

Increasing Step Motor Performance

How Anti-Resonance Increases Step Motor Performance and Throughputs

The goal in step motor/drive selection is to identify the most economical motor/drive package that will reliably perform all the moves required in a given application. This can be a challenging task, since using conventional step motor systems is not always a straightforward procedure. Step motors can lose synchronization (stall), which causes a loss of positional accuracy resulting in an unsuccessful move. Step motor systems will stall when the torque demand for the move being executed, plus the torque lost in overcoming vibration, exceeds the available torque from the motor. One of the major causes of step motor stalling is a phenomenon called Resonance.

In conventional step motor systems, the increased torque demand on the motor due to Resonance decreases the performance of the motor throughout the motor's speed range due to a reduction in useable

torque to accelerate the load. This reduction in useable torque can either severely limit the system's performance, leading to reduced throughput, or prevent the stepper system from working at all. In Microstepping systems, Resonance is especially troublesome in the motor's speed range of 10-15 rps where it is commonly called Mid Range Instability. IDC's microstepping drives eliminate the problem of Resonance via proprietary Anti-Resonance circuitry, and thereby give the user the maximum amount of torque possible throughout the motor's speed range. To illustrate the negative impact of resonance on conventional step motor performance, and to show how much better the same system will work with an IDC microstepping drive, a look at the causes and effects of resonance on underdamped microstepping systems is in order.

Step Motor Dynamics

Motor torque is delivered to the step motor's rotor when the rotor lags behind or leads the commanded position (see **Figure 4**). The maximum amount of torque the motor will exert on the rotor occurs when the rotor is displaced 1.8° from the commanded position (Torque equals T_m). Any deflection past 1.8° from the commanded position will cause a reduction in applied motor torque from the max torque T_m (see **Figure 4**). When the rotor is deflected from the commanded position, a restoring torque acts on the rotor to move it back to the commanded position (equilibrium) much like a spring. The torque seen by the rotor at any time is a sinusoidal function of its displacement from the commanded position. In **Figure 4** a 1.8° full step (dashed line) is applied to a rotor which is located at the previous commanded position. The instantaneous torque seen by the rotor when the full step is applied is T_m . Since the torque seen by the rotor is a function of position, the 1.8° step command has caused a step change in applied torque to the rotor that will cause the motor to ring about the new commanded position (See **Figure 6**).

Resonance

Resonance is troublesome to step motor users due to the increased torque demand caused by motor vibration. This vibration causes the difference between the commanded and actual position of the rotor to vary in an undesirable manner. The difference between the commanded and actual position is called the position error. It is this position error that dictates the amount of torque that is applied to the load. Resonant behavior

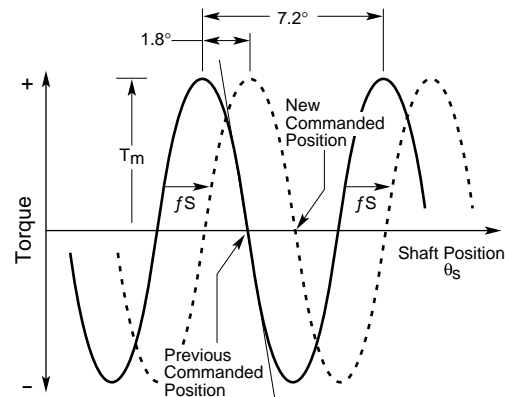


Figure 4. Operating detent of a step motor.

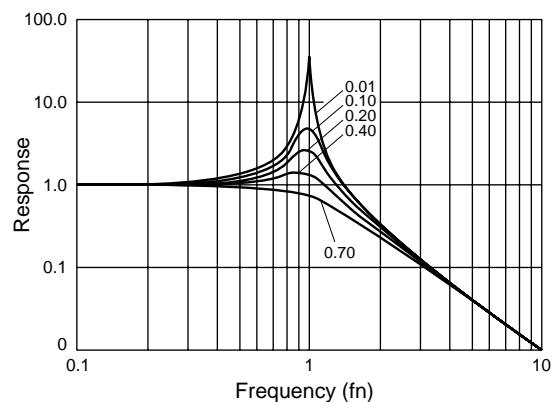


Figure 5. Frequency response of step motor system. Higher Values of ζ lead to reduced shaft vibration.

in a poorly damped step motor system increases the likelihood of the position error exceeding 1.8° (point of maximum motor torque). Once the rotor has slipped past 1.8° there is a decrease in torque applied to the load which can quickly lead to a motor stall if the required move needs the motor torque that was lost. This torque loss due to shaft vibration is why we look to increase the amount of damping present in the system. Minimizing shaft vibration leads to optimal torque utilization.

