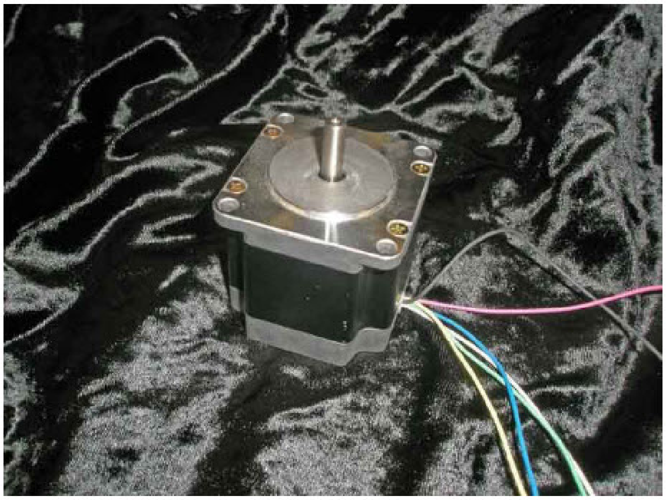
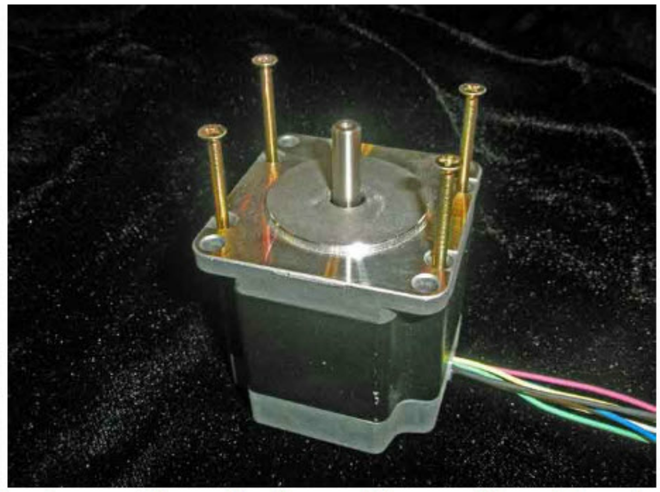
Stepper Motor Disassembled



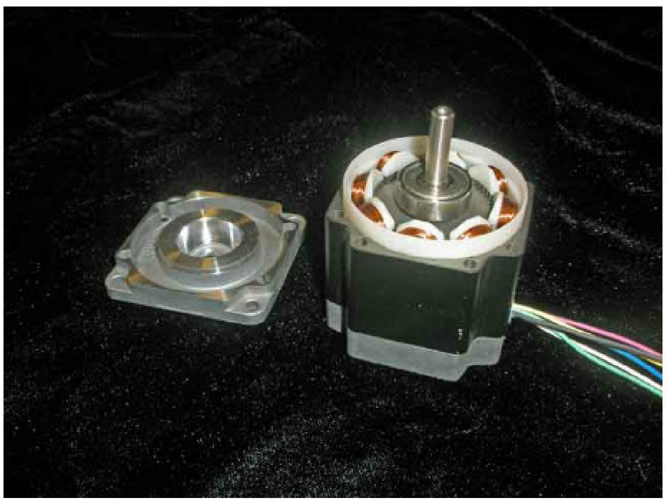
What Does a Stepper Motor Look Like on the Inside?

Stepper Motor Disassembled



The Screws Clamp the Top and Bottom Plates Together.

