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How Feedback Devices Work with Stepper Motors

Learn how feedback-equipped stepper motors can close the control loop and improve performance closer to servo motor levels.

STEPPER motors are a popular choice for many motion control applications. They're available in a range of sizes and torque ratings and, importantly, are significantly less expensive than high-end servo motors. So, let's examine ways of bringing stepper motor performance closer to servo motors levels by adding feedback devices.

STEPPER MOTOR BASICS

Stepper motors are brushless DC electric motors designed to move in discrete steps, rather than continuous motion. These step motions are driven by shifts in the magnetic field created by sets of electromagnetic stator coils.

Stepper motor operation depends on a **controller** — an electronic device that feeds current to the motor's stator coils in a sequence that drives step motions. The controller's capabilities will have a large impact on motor performance.

Several types of stepper motors are available, and the most widely used varieties offer good resolution (200 steps per revolution or better), good low-speed torque, rugged construction, long service life and relatively low costs.

They do have some limitations. Torque output drops off at higher rotational speeds, and with simple controllers, the motors can be subject to ringing (high-frequency vibrations).

And, while stepper motors can be useful for position-control tasks, in their basic form, stepper motors operate in an open-loop control mode.

Stepper motors respond to instructions from their controller to move a certain number of steps, but they don't provide any feedback to confirm this motion has occurred. Failure of the motor to complete the requested steps will create a discrepancy between what the controller ***believes*** the rotary position of the motor shaft to be and the ***actual*** position of the shaft and whatever mechanism the shaft is driving.

This can happen when the torque generated by the motor is insufficient to overcome mechanical resistance and can become a significant problem at higher rotation speeds when torque is reduced. To avoid this, stepper motors often are over-specified for the task they are intended to perform, meaning larger, heavier motors.

Also, when the motor comes to a stop, current is required to flow through the motor windings to hold the stepper motor shaft in position. This results in a warm motor and extra power consumption.

Adding feedback can close the control loop by providing information about the true shaft position.

WHAT DOES ADDING FEEDBACK DO?

Adding feedback can close the control loop by providing information about the true shaft position. While feedback devices increase costs, the combination may still be much less expensive than servo-motor alternatives.

One approach for adding feedback is to operate in "move-and-verify" mode. In this case, a simple incremental encoder is added to the tail shaft of a stepper motor, with a resolution that's typically a multiple of 200 positions per revolution.

In this mode, when the controller issues step commands to the motor, the encoder tracks the motion and sends a signal to verify that this motion has taken place. If the motor fails to complete the requested number of steps, the controller can request more steps until the motor ends up in the intended position.

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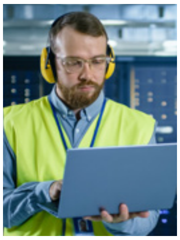

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More sophisticated controllers increase the phase current to the motor, boosting torque for the extra steps. With move-and-verify, it may still be a good idea to use oversized motors, but not to the degree required with simple open-loop systems. When the motor shaft is stopped in position, intelligent controllers also may be able to fine-tune the holding currents to an appropriate level, though it's possible that the stepper motor phase currents — and overall energy consumption — can still be high.

CLOSED LOOP FOR POSITION CONTROL

For position control applications, full closed-loop control based on multiturn absolute encoders can be an effective alternative. This type of encoder would be attached to a stepper motor's tail shaft to monitor absolute rotation angle and rotation count.

In this configuration, the stepper motor is controlled like a high pole-count brushless DC (BLDC) motor, with the encoder providing position feedback to the controller. When the stepper motor is controlled like a BLDC motor, the "holding" current supplied to the motor can be limited to the amount required to maintain position within a given position tolerance.

A stepper motor controlled like a brushless servo motor is energy efficient and less expensive than a true BLDC servo motor. So, why not use low-cost stepper motors for all BLDC servo applications?

Stepper motors used in closed-loop servo systems still will have physical limitation when compared with true BLDC servo motors. A stepper motor operated in this manner would be, in effect, a 50-pole brushless motor. This will limit operating speeds (RPM). Also, the stepper motor's rotor has higher inertia than a true BLDC servo motor of equivalent power, so accelerations are limited.

When a stepper motor is used in BLDC mode, the encoder performs a vital **commutation** role, reporting the exact rotary position of the motor shaft so the controller can energize that appropriate set of stator electromagnets for continuous rotation when this is called for. Precision absolute encoders also can be used with advanced microstepping controllers to fine-tune the phase current for reduced ringing (vibration).

Figure 1. Absolute encoders report the shaft's rotary position and are ideal for critical position control tasks. They're available in self-contained or kit forms, like the magnetic, capacitive and optical kit encoders shown here.

ENCODERS FOR THE RIGHT APPLICATION

As mentioned previously, simple **incremental encoders** can be effective when a stepper motor is used in move-and-verify mode. They also can be used when speed control is the primary objective, although stepper motors aren't usually the best choice for continuous operation at steady speeds.

Absolute encoders, which report the shaft's rotary position, are ideal for critical position control tasks. These are available in self-contained (with their own closed housing and shaft) or kit forms (see **Figure 1**). While self-contained encoders require a coupler to connect them to the motor's shaft, kit or modular encoders are designed to be integrated into a motor or drive mechanism, measuring rotary motion directly from the drive shaft. Kit encoders might be built into the motor's housing or attached externally to a motor's end bell.

Absolute magnetic encoders (see **Figure 2**), which measure rotations through a set of Hall-effect sensors, are an option for feedback control of stepper motors. Available in self-contained or kit form, they're easy to