How to Tune the ACS Servo Drive

For this Tech Note we have repeated the tuning section of the User Guide for the ACS Tolomatic Motion Interface. See Tolomatic literature #3604-4184 for complete ACS software instructions.

Contents

16 Tuning Filter .... ***16_1***
16.1 Tuning Filter Dialog .... 16_2
16.1.1 Parameter Adjustment Pane........ 16_2
16.1.2 Graphing Pane .... 16_3
16.2 Gain Adjustments and Effects........ 16_5
16.2.1 Position Proportional........ 16_5
16.2.2 Position Integral .... 16_7
16.2.3 Velocity Proportional .... 16_9
16.2.4 Velocity Integral........ 16_10
16.2.5 Velocity Feed Forward........ 16_12
16.2.6 Current Proportional .... 16_13
16.2.7 Current Integral........ 16_14
16.2.8 Current Tuning .... 16_15

List of Figures

Figure 16-1: Control Loop .... 16_1
Figure 16-2: Tuning Filter Dialog........ 16_2
Figure 16-3: Position PID Loop .... 16_4
Figure 16-4: Velocity PID Loop........ 16_4
Figure 16-5: Current PID Loop........ 16_5
Figure 16-6 - Good Position Proportional Gain........ 16_5
Figure 16-7: Position Proportional Gain - Too High: Oscillations........ 16_6
Figure 16-8: Position Proportional Gain - Too Low: Large Position Error........ 16_6
Figure 16-9: Good Position Integral Gain........ 16_7
Figure 16-10: Position Integral Gain - Too Low: Slow steady-state response........ 16_8
Figure 16-11: Position Integral Gain - Too High: Overshoot which gets corrected over time........ 16_8
Figure 16-12: Good Velocity Proportional Gain........ 16_9
Figure 16-13: Velocity Proportional Gain - Too High: Large Oscillation Veloci........ 16_9
Figure 16-14: Velocity Proportional Gain - Too Low: Slow Velocity Response........ 16_10
Figure 16-15: Good Velocity Integral Gain .... 16_10
Figure 16-16: Velocity Integral Gain - Too High: Oscillations........ 16_11
Figure 16-17: Velocity Integral Gain - Too Low: Steady-state velocity error........ 16_11
Figure 16-18: Default Velocity Feed Forward Gain (75%) .... 16_12
Figure 16-19: Velocity Feed Forward Gain (0%) - Higher Position error........ 16_12
Figure 16-20: Modified Velocity Feed Forward Gain (100%) Low positi........ 16_13
Figure 16-21 - Good Current Proportional Gain........ 16_13
Figure 16-22: Current Proportional - Too High: Visible Oscillations........ 16_14
Figure 16-23: Current Proportional - Too Low: Sluggish Response........ 16_14
Figure 16-24: Good Current Integral........ 16_14
Figure 16-25: Bad Current Integral - Too High: Large Overshoot and oscill........ 16_15
Figure 16-26: Bad Current Integral - Too Low: Actual not reaching co........ 16_15
Figure 16-27: Current Loop Starting Point........ 16_16
Figure 16-28: Current Loop Tuning - Proportional Bandwidth Oscillations........ 16_16
Figure 16-29: Current Loop Tuning - Integral Bandwidth @ .01........ 16_17
Figure 16-30: Current Loop Timing - Integral Bandwidth @ 180........ 16_17

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Tuning a servo motor is an advanced procedure. Tolomatic standard motors have predetermined tuning values that should work for most applications. Tuning should be performed when more performance is required for the application or when a new motor is added. A basic understanding of PI (Proportional Integral) Control Loops is required for tuning.

The Servo Control Loop for Position Control is made up of three separate PI loops: Position, Velocity, and Current loops. These three control loops are cascaded, meaning that the output of one loop feeds into the input of the next loop. The position loop uses profile position from the trajectory generator and actual position from the feedback device to commanded velocity. The velocity loop uses the sum of commanded velocity from the position loop and profile velocity and compares it to actual velocity to generate a commanded current. This commanded current, along with the actual current, is used to control the PWM to the bridge circuit which in turns drives the servo motor.

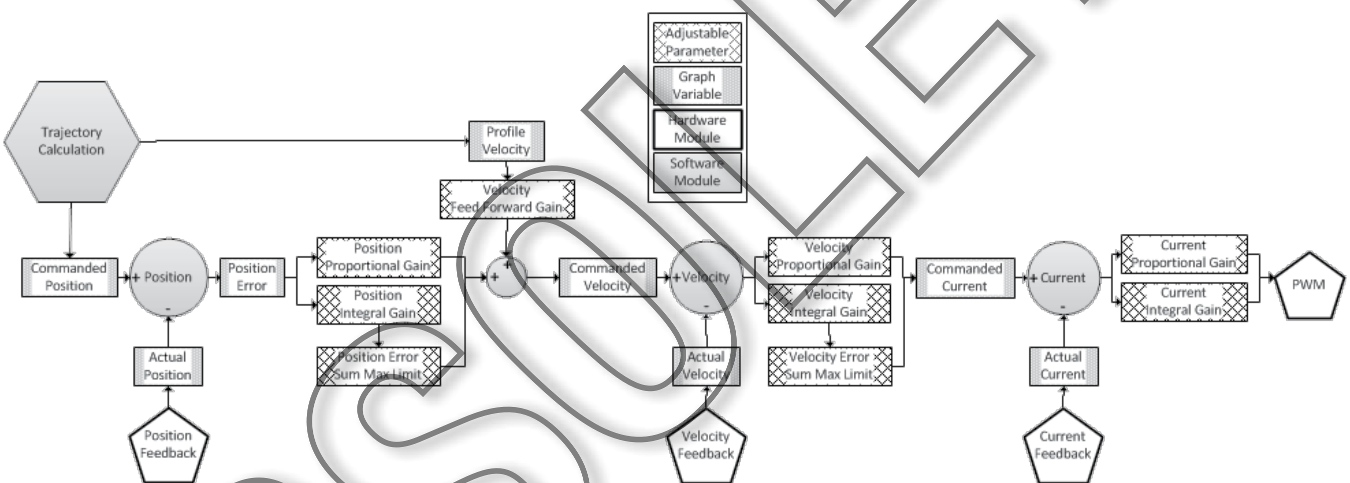


Figure 16-1: Control Loop

Each control loop corresponds to a set of tunable parameters in the Tuning Filter.

16.1 Tuning Filter Dialog

The Tuning Filter tool is broken into two distinct parts – the Parameter Adjustment pane, and the Graphing Pane. The parameters are adjusted in the left hand side of the window, and the effects can be observed on the right hand side of the window.

