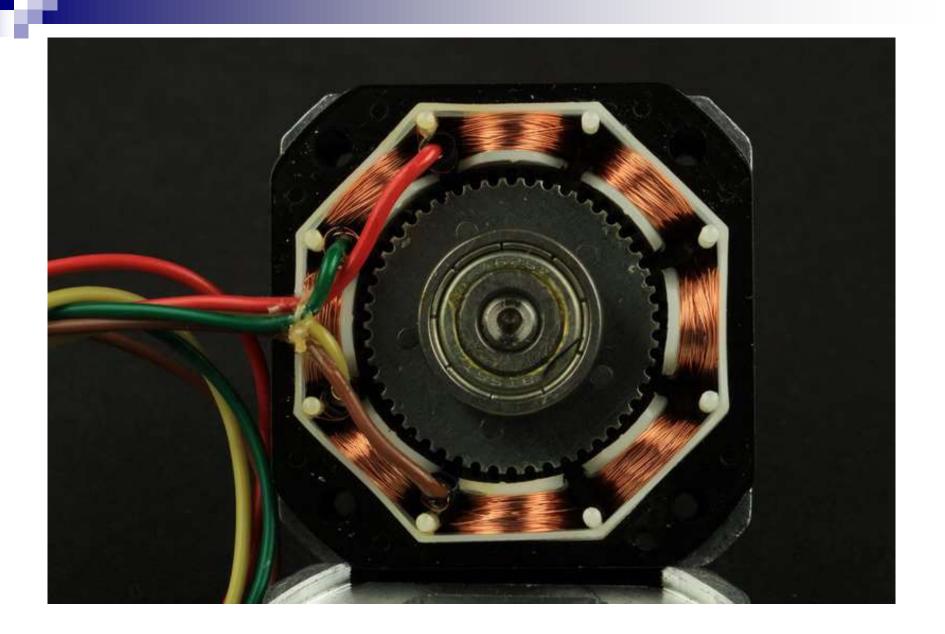
# Stepper Motors

Md. Khairul Alam UAP



M

Stepper motors are DC motors that move in discrete steps. They have multiple coils that are organized in groups called "phases". By energizing each phase in sequence, the motor will rotate, one step at a time.

With a computer controlled stepping you can achieve very precise positioning and/or speed control. For this reason, stepper motors are the motor of choice for many precision motion control applications.

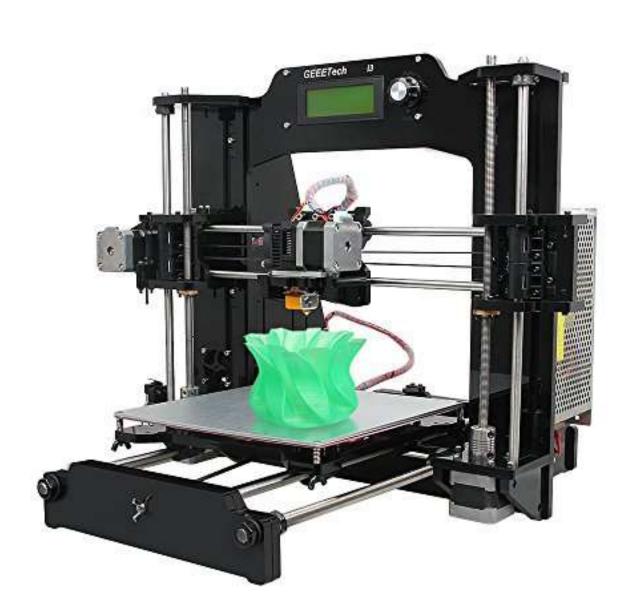


# Advantages

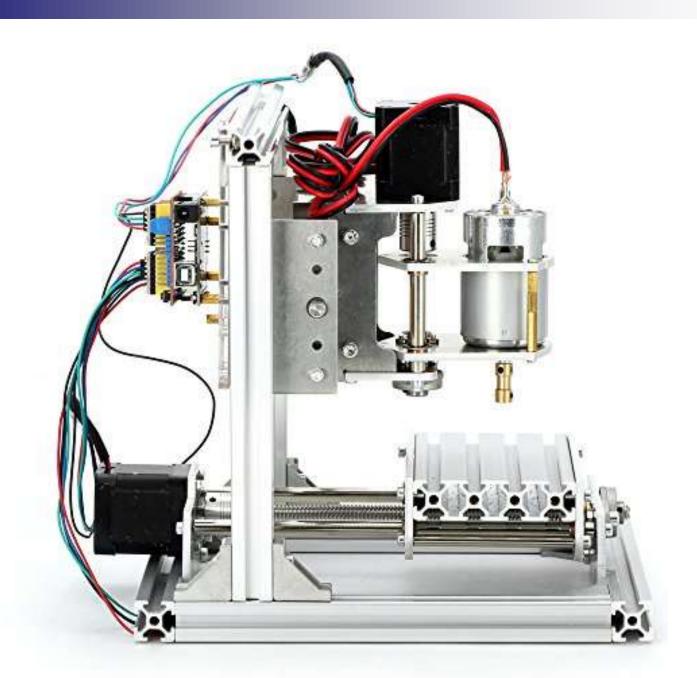
- High accuracy
- Reliability
- Holding torque
- Load independent
- No feedback
- Rapid response to starting, stopping and reversing

# **Application**

- CNC machines
- 3D printers
- Robotic
- Computer printers, plotters, image scanners

