NOTE: *Before proceeding with this document. It is required to consult the "Mach4 Integration Manual" for the current motion controller in order to perform the preliminary integration with Mach4 (i.e. ESTOP, Limit switch setup, etc.).*

NOTE: *It is advised to read this document thoroughly before attempting rigid tapping in Mach4. Improper parameter configuration, and hardware/software setup may damage tap heads and possibly result in personal injury.*

Contents

Rigid Tapping in Mach4/MachPro

Rigid tapping mode in Mach is started with the "G84.2 Z__ R__ F__" command, and stopped with the "G80" command. While in Rigid tapping mode, specifying motion coordinates will cause the machine to move to each coordinate position and execute a rigid tap cycle upon reaching specified destination(drill and retract).

Electronic gearing is used with VSI Motion Controllers such as the "7763 DSPMCv3", "7866 HiCON Integra" and "7766 HiCON Integra". Electronic gearing allows directly controlling the Z axis motion based on the actual spindle RPM. This allows the Z axis to slow down when the Spindle RPM decreases as a result of friction incurred when tapping through materials.

Parameters:

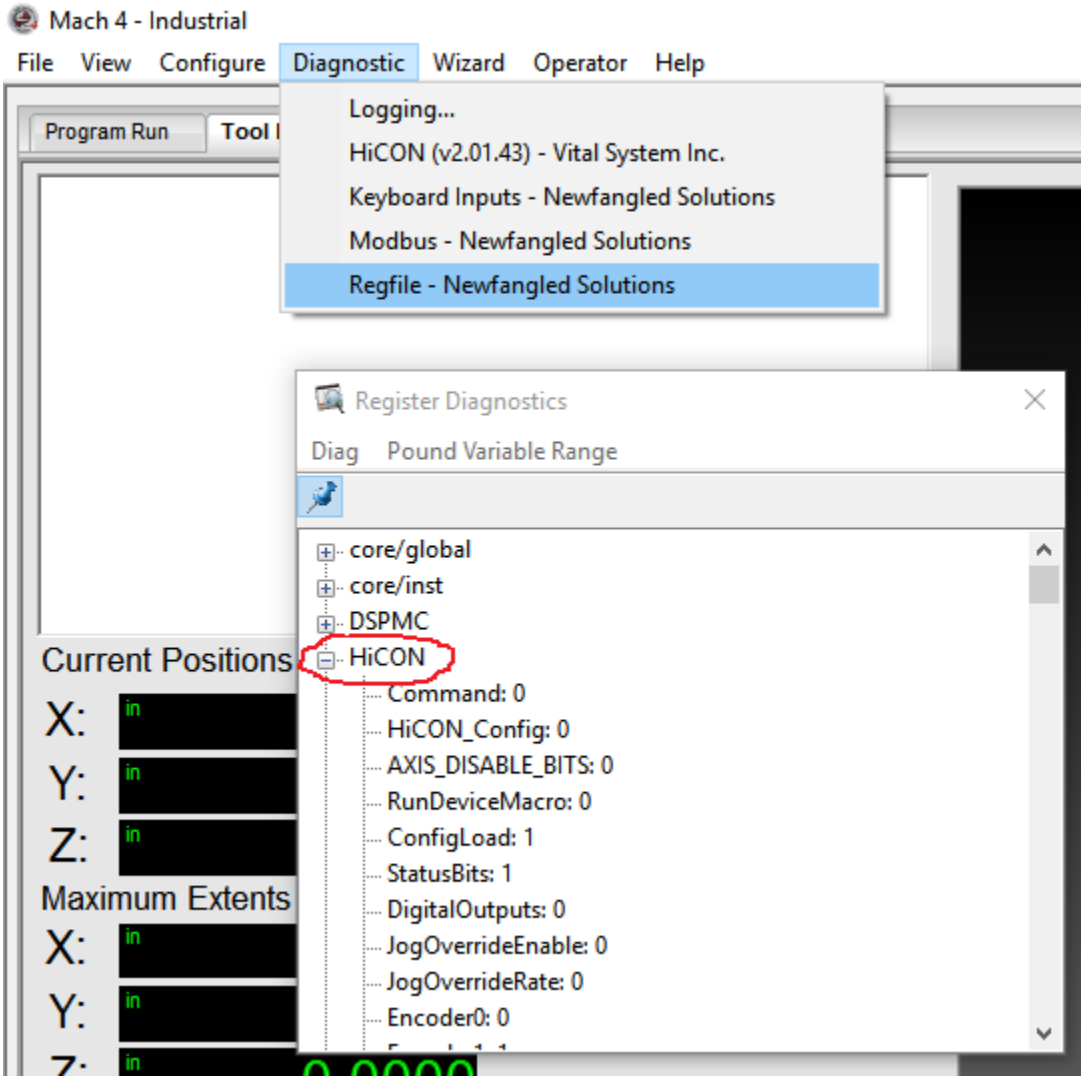
G84.2	GCode command to start rigid tapping mode
Z__	Parameter to specify the end depth position of the tap cycle before retracting the cutting head.

