# Stepper Motors

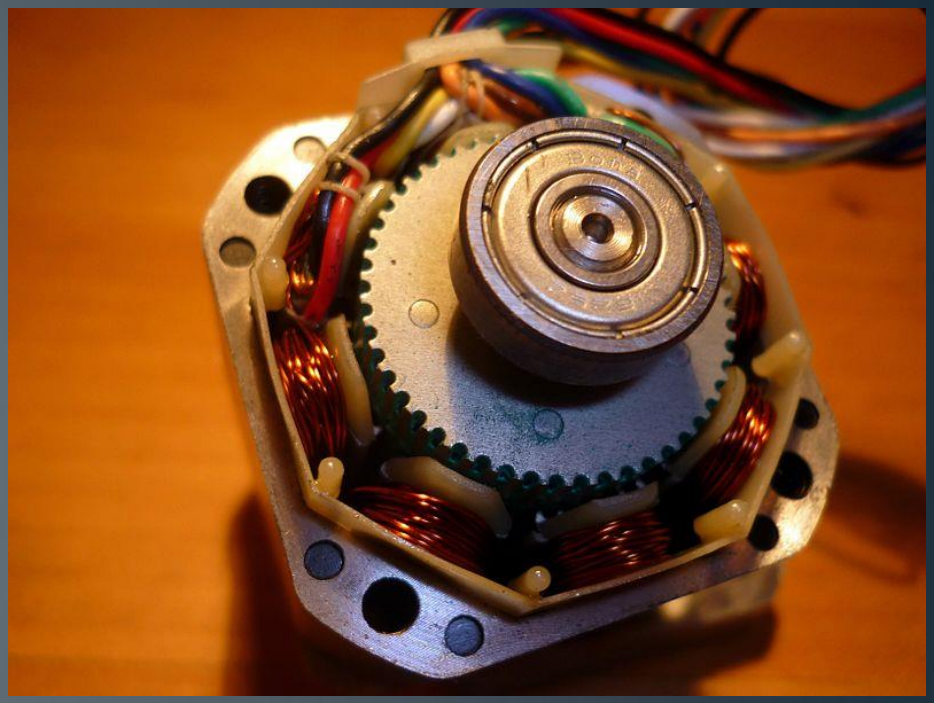
# Stepper Motor Applications

Stepper motors are used in many controlled-position applications.

Some of these applications include . . .

Printers, scanners, positioning laser optics, controlling valves, etc.

# Stepper Motor Guts



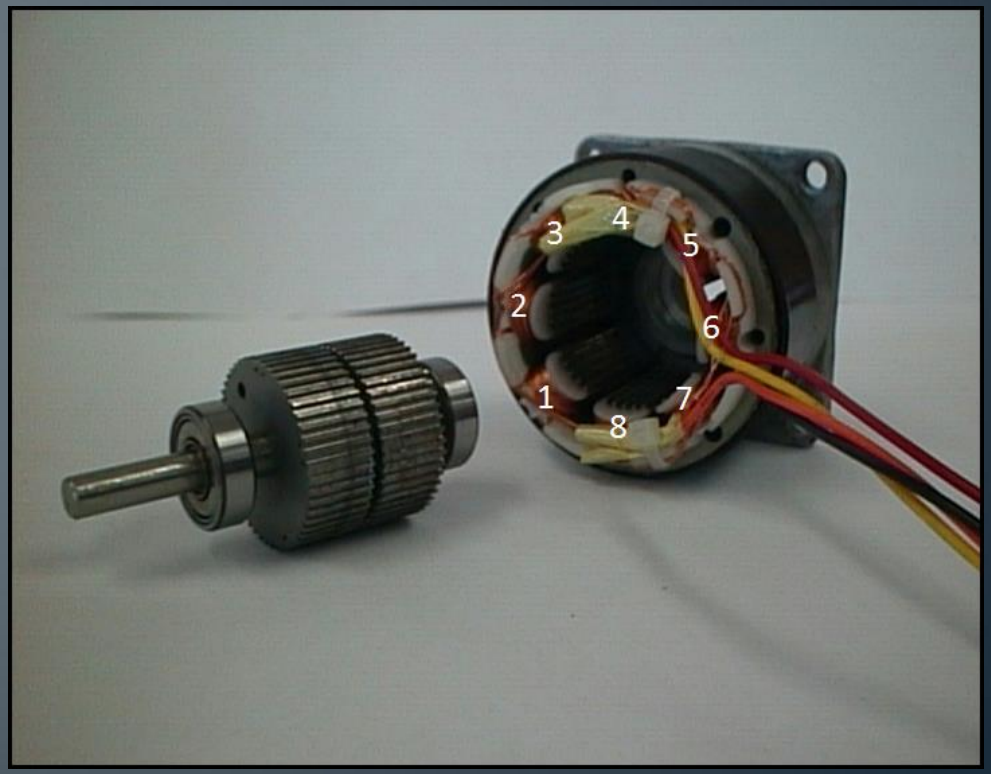
The stator is made up of coil windings and the rotor is either a permanent magnet or an induced magnet (more on the rotor later).

# How Stepper Motors Work

A stepper motor is a special kind of motor that moves in steps. Each step is controlled by energizing one or more of the coils (electromagnets) in some kind of rotational pattern.

This picture shows 8 coils that can be energized.

For example, we could energize coil 1, then coil 2, then coil 3, and so on so that the rotor moves in a rotational fashion.



