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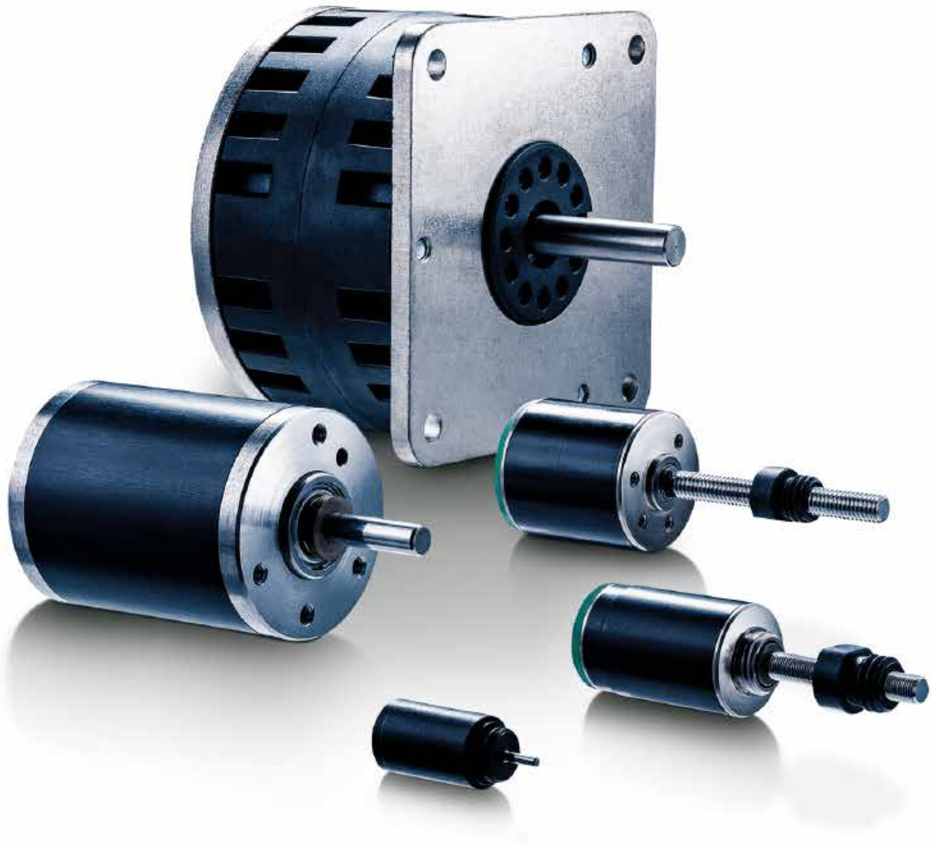
Stepper Motor Technical Note: Microstepping Myths and Realities



WE CREATE MOTION

Stepper Motor Technical Note: Microstepping Myths and Realities

The lure of Microstepping a two-phase stepper motor is compelling. Visions of Microstepping a 1,8-degree hybrid stepper motor with 256 microsteps per full step flash in your mind. The resolution of 51.200 microsteps per revolution entices you. You're glad you don't own stock in high-resolution encoder companies.

