inside the AC.

- Now when the temperature increases beyond 30 degrees, the microcontroller outputs a small current which causes the relay to switch. While the AC works on the grid supply (high voltage, high current), the **relay is able to switch it on with a small current from the microcontroller**.

Nomenclature in Relays

In any switch, there is a **pole** and a **throw**. The pole is the part that switches the circuit and the throw is the part that makes contact with the pole.

For example in the SPDT (single pole double throw) relay shown below: **C is the pole** whereas **A and B are throws**. Corresponding to each pole there are two throws, hence this is a single pole double throw relay.



Types of Relays

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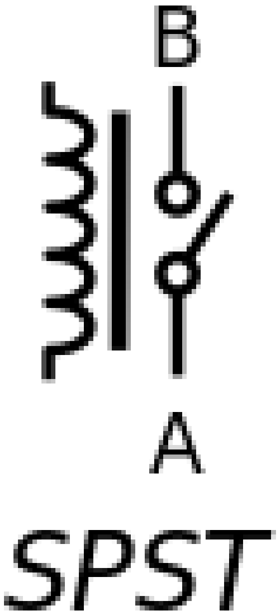
SPST relay: Here, A is the pole and B is the throw, and for every pole there is only one throw. Thus this is a **Single Pole Single Throw Relay**. In this case, when the relay is de-energised, the relay is open and there is no contact and so this is a **NO (Normally Open) SPST Relay**.

We can also have a SPST relay where when the relay is de-energised, the switch is closed (this can be by simply using a spring mechanism). Such a relay is called a **NC (Normally Closed) SPST Relay**.



Types of Relays

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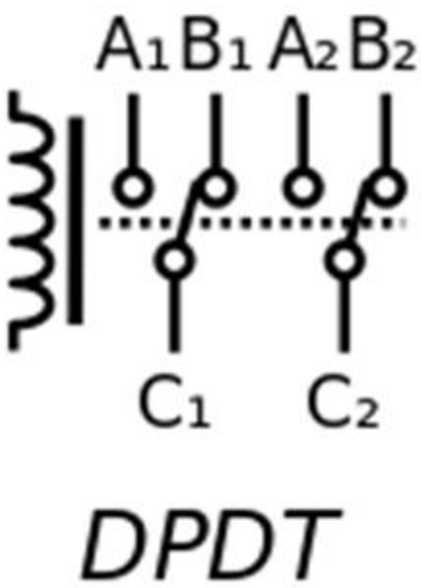
Next we consider relays with two poles.

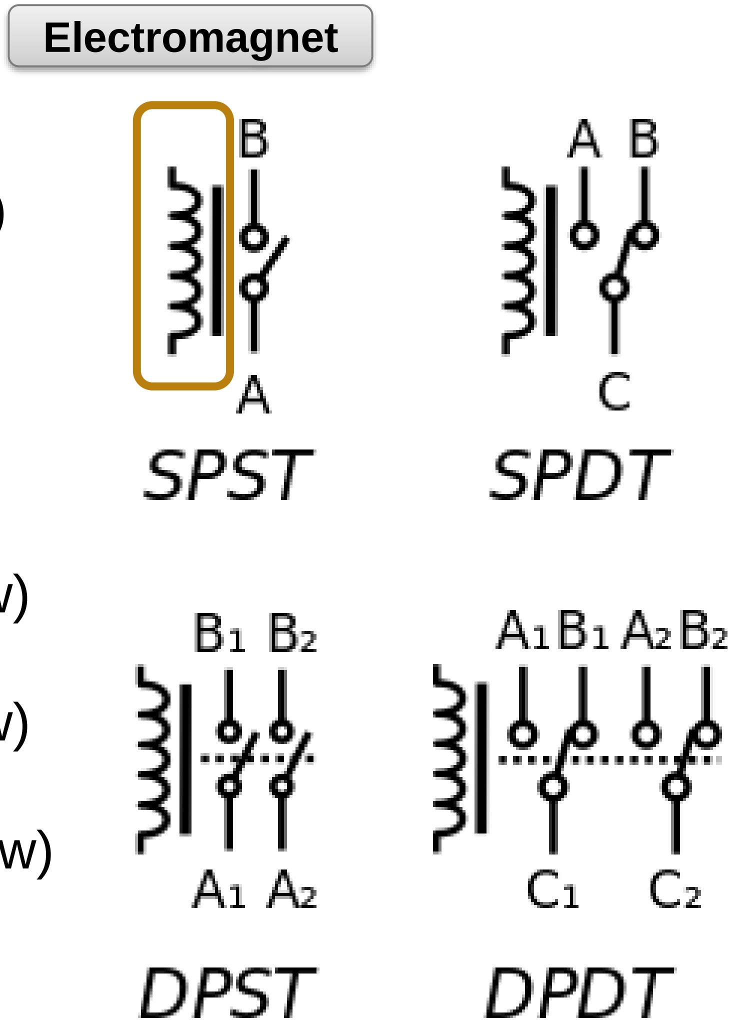
DPST relay: for each pole there is only one throw, i.e. A1 can connect to B1 and A2 can connect to B2.