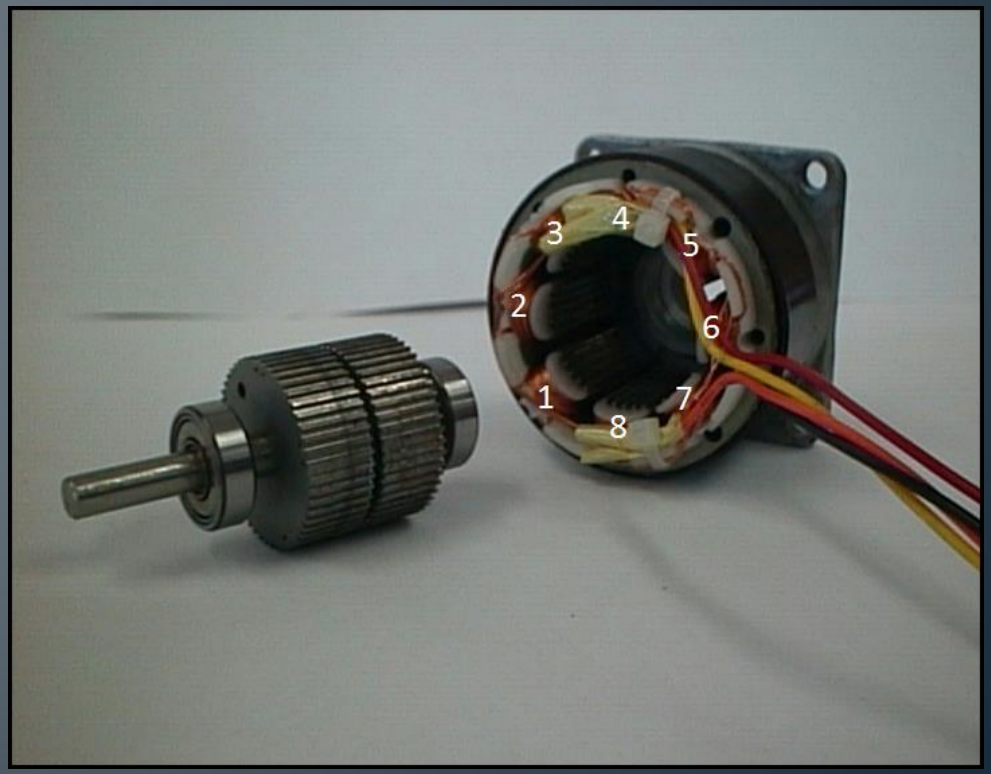
# How Stepper Motors Work

The rate at which we energize consecutive steps determines the motor's speed *(unless the rate is too fast and the motor can't keep up)*.

Stepper motors can move continuously or a finite amount.

The resolution can be from 90 deg (4 steps/revolution) down to 0.72 deg (500 steps/revolution).

The most common stepper motor has 200 steps or 1.8° resolution.



# Stepper Motor Advantages & Disadvantages

Advantages

No brushes (less maintenance)

Do not need an encoder since we can keep track of the number of steps the motor has rotated.

Disadvantages

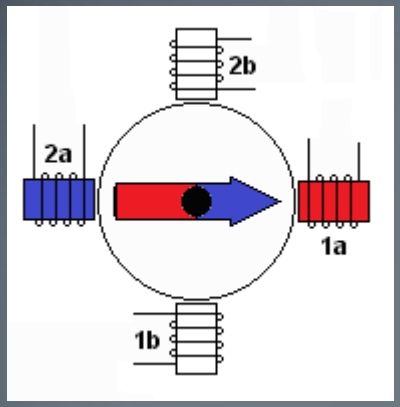
Low torque compared with brushed DC Motors

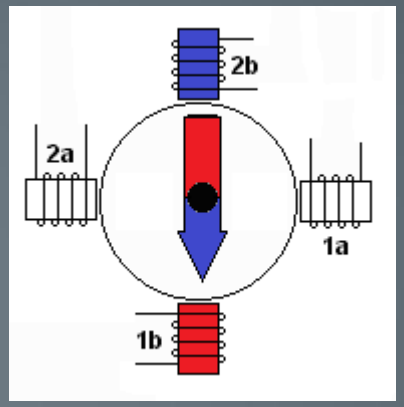
Limited Speed

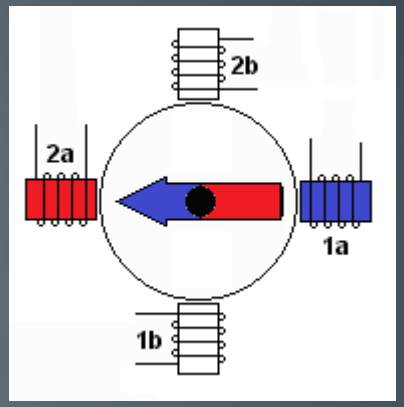
High Vibration (b/c of the steps)

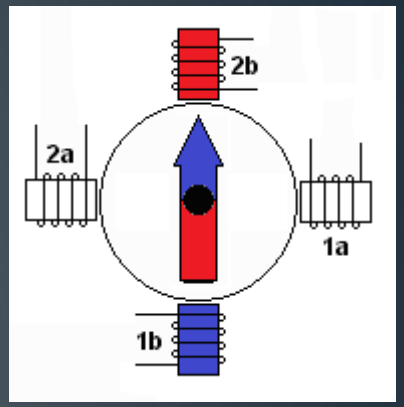
Note: Stepper motors were designed to provide positioning capability without the need for feedback.

# Stepping Mode 1: Single Stepping



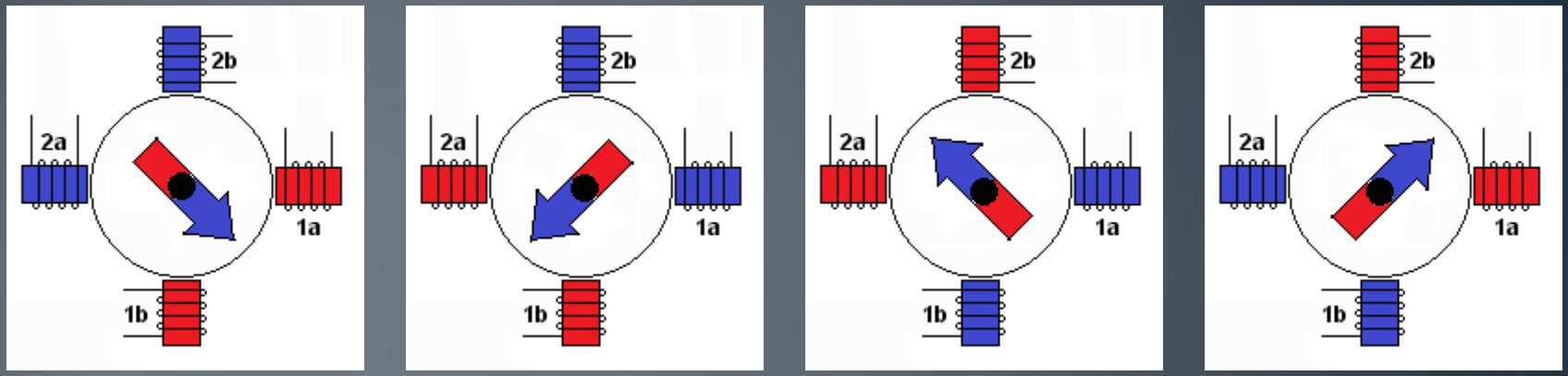




Single stepping energizes one pair of coils sequentially. This type of stepping has the least amount of torque, but uses the least amount of power.

