PID Configuration

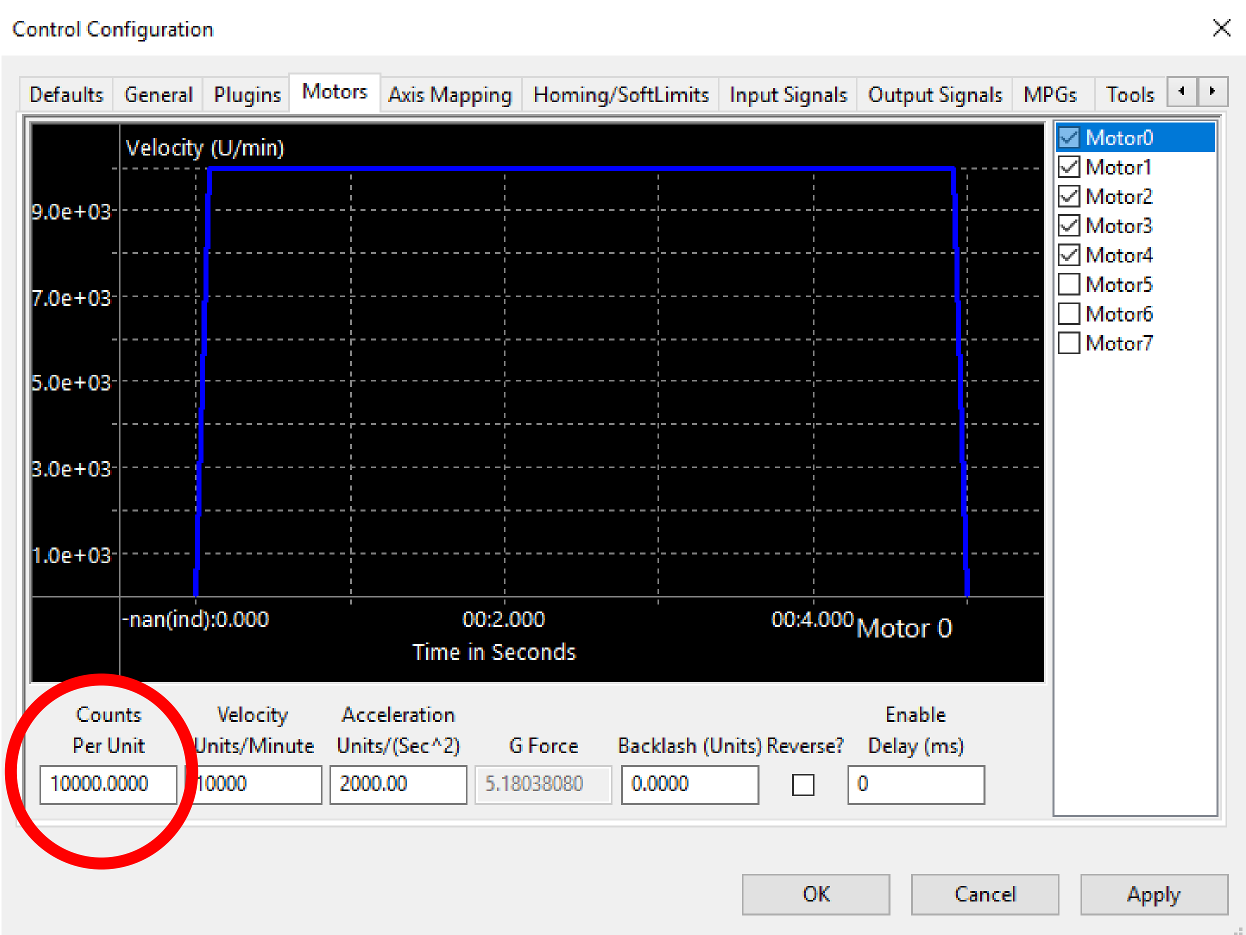
Before setting PID the user must ensure that motors and encoders are functioning properly. In addition, the user must ensure that the correct motor counts per unit and feedback gain is set in order to get the most accurate positioning of motors.

BEFORE ENABLING PID

Step 1: Set the Motor Counts per unit in Mach:

In the motor config window (below), set the counts per unit for each motor.