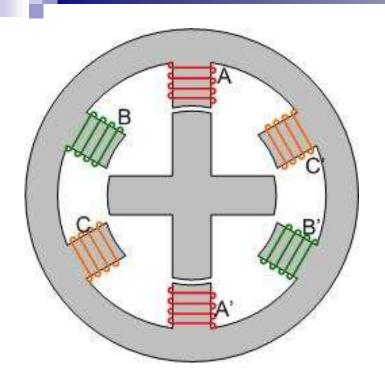


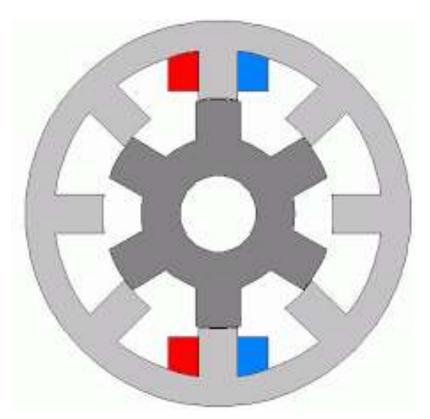




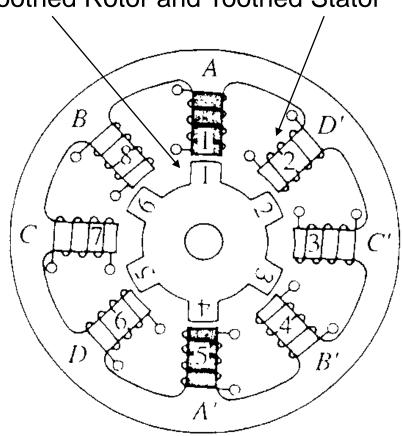
# **TYPES OF STEPPER MOTORS**

- Variable Reluctance Motor (VRM)
  - Magnetic rotor
- Permanent Magnet Stepper Motor (PMSM)
  - Non-magnetic, geared rotor
- Hybrid Stepper Motor (HSM)
  - Magnetic, geared rotor





Toothed Rotor and Toothed Stator

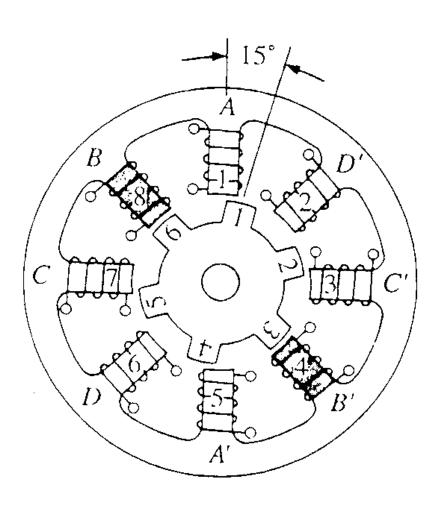


#### **Principle of Operation:**

Reluctance of the magnetic circuit formed by the rotor and stator teeth varies with the angular position of the rotor

Here, energize coils A and A' (Phase A)

Rotor "steps" to align rotor teeth 1 and 4 with stator teeth 1 and 5



# Energize coils B and B' (Phase B)

Rotor steps "forward"

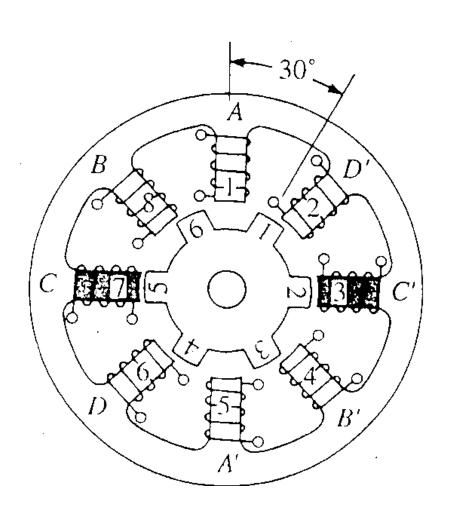
Rotor teeth 3 and 6 align with Stator teeth 1 and 5