DPDT relay: there are two throws for each of the two poles, i.e. C1 can connect to A1 and B1 and C2 can connect to A2 and B2.



Summary: Types of Relays

- SPST Relay (Single Pole Single Throw)
  - NO (Normally Open)
  - NC (Normally Closed)
- SPDT Relay (Single Pole Double Throw)
- DPST Relay (Double Pole Single Throw)
- DPDT Relay (Double Pole Double Throw)



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Electrical actuators: Solenoids

What is a Solenoid?

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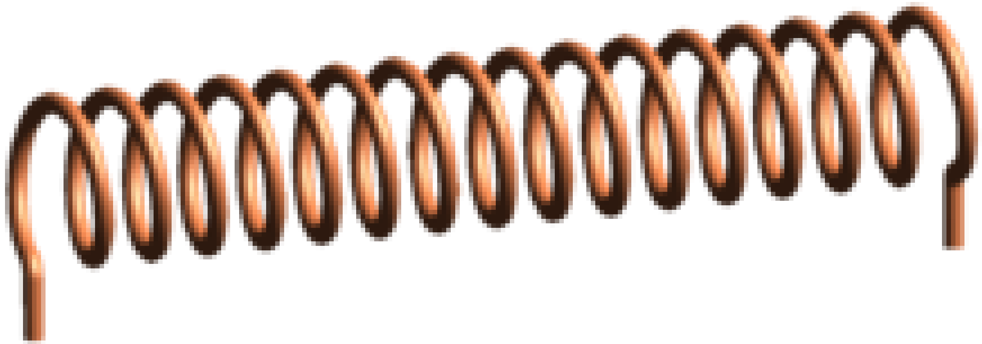
A solenoid is simply a coil of wire which is tightly wound into a helix.