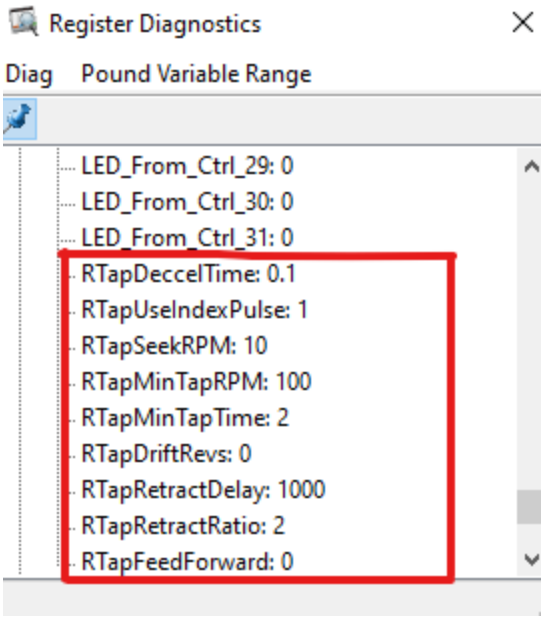
	<u>Example</u>: "Z-4" specifies that the Z axis will keep drilling until it reaches a position of -4 (inches or mm).
R__	Parameter to specify the retract height position at the end of the tap cycle. *<u>Example</u>: "R1" specifies that the Z axis will retract until it reaches a position of 1 (inch or mm).*
F__	Parameter to specify the Z feedrate when performing a tap cycle. The usage of this parameter varies depending on if G94 or G95 was executed prior to the G84.2 command to start rigid tapping mode.
S__	Command to specify the spindle RPM.
M3	Command to turn ON the Spindle.
M5	Command to turn OFF the spindle.
G94	GCode command that indicates the "F" parameter is specified in terms of **<u>units/min.</u>** With this setting the "Threads/Unit" value is calculated by: • *Threads/Unit = SpindleRPM / F-ParameterValue* • *ThreadPitch = 1 / (Threads/Unit)* *<u>Example</u>*: - **G94** - **S200 M3** - **G84.2 Z-4 R1 F20** The aforementioned code snippet turns on the spindle and sets it to a target RPM of 200, then starts Rigid tap mode where the Z axis will drill until a position of -4, and will retract to a position of 1, while the Z axis will move at a rate of 5 units/min. Threads/Unit = 200 / 20 Threads/Unit = 10
G95	GCode command that indicates the "F" parameter is specified in terms of **<u>units/rev</u>**. With this setting, the "F" parameter directly specifies the Thread pitch value. *<u>Example</u>*: - **G95** - **S200 M3** - **G84.2 Z-3 R2 F0.1** The aforementioned code snippet turns on the spindle with a target RPM of 200, then starts Rigid tap mode where the tap cycles will thread holes with 0.1 pitch, and the Z axis will drill until a position of -3, and will retract to a position of 2,

