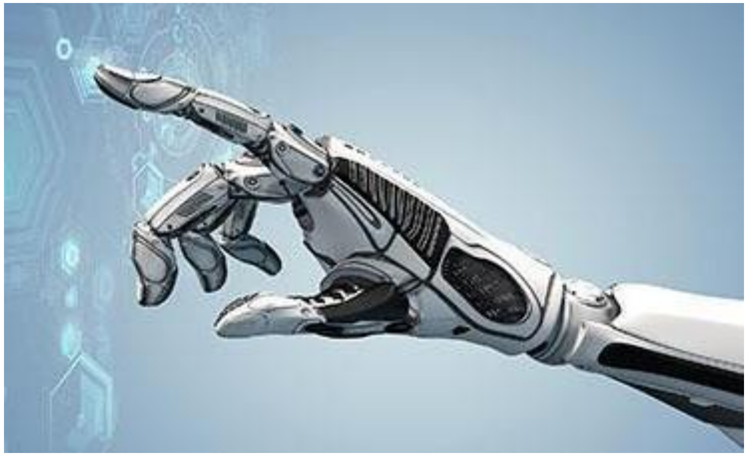


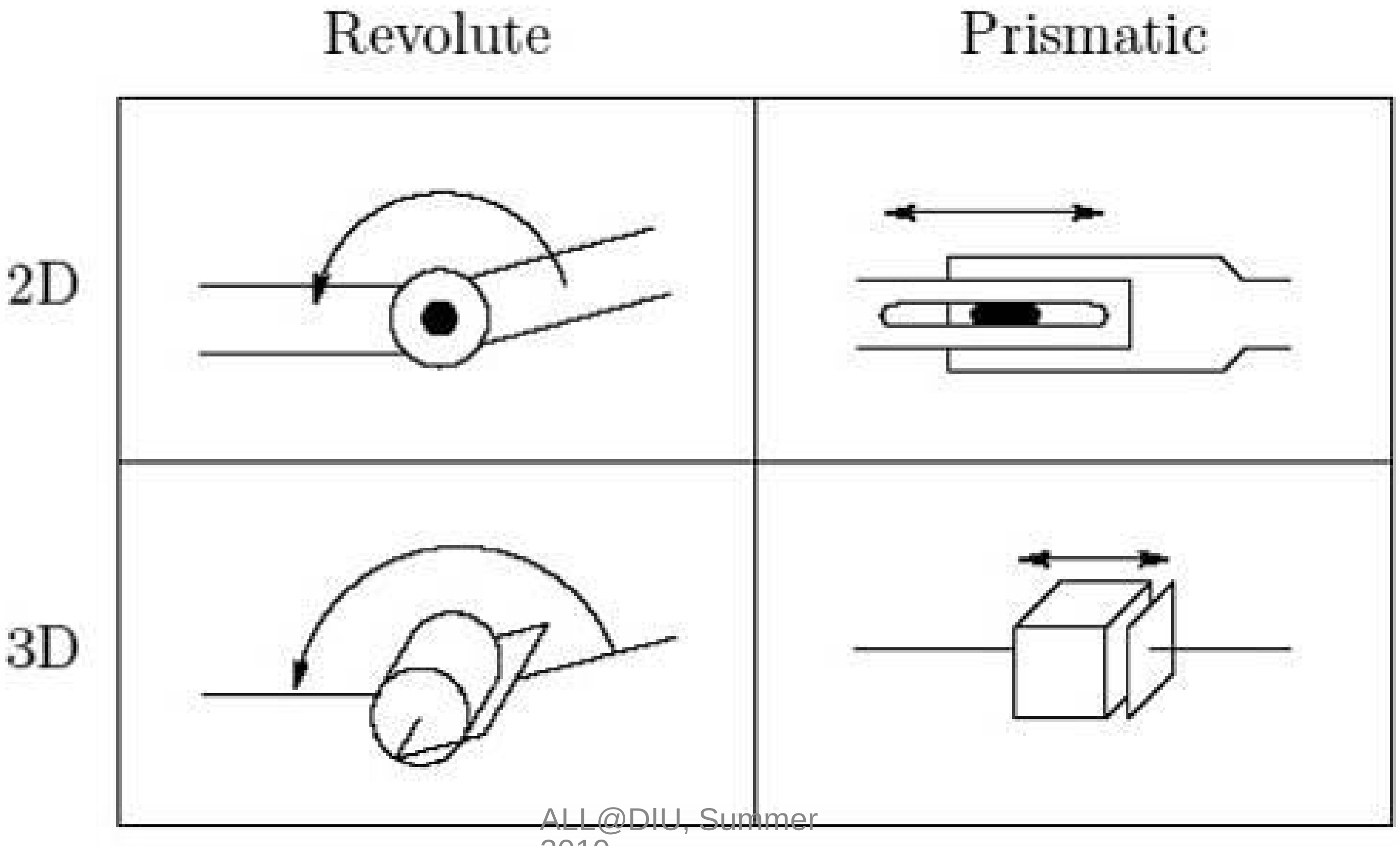
CSE444: Introduction to Robotics

Lesson 5a: Working with Actuators

Robot Joints

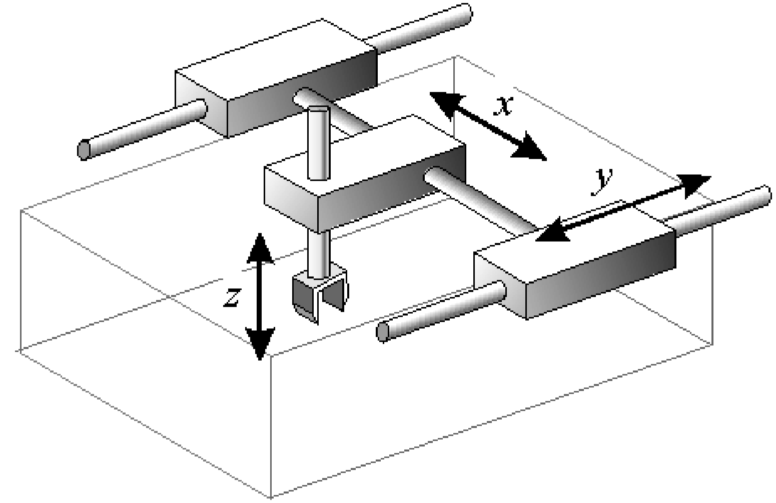
Robot Joints

•Robot joints can be either **rotary** (also known as revolute) or **prismatic** (telescoping)

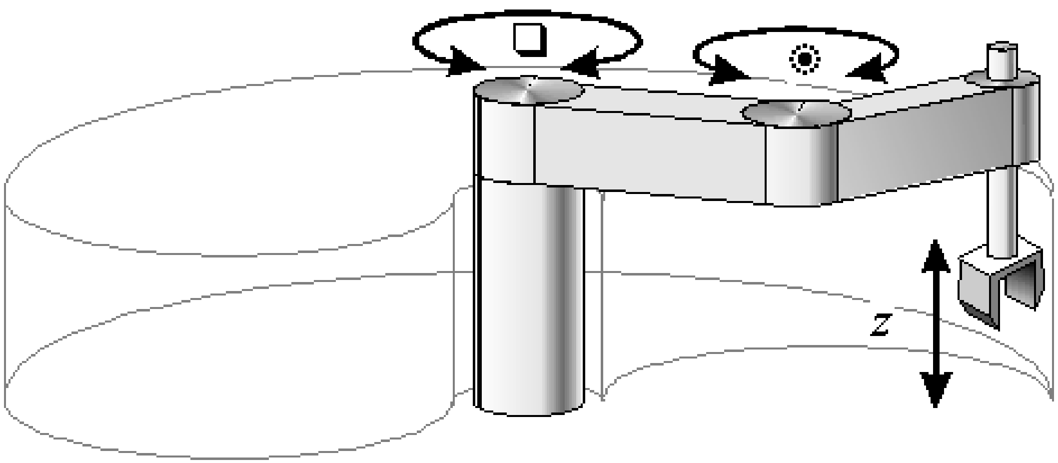


Robot Joints (cont...)

- Prismatic
  Cartesian
  robot



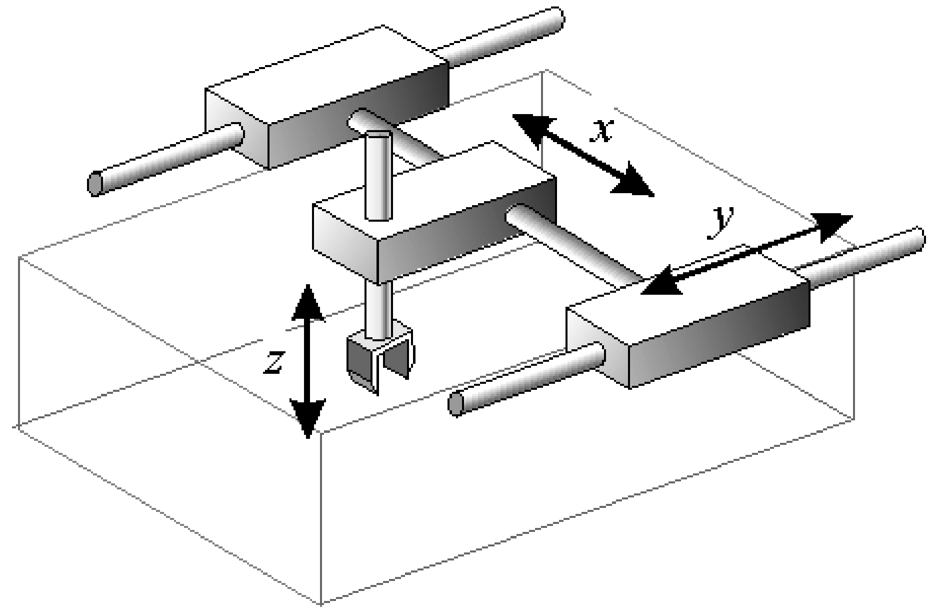
- Actuators are used in order to produce mechanical movement in robots.

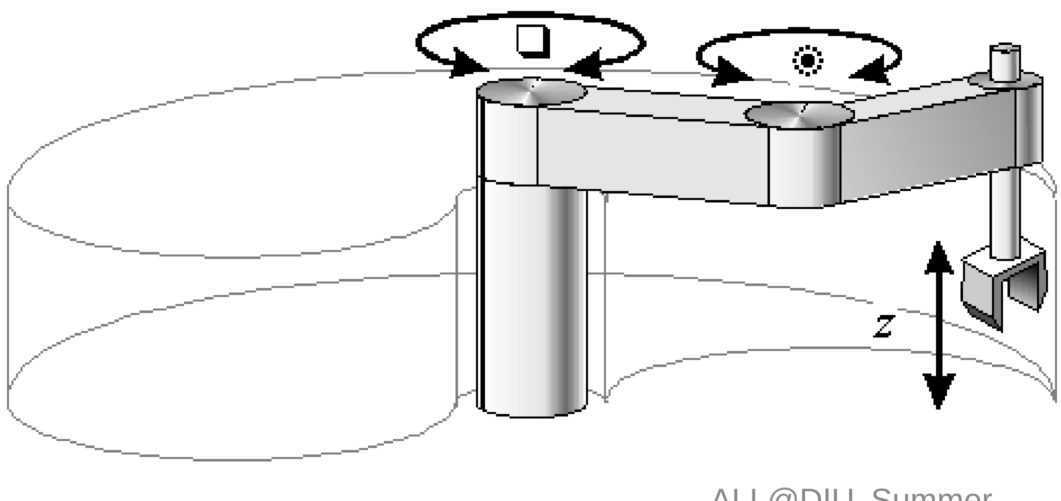


Rotary
SCARA
robot

Robot Joints (cont…)

Prismatic
Cartesian
robot





Rotary
SCARA
robot

Robot Joints (cont...)

