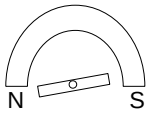
Stepper Motors

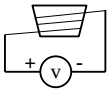
Physics review:

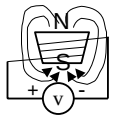
Nature is lazy.

Things seek lowest energy states.
- iron core vs. magnet
- magnetic fields tend to line up



Electric fields and magnetic fields are the same thing.





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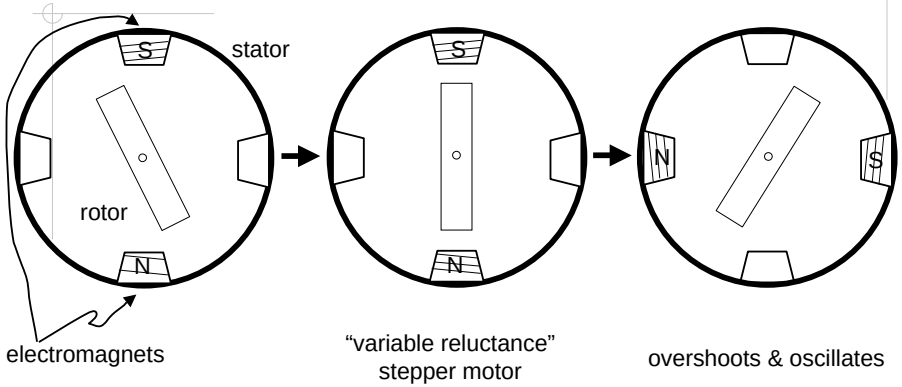
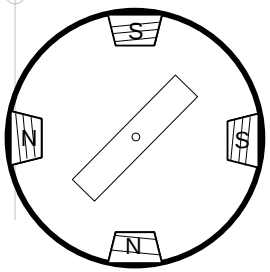
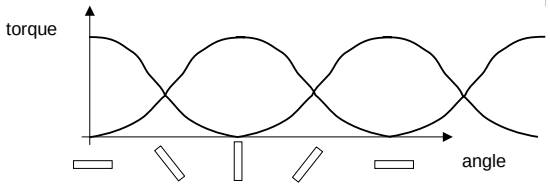


- Direct control of rotor position (no sensing needed) → printers, computer drives, machining
- May oscillate around a desired orientation
- Low resolution

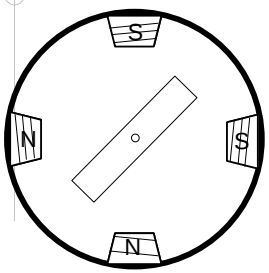
Increased Resolution





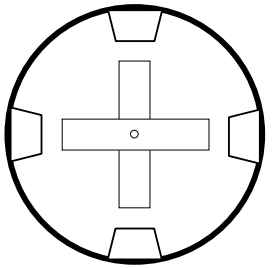
Half stepping

Increased Resolution

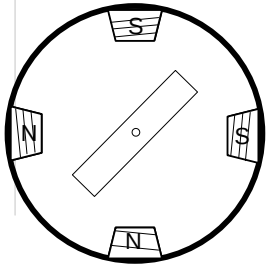


Half stepping

More teeth on rotor or stator

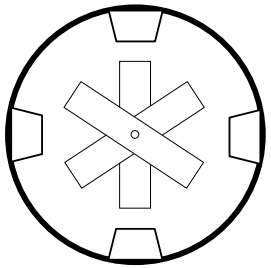


Increased Resolution



Half stepping

More teeth on rotor or stator



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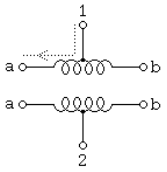
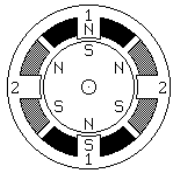
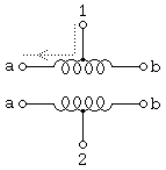
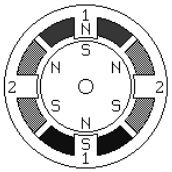




30 degree per step permanent magnet motor. Motor winding number 1 is distributed between the top and bottom stator pole, while motor winding number 2 is distributed between the left and right motor poles. The rotor is a permanent magnet with 6 poles, 3 south and 3 north, arranged around its circumference.

