

Mach4 Tutorial

Setting up basic CNC machine or controller with ESS connection

Based on Mach4 Hobby

Purpose.

The purpose of this tutorial is to help and to guide the user to, step by step, set up and tune the Mach4 CNC controller application for use on a basic CNC machine or controller with ESS connection. We will go thru the steps of setting up the emergency stop, the main axis motors, the spindle and coolant as well as the home switches and the software based over-travel limits. The tutorial is based on the Mach4 Hobby and is meant to be used as complement to the existing Using Mach4 Hobby.

A good place to get **Fully Licensed versions of Mach4**

<https://www.automationtechnologiesinc.com/products-page/featured-cnc-products/mach4-cnc-controller-software/>

Let's get started.

When first installing the software it's vital to reboot the computer as the installer prompts. If you don't do this the software will not work and you will have to manually remove the Mach4 driver from the system. After installing the software and rebooting the computer you should have four icons on your desktop. These icons all launches Mach4 but it also loads a different set of screens depending on what kind of machine it is we are running. This tutorial we'll start the software with the one labelled Mach4 Loader. When the software is started you may be presented with the following dialog.

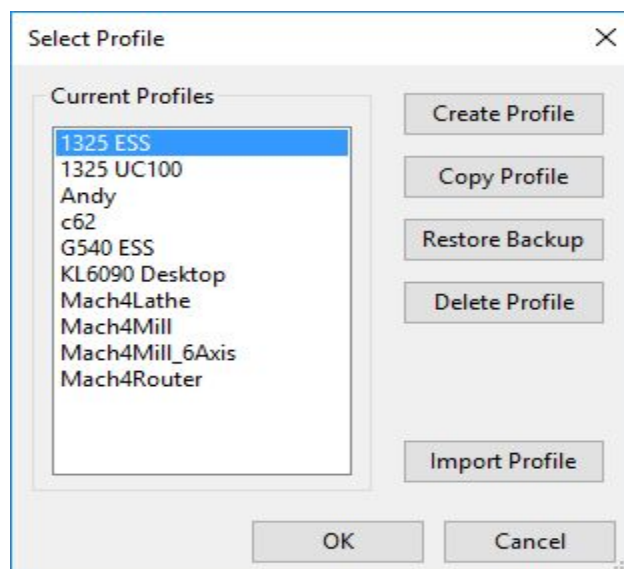


Figure 1: Select Profile

Then we can click “Create Profile” to create your own profile.