*Note: Red means either north or south pole of magnet, blue is the opposite polarity as the red pole, and the white coil means it is not energized.*

| Red Coil Energized | | | |
|---|---|---|---|
| 1a | 1b | 2a | 2b |
| 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 |

# Stepping Mode 2: Power Stepping

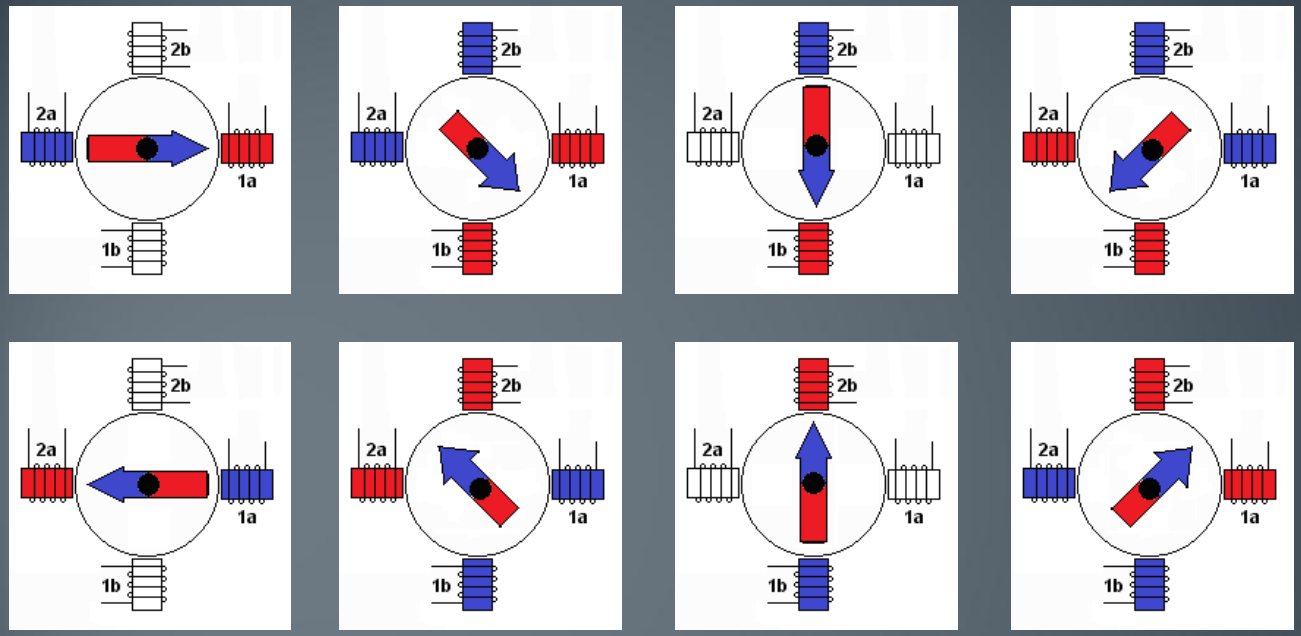



Power stepping energizes all of the coils.

Power stepping consumes twice the power and has 1.4 times more torque than single stepping.

| Red Coil Energized | | | |
|---|---|---|---|
| 1a | 1b | 2a | 2b |
| 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 |

# Stepping Mode 3: Half Stepping

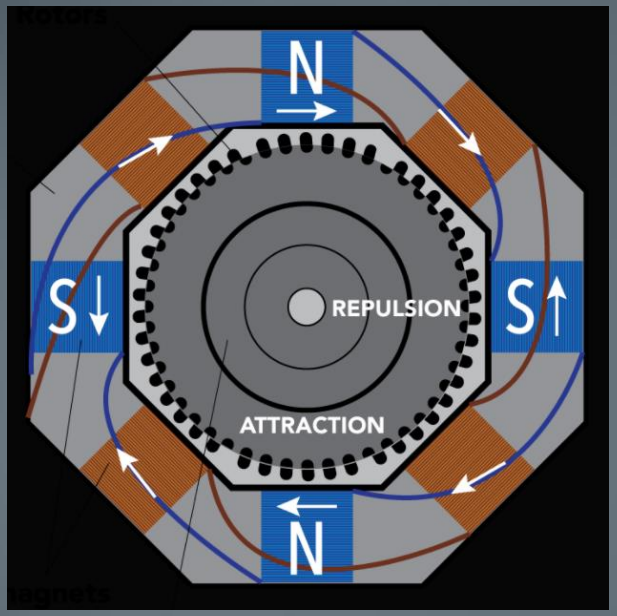



This combines both single stepping and power stepping.

Consumes 1.5 times the power and has ~1.2 times more torque as single stepping (note: torque varies with # coils on).

| Red Coil Energized | | | |
|---|---|---|---|
| 1a | 1b | 2a | 2b |
| 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 |

# More Accurate Depiction Inside a Stepper Motor




There exist teeth on both the rotor as well as the stator. The stator has a couple of fewer teeth than the rotor (see image). This makes it so that the top & bottom sides are completely aligned (attraction) and the left & right sides are completely unaligned (repulsion).

# Step Size (Resolution)

Step size is the number of degrees per step. Half-stepping gives you twice the resolution as power or single stepping.