Stepper Motors





Note the following:

1.This 6-pole rotor turns in a direction opposite the rotation of the stator field; a two-pole rotor inside the exact same stator would rotate with the field.

2.This illustration is based on half-step control, where alternate half steps involve one and two motor windings.

3. It takes three complete cycles of the control system to turn this 6-pole rotor one revolution. A two-pole rotor would turn a full revolution per control system cycle.

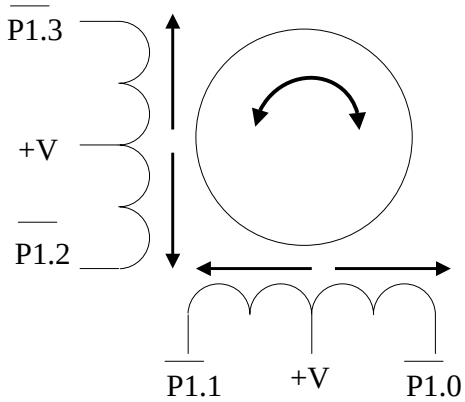
Stepper Motor Basics

1001

1010

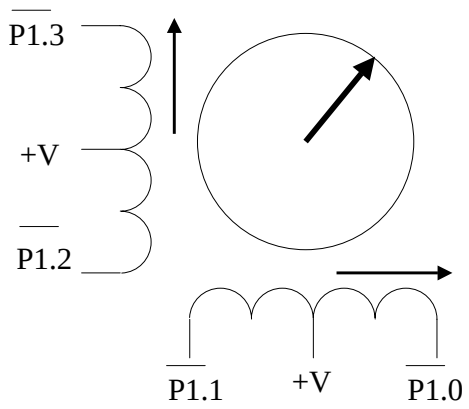
0110

0101



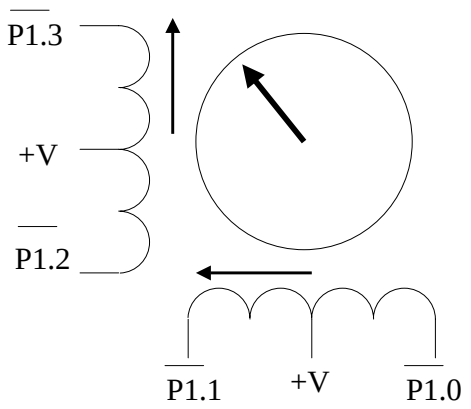
Stepper Motor Basics

1001



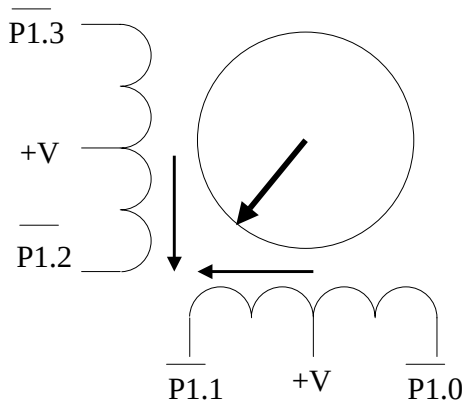
Stepper Motor Basics

1010



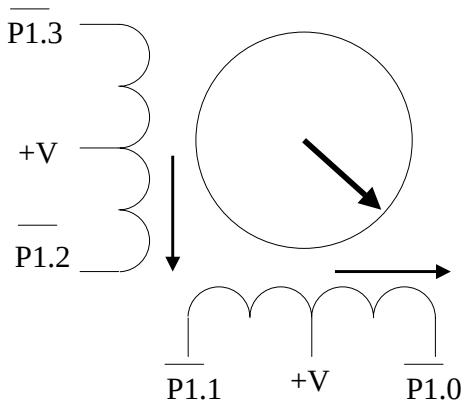
Stepper Motor Basics

0110



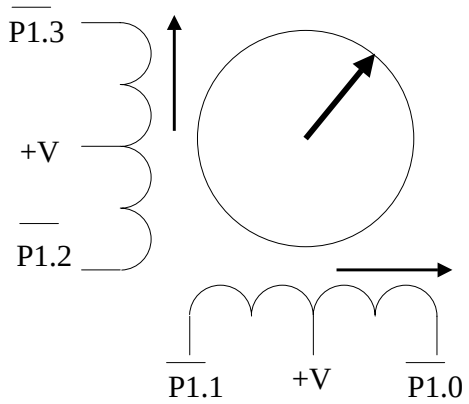
Stepper Motor Basics

0101



Stepper Motor Basics

1001



Stepper Motor Basics

1001
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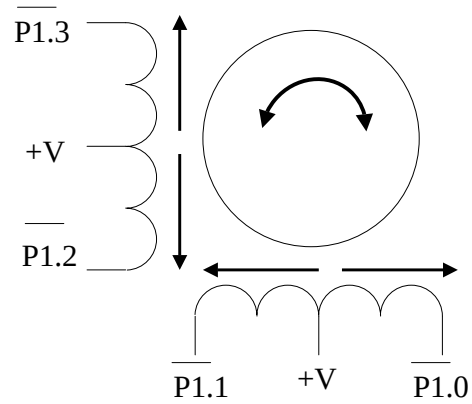
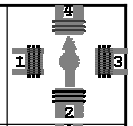
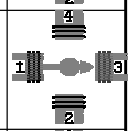
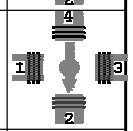
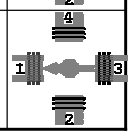


Stepper Motor Basics

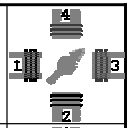
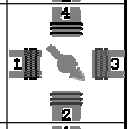
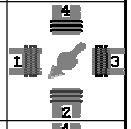
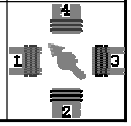
- Each step may only be a few degrees
- Step rate limited by motor inertia
- Example
  - One step equals 6 degrees
  - One step per millisecond

$$\frac{6^o}{10^{-3}\,\text{sec}} \times \frac{\text{rev}}{360^o} \times \frac{60\,\text{sec}}{\text{min}} = 100\text{rpm}$$