Let  $N_s = \#$  of teeth on the stator

 $N_r = \#$  of teeth on the rotor

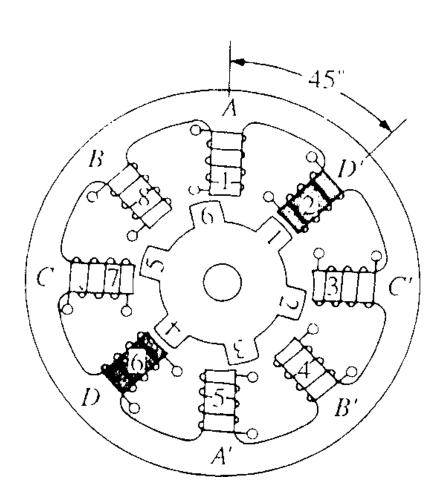
β = Step Angle in space degrees

$$\beta = \frac{\left| N_s - N_r \right|}{N_s \cdot N_r} \times 360^{\circ}$$



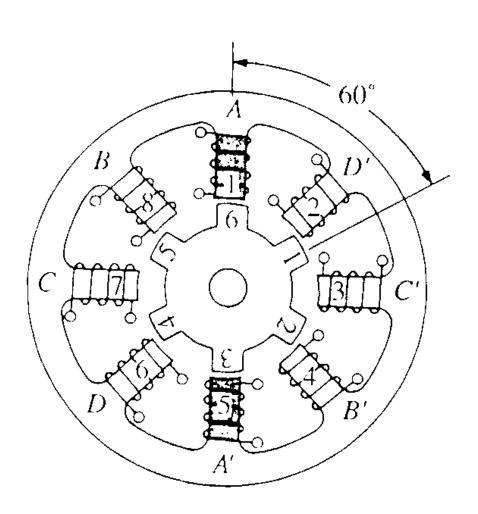
#### **Energize Phase C**

Rotor steps forward another 15°



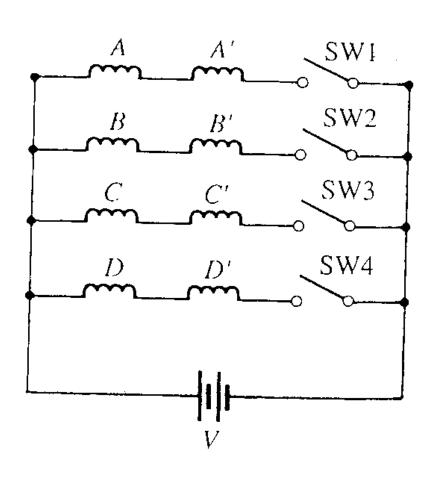
#### **Energize Phase D**

Rotor steps forward another 15°



# Repeat the sequence Energize Phase A

Rotor steps forward again



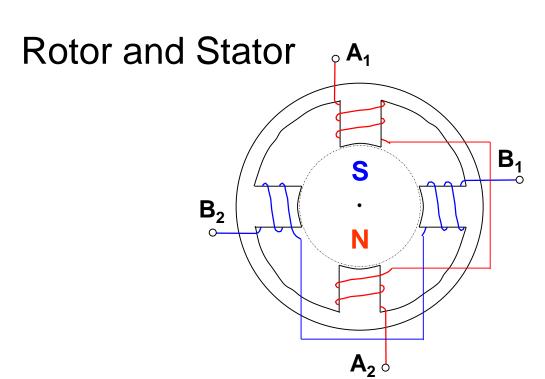
# Switching Circuit for the stepper motor

Close switches in order 1, 2, 3, and 4 to turn the rotor "clockwise"

Close switches in reverse order - 4, 3, 2, and 1 to change rotation to the opposite (counter-clockwise) direction