The amount of damping in a system can be described by the system's damping ratio ζ (Zeta). The higher the value of ζ the more the system is damped. A typical value of ζ for a conventional underdamped step motor system is 0.02. A step motor system with the optimal amount of damping has a ζ value of approximately 0.7. The effect of increasing the damping ratio is shown in **Figure 5**. A typical underdamped step motor system magnifies disturbances (vibration) around its natural frequency by a factor of 50. It is this vibration magnification which often causes step motors to stall. An optimally damped step motor system (like the *NextStep*) with a damping ratio of 0.7 shows no such vibration amplification. This well behaved system can fully utilize a motor's torque to do real work in your application, hence higher acceleration rates are possible and greater headroom is provided for varying loads.

To illustrate how increasing the damping of a step motor system reduces ringing and improves settling time, it is useful to look at the response of a step motor to a unit step input for different values of ζ . This is shown in **Figure 6**. A system with a damping ratio (ζ) of 0.7 settles to the commanded position promptly, while a conventional step motor system with a damping ratio of 0.02 rings far off to the right of the graph. Reducing a system's settling time increases your system's throughput, allowing a user to make more parts per minute.

A step motor system that lacks adequate damping not only has ringing when a position step is applied, but also has significant ringing when the motor is commanded to follow a given velocity profile. A popular velocity profile used in most applications is the trapezoidal velocity profile (accel-slew-decel). A typical step motor system's response to a trapezoidal velocity profile is shown in **Figure 7**. Notice the ringing in the motor's velocity both at the higher speed and after the ramp. Compare this to the velocity tracking found in an optimally damped system like the *NextStep* (**Figure 8**). The superb velocity tracking and quick settling found in the IDC microstepping drives allows a user to make very aggressive moves without having excessive ringing at speed.

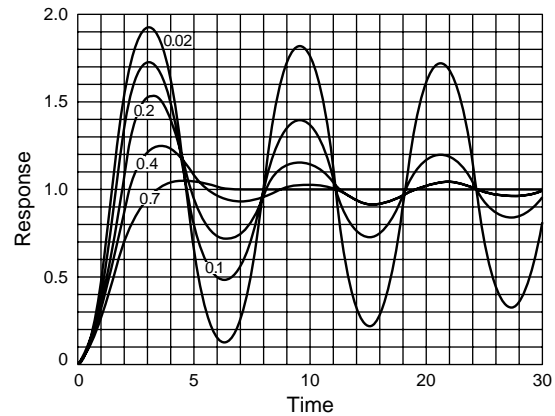


Figure 6. Ringing transients following a unit step. Increasing ζ results in more rapid settling.

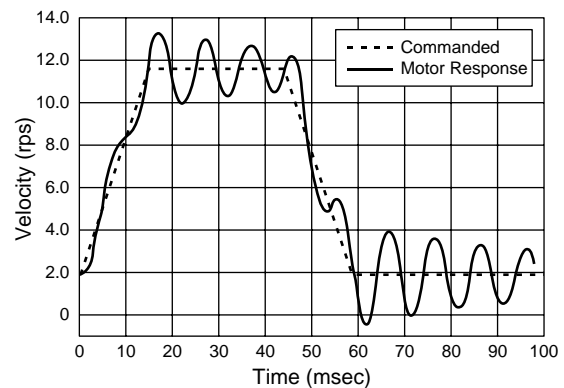


Figure 7. Typical step motor system's response to a trapezoidal velocity profile. Lack of damping leads to vibration at the top and bottom of the profile.

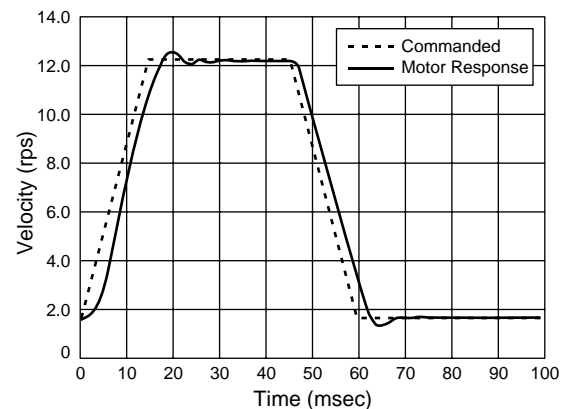


Figure 8. *NextStep* system response to a trapezoidal velocity profile. Increasing the damping leads to better velocity tracking and smoother overall motion.