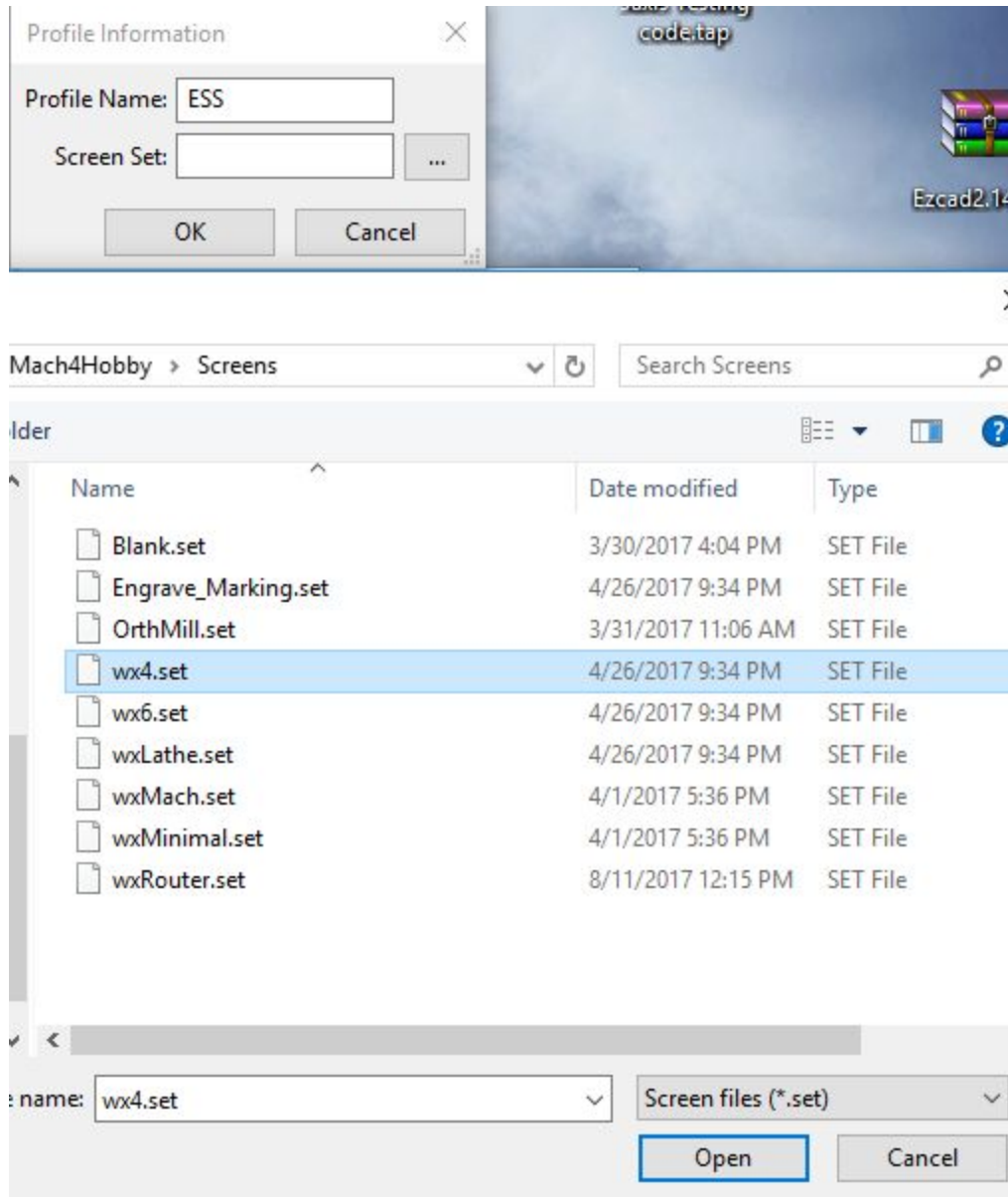


Figure 2: Create Profile

We choose the “wx4.set” as “Screen set”

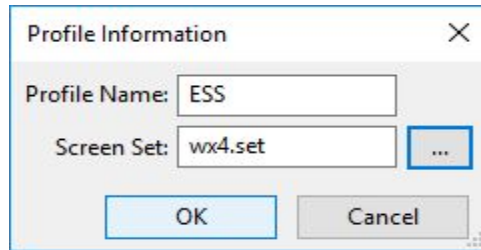


Figure 3: Profile Information

Then click “OK” and double click this profile to open. The next step is select ESS IP address. The IP address will automatically show in the below window, then click “OK”.