Types of Actuators

Actuators are the devices that actually move the **robot** joints. And there are a number of different types of **actuators** in common use for **robotics**. A good definition of an **actuator** is it is a device that causes motion and it can cause linear motion or rotary motion.

Some of the most common actuators are:

1. **Electric motors**, the most common actuators in mobile robots, used both to provide location by powering wheels or legs, and for manipulation by actuating robot arms

2. **Artificial muscles** of various types, none of which are very good approximations of living muscles

3. **Pneumatic** and **hydraulic** actuators, used in industry for large manipulation tasks but seldom for mobile robots

Actuators

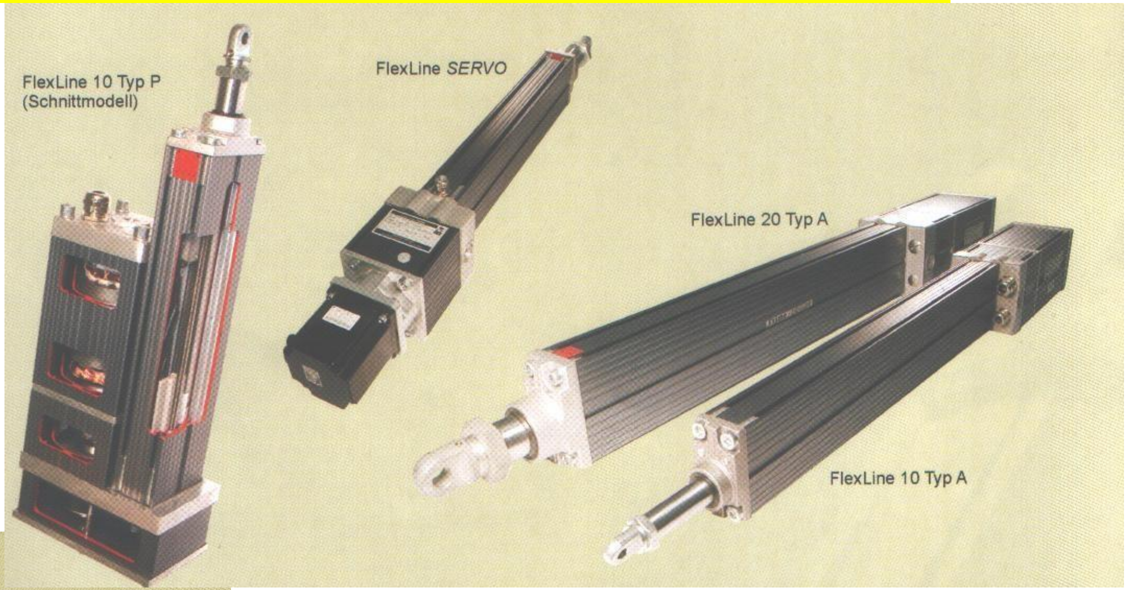
- Motor
- Encoder
- Pulse Width Modulation (PWM)
- Servos
- Other electric actuators

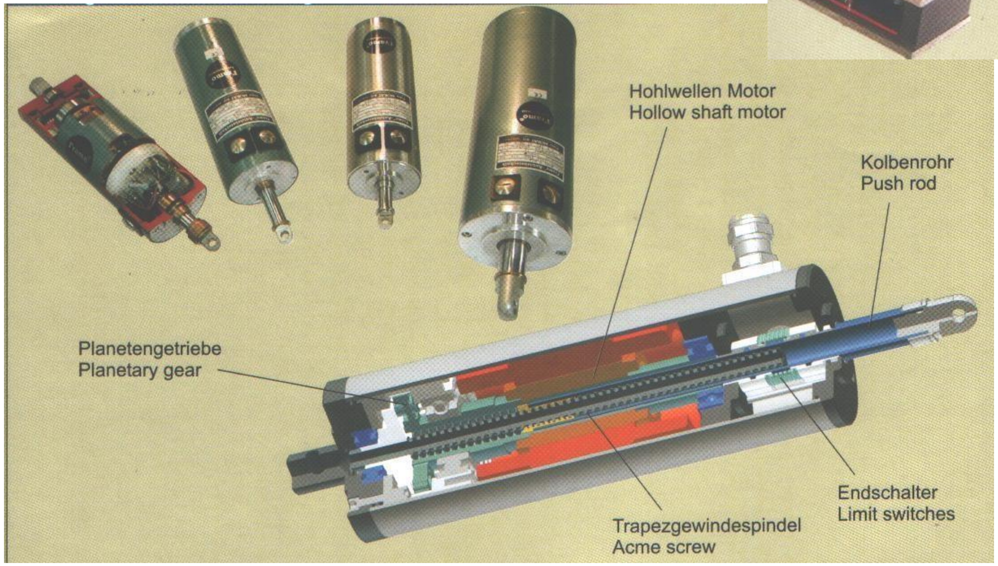
Actuators and motors

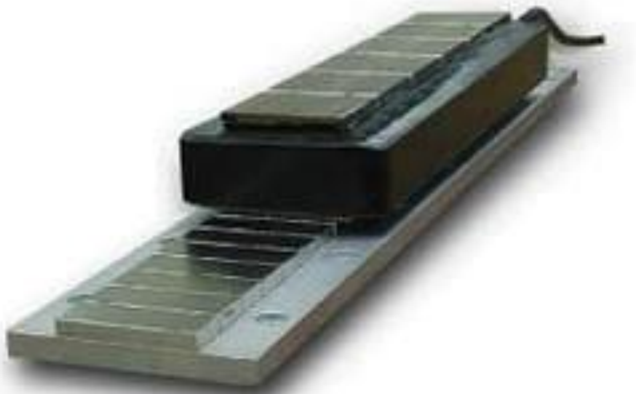
- Most actuators convert electrical energy into mechanical energy through the use of electromagnetic fields and rotating wire coils.

- When a voltage is applied to a motor, it outputs a fixed amount of mechanical power.
  - (usually to a shaft, gear, and/or wheel),
  - spinning at some speed
  - with some amount of torque.

Electric actuators







Electrical Actuator Types

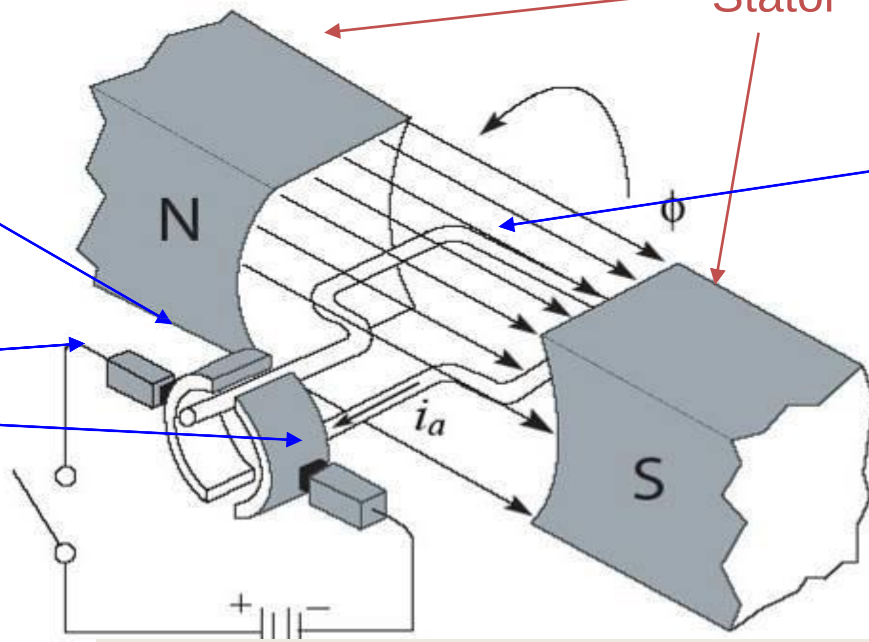
- DC-motors
- brushless DC-motors
- asynchronous motors
- synchronous motors

Not discussed

How Do Electric Motors Work?

Components of An Electric Motor

- The principle components of an electric motor are:
  1. North and south **magnetic poles** to provide a strong magnetic field.
     1. Being made of bulky ferrous material they traditionally form the outer casing of the motor and collectively form the **stator**
  2. An **armature**, which is a cylindrical ferrous core rotating within the stator and carries a large number of windings made from one or more conductors



Brushes in fixed positions and in contact with the rotating commutator contacts. They carry direct current to the coils, resulting in the required motion

A **commutator**, which *rotates with the armature* and consists of copper contacts attached to the end of the windings

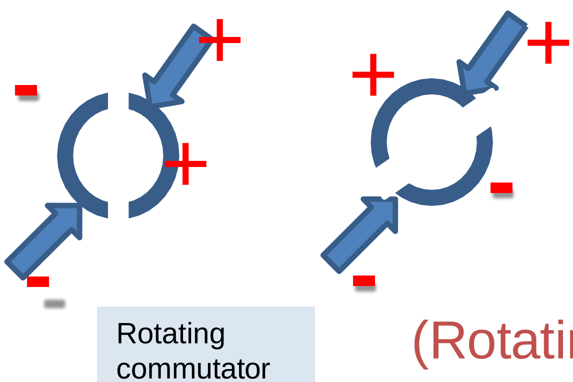
How Do Electric Motors Work?

