

MDXK

Integrated Servo



Tuning Guide Manual

Applied Motion Products, Inc.

Like most modern servo drives, the MDX integrated series employs sophisticated algorithms and electronics for controlling the torque, velocity and position of the motor and load.

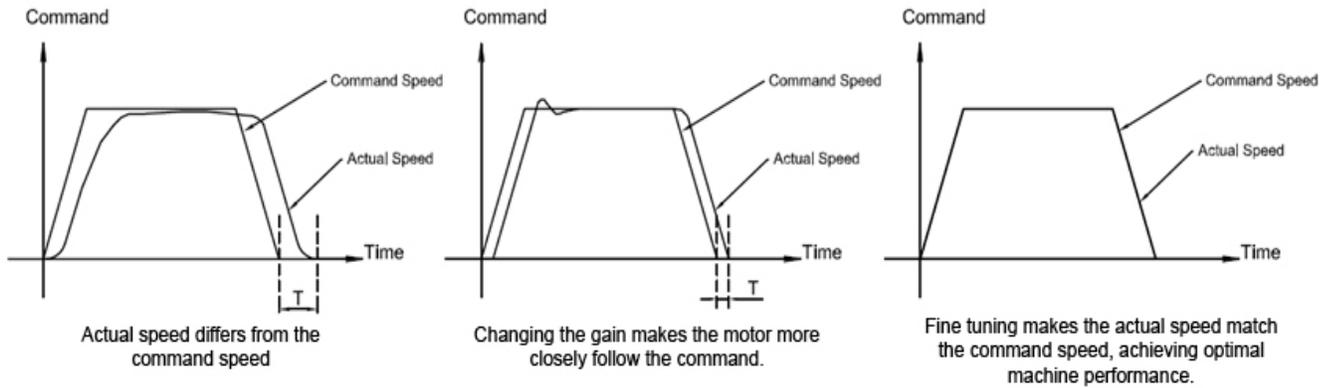
Feedback sensors are used to tell the drive what the motor is doing at all times. That way the drive can continuously alter the voltage and current applied to the motor until the motor meets the commanded torque, velocity or position, depending on the control mode selected. This form of control is called “closed loop control.”

One of the loops controls the amount of current in the motor. This circuit requires no adjustment other than specifying the maximum current the motor can handle without overheating.

The PID loop compares the intended motor position to the actual motor position as reported by the encoder. The difference is called error, and the PID loop acts on this error with three gain terms: the Proportional term, the Integral term and the Derivative term. The Acceleration Feedforward term is also added to achieve greater system control.

1 Servo Tuning – Adjustment of Gain Parameters

Servo tuning is used to optimize the servo system’s overall performance and reduce system response time. Servo tuning allows the servo motor to execute host control commands more precisely in order to maximize its system potential. Therefore, it is highly recommended that the gain parameters be optimized before actual system operation.



The PID loop compares the intended motor position to the actual motor position as reported by the encoder. The difference is called error. The PID loop acts on this error with these three gain terms: Position Loop Gain (KP), Integrator Gain (KI), Derivative gain (KD). In addition to the PID loop control, the MDX series add a number of extra terms to enable greater system control. These additional terms include: Damping gain (KV), Inertia feed forward gain (KK), Derivative filter gain (KE), and PID filter (KC), Follow Factor (KL).

In general, for systems having stiff mechanical transmissions, increasing the servo gain parameters will improve response time. On the other hand, for systems having more compliant mechanical transmissions, increasing servo gain parameters will potentially cause system vibrations and reduce system response time.

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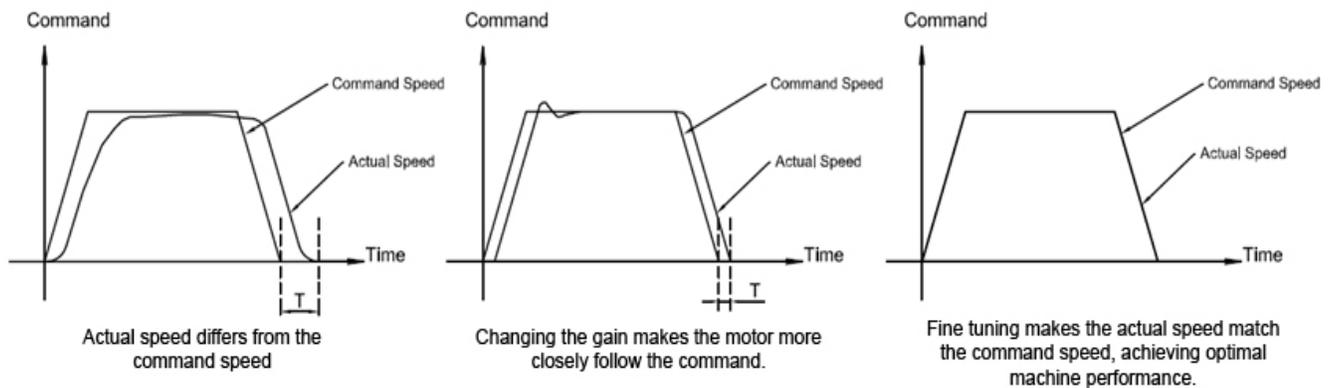
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1.1 Gain Parameter Introduction

Position loop gain (KP):

This parameter is the primary gain term for minimizing the position error. It defines the system stiffness. Larger KP values means higher stiffness and faster response times. However, if gain values are too high, vibration can result.

Values ranging from 5000 to 10000 are commonly used. In general, use default parameter values when possible.

Derivative gain (KD):

This parameter is used to damp low speed oscillations and increase system smoothness. If gain value is too high, vibration can result and increase system settling time.

Values ranging from 6000 to 23000 are commonly used.

Damping gain (KV):

KV minimizes the velocity error and reduces system vibration in position control mode.

Values ranging from 4500 to 11500 are commonly used.

Integrator gain (KI):

This parameter minimizes (or may even eliminate) position errors especially when motor is holding position.

Values ranging from 40 to 125 are commonly used.

Inertia Feedforward Constant (KK):

KK improves acceleration control by compensating for the load inertia.

Values ranging from 2500 to 7000 are commonly used.

Derivative Filter (KE):

KE is a derivative gain filter. This filter is a one-pole, low-pass filter intended for attenuating high frequency oscillations. This value is a constant that must be calculated from the desired roll off frequency.

Values ranging from 3000 to 8000 are commonly used.

PID Filter gain (KC):

The servo current loop control overall filter frequency. This filter is a simple one-pole, low-pass filter intended for attenuating high frequency oscillations. The value is a constant that must be calculated from the desired roll off frequency.

Values ranging from 5000 to 16000 are commonly used.