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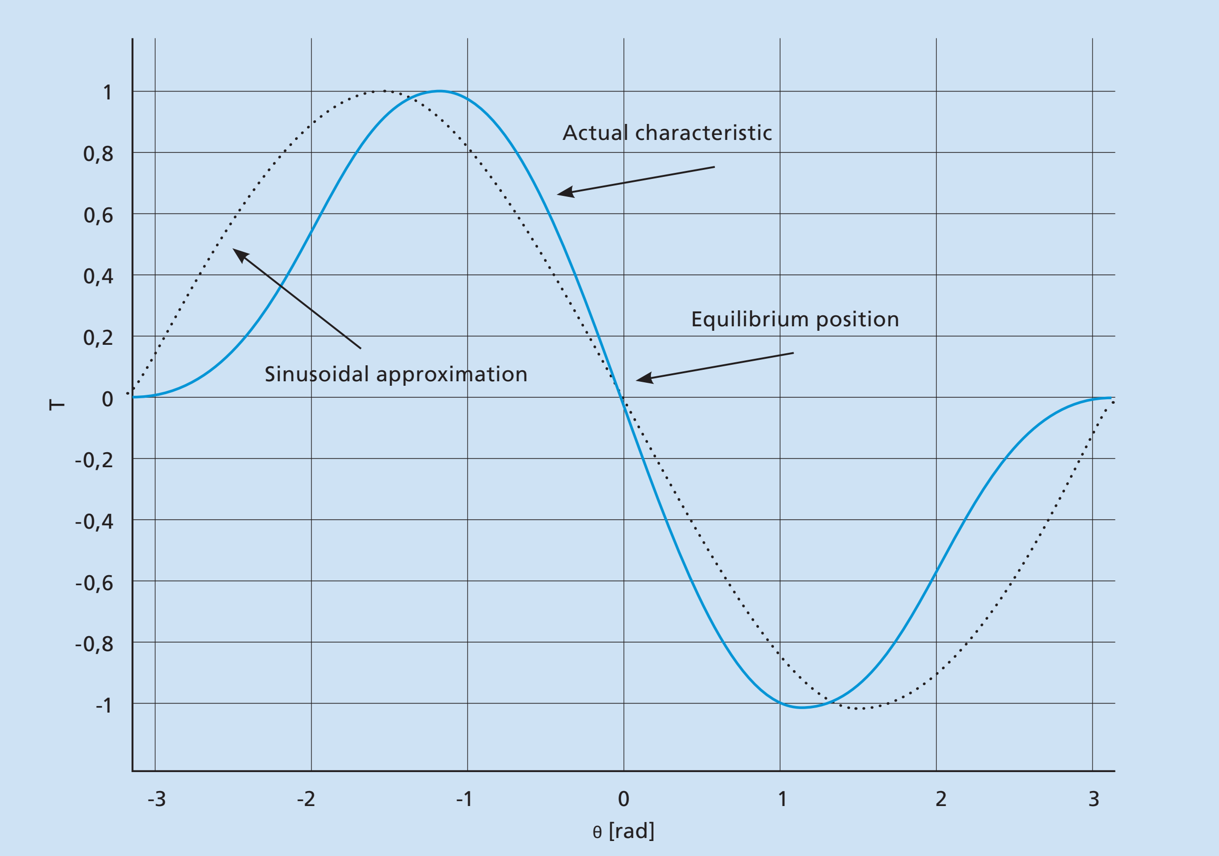
DR. FRITZ FAULHABER GMBH & CO. KG

Schönaich · Germany

Email: info@faulhaber.de

www.faulhaber.com

Torque vs. shaft position



Dotted line: Suitable response for precise microstepping positioning. Blue line: Distorted curves.

Where's the 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. However, accuracy will suffer. Few stepper motors have a pure sinusoidal torque vs. shaft position and all have higher order harmonics that distort the curve and affect accuracy (see graph above). While microstepping drives have come a long way, they still only approximate a true sine wave.

It's also critical to note that any load torque will result in a "magnetic backlash", displacing the rotor from the intended position until sufficient torque is generated.

The actual expression for incremental torque for a single microstep is 1.:

$$M_{INC} = M_{HFS} \cdot sin\left(\frac{90}{\mu_{PFS}}\right)$$

The incremental torque for N microsteps is 2.:

$$M_{N} = M_{HFS} \cdot sin\left(\frac{(90 \cdot N)}{\mu_{PFS}}\right)$$

Where:

μ_{PFS} = Number of Microsteps per Full Step [Integer]
N = Number of Microsteps Taken [Integer]
N Less than or equal to μ_{PFS}
M_{HFS} = Holding Torque-Full Step [Nm]
M_{INC} = Incremental Torque per Microstep [Nm]
M_{N} = Incremental Torque for N Microsteps [Nm]
N Less than or equal to μ_{PFS}