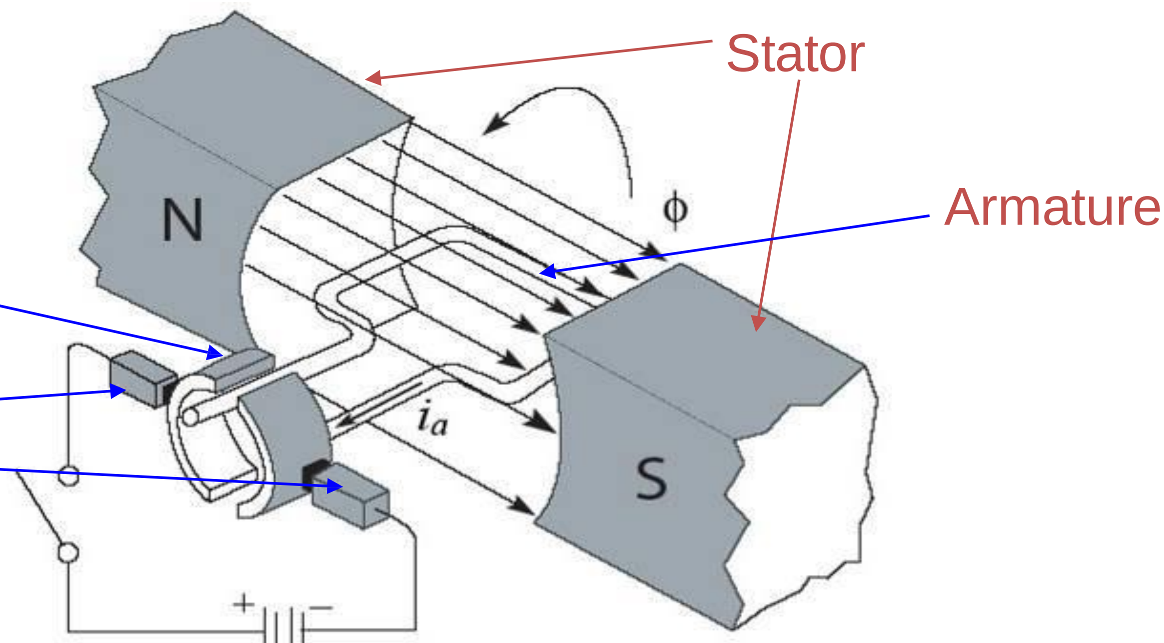
1. The classic DC motor has a rotating armature in the form of an electromagnet

2. **A rotary switch called a commutator** reverses the direction of the electric current twice every cycle, to flow through the armature so that the poles of the electromagnet push and pull against the permanent magnets on the outside of the motor

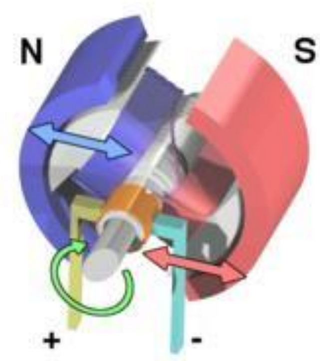
3. As the poles of the armature electromagnet pass the poles of the permanent magnets, the commutator reverses the polarity of the armature electromagnet.

4. During that instant of switching polarity, inertia keeps the motor going in the proper direction



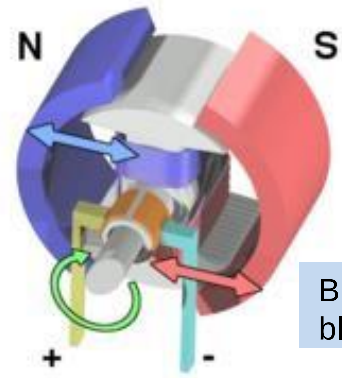


How Does Electric Motors Work?

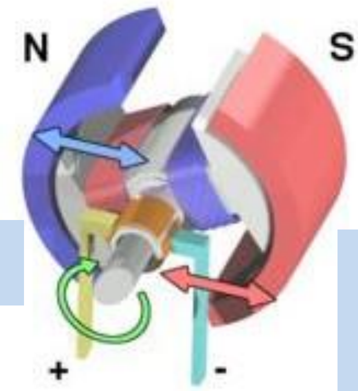


t...)

Blue in armature near blue in stator



Blue between blue and red



Blue near red, because of commutator rotation

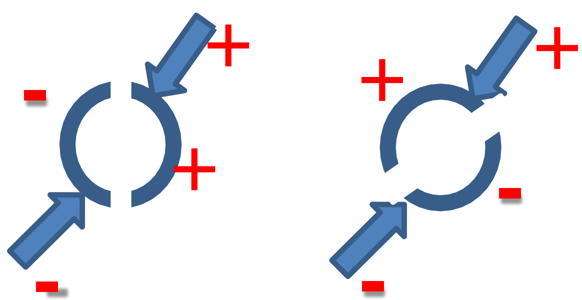
1. A simple DC electric motor: when the coil is powered, a magnetic field is generated around the armature.

2. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation

The armature continues to rotate

- When the armature becomes *horizontally aligned*, the commutator reverses the direction of current through the coil, ***reversing the magnetic field***.

- The process then repeats.



Rotating

Application of Electric Motors

1. Electric motors usually have a small rating, ranging up to a few horsepower

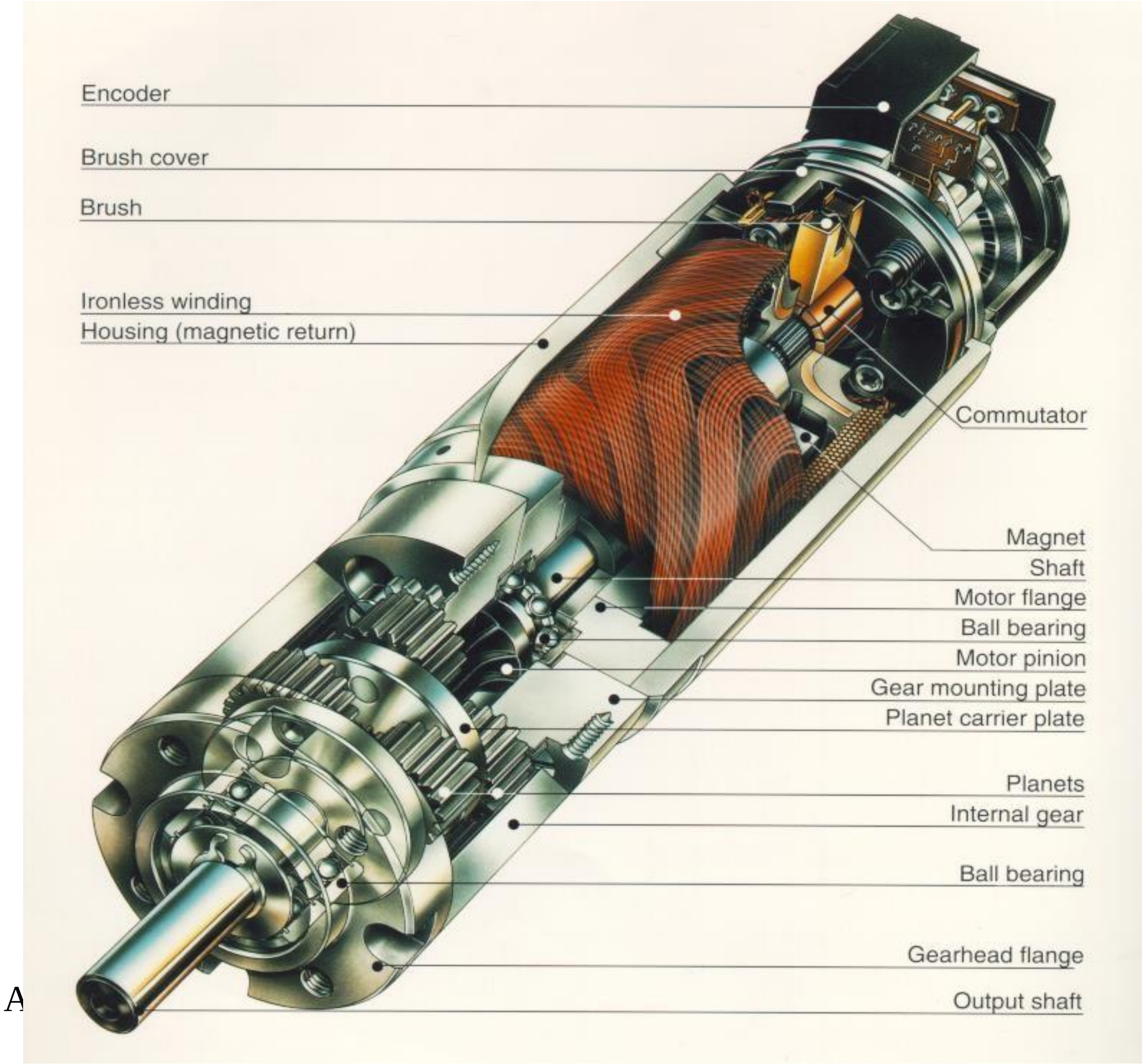
2. They are used in small appliances, battery operated vehicles, for medical purposes and in other medical equipment like x-ray machines

3. Electric motors are also used in toys, and in automobiles as auxiliary motors
   - for the purposes of seat adjustment, power windows, sunroof, mirror adjustment, blower motors, engine cooling fans and the like