Follow Factor (KL):

Higher values will reduce system noise and eliminate overshoot, but will reduce the system's dynamic following performance. Lower values will raise system stiffness, but may cause system noise.

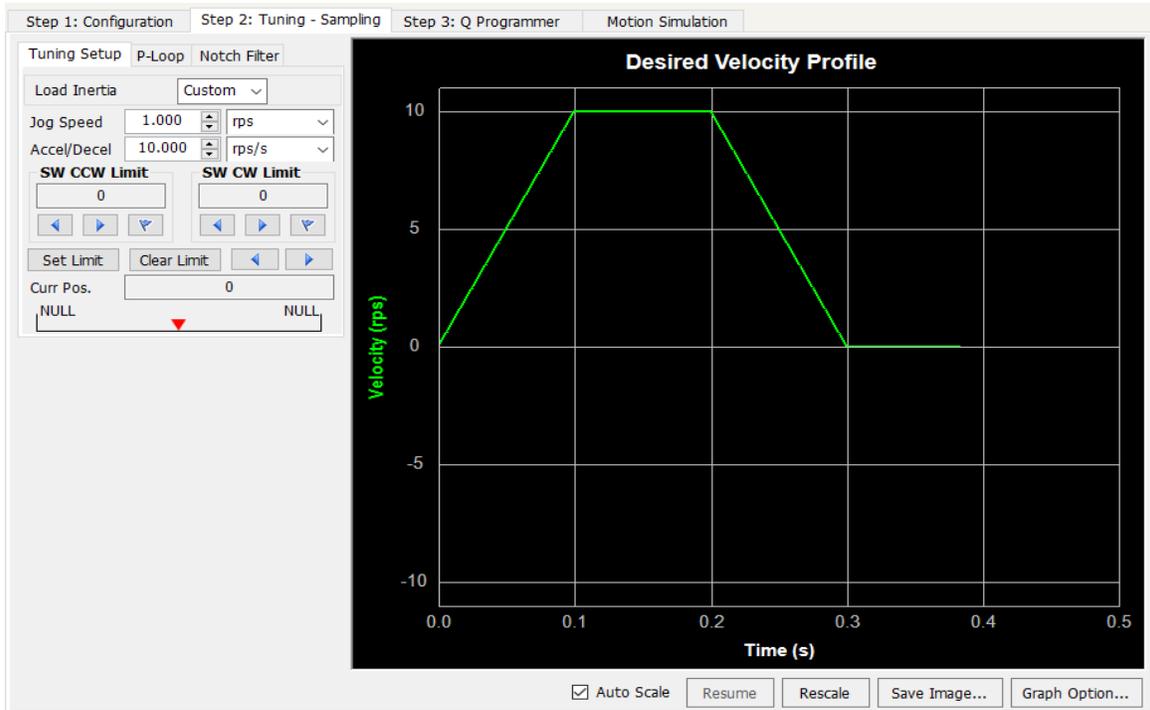
Values ranging from 0 to 5000 are commonly used. In general, use default parameter values when possible.

1.2 Setting the Software Position Limits

The Software Position Limit function uses encoder counts to set “soft” limits at user-defined locations that can then be used during the tuning process. These position limits ensure that the motor will ONLY rotate between the CCW and CW limits, which will help to prevent accidental system damage. This is especially useful when the motor is coupled to a linear actuator, for instance.

NOTE: The software Position Limits will ONLY be effective during current power-up operation and will not be saved to non-volatile memory for use at the next drive power up. Therefore, DO NOT rely on these software limits during actual system operation. Refer to LP and LM commands in MDX Servo Suite’s built-in Q Programmer help for more details.

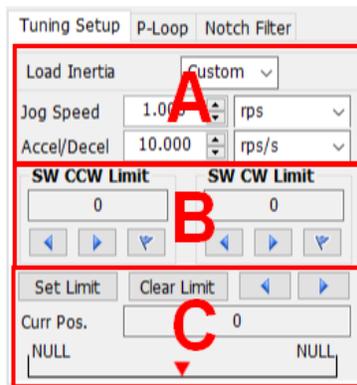
On the “**Tuning- Sampling**” panel, select the “**Tuning Setup**” tab to setup software position limits. If software position limits are not required, then click “**Clear Limit**” and go to the next step for the “**P loop**” tuning function.



1.3 Setup Software Position Limits

Here are the steps to set the soft limits, also shown below:

- A. Before rotating the motor and setting limits, first select load inertia recommendation according to your mechanical system, Setup Jog Speed, and Accel/Decel rate based on your system length for reach your system position limit, **low speed is recommended.**
- B. Set CW/CCW limit – move to desired position with arrow buttons, then click the flag button to set.
- C. Confirm or Cancel position limits set in step B with the Set Limit or Clear Limit buttons

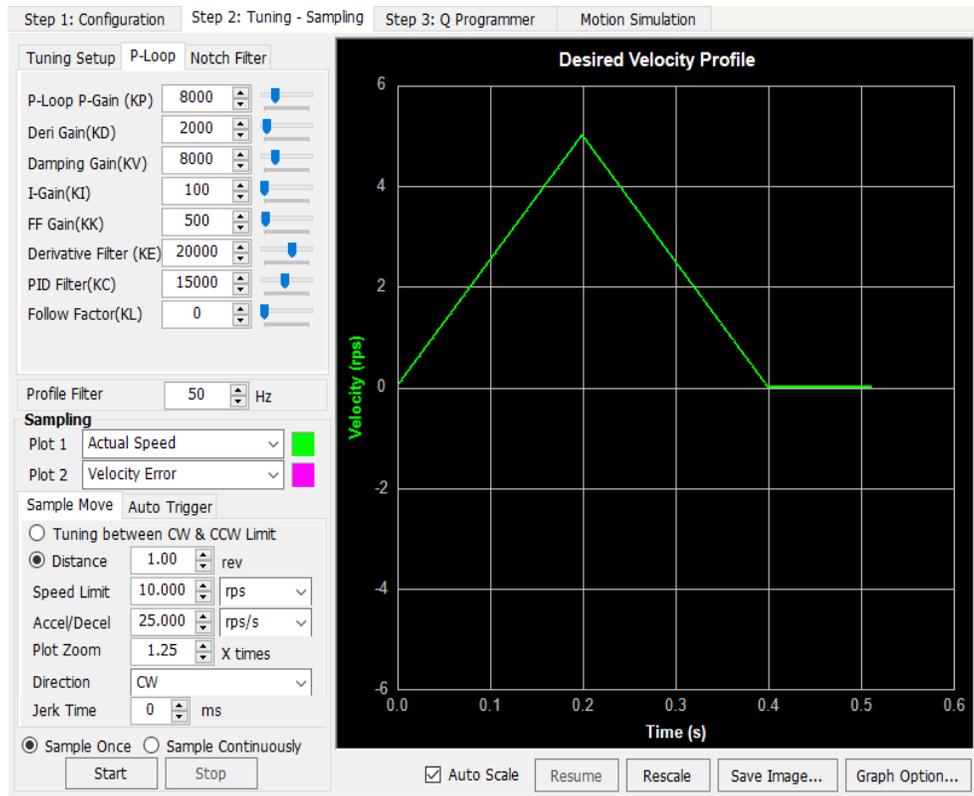


Detailed Steps for Software Position Limit

Step	Operation	Software
1	Make sure Servo is Enabled	
	Click or to rotate motor in CCW or CW direction	
	When target position reached, click to accept and store position	
2	Same process as above	
3	Confirm position limits Click on	
4	Setting complete	

