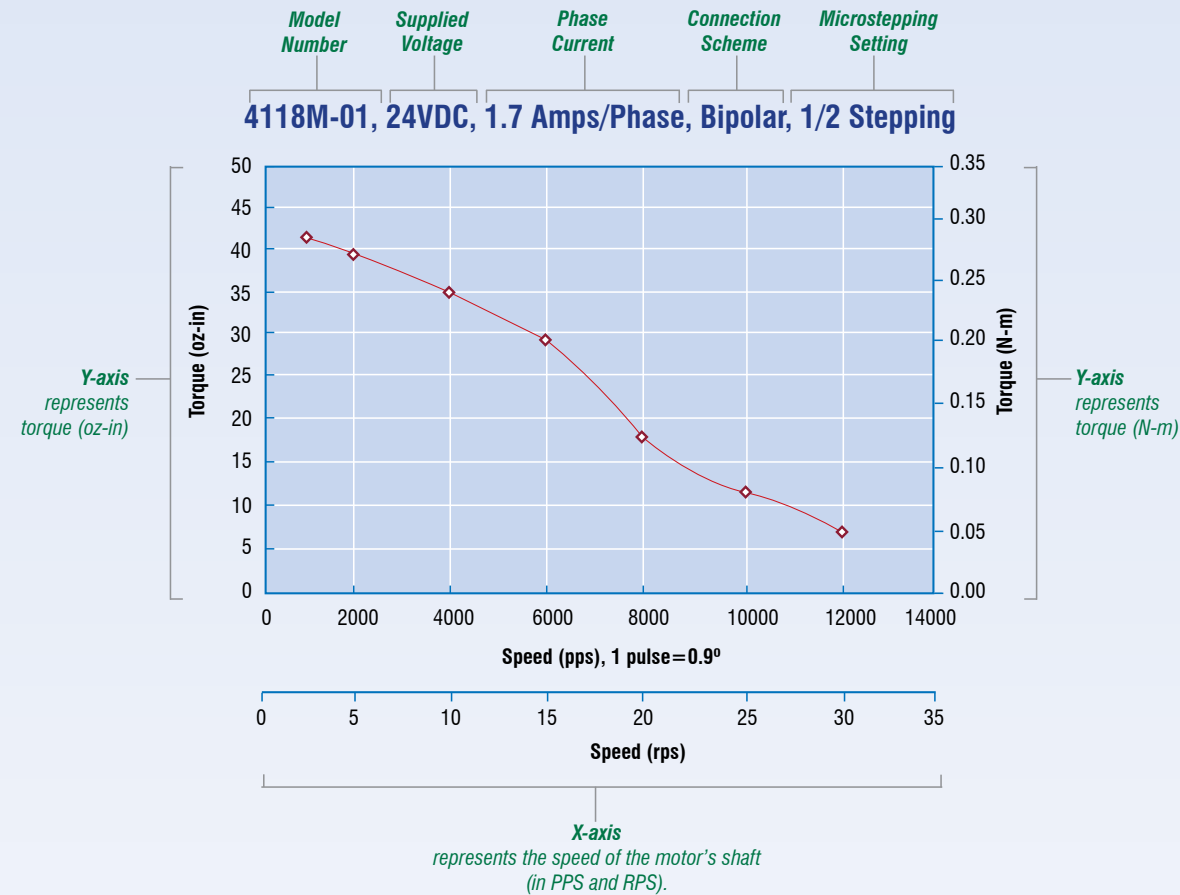


A Simple Tutorial for Common Stepper Terminology

READING A SPEED & TORQUE CURVE

The graph below depicts the relationship between speed and torque while a step motor is running. The output torque is very critical during the motor selection process. On the graph, the vertical y-axis represents torque (oz-in and N-m) while the horizontal x-axis represents the speed of the motor's shaft (in PPS and RPS).