Stepper Motor Disassembled



Top Plate Removed Revealing Stator and Rotor

Stepper Motor Disassembled

The Rotor Slides Right Out

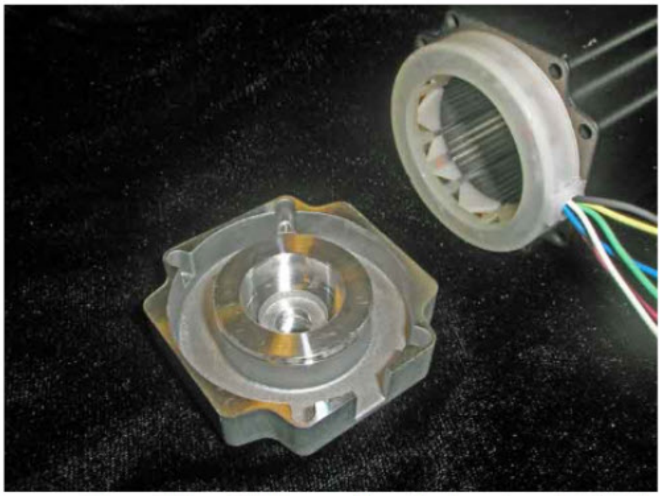
Stepper Motor Disassembled

Rotor Removed. Note Bearings Pressed on Both Sides. The Rotor is Really a Stack of Around 60 Magnetic Disks

Stepper Motor Disassembled

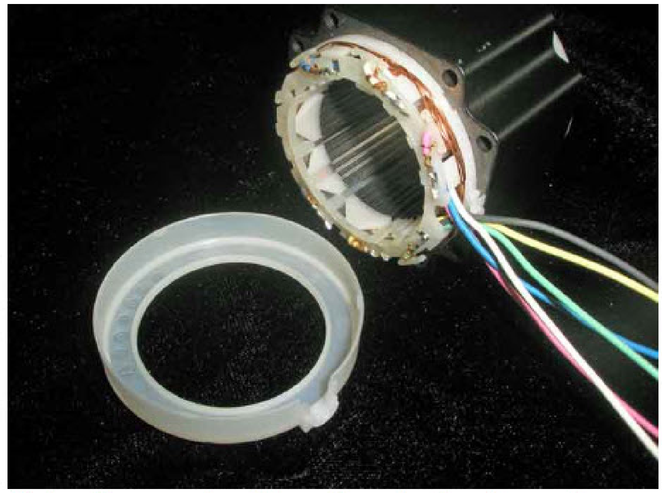
Stator with Windings. You Can See the Race Where the Bottom Bearing Rests.

Stepper Motor Disassembled



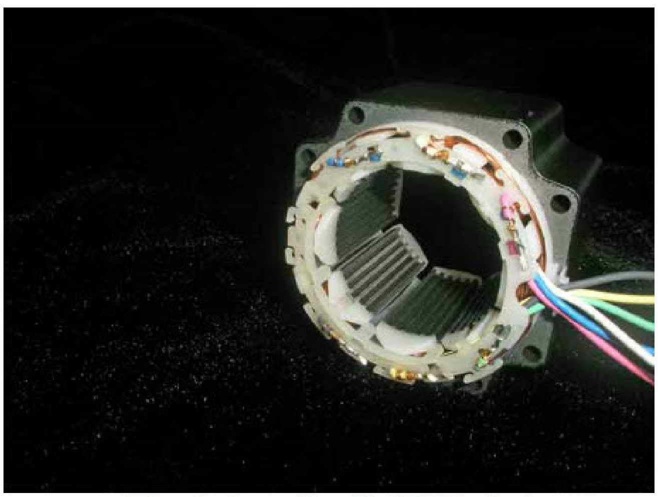
Bottom Plate Slides Off Revealing the insulated Coil Ring.

Stepper Motor Disassembled



Insulation Removed to Show How the Leads are Connected.

Stepper Motor Disassembled



That is Some Detailed Soldering!

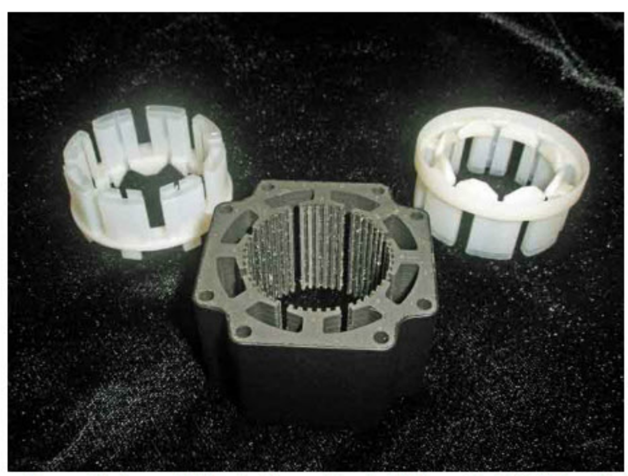
Stepper Motor Disassembled

Wire From Just One of Eight Poles.