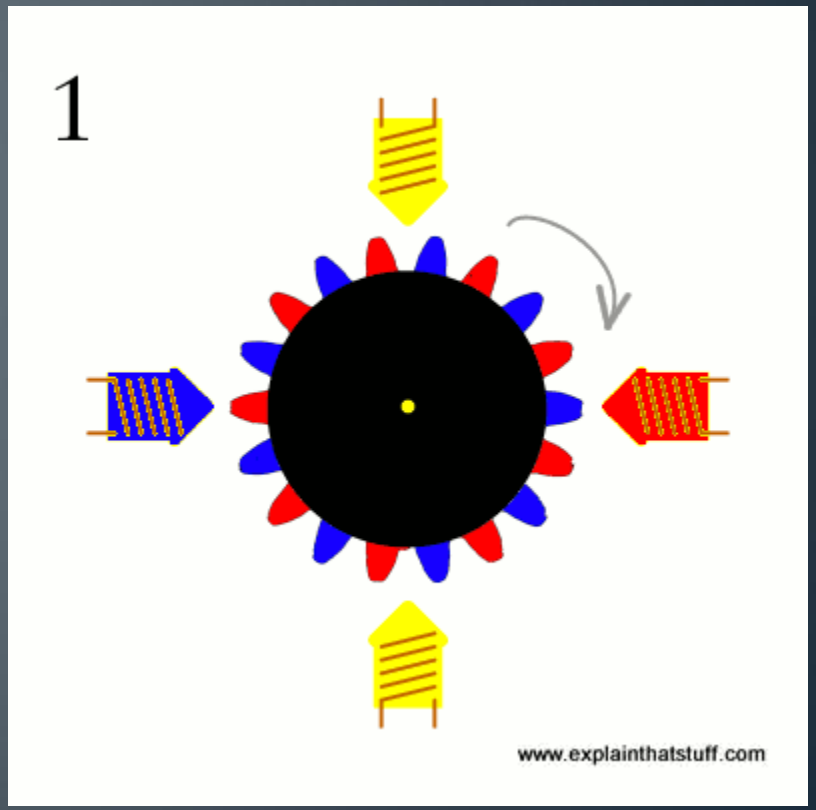
Stepper Motor Resolution is equal to…

$$\frac{360^\circ}{2 \times \left(\text{\# of Rotor Teeth}\right) \times \left(\text{\# of Stator Phases}\right)}$$

For example:
The diagram on this slide has 18 teeth and 4 coils.

Resolution = 360˚ / (2*18*2) =
5 degree resolution.

Note: Most steppers have only 2 phases



# Three Types of Stepper Motors

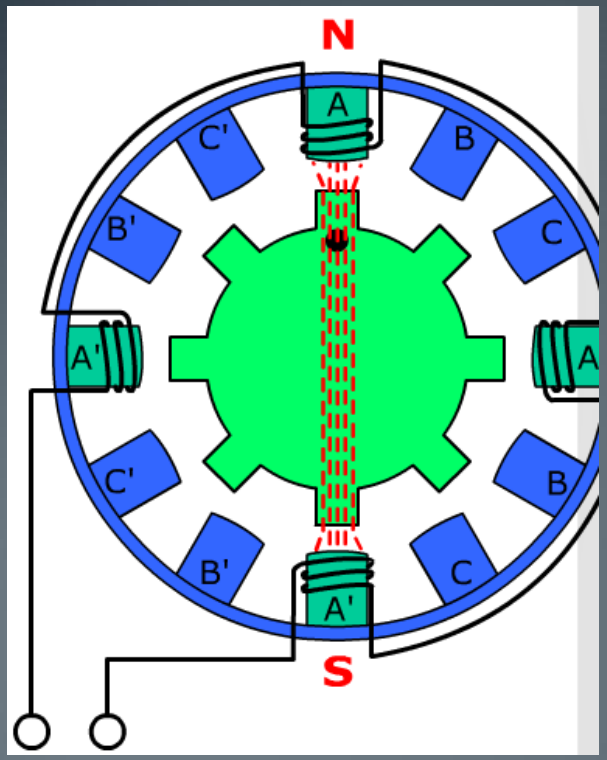
I. Variable Reluctance
II. Permanent Magnet
III. Hybrid

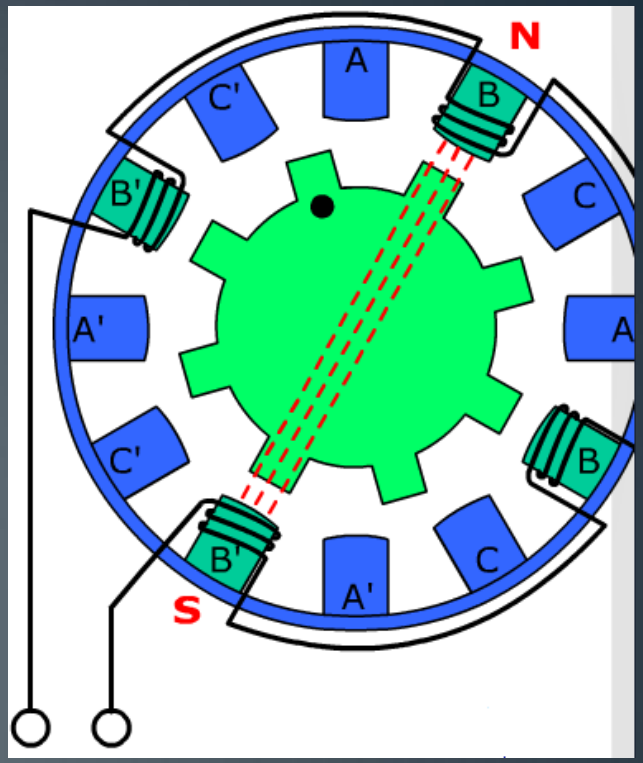
# I. Variable Reluctance Stepper Motor

A **variable reluctance** stepper motor has a ferromagnetic rotor instead of a permanent magnet. The iron rotor becomes an induced magnet when exposed to a magnetic field.

Magnetic Reluctance is analogous to Electric Resistance. Since the iron has less reluctance than air, the magnetic field lines want to travel through the iron instead of around the iron through the air, which causes the iron to magnetize.

The rotor is always becoming magnetized and moves in a manner such that the closest tooth moves toward the energized coil. This type of motor always works by attraction and never by repulsion.




The coils opposite from one another are wired in such a way so that one side is N while the other side is S. Note: each diagram has more wires on it than shown to make the pictures easier to look at.

Notice that we start with the dotted tooth being attracted to A. When we switch the energized coil in the clockwise fashion from A to B, the rotor spins counter-clockwise (the opposite direction). Remember the rotor always moves so that the closest tooth is attracted since we are magnetizing the iron each time. Also note that the dotted tooth is no longer magnetized in the second diagram.

Variable reluctance motors always move in the opposite direction as the energized coils.

# Advantages and Disadvantages to Variable Reluctance Stepper Motors

Advantages

- Since we are not using a permanent magnet, these motors are cheaper.
- Have higher torque at higher speeds than PM Steppers.

Disadvantages

- High torque ripple (doesn't maintain a constant torque)
- Less overall torque at lower speeds than PM Steppers.