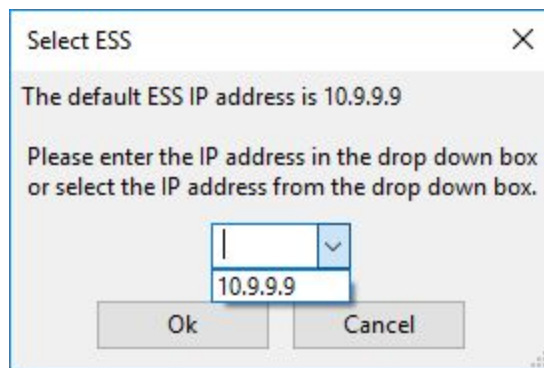


Figure 4: Select ESS

Mach4 will remind you the next step

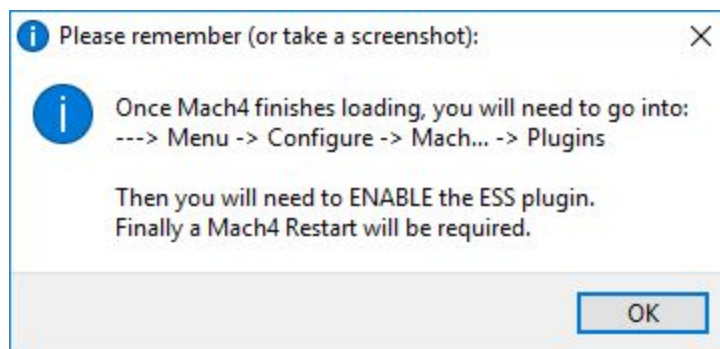


Figure 5: Reminder

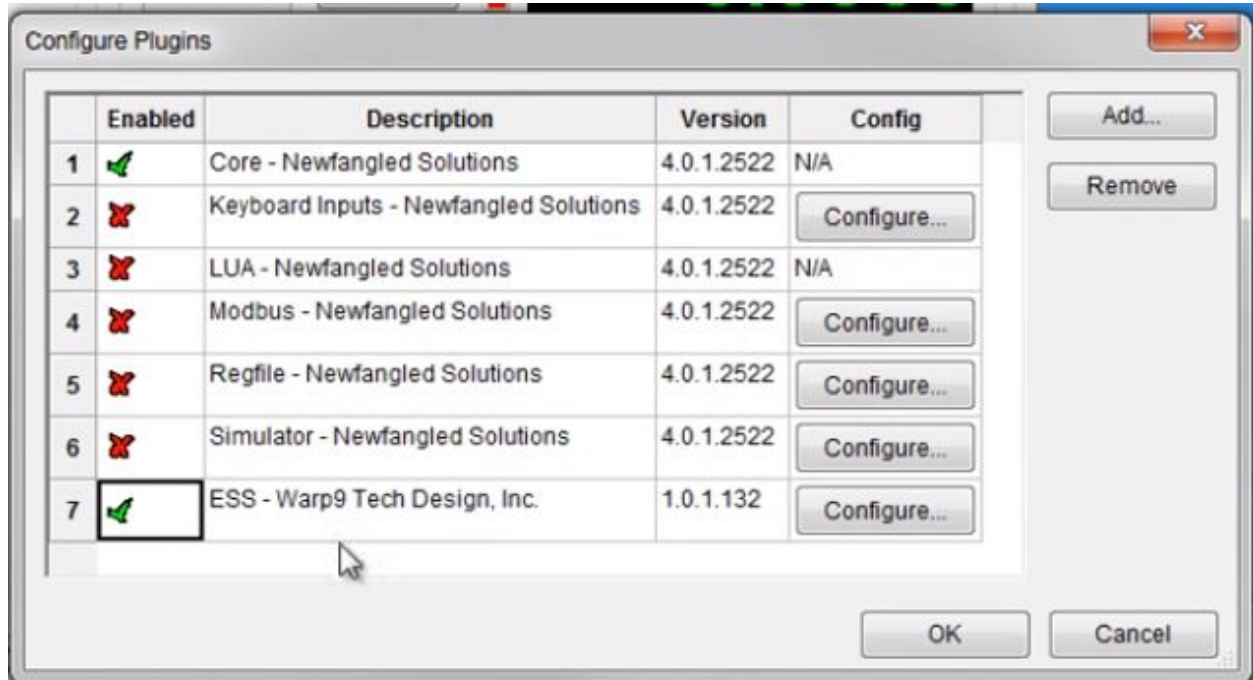


Figure 6: Plugins

Restart your Mach4 software.

Now we need to set ESS Configuration (Go to "Configure>>Plugins>>ESS")

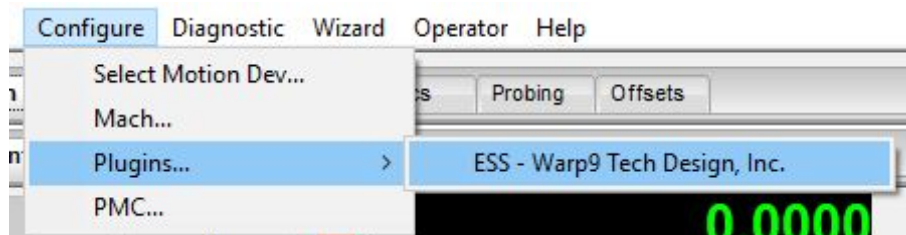


Figure 7: Configure-Plugins

This is where we tell Mach4 how many motors we want to control and to which pins in our printer port the each motor driver is connected. First click the "Pins config", we can add words in the "Alias" column to define each pin's function. The actual pin out of your machine may be different. If you have wired it yourself you probably know the pin out and if you bought the machine and/or driver box please consult the documentation for that particular machine or check with the hardware manufacturer.

