

Interfacing with Standard Servo Controls

Application Note # 102

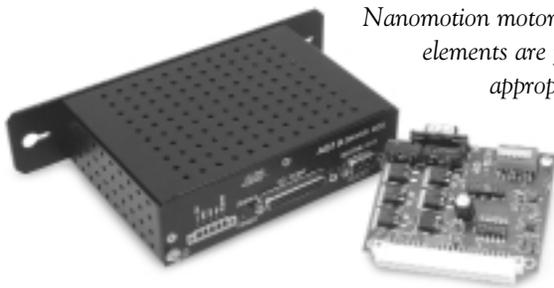
The operating nature of Nanomotion's motors provides the ability to meet a wide range of demanding motion control applications. The standing wave, piezoelectric effect makes Nanomotion's motors ideal for applications starting from slow speed constant velocity to high speed move and settle. The motor technology provides a bridge between high speed operation and exceptionally high resolution, in a very small footprint with unlimited travel.

Nanomotion's motor is most often controlled as a closed loop servo motor, quite synonymous to a brushless dc motor. Just like standard motors that drive either linear or rotary motion, feedback from a linear or rotary encoder should be provided to control position. The purpose of this Tech Note is to provide an understanding of how to integrate Nanomotion's motors with the standard servo controllers on the market.

Nanomotion Motors are presently being controlled with the following controllers:

- **Acroloop**
- **ACS/Tech 80**
- **Delta Tau**
- **Galil**
- **MEI**
- **National Instruments**
- **Nyquist**
- **Parker Compumotor**
- **And several others**

The Uniqueness of Nanomotion Motors



While based on the principles of reversed piezoelectric operation, the Nanomotion motor generates ultrasonic standing waves. When the motor elements are preloaded (compressed) against a bearing structure with an appropriate friction material, the motor works as a friction drive, pushing the mass in a linear, rotary or spherical manner.

The applied voltage on the preloaded motor, determines the oscillation amplitude, which in turn determines the range of speed and force that is achievable with the motor. This range is as wide as 1:250,000. On the preloaded motor, a static friction exists. This intrinsic friction in the

technology provides significant advantage for vertical applications as well as for high speed move & settle, adding the ability of rapid braking and holding of position stability while at power off. Nevertheless, it is the same friction that must be managed through the servo tuning process in order to generate high performance motion profiles.