Stepper Motor Disassembled

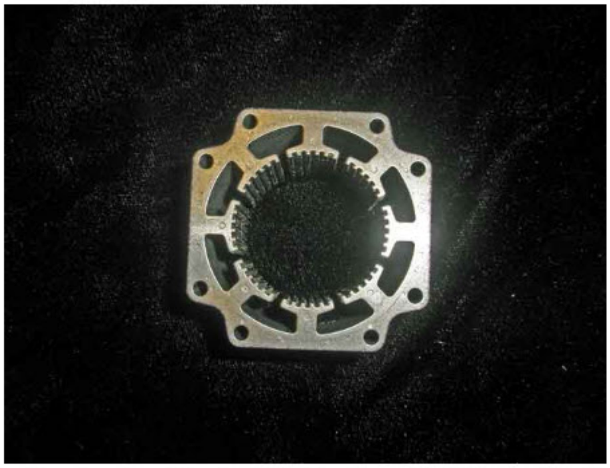
Stator with All of the Wire Removed.

Stepper Motor Disassembled



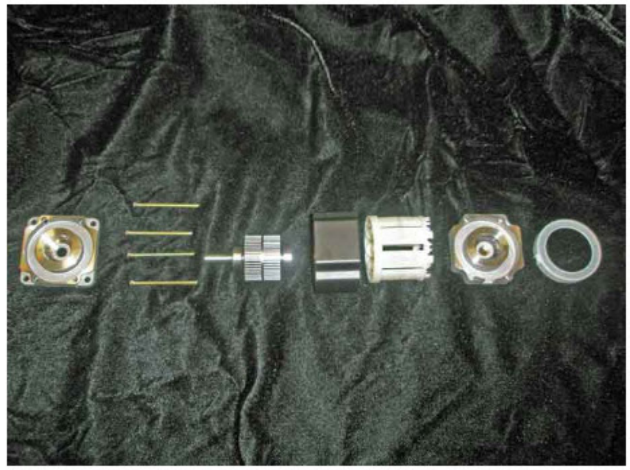
Insulator Halves Slide in from Both Sides. Coil Wiring Holds them Together.

Stepper Motor Disassembled



The Housing is a Stack of Plates Too. Not Magnetized. Coils do that.

Stepper Motor Disassembled



A Lot of Parts in the Humble Stepper.

Stepper Motor Disassembled

Oops, Forgot the Wire. 60 Yards of it!

<u>What is a stepper motor?</u>

1. **A stepper motor (or step motor) is a brushless, synchronous electric motor t**hat can divide a full rotation into a large number of steps. The motor's position can be controlled precisely without any feedback mechanism (see Open-loop controller), as long as the motor is carefully sized to the application. Stepper motors are similar to switched reluctance motors (which are very large stepping motors with a reduced pole count, and generally are closed-loop commutated.

2. **Stepper motors operate differently from DC brush motors**, which rotate when voltage is applied to their terminals. Stepper motors, on the other hand, effectively have multiple "toothed" electromagnets arranged around a central gear-shaped piece of iron. The electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet. So when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those slight rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle.

3. **<u>Stepper motor characteristics</u>**

1. Stepper motors are constant power devices.

2. As motor speed increases, torque decreases. (most motors exhibit maximum torque when stationary, however the torque of a motor when stationary 'holding torque' defines the ability of the motor to maintain a desired position while under external load).

3. The torque curve may be extended by using current limiting drivers and increasing the driving voltage (sometimes referred to as a 'chopper' circuit, there are several off the shelf driver chips capable of doing this in a simple manner).

4. Steppers exhibit more vibration than other motor types, as the discrete step tends to snap the rotor from one position to another (called a detent). The vibration makes stepper motors noisier than DC motors.