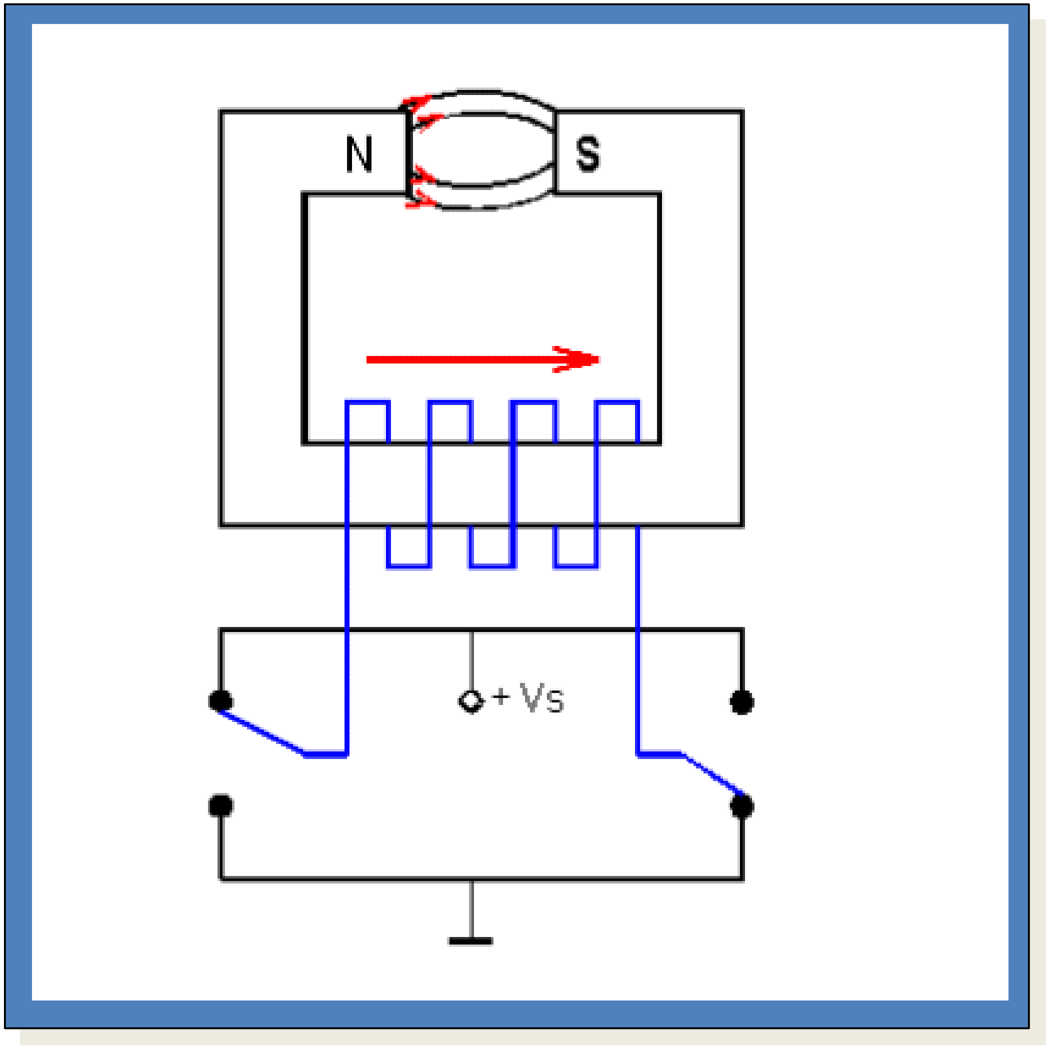
High quality DC-Motors

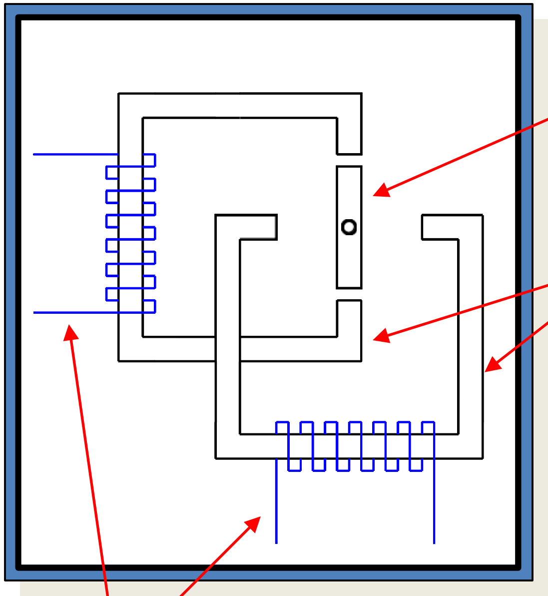
- Not cheap
- easy to control
- 1W - 1kW
- can be overloaded
- brushes wear
- limited overloading on high speeds

