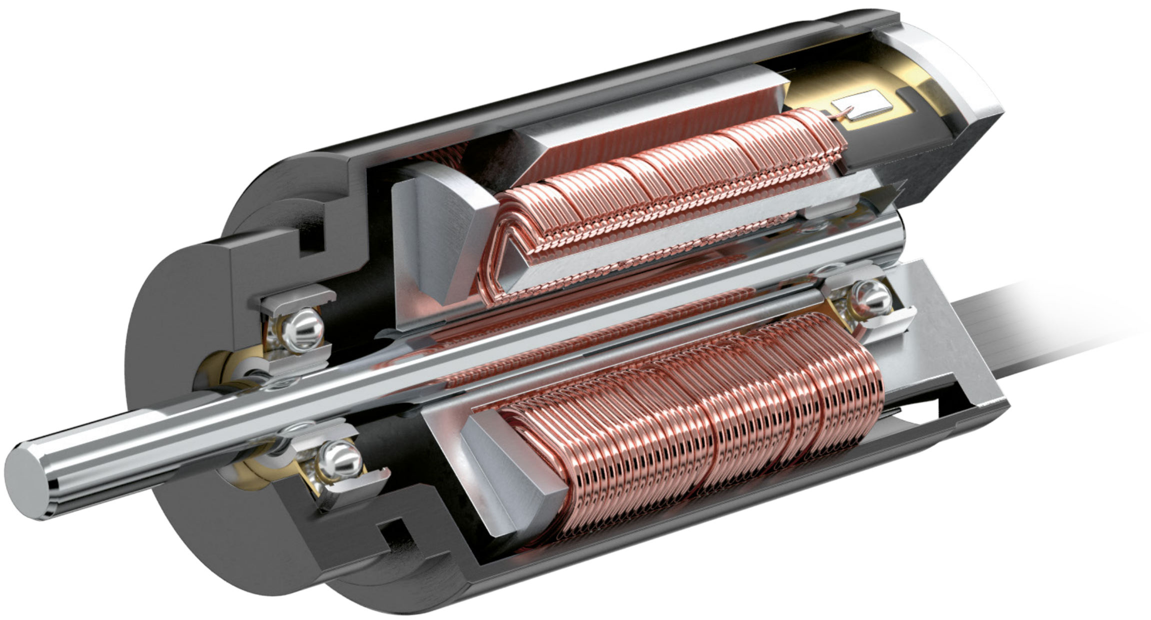
FAULHABER Tutorial

How to recognize and prevent step losses with stepper motors



WE CREATE MOTION

How to recognize and prevent step losses with stepper motors

When a stepper motor does not operate correctly in certain situations, this is usually due to a so-called step loss: The motor jumps uncontrollably or simply stops. The cause is either in the motor or the control electronics, but where exactly the defect is located is not that easy to determine because the readily available motor current is of no help here and only very few stepper motors are equipped with devices that provide feedback regarding operating behavior.

The FAULHABER tutorial: How to recognize and prevent step losses with stepper motors

To help you choose the right product from the FAULHABER range as well as plan and configure your applications, we introduce you to the most common causes of step loss with stepper motors.

Below you will find out:

1. How you determine, when **selecting a stepper motor,** which models come under consideration for the planned application.

2. Why stepper motors sometimes do not start correctly in **start-stop operation**.

3. What problems in the case of stepper motors with **trapezoidal velocity profile** can lead to step loss.

4. How **commutation faults** affect the operation of a stepper motor.

5. Which failure modes indicate that the step loss of a stepper motor is attributable to **external factors**.

As one and the same problem can have different causes, we also show you which tests you can use to find out, based on the failure mode, what caused the step loss of your stepper motor in the specific application case.

1. Selecting the right stepper motor for a planned application

Step losses with stepper motors can occur for several reasons: Either the motor is damaged or there is a marked discrepancy between the motor parameters and the requirements of the application. To rule out step losses with stepper motors, it must first be checked whether the selected model can deliver the necessary power in the specific application case. For an optimum result, we recommend that you factor in extreme power peaks from the outset.

1. **Bear the worst-case scenario in mind.** When selecting a stepper motor, always base your decision on the operating point at which the application requires the highest values for torque/speed.

2. **Include a generous safety margin in your calculation.** We recommend a safety margin of 30 percent on the torque-speed curve (pull-out torque). Even if the power peaks are higher than originally anticipated, this buffer will allow you to prevent step number losses with stepper motors effectively.

3. **Ensure that the application cannot be stalled by external events.** The cause of a step loss is not always the stepper motor itself: The suitability of the selected model to its environment in the specific application case also plays a key role.

When selecting a stepper motor, it is also important to consider its characteristic properties. Unlike a DC-motor, with a stepper motor there is e.g. no operating point adjustment and also the phase current does not adapt to changes in load, but instead remains constant.