1.4 P loop Tuning Function

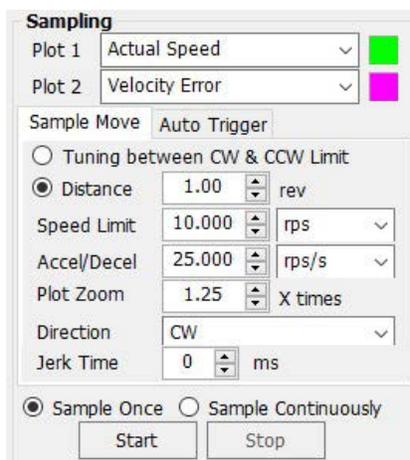
From the “P Loop Tuning” tab, follow these steps to configure our motion profile:



Operation steps

1. Set Tuning Distance, Speed target, and Accel/Decel

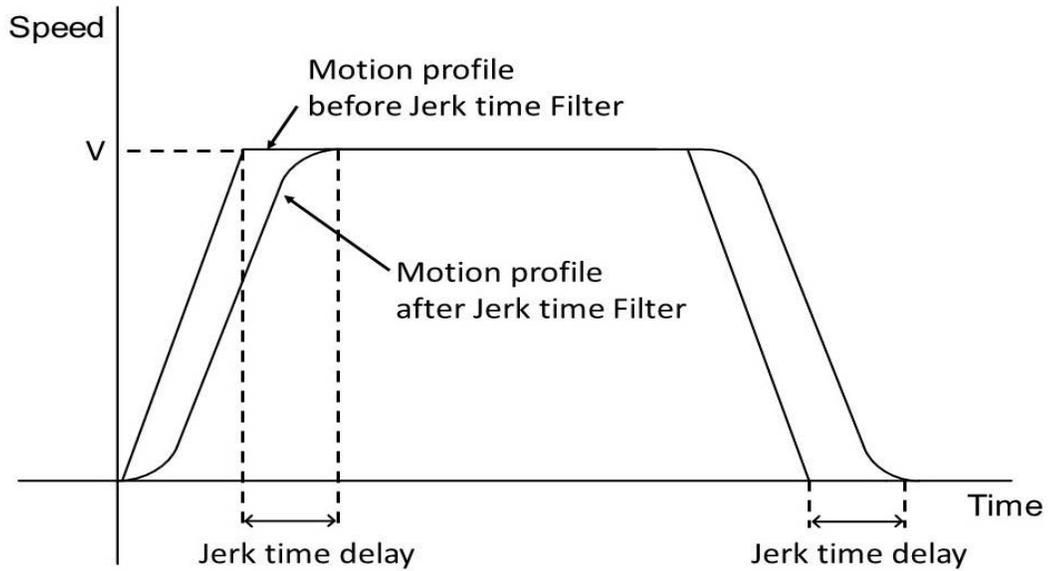
NOTE: If software position limit is set, select “Tuning Between CW and CCW Limit”
If no limit is required, select “Distance” (ensure software position limits have been cleared)



1.5 Jerk time

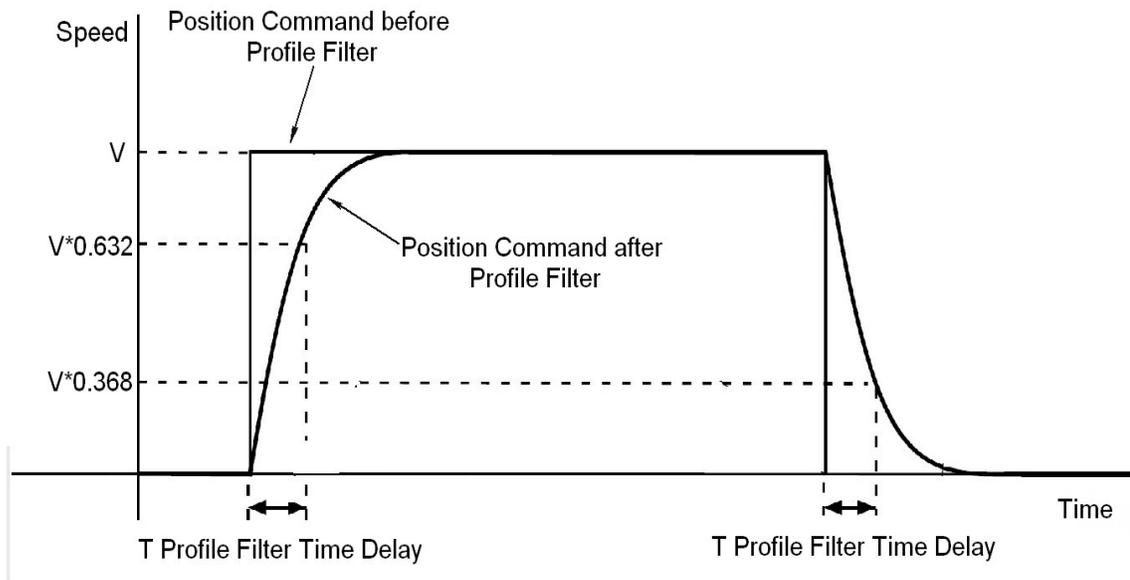
This parameter sets the jerk Time . The higher jerk time value will have more pronounced the S-curve profile. Setting the value to 0 will disable the Jerk time.

The Jerk time sets the S-curve acceleration/deceleration to improve the motion smoothness and reduce the settling time after the change of acceleration/deceleration. However it will increase the time of acceleration/deceleration, and total time of the motion. One example is when the load is connected to the motion actuator via a long movement arm. If the arm is not sufficiently rigid, changes in speed at the actuator can result in undesirable oscillations and increased settling time at the load. Smoothed transitions in speed changes can alleviate this unwanted motion and reduce settling time.