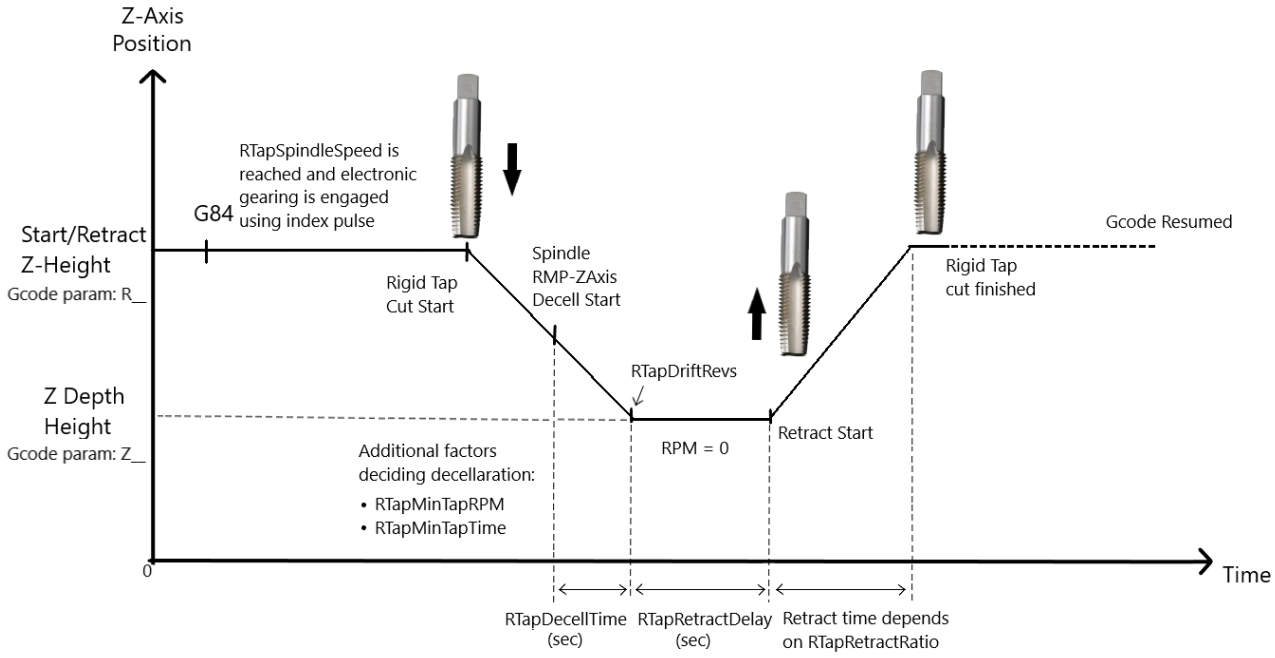
	Z-Feedrate = SpindleRPM / (1 / ThreadPitch) Z-Feedrate = 200 / (1 / 0.1) Z-Feedrate = 20 units/min
G80	GCode command to end rigid tap mode.

Rigid Tap Parameters

The Rigid Tap configuration parameters can be accessed from the “Register Diagnostic” window in Mach. The parameters themselves can be found by scrolling down under either “HiCON” or “DSPMC”. Double-clicking each parameter allows the value to be modified.