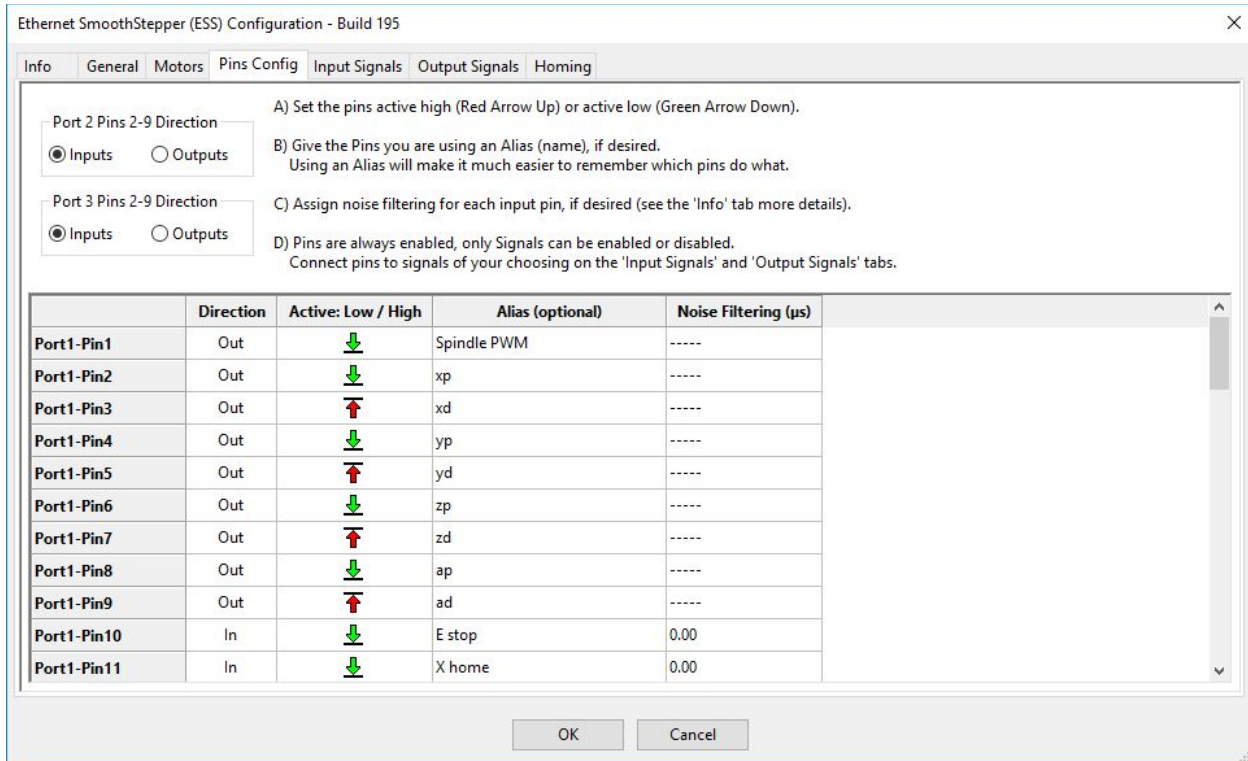


Figure 8: ESS Configuration

In this case the X axis drive step input is connected to pin 2, Y to pin 4, Z to pin 6 and A to pin 8. The drives wired to 3, 5, 7 and 9 on this machine. This setting depends on how the drives are built and how we have them wired.