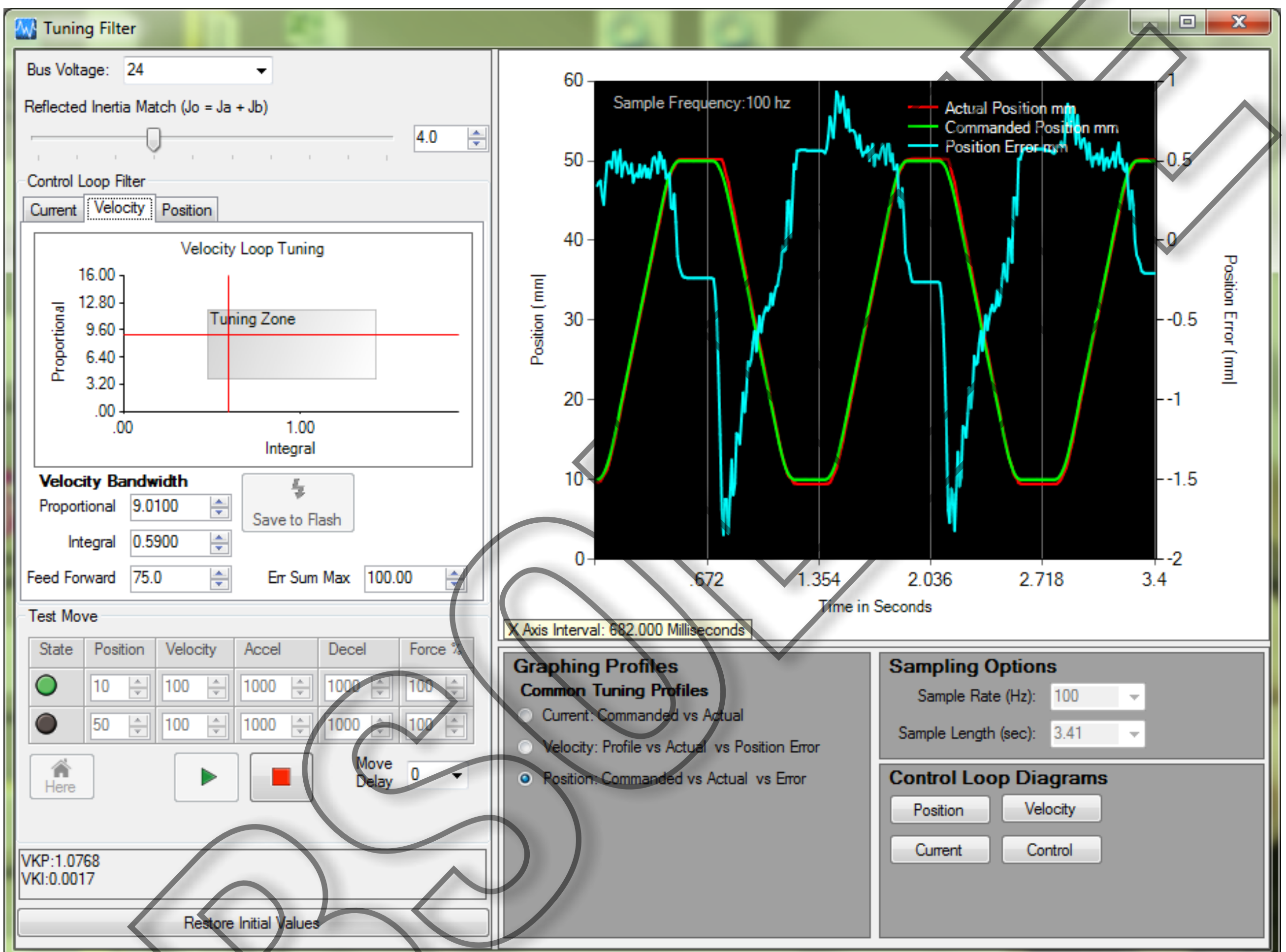


Figure 16-2: Tuning Filter Dialog

16.1.1 Parameter Adjustment Pane

- Bus Voltage: Bus voltage of the system, typically 24V or 48V. Note: This setting affects the calculation of current loop gains.
- Reflected Inertia Match: Inertia match of the system. Note: This setting affects the calculation of velocity loop gains.
- Proportional Bandwidth: Proportional bandwidth value for the given PI loop (Position, Velocity, Current) used to calculate proportional gain. The value can be changed using the numeric up/down box or by clicking on the graph.
- Integral Bandwidth: Integral bandwidth value for the given PI loop(Position, Velocity, Current) used to calculate integral gain. The value can be changed using the numeric up/down box or by clicking on the graph.
- Feed Forward: Percentage value that helps match commanded output to

profile output. Typically used to smooth at the cost of precision

- Err Sum Max: Percentage value that can be used to limit the amount of error calculated in the loop. Useful in limiting runaways and over corrections.
- Save to Flash: Saves the tuning settings of the specific loop to internal storage on the drive so that it can be maintained when the system power cycles
- Test Move: Configures the drive for a continuous sequenced position move between two points using the user defined settings. Current tuning inputs a square wave of specified force amplitude into the current loop instead of performing a position move. NOTE: Tuning uses relative positioning. Make sure that you are aware of your actuators position with relation to its stroke length before performing any moves to prevent a crash.
- Home Here: Declares home position value of 0.0 at the current position
- Restore Initial Values: Restores to the drive the initial tuning values saved when the tool was opened. Note that is not a restore to factory defaults. In order to do this, you should run the File->Restore Drive to Factory Settings command from the TMI menu

For the majority of setups, the user will only need to adjust the Bus Voltage and the Reflected Inertia Match slider. It is recommended that users do not modify the Current PI loop tuning parameters if using Tolomatic standard motors.

Advanced Option - Adjusting the Tuning Range Min/Max: If more range is desired, each bandwidth's combo box min/max can be adjusted by right clicking on that parameter's combo box, and selecting "Adjust Min/Max".

16.1.2 Graphing Pane

The graphing pane can display variables recorded during motion so the effects of changing tuning parameters can be seen. The drive supports a limited sized internal buffer for onboard sampling. The data is transferred after a move has completed.

- Graphing Profiles: Selectable outputs that can be graphed for analysis
- Sample Rate: Rate in Hertz at which parameters are sampled
- Sample Length: The total length of the sampling period, in seconds
- Control Loop Diagrams: Helpful diagrams that display the input and outputs of each PI loop

NOTE: The linear units are always in drive default (mm), even if the user units are in inches or revolutions. This is solely for graphing speed purposes.