1.5.1 Profile Filter

This is a lower pass filter for position command. When a square wave position command comes in, this will add in time delays and smooth the acceleration and deceleration process to minimize system position error and smooth the motion profile.



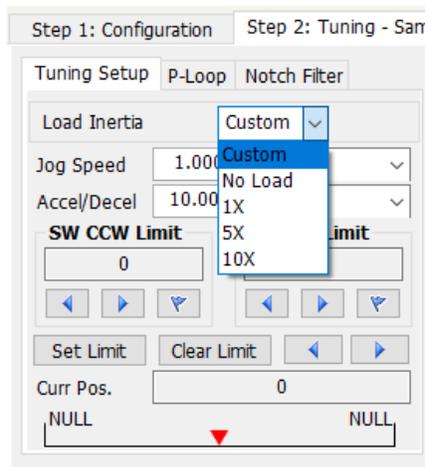
2 Tuning

2.1

Depending on the mechanical system characteristics and the servo motor used, the following parameters are available and may need to be adjusted to improve system performance:

- Position loop gain (KP)
 - Derivative gain (KD)
 - Damping gain (KV)
 - Integrator Gain (KI)
- Inertia feed forward gain constant (KK)
 - Derivative filter gain (KE)
 - PID filters (KC)
 - Follow Factor (KL)

Based on your mechanical system, you can choose from Applied Motion recommended load inertia ratio to start with.



2.2 Position Loop Gain (KP)

This parameter is the primary gain term for minimizing the position error. Increase of KP will increase stiffness and reduce in position time duration. However, it might cause vibration if gain value is too large. This is simplest part of the PID loop. The drive applies current to the motor in direct proportion to the error. Here's an example: if the motor were standing still, and you suddenly turned the shaft by hand, you'd want the drive to increase the motor current so that it goes back into position. The further you disturb the motor from its target position, the more the torque will increase. In general, Increase of KF will increase stiffness and reduce in position time duration. However, it might cause vibration if gain is too large.

As shown in Figure below, if KP is small, motor position error will be high at all times (including acceleration, constant velocity, and deceleration).



KP too small

If KP value is appropriate, the position error during acceleration and deceleration will be settled very quickly.



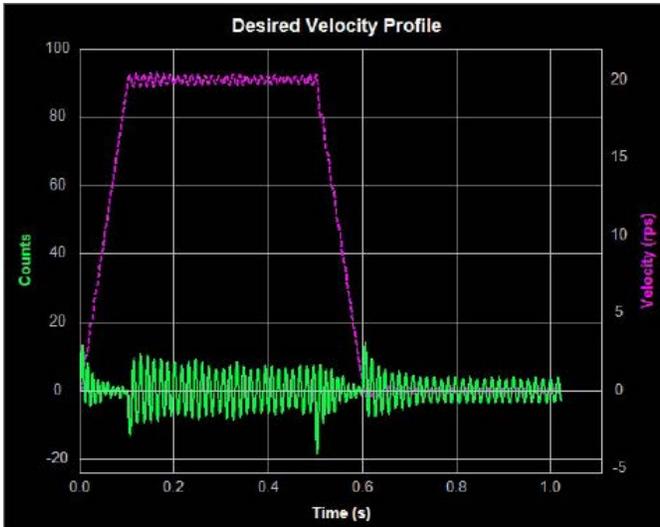
KP Optimized

2.3 Derivative gain (KD)

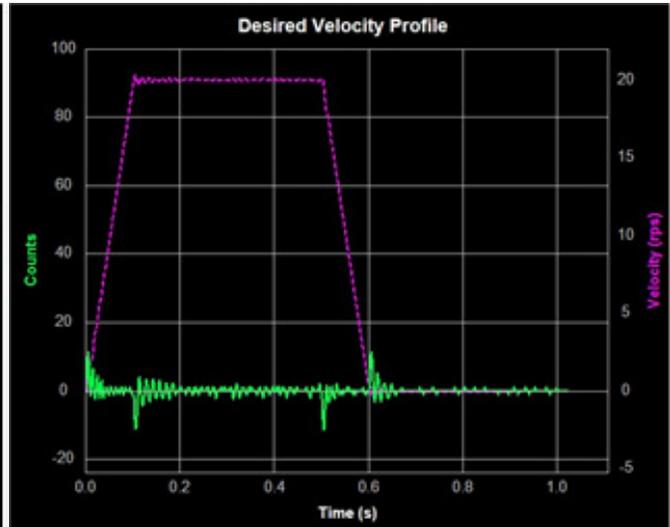
This parameter is used to damp low speed oscillations and increase system smoothness.

A simple PI controller without Derivative gain (KD) would cause the motor to overreact to small errors, creating ever larger errors and, ultimately becoming unstable. If you knew what the motor was going to do before it did it, this behavior could be prevented. When pulling a car into a garage, for example, most people do not wait until the car is fully into the garage before stepping on the brakes. Instead, most people slow down as they see the distance between them and their objective get smaller.

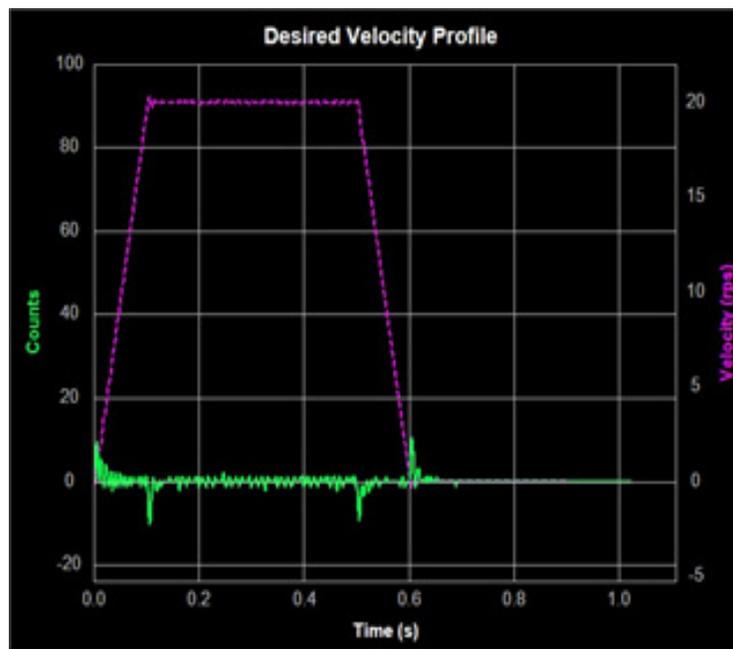
A motor drive can control a motor better if it examines the rate of change of the position error and includes that in its torque calculation. So, as the position error decreases, the torque commanded to the motor can be reduced with the appropriate KD setting. In the example shown below, when KD is small, the system does not settle quickly after changes in the move profile. Instead, the response indicates that the motor is oscillating around the target position that is being defined throughout the move profile.