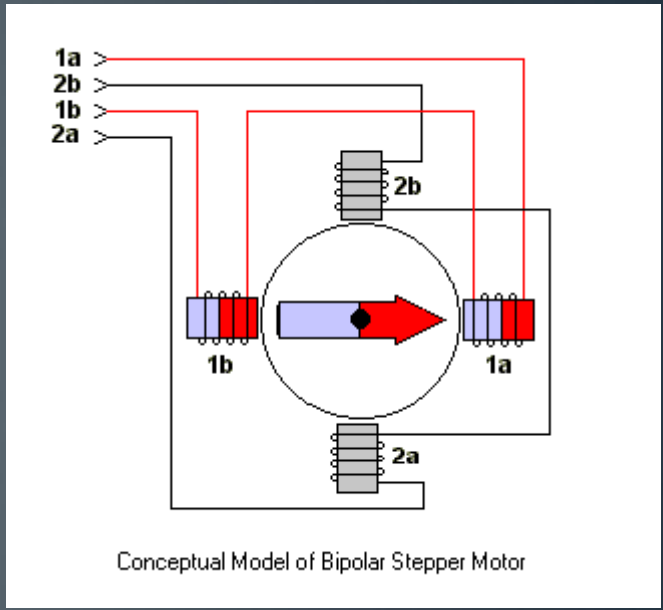
# Permanent Magnet Stepper Motors

- Permanent Magnet Stepper Motors (as the name suggests) has a rotor that consist of a permanent magnet.
- These motors spin in the same direction as the rotating magnetic field.
- These motors have higher torque than variable reluctance motors at lower speeds.

# II-a. Bipolar Stepper Motor

A bipolar stepper motor wiring have coils across from each other are wired together with the polarity of these coils being opposite.

Bipolar motors have 4 wires coming from the motor.



Conceptual Model of Bipolar Stepper Motor

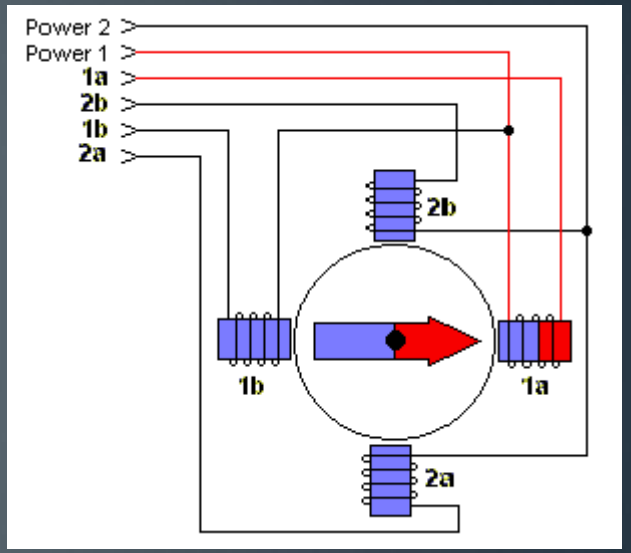
# II-b. Unipolar Stepper Motor

A unipolar stepper motor is exactly like a bipolar stepper motor except the two opposite coils have a center tap.

This allows you to have one coil on and not both coils if you desire.

This gives you more flexibility so that you can use less power (sacrificing less torque) or you can run the motor just like a bipolar stepper motor.

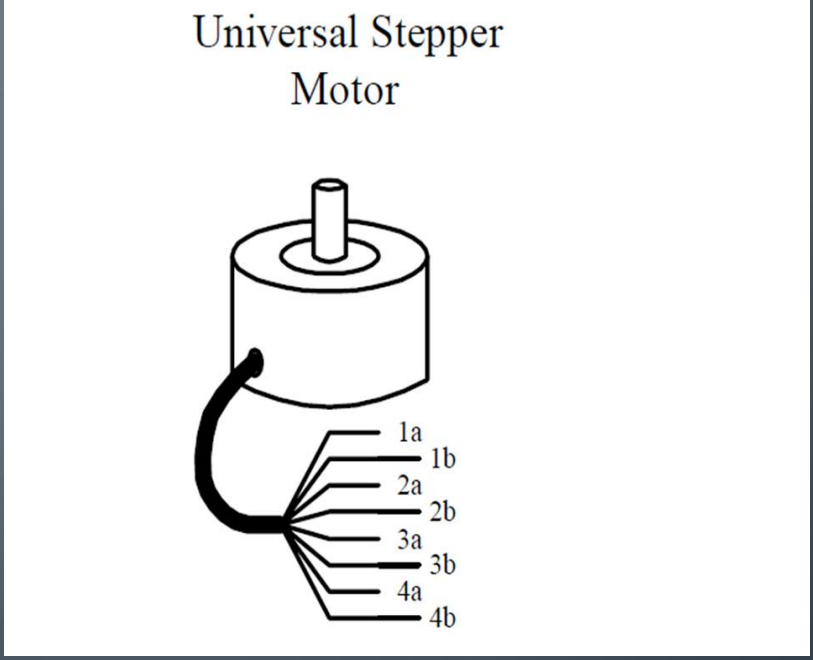
Unipolar stepper motors usually consist of 5 or 6 wires. A 5 wire motor means that the two center taps are connected together, whereas a 6 wire motor means that the center taps are isolated.