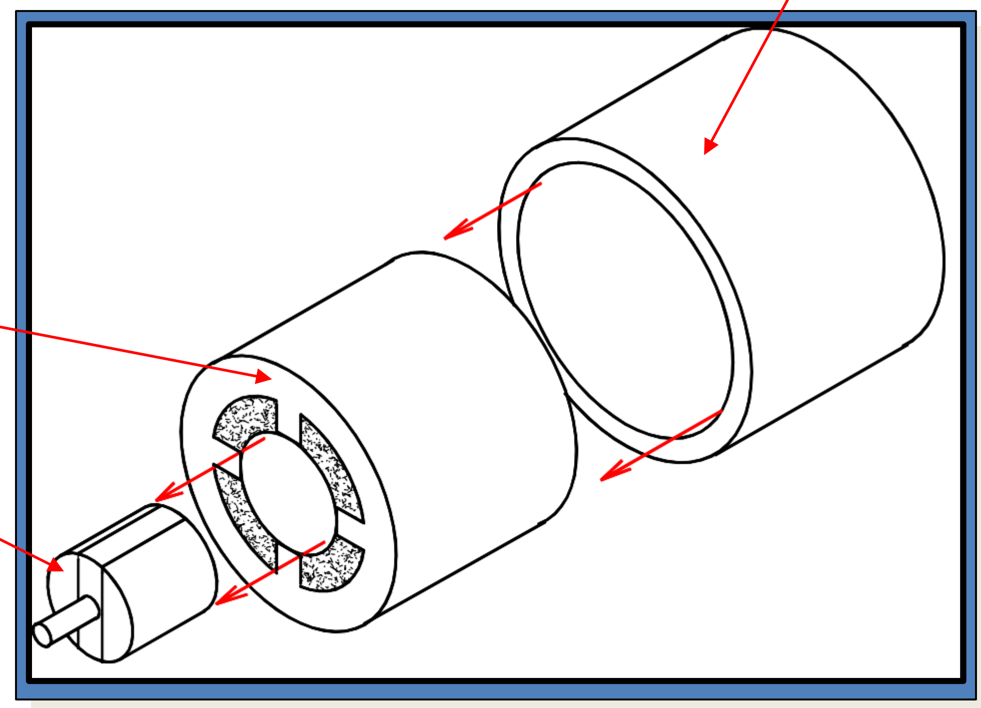
A

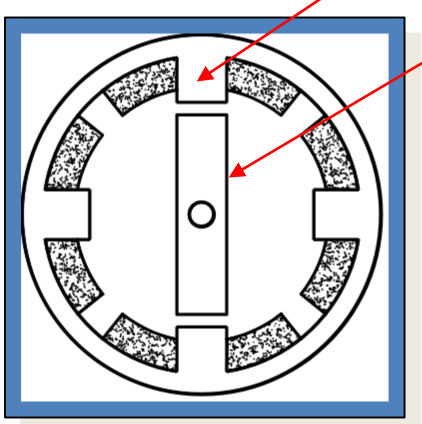


Stepper Motor / Electro magnet



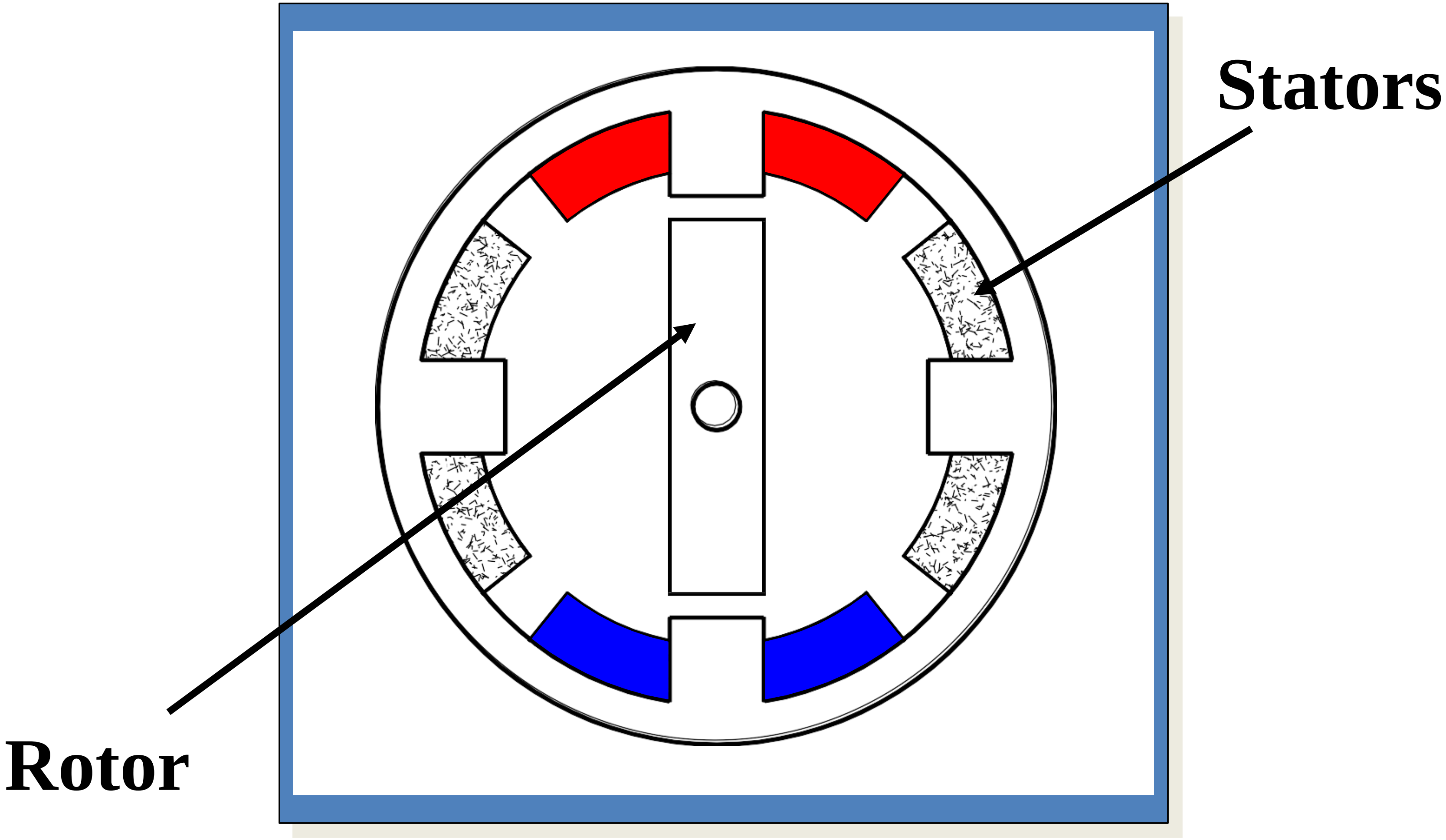


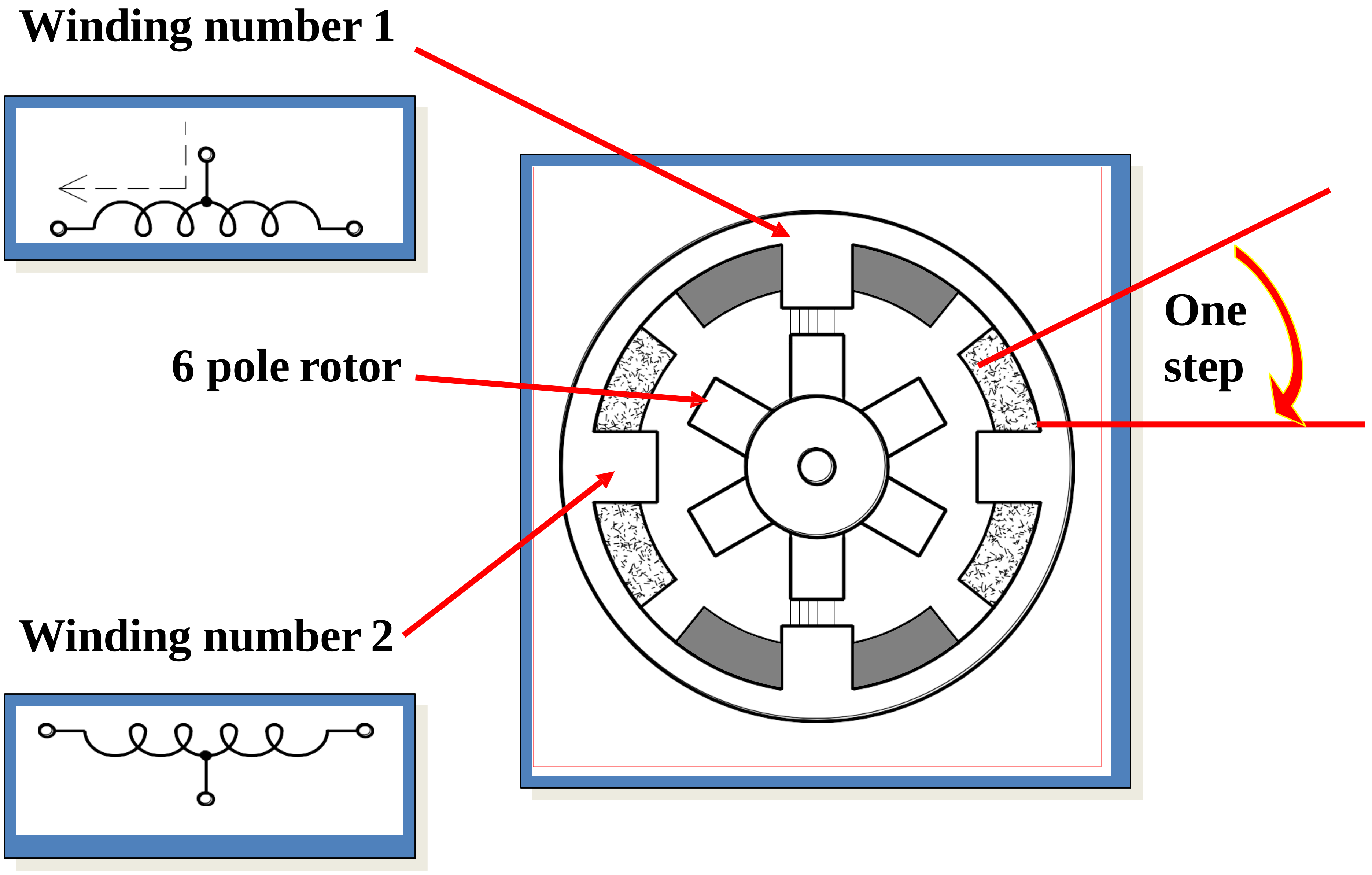




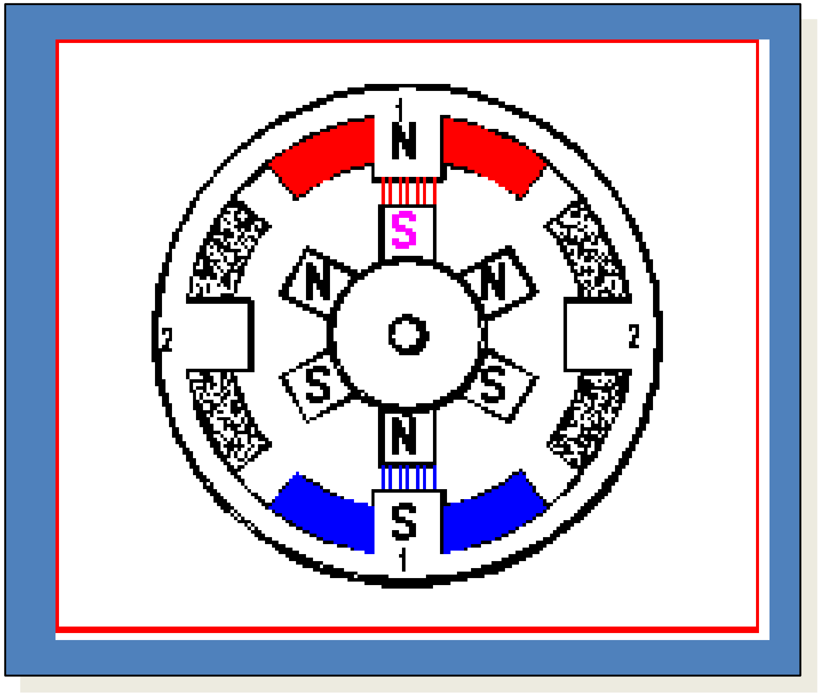
Internal components of a Stepper Motor

Cross Section of a Stepper Motor



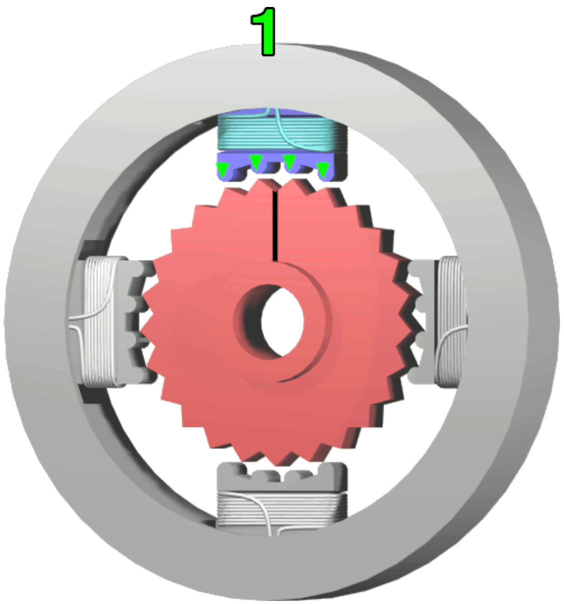

Winding number 1
6 pole rotor
One step
Winding number 2

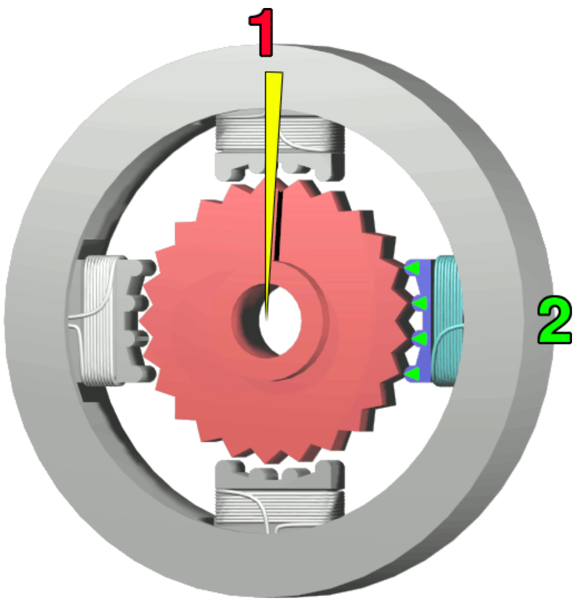
Six pole rotor, two electro magnets.



How many steps are required for one complete revolution?

Practical Stepper motor operation

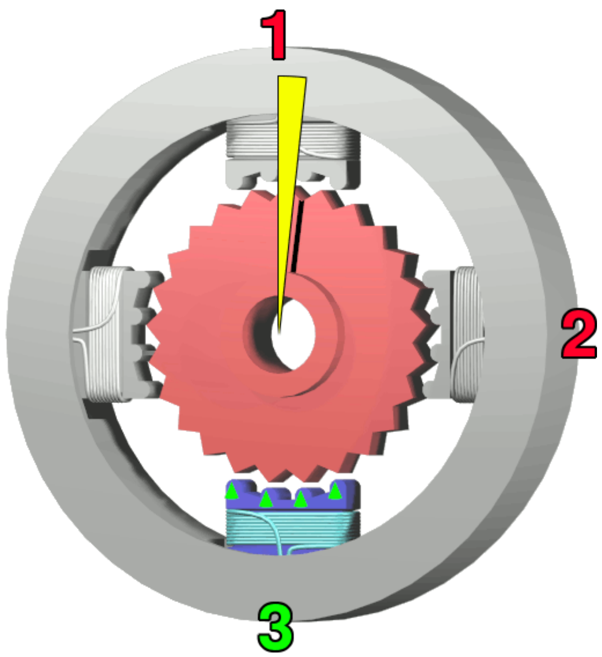


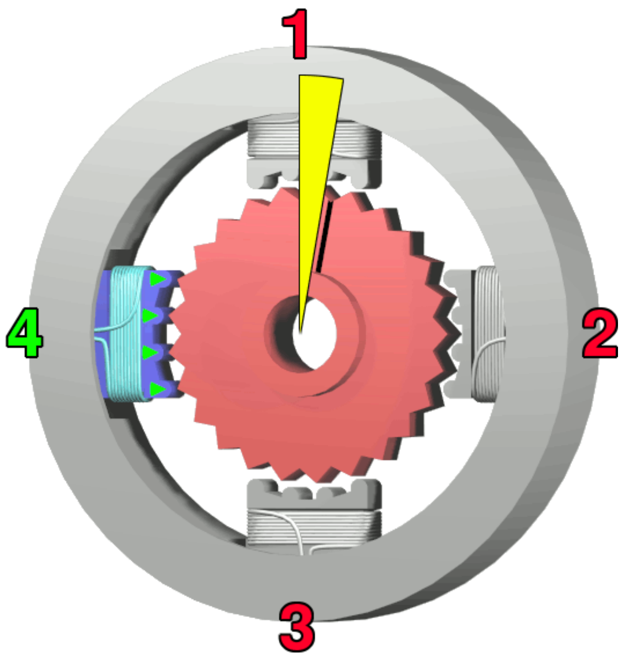


The top electromagnet (1) is turned on, attracting the nearest teeth of a gear-shaped iron rotor. With the teeth aligned to electromagnet 1, they will be slightly offset from electromagnet 2

The top electromagnet (1) is turned off, and the right electromagnet (2) is energized, pulling the nearest teeth slightly to the right. This results in a rotation of 3.6° in this example.