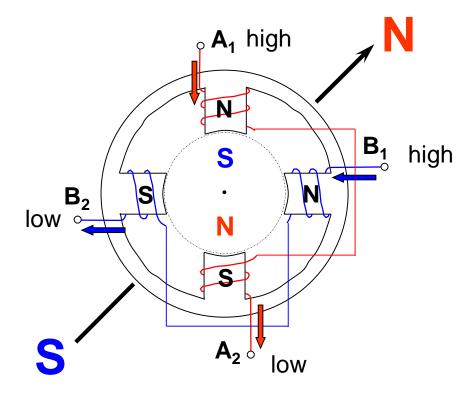
#### DIFFERENT MODES OF EXCITATION

- Full step
- Half step
- Micro step



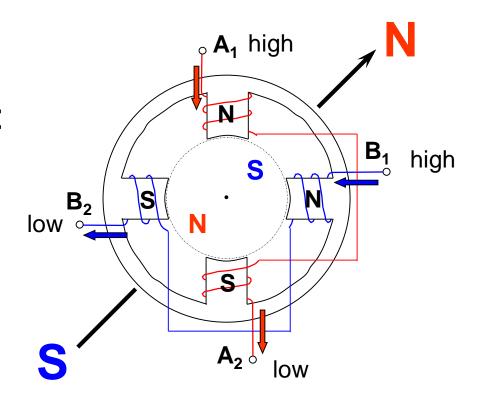
Step 1a

- A₁ and B₁ high
- A<sub>2</sub> and B<sub>2</sub> low



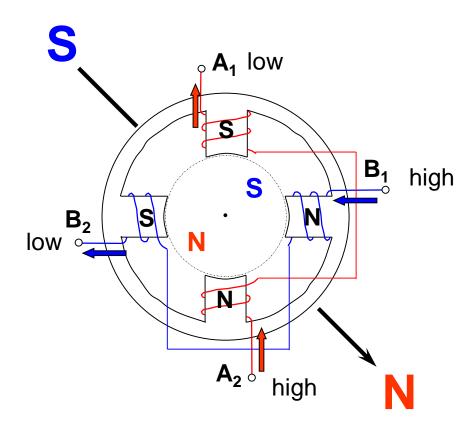
Step 1b

#### Energize windings:



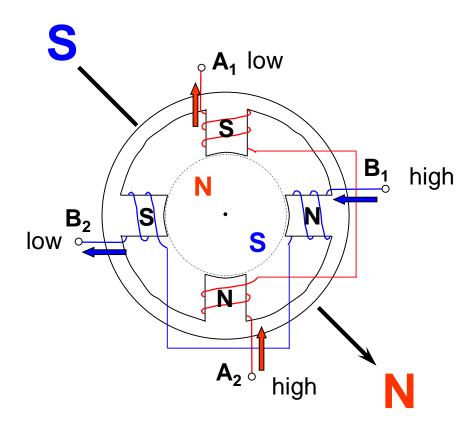
Step 2a

- A₂ and B₁ high
- A<sub>1</sub> and B<sub>2</sub> low



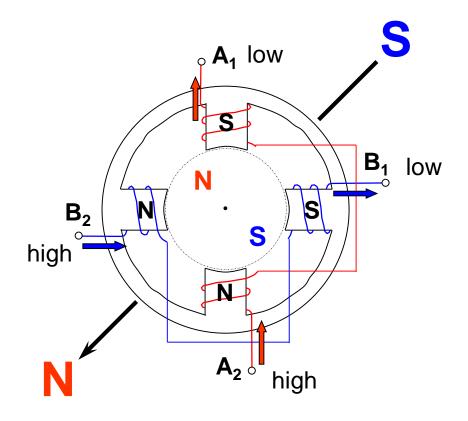
Step 2b

#### Energize windings:



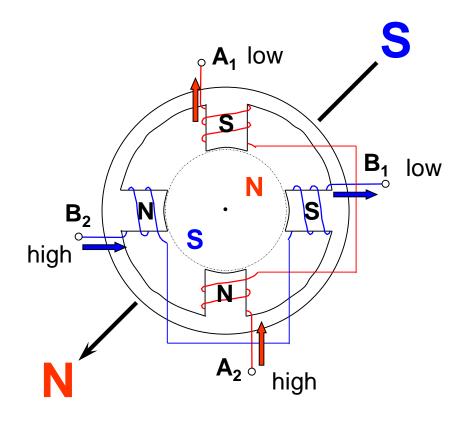
Step 3a

- A<sub>2</sub> and B<sub>2</sub> high
- A₁ and B₁ low



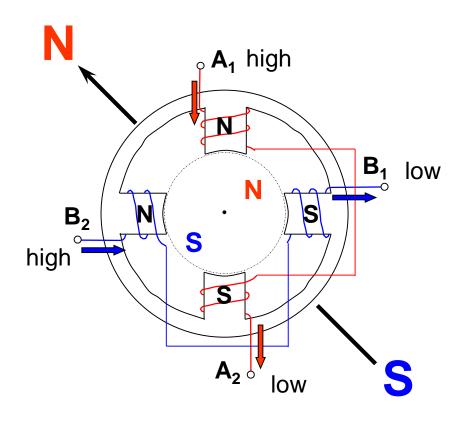
Step 3b

#### **Energize windings:**



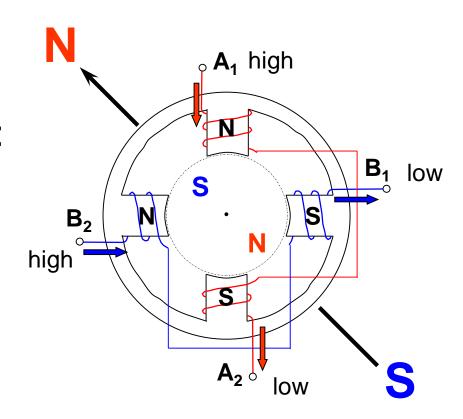
Step 4a

- A₁ and B₂ high
- A<sub>2</sub> and B<sub>1</sub> low



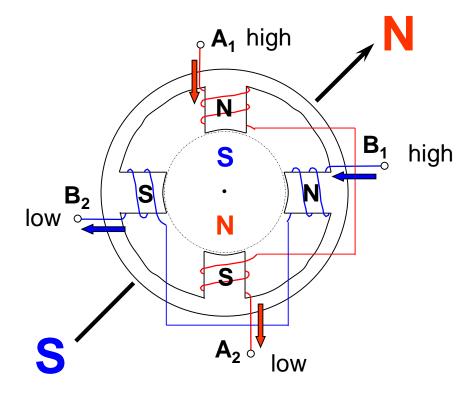
Step 4b

Energize windings:



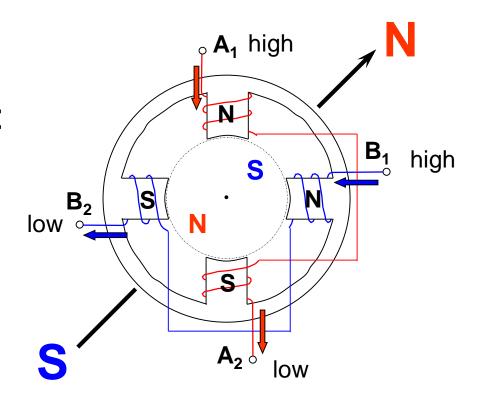
Step 1a

- A₁ and B₁ high
- A<sub>2</sub> and B<sub>2</sub> low



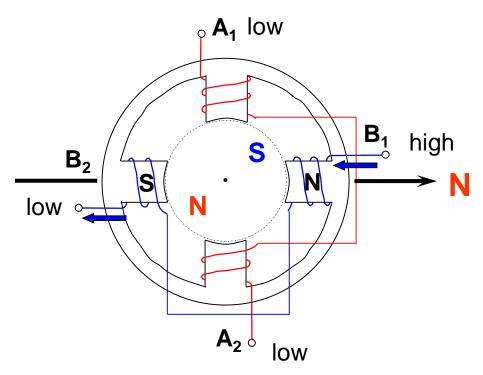
Step 1b

#### Energize windings:



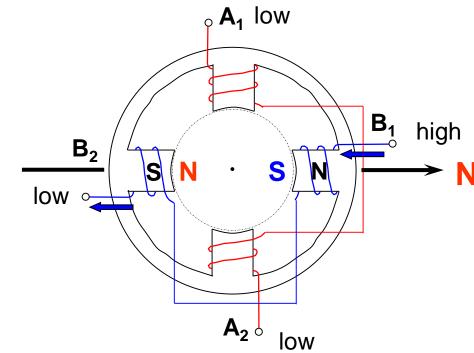
Step 1a

- Just B₁ high
- $A_1$ ,  $A_2$  and  $B_2$  low



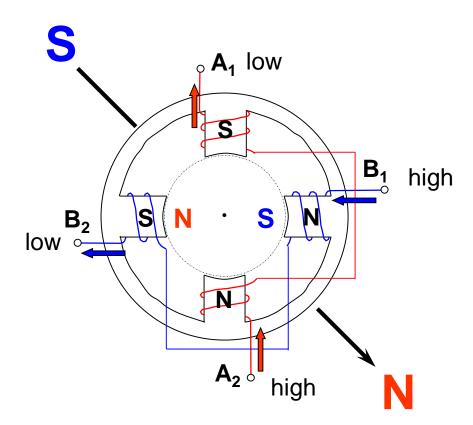
Step 1b

- Rotor moves to align with net magnetic field
- Only 45 deg. rotation!