ROTATIONAL SPEED

Step motors rotate continuously when given a specific series of pulses. Motor phases are turned on and off in a designated step sequence and thus, the faster the step pulses are sent to the motor, the faster it will rotate. Pulses per second, or PPS, is the rate at which the step pulses are sent to the motor per second. To translate this to revolutions per second, or RPS, one would need to know how many steps are in 1 revolution. In the example above, the motor is a 1.8 degree stepper and requires 200 steps to make 1 full revolution. The motor is operating at half stepping, so each step is now 0.9 degrees resulting in 400 steps needed per revolution. In the above example, 400 PPS is the equivalent to 1 RPS.

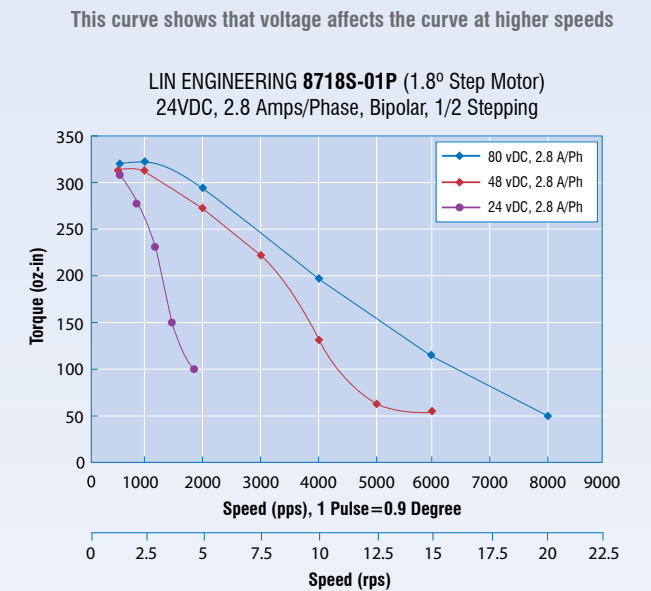
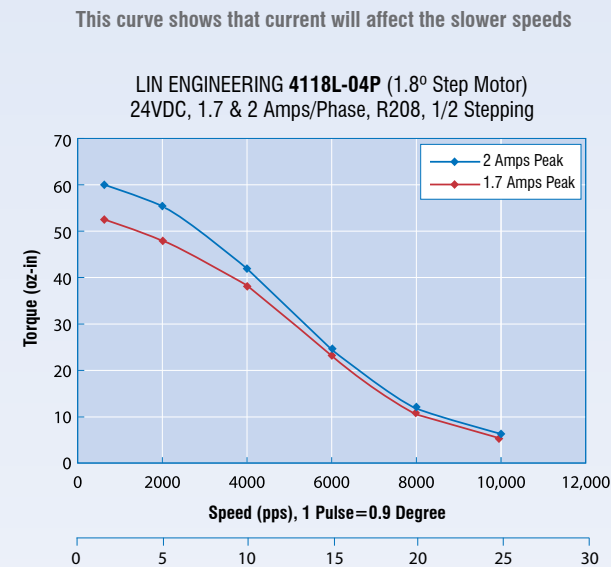
TORQUE

Torque is the measurement of rotational force that a step motor can output; this force is measured at the motor's front shaft. For example, 1 oz-in means that the motor can handle a 1 ounce load that is 1 inch away from the motor shaft. As the motor rotates faster, it will output less torque and be less likely to continue carrying a heavy load. Designing in a torque margin of 20% is typical in most applications.

CURRENT & VOLTAGE

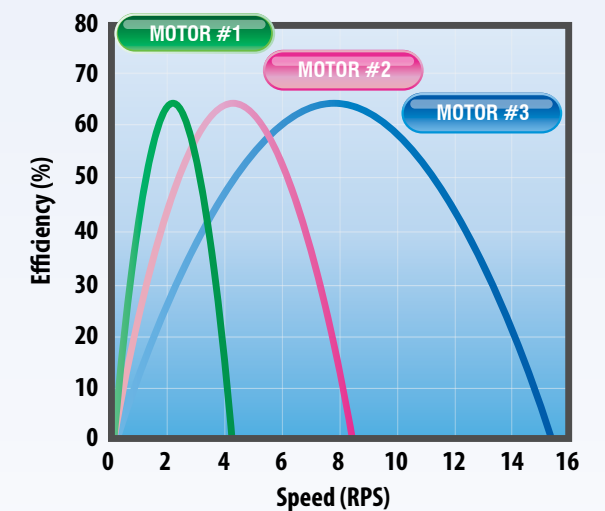
Since step motors rotate by sending current to the different phases in a specific switching sequence each pulse that is sent to the motor must rise and deplete (also known as a current-rise time). At slow speeds, each step it takes should have plenty of time to fully rise to 100% current and deplete. You will receive maximum power and thus, the reason why torque-speed curves have high torque at the low speeds. Voltage acts like a means to allow current to flow faster or slower. If you increase voltage, you are pushing the current through the motor windings at a faster rate. Now, instead of only rising and depleting about 50% of the max current, perhaps it has increased to about 60 or 75% by increasing the voltage.

