Microstepping

Introduction

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.

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 but accuracy will actually suffer.
Few, if any, stepper motors have a pure sinusoidal torque vs. shaft position and all have higher order harmonics that in fact distort the curve and affect accuracy. And while microstepping drives have come a long way too, 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 actual expression for incremental torque for a single microstep is:

$$T_{INC} = T_{HFS} \cdot \sin\left(\frac{90}{\mu_{PFS}}\right) \tag{1}$$

The incremental torque for N microsteps is:

$$T_N = T_{HFS} \cdot \sin\left(\frac{90 \cdot N}{\mu_{PFS}}\right) \tag{2}$$

Where:

Symbol	Definition	Unit
μ_{PFS}	Number of Microsteps per Full Step	Integer
N	Number of Microsteps Taken N Less than or equal to μ_{PFS}	Integer
T_{HFS}	Holding Torque-Full Step	oz-in
T_{INC}	Incremental Torque per Microstep	oz-in
T_N	Incremental Torque for N Microsteps N Less than or equal to μ_{PFS}	oz-in

Table 1 quantifies the significant impact of 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. A half step is two microsteps per full step.

Table 1: Incremental torque per microstep as the number of microsteps per 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%

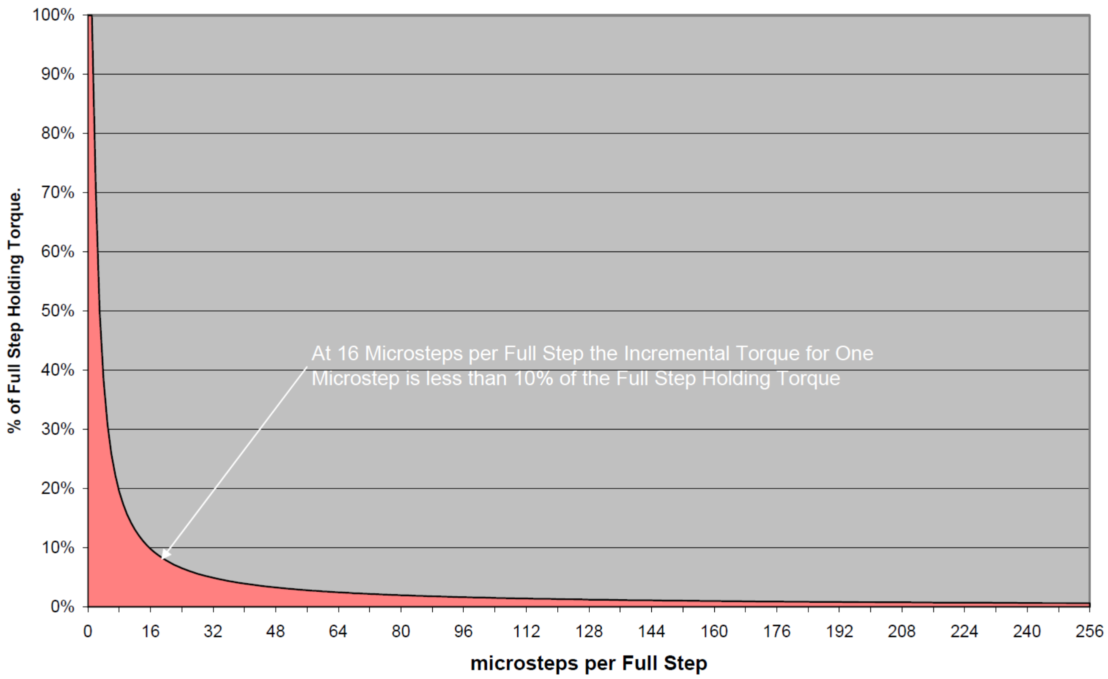

Figure 1: Incremental torque per microstep as the number of microsteps per full step increases.

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 microsteps 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! And if reversing direction is desired a whopping number of microsteps 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?" you ask? 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, sometimes it is subtracting from the powered torque generation. In any case it wrecks havoc with your overall accuracy.
Indeed, some manufacturers fabricate "microstepping" versions of their motors. Their efforts typically are to reduce the detent torque, usually at the expense of holding torque, to make the torque vs. rotor position closer to a sine wave, and to improve linearity of torque vs. current. These efforts reduce, but do not eliminate the compromises associated with microstepping in regards to accuracy.
How about using a lookup table to "correct" for the inaccuracies in the motor and microstepping drive? That too has been utilized. 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 at all!

Why microstepping then?

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 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 permanent magnet 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.

Legal notices

Industrial property rights. In publishing the Application Note Dr. Fritz Faulhaber & Co. KG does not expressly or implicitly grant any rights in industrial property rights on which the applications and functions of the Application Note described are directly or indirectly based nor does it transfer rights of use in such industrial property rights.

No part of contract; non-binding character of the Application Note. Unless otherwise stated the Application Note is not a constituent part of contracts concluded by Dr. Fritz Faulhaber & Co. KG. The Application Note is a non-binding description of a possible application. In particular Dr. Fritz Faulhaber & Co. KG does not guarantee and makes no representation that the processes and functions illustrated in the Application Note can always be executed and implemented as described and that they can be used in other contexts and environments with the same result without additional tests or modifications.

No liability. Owing to the non-binding character of the Application Note Dr. Fritz Faulhaber & Co. KG will not accept any liability for losses arising in connection with it.

Amendments to the Application Note. Dr. Fritz Faulhaber & Co. KG reserves the right to amend Application Notes. The current version of this Application Note may be obtained from Dr. Fritz Faulhaber & Co. KG by calling +49 7031 638 385 or sending an e-mail to mcsupport@faulhaber.de.