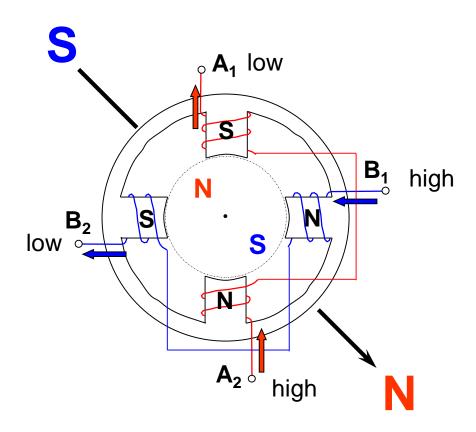
#### Step 2a

- A<sub>2</sub> and B<sub>1</sub> high
- A<sub>1</sub> and B<sub>2</sub> low

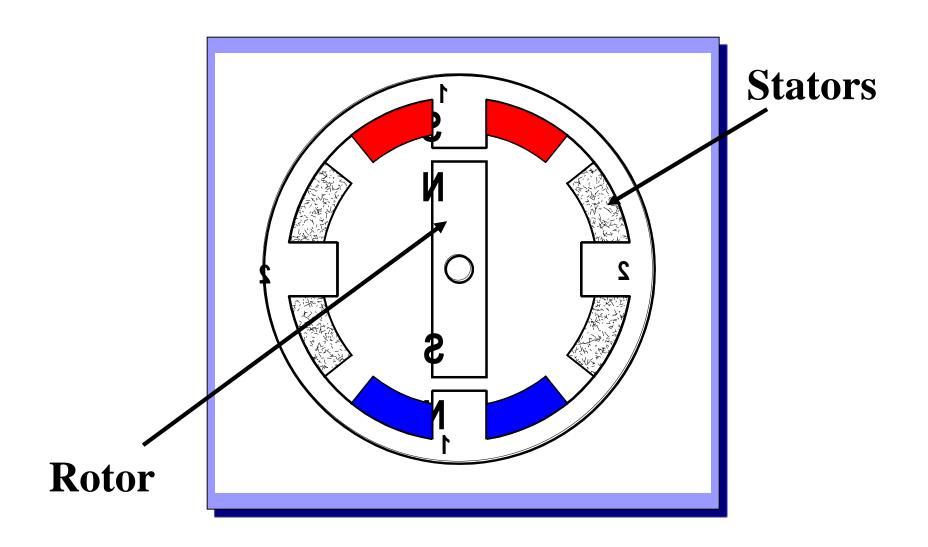


#### Step 2b

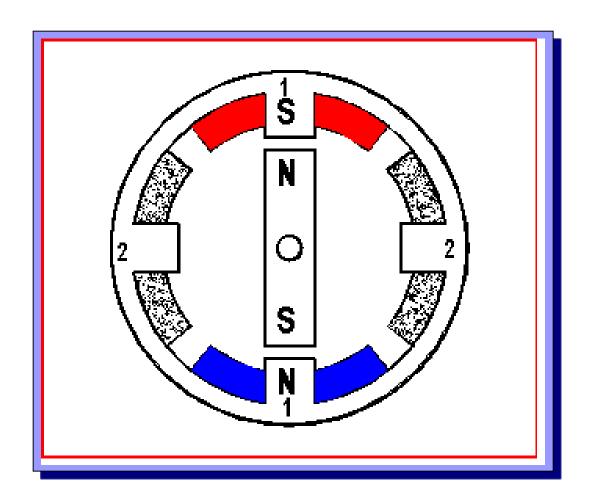
#### **Energize windings:**



# **Cross Section of a Stepper Motor**

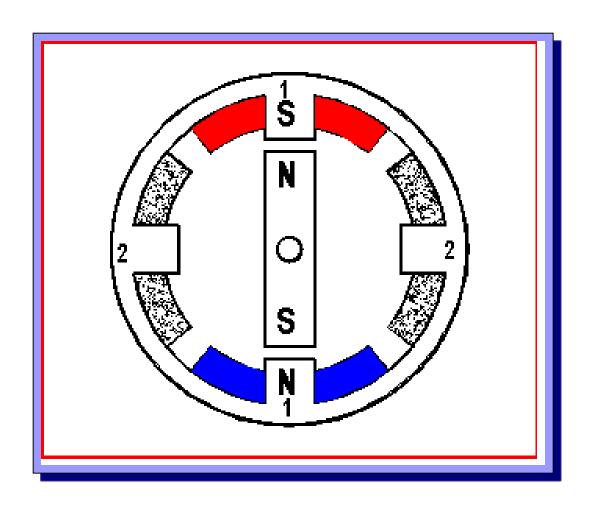


# Full Step Operation



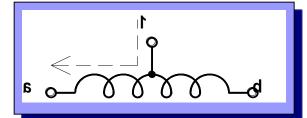
Four Steps per revolution i.e. 90 deg. steps.

# Half Step Operation



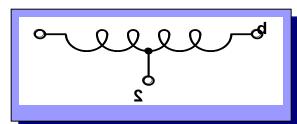
Eight steps per. revolution i.e. 45 deg. steps.