Understanding what happens when we pass current through a solenoid

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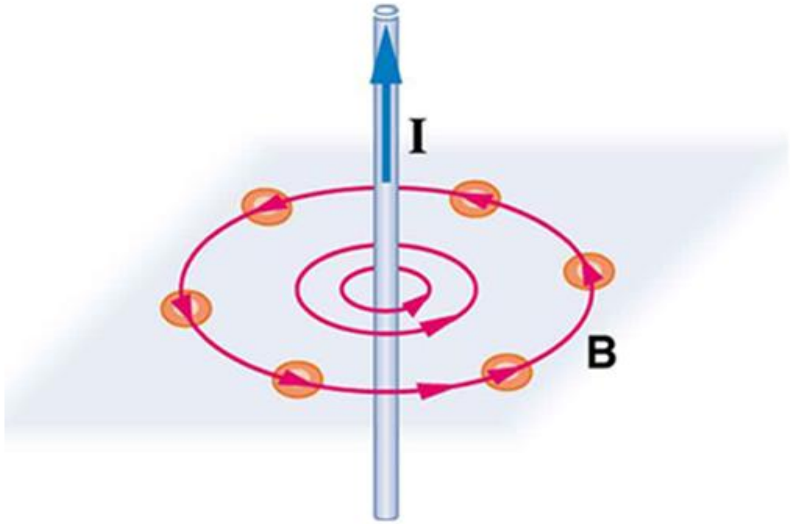
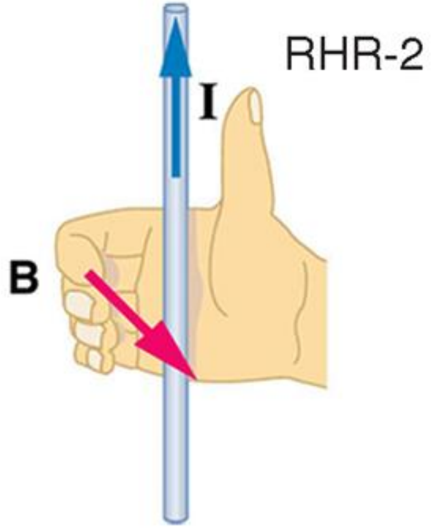
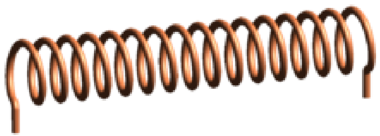
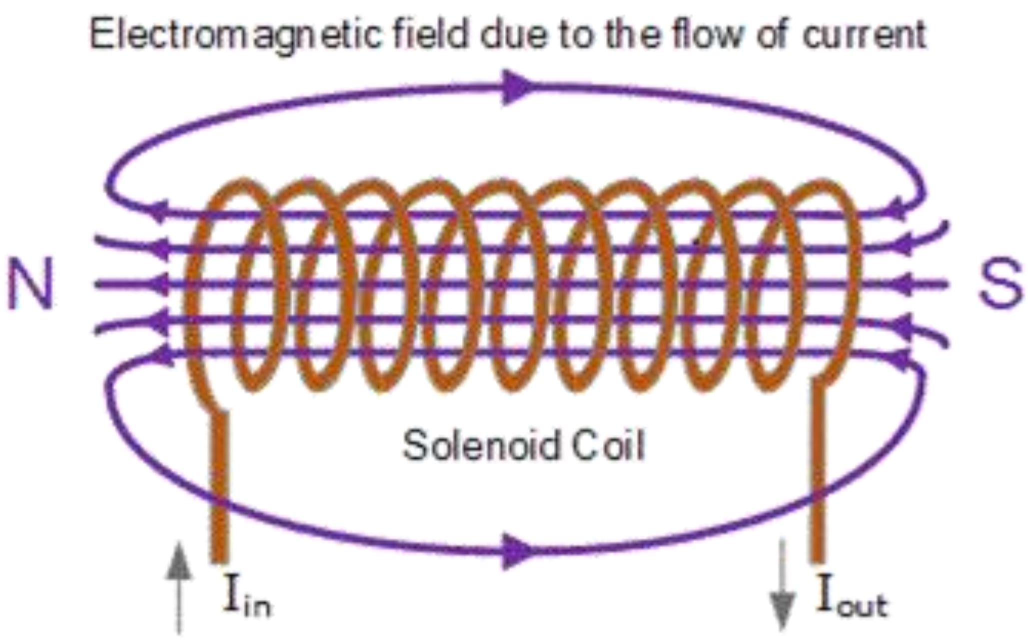
- If electric current is passed through a conducting wire, it generates a magnetic field (Ampere’s Law).
- Direction of magnetic field is decided by the direction of the current along the length of the wire.
- Using this principle, when current is passed through a tightly wound coil of wire, it gives rise to a magnetic field that is similar to that of a bar magnet !

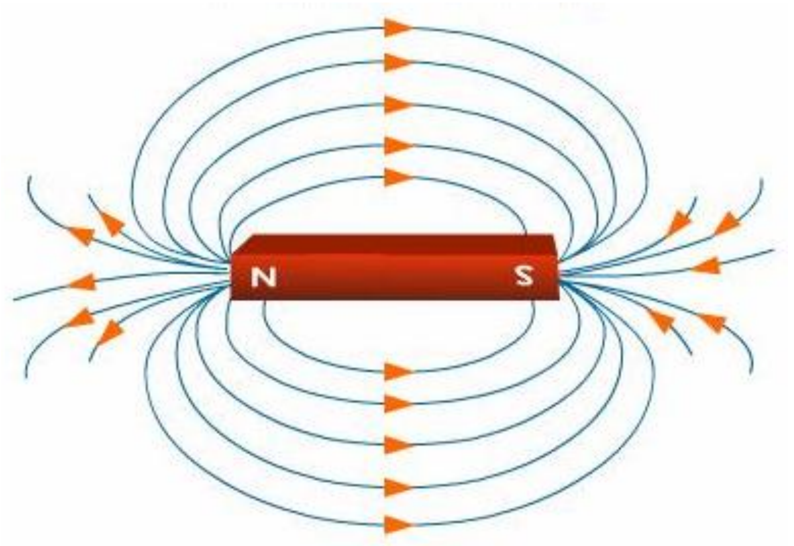






That's how solenoid becomes a magnet





Solenoid

Bar magnet

What is a Solenoid?