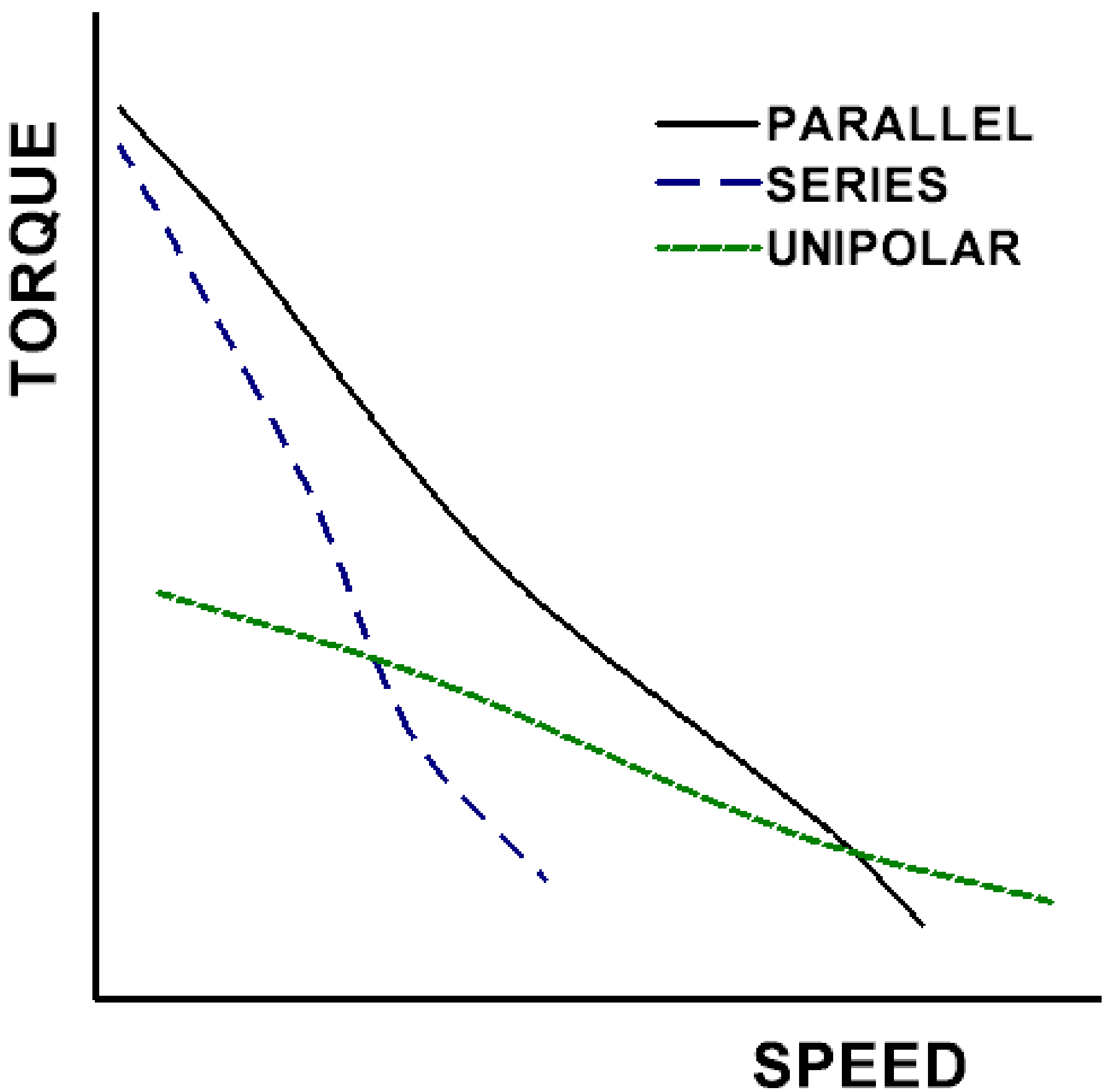
5. This vibration can become very bad at some speeds and can cause the motor to lose torque or lose direction. This is because the rotor is being held in a magnetic field which behaves like a spring. On each step the rotor overshoots and bounces back and forth, "ringing" at its resonant frequency. If the stepping frequency matches the resonant frequency then the ringing increases and the motor comes out of synchronism, resulting in positional error or a change in direction. At worst there is a total loss of control and holding torque so the motor is easily overcome by the load and spins almost freely.