KD too small

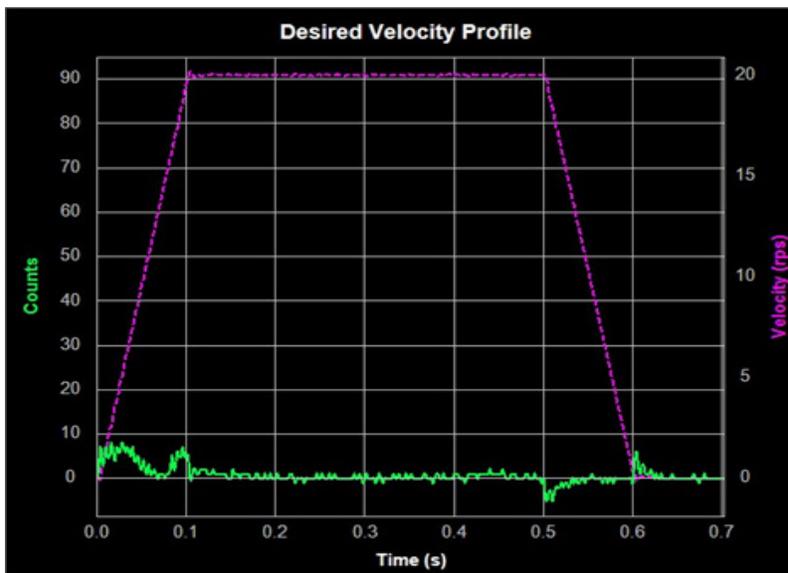


As KD increases



KD Optimized

When KD is too large, however, the system will become highly sensitive to the commanded changes in motion, which can potentially cause unexpected system vibrations and noise as shown below.

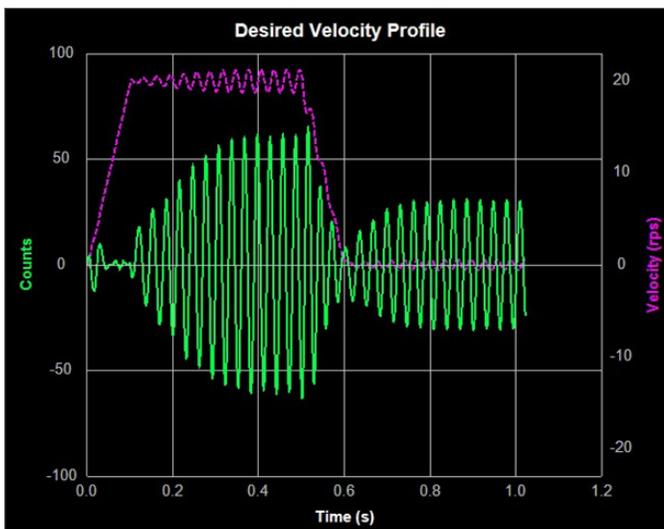


KD too large

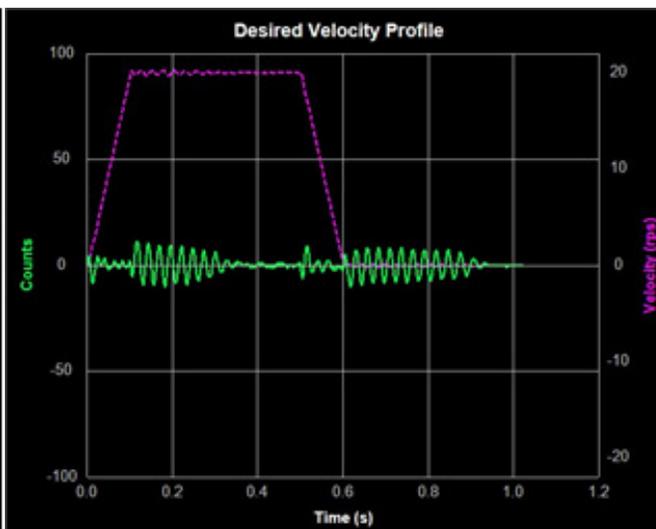
2.4 Damping gain (KV)

As the motor load inertia increases, the servo system will require higher damping gain (KV) to reduce position errors during constant speed and when the motor stops.

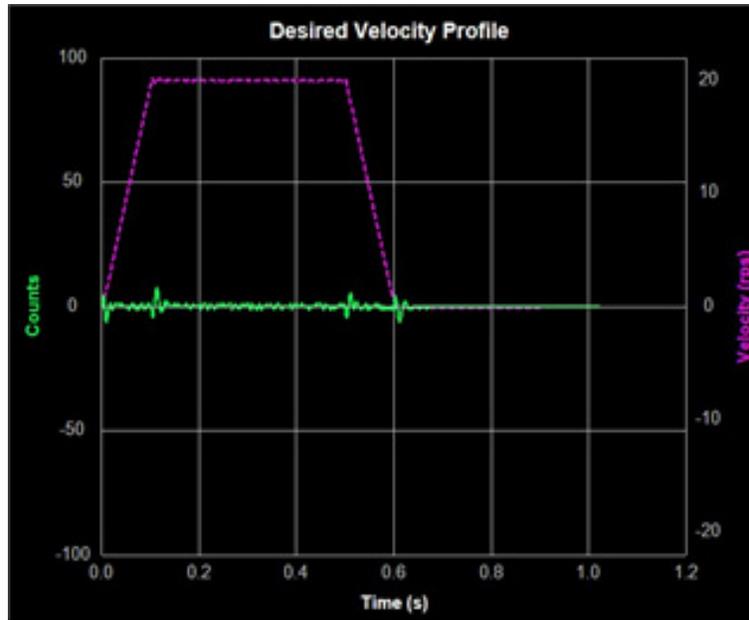
When KV is too small, this low damping value will cause large position error fluctuations while the motor is running at constant velocity and while stopped, holding position. As the next chart shows, an increasing amount of position error occurs during constant velocity and when stopped. These oscillations seen on the graph will result in motor and system vibration, as well as audible noise.