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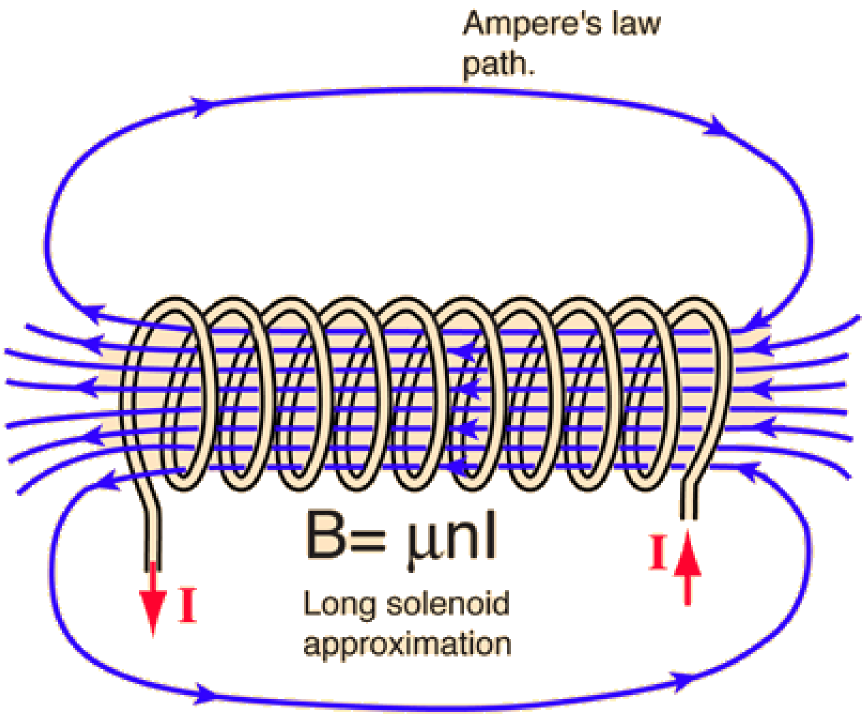
Thus we have seen, that a tightly wound coil of wire generates a magnetic field (when current is passed through it) that makes the coil act like a bar magnet.

It is important to note, that the magnetic field lines are present inside the solenoid as well, whereas, while there exists magnetic field lines inside the magnet, there is no way to make use of the same.



The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

The solenoid core

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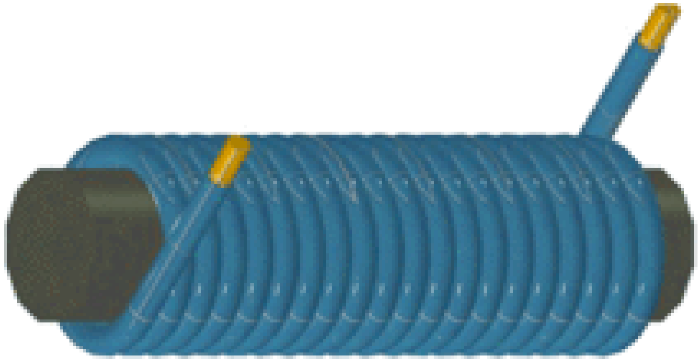
At times solenoid consists of the wire wrapped around a material with high magnetic permeability (such as iron, electric steel, perm alloy etc.). Magnetic permeability (μ) is the ability of a magnetic material to support magnetic field development.



The magnitude of the magnetic field due to a solenoid depends on the magnetic permeability of the core.

$$B = \mu n I$$

B is the magnitude of the magnetic field in teslas, μ is the magnetic permeability of the core, n is the number of turns of the coil and I is the current in amperes flowing through the coil.