	Direction	Active: Low / High	Alias (optional)	Noise Filtering (µs)
Port1-Pin1	Out	↓	Spindle PWM	-----
Port1-Pin2	Out	↓	xp	-----
Port1-Pin3	Out	↑	xd	-----
Port1-Pin4	Out	↓	yp	-----
Port1-Pin5	Out	↑	yd	-----
Port1-Pin6	Out	↓	zp	-----
Port1-Pin7	Out	↑	zd	-----
Port1-Pin8	Out	↓	ap	-----
Port1-Pin9	Out	↑	ad	-----
Port1-Pin10	In	↓	E stop	0.00
Port1-Pin11	In	↓	X home	0.00

Figure 9: ESS Pins Configure (1)

	Direction	Active: Low / High	Alias (optional)	Noise Filtering (μ s)
Port1-Pin10	In		E stop	0.00
Port1-Pin11	In		X home	0.00
Port1-Pin12	In		Y home	0.00
Port1-Pin13	In		Z home	0.00
Port1-Pin14	Out			-----
Port1-Pin15	In		B home	0.00
Port1-Pin16	Out			-----
Port1-Pin17	Out			-----
Port2-Pin1	Out			-----
Port2-Pin2	In			0.00
Port2-Pin3	In			0.00

Figure 10: ESS Pins Configure (2)

Move to “Input signal”, in this case we enable those E-Stop and Motors by making sure that there is a green check mark in the first column, and select their corresponded pins in the third column.

Ethernet SmoothStepper (ESS) Configuration - Build 195

Info	General	Motors	Pins Config	Input Signals	Output Signals	Homing
A) When you enable an input signal here, it will automatically be enabled and mapped into Mach.						
B) An Input Pin (or Alias) may be assigned to multiple Input Signals.						
	Enable	Mach Mapping	Mapped Pin			
E-Stop		ESS	E stop			
Motion Inhibit						
Limit Override						
Motor 0 ++						
Motor 1 ++						
Motor 2 ++						
Motor 3 ++						
Motor 4 ++						

Figure 11: ESS Input Signals (1)

The Emergency Stop button.

Any decent machine tool should have an Emergency Stop button that, in the safest possible way, halts all machine movement and prevents damage to the operator in the first place and/or the machine – so will this one. This tutorial will not go into the actual hardware design of a proper E-stop system but will focus on getting Mach4 to understand that the big red button has been pushed.

Ethernet SmoothStepper (ESS) Configuration - Build 195









Info	General	Motors	Pins Config	Input Signals	Output Signals	Homing
A) When you enable an input signal here, it will automatically be enabled and mapped into Mach.						
B) An Input Pin (or Alias) may be assigned to multiple Input Signals.						
	Enable	Mach Mapping	Mapped Pin			
Motor 2 --						
Motor 3 --						
Motor 4 --						
Motor 5 --						
Motor 0 Home		ESS	X home			
Motor 1 Home		ESS	Y home			
Motor 2 Home		ESS	Z home			
Motor 3 Home						

Figure 11: ESS Input Signals (2)

Move to “Output signal”, we should enable those “Motors’ Step / Dir”, “Enable #1” and “Output #1” by making sure that there is a green check mark in the first column, and select their corresponded pins in the third column

	Enable	Mach Mapping	Pin1 Mapping	Pin2 Mapping	Pin3 Mapping
Motor 0 Step		ESS-only	xp		
Motor 0 Dir		ESS-only	xd		
Motor 1 Step		ESS-only	yp		
Motor 1 Dir		ESS-only	yd		
Motor 2 Step		ESS-only	zp		
Motor 2 Dir		ESS-only	zd		
Motor 3 Step		ESS-only	ap		
Motor 3 Dir		ESS-only	ad		
Motor 4 Step		ESS-only			
Motor 4 Dir		ESS-only			
Motor 5 Step		ESS-only			
Motor 5 Dir		ESS-only			
Enable #0					
Enable #1		ESS	Port1-Pin17		

Figure 11: ESS Output Signals (1)

	Enable	Mach Mapping	Pin1 Mapping	Pin2 Mapping	Pin3 Mapping
C ++					
C --					
C Home					
Output #0					
Output #1		ESS	Spindle PWM		
Output #2					
Output #3					

Figure 11: ESS Output Signals (2)

After finish above steps, click “OK” to save the settings and close the dialog. The we move to Configure>>Mach

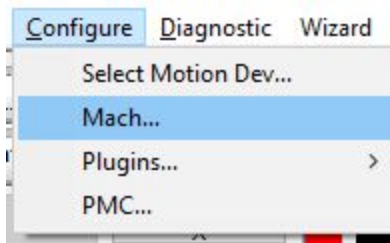


Figure 12: Configure-Mach

Move to “Axis Mapping”, enable X, Y, Z and A four axis and select their master motor.

