

# Automating a Manual Machine

Converting the PM 728V-T mill to CNC

# Step by Step Instructions

For mechanical conversion and software setup.

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For

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# Uncrating



# Materials

This slide set details each step.

A USB Memory stick is provided that contains the software.

A single sheet exploded view of the machine is shipped with the machine.

After the Mach4 software is installed a folder of documents will be found at

`C:\Mach4Hobby\Docs`



# Software License

Mach4 is licensed software.

For this project 4 registration codes, equivalent to a coupon code, are provided.

The software must be installed before a license can be generated.

Each license will be keyed to one laptop PC.

The procedure to get the license is explained near the end of this document.

# Extra Parts

Memory stick, with software

Two angle brackets to mount Y axis limit switches.

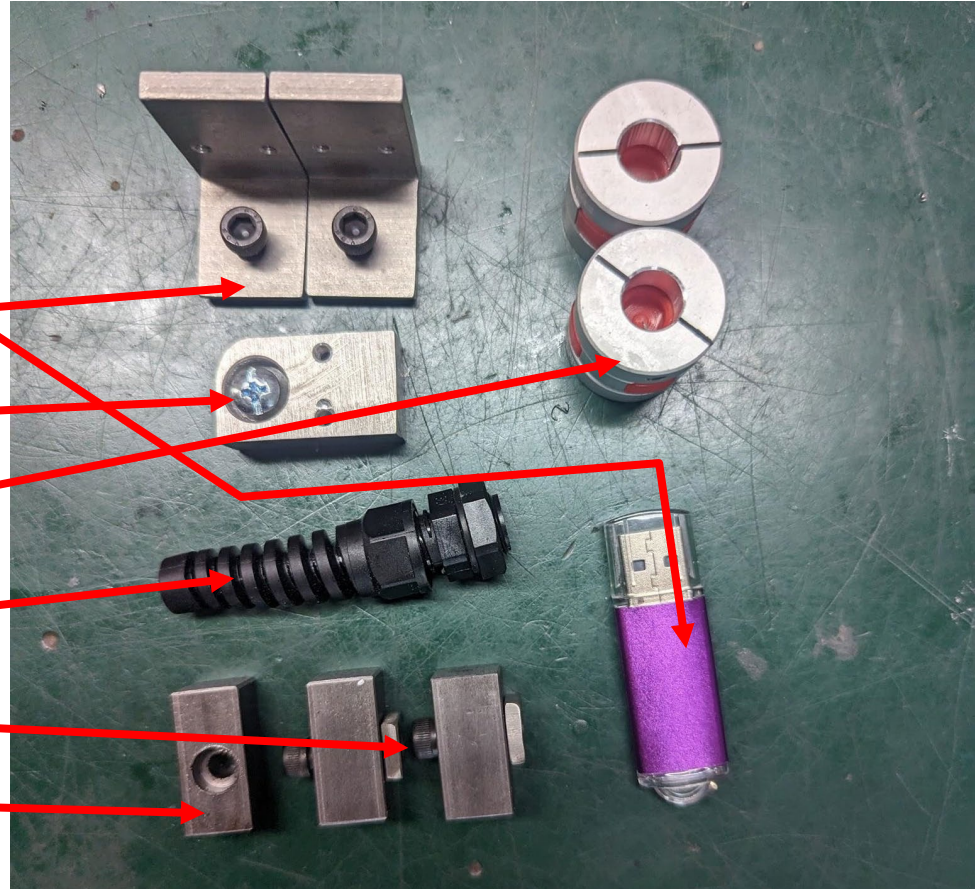
Spacer for Z axis switch

Couplings for X and Y axis

Strain relief connector for VFD cable

Target for X limit switches

Target for Z axis limit switch

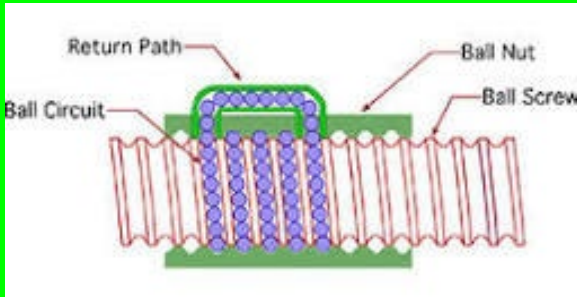


# Move mill to a safe workplace

- The mill is heavy- 370 pounds
- Do not attempt to lift if by hand
- Since we will need to disassemble the mill it may be wise to do it before moving to a work space