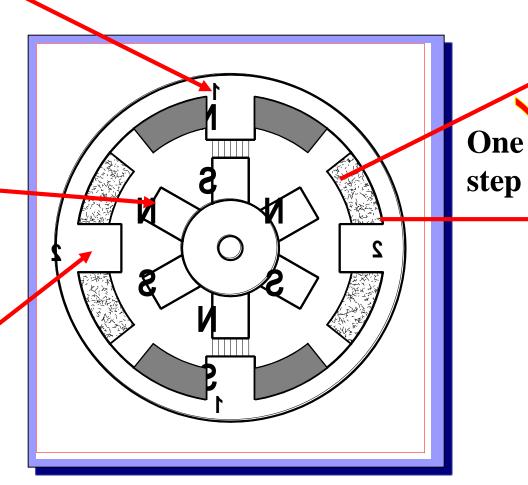
### Winding number 1



6 pole rotor

Winding number 2





$$\theta = \frac{360}{m * N_r}$$
 or  $\theta = \frac{360*(N_s - N_r)}{N_s * N_r}$ 

Where

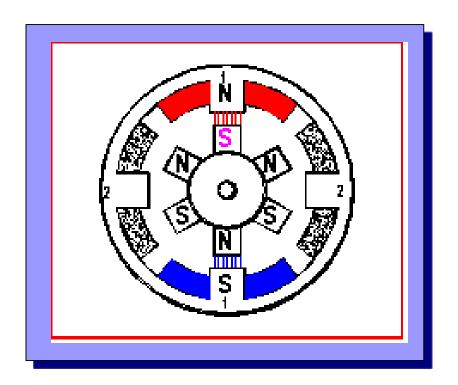
 $\theta$  - Step angle in degrees

N<sub>s</sub> - Number of stator teeth

N<sub>r</sub> - Number of rotor teeth

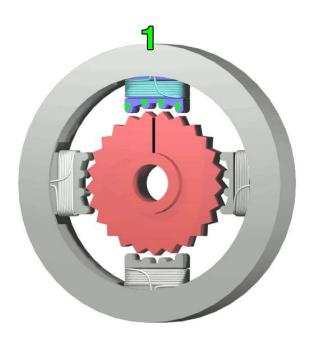
m - Number of phases

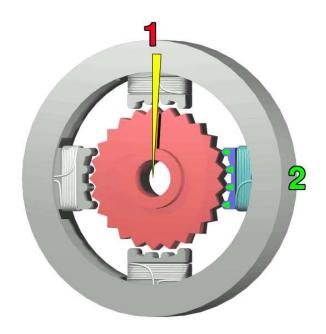
## Six pole rotor, two electro magnets.



How many steps are required for one complete revolution?

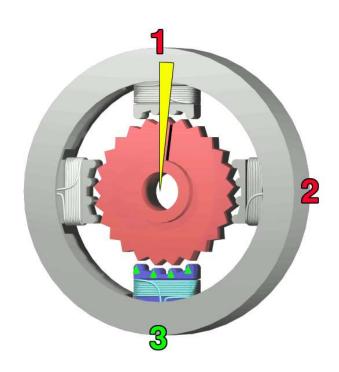
### Practical Stepper motor operation

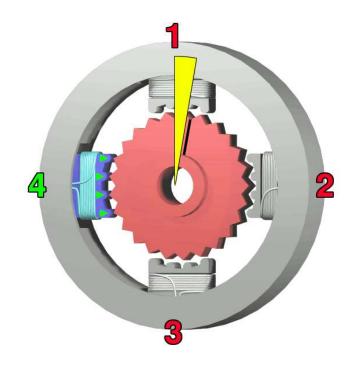




The top electromagnet (1) is turned on, attracting the nearest teeth of a gear-shaped iron rotor. With the teeth aligned to electromagnet 1, they will be slightly offset from electromagnet 2

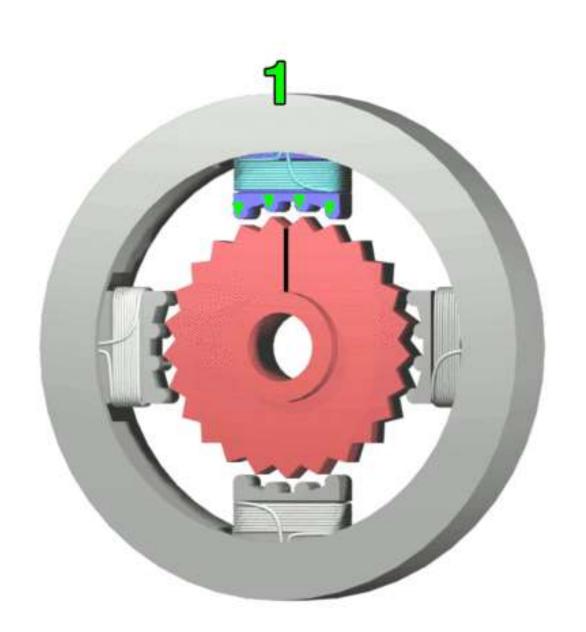
The top electromagnet (1) is turned off, and the right electromagnet (2) is energized, pulling the nearest teeth slightly to the right. This results in a rotation of 3.6° in this example.





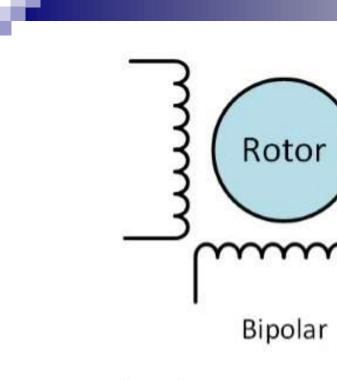
The bottom electromagnet (3) is energized; another 3.6° rotation occurs.