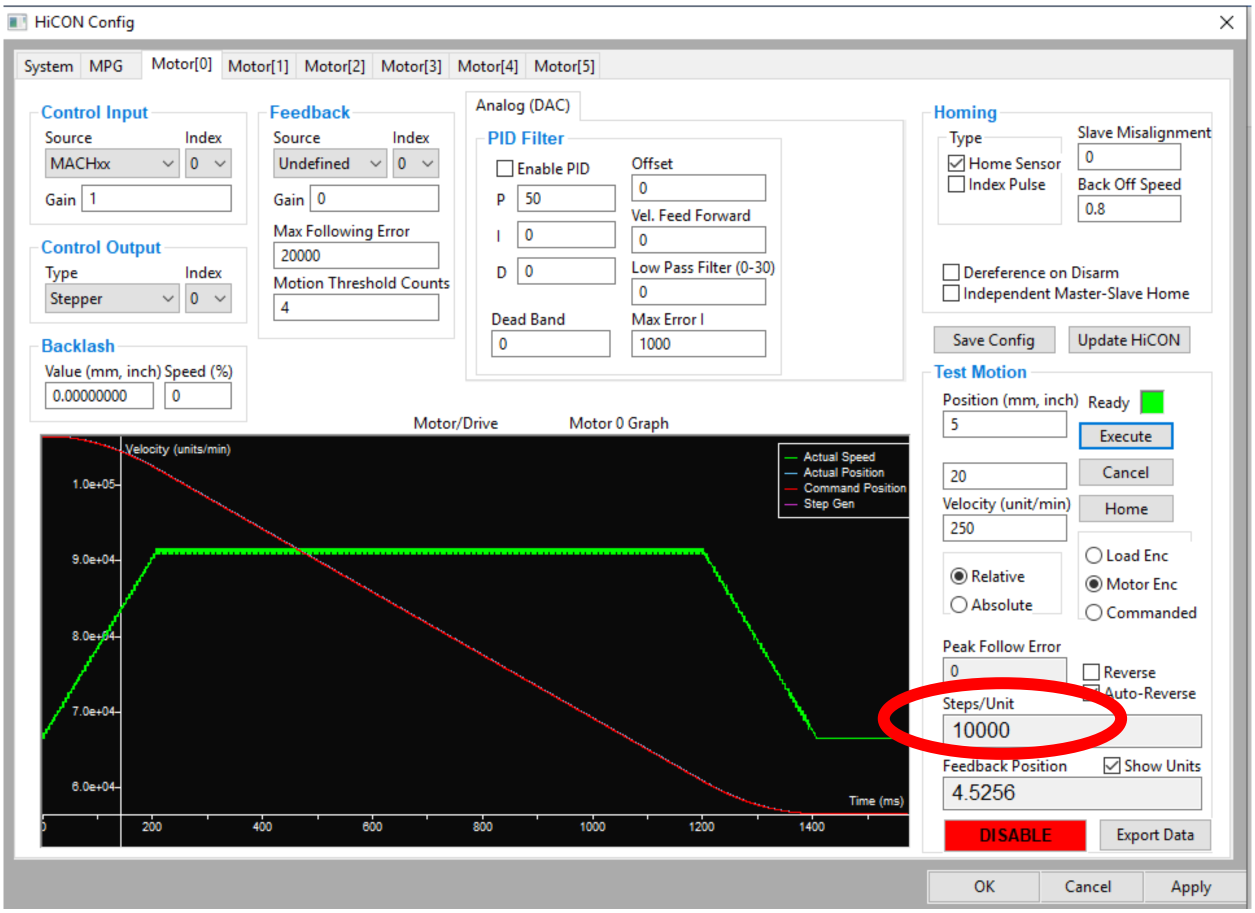
The counts per unit takes into account the motor driver setting, gear ratio and lead screw pitch.



Step 2: Set the Encoder Feedback gain:

The preferred (most accurate) method is to get the specifications for the lead screw and any gearbox attached to the motor. Determine the lead screw pitch, gear box ratio, and pulse per revolution (PPR) of the encoder from their datasheets.

Dividing this value by the steps per unit from Mach will yield the feedback gain.



Following the formula below will give the user the feedback gain. Here we multiply by 4 since the encoders are quadrature.

$$\textit{Feedback gain} = \left(\frac{\textit{Motor Steps per Unit}}{\textit{Lead screw Pitch} \times \textit{PPR} \times 4}\right)$$

