Keeping it Quiet

Designing out resonance, noise and vibration in stepper motor systems

Stepper motors have a number of features that make them the motor of choice for a wide range of applications, particularly in measurement and control. They are low cost, highly reliable, produce high torque at low speeds and benefit from a simple, rugged construction. When designing systems using stepper motors, there are many technical aspects to take into account. One aspect is the presence of resonance, noise or vibration, which have the potential to cause problems in numerous applications of stepper motors.

Audible noise is not a problem in most cases, but it can be unacceptable in certain applications such as in medical equipment or theatre lighting systems. Noise generated by stepper motors arises from the pulsed driving technique that is fundamental to their operation. The rotor oscillation cycle from rest, though rapid acceleration, deceleration, marginal overshoot etc can generate audible noise, and at higher speeds this can be accompanied by a higher-pitched whine.

Vibration is inherent in all motor systems and is the result of imbalances in the moving mechanical parts. It too is not usually a serious problem, although it can be crucial in panning motions for cctv cameras for example or for image processing applications and sample movement in scientific instruments.

In these circumstances the solution may be to use a three phase stepper motor, such as this MY4301 from Astrosyn. Unlike the more common two or four phase motors, three phase steppers are inherently smoother and capable of exceptionally quiet operation with a low level of vibration. They also have the advantage of having a smaller step angles.

Resonance

Resonance is a natural phenomenon inherent in the torque-speed characteristics of all stepper motors and in some circumstances can cause a sudden loss of torque with possible skipped steps and loss of synchronisation. It tends to occur mostly a low speeds, especially in lightly loaded motors, when the rotor's natural frequency oscillations overlap with the driver stepping frequency. At higher speeds it is usually masked by the drop off in torque at these speeds.

In most cases the effects of resonance can be eliminated or greatly reduced using a variety of techniques. These include the initial selection of system parameters such as operating voltage and step resolution, and the control techniques and algorithms employed in the stepper drive electronics. If it is not possible to change the operating parameters enough to improve performance without jeopardising the overall design, it may be possible to use a damper.

Dampers coupled between motor and load will exert a damping torque when the motor speed is changing but produce no drag torque when the motor speed is steady. They normally consist of a lightweight housing, which is fixed rigidly to the motor shaft, and an inertia ring, which can rotate relative to the housing. The ring and the housing are mechanically isolated by a viscous gel or by an elastomer disc.

By selecting the appropriate damper, dips in the torque-speed curve can be eliminated. The only real drawback with dampers is that they increase the effective inertia of the system somewhat, reducing the maximum acceleration.

Using a different approach, resonance, as well as vibration and noise, can also be substantially lessened by mounting the stepper motor on an elastomer damper., such as the Llow profile dampers from Astrosyn which are mounted on the motor flange. These rubber pads are thin enough to be used with standard shaft length motors.

Driver algorithms

In recent years, Astrosyn motor drivers have incorporated high level damping algorithms within their firmware. These automatically calculate the system's natural frequency and apply damping to the control algorithm. This greatly improves midrange stability, allows higher speeds and greater torque utilisation and also improves settling times.

Other firmware functions included in these units include microstep emulation, torque ripple smoothing and command signal smoothing. With microstep emulation, low resolution systems can still provide smooth motion as the drive can modify low resolution step pulses and create fine resolution motion.

All stepper motors have an inherent low speed torque ripple that can affect the motion profile of the motor. By analysing this ripple, torque ripple smoothing can apply a negative harmonic to negate this affect. This gives the motor much smoother motion at low speed.

Command signal smoothing can soften the effect of immediate changes in velocity and direction, making the motion of the motor less jerky. An added advantage is that it can reduce the wear on mechanical components.

Options for minimising resonance, noise and vibration in stepper motor systems	
Technique	**Options**
Choice of motor	Choice of standard 4-phase or smoother 3- or 5-phase. Sizing to ensure adequate dynamic torque to match load. Choice of step angle: 3.6°, 1.8°, 1.2° or 0.9°.
Gearing and coupling	Selection of speed / range / pulleys / gears. Flexible or rigid coupling.
Damping	Anti-vibration mount on front flange. Damper connected to rear shaft.
Driver	Full step, half step or microstepping modes. Sophisticated drivers can apply electronic damping at natural resonant frequency. Low speed torque ripple smoothing. Command signal smoothing. Optimisation of driver filtering frequencies and gain.