Factors affecting strength of solenoid

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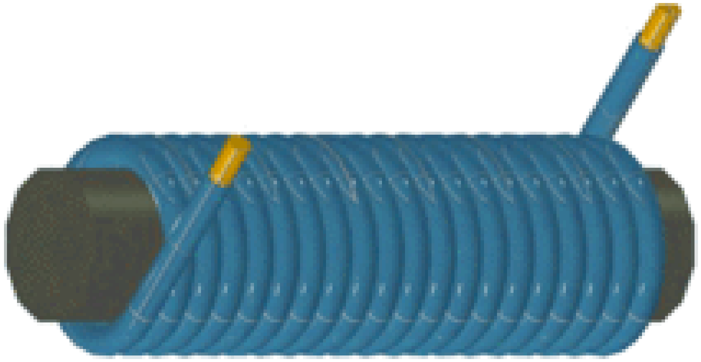
Magnitude of the magnetic field due to a solenoid is given as

$$B = \mu n I$$

So its magnitude depends on:

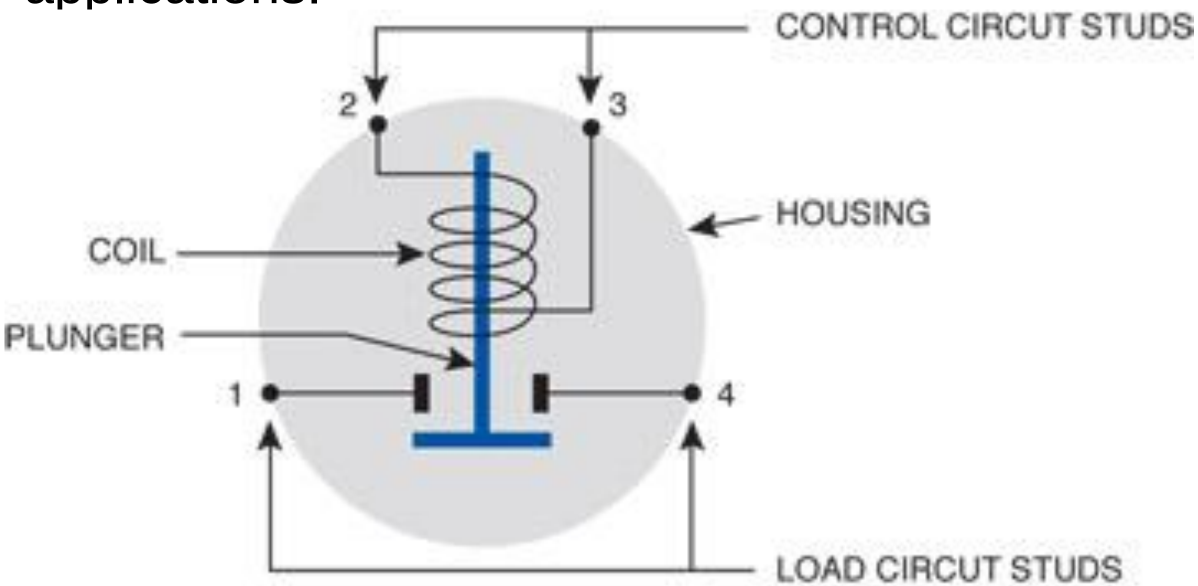
1. μ (magnetic permeability of the core)
2. n (number of turns of the coil)
3. I (current in amperes flowing through the coil)



Solenoid Valve (or simply Solenoid)

A solenoid valve is an electromechanical device in which the solenoid uses an electric current to generate a magnetic field and thereby operate a mechanism which regulates the opening of fluid flow in a valve.

A solenoid valve is often simply referred as a solenoid for real life applications.