As long as the torques required by the application for the respective speeds correspond to the motor specifications, no problems are to be expected if you convert an existing system from a DC-motor to a stepper motor. If the application requires higher values, however, no step losses occur at the stepper motor: In this case, the motor simply stops (for further information, see section 3 of this tutorial).

2. Standstill and step number losses with stepper motors in start-stop operation

In so-called start-stop operation (also: ON/OFF mode), the stepper motor is permanently connected to the load and operated at a constant speed. This means that the motor has to overcome both the inertia and the friction of the load within the first step in order to accelerate to the commanded frequency. In this operating mode, a typical indication of step losses in the stepper motor is that the motor does not move at all because this very first step proves to be an insurmountable hurdle.

Figure 1 shows the typical progression of the start-stop frequency of a stepper motor without step losses.

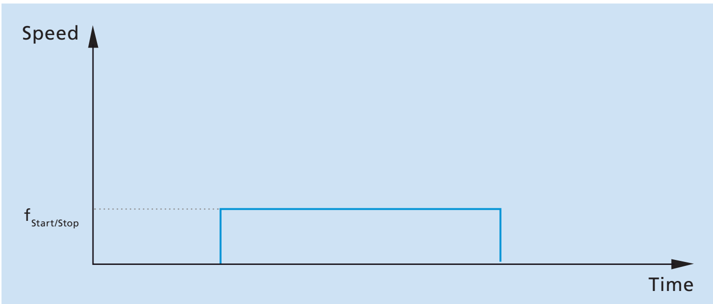


Figure 1: Start-stop frequency of a stepper motor

Typical fault pattern: The stepper motor does not start when in start-stop operation.

If a stepper motor does not start when in start-stop operation, this can usually be attributed to one of the following four problems:

1. **The load is too high.** In this case, the step loss in the stepper motor cannot be prevented by adjusting the operating parameters. If the motor cannot move the load in start-stop operation, a different, more powerful model must be used instead.

2. **The frequency is too high.** Reducing the frequency usually solves this problem. Here, however, it is important that the motor delivers the power required for the respective application case even at low frequencies: If the load is too high at reduced frequency, the stepper motor will remain stationary.

3. **The motor moves.** If the motor moves from left to right in start-stop operation, this can interrupt the phases and therefore the power supply – this becomes noticeable through step loss of the stepper motor or complete standstill. If this fault cannot be rectified by repair, the motor must be changed in this case too.

4. **The phase current is too low.** If the phase current is too low, the motor cannot reach the torque that it needs to overcome the inertia and friction of the load. In stepper motors, this problem also manifests itself as step loss – which means standstill in the case of start-stop operation. If you increase the phase current at least for the first steps, however, this may be enough to set the motor in motion.

3. Acceleration and ramp profile (trapezoidal)

In this operating mode, the motor can accelerate to its maximum frequency at an acceleration rate specified in the controller. **Figure 2** shows the typical characteristic of an acceleration sequence with trapezoidal velocity profile (ramp profile).

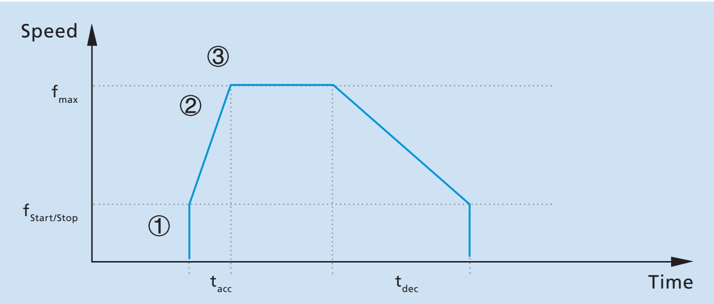


Figure 2: Acceleration of a stepper motor with trapezoidal velocity profile

Typical fault pattern #1: A stepper motor with trapezoidal velocity profile does not start.

If a stepper motor with trapezoidal velocity profile does not start to move, this is usually due to one of the four causes that can also result in standstill of a stepper motor in start-stop operation. The acceleration in the first step is to blame in this case: In both operating modes, the motor must reach a sufficient torque here in order to overcome the friction and inertia of the load. If the motor does not manage this, the resulting step loss in stepper motors manifests itself as a standstill because the very first step fails.

A concise overview of the four most common causes of this particular form of step loss in stepper motors – and of course the appropriate solutions – can be found in section 2 of our tutorial.

Typical fault pattern #2: The stepper motor does not get to the end of the acceleration ramp.

A second typical failure mode by which you can recognize step losses in stepper motors is if the motor does not complete the acceleration ramp. If a stepper motor does not reach the maximum frequency, it is worth checking whether one of the following four faults exists:

1. **The motor only reaches its resonance frequency.** In this case, you can prevent the step loss in the stepper motor e.g. by accelerating more strongly at the start of operation, by changing to half-stepping or microstepping operation or by implementing mechanical damping.

2. **Power supply and/or supply current are not optimally set.** Whether this could be the case can often be established by comparing the current operating parameters with the data sheet of the used motor. To determine whether the power supply is the cause of the step loss, you can temporarily increase the voltage or current, for example.