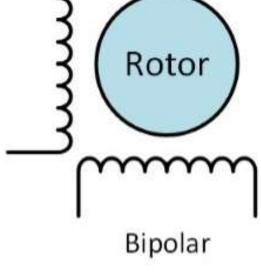
The left electromagnet (4) is enabled, rotating again by 3.6°. When the top electromagnet (1) is again enabled, the teeth in the sprocket will have rotated by one tooth position; since there are 25 teeth, it will take 100 steps to make a full rotation in this example.

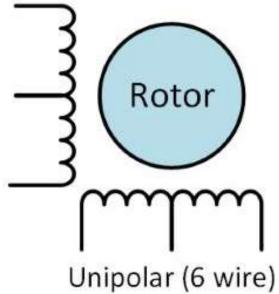


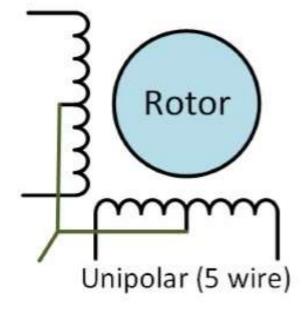
# **TYPES OF DRIVERS**

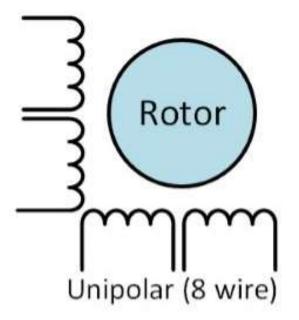