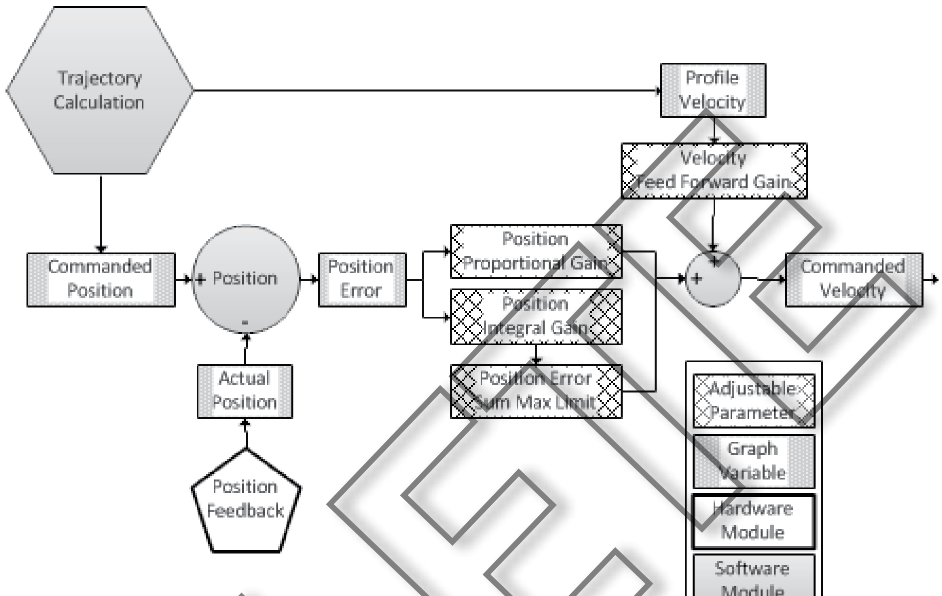


Figure 16-3: Position PID Loop

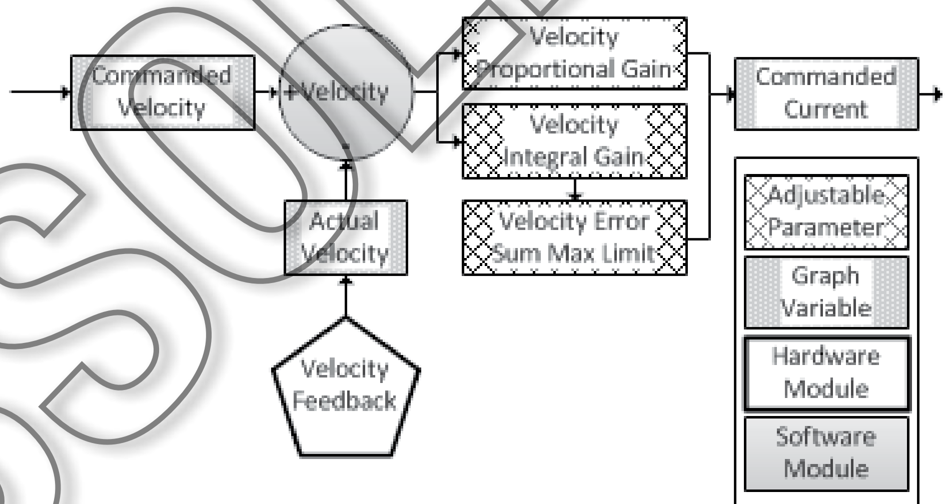


Figure 16-4: Velocity PID Loop

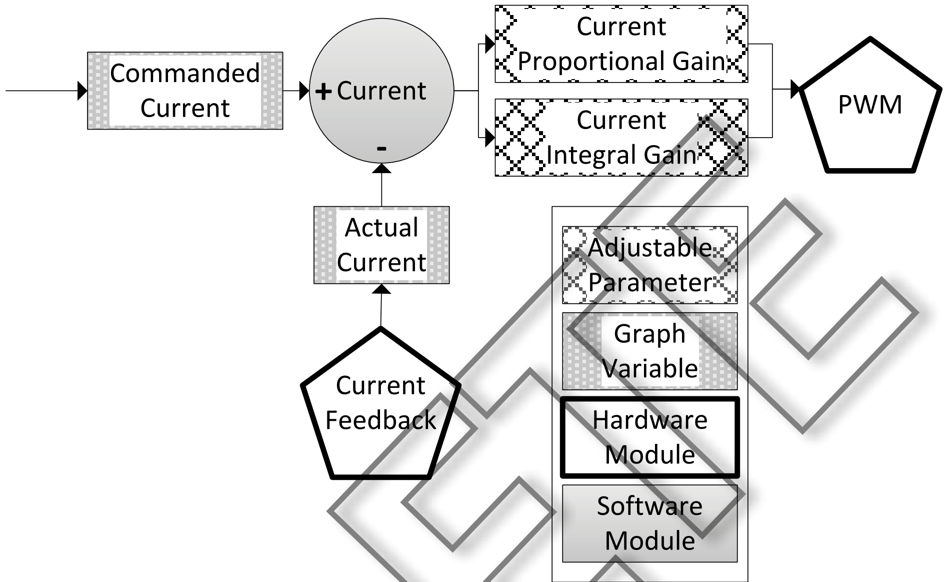


Figure 16-5: Current PID Loop

16.2 Gain Adjustments and Effects

The following section describes generally what each gain adjustment does with relation to motion using the Tuning Filter dialog.

16.2.1 Position Proportional

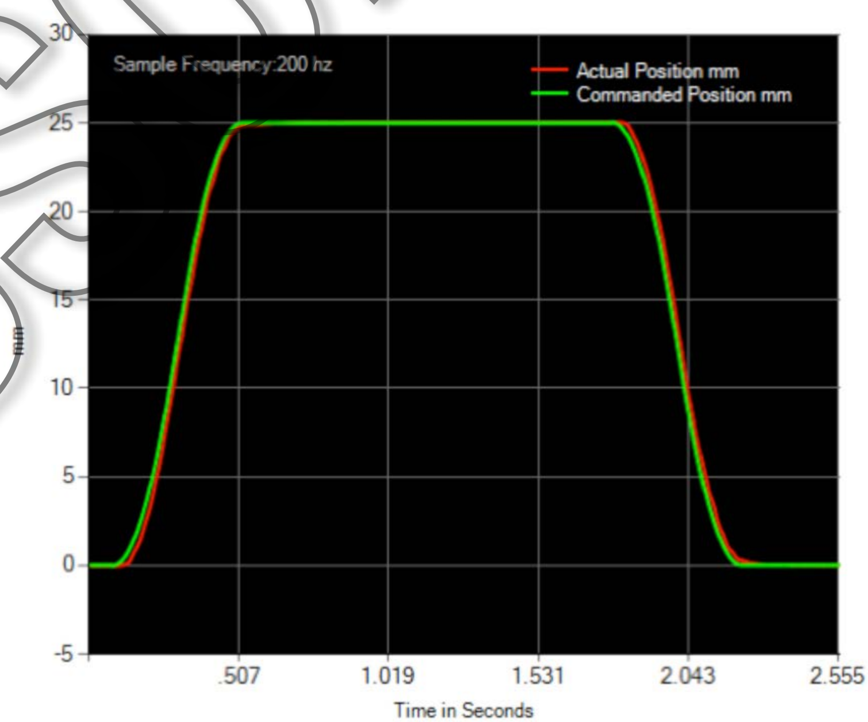


Figure 16-6 – Good Position Proportional Gain

A good position proportional gain setting should follow the position profile closely without much overshoot. This gain affects how quickly the control loop can follow a fast change in commanded position.

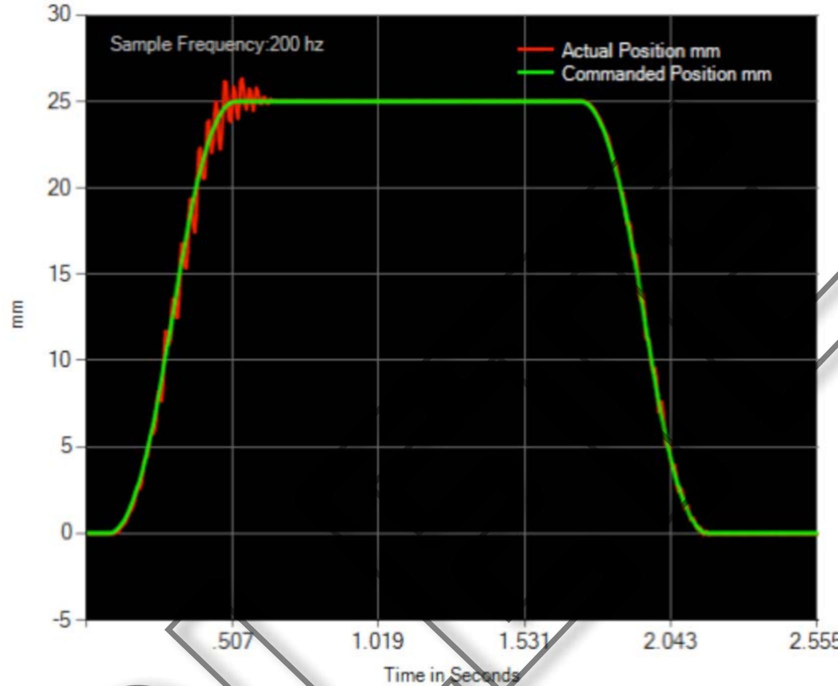


Figure 16-7: Position Proportional Gain - Too High: Oscillations

Figure 16-7: Generally the higher the proportional gain the faster the control loop can follow a fast change in the position command. A Position proportional gain too high can create oscillations and rough motion.

