

# Servo System Speed Regulation

Servo systems, by definition, include the use of a feedback device to control or regulate the required function. For servomotors and amplifiers, feedback is accommodated by a motor connected tachometer (or other device) that provides an indication of motor speed. This device gives the system speed regulation.

Speed regulation can be an ambiguous term. It is generally represented as a percentage of the operating speed, specifying a maximum allowable deviation. This percentage of speed is with respect to the maximum speed of the motor or a particular commanded speed. Speed regulation can also be short-term (instantaneous) or long-term regulation. Speed regulation needs to be defined with respect to a specific operating speed range.

## Short-term (instantaneous) Regulation

The concept of short-term or instantaneous regulation implies immediate response by the system to correct for speed changes. In order for the system to respond, there must first be a detectable speed change, as indicated by the tachometer signal. The response time of the system is further delayed by factors such as amplifier gain and bandwidth. These delays for typical systems are a few milliseconds. Other factors affect the amount of speed regulation that is obtainable. Some of these factors are internal to the servo system, while others are a function of external considerations.

Tach ripple is one factor affecting regulation internal to the system. At the input summing junction of the amplifier, the input command signal is added to the tach feedback signal (having opposite polarity) resulting in the velocity error signal. This signal is amplified to provide current in the motor to correct for any deviation. The amplifier responds to a varying tach voltage, regardless of whether the tach voltage change results from a motor speed change or the voltage ripple in the tach itself. For this reason, the speed regulation is only as good as the tachometer controlling the speed. This does not take into account the additional benefit that a position loop can contribute.

Another consideration within the system is the motor's torque ripple. Torque ripple has the tendency to cause speed ripple. The tach works to correct for this as it would for any load change causing a speed change. Its ability to do this has largely to do with the bandwidth of the system. Bandwidth is defined as a frequency at which the system can respond. A system with 100 Hz bandwidth means that at 100 Hz, the system responds and corrects at a relative gain of 0.5, a 3 dB reduction in response. At any given speed, the system regulates if the motor's torque ripple frequency is within the amplifier's bandwidth. Amplifier bandwidth is a function of the compensation that takes into account the combined motor and load inertia, among other things.

Considerations for speed regulation outside the system are a function of load changes, both in terms of magnitude and frequency. Some generalized statements can be made about our system regulation. Danaher Motion's brush or brushless systems can usually provide short-term regulation of 1 % or better. This means, for a 1000 rpm motor, the deviation of speed is no more than  $\pm 10$  rpm. The low ripple tachometer further benefits the regulation downward to 0.5 %.

## Long-term Regulation

Long-term regulation defines the ability of the system to provide the same speed (assuming the same input) over significant time periods of minutes, hours, or longer. For this discussion, we will consider periods of time prior to the long-term effects of aging on amplifier components, that occur after months or years. Regulation is affected by the temperature coefficients of amplifier components and the tachometer magnets. These change both amplifier offsets and the  $K_B$  of the motor-connected tachometer.



***For standard brushless motor systems using only resolver feedback, tachometer coefficients are not a factor.***

Long-term regulation will, at worst, be 1 % to 2 %. This takes into account the range of maximum operating temperatures for the amplifier and motor tachometer. Low drift op amps are available on many products to better this number by about 50 %. The long-term regulation of a system that has become temperature-stabilized, is as much as 10 times better or 0.1 % to 0.2 %.

If better long-term regulation is required, the use of a position loop controller around the velocity loop provides this to the extent of the accuracy of the clock frequency regulation within it. This is because velocity is now also controlled by a time-based displacement command that corrects for the servo system's inaccuracies.

## Conclusion

Many factors affect the various aspects of speed regulation. Response to questions concerning speed regulation must be qualified by an understanding of this information with respect to the customer's concern and load information.