Incremental Torque per Microstep/Full Step

Table 1

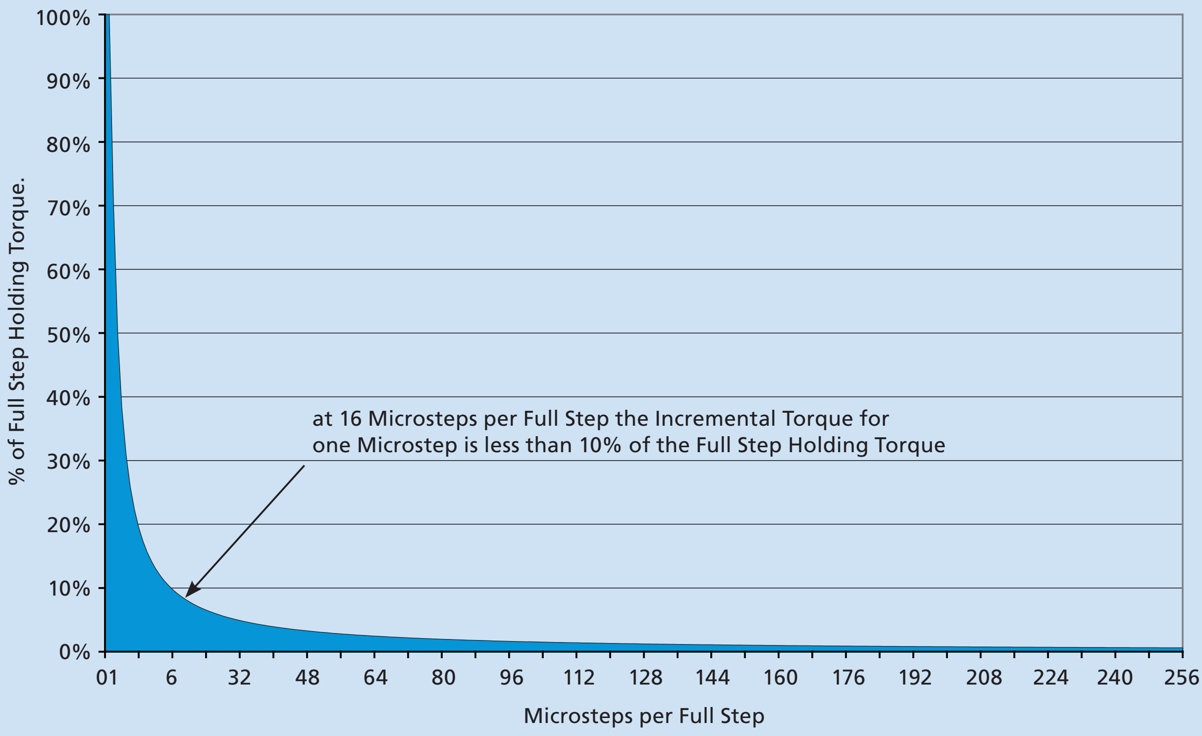


Table 1 dramatically quantifies the significant impact on the incremental torque per microstep as a function of the number of microsteps per full step.
A full step is considered one microstep per full step for Equations 1 and 2.

Incremental Torque per Microstep As the Number of Microsteps per Full Step Increase

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%

What Does It Mean?

The consequence is that if the load torque plus the motor's friction and detent torque is greater than the incremental torque of a microstep, successive micro-steps will have to be realized until the accumulated torque exceeds the load torque plus the motor's friction and detent torque. Simply stated, taking a microstep does not mean the motor will actually move. If reversing direction is desired, a significant number of micro-steps may be needed before movement occurs. That's because the motor shaft torque must be decremented from whatever positive value it has to a negative value that will have sufficient torque to cause motion in the negative direction.

Accuracy vs. Resolution

What if the motor is not loaded? Thinking of using microstepping for some type of pointing or inertial positioning? Well, the stepper motor still has friction torque due to its bearings and it 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 is adding to the overall torque generation. However, it can also subtract from the powered torque generation. In any case, it wrecks havoc with your overall accuracy. Indeed, some manufacturers fabricate "microstepping" versions of their motors. With standard motor constructions, the efforts typically are to reduce the detent torque. This can be at the expense of holding torque in order, to make the torque vs. rotor position closer to a sine wave, and it can also serve to improve linearity of torque vs. current. These efforts reduce but not eliminate the compromises associated with microstepping in regards to accuracy. Only specific magnetic designs (like the Faulhaber DM1220, or DM52100R) are intrinsically detent torque "free".

How about using a lookup table to "correct" for the inaccuracies in the motor and microstepping drive? The problem is that if the load torque changes from when the lookup table was made, the results can be worse than if you had not utilized a "calibrated" table.

Why Microstep?

There are still compelling reasons other than high resolution for microstepping. They include:

- reduced Mechanical Noise
- gentler Actuation Mechanically
- reduces Resonances Problems

In summary, although Microstepping gives the designer more resolution, improved accuracy is not realized. Reduction in mechanical and electromagnetically induced noise is, however, a real benefit. The mechanical transmission of torque will also be much gentler and resonance problems reduced. 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 permanent magnet ac motor operation.