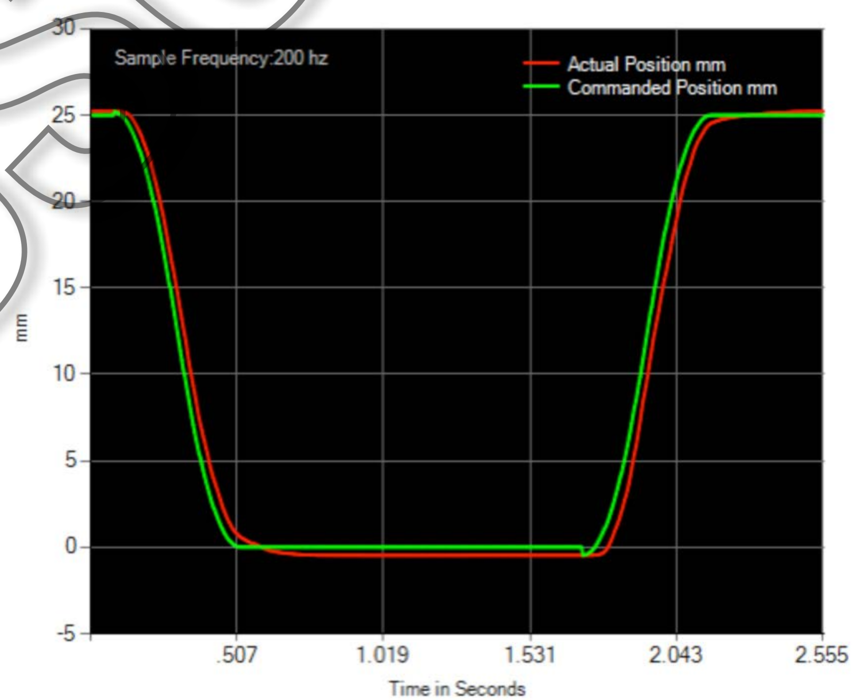


Figure 16-8: Position Proportional Gain - Too Low: Large Position Error

Figure 16-8: Position proportional gain too low can be sluggish and fall behind the desired motion profile. Falling behind creates position error that can accumulate during the move and then take a while to wind down causing an overshoot of the desired position.

16.2.2 Position Integral

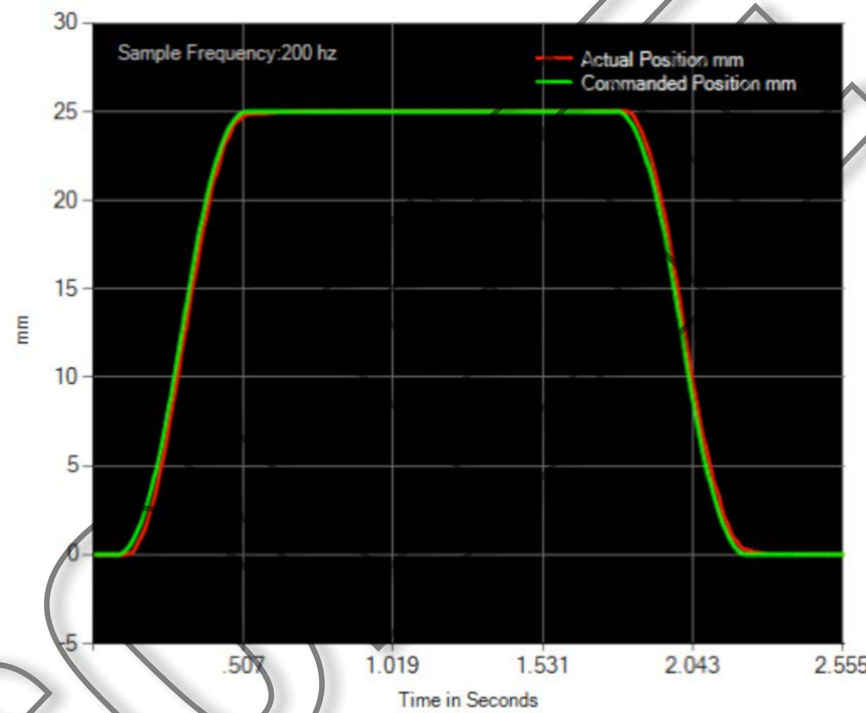


Figure 16-9: Good Position Integral Gain

Figure 16-9: A good position integral gain setting should follow the position profile closely without much overshoot and it should settle to a steady state position equal to the commanded position.

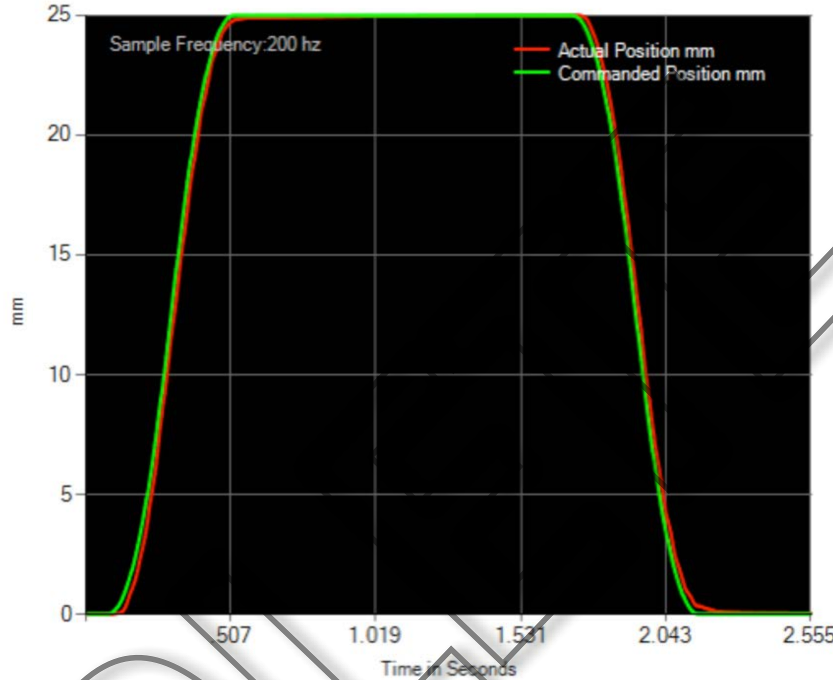


Figure 16-10: Position Integral Gain – Too Low: Slow steady-state response

Figure 16-10: A position integral gain set too low can increase position error during motion and slow the steady-state response of seeking the final position value.