Single Coil Excitation

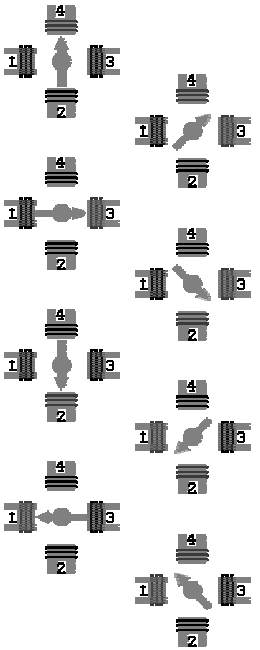
Coil 4	Coil 3	Coil 2	Coil 1	
On	Off	Off	Off	
Off	On	Off	Off	
Off	Off	On	Off	
Off	Off	Off	On	

Two Coil Excitation

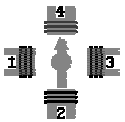
Coil 4	Coil 3	Coil 2	Coil 1	
On	On	Off	Off	
Off	On	On	Off	
Off	Off	On	On	
On	Off	Off	On	

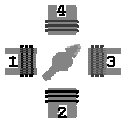
Interleaving for Half-stepping…

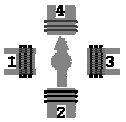
Coil 4	Coil 3	Coil 2	Coil 1
On	Off	Off	Off
On	On	Off	Off
Off	On	Off	Off
Off	On	On	Off
Off	Off	On	Off
Off	Off	On	On
Off	Off	Off	On
On	Off	Off	On



Running...







Step Motor Precautions

Stepper motors are simple rugged devices and are generally immune from:

A. Stall Condition- when the motor shaft is locked and the drivers continue to attempt to rotate it, the motor current is actually reduced, preventing damage. Stall's from operation at the natural resonance's step rates will similarly not result in damage.

B. High Currents - as long as the motor DOES NOT overheat it takes extremely high current to damage the magnets. A step motor can be driven with high current or high voltage power drives, provided that it is not allowed to over heat.

Step Motor Precautions

Most stepping motors can withstand 100 degree C. temperatures without damage. Excessive heat will melt insulating materials and cause the motor to freeze up beyond repair.

Factors that must be considered include duty cycle, thermal time constant, heat conduction (sinking) to the system, ambient temperatures and air flow. As a rule of thumb (ROT) if you can hold onto the motor, than it isn't too hot.