Below shows a few curves that depict what different voltages and currents do to the torque-speed curves of several motors.



EFFICIENCY

An efficiency curve exists for every motor to help ensure that the proper one has been selected. The image depicts three different motor efficiencies when plotted across a speed range. Some motors, such as #1, perform at their best only at low speeds while others, such as #3, perform better at high speeds.



WHAT IS MICROSTEPPING?

The following table shows the number of pulses, or steps, for a given type of step motor:

Type of Motor	Number of steps in one revolution
1.8°	200
0.9°	400
0.45°	800

When microstepping the motor, the number of pulses increases. This is because microstepping will cause the motor to step in finer, or smaller, increments. Instead of a 1.8° motor stepping every 1.8°, half stepping it will then force the motor to move every 0.9°. The motor then needs to step twice as much to go 1 full revolution, or a total of 400 steps.

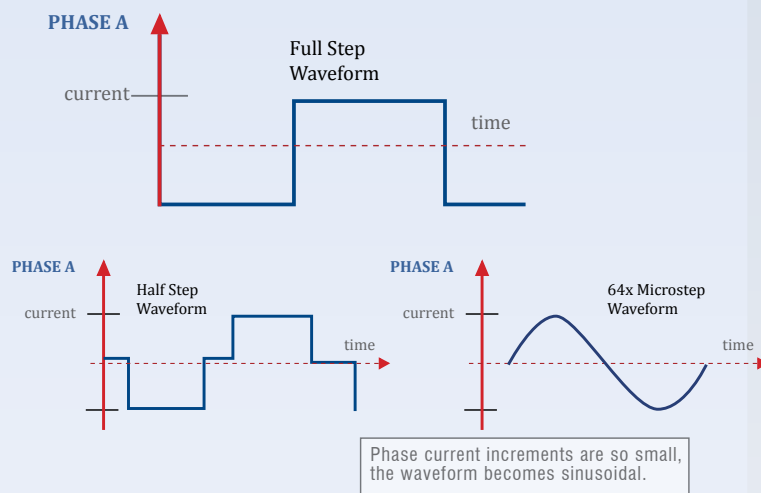
The following table provides the multiplier for each microstep:

Microstep value	Multiplier to the motor's natural steps in one revolution	Number of steps per revolution for 1.8° motors
Full step	no multiplier	200
Half step	2x	400
Quarter step	4x	800
Eighth step	8x	1600
Sixteenth step	16x	3200
5 step	5x	1000
10 step	10x	2000
25 step	25x	5000
128 step	128x	25600
256 step	256x	51200
etc	etc	etc

AFFECTS OF MICROSTEPPING ON TORQUE

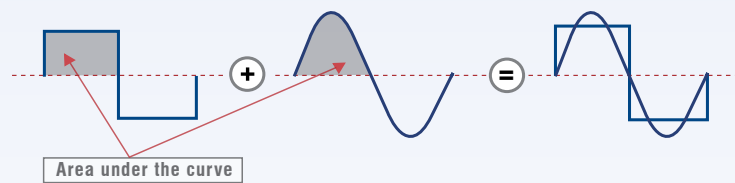
The amount of current going from the driver to the motor continuously changes in order to rotate the motor constantly. When you change microstep values this current waveform also changes.

For example, below are three different current waveforms to compare:



The area under each curve provides the total amount of torque available to the motor. Therefore, when you overlay one curve on top of another you will be able to see which microstepping provides more area under the curve.