 A screenshot of the Mach4 software's 'Axis Mapping' dialog box. The dialog has tabs for 'General', 'Plugins', 'Motors', 'Axis Mapping' (selected), 'Homing/SoftLimits', and 'Input Signals'. Below the tabs is a table with columns: 'Enabled', 'Master', 'Slave 1', 'Slave 2', and 'Slave 3'. The rows represent axes X(0), Y(1), Z(2), and A(3).

	Enabled	Master	Slave 1	Slave 2	Slave 3
X (0)	<input checked="" type="checkbox"/>	Motor0			
Y (1)	<input checked="" type="checkbox"/>	Motor1			
Z (2)	<input checked="" type="checkbox"/>	Motor2			
A (3)	<input checked="" type="checkbox"/>	Motor3			

Figure 13: Axis Mapping

Move to “Homing/SoftLimits”, enable X, Y and Z axis “Soft Enable”.

Software limits:

Mach4 has the capability to prevent you from damaging your machine by constantly monitoring its position. If you or a G-code program tries to move it outside its working envelope it won't go there but instead present you with an error message. To set this up we go back to Home/Limits dialog. As we have our home switches located at extreme ends of travel in the negative direction for the X- and Y-axis we need to set the Soft Min value to 0. Doing so will prevent the machine from going beyond 0 in the negative direction. In the Soft Max we put whatever amount of travel we have available. In this case it's 0 in X and 0 in Y. Since we home Z in the positive direction but still call the home position 0 we need to put 0 as the Soft Max value.

The Soft Min value is again what amount of travel we have available, 0 in this case goes into the Soft Min column for the Z-axis. The Slow Zone setting is the amount travel there's left in the axis when the machine automatically starts to slow down when you are approaching a limit. For example, with a value of 3.00 in the Slow Zone, if we jog the

X-axis at high speed towards the negative limit, which is at 0.00 the machine will start to slow down when it passes 3.00. This prevents the machine from losing its home position due a too sudden stop of the motors. However, this automatic breaking is only available when jogging and not when running a G-code program.

	Home Dir	Home Order	Home Offset	Home Speed%	Home In Place	Soft Enable	Soft Min	Soft Max
X (0)	Pos	2	0.0000	20.00			0.0000	0.0000
Y (1)	Pos	3	0.0000	20.00			0.0000	0.0000
Z (2)	Pos	1	0.0000	20.00			0.0000	0.0000
A (3)	Pos	4	0.0000	20.00			0.0000	0.0000
B (4)	Pos	5	0.0000	20.00			0.0000	0.0000

Figure 14: Homing/SoftLimits

Move to “Input Signals”. Enable those “Motors’ Home”, “E-Stop” and “Jog X+/-” to “Jog Z+/-”, select the right pins in the “Input Name” column. These setting selections are halfway down or in the bottom of list, be patient to find them.

	Mapping Enabled	Device	Input Name	Active Low
Input #63				
Motor 0 Home		ESS	X home	
Motor 1 Home		ESS	Y home	
Motor 2 Home		ESS	Z home	
Motor 3 Home				
Motor 4 Home				

Figure 15: Input Signals (1)

General	Plugins	Motors	Axis Mapping	Homing/SoftLimits	Input Signals	Outp
					Mapping Enabled	Device
					Input Name	Active Low
					E-Stop	ESS
					THC On	
					THC Up	
					THC Down	
					Timing	
					Jog X+	
					Jog X-	
					Jog Y+	
					Jog Y-	
					Jog Z+	
					Jog Z-	

Figure 16: Input Signals (2)

Move to “Output Signal”, make sure the “X Home”, “Y Home” and “Z Home” have green mark in the “Mapping Enabled” and “Active Low” columns.

Home switches:

As you probably have noticed Mach4 is very flexible in its use of inputs and outputs. To set up the home switches we need to enable the home inputs. In the Mach Config menu go to the Input Signals tab. We already enabled the inputs “Motor 0 Home”, “Motor 1 Home” and “Motor 2 Home” and set the port # to 1 and pin # 11 to 13 and check the Active Low setting on all three.