6. The effect can be mitigated by accelerating quickly through the problem speeds range, physically damping (frictional damping) the system, or using a micro-stepping driver.

7. Motors with a greater number of phases also exhibit smoother operation than those with fewer phases (this can also be achieved through the use of a micro stepping drive)

Stepper Motor Connection Options

Stepper motors with more than 5 wires can me connected in different ways. As this graph illustrates, each has advantages and disadvantages. Notice that although parallel windings appear to give the best performance, they do require a more expensive bi-polar driver and more than 40% additional drive current... /and/ most motors in parallel bipolar mode will loose torque at high speeds faster than they do in unipolar mode.



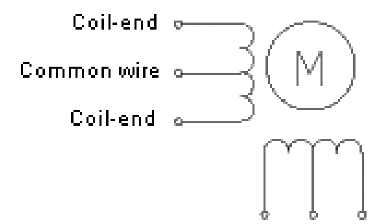
Comparing Wiring Options for Stepper Motors

Wiring	Motor Wires	Connections	**Resistance** in Ohms	**Inductance** in millihenries	**Current** in Amperes	**Voltage** in Volts	**Holding Torque**
Unipolar	4	not an option	as rated	as rated	as rated	as rated	as rated
	5	Common wire to + power, then A+,A-,B+,B- to unipolar driver					
	6	Short common A to common B, connect common wires to + power, then A+,A-,B+,B- to unipolar driver					
	8	Connect A coils in series (A+' to A-'), and B coils in series (B+' to B-'), short the center between A to the center between B (A+'/A-' to B+'/B-'), connect all those center wires to + power, then A+,A-,B+,B- to unipolar driver					
Bipolar -Series	4	A+,A-,B+,B- to bipolar driver	twice the rated value	4 times the rated value	0.707 * rated	1.414 * rated	1.414 * rated
	5	not an option					
	6	Common A and common B are held apart and not connected to anything. A+,A-,B+,B- to bipolar driver with 41% higher voltage than the motor rating.					
	8	Connect A coils in series (A+' to A-'), and B coils in series (B+' to B-'), then A+,A-,B+,B- to bipolar driver with 41% higher voltage than the motor rating.					
Bipolar -Half Coil	4	not an option, unless wired internally by mfgr (very rare)	as rated	as rated	as rated	as rated	as rated
	5	not an option					
	6	not an option					
	8	Only one A coil and one B coil are connected. A+,A+',B+,B+' to bipolar driver (A-, A-', B-, B-', are held apart, disconnected from everything)					
Bipolar -Parallel	4	not an option, unless wired internally by mfgr	half the rated value	as rated	1.414 * rated	0.707 * rated	1.414 * rated
	5	not an option					
	6	not an option					
	8	A coils in parallel (A+ to A-, A+' to A-'), B coils in parallel (B+ to B-, B+' to B-'), each set (A+/A-, A+'/A-', B+/B-, B+'/B-') to bipolar driver with 41% more current capacity than the motor rating.					

Unipolar motors

A unipolar stepper motor has two windings per phase, one for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (eg. a single transistor) for each winding. Typically, given a phase, one end of each winding is made common: giving three leads per phase and six leads for a typical two phase motor. Often, these two phase commons are internally joined, so the motor has only five leads.

A microcontroller or stepper motor controller can be used to activate the drive transistors in the right order, and this ease of operation makes unipolar motors popular with hobbyists; they are probably the cheapest way to get precise angular movements.



Unipolar stepper motor coils

(For the experimenter, one way to distinguish common wire from a coil-end wire is by measuring the resistance. Resistance between common wire and coil-end wire is always half of what it is between coil-end and coil-end wires. This is because there is twice the length of coil between the ends and only half from center (common wire) to the end.) A quick way to determine if the stepper motor is working is to short circuit every two pairs and try turning the shaft, whenever a higher than normal resistance is felt, it indicates that the circuit to the particular winding is closed and that the phase is working.