Practical Stepper motor operation

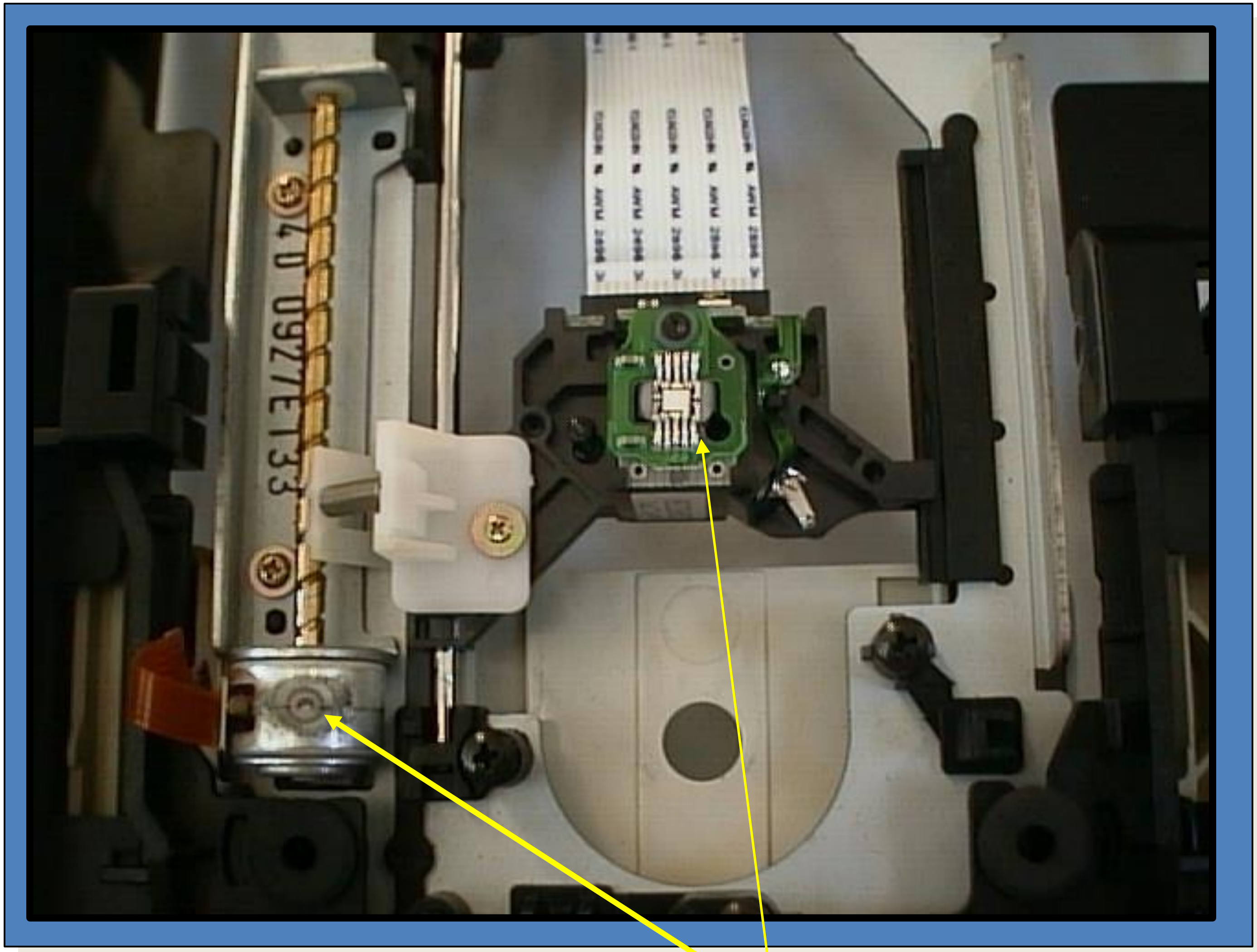




The bottom electromagnet (3) is energized; another 3.6° rotation occurs.

The left electromagnet (4) is enabled, rotating again by 3.6°. When the top electromagnet (1) is again enabled, the teeth in the sprocket will have rotated by one tooth position; since there are 25 teeth, it will take 100 steps to make a full rotation in this example.

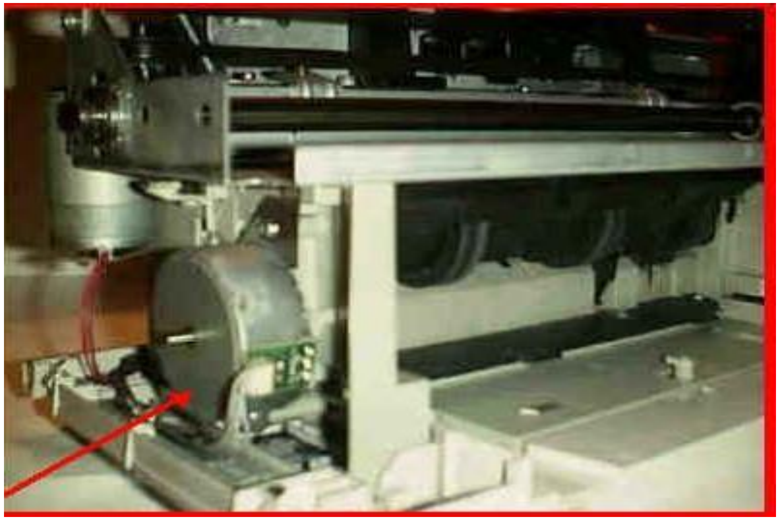
Stepper motor applications



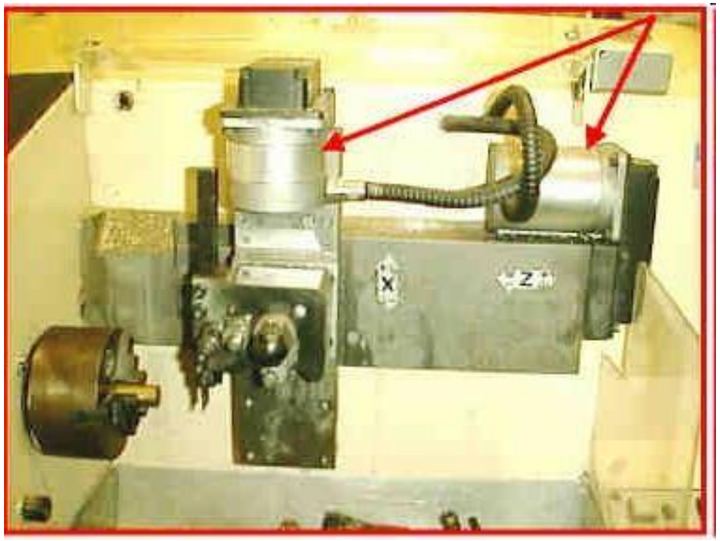
Stepping Motor to move read-write head

Stepper motor applications

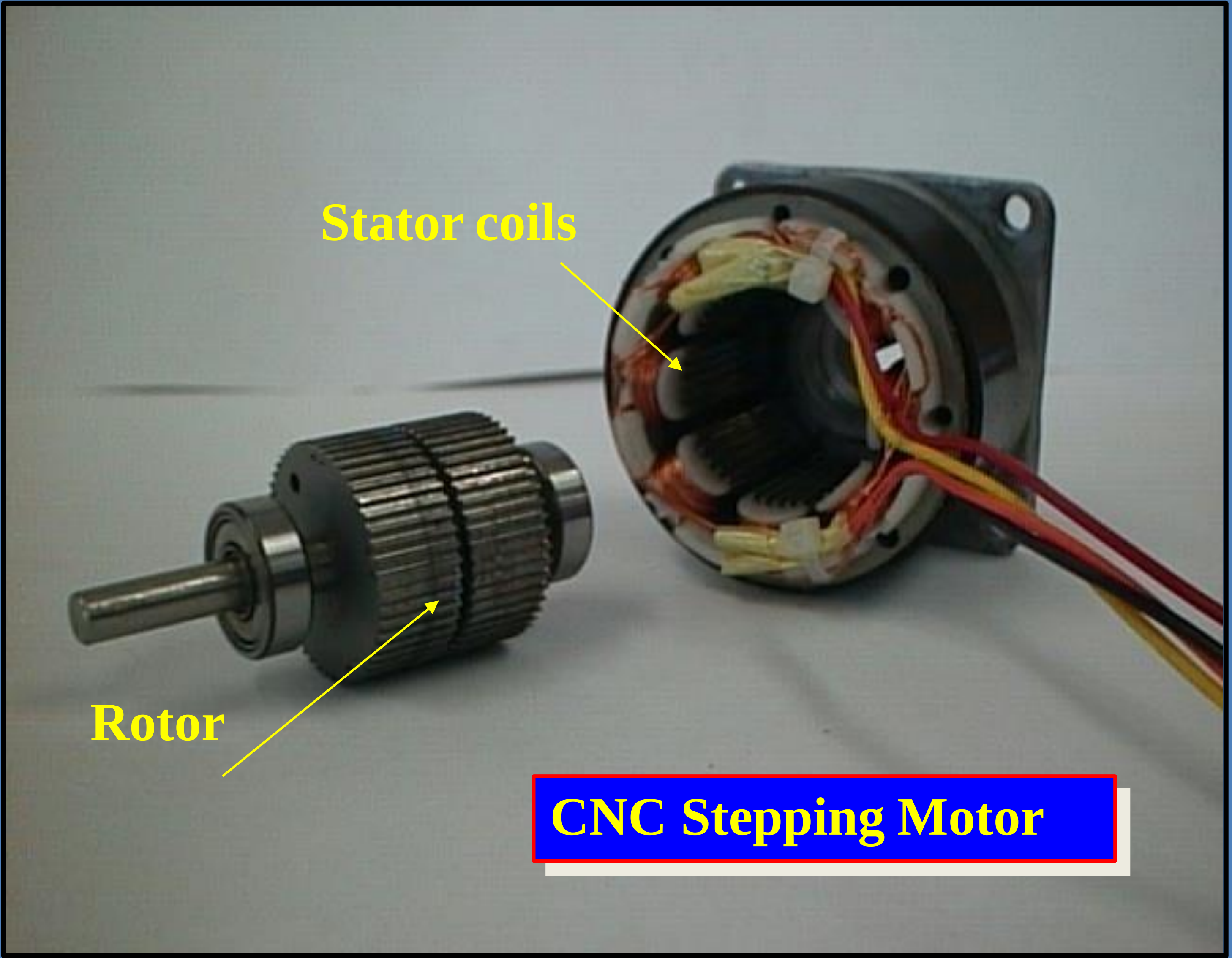
Paper feeder on printers



Stepper motors



CNC lathes


Stator coils
Rotor
CNC Stepping Motor

Stepper Motors

When incremental rotary motion is required in a robot, it is possible to use **stepper motors**

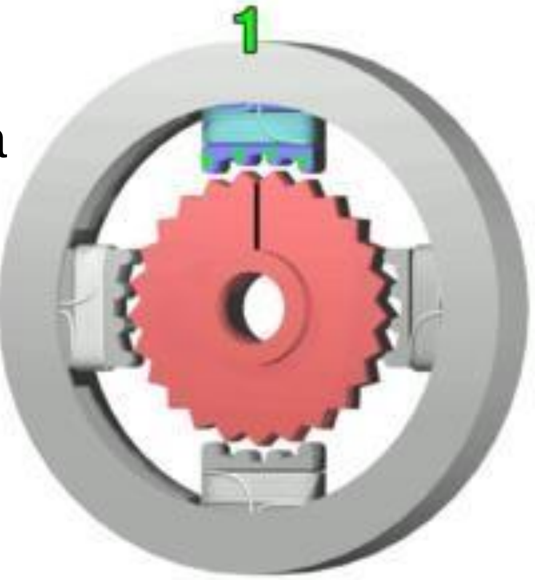
A stepper motor possesses the ability to move a specified number of revolutions or fraction of a revolution in order to achieve a fixed and consistent angular movement

This is achieved by increasing the numbers of poles on both rotor and stator

Additionally, soft magnetic material with many teeth on the rotor and stator cheaply multiplies the number of poles (reluctance motor)

Stepper Motors

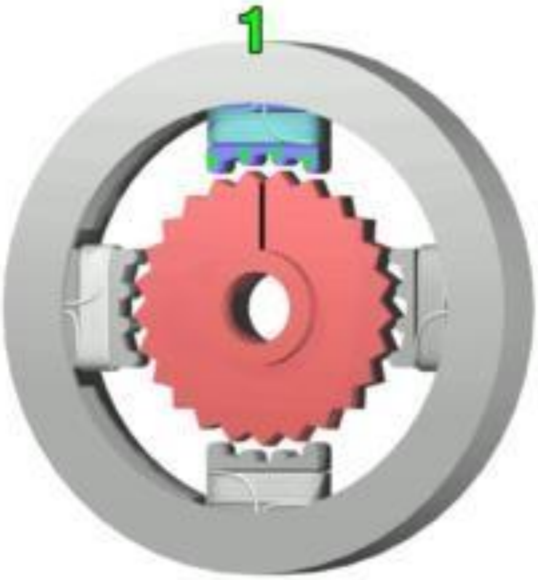
This figure illustrates the design of a stepper motor, arranged with four magnetic poles arranged around a central rotor



Note that the teeth on the rotor have a slightly tighter spacing to those on the stator, this ensures that the two sets of teeth are close to each other but not quite aligned throughout.

