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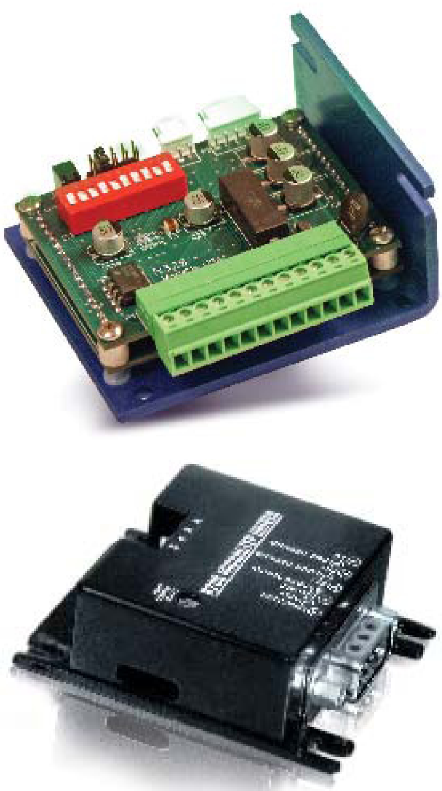
[HOW-TO FOR TECHIES]

How to Use Microstepping to Get More Torque

A fair comparison reveals some surprises

Many step motor users are faced with a question of whether or not to use microstepping in their stepper motor application. "What will it affect and how will I benefit from it?" one may ask. The answer requires understanding the relationship between step resolution and torque in a comparative analysis. For this analysis, we'll look at three of the most often-used step resolutions: full stepping, half stepping, and 64x microstepping.

In order to understand the relationship between microstepping and torque let's first take a look at microstepping at a basic level. Typically, step motors move 1.8 degree per full step. Drivers, such as Lin Engineering's R325, are capable of sending different amounts of current to both the A and B phases of a stepper, forcing it to move at various increments. These small increments are called microstepping a motor. For example, setting the driver at half stepping will move a typical 1.8 degree motor at 0.9 degree per pulse. Furthermore, drivers are capable of splitting the current in many different amounts in order to force the motor to step in miniature step angles, even as small as 0.007 degree per step.



The R235 microstepping driver (top) produces 256x microsteps compared to the R208 that produces 8x microsteps.

When viewing a driver's waveform, the different amounts of current the driver provides to the motor phases are visible. Since current is one of the main forms of input power, and power in equals power out, more current going to the motor will produce more output power.

The area under the curve on the waveform identifies how much potential output power can be achieved. Thus, overlaying the waveforms shows how much more output power is generated when using different step resolutions. The area under the full step curve is greater than the area under the 64x microstepping curve. Therefore, more output power can be achieved when operating at full step mode versus the 64x microstepping mode.

With this basic knowledge, one might question

Microstep Setting	Step Increment
Full	1.8
Half	0.9
4x	0.45
8x	0.225
16x	0.112
32x	0.056
64x	0.028
128x	0.014
256x	0.007

A microstep setting of 64 reduces the full step increment of 1.8 degrees to 0.028 degree. Step angles as small as 0.007° per step are possible.

I found this article informative and useful. The discussion on the effects of driver step resolution versus motor torque helps us to consider some of the trade-offs when deciding on which driver to use for certain stepper motor applications. With the widespread availability of microstepping drivers, it is easy to forget the torque benefit of a full step drive.
Ben Buell
Project Manager,
TriContinent

I believe many would certainly benefit by reading this article on the results of motor output torque between full stepping and micro-stepping. The information is accurate and I appreciate the clarity with which it was written. The charts are most helpful in explaining the results of implementing micro-stepping.
Anthony Lorring
(tony@gotmotion.com)
President,
Lorring & Associates
(a Got Motion Company)