Bipolar motor [edit]

Bipolar motors have a single winding per phase. The current in a winding needs to be reversed in order to reverse a magnetic pole, so the driving circuit must be more complicated, typically with an H-bridge arrangement (however there are several off the shelf driver chips available to make this a simple affair). There are two leads per phase, none are common.

Static friction effects using an H-bridge have been observed with certain drive topologies[*citation needed*].

Because windings are better utilized, they are more powerful than a unipolar motor of the same weight. This is due to the physical space occupied by the windings. A unipolar motor has twice the amount of wire in the same space, but only half used at any point in time, hence is 50% efficient (or approximately 70% of the torque output available). Though bipolar is more complicated to drive, the abundance of driver chip means this is much less difficult to achieve.

An 8-lead stepper is wound like a unipolar stepper, but the leads are not joined to common internally to the motor. This kind of motor can be wired in several configurations:

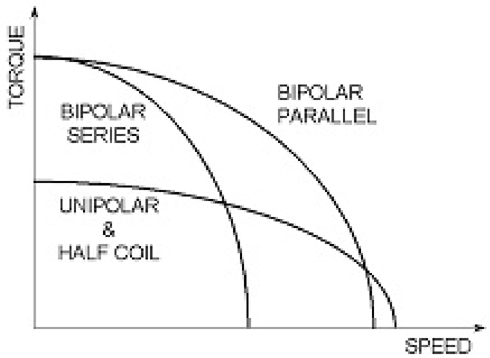
- Unipolar.
- Bipolar with series windings. This gives higher inductance but lower current per winding.
- Bipolar with parallel windings. This requires higher current but can perform better as the winding inductance is reduced.
- Bipolar with a single winding per phase. This method will run the motor on only half the available windings, which will reduce the available low speed torque but require less current.

Unipolar / Bipolar Connections (2-Phase Motors)

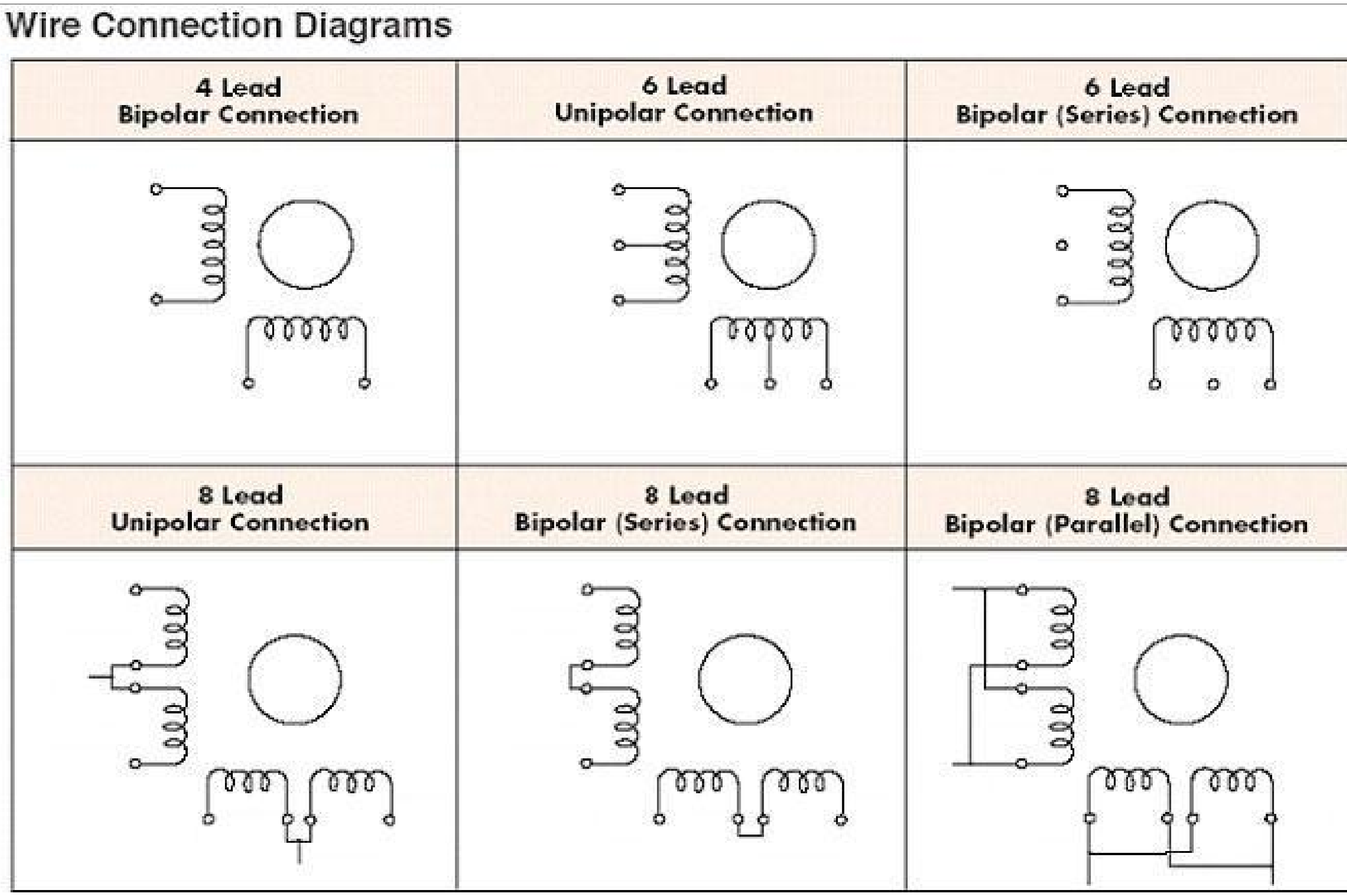
Unipolar and Bipolar Half Coil, because we're using less turns, doesn't give us great low speed torque, but because of the low inductance, holds the torque out to high speeds.