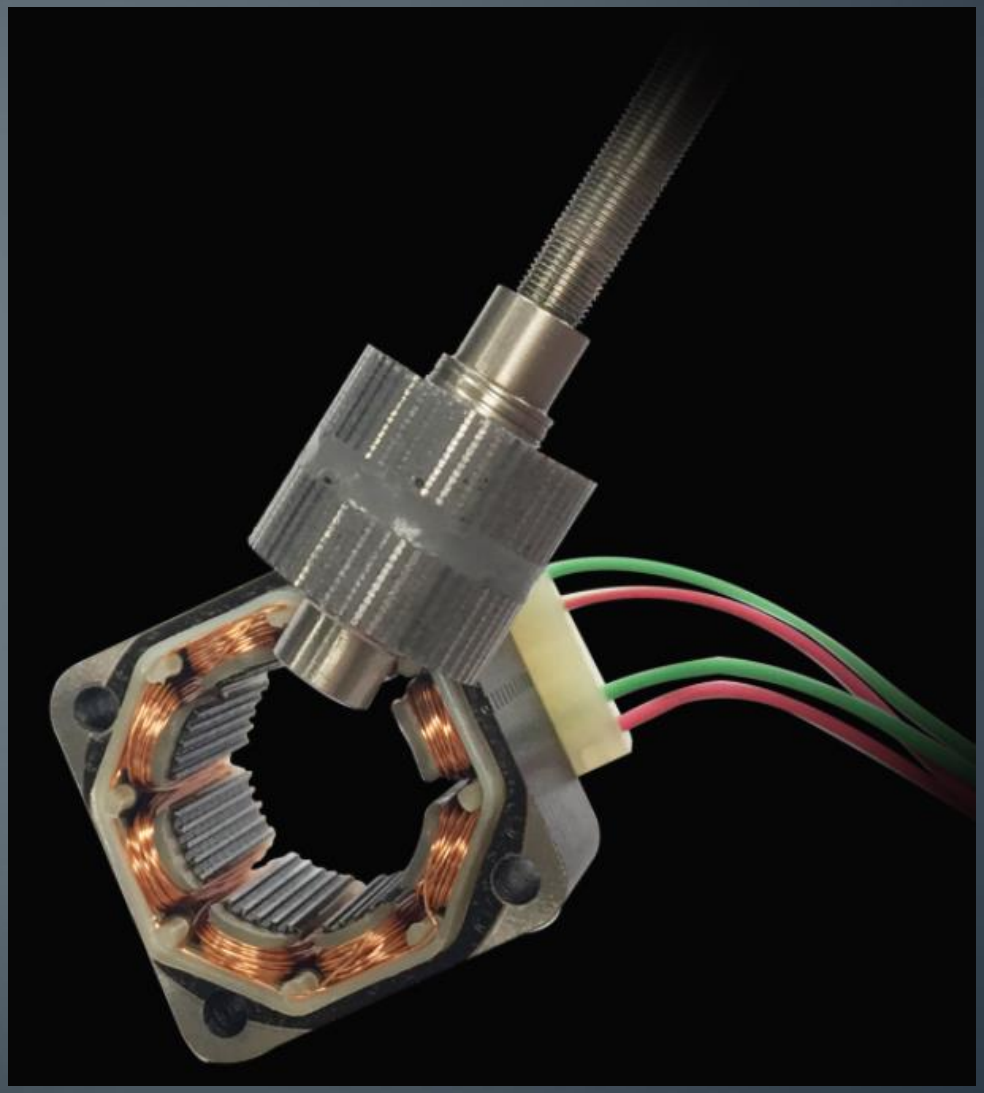
# II-c. Universal Stepper Motor

A universal stepper motor has a pair of wires for each coil, therefore these motors can be run like unipolar or bipolar stepper motors.

These motors give you ultimate flexibility at the expense of having to deal with 8 wires.