KV too small

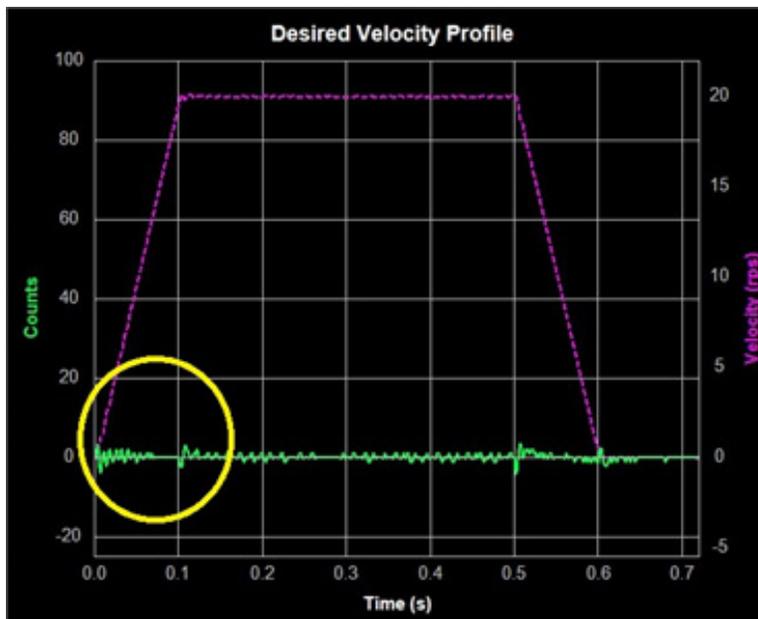


As KV increases.



KV Optimized

When KV is too large, however, the strong damping yellow below:

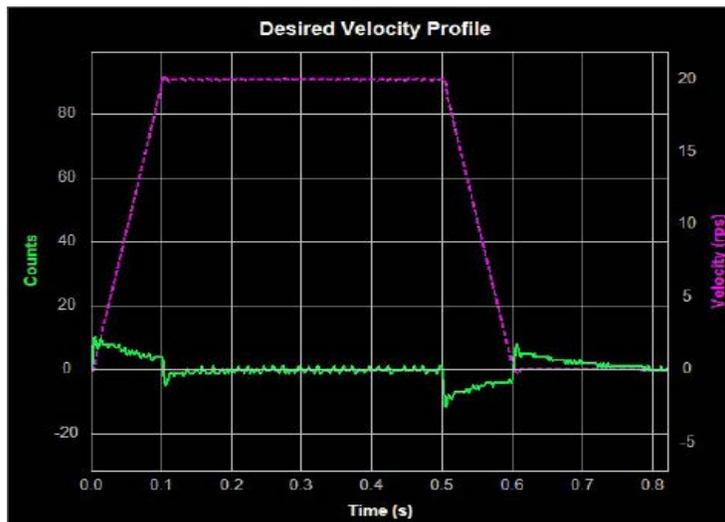


KV too large

2.5 Integrator Gain (KI)

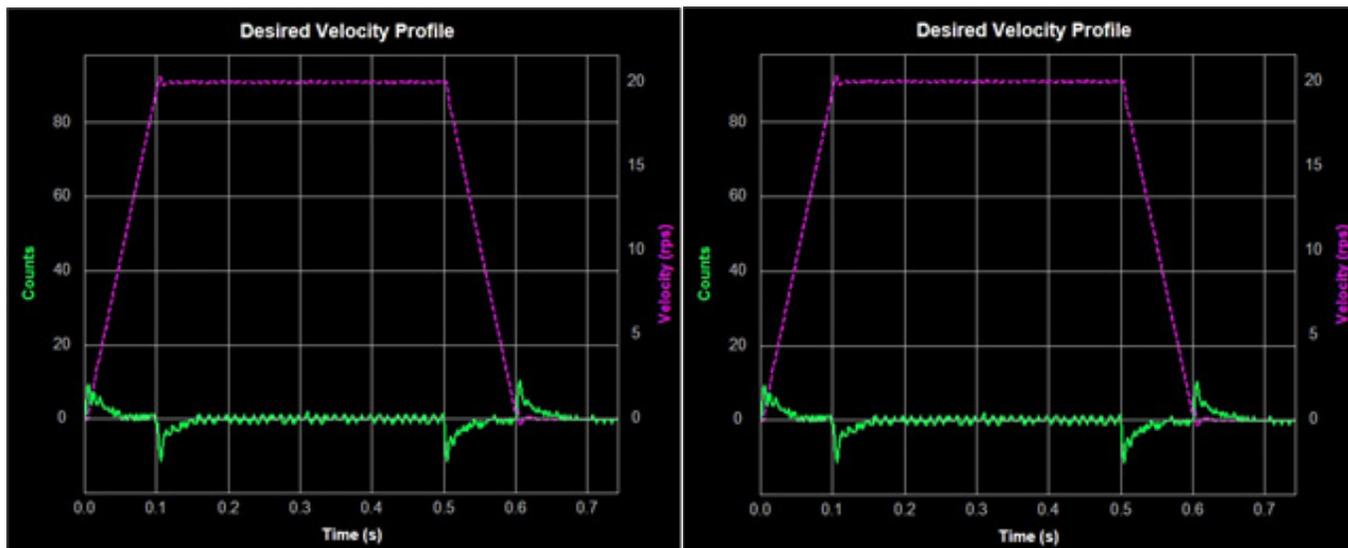
The position loop gain (KF) alone will often not be enough to give the best performance in terms of minimizing the position error and may require a long time settling time. In these cases, the Integral gain (KI) will keep adding up that error and continue to increase the torque until the motor truly returns to the target position.

As the next chart shows, when KI is small, the system will require excessive time for position errors to settle out and during acceleration, deceleration, and when the motor stops.



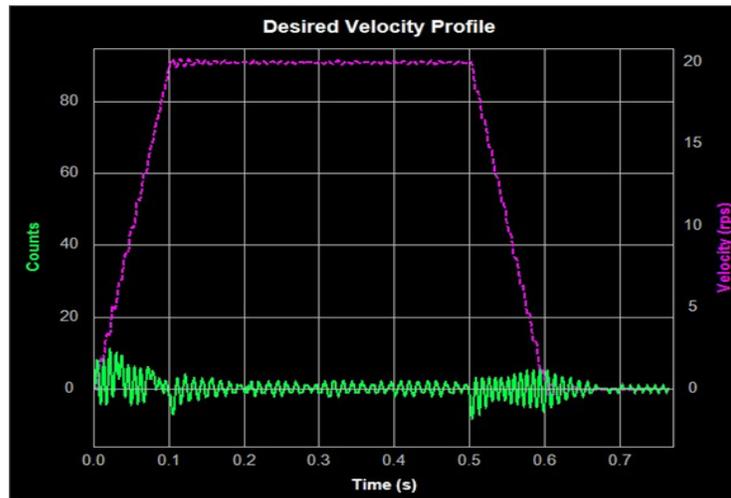
KI too small

As the next charts show, increasing KI can improve system response time and reduce position error and settling time during motor acceleration, deceleration, and when the motor comes to rest.