# Background

- We are working with a 3 axis mill
- Each axis is moved by a lead screw with a large Acme thread
- For plain threads to move there must be some clearance between the threads
- This clearance leads to backlash
- Backlash leads to inaccurate parts and broken tools.



A ballscrew solves the problem by placing ball bearings in the screw.

We will be replacing the lead screws with ballscrews on all 3 axes

*Green slides are background information*

# Dovetail slide with gib

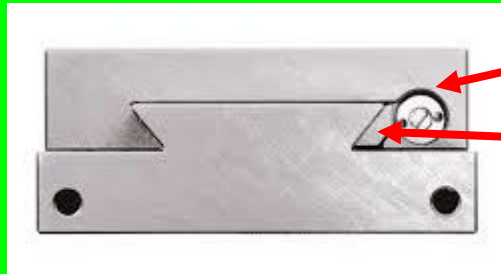
Machine tables must slide freely, but not be loose in any direction.

A dovetail joint has two sides angled to create an interlock

A tapered gib strip slides in between two faces to take out any slack

An adjustment screw can push the gib into the joint to make it tighter.

There is an adjustment screw at each end of the gib to lock it in place



# Remove the head (optional)

It is possible to change the Z axis screw with the head in place, but it is safer to remove the head.

It will require two people to carry the head.

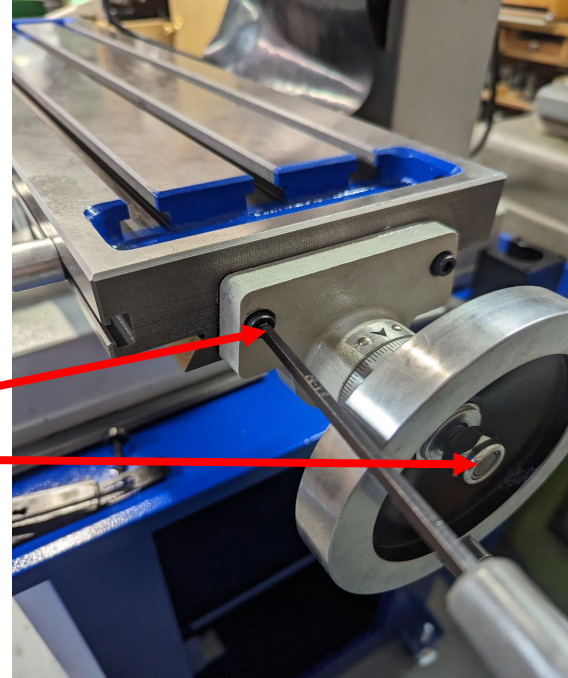
- Brace the head off the table with a block of wood
- Or support it with a sling and crane.
- Remove the two nuts on the side of the head
- Pull the head away from the column.

Store the head on its back in a safe place.