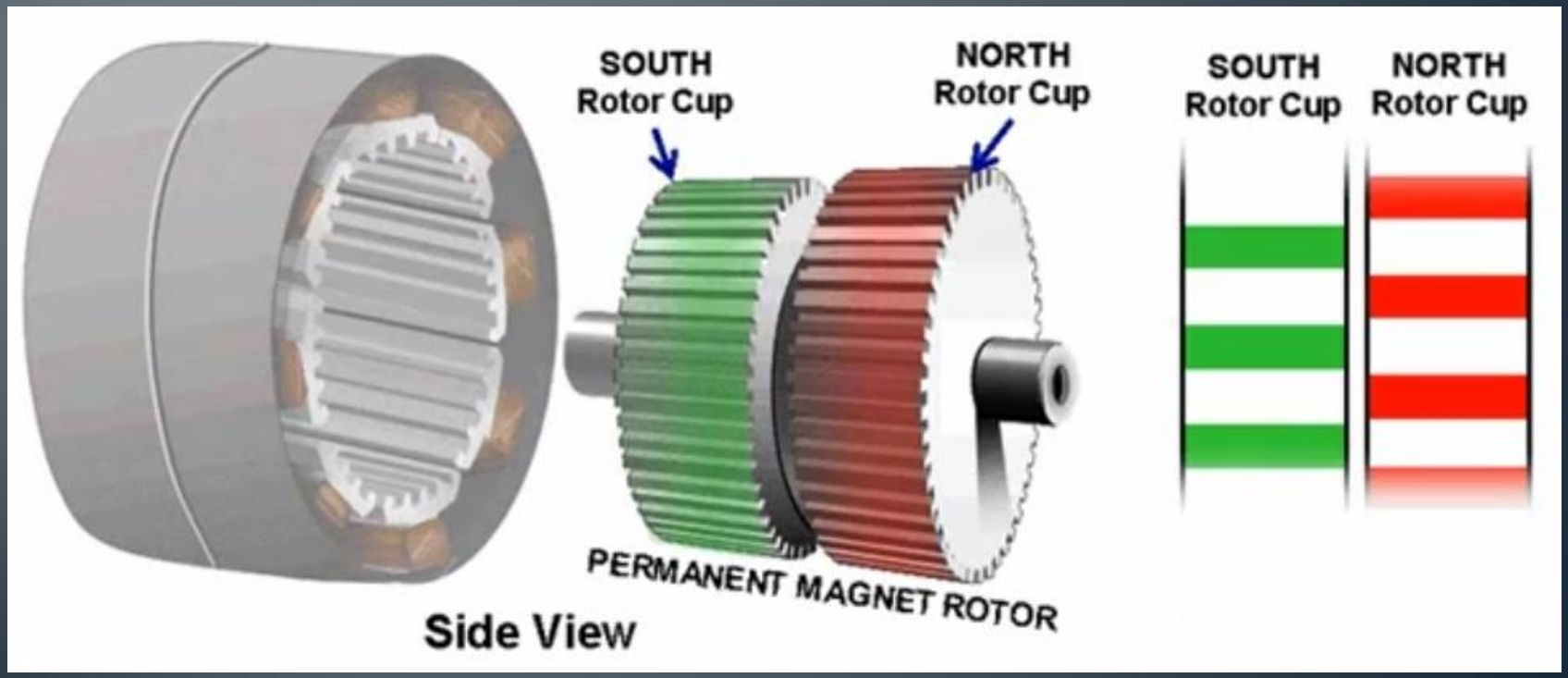


# III. Hybrid Stepper Motor



# III. Hybrid Stepper Motor

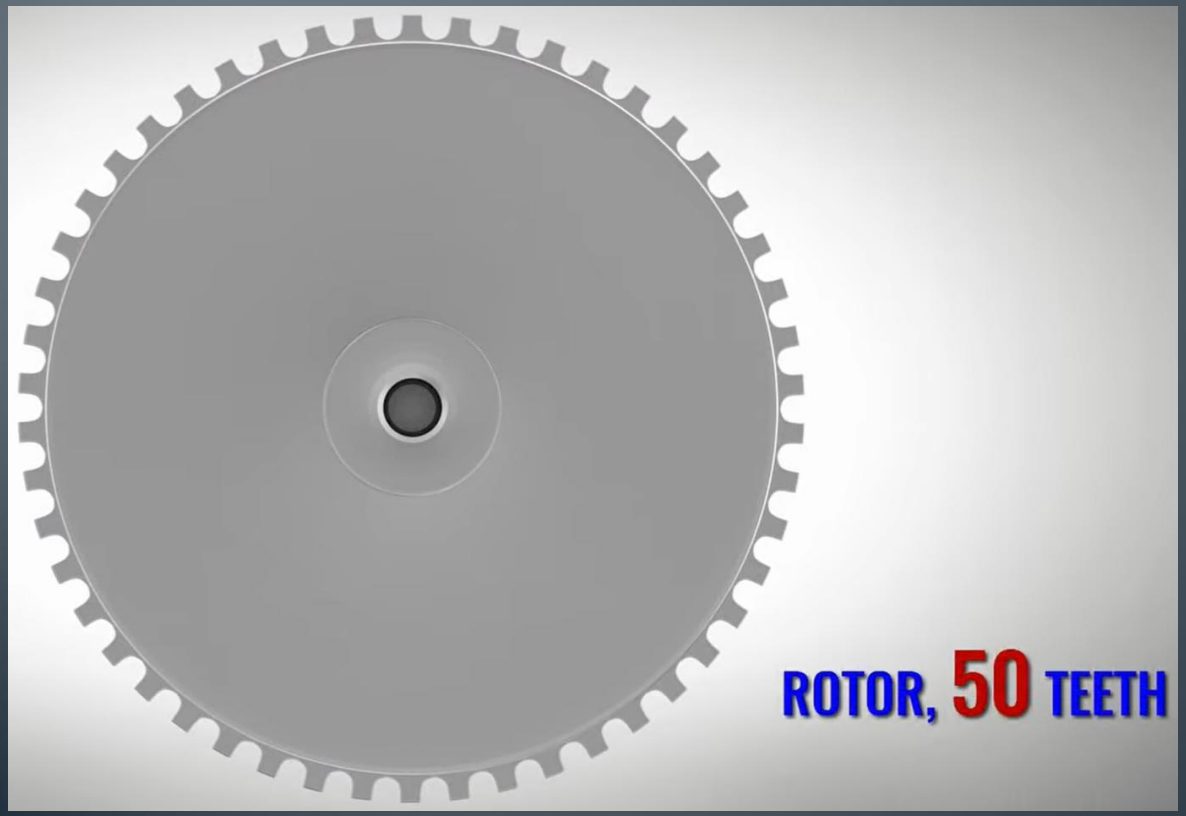
A hybrid stepper motor combines variable reluctance motor with a permanent magnet motor. The cylindrical shaft of the rotor is a permanent magnet while the teeth are made of iron. One set of teeth makes up a north side while the other set is the south side. Notice that the two sets of teeth are out of phase with each other.



# Hybrid Stepper Motor

The advantage to a hybrid stepper motor is that you can get a smaller step size since you have 2 sets of teeth.

If a rotor has 50 teeth, then the resolution would be 360°/(2*50*2) = 1.8°. But since the motor is a hybrid, the resolution is half as small at 0.9° per step.



# Decoding Stepper Motors

If you are handed a stepper motor, then how can you tell which type of motor you have since there are so many varieties?

If the shaft spins freely, then it's a variable reluctance motor.

If it has 4 wires, then it is likely a bipolar stepper motor

If it has 5 or 6 wires, then it's likely a unipolar stepper motor. 5 wires means the two center taps are connected and 6 wires means the two center taps are not connected.

If it has 8 wires, then it's likely a universal stepper motor.

I don't know how you can tell if it's a hybrid stepper motor or not.

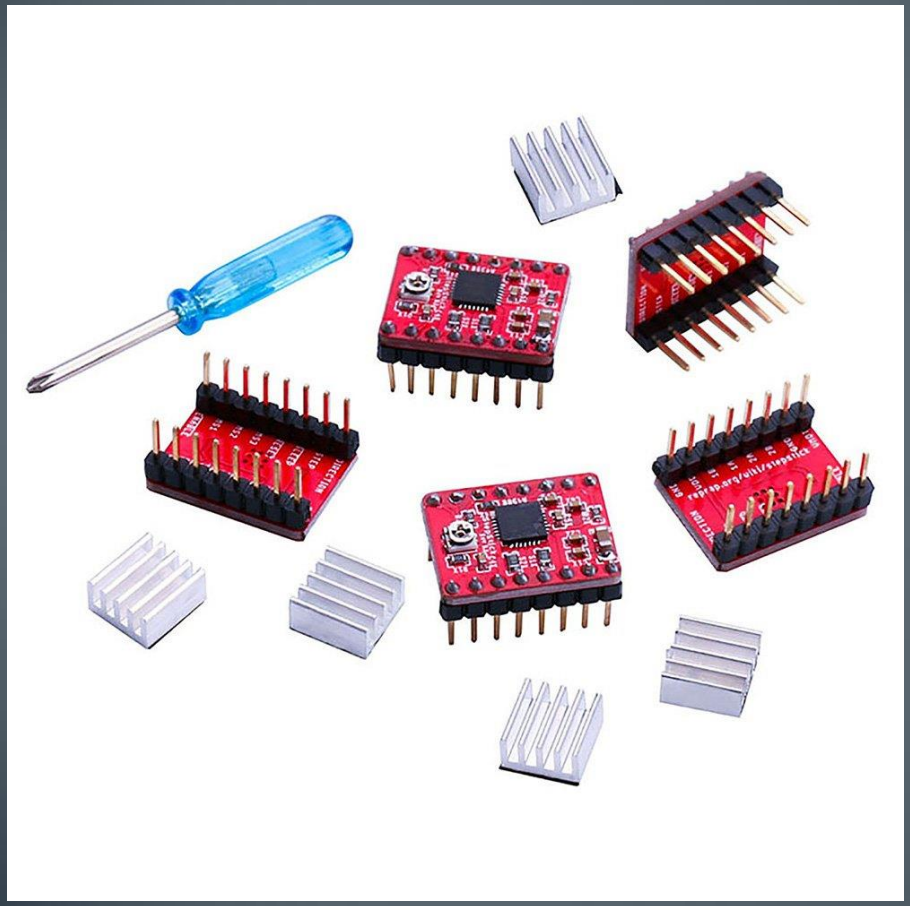
# Decoding the stepper motors leads

You can decode the stepper motor's leads by measuring the resistance.

