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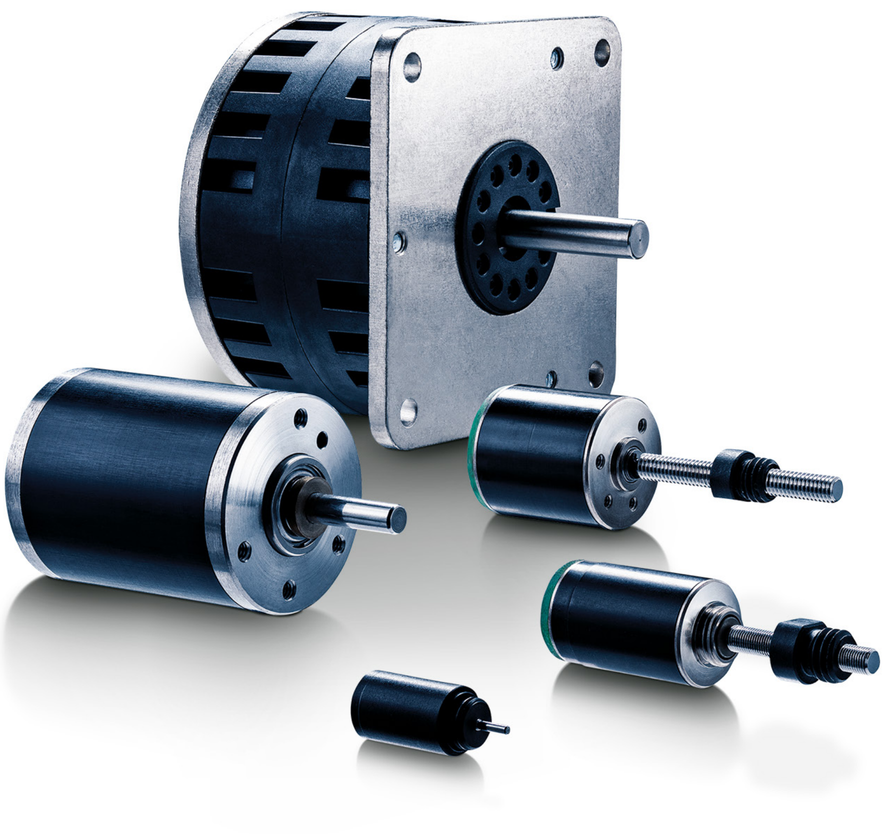
Eight facts and myths surrounding microstepping operation with stepper motors



WE CREATE MOTION

Eight facts and myths surrounding microstepping operation with stepper motors

There are many good reasons for operating a two-phase stepper motor in microstepping mode. Dividing the full step not only reduces wear in the mechanical transmission system - it also makes the mechanical torque of the stepper motor much smoother. It has even been suggested that a stepper motor operating in microstepping mode is more accurate. But is this fact or myth? What can microstepping operation really achieve and where does the torque of a stepper motor in microstepping mode meet its limits? Below you will find answers to the most frequently asked questions regarding microstepping operation.

FAULHABER tutorial: What you need to know about microstepping operation with stepper motors

To assist you in choosing and subsequently using a stepper motor from the FAULHABER product range, we have compiled a total of eight frequently addressed topics regarding microstepping operation with stepper motors. In addition to data and facts that will help you select the right motor for a specific application, our experts also reveal the persistent myths surrounding stepping operation.

Below you will find out:

1. What **benefits** microstepping operation with stepper motors has to offer.
2. How microstepping operation affects the **accuracy** of a stepper motor.
3. How a **large number of microsteps** changes the speed of a stepper motor.
4. How the **shaft position** behaves relative to the torque of a stepper motor in microstepping operation.
5. How to calculate the **incremental torque** of a stepper motor.
6. What happens if the incremental torque in microstepping operation is **too low**.
7. What effect **friction torque** and **cogging torque** have in stepping operation.
8. Whether it is worth mathematically offsetting **inaccuracies caused by microstepping operation** using a table containing correction values.

1. What are the benefits of microstepping operation?

In microstepping operation, every basic step of a motor is divided into a large number of small steps. This not only increases the resolution, but also reliably maintains synchronization of the open control loop. At the same time, microstepping operation smooths the mechanical torque in the stepper motor. This reduces the mechanical noise level and allows for extremely low-wear operation, especially in the case of mechanical transmission systems.