Example: If lead screw pitch = 10 rotations/inch

PPR = 500 Pulses/rotation

Motor Steps/Unit = 10,000

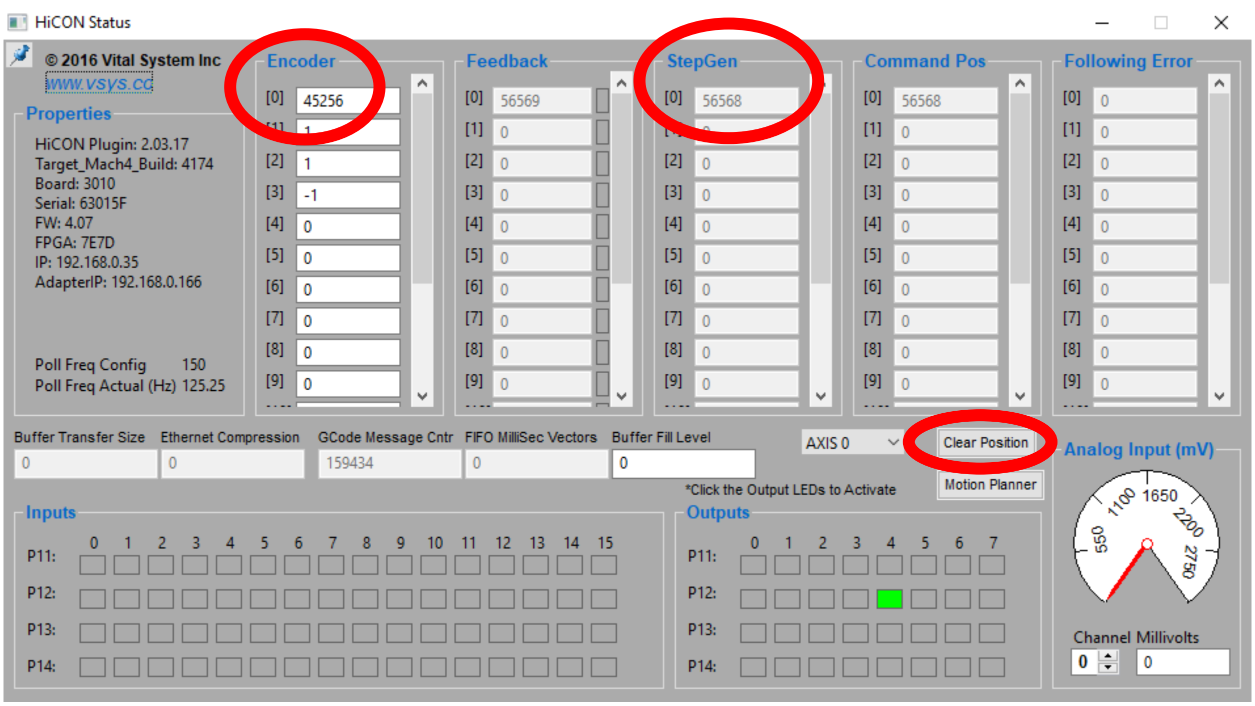
$$\text{Feedback gain} = \left(\frac{10{,}000}{20{,}000}\right) = 0.5$$

Alternatively, if you don't have access to the encoder specifications then you can follow this (less accurate) procedure to calculate the feedback gain.

To calculate the feedback gain, turn off the encoder feedback in the plugin config (set feedback to undefined).

Then command motor to a known length and monitor the encoder counts in the Hicon status window. **Be sure to first zero out the encoder values and the StepGen.**

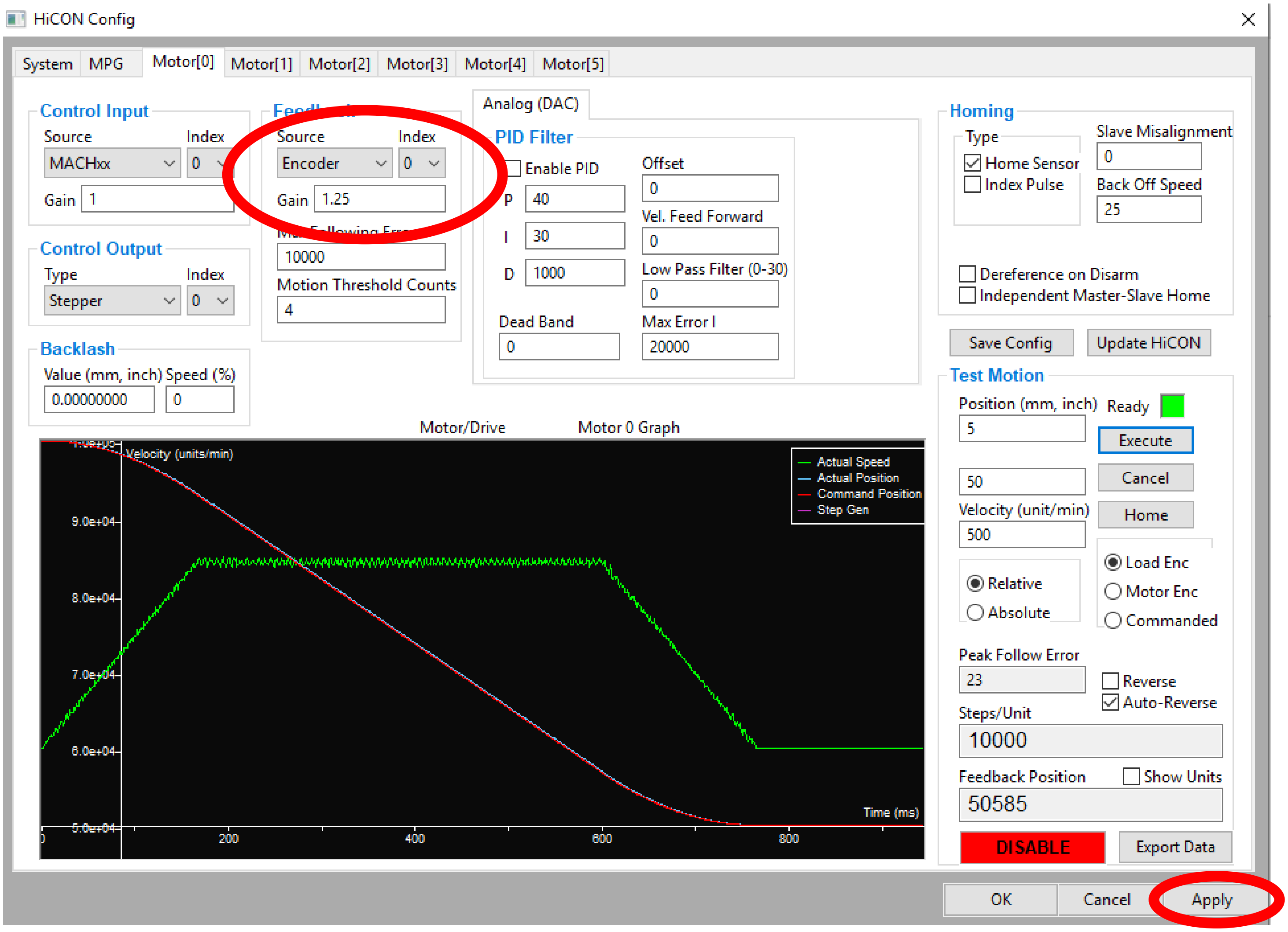
To zero the encoder, first disable mach4. Then click on the white box corresponding to the encoder number. To zero the StepGen click on the button just below the 'Command Pos' column named 'Clear Position'.