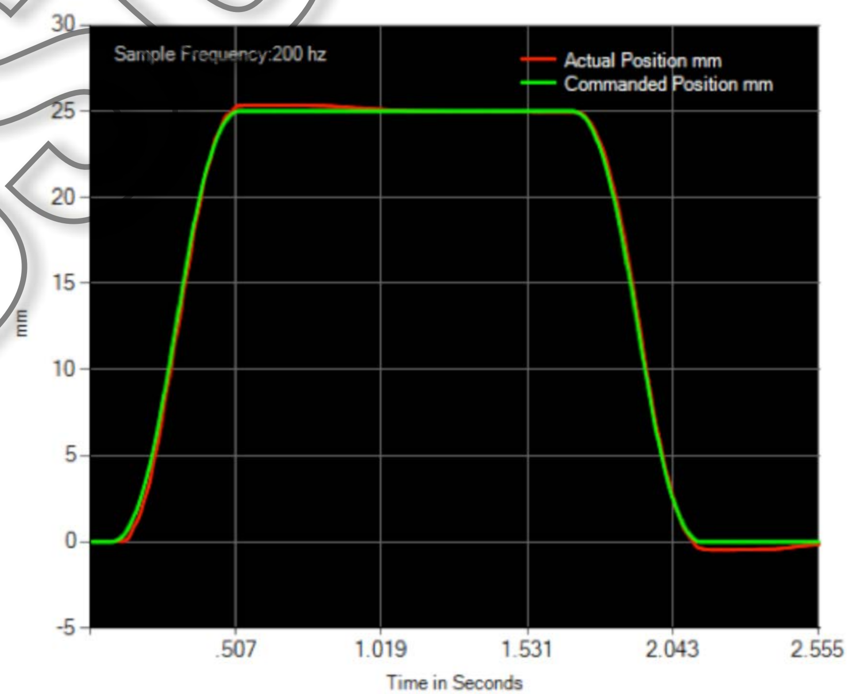


Figure 16-11: Position Integral Gain - Too High: Overshoot which gets corrected over time

Figure 16-11: A high position integral setting can accumulate error during the move and cause too much overshoot of the final position. Some overshoot oscillation can occur also.

16.2.3 Velocity Proportional

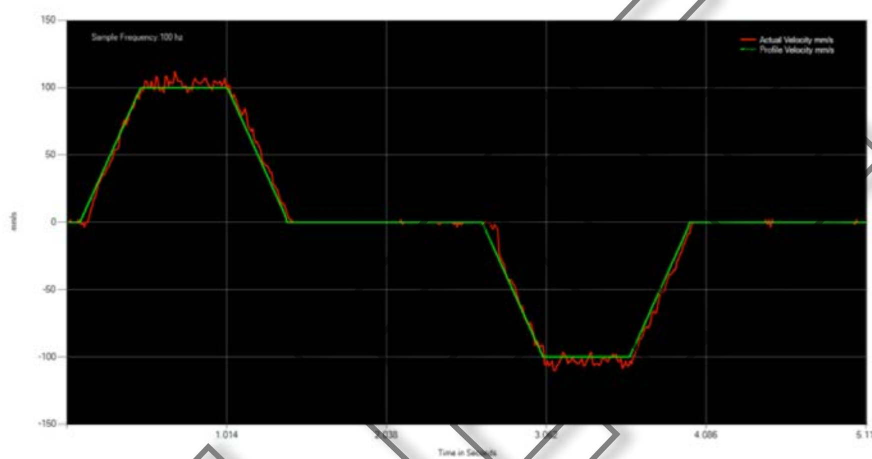


Figure 16-12: Good Velocity Proportional Gain

Figure 16-12: A good velocity proportional gain should create quick loop response to a fast change in velocity. Proportional gain will affect mainly the rising and falling slopes of the velocity profile.

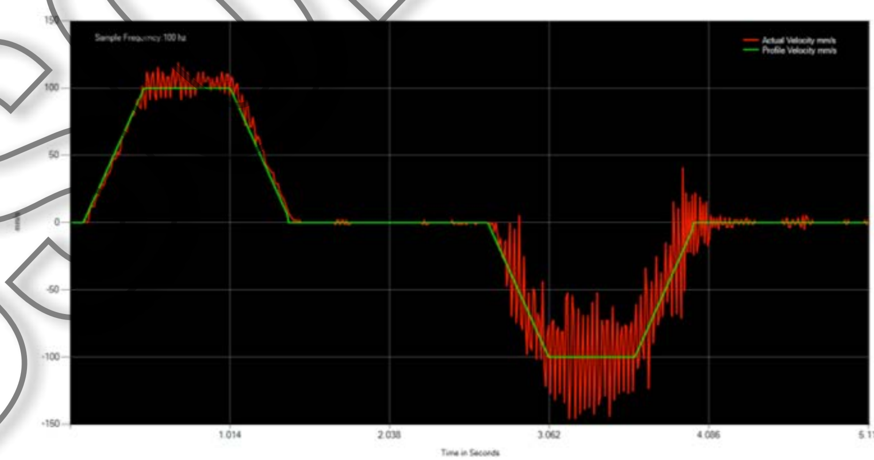


Figure 16-13: Velocity Proportional Gain - Too High: Large Oscillations in Velocity

Figure 16-13: Setting velocity proportional gain too high can result in large oscillations in velocity during a move.

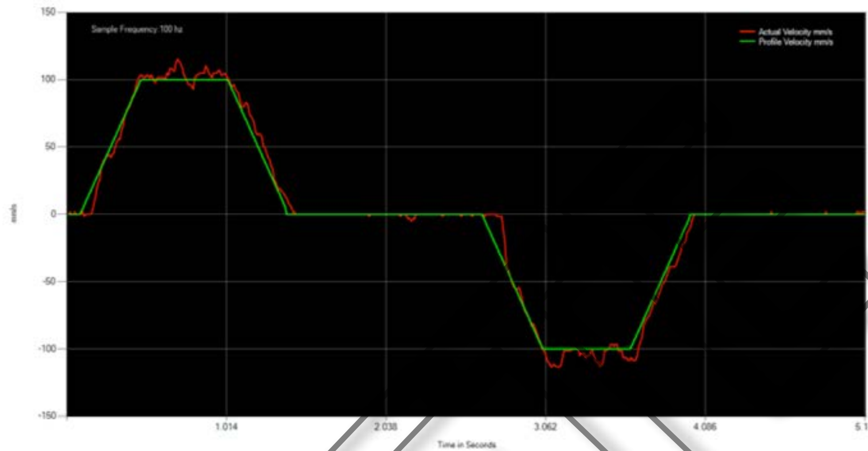


Figure 16-14: Velocity Proportional Gain - Too Low: Slow Velocity Response

Figure 16-14: Setting a velocity proportional gain too low can result in sluggish response to changes in velocity. It may not even reach the commanded velocity value.

16.2.4 Velocity Integral

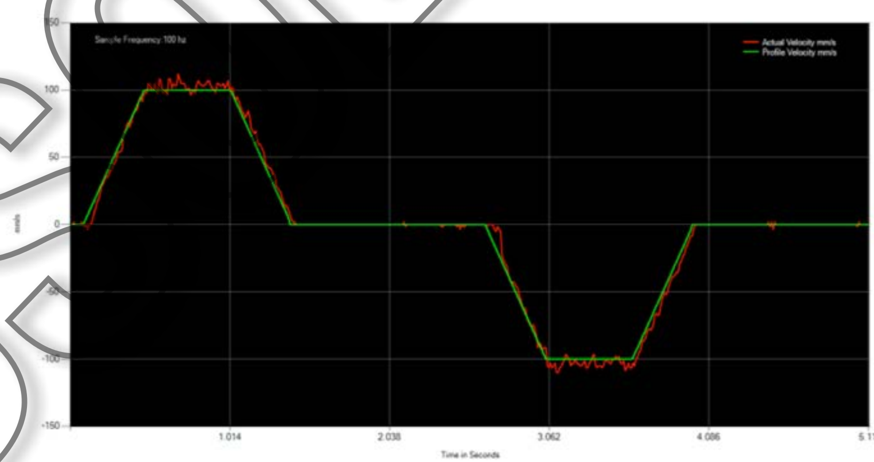


Figure 16-15: Good Velocity Integral Gain

Figure 16-15: A good velocity integral setting will help reduce the error in the constant velocity section of the velocity profile.