Another advantage of microstepping is that the motor produces less vibration as a result of the large amount of small steps. The microsteps of a stepper motor therefore often prove to be particularly beneficial for applications that could be impaired by severe resonance.

2. Does the accuracy of a stepper motor increase in microstepping operation?

Despite the higher resolution that can be achieved by the smaller steps, the accuracy of a stepper motor does not increase in microstepping operation. Quite the opposite: The accuracy may even decrease as a result of converting to microsteps (see also section 3).

If a motor is not accurate enough for a certain application, instead of using microstepping operation it is worth considering a motor model that will fulfill the required parameters even in full-stepping operation. If accuracy plays a secondary role in the specific application, converting an existing stepper motor to microstepping operation may nevertheless prove to be an effective solution because microstepping significantly reduces both the mechanical and the electromagnetic interference factors.

3. How does the large number of microsteps affect the torque of a stepper motor?

The larger the number of microsteps per full step, the greater the resolution. At the same time, however, the incremental torque of a stepper motor - i.e. the torque per microstep - falls drastically as the number of microsteps 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: Effect that a large number of micro-steps has on the torque of a stepper motor

Figure 1 and **Figure 2** show just how drastically an increasing number of microsteps can affect the incremental torque of a stepper motor. Whereas the static torque - i.e. the torque that in nominal current operation can hold a stationary stepper motor without rotating the rotor - is 100 percent in full-stepping operation, microstepping operation with just eight microsteps already reduces the static torque to less than 20 percent.

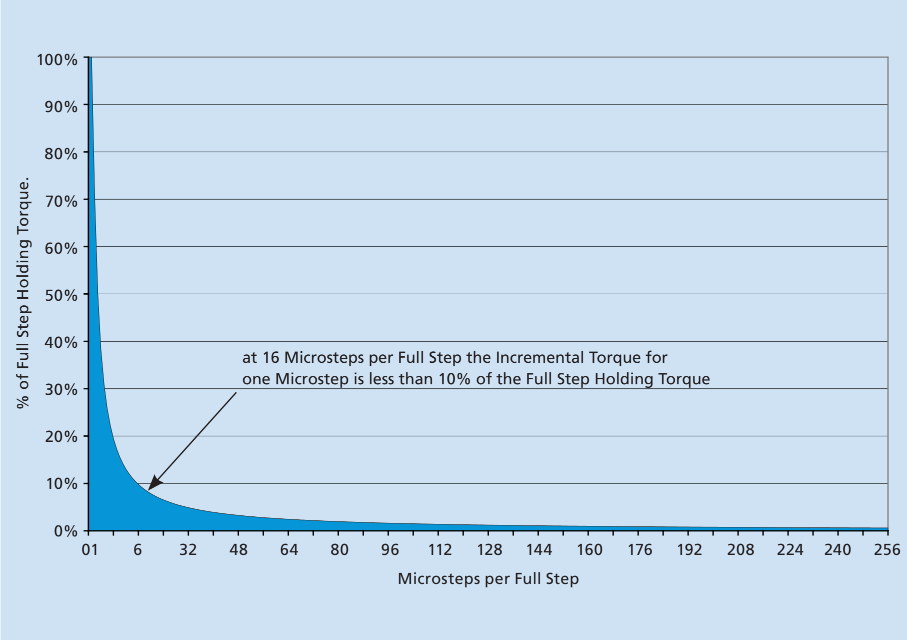


Figure 2: Development of the static torque for a stepper motor in microstepping operation

4. How does the shaft position behave relative to the torque of a stepper motor in microstepping operation?

Despite microstep drives being well developed to the current state of technology, the ratio of the shaft position to the torque of the stepper motor is never completely sinusoidal: At present, not even sophisticated models are able to fully achieve a true sinusoidal curve. Furthermore, harmonics that distort the curve and affect accuracy occur with all stepper motors.