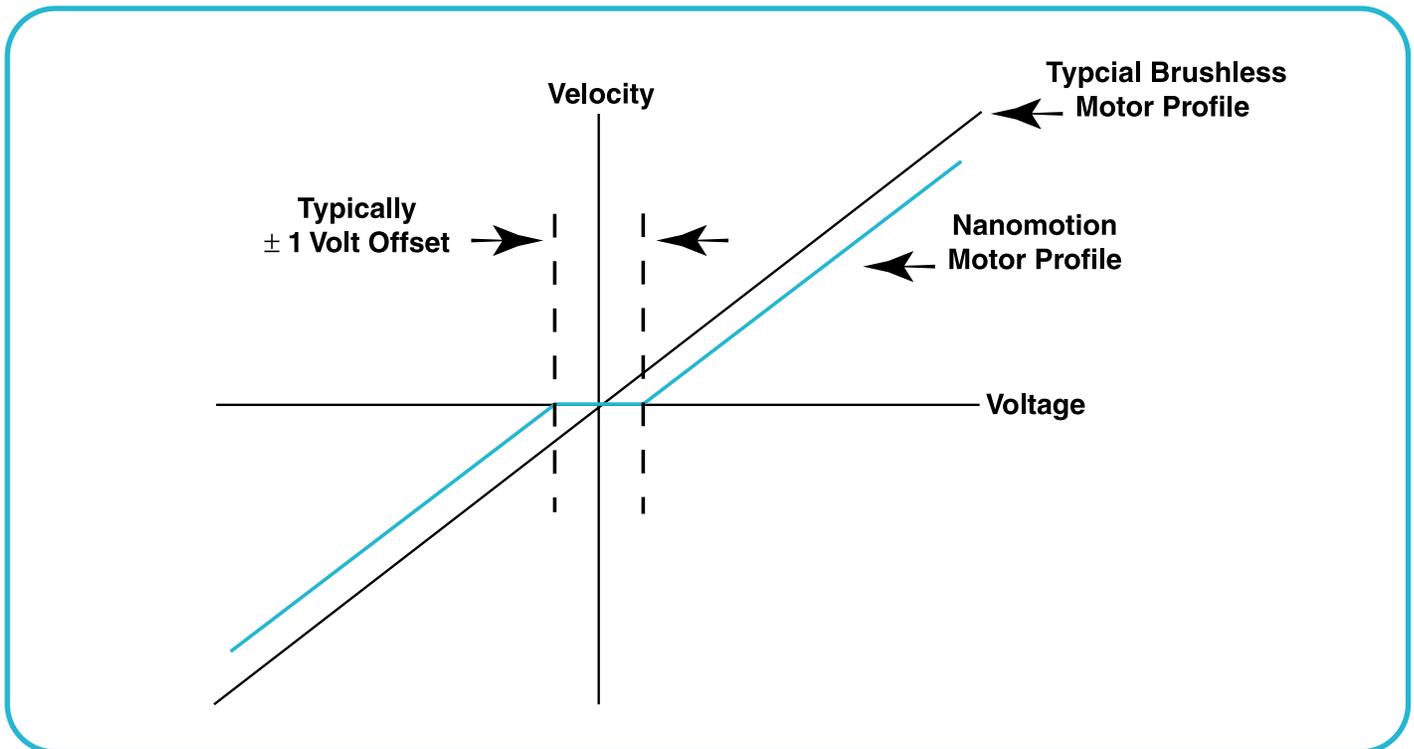
So ... What is the Affect

The Non-Linear Voltage to Velocity Profile

In simple terms, when you consider the voltage to velocity profile of a brushless dc motor, the only resistance to motion is the friction in the bearing. As motor bearings are typically low friction ball bearings, the slightest current to the motor will generate velocity

In Nanomotion's motor configuration, the preload of the motor against a work surface (ceramic strip) creates a deadband, or dead-zone, around ± 1 volt of command voltage, where no motion occurs. Once an offset is established, the profile is linear.

NANOMOTION MOTOR/BRUSHLESS MOTOR PROFILES



In any servo system that possesses a certain amount of stiction (static friction), there needs to be some compensation for this at the control level. This is no different that using a recirculating linear guide with negative bearing clearance, which results in a high drag force. Additionally, using high efficiency ball screws in a vertical orientation, lifting a reasonable load has offset requirements (in the upward direction).

With no compensation for the stiction, the control parameters would be disproportionate, with the P (proportional) gain being excessively high. Once the P gain is raised to a level to overcome the friction, the motor would be at a point of instability and never be able to settle. Preferably, there are several standard controller features, or custom algorithms, which can be used to compensate for the friction very effectively. Standard control features such as Velocity Feed Forward or Torque Offsets (provided it is bi-directional) provide adequate compensation for system stiction. While virtually all servo controls have standard features to address this situation, many servo control manufacturers have taken the initiative to implement custom algorithms to manage the stiction mode of the Nanomotion ultrasonic motors, with a simple command set, assuring ease of use for high resolution applications.

Motor Servo Algorithms

While most servo control manufacturers have implemented custom algorithms with a simple command set, there are two distinct methods for accomplishing this. As the stiction is only present during the start of motion, it is preferable that the offset function be provided as part of the control's integrator, and only be applied during the acceleration portion of the move. After a motion profile is initiated through the acceleration curve, there is no need for the offset voltage. This will also minimize excitation of the system's natural frequencies due to the smoother command.

Alternatively, some manufacturers have provided a fixed offset that is constantly present. Whether accelerating, at constant speed, or even at a stop position, the offset voltage is still streaming from the DAC output. While this algorithm will work, it is much less desirable than the preferred method mentioned above. In vacuum application the offset command at stop unnecessarily generates heat which might limit the Envelope of Performance.