Bipolar Series uses the full coil so it gives very good low speed torque. But because of the high inductance, the torque drops off rapidly.

Bipolar Parallel also uses the full coil so it gives good low speed performance. And its low inductance allows the torque to be held out to high speeds. But remember, we must increase current by 40% to get those advantages.



Connections	**Resistance (Ohms)**	**Inductance (mH)**	**Current (A)**	**Voltage (V)**	**Holding Torque (oz-in)**
Unipolar	Same as NamePlate	Same as NamePlate	Same as NamePlate	Same as NamePlate	Same as NamePlate
Bipolar Series	NamePlate X 2	NamePlate X 4	NamePlate X 0.707	NamePlate X 1.414	NamePlate X 1.414
Bipolar Half Coil	Same as NamePlate	Same as NamePlate	Same as NamePlate	Same as NamePlate	Same as NamePlate
Bipolar Parallel	NamePlate X 0.5	Same as NamePlate	NamePlate X 1.414	NamePlate X 0.707	NamePlate X 1.414
Driver	**Motor Choices**	**What to Do**	**How to Do It**		**End Result**
Unipolar (6 Leads)	6 Lead Motor	Use as is (Unipolar)			6 Leads
	8 Lead Motor	Convert to Unipolar	Tie yellow and orange together and use AND Tie white and brown together and use		6 Leads
Bipolar (4 Leads)	6 Lead Motor	Convert to Series	Tape off yellow and white leads and don't use		4 Leads
		Convert to Half Coil	Tape off black and red leads OR Tape off green and blue leads		4 Leads
	8 Lead Motor	Convert to Series	Connect yellow and orange and tape off AND Connect white and brown and tape off		4 Leads
		Convert to Parallel	Tie black and orange together AND Tie yellow and green together AND Tie red and brown together AND Tie white and blue together		4 Leads
		Convert to Half Coil	Tape off black, yellow, red, and white OR Tape off orange, green, brown, and blue		4 Leads



1 Nm = 141.6192 oz in

For an in depth look at how stepper motors can be wired please look up the following link

[**http://www.piclist.com/techref/io/stepper/wires.htm**](http://www.piclist.com/techref/io/stepper/wires.htm)