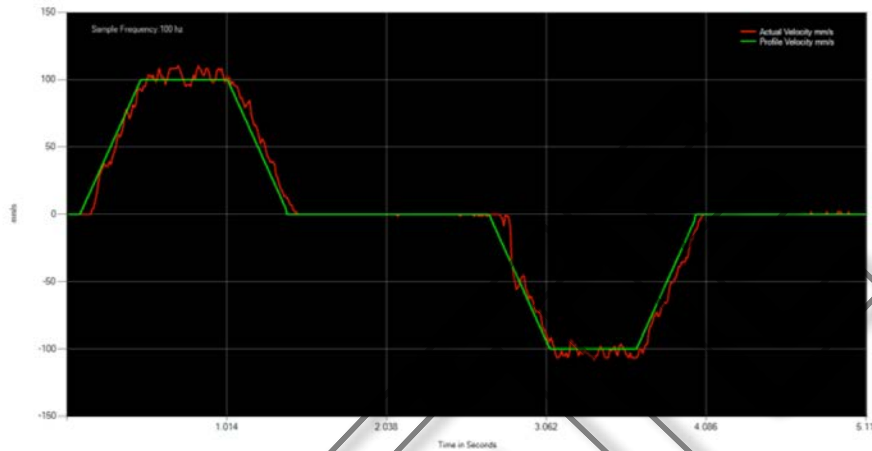


Figure 16-16: Velocity Integral Gain - Too High: Oscillations

Figure 16-16: Setting the velocity integral gain too high can cause oscillations in the constant velocity section of the velocity profile. It can increase the velocity overshoot.

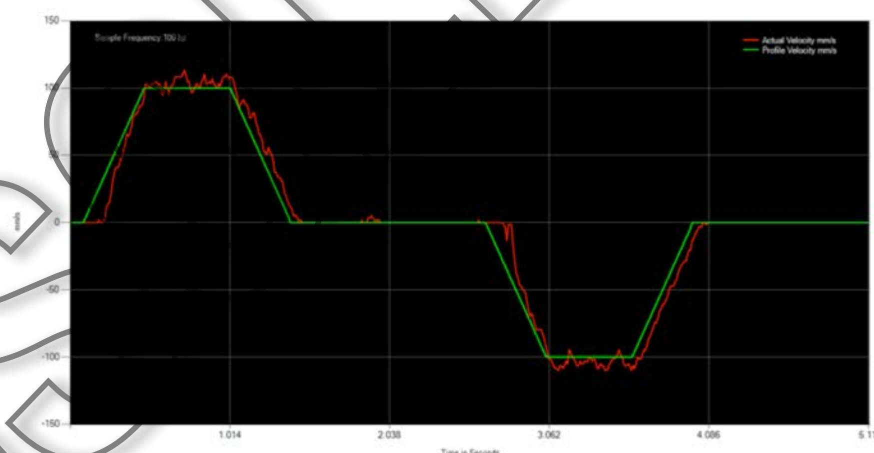


Figure 16-17: Velocity Integral Gain - Too Low: Steady-state velocity error

Figure 16-17: Too low of velocity integral gain will result in the loop not tracking to desired velocity resulting in steady-state velocity error.

16.2.5 Velocity Feed Forward

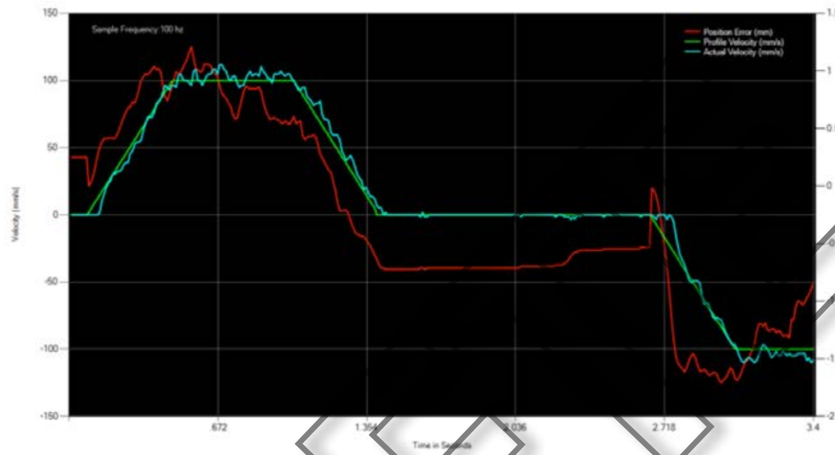


Figure 16-18: Default Velocity Feed Forward Gain (75%)

Figure 16-18: To increase performance and lessen the burden of control on the position loop, a velocity feed-forward (VFF) gain as an input to the velocity loop. Generally this value should not need to be adjusted much from the factory default setting.

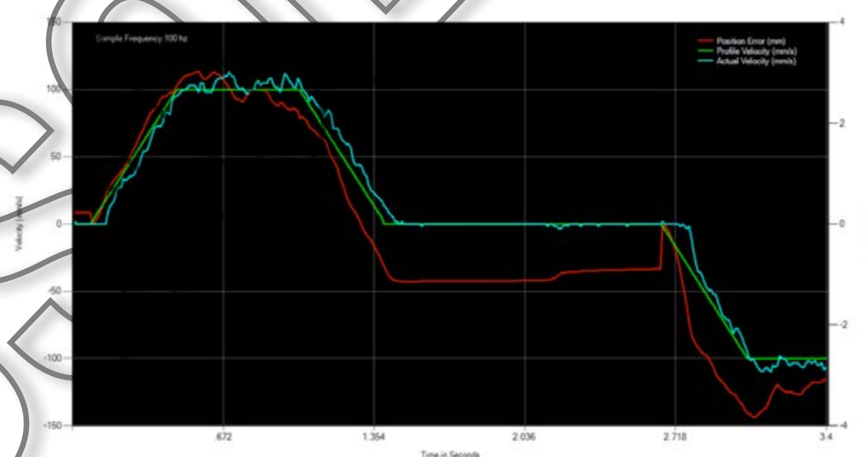


Figure 16-19: Velocity Feed Forward Gain (0%) - Higher Position error, higher velocity error

Figure 16-19: Decreasing the VFF gain or setting it to zero will cause the control response to be very sluggish. A higher position loop gain may be needed to get acceptable motion. The maximum velocity achievable may be reduced based on the position loop gains. Position and velocity error will increase.

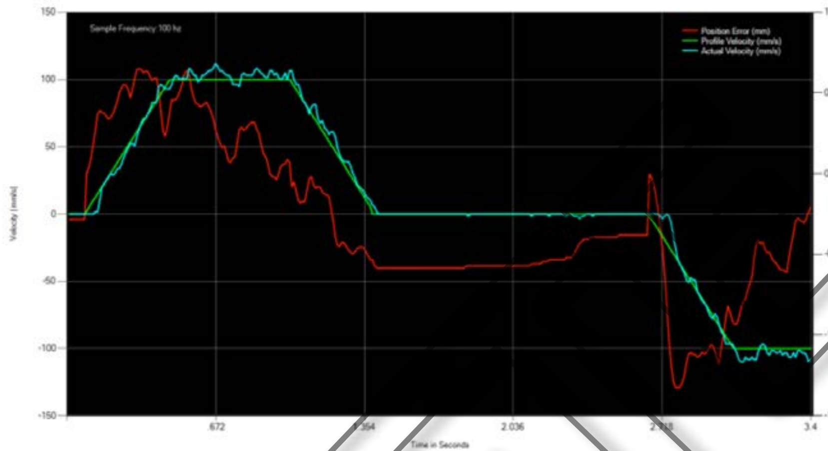


Figure 16-20: Modified Velocity Feed Forward Gain (100%) Low position and velocity error, causes overshoot

Figure 16-20: Too much VFF gain will cause velocity overshoot and possibly position overshoot.