KI Optimized

As seen below, if KI is too large, the whole servo system will vibrate and make noise. This, in turn, will increase the position error and may greatly extend settling time due to system oscillations around the target position.

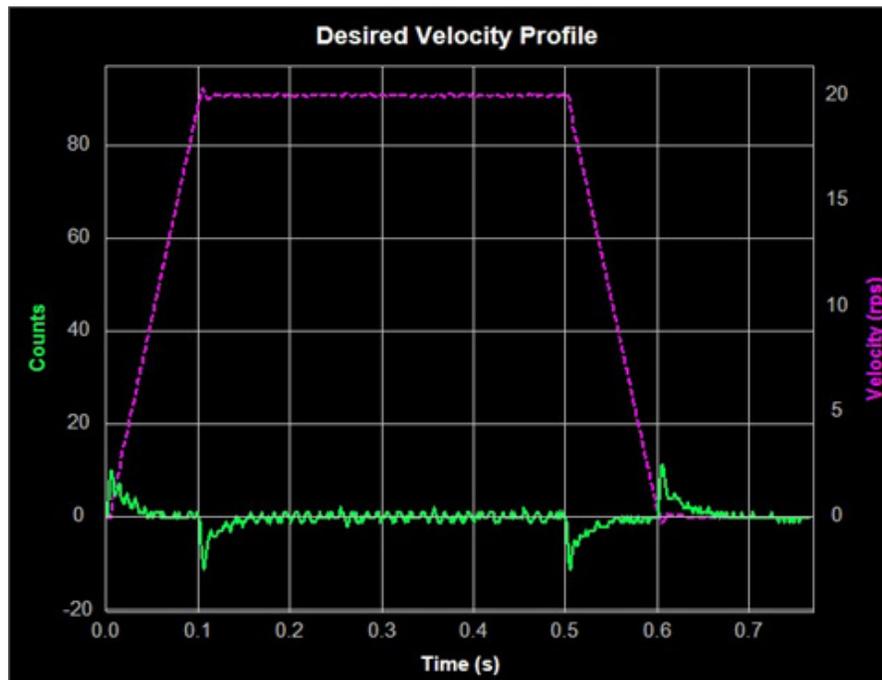


KI too large

2.6 Inertia Feedforward Constant (KK)

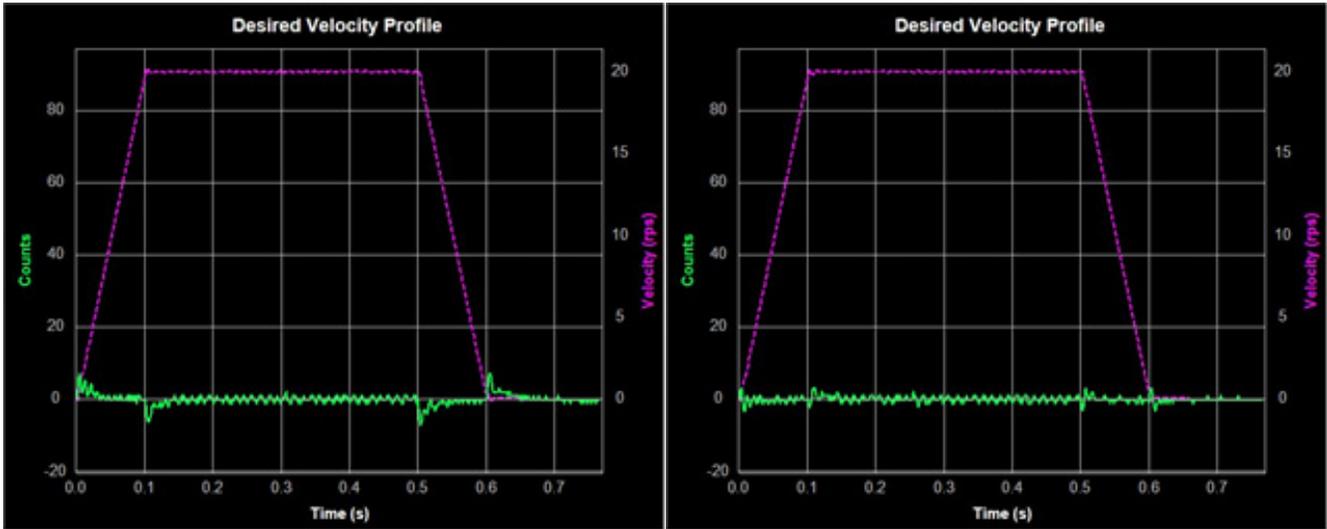
With larger loads typically comes larger load Inertia. These larger inertias can be more easily accelerated or decelerated by anticipating the control system needs. The Acceleration Feedforward gain term (KK) does this by adding an acceleration value to the control value, which reduces position error during acceleration and deceleration.

When KK is small, the feedforward constant will not be enough to effectively reduce position error. This will cause undesirable effects on the system's dynamic performance during the acceleration and deceleration. The result will be larger position error and longer settling time as shown below.



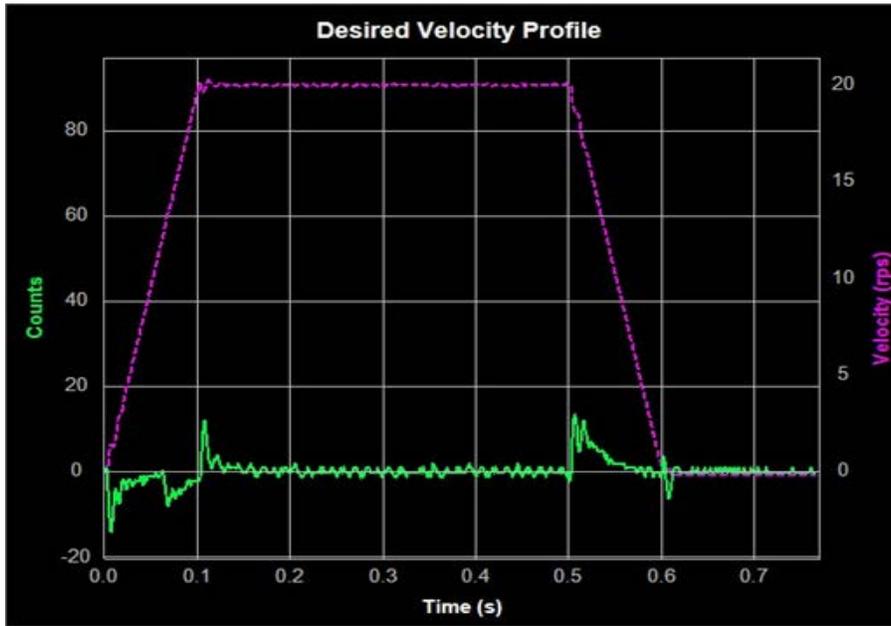
KK too small

As shown below, as KK increases, the system's dynamic performance improves. The position error during acceleration and deceleration is reduced significantly as a result.