Next, command motion, for example 100 inches, and then physically measure how much the axis has actually moved. Feedback gain is then calculated as:

$$\textit{Feedback gain} = \left(\frac{\textit{Actual displacment measured on the table} \times \textit{Motor Coounts Per Unit}}{\textit{Encoder Counts}} \right)$$

The user can then input this feedback gain value in the plugin config window and set the 'Feedback source' to 'Encoder'. Then click on 'Apply'.



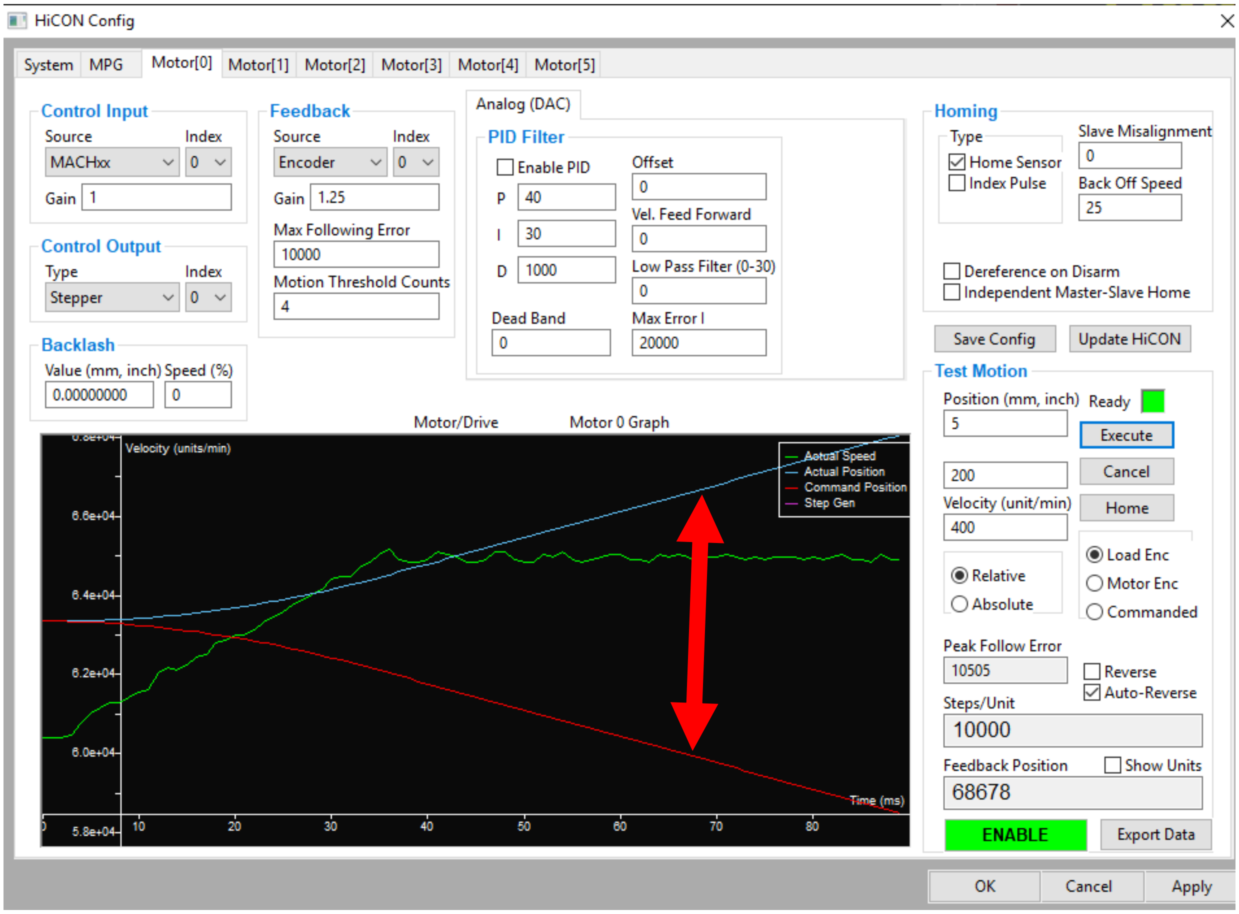
Step 3: Test motion with feedback gain set:

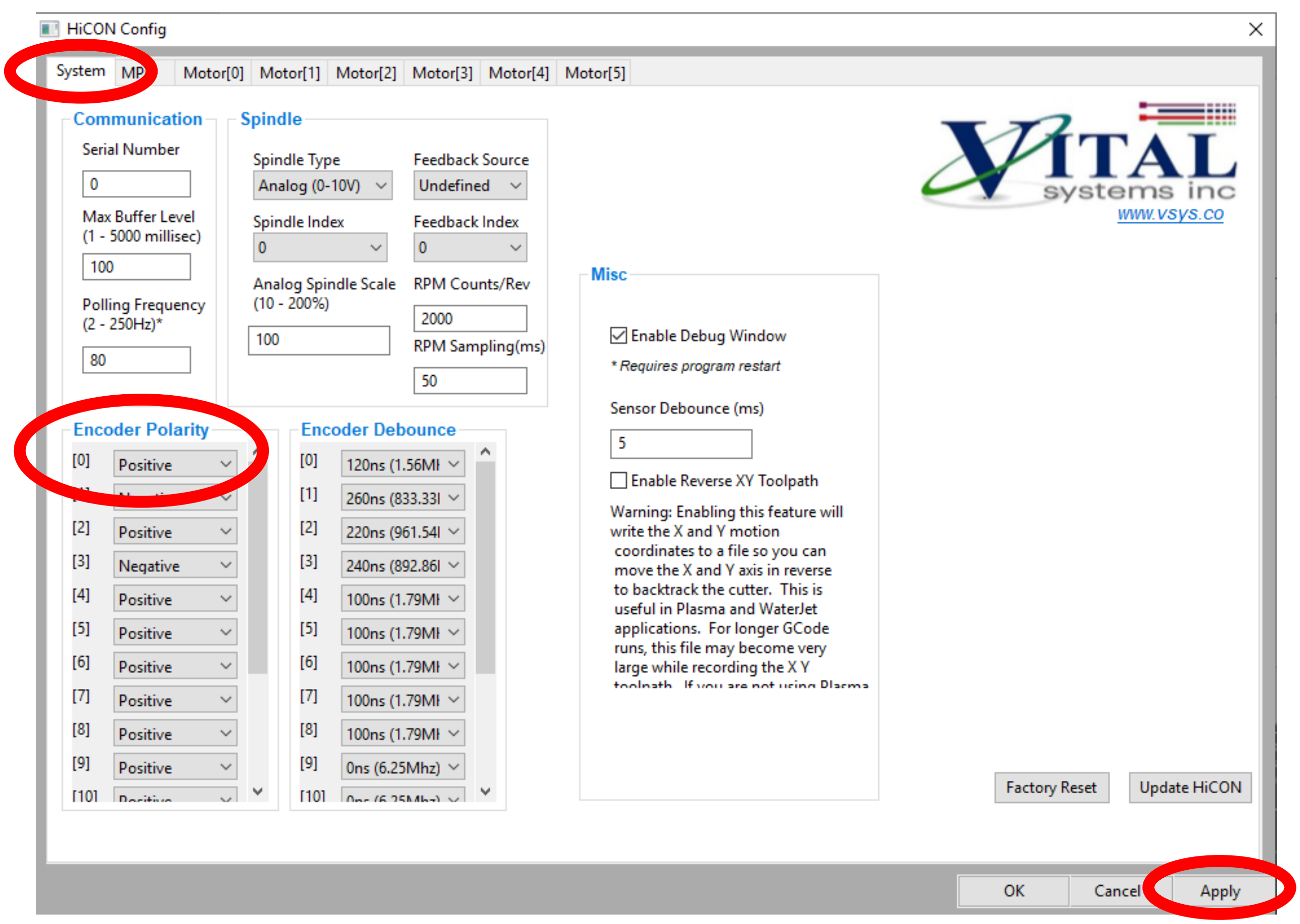
Execute a test motion of a known distance. With the correct feedback gain set, the Stepgen and Feedback should differ marginally. Any large discrepancies would indicate an incorrect feedback gain value.