Overlaying Full Stepping with 64x Microstepping:



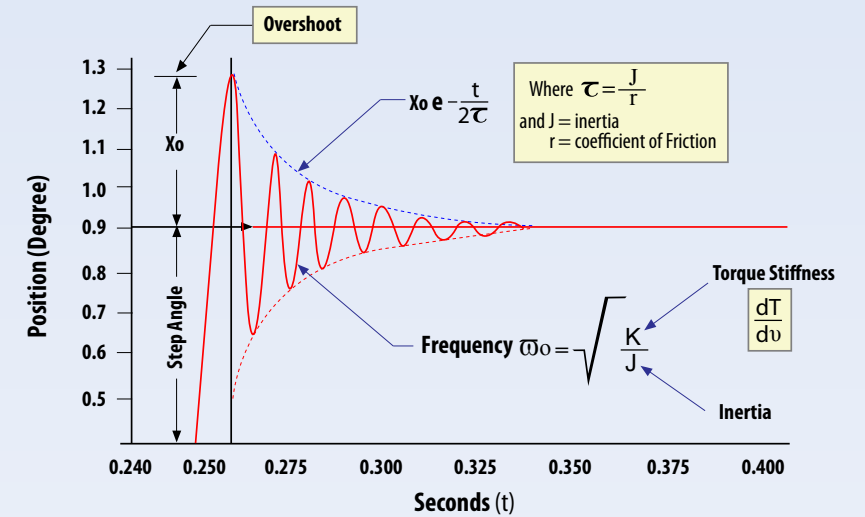
Our test results have proven the theory that you will in fact get the most torque when full stepping the motor. The next best torque result is when microstepping at 64x or higher. The least torque output is when users use half stepping. The torque differences are only within 5 to 10%, but sometimes, it is enough to make a difference. Keep in mind, with more torque, gives more vibration. If both torque and vibration are an issue, it is recommended to use 64x microstepping.

TIPS ON REDUCING RESONANCE:

Every step motor has a resonant frequency wherein more vibration will be seen by the motor at a specific speed. This resonant frequency is due to the oscillation (i.e. back and forth movement) that occurs before the motor settles into each desired position. The oscillation frequency will resonate at certain speeds and cause a 1st order, 2nd order and sometimes even a 3rd order amplitude at several speed ranges. A classic example is vibration seen at 1 RPS (the 1st order), and then slightly less vibration at 2 RPS (the 2nd order).

Below is a graph of a step motor's step response or the oscillation that the motor makes just prior to settling into the desired position. In this particular graph, the desired position was going from 0 to 0.9 degrees.

STEP RESPONSE



Although resonance cannot truly be avoided, there are ways to both reduce resonance and shift the resonance to a different speed location altogether. Looking at the equation for the resonant frequency, ω , the two main factors are Torque Stiffness and Inertia. By changing one of these factors, you can shift the resonance to a lower or higher speed.

INCREASE OR DECREASE VOLTAGE AND/OR CURRENT

By changing the input voltage to the drive, or changing the current (Amps) going from the driver to the motor windings you are essentially altering the torque, and therefore the top numerator of the frequency equation. If you are able to sacrifice some torque, try decreasing the overall power as this could help reduce or shift resonance away from your operating point.

INCREASE YOUR INERTIA LOAD

When you add more load to the shaft of the motor, you are essentially dampening the vibrations. Based on the equation, increasing the bottom denominator will shift the resonance to a lower spot.

INCREASE MICROSTEPPING

If you have capabilities to increase microstepping from the driver this will force the motor to take much smaller steps which will oscillate much less. Reducing the amount of oscillation directly reduces the amount of resonance. This method reduces resonance across the entire speed range.

CHOOSE A DIFFERENT MOTOR

If all else fails you may need a different motor. In most cases, the motor is too powerful and causes vibration and resonance since it is expecting to move a much heavier load. Choosing a motor that is more suitable for the job could be the solution. If all else fails try Lin Engineering's Signature Series line of step-motors which are mechanically designed to reduce vibrations for a smoother motion profile. See page 17 for further details.