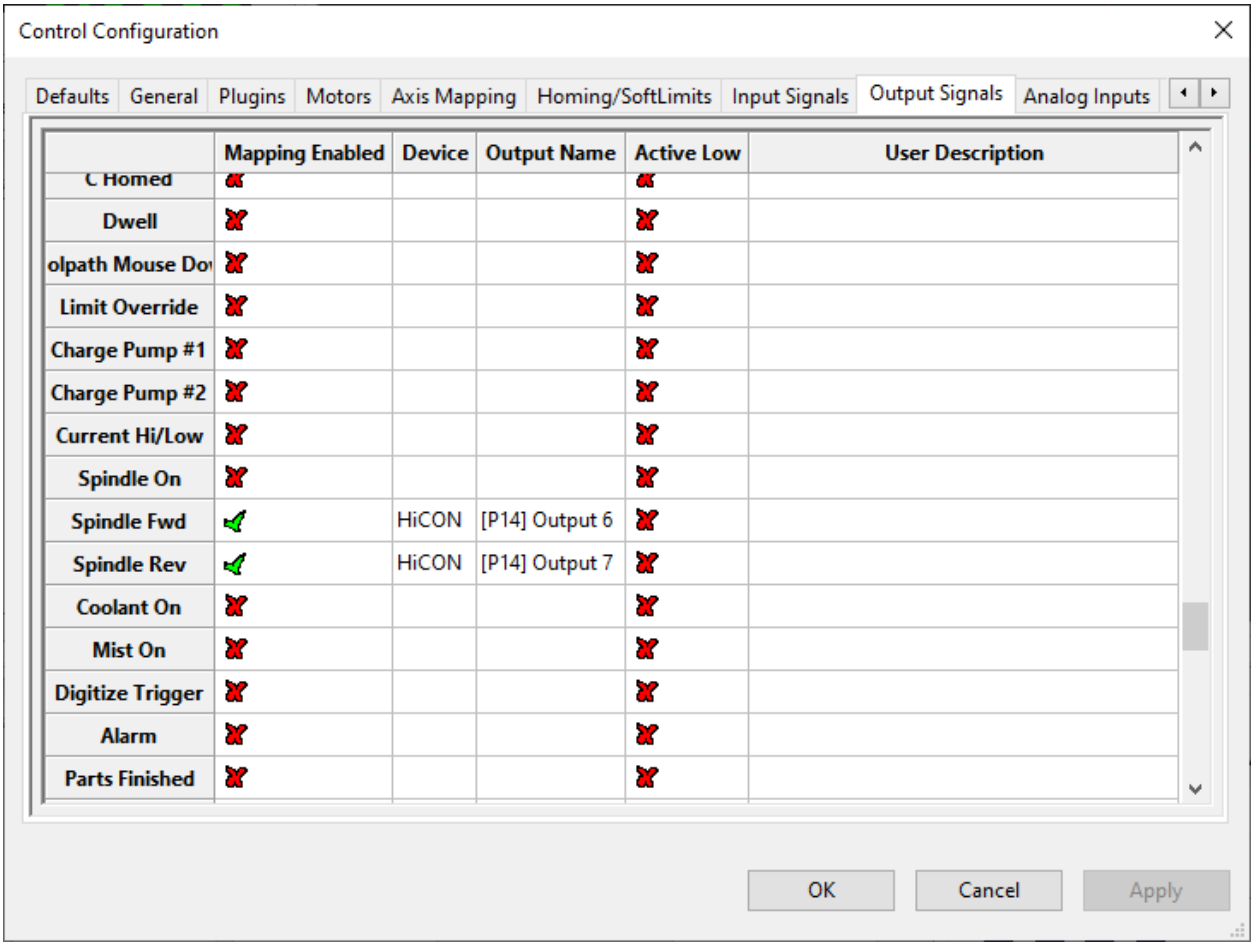



Register Diagnostics
Diag
Pound Variable Range
LED_From_Ctrl_29: 0
LED_From_Ctrl_30: 0
LED_From_Ctrl_31: 0
RTapDeccelTime: 0.1
RTapUseIndexPulse: 1
RTapSeekRPM: 10
RTapMinTapRPM: 100
RTapMinTapTime: 2
RTapDriftRevs: 0
RTapRetractDelay: 1000
RTapRetractRatio: 2
RTapFeedForward: 0