Now the user can enable PID mode.

When running the test motion be sure to inspect the graph. If the 'actual position' and 'command position' or blue and red lines respectively are diverging, then the user must change the polarity of the encoder. As seen in the illustration below the blue and red lines are moving away from each other. To change the polarity, navigate to the 'System' tab. Under the 'Encoder Polarity' select the encoder number and change its polarity. Click 'Apply' to save the changes.

Execute another test motion to verify that the lines are no longer diverging.


HiCON Config
System
MPG
Motor[0]
Motor[1]
Motor[2]
Motor[3]
Motor[4]
Motor[5]
Control Input
Source
Index
MACHxx
0
Gain
1
Control Output
Type
Index
Stepper
0
Backlash
Value (mm, inch) Speed (%)
0.00000000
0
Feedback
Source
Index
Encoder
0
Gain
1.25
Max Following Error
10000
Motion Threshold Counts
4
Analog (DAC)
PID Filter
Enable PID
P
40
I
30
D
1000
Offset
0
Vel. Feed Forward
0
Low Pass Filter (0-30)
0
Dead Band
0
Max Error I
20000
Homing
Type
Home Sensor
Index Pulse
Slave Misalignment
0
Back Off Speed
25
Dereference on Disarm
Independent Master-Slave Home
Save Config
Update HiCON
Test Motion
Position (mm, inch)
Ready
5
Execute
200
Cancel
Velocity (unit/min)
Home
400
Load Enc
Relative
Motor Enc
Absolute
Commanded
Peak Follow Error
10505
Reverse
Auto-Reverse
Steps/Unit
10000
Feedback Position
Show Units
68678
ENABLE
Export Data
Motor/Drive
Motor 0 Graph
Velocity (units/min)
Actual Speed
Actual Position
Command Position
Step Gen
6.6e+04
6.4e+04
6.2e+04
6.0e+04
5.8e+04
Time (ms)
10
20
30
40
50
60
70
80
OK
Cancel
Apply


HiCON Config
System
Motor[0]
Motor[1]
Motor[2]
Motor[3]
Motor[4]
Motor[5]
Communication
Serial Number
0
Max Buffer Level
(1 - 5000 millisec)
100
Polling Frequency
(2 - 250Hz)*
80
Spindle
Spindle Type
Analog (0-10V)
Feedback Source
Undefined
Spindle Index
0
Feedback Index
0
Analog Spindle Scale
(10 - 200%)
100
RPM Counts/Rev
2000
RPM Sampling(ms)
50
VITAL
systems inc
www.vsys.co
Misc
Enable Debug Window
* Requires program restart
Sensor Debounce (ms)
5
Enable Reverse XY Toolpath
Warning: Enabling this feature will
write the X and Y motion
coordinates to a file so you can
move the X and Y axis in reverse
to backtrack the cutter. This is
useful in Plasma and WaterJet
applications. For longer GCode
runs, this file may become very
large while recording the X Y
Encoder Polarity
[0] Positive
[2] Positive
[3] Negative
[4] Positive
[5] Positive
[6] Positive
[7] Positive
[8] Positive
[9] Positive
Encoder Debounce
[0] 120ns (1.56M
[1] 260ns (833.33
[2] 220ns (961.54
[3] 240ns (892.86
[4] 100ns (1.79M
[5] 100ns (1.79M
[6] 100ns (1.79M
[7] 100ns (1.79M
[8] 100ns (1.79M
[9] 0ns (6.25Mhz)
Factory Reset
Update HiCON
OK
Cancel
Apply

AFTER ENABLING PID

Step 4: Configuring PID

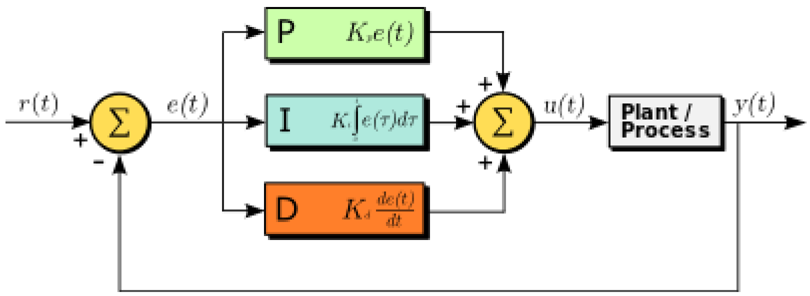
If all the above steps have been completed successfully the user can now move onto configuring the PID filter.