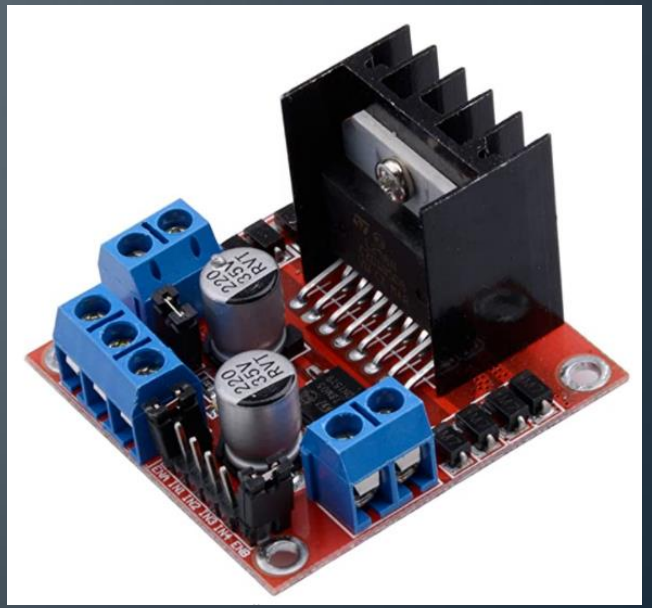
If you get infinite resistance, then this means that you are measuring on different coils.

If you get say 30 Ω between wires A & B and then you get a value that is half of that (15 Ω) between wires A & C, then C is the center tap and you can conclude that the resistance between B & C will also equal 15 Ω.

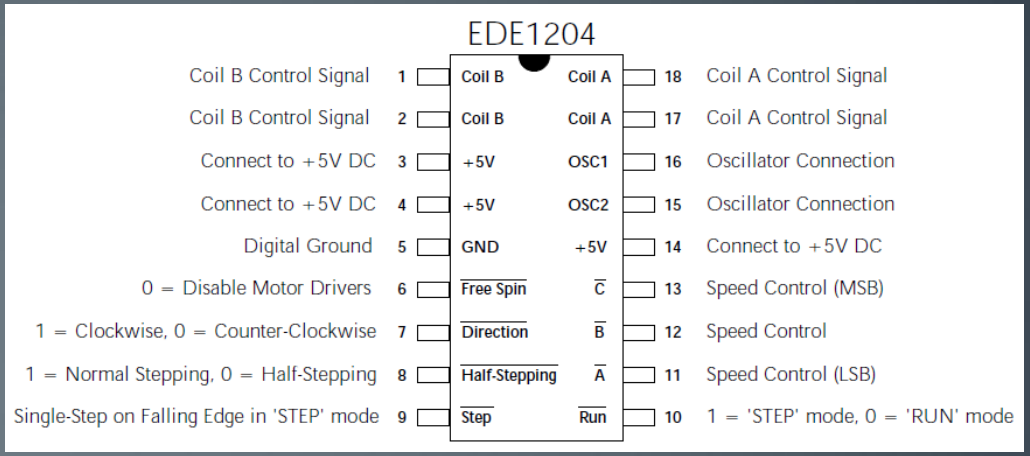
# Stepper Motor Driver



You can purchase stepper motor drivers from Amazon. These come in a pack of 5 for only $13. I just did a quick search on Amazon for stepper motor driver to find these.



# Bipolar Stepper Motor Controller – EDE1204 OUTDATED ☹




Here is an IC that controls a bipolar stepper motor.

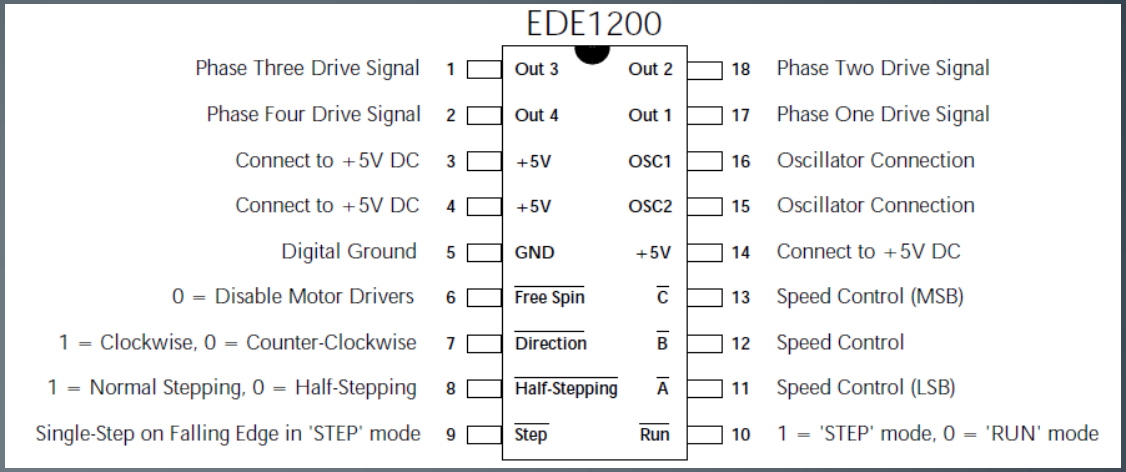
Pin 10 controls Step mode or Run mode. Run mode continuously spins while step mode steps the motor once. Use a falling edge on pin 9 to step the motor (in step mode).

Pins 11 thru 13 control the speed of the motor. Note: It shows it as active low, but it's actually active high.

Typically you connect a crystal from pin 16 to pin 15 (maximum frequency is 4 MHz). You can also connect the TTL output of the function generator to either one of these pins.

The spec sheet shows hooking up this IC to the L293 H-Bridge. The H-Bridge is used to provide current to the motor (current amplifier)

# Unipolar Stepper Motor Controller – EDE1200 OUTDATED ☹




This chip works exactly the same as the previous chip, except pins 1, 2, 17, 18 are different.

These outputs provide the grounds for the coils. The power is supplied through the center taps of the coils.