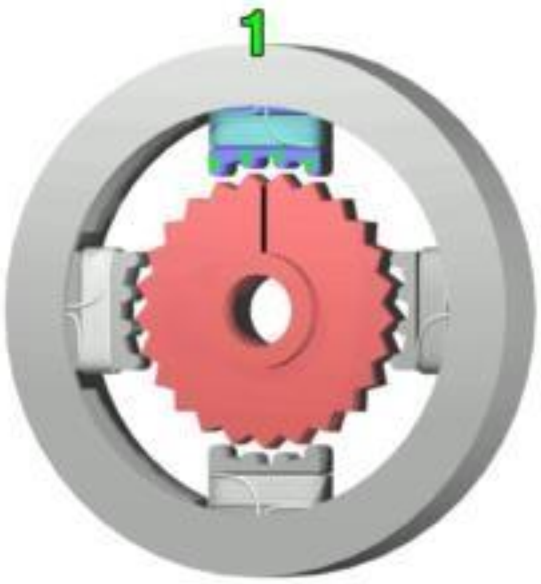
Stepper Motors Continued

Movement is achieved when power is applied for short periods to successive magnets



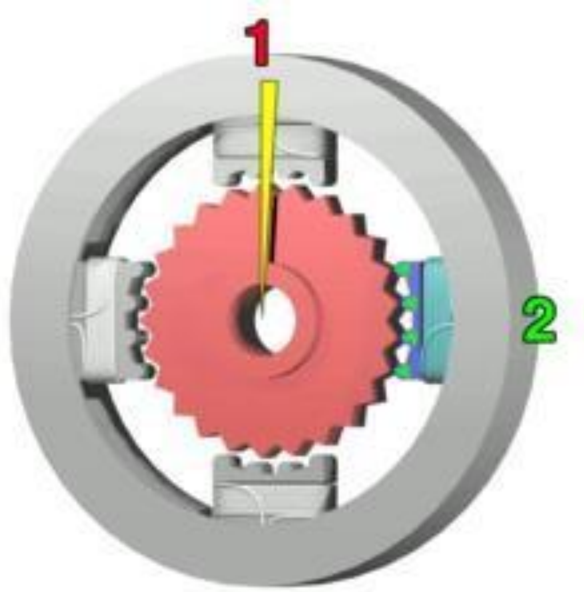
Where pairs of teeth are least offset, the electromagnetic pulse causes alignment and a small rotation is achieved

How Does A Stepper Motor Work?



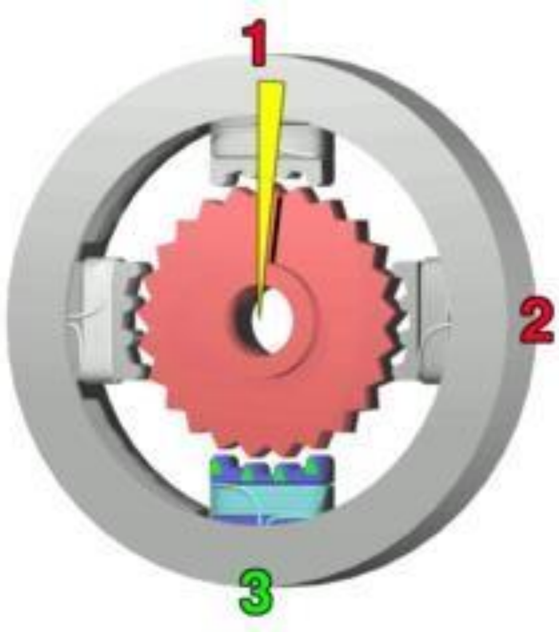
The top electromagnet (1) is charged, attracting the topmost four teeth of a sprocket.

How Does A Stepper Motor Work? (cont…)



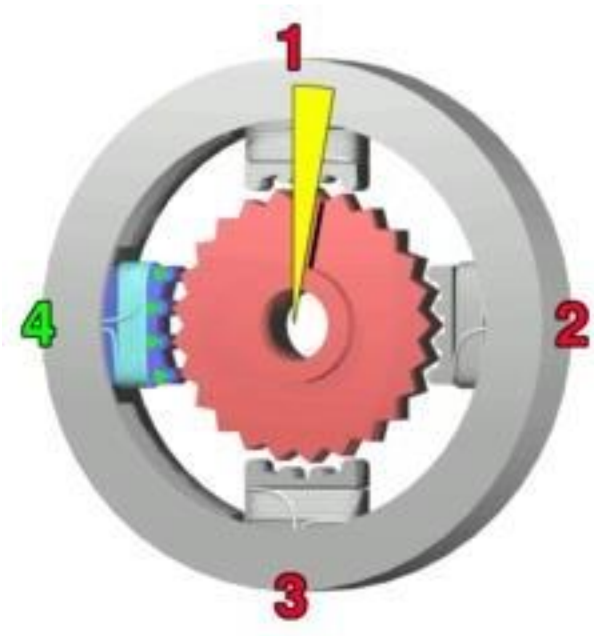
The top electromagnet (1) is turned off, and the right electromagnet (2) is charged, pulling the nearest four teeth to the right. This results in a rotation of 3.6°

How Does A Stepper Motor Work? (cont…)



The bottom electromagnet (3) is charged; another 3.6° rotation occurs.

How Does A Stepper Motor Work? (cont…)



The left electromagnet (4) is enabled, rotating again by 3.6°. When the top electromagnet (1) is again charged, the teeth in the sprocket will have rotated by one tooth position; since there are 25 teeth, it will take 100 steps to make a full rotation.

Advantages / Disadvantages

Advantages:-

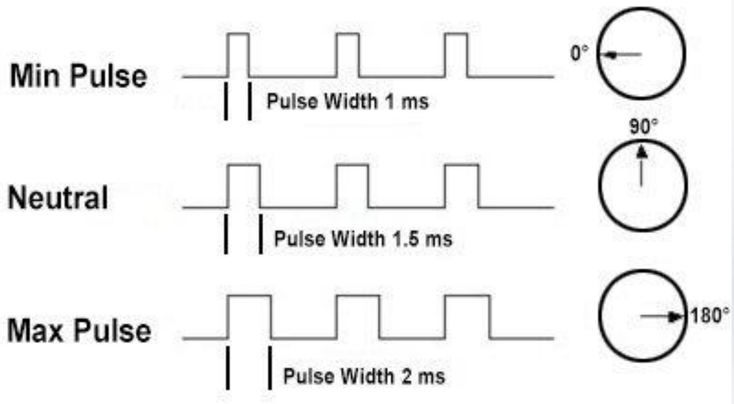
- Low cost for control achieved
- Ruggedness
- Simplicity of construction
- Can operate high load
- Low maintenance
- Less likely to stall or slip
- Will work in any environment

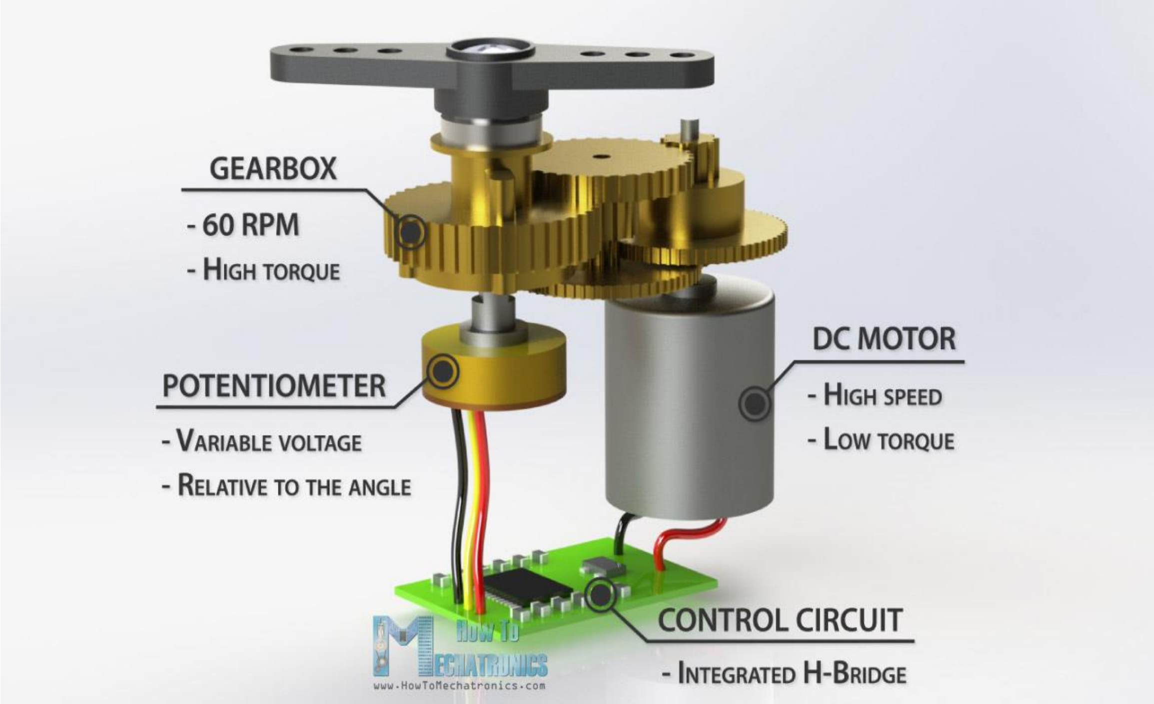
Disadvantages:-

- Require a dedicated control circuit
- Use more current than D.C. motors
- High torque output achieved at low speeds