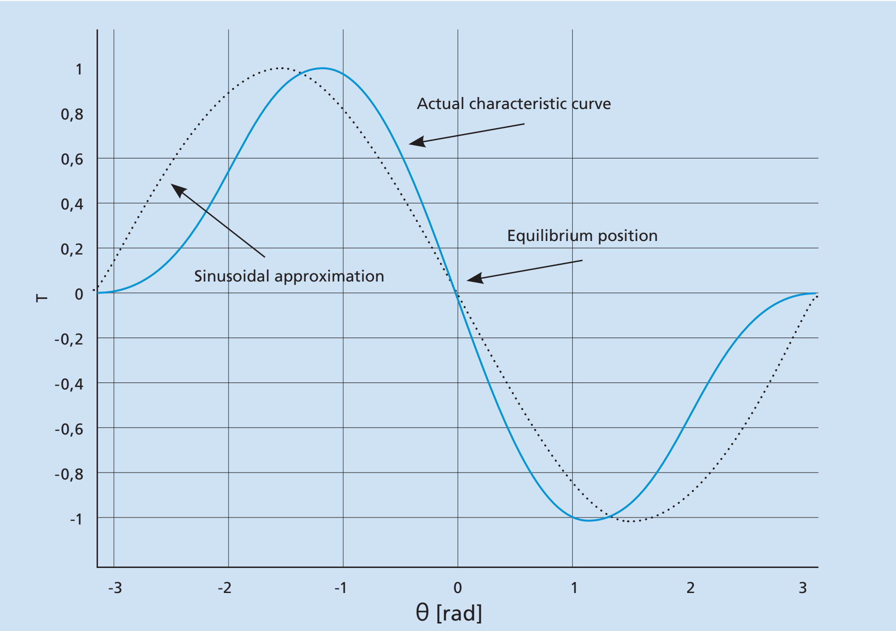


Figure 3 Shaft position characteristic curve for the desired precise microstep positioning in relation to the actual torque of a stepper motor

To visualize the difference between the ideal and actual curves, in **Figure 3** we have determined the ratio of the shaft position to the torque of a stepper motor as an example. The dotted line shows the optimum characteristic curve for precise microstep positioning, while the blue line shows the slightly distorted curves of the actual characteristic for the stepper motor in microstepping operation.

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.

5. How is the incremental torque of a stepper motor calculated?

To determine the incremental torque of a stepper motor, we first need to calculate the incremental torque for an individual microstep:

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

Where:

- **μ_{PFS}** = Number of microsteps per full step [integer]
- **N** = Number of executed microsteps [integer]
  Here **N** must be less than or equal to μ_{PFS}
- **M_{HFS}** = Holding torque in full-stepping operation [Nm]
- **M_{INC}** = Static torque per microstep [Nm]
- **M_{N}** = Incremental torque for N microsteps [Nm]
  Here too, **N** must be less than or equal to μ_{PFS}

Based on this data, we can then determine the incremental torque for N microsteps as follows:

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

6. What happens if the incremental torque of a stepper motor in microstepping operation is too low?

If the sum of load torque, motor friction and cogging torque is greater than the incremental torque of a stepper motor, consequently several microsteps have to be executed in succession until the accumulated torque exceeds this sum. For this reason, it may also be the case that the motor does not move when a microstep is executed.

Furthermore, changing the direction of rotation may require a considerable number of microsteps. This is the case because in order to change the direction of rotation in microstepping operation, the shaft torque first needs to be changed from the current, positive value to a negative value at which the stepper motor reaches a torque that is high enough to trigger movement in the opposite direction.

7. How do friction torque and cogging torque affect a stepper motor in microstepping operation?

Basically, due to its bearing, every stepper motor has a friction torque. To overcome this bearing friction in microstepping operation, the incremental torque of the stepper motor must exceed a certain initial value. This value varies depending on the model, application and number of microsteps.

The cogging torque typical for electric motors - including the interfering harmonics mentioned in section 4 - is an added factor which also persists in microstepping operation and reduces the accuracy of the motor. Only special magnetic stepper motors, e.g. the FAULHABER DM1220 or DM52100R, are intrinsically free of cogging torque.

The cogging torque is usually 5 to 20 percent of the static torque. In some cases, it acts in addition to the total generated torque. However, there are also cases where it counteracts the generated torque of the stepper motor.

8. Could a table with correction values be used to remove inaccuracies caused by microstepping operation?

Theoretically, it is of course possible to use a table of correction values to offset any inaccuracies that can occur as a result of using a stepper motor in microstepping operation. In practice, however, this approach is only of limited use: As each table with correction values applies only to a certain load torque, the results for a deviating load torque may be even worse than without the use of a „calibrated" table.

You have questions regarding microstepping operation? Our team has the answers!

Are you looking for the right stepper motor for a new application? Or do you want to find out whether an existing application could benefit from the conversion to microstepping operation? No matter what project you're working on: The experts at FAULHABER will gladly advise you. Simply complete the contact form on our website and our experts will quickly get in touch with you.

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