16.2.6 Current Proportional

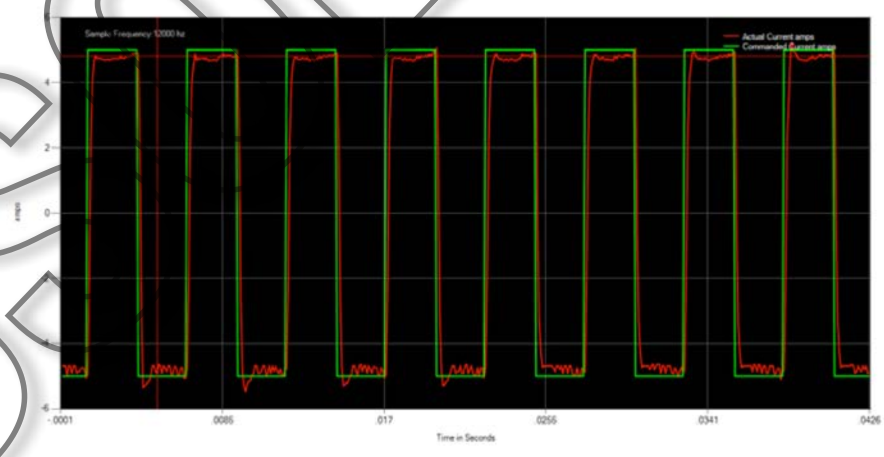


Figure 16-21 - Good Current Proportional Gain

Figure 16-21: A good current proportional gain setting will have a fast response to changes in current command.

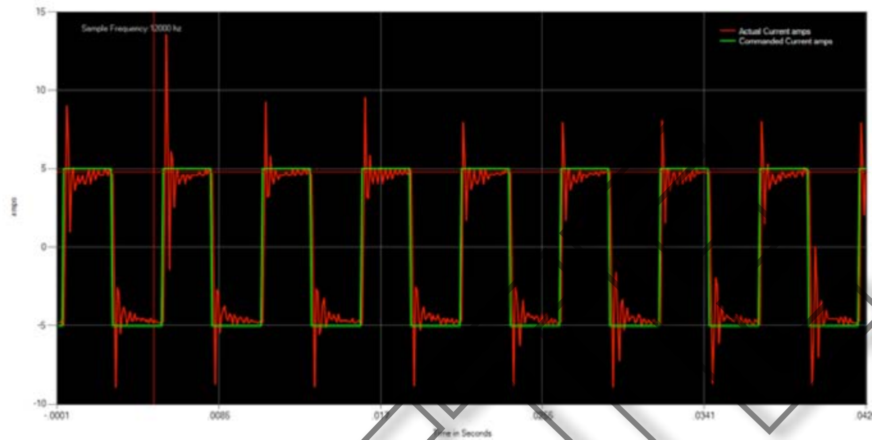


Figure 16-22: Current Proportional - Too High: Visible Oscillations

Figure 16-22: Setting the current proportional gain too high will cause high overshoot and oscillations in response to fast changes in current command.

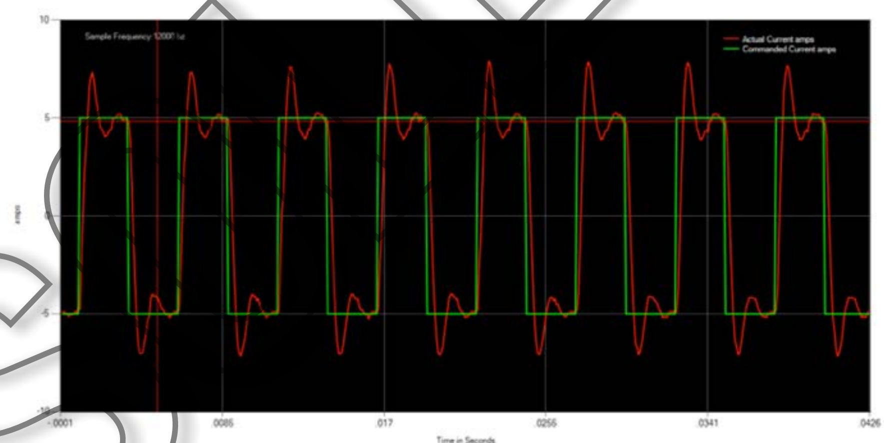


Figure 16-23: Current Proportional - Too Low: Sluggish Response

Figure 16-23: Setting current proportional gain too low will cause sluggish response to changes in current command.

16.2.7 Current Integral

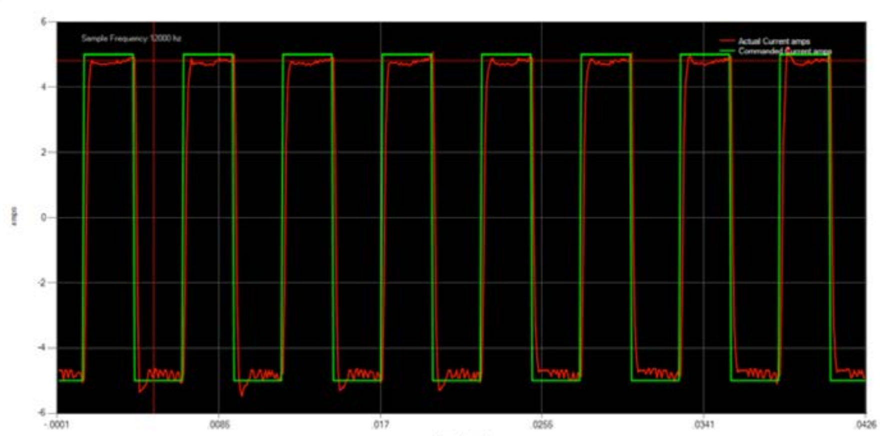


Figure 16-24: Good Current Integral

Figure 16-24: Good current integral gain should reduce steady state current error.

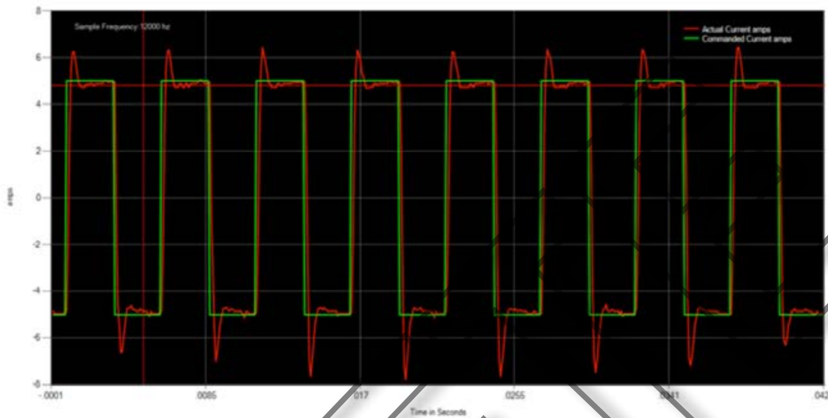


Figure 16-25: Bad Current Integral - Too High: Large Overshoot and oscillations

Figure 16-25: Too much current integral gain will cause large overshoot spikes in current and oscillations to occur