Here you can see the power of Mach4’ s I/O capabilities. Even though we have three axis we wire them in series and connect them to one input. When Mach4 homes the machine it will do it one axis at the time and when the switch is hit it reverses the direction of the motor until the switched is cleared and then it does the next axis. It is even possible to use same switch as limit switch – Mach4 will know that the switch is a home switch when homing and from there on it’s considered to be a limit switch.

General	Plugins	Motors	Axis Mapping	Homing/SoftLimits	Input Signals	Out
	Mapping Enabled	Device	Output Name	Active Low		
X ++						
X --						
X Home						
Y ++						
Y --						
Y Home						
Z ++						
Z --						
Z Home						
A ++						
A --						
A Home						

Figure 16: Output Signals (1)

Enable #0				
Enable #1		ESS	Port1-Pin17	
Enable #2				
Enable #3				

Figure 17: Output Signals (2)

Output #0				
Output #1		ESS	Spindle PWM	
Output #2				
Output #3				
Output #4				

Figure 18: Output Signals (3)

Move to “Motors”, mark “Motor 1” to “Motor 3”

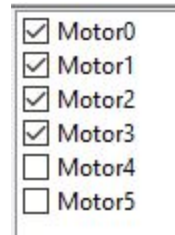


Figure 19: Motors

Motor Tuning:

Finally we'll get to actually spin some motors. The first thing in the tuning process is to calculate how many steps per unit of travel we have. This depends on a few things:

In case of a step motor:

- The amount of steps per revolution, most commonly 200.
- The step resolution of the motor drive, full step, half step, 5, 10, 100 micro steps etc.

In case of a servo motor.

- The amount of quadrature counts produced by the encoder on the motor
- The 'encoder mode' of the motor drive. 1, 2 or 4 encoder counts.

In both the above cases:

- The reduction ratio between the motor shaft and lead screw.
- And finally, the thread pitch of the screw. (How far the table moves with each rotation of the screw).

It should be noted that other actuating systems could be used like belts, rack & pinions etc but here we will use a lead or ball screw as the basis for our calculation. We will do one metric and one imperial example.

The metric one:

Let's assume we have a standard step motor with 200 steps per rev. This motor is driven by a driver set to 5 micro steps per full step. A Gecko G210 from GeckoDrive for example. The motor is directly coupled to the lead screw which has a pitch of 5mm per revolution. That means the axis will move 5mm for each revolution of the screw.

So we'll take the motors 200 steps multiply that by the drives 5 micro step. ($200 \times 5 = 1000$) The drive needs 1000 pulses (or steps) to turn the screw one revolution thus making the axis move 5mm. So now we take those 1000 steps and divide by the pitch of the screw, which is 5. ($1000 / 5 = 200$). In other words we need 200 steps to move one unit or mm.

The imperial one:

Let's assume a DC-servo with a 500 line encoder and a drive that uses all four quadrature counts of the encoder effectively making it a 2000 counts per rev motor/encoder combo. Let's also assume we have 3:1 belt reduction driving our screw which has a 5TPI pitch.

The drive needs 2000 pulses, or steps, to turn the motor one revolution. But since we have the 3 to 1 belt reduction between the motor and the screw we need to multiply the 2000 by 3 to make the screw turn one revolution.

6000 steps will make the screw turn one revolution, making the axis move 1/5 of an inch. To make the axis move one inch we need the screw to make five revolutions so $6000 \times 5 = 30.000$ steps per unit or inch.

In reality a steps per unit value as high as 30.000 will greatly reduce the speed at which the machine can move.

So now we have determined how many steps the computer needs to send out to the drives in order to move the machine one of our selected units, be it inch or mm. Let's tell Mach4 what we've come up with. In the Config menu, we select Motors and the following dialog should present itself:

(When I test, I used Gecko G540 Controller with ESS connection and Stepper Motor KL23H2100-35-4BC

<https://www.automationtechnologiesinc.com/products-page/cnc-controller-box/g540-73/>
<https://www.automationtechnologiesinc.com/products-page/nema-23/nema23-381ozin-3-5a-dual-shaft-stepper-motor-kl23h2100-35-4b-cable/>)