Z-Axis Position
RTapSpindleSpeed is reached and electronic gearing is engaged using index pulse
G84
Start/Retract Z-Height
Gcode param: R__
Rigid Tap Cut Start
Spindle RMP-ZAxis Decell Start
RTapDriftRevs
Gcode Resumed
Rigid Tap cut finished
Z Depth Height
Gcode param: Z__
Additional factors deciding decellaration:
• RTapMinTapRPM
• RTapMinTapTime
RPM = 0
Retract Start
0
Time
RTapDecellTime (sec)
RTapRetractDelay (sec)
Retract time depends on RTapRetractRatio

Register Name	Description
RTapDeccelTime	The amount of time (in seconds) that it takes for the Max Spindle RPM to decelerate to the Min Tap RPM. In practice the time given to decelerate will be scaled by the ratio of currentRPM/maxRPM. A slow moving spindle will need less time to decelerate.
RTapUseIndexPulse	MUST BE ENABLED. this setting will allow the Z axis to wait for the index pulse trigger (from the spindle encoder) before initiating the tap cycle. This allows for consistent threading orientation on all tap cycles.
RTapSeekRPM	The RPM of the spindle while searching for its initial start position using the Index pulse. Note that once the start position has been found, the RPM will change to the value configured by the 'S' command in GCode.
RTapMinTapRPM	The minimum RPM that the spindle will decelerate to. This stabilizes the spindle as it approaches the target depth of the tapping cycle which allows the spindle to come to a complete halt when the target depth is reached.
RTapMinTapTime	The amount of time (in seconds) that the spindle will maintain the "Min Tap RPM" before completely turning off the spindle. Minimizing the RPM by the end of the tap cycle allows the spindle to take less time decelerating, which helps prevent "overshooting" the depth.
RTapDriftRevs	The estimated number of extra revolutions that the spindle will make upon setting the RPM from 'MinTapRPM' to Zero. This provides another method to correct for Overshoot.
RTapRetractDelay	The amount of time (in milliseconds) to delay before retracting the spindle after drilling.
RTapRetractRatio	This value is a multiplier for the RPM of the spindle when retracting. For example, if a spindle RPM of 500 is used for the tapping cycle and a "Retract Ratio" of 1.75 is set, then the spindle will retract at an RPM of 875.
RTapFeedForward	LEGACY SETTING. NOT RECOMMENDED FOR USE. It may still preferable to perform feed forward tuning on servo drives. *Set this to zero to disable it*. This parameter is used to minimize the following error between the spindle and Z motion by applying a feed forward multiplier. It is recommended to use small values (ex. 0.1), then gradually increase the value to the desired performance.

Mach4/MachPro Output Mapping



Make sure to perform dry run for rigid tapping. If the Z-Axis is moving in opposite direction opposed to the intended please flip the "Spindle Fwd" and "Spindle Rev" mapping.

If the user desires a clock wise / anticlockwise spin, user must set the spindle reverse option inside Mach control ->Spindle tab. Please do not flip the mapping/wiring to reverse the default direction.

Example GCode Program

The short program below demonstrates a simple sequence that utilizes rigid tapping.

G90	Set Absolute Position Mode
G00X0Y0Z2	Rapid move to position X at 0, Y at 0, and Z at 2
G95	Use inches/rev (F-Parameter specified thread pitch)
S200 M3	Start spindle with 200RPM
G84.2 Z-3 R2 F0.1	Start rigid tap mode. Each tap cycle will thread a hole with 0.1 pitch, and keep drilling until Z reaches a position of -3, and retract until Z reaches a position of 2.
X1.5	Move X position to 1.5 and start tap cycle upon reaching target position
X2.5	Move X position to 2.5 and start tap cycle upon reaching target position
X3.75Y1	Move X position to 3.75 and Y position to 1 and start tapping cycle upon reaching the target position
G80	End rigid tap mode.
M5	Disable Spindle