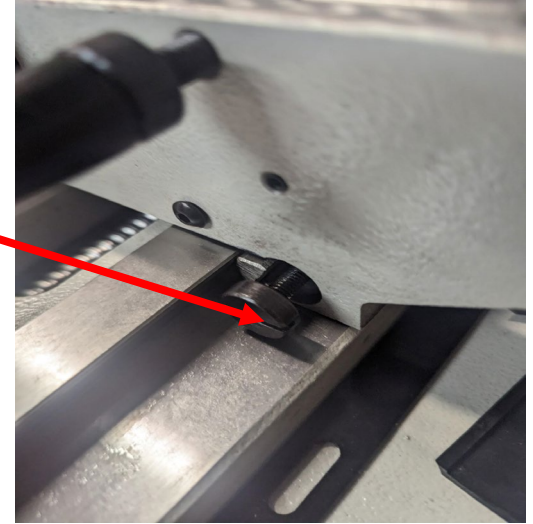
# Remove the table

- The table must be removed.
- It weighs over 50 pounds, so have two people move it.
- Remove the handwheel. Note it has a set screw above the key. ~~\_\_\_\_\_~~
- Remove the end cap bearing at each end of the table. ~~\_\_\_\_\_~~



## Remove the table- 2

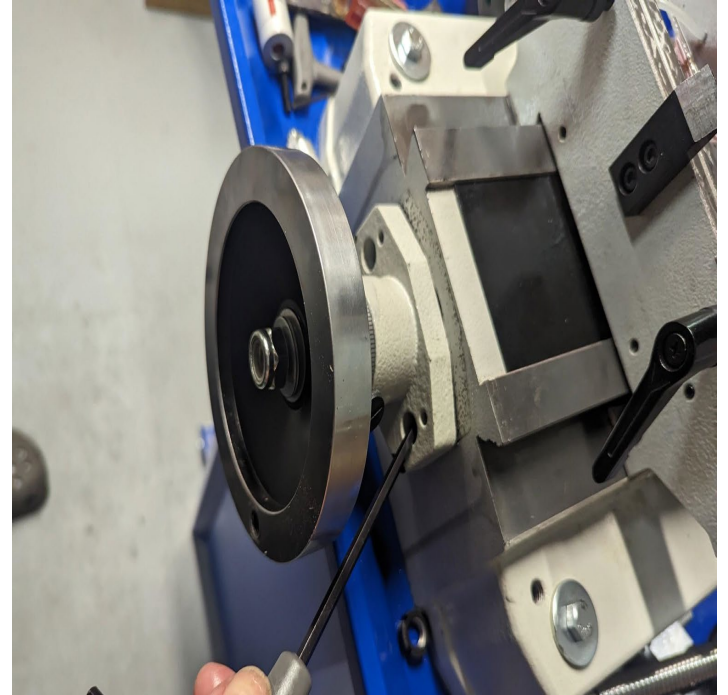
- Remove the gib adjustment screw
- Slide out the gib
- Slide the table off the saddle. It will slide over the lead screw.
- Remove the leadscrew and its mid bearing.





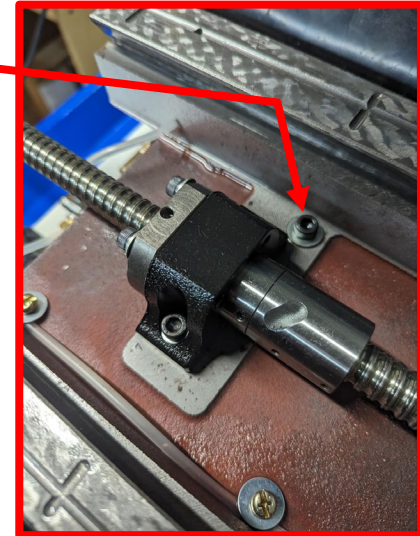
# Remove the saddle

- Remove the handwheel from the Y axis
- Remove two screws from the Y axis bearing
- Slide the Y axis bearing off the screw