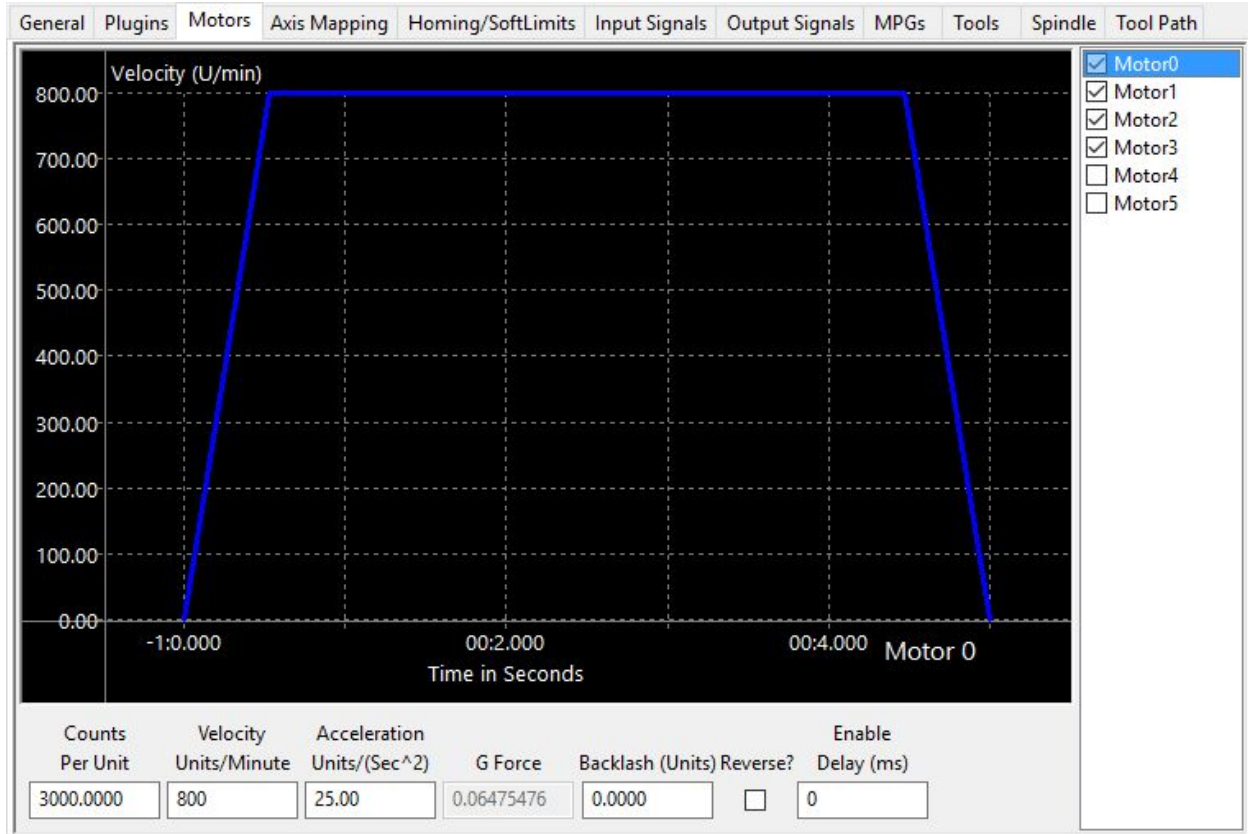


Figure 20: Motor Turning and Setup

The first thing to do is to enter the steps per unit we found in our calculation. By adjusting the Velocity and Accel sliders try to find a speed and acceleration that feels comfortable and where the motor run smoothly without any tendency to jerk, halt, or loose steps. Then, and this is important, click "Apply" to save settings. Next click the "Motor2" button and repeat the process for that axis and then do the same for the other Motor. Don't forget to press "Apply" and "OK" after done all the settings. If you don't want your setting will be lost.

Please note: It's in perfect order to have a different step per unit setting as well as Velocity and Accel values for each axis. Mach3 will keep them I perfect sync either way. You may even have fractional steps per unit set for one or more axis, for example 201.3 if that is what you need.

If you can't seem to get the motors to run smoothly there are a few things to check, first the easy one: Some motor drives need to have a longer step pulse and this can be set by changing the Step Pulse setting. See the manual for your particular drive.