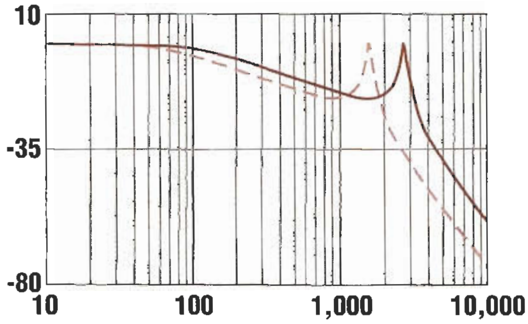
What goes wrong when inertias aren't right

Q: I've been told that motor and load inertias should match as closely as possible. But now I understand this doesn't apply to servomotors. True? What exactly should the ratio be in this case?

A: The inertia ratio of a servosystem is commonly misunderstood. The 1:1 motor-to-load inertia figure you mention applies only to stepper motors. Servomotors specified using the same rule will be unnecessarily big and expensive. They will also draw more power than they need to and thus waste energy, especially if they must settle quickly after a move.



The reason is that closed-loop servos with controlled commutation are not prone to the same kinds of desynchronization issues and torque losses that may plague steppers. A servosystem maintains a linear and predictable speed-torque curve and does so without the need for special commutation sequences or antiresonance measures.

In contrast, stepper motors are typically sized to match the load so they have enough inertia to overcome disturbances when the torque is low. These disturbances arise because of nonlinearities caused by a torque rolloff or resonances that arise at certain stepmotor speeds. Given this, it's logical to assume the current needed to move the system will divide equally between the load and stepmotor. So half the available current goes toward accelerating the motor alone. That's a somewhat wasteful use of available power.

In a typical servosystem with a "stiff" coupling, it's not hard to have a 5:1 load-to-motor inertial mismatch with no special techniques. I have successfully tuned ratios up to 1,600:1 with direct-coupled motors like the Danaher Motion DDR (direct-drive rotary). Here, "stiff" means the system isn't compliant and has no backlash. A stiff system mechanically would be conducive to a higher frequency response than a system with compliance. A compliant or soft system is one that allows for movement of the load while the motor is stationary.

To show what happens graphically, I've devised a simple example. The accompanying response versus frequency plot shows the response of two different motors each driving a load with an inertia of 0.001 oz-in.-sec^2. Motor no. 1 (red line) has a rotor inertia of 0.0002 oz-in.-sec^2; thus the load-to-motor inertia in this case is 5:1. Motor no. 2 (blue dotted line) has a rotor inertia identical to that of the load, so load-to-motor inertia is 1:1. Note the –3-dB rolloff point for motor 1 is 133 Hz, but motor 2 rolls off at 80 Hz. If the system must be responsive at 100 Hz, you are in trouble with motor no. 2.

Phase considerations and bandwidth also enter into the discussion, but I'll save those topics for next month's column.

— Lee Stephens

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