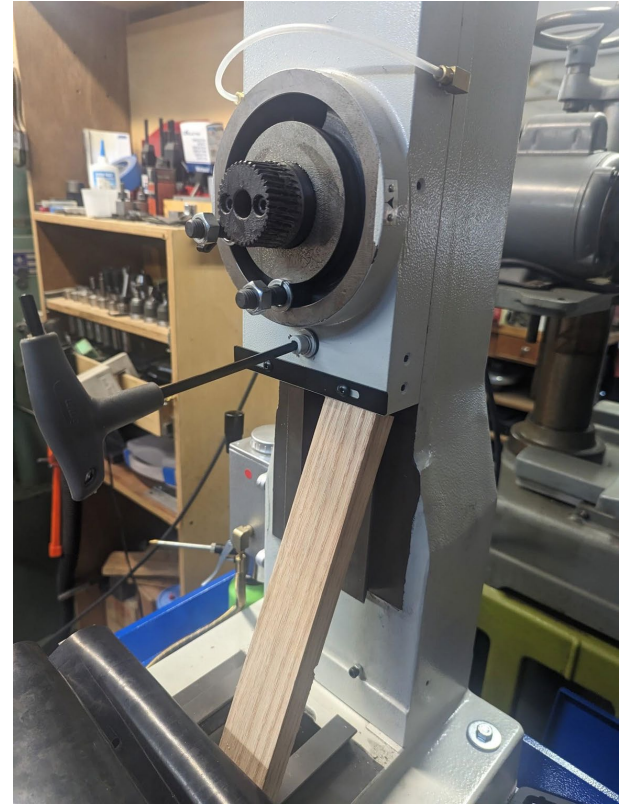
## Remove the saddle (2)

- Remove the Y axis gib adjusting screw and the gib
- Slide the saddle forward to extend the screw out of the base
- Remove the screw that holds the Y axis nut.
- Reaching through the base casting slot grasp the screw and drop it out of the base. The nut will remain on the screw.



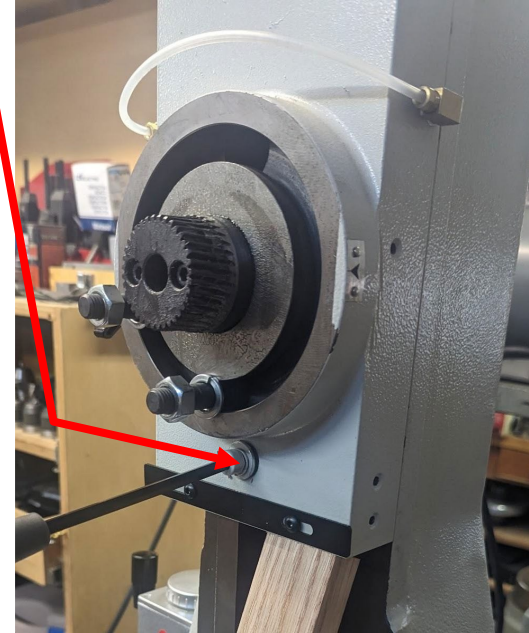
# Remove the Z axis screw

- Block the head or its mount if you removed the head.
- Remove the blank cover at the top of the column.



## Remove Z axis screw (2)

- Remove the nut at the top of the Z axis screw
- Remove the screw that holds the Z axis nut
- Reach in the slot in the column casting, grasp the screw and push it back to pull the nut away from the slide.



# Remove the Z axis screw

- Use a punch or rod to tap the Z axis screw out of the bevel gear. Use caution to catch the gear so it doesn't fall to the bottom of the column.
- Remove 4 screws to release the bevel gear assembly on the side of the column.
- Pull the gear assembly out of the side of column casting.
- Pull the z axis screw out the top of the column



## Part 2- Reassembly of the mill

With all the lead screws removed we start replacing them with the ballscrews.

The ballscrews come with the nut on it in about the center of the screw.

**Use extreme caution to ensure a nut does not get to the end of the screw.**

**If the balls are released from the nut it is essentially destroyed.**

*Green slides are background information*

# Clean and oil

As you reassemble the mill carefully clean all the sliding surfaces.

Wipe on a thin film of Way Oil to all the sliding surfaces, including the gib strip.

