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Microstepping myths

The lure of microstepping a stepper motor for precision must be tempered by torque considerations.

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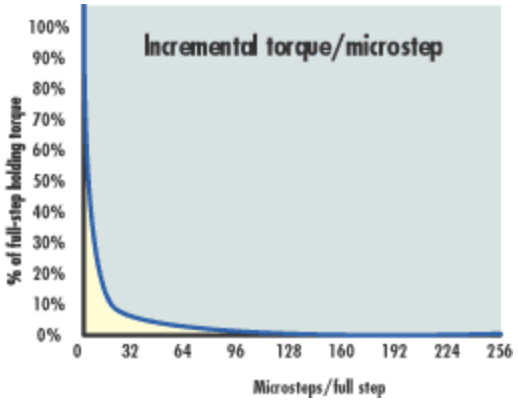

The graph shows that at 16 microsteps/full step, the incremental torque for one microstep is less than 10% of the full-step holding torque.

The lure of microstepping a two-phase stepper motor is compelling. For instance, microstepping a 1.8° hybrid stepper motor with 256 microsteps per full step would yield 51,200 steps/revolution.

Sounds great. But there's a catch. The real compromise is that as you increase the number of microsteps per full step, the incremental torque per microstep drops off drastically. Resolution increases but accuracy actually suffers.

Few if any stepper motors have a pure sinusoidal torque vs. shaft position curve and all have higher-order harmonics that distort the curve and affect accuracy. And even though microstepping drives have come a long way, they still only approximate a true sine wave. Significant too is that any load torque will result in a magnetic backlash, displacing the rotor from the intended position until sufficient torque is generated.

The expression for incremental torque for a single microstep is

$$T_{INC} = T_{HFS} \text{ X } \sin(90/\mu_{PFS})$$

and the incremental torque for *N* microsteps is

$$T_N = T_{HFS} \text{ X } \sin((90 3N)/\mu_{PFS})$$

where T_{INC} = incremental torque/microstep in oz-in., μ_{PFS} = the number of microsteps/full step, *N* = the number of microsteps taken, T_{HFS} = the holding torque, full step, oz-in., and T_N = the incremental torque for *N* microsteps in oz-in.

The consequence is that if the load torque plus motor friction and detent torque exceeds the incremental torque of a microstep, successive microsteps will have to be realized until the accumulated torque exceeds the load torque plus the motor friction and detent torque. Simply stated, taking a microstep does not mean the motor will actually move. And reversing direction can require a large number of microsteps to get the motor to move.

But what if the motor is not loaded, as in some type of pointing or inertial positioning? The motor still has friction torque from its bearings. It also has a detent torque, in addition to other harmonic distortions. You'll have to wind up enough incremental torque to overcome the bearing friction. Even more disruptive than the bearing friction is the detent torque, which is typically 5 to 20% of the holding torque. Sometimes the detent torque adds to the overall torque generation. Sometimes it subtracts from the power torque generation. In any case, it wreaks havoc with overall accuracy.

Some manufacturers fabricate microstepping versions of their motors. Their aim typically is to reduce the detent torque, usually at the expense of holding torque, so the torque-versus-rotor position is closer to a sine wave. They also hope to improve linearity of torque versus current. These efforts reduce but do not eliminate the compromises associated with microstepping in regards to accuracy.

Using a lookup table to correct for the inaccuracies in the motor and microstepping drive also doesn't solve the problem. If the load torque changes from when the lookup table was made, the results can be worse than if you had not used a calibrated table at all.

Then why microstep? There are still compelling reasons other than high resolution for microstepping. They include reducing mechanical noise, gentler mechanical actuation, and reducing resonance problems. Although microstepping gives designers more resolution it doesn't always improve accuracy. Reduction in mechanical and electromagnetically induced noise is, however, a real benefit. The mechanical transmission of torque will also be much gentler as will a reduction in resonance problems. This gives better confidence in maintaining synchronization of the open-loop system and less wear and tear on the mechanical transmission system.

In fact, taking an infinite number of microsteps per full step results in two-phase synchronous ac motor operation, with speed a function of the frequency of the ac power supply. The rotor will lag behind the rotating magnetic field until sufficient torque is generated to accommodate the load.

Incremental torque/microstep as the number of microsteps/full step increases

Microsteps/ full step	% holding torque/microstep
1	100.00%
2	70.71%
4	38.27%
8	19.51%
16	9.80%
32	4.91%
64	2.45%
128	1.23%
256	0.61%

The table shows the significant impact of the incremental torque/microstep as a function of the number of microsteps/full step.

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