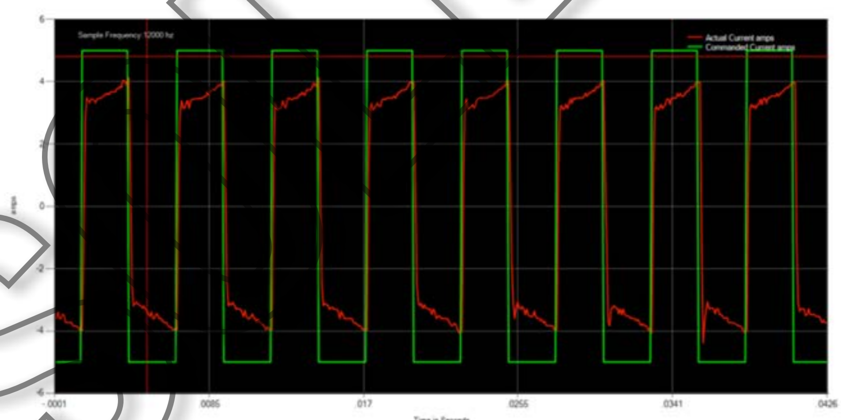


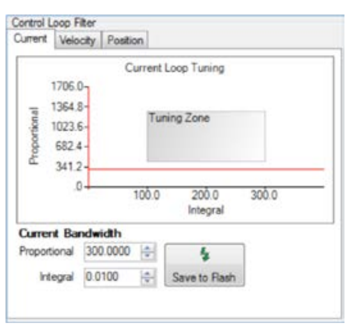
Figure 16-26: Bad Current Integral - Too Low: Actual not reaching commanded

Figure 16-26: Too little current integral gain will have large steady state current error.

16.2.8 Current Tuning

The user should not need to touch the current tuning gains for Tolomatic motors. However, if the need should arise, the following method can be used to tune the current loop.

Step 1: Set Integral Gain to 0, and set proportional gain to about 300



Step 2: Set Step force to 30% and start the Test Move

This will inject a 100 Hz commanded current square wave directly into the current loop to see how the control loop response to an ideal step input signal. The gains should be adjusted to make the actual current fit closely to the commanded current with little overshoot and steady-state error.

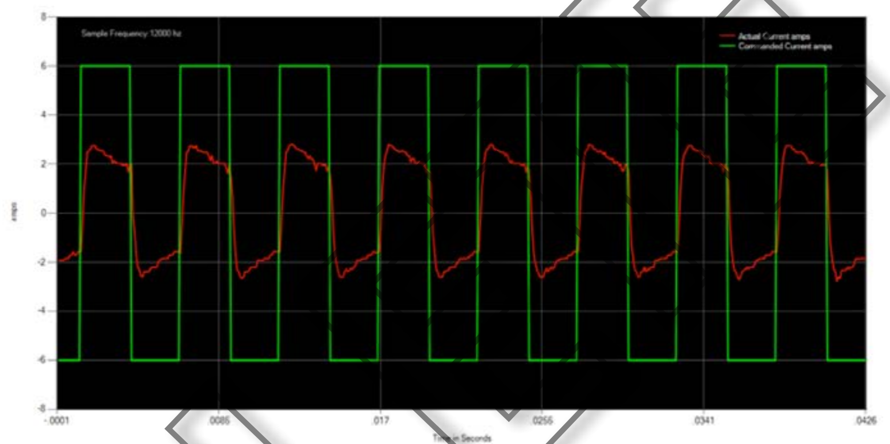


Figure 16-27: Current Loop Starting Point

Step 3: Increase Proportional Bandwidth until visible oscillations appear.

About 3-4 oscillation periods should be visible after the edge of the step input signal.

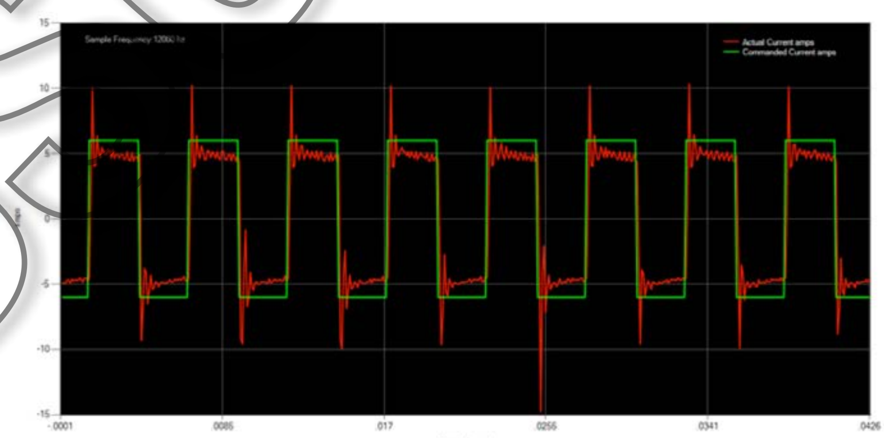


Figure 16-28: Current Loop Tuning - Proportional Bandwidth Oscillations

Step 4: Set Proportional Bandwidth to 40% of the oscillation bandwidth.

In our example, we saw oscillations at a bandwidth of 1931.18. 1931.18 x .40 = 772.472

Step 5: Increase Integral Bandwidth slowly until desired response is reached.

This starting point is as follows, with integral set at .01:

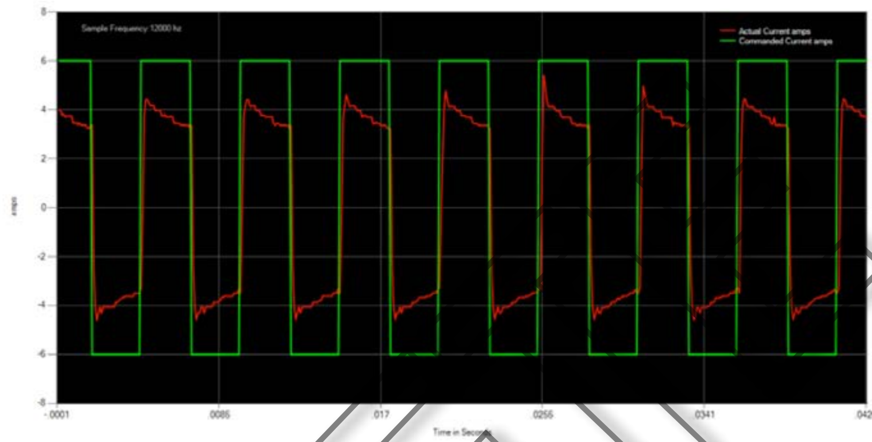


__Figure 16-29: Current Loop Tuning - Integral Bandwidth @ .01__

As you increase, the level of the signal will rise. Try to keep the overshoot under 10%.

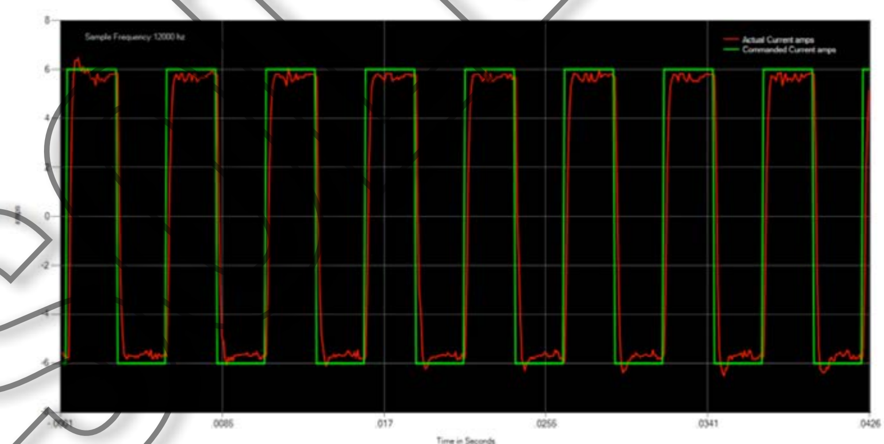


__Figure 16-30: Current Loop Tuning - Integral Bandwidth @ 180__