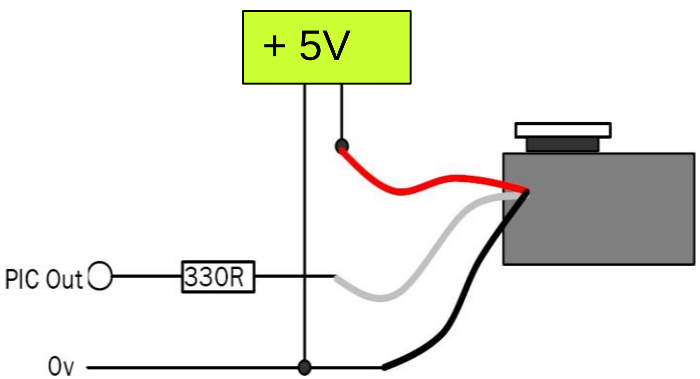
Servo Motor

Servo motor works on the PWM (Pulse Width Modulation) principle, which means its angle of rotation is controlled by the duration of pulse applied to its control PIN. Basically **servo motor** is made up of DC **motor** which is controlled by a variable resistor (potentiometer) and some gears





Servo Motor Detail



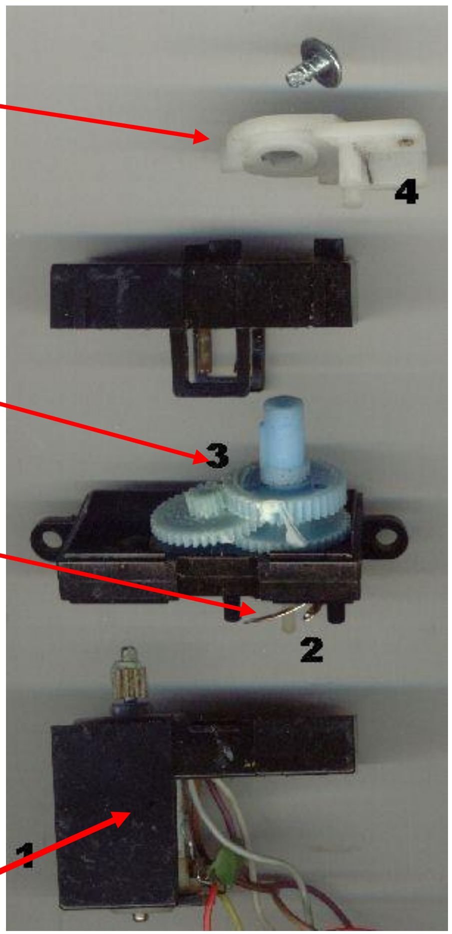
Actuator

Reduction gear

Position feedback

Potentiometer

Small electric DC motor



A/D Converter

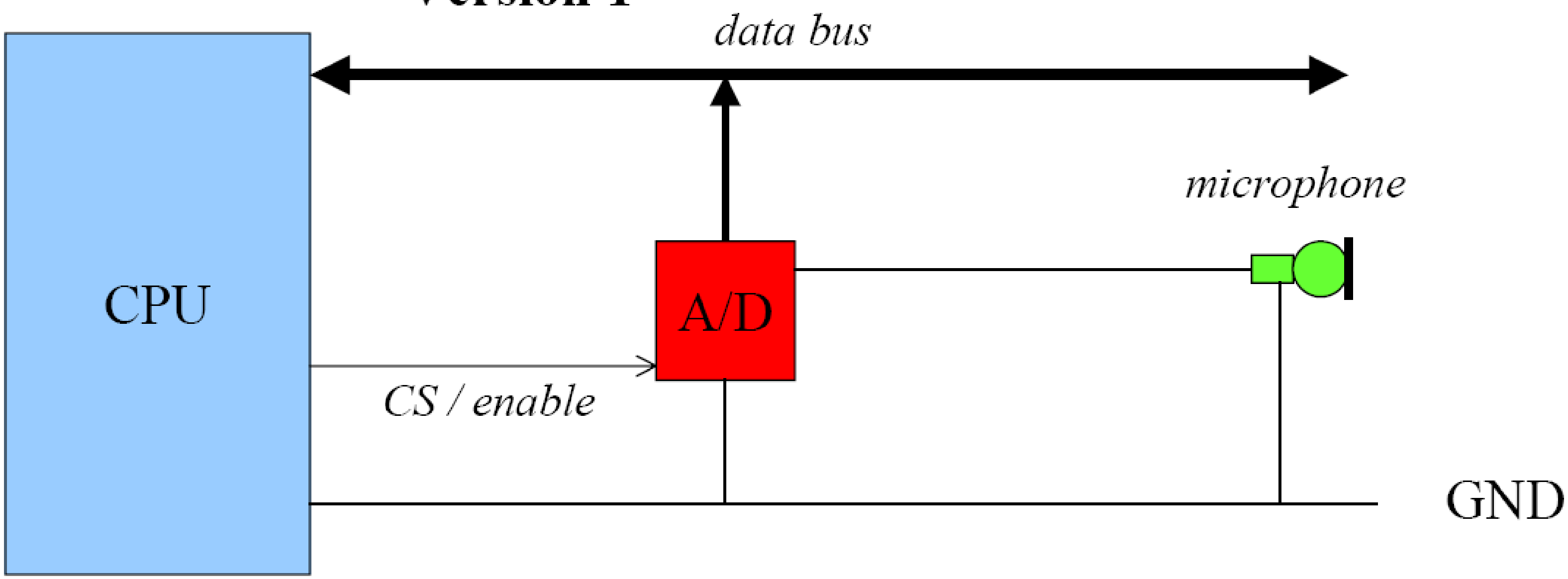
- Signal has to be provided at correct level, e.g. between 0.. 5V
- A/D converter translates analog voltage level into digital value
- Digital output from A/D converter can be
  - parallel

    (e.g. 8 bit, direct connection to data bus)
  - serially digital

    (provide programmed clock signal to converter to read data bit by bit)

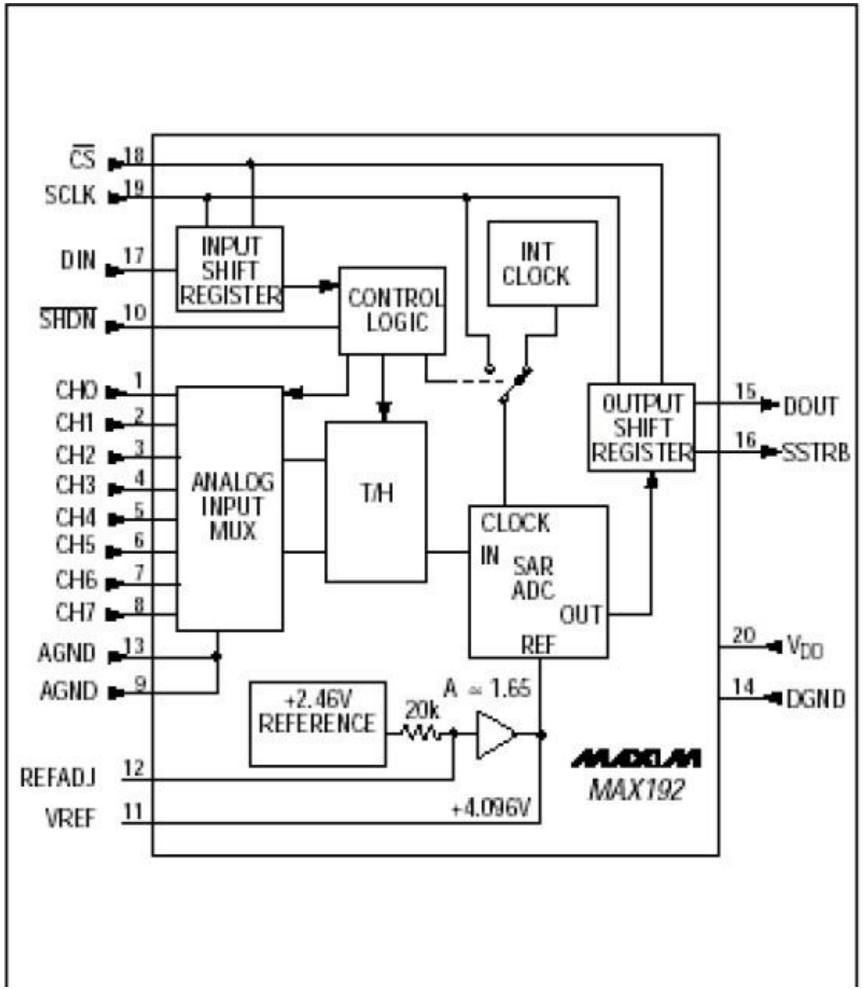
A/D

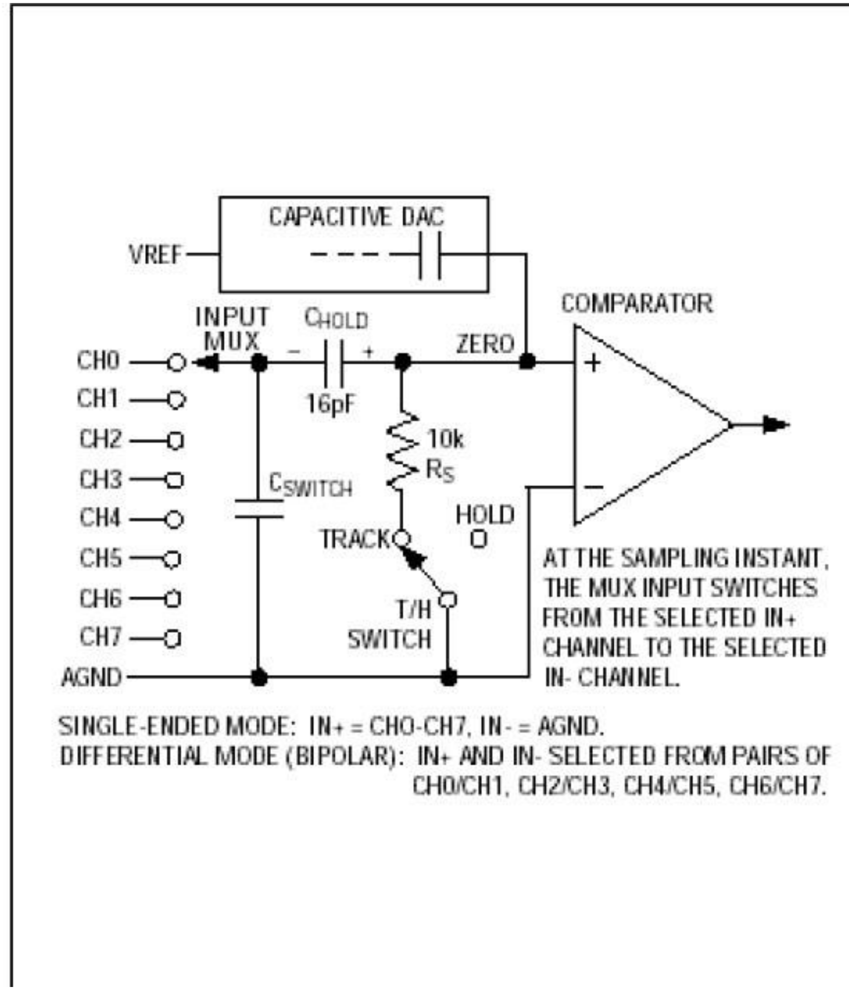
Version 1



A/D Converter

MAX192





A/D Converter