Simplified diagram of a solenoid valve

Using solenoid valve to control air flow

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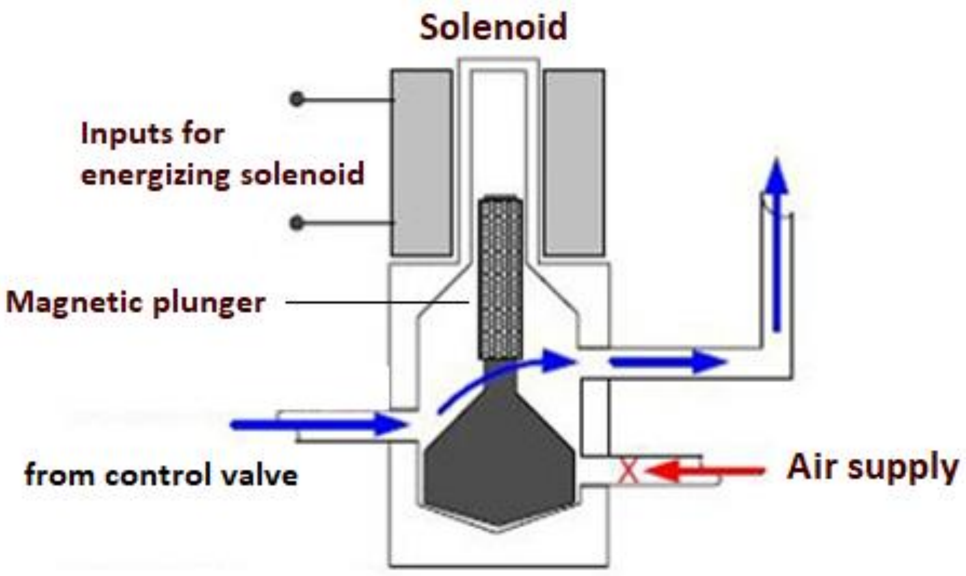
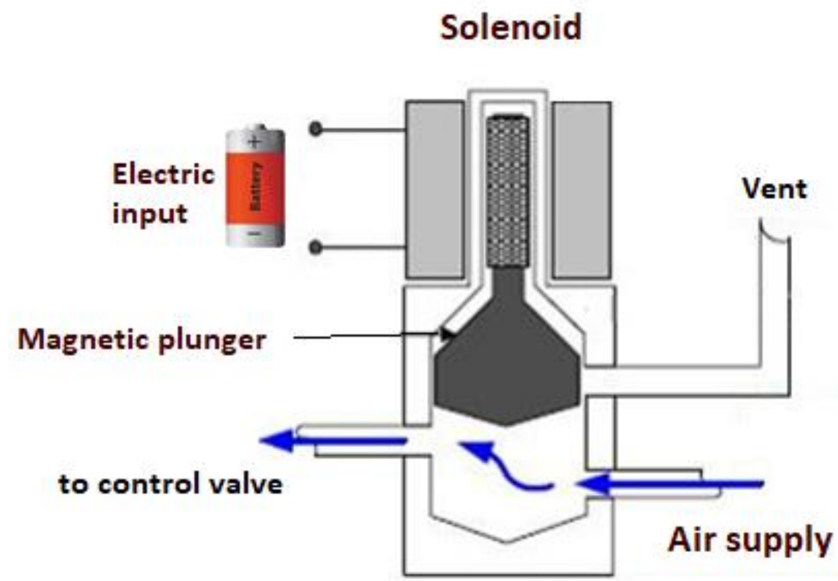
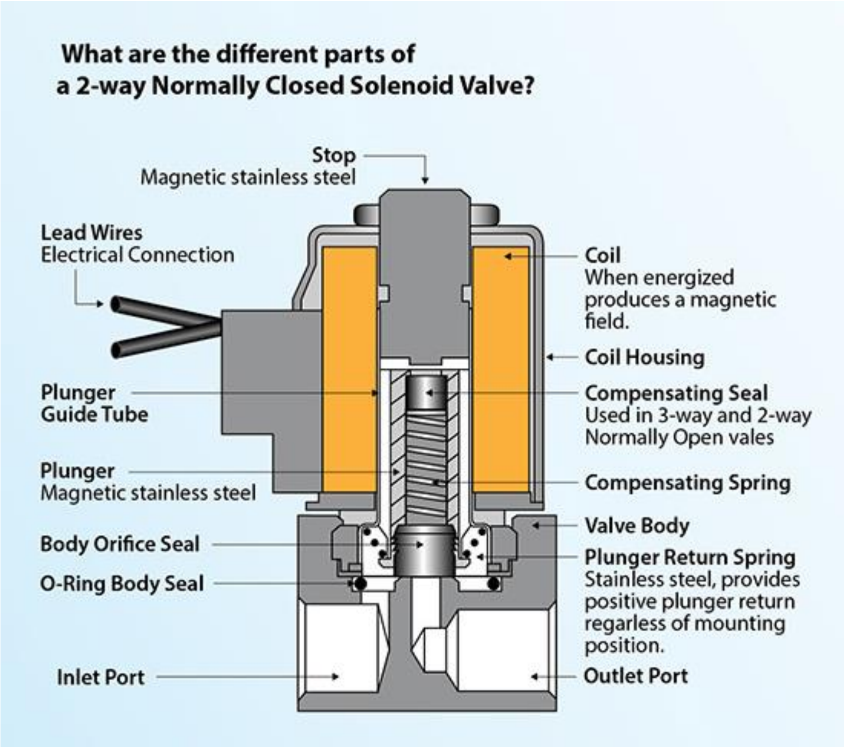