KK Optimized

When the feedforward (KK) gain is too large, however, the opposite effect can be seen. This will also decrease system dynamic performance by increasing position error and system settling time, as shown below.

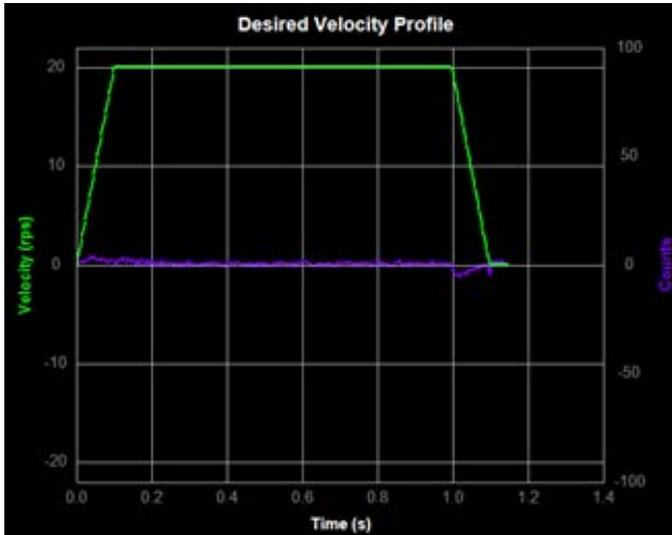


KK too large

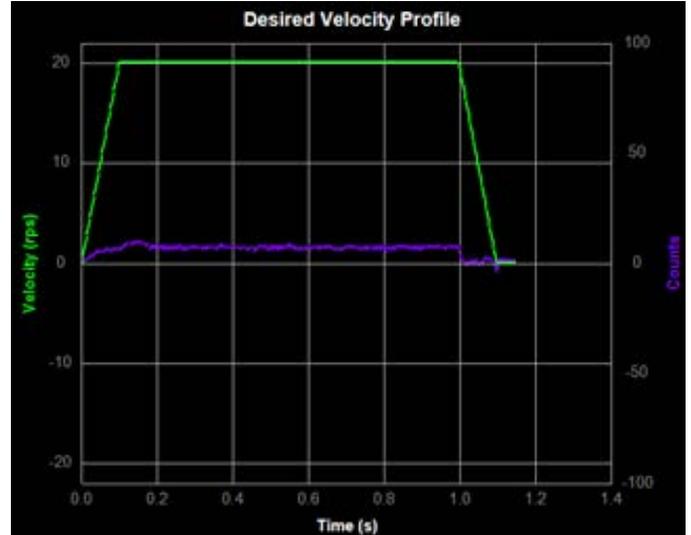
NOTE: When adjusting control loop gain values remember that the Feedforward Term (KK) has no effect when operating in the Position – Pulse & Direction Control Mode.

2.7 Follow Factor (KL)

A larger Follow Factor (KL) value will reduce system noise and eliminate overshoot, but will reduce the system's dynamic following performance. Lower values will increase system stiffness, but may cause system noise as shown below (Green = Actual Speed; Purple = Position error).



KL=0



As KL increase

2.8 Derivative Filter (KE)

KE is a low pass filter for derivative gain. This filter is a one-pole, low-pass filter intended for attenuating high frequency oscillations, as the filter value increase, it will filter out the high frequency noise from the derivative gain setting to smooth the gain input. As a result, the motion will be smoother, but some delay might occur.

2.9 PID filter (KC)

KE is a current loop control filter. This filter is a one-pole, low-pass filter intended for attenuating high frequency oscillations. This value is a constant that must be calculated from the desired roll off frequency.

As the KE value increase, it will smooth the current input, as a result torque output will be less jerk, less torque ripple will be shown. The torque increase time will be longer. When KE is too large, system response time will become long, or not enough torque will be

delivered.

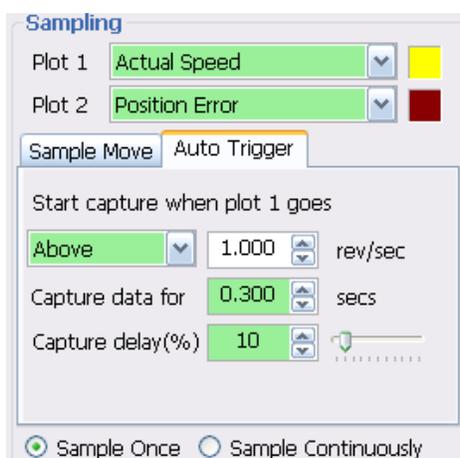
3 Using Auto Trigger Sampling

In cases where an external controller is used to perform move profiles, such as in **Position**

Control Mode using **Pulse & Direction** input, the **Auto Trigger** function will allow the **Sampling** tool to collect data and display the move profile.

This sampling technique is different in that it is not triggered by the start of a move profile as the drive cannot know when the move is actually started (remember the controller is external). Instead, the **Auto Trigger** function waits for a predefined set of conditions, or triggering event, before the move profile data is collected.

When using **Auto Trigger**, it's important to first select the conditions that will trigger the sampling. Begin by selecting the desired trigger value in the **Plot 1** list. This selection is what is monitored by the Auto Trigger; **Plot 2** will be displayed, but is not monitored for scope triggering purposes. See below.



In the Auto Trigger tab the displayed text will indicate the value to be used and the condition that will trigger the capture of the selected data plots. In the example above, the capture will begin when **Actual Speed** is **Above 1.000 rev/sec**, the capture will **Capture data** for **0.300 seconds** and there will be a **10% Capture delay** from the beginning of the capture to the trigger point. The **Capture delay** allows viewing of the data prior to the trigger point so that a more complete profile can be observed.

When changing **Plot 1** to other selections notice that the units for the capture trigger will change with it. For example, when selecting **Position Error** the capture will look at **Counts** for determining the trigger point.

Sample Once: when the **Start** button is clicked, the servo drive begins continuous collection of data. It will constantly check the data to see if the value meets the capture trigger conditions. At the same time SVX Servo Suite monitors the status of the servo drive to detect if the capture is complete.

When the capture is complete the data is displayed in the profile window.

Sample Continuously: when the **Start** button is clicked, the capture is repeated each time the trigger condition is met until the **Stop** button is clicked. During continuous sampling the tuning gains can be changed at any time and will be updated automatically. This allows for more dynamic adjustment of the gains, thereby speeding up the tuning process.



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