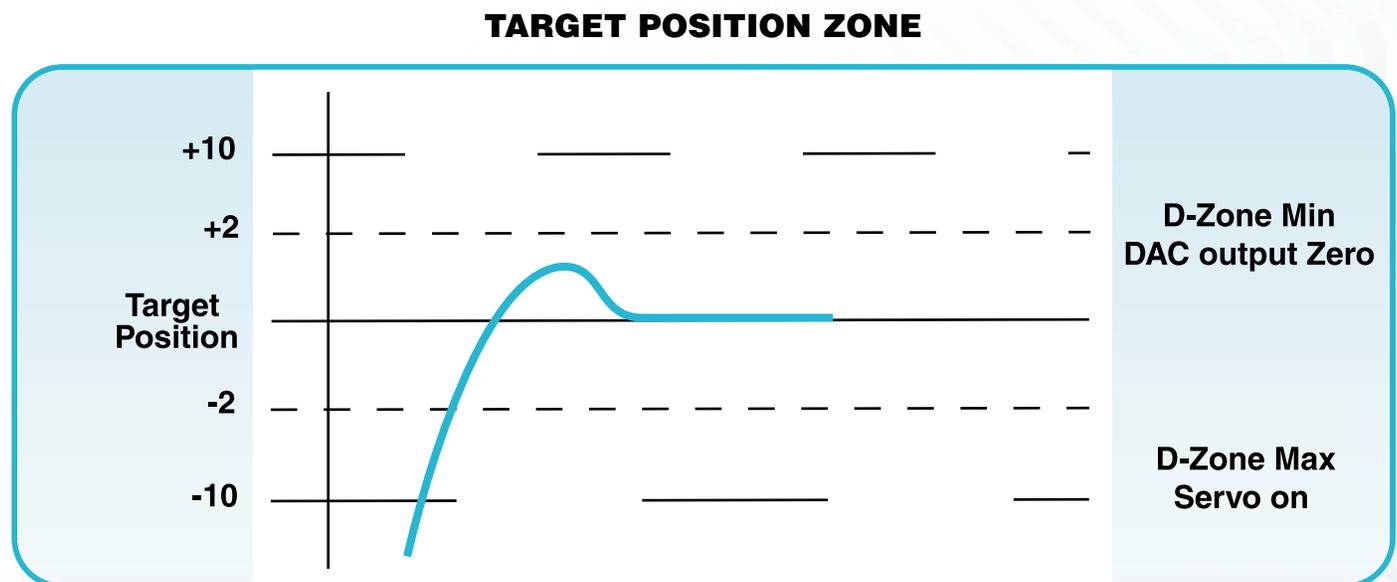
Motor Offset Tuning

The process for tuning Nanomotion motors is straightforward and similar to other motors. After the motor conditioning and cleaning process, defined in the product manual, an open loop DAC output should be provided to the motor to determine the voltage level when the stage starts to move smoothly across its travel. It is best to start at an output command voltage of .5 volts and increase in .1 volt increments. Once the voltage is identified, separately in each direction, the offset value should be established at 65% to 70% of the actual offset voltage. At this point, normal servo tuning processes should be used.

It should be noted that as the motor has high stiffness and intrinsic friction, the ultimate tuning values are typically lower than a brushless dc motor equivalent.

Target Position Zone

In addition to utilizing an offset for managing the stiction, it is preferable that "dead (D) zone" or position target be established for settling. It is quite common in high performance motion applications that a target position be established to control position accuracy and repeatability. In the instance of Nanomotion's motor, the objective is to use the intrinsic friction in the motor to settle rapidly, and then eliminate the voltage to the motor when in position.



Through an algorithm, a minimum zone and maximum zone are established. The minimum zone is typically set at one, or two, encoder counts and provides the function of bringing the command to the motor zero. The maximum zone is established at the repeatability requirement of the application and provides the function of turning the servo on again, when outside this zone.

For example, if using a 0.1 micron encoder to repeat position to within 1 micron, the D-Zone Min can be set to 2 counts and the D-Zone Max can be set for 10 counts. The result will be a system that will continuously servo until in the required target position - D-Zone Min, and use the intrinsic friction to stop and hold position in the minimum range. This is a common function today, without any specific algorithm, when a loop is written to monitor position and stop when inside that target.

Servo Control Manufacturers and Nanomotion Algorithms

Manufacturer	Current Status of Algorithm
Acroloop	Acroloop has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max.
ACS/Tech80	ACS has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max. Additionally, ACS has several unique algorithms, exclusive to Nanomotion for exceptionally slow speed motion (microns/second range), to enhance performance.
Delta Tau	Delta Tau has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max. Additionally, Delta Tau's Velocity Feed Forward is an effective tool to address the offset, if operating with the algorithms.
Galil	Galil has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max. It should be noted that Galil uses a fixed offset value that provides a DAC output on a continuous basis.
MEI	MEI has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max.
National Instruments	NI has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max. Algorithms are available for downloading off of their website.
Nyquist	Nyquist has a Nanomotion algorithm that provides a command set for offset values in each direction and establishing a D-Zone min and max. Additionally, Nyquist has several slow speed and pulse algorithms that are very effective for small steps and slow speed constant velocity.
Parker Compumotor	Parker Compumotor does not have Nanomotion algorithms at this time. The use of Velocity Feed Forward is helpful to manage the stiction.



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