In order to use the PID mode more effectively you must complete all the above steps correctly as this sets the foundation for the PID. If any of these steps are not completed successfully then the PID will not have the desired effect on the encoder.

To achieve the most accurate results all PID parameters need to be configured appropriately.

The PID filter calculates the difference between the commanded position and the actual position, which constitutes the error.

The diagram below illustrates how the PID functions are implemented into the system:



P - Proportional Gain

The 'P' value is multiplied with the instantaneous error to create motor power proportional to the error. Thus higher values increase the output volts for DAC.

I – Integral Gain

The 'I' value works the same as the 'P' value with the exception that it adds the error for each instantaneous step along the move to correct the position. When setting a value for 'I' the user must also set a 'Max Error I" value. The 'Max Error I' puts an upper limit on the accumulated error in order to avoid uncontrolled oscillation. To begin with the user may set MaxError I to 100.

D – Derivative Gain

The D parameter is multiplied to the difference of the following-error between the current and previous cycle.

Velocity Feed Forward

The value bypasses the PID filter and directly increases the output command. This parameter only takes effect when the motor is moving at higher velocities. Velocity feed forward has little to no effect on lower velocities.

Offset

Applying an offset will simply command the motor to counteract the motor creeping in an open loop condition. The offset can also help compensate for the effects of gravity in a vertical axis configuration

Low Pass Filter (0-30)

Determines how gradually the PID filter takes effect. In doing so it reduces noise to allow the for smoother motor movement. The PID loop runs at 1Khz, thus a low pass value of 2 is an ideal initial starting point. Not all systems will require a low pass filter.

Max Error I

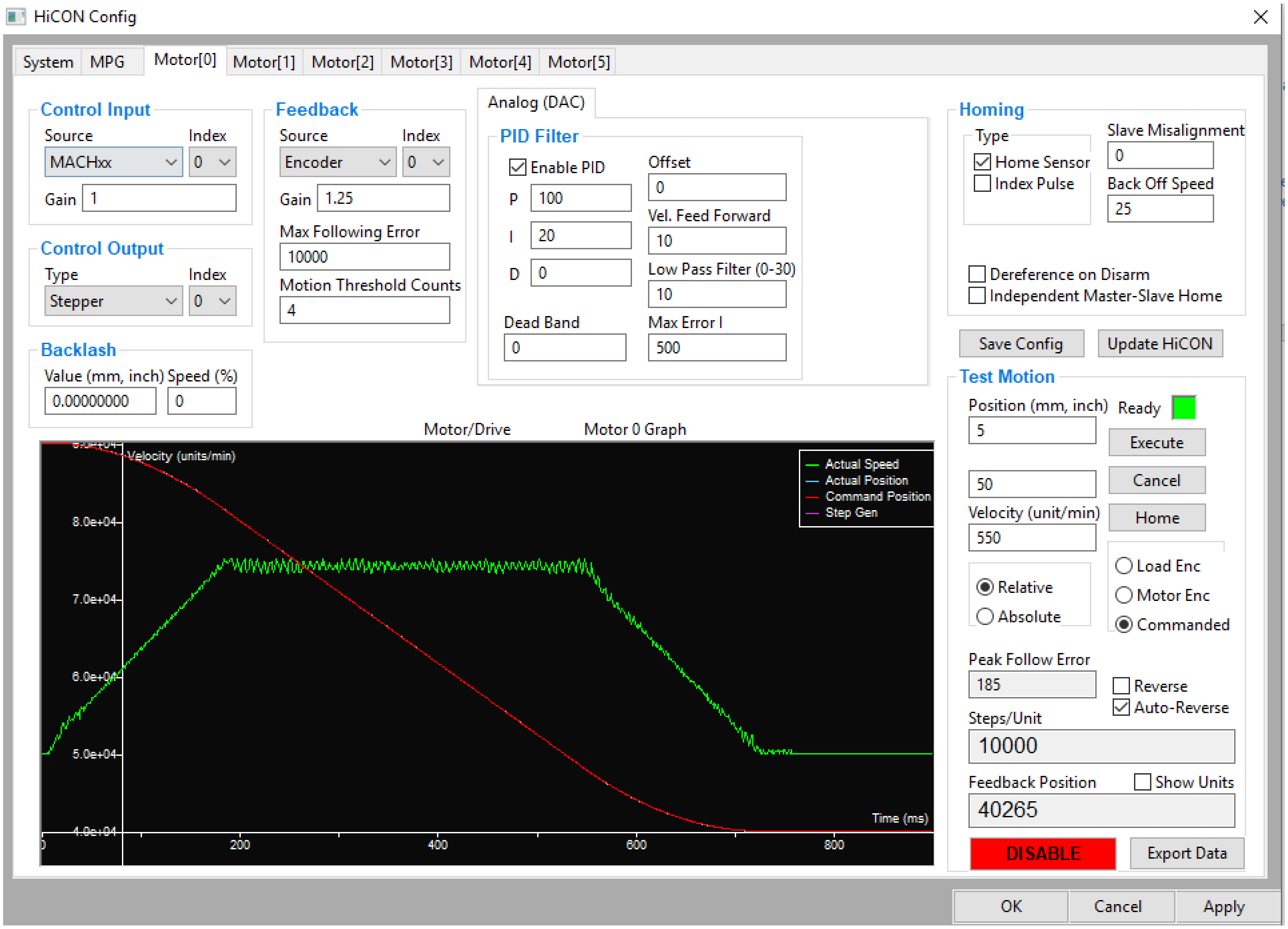
The 'Max Error I' puts an upper limit on the accumulated error in order to avoid uncontrolled oscillation. To begin with the user may set MaxError I to 100.