3. **The maximum speed is too high.** If the acceleration ramp is too steep, it may be the case that the speed characteristic has a plateau which, although below the desired maximum speed, corresponds to the output maximum of the motor. This discrepancy can, however, often be offset by reducing or flattening the acceleration ramp.

4. **The electronics do not predefine an optimum acceleration ramp.** If you use an electric controller, it may be that the digitally controlled acceleration is not optimally matched to the stepper motor. In this case, it may be worth using a different controller which enables a more precise control of the acceleration process.

Typical fault pattern #3: The stepper motor accelerates up to the final speed and stops as soon as it reaches a constant speed.

This failure mode usually occurs in motors that are operated at their power limit. If they accelerate just slightly too much, they exceed the intended speed. This triggers vibrations, which in stepper motors can lead to step loss and consequently to standstill.

If you observe that your stepper motor accelerates correctly up to the maximum speed, but then stops, it is worth considering one of the following four measures to more precisely refine the speed profile or to increase the stability of the motor:

1. **Reduce the vibration,** e.g. by means of a lower acceleration rate.
2. **Increase the torque.**
3. **Operate the motor in microstepping mode.**
4. **Use mechanical damping**, e.g. in the form of an inertia disk at the rear end of the shaft.

If one of these measures on its own is not successful, you can use a combination of measures – e.g. a lower acceleration rate and mechanical damping – to prevent the step loss of the stepper motor.

4. External commutation errors

For design reasons, a stepper motor cannot lose only one step, but rather always a multiple of four steps, i.e. eight, twelve or sixteen steps. At high speeds, step losses in stepper motors lead to the loss of synchronicity – and this in turn results in the motor stopping.

If, however, the number of lost steps is not a multiple of four steps, this is a clear indication that the motor itself is OK: The cause of this step fault is somewhere else. The problem is usually in the commutation sequence predefined for the stepper motor by the electronics.

Frequently asked question:

How do I rectify a step loss at the stepper motor that is caused by a fault in the external commutation?

If the step loss of a stepper motor is attributable to the external commutation, the correct counter state is the determining factor for precise resumption of operation. Before switching off the power supply, save the 4 bit word required for normal operation so that you can then reload it from the memory to allow counter initialization. When you restore the power supply, simply load this position before continuing the commutation.

5. Step losses caused by external events

Besides discrepancies between the motor parameters and the requirements of the application, external events can also cause step losses in stepper motors. The resulting failure modes are, however, at least easy to identify: They are characterized by the fact that the step loss does not occur each time the motor is used or that the drive runs without fault for some time before the first problems arise.

Typical fault pattern #1: The step loss occurs only occasionally when the motor is switched on.

This failure mode can be attributed to backdriving, because the mechanism driven by the motor – or more precisely: the load – is sometimes „wound up" by movement. If the power supply is switched off, this energy is returned to the motor.

If in this case the shaft turns by an angle that corresponds to more than one step, this can cause a step loss in the stepper motor which basically corresponds to failure mode #1 described in section 2 of this tutorial: The next time the motor is switched on, it is unable to generate enough torque to execute the first step. Consequently, the motor either does not start at all or only after four full steps.

Frequently asked question:

Can a step loss caused by backdriving occur in all stepper motors?

No. This particular type of step loss in stepper motors only occurs in applications where the motor current is considerably reduced or switched off after the movement. To prevent or rectify the step loss, you can program the commutation in such a way that the value and polarity of the motor currents are saved before they are switched off and retrieved when they are switched on again – or you simply maintain a reduced standby current during motor standstill.

Typical fault pattern #2: Step loss occurs over time.

Some stepper motors run without fault for a long time before the first step losses occur. In such cases, it is highly likely that the load has changed. This can on the one hand indicate wear of the motor bearings. On the other hand, however, it can also be attributable to an external event, e.g. slippage or change of the load to be moved.

Frequently asked question:

How do I find out whether the step loss of a stepper motor is caused by a change of the load?

To determine the cause of the step loss, first check whether an external event has occurred: Has the mechanism driven by the motor changed? If this is not the case, it is worth conducting a thorough examination of the bearings and lubricant.

1. **Check the bearing wear.** If the bearings are severely worn, the effect of the load can be greater than originally calculated. To reduce material wear and thus avoid the resulting step loss from occurring in stepper motors, it is recommended to use ball bearings instead of sintered sleeve bearings.

2. **Check whether the ambient temperature has changed.** The effect of temperature on the viscosity of bearing lubricant should not be underestimated, particularly in the case of micromotors. Use lubricants suitable for all operating temperatures.

Do you have questions regarding step losses with stepper motors?

You need more information to find out which stepper motor is the best for your application? Or you have a specific problem with step losses when operating your drive system? The experts from FAULHABER will gladly help you. Simply complete the contact form on our website and our experts will then quickly get in touch with you.

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