- Unipolar Driver
- Bipolar Driver





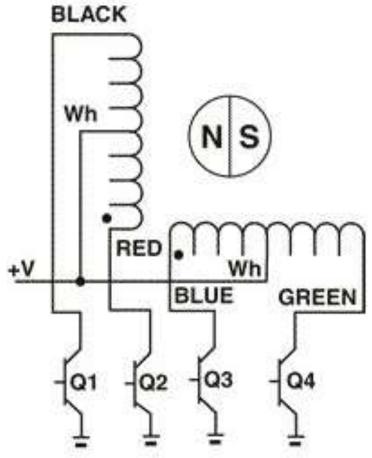


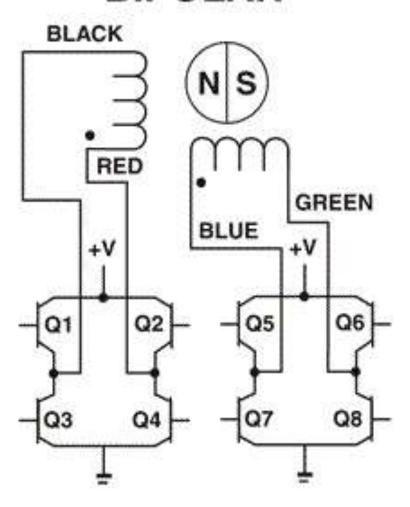


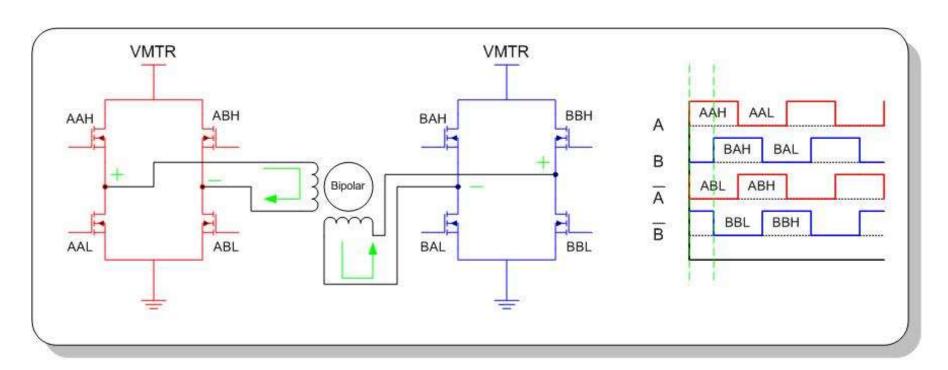


### UNIPOLAR

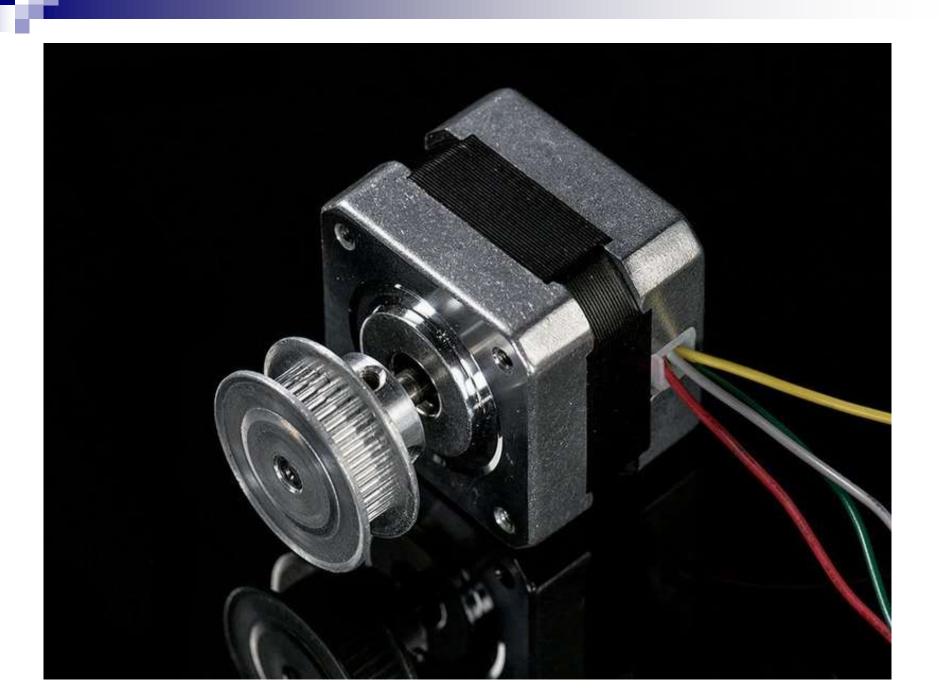
### **BIPOLAR**



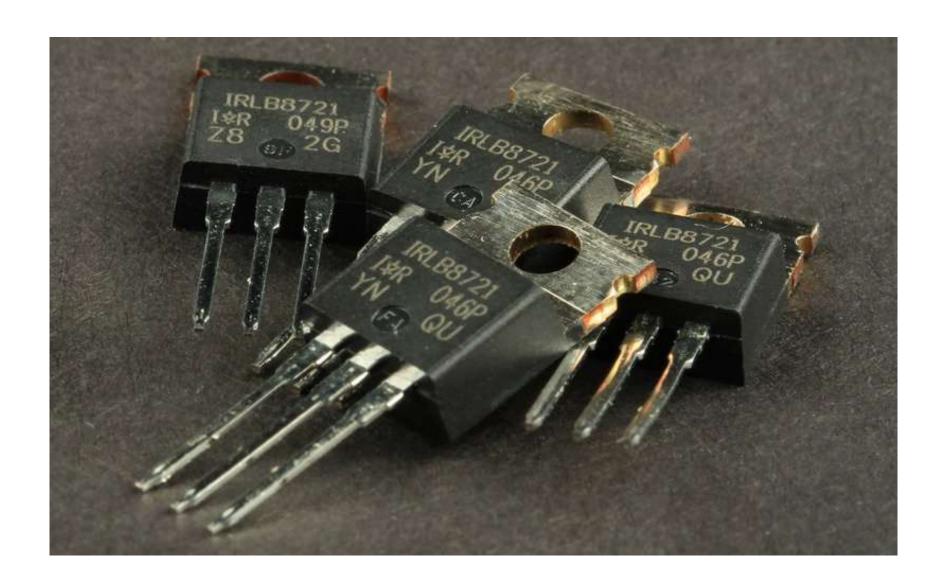


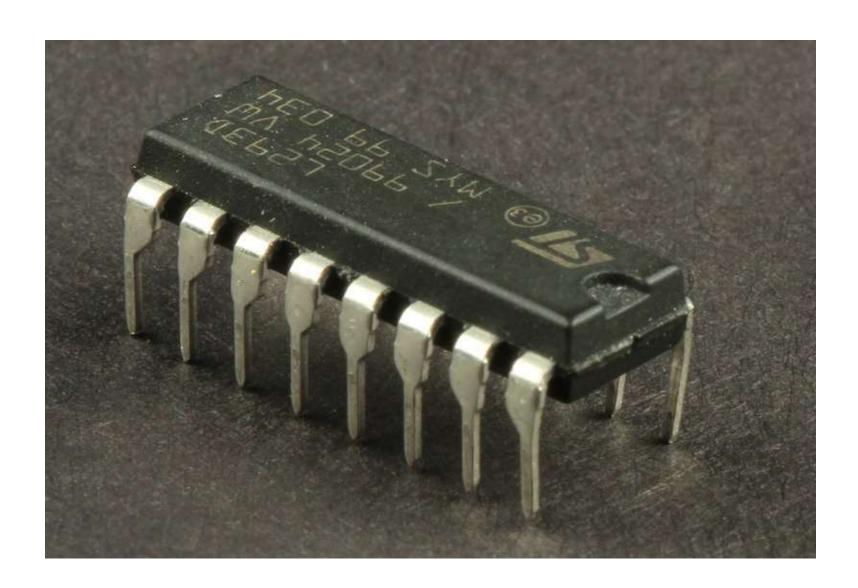


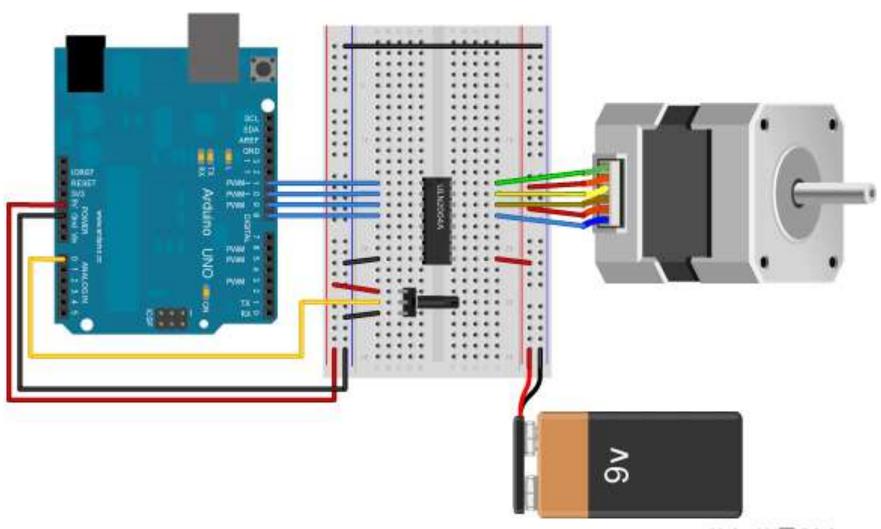
**Bipolar Motor and Drive** 











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