Dead Band

Allows the user to set the limit for the system to fluctuate within before the PID takes effect. The system will be allowed to deviate within the parameter of the 'Dead band' before any correction takes place by the PID.

Step 4: Tuning PID Steps

1. Set 'P' to 10, 'Max Follow Error' at 10000, and 'Low Pass Filter' to 2. Set all other parameters to zero.
2. Execute a test motion with high acceleration and velocity over a short distance such as 1 inch or 20-30mm.
3. If no motion is observed, start increasing "P" until the user motion can be observed physically and on the motion graph. Check the Response graph for details on the motion.
4. If the actual position moves in the opposite direction of commanded, reverse the "Encoder Polarity" in the system tab.
5. Once a satisfactory motion graph is achieved (i.e. actual position follows commanded), the motion can be further tuned:
    a. Initially set 'I' to 5 and 'MaxError I' to 100. Start gradually increasing the 'I' value to close the gap between the commanded and actual positions. If required, increase 'Max Error I', however, large values of this parameter will result in excessive oscillations
    b. Start increasing 'Velocity Feed Forward' to reduce the error during while motor is in motion. (a value of 20 seems to work well)
    c. If oscillations (jittering moves) are observed with the motion, increase the 'D' term to balance out the oscillations (start at a tenth of the 'P' Parameter and gradually increase as necessary).
6. Ideally, the actual position (blue line) should be as close to commanded position (red line) as possible. Execute test motions for short and long distances with 'Auto-reverse' checked. Repeat the test motion as necessary, while tweaking the PID parameter values. If the drive does not have enough power then the user may not achieve perfect tuning. Be sure that the driver is configured to deliver maximum current required for the user application.
7. The screenshot below is an example of an ideal graph utilizing the PID configuration:


HiCON Config
System
MPG
Motor[0]
Motor[1]
Motor[2]
Motor[3]
Motor[4]
Motor[5]
Control Input
Source
Index
MACHxx
0
Gain
1
Control Output
Type
Index
Stepper
0
Backlash
Value (mm, inch) Speed (%)
0.00000000
0
Feedback
Source
Index
Encoder
0
Gain
1.25
Max Following Error
10000
Motion Threshold Counts
4
Analog (DAC)
PID Filter
Enable PID
P
100
I
20
D
0
Offset
0
Vel. Feed Forward
10
Low Pass Filter (0-30)
10
Dead Band
0
Max Error I
500
Homing
Type
Home Sensor
Index Pulse
Slave Misalignment
0
Back Off Speed
25
Dereference on Disarm
Independent Master-Slave Home
Save Config
Update HiCON
Test Motion
Position (mm, inch)
Ready
5
Execute
50
Cancel
Velocity (unit/min)
Home
550
Load Enc
Relative
Motor Enc
Absolute
Commanded
Peak Follow Error
185
Reverse
Auto-Reverse
Steps/Unit
10000
Feedback Position
Show Units
40265
DISABLE
Export Data
Motor/Drive
Motor 0 Graph
Velocity (units/min)
Actual Speed
Actual Position
Command Position
Step Gen
8.0e+04
7.0e+04
6.0e+04
5.0e+04
4.0e+04
Time (ms)
200
400
600
800
OK
Cancel
Apply