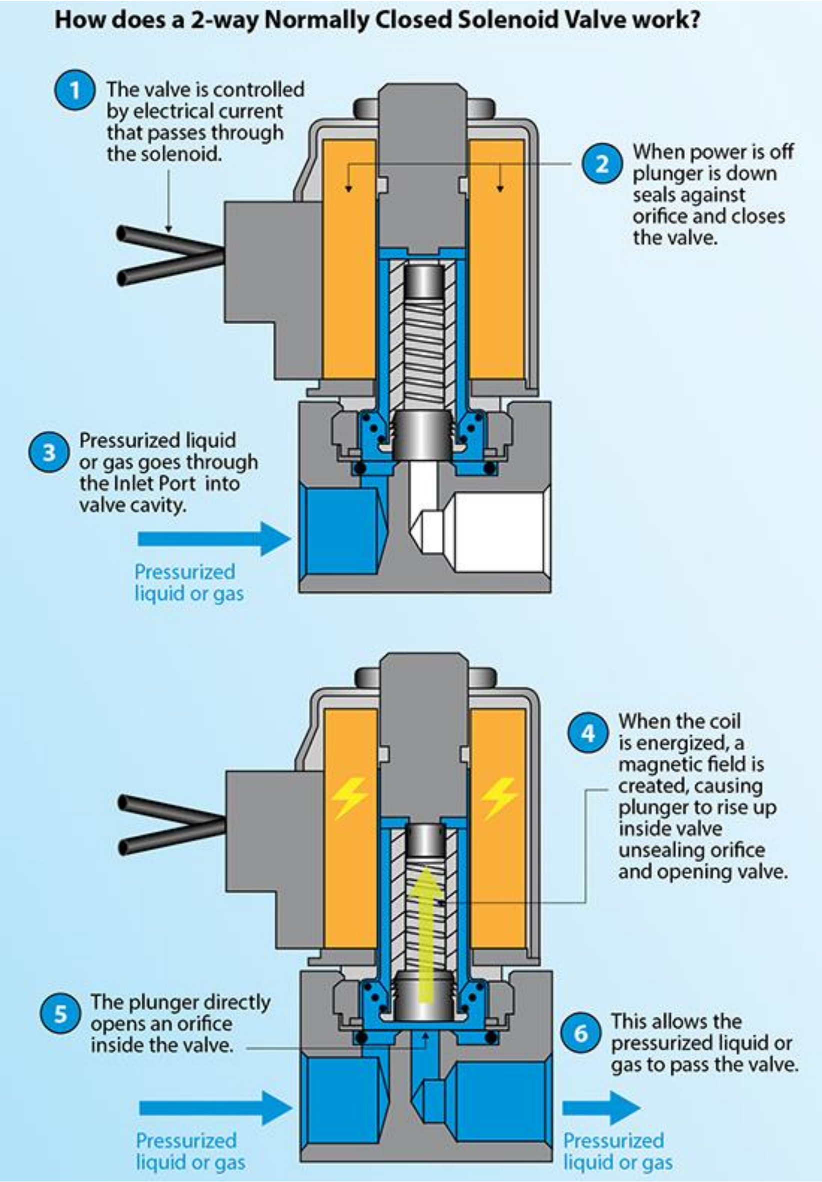
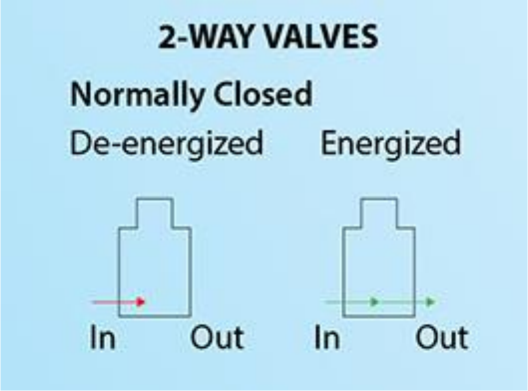




Solenoid Valve







Application of Solenoids

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- Control of water flow in a garden irrigation system