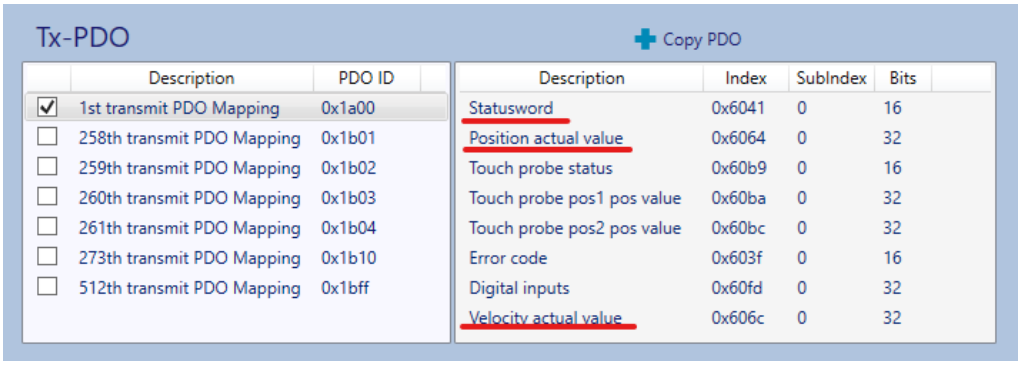
```
G90
G00 X0Y0Z2
G95
S200 M3
G84.2 Z-3 R2 F0.1
X1.5
X2.5
X3.75Y1
G80
M5
```

EtherCAT Drive Configuration

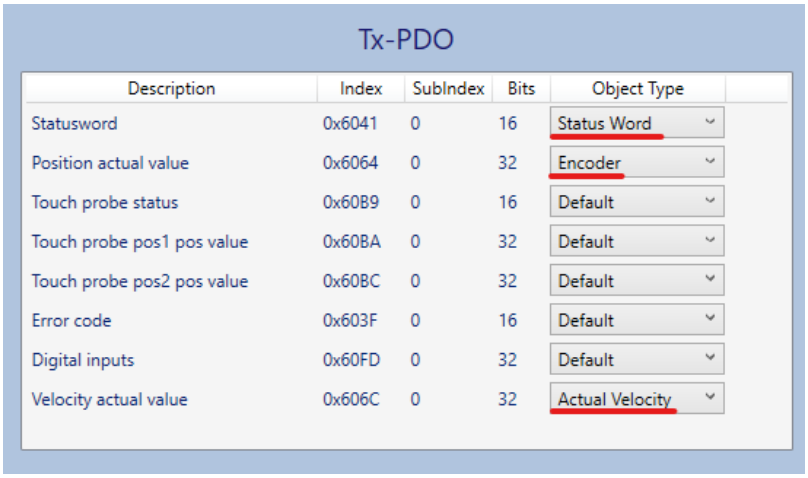
If the spindle is an EtherCAT Drive, there is some further configuration necessary. You should first follow along the ECAT VFD Quick Start Guide in order to get the drive running before performing the steps in this Rigid Tap guide.

EC-Link Configuration

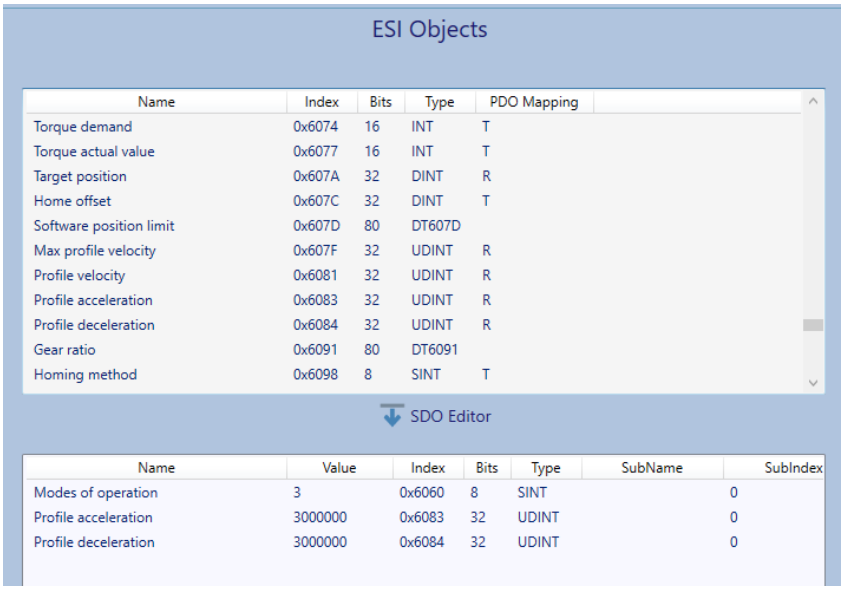
Once you can enable the spindle with M3, you can move on to the configuration needed for Rigid Tap. In EC-Link in the Tx-PDO section, you must have 'Position Actual Value' in addition to the 'Velocity Actual Value' and 'Statusword' that are usually needed for ECAT VFDs:



In the Object Map tab, you must then map the Position Actual Value to an Encoder:

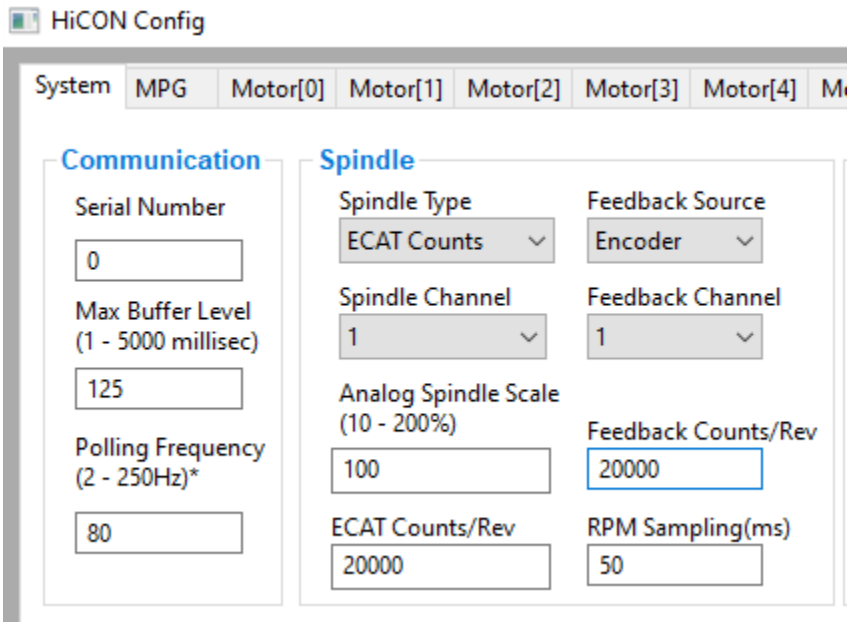


Down the line you may also want to configure the acceleration and deceleration of the VFD (if not done through the device's Configuration software), which can be added on the SDO tab:



HiCON Plugin Configuration:

On the system tab of the HiCON Plugin, you will need to set the following settings in the Spindle section:



Type	Set to the unit your drive takes as command, either ECAT Counts or ECAT RPM. Some drives directly take an RPM value as command, while others take a Counts/Sec as command.
Feedback Source	Should be encoder. If you do not, you will not get Actual Velocity back from the drive to the Mach UI.
Spindle Channel	Unused in an EtherCAT VFD configuration. Should be set to an unused analog output channel (Channel 0 is the onboard analog output on EC01).
Feedback Channel	Should match the channel the Encoder channel the position feedback is coming back on. The actual position of the VFD should be mapped in ECLink to an encoder. You can verify the index of the position value in the Encoder column in the HiCON diagnostic window.
Feedback Counts/Rev	This should match the number of feedback counts in one revolution of the motor. You can move the motor by hand and view the change in counts in the HiCON diagnostic window.
ECAT Counts/Rev	Only needed for ECAT Counts Spindle Type. Will likely match the above Feedback Counts/Rev unless a gain is applied.

With these settings applied, the ECAT Spindle will be fully compatible with the RigidTapping cycle.