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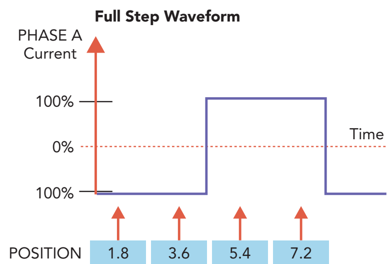
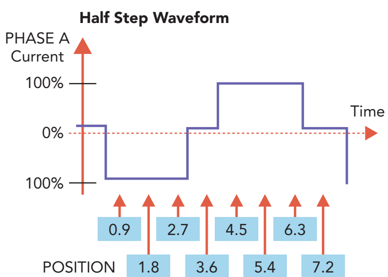
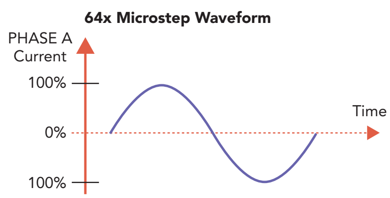
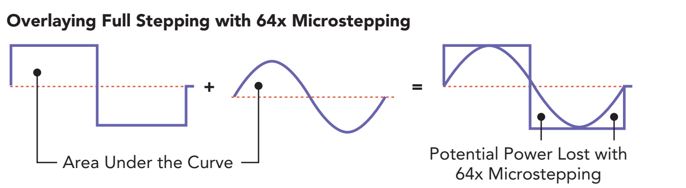
The waveforms for full stepping, half stepping and 64x microstepping show the phase current versus angular position. For 64x microstepping, the phase current increments are so small the waveform becomes sinusoidal.



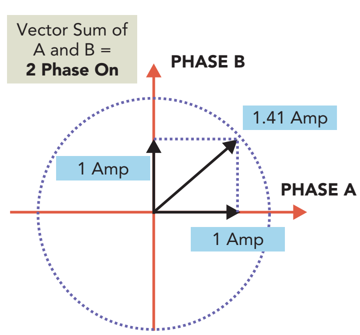


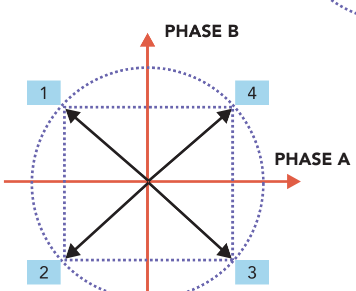




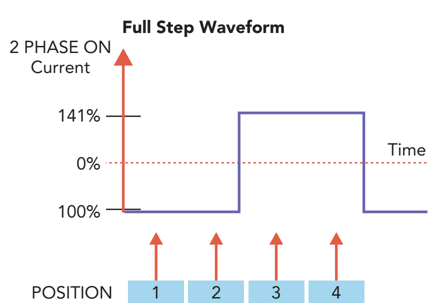
Overlaying full stepping with 64x microstepping easily shows the difference between the two techniques and the power lost by microstepping.

The full stepping phase diagram shows the two phases On provides a 41 percent increase in current.





Phase Diagram for Full Stepping



how much more torque can really be captured by changing step resolutions? In order to do a fair comparison between full step, half step, and 64x microstep, the same amount of power must be used. With certain step resolutions, the input current versus the average output current differs. Let's first find out what the differences are, and then identify values for all three step resolutions that will equate to the same amount of output current.

Full Stepping

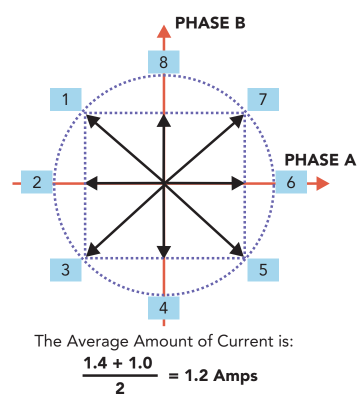
During full stepping, both phases are always on, creating a vector sum of 1.4 times more current than the phase currents. For a motor rated at 1 A/Phase, the driver will actually produce an overall current of 1.4A. If A and B are both energized, or "on," together they create the vector sum of 1.41 A.

Half Stepping

During half stepping, a motor rated at 1 A/Phase will actually output an average current of 1.2A of current. Fifty percent of the time, the motor will have one phase on, and 50 percent of the time the motor will have two phases on.

64x Microstepping

Finally, looking at 64x microstepping, 1.4A is the average amount of current that the motor will receive when given 1 A/phase. The vector sum of phase A and phase B, regardless if there are one or two phases on, is always 1.4A.



The Average Amount of Current is:

$$\frac{1.4 + 1.0}{2} = 1.2 \text{ Amps}$$

At positions 2, 4, 6, and 8, in the half stepping phase diagram, the motor has one phase On. At positions 1, 3, 5, and 7, the motor has two phases On. During the one phase On position, current is 1A. During the two phases On position, current is 1.4A.

IN ORDER TO MAKE AN ACCURATE COMPARISON BETWEEN FULL STEP, HALF STEP AND 64X MICROSTEP, IT IS NECESSARY TO ENSURE THAT ALL TESTS WILL PRODUCE THE SAME AMOUNT OF AVERAGE CURRENT.

In order to make an accurate comparison between full step, half step and 64x microstep, it is necessary to ensure that all tests will produce the same amount of average current.

	Amp/Phase (Motor Rating)	Average Output Current
Full Step	1.0	1.4
Half Step	1.0	1.2
64x Microstep	1.0	1.4

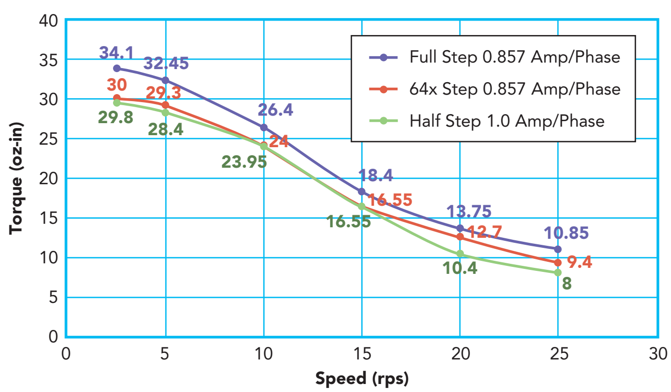
The summary of the different current inputs and average output currents identifies the correction factor required to provide equal output current: =1.2*(1/1.4).

As we had expected from overlaying the full step and 64x microstep waveform, full stepping outputs more torque than 64x microstepping. Overall, full stepping will output about 8 percent to 10 percent more torque than half step or 64x microstep. At lower speeds, there is little difference between half step and 64x microstep. At higher speeds, 64x microstep performs better than half stepping by about 10 percent or more.

	Amp/Phase (Motor Rating)	Average Output Current
Full Step	0.857	1.2
Half Step	1.0	1.2
64x Microstep	0.857	1.2

Ensuring an equal amount of output current with different step resolutions requires adjusting the A/Phase during any comparison testing.

Lin Engineering 4118S-25 (1.8 Step Motor)
24vDC, Bipolar Drive, Full, Half, 64x Stepping



Full stepping always produces the highest torque. However, the half stepping and microstepping have regions where the improvement in torque must be understood versus the tradeoffs.

As always, there are sacrifices that need to be made if you choose to use full stepping in order to gain more torque. Smoothness of motion will be less at full or half stepping compared to 64x microstepping because during full or half steps, the distance that the motor needs to travel per step is greater, causing a lot of oscillation. Although the steps are jagged, the positions are precise resulting in higher accuracy. During microstepping, the motor is forced to make many small steps. Although forcing the motor to make such small steps results in a decreased level of accuracy, the steps are so small that the overall motion of the motor becomes smoother. With every application, choices are still made in order to meet the needs of the project, but at least we are now aware of the relationship between microstepping and torque.

A Step in the Right Direction

The process of selecting the right torque versus operation tradeoffs can be accomplished with any driver that is capable of the various microstep settings. Some drivers might not necessarily have full step, half step, 4x, 8x, 64x, etc. However, smooth motion is so critical with step motors that most newer drivers will have this capability. Since selecting full step verses microstepping is accomplished by initial programming, it is simply a matter of choosing the acceptable performance tradeoffs for the application.

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Parameter	Full Step	Half Step	Microstep
Overall Torque	8 to 10% Higher	Depends Upon Operating Conditions	Depends Upon Operating Conditions
At High Speeds	Best	Good	Better
Smoothness	Good	Better	Best
Step Accuracy	Best	Better	Good
Price	$	$	$$

Tradeoffs for increased torque include smoothness, step accuracy and cost.

USEFUL LINKS

//Check out the links below for more stepper motor info.//

- For more information on Lin Engineering's 8x microstepper R208, go to: http://rbi.ims.ca/4927-562.
- For more information on Lin Engineering's 256x microstepper R325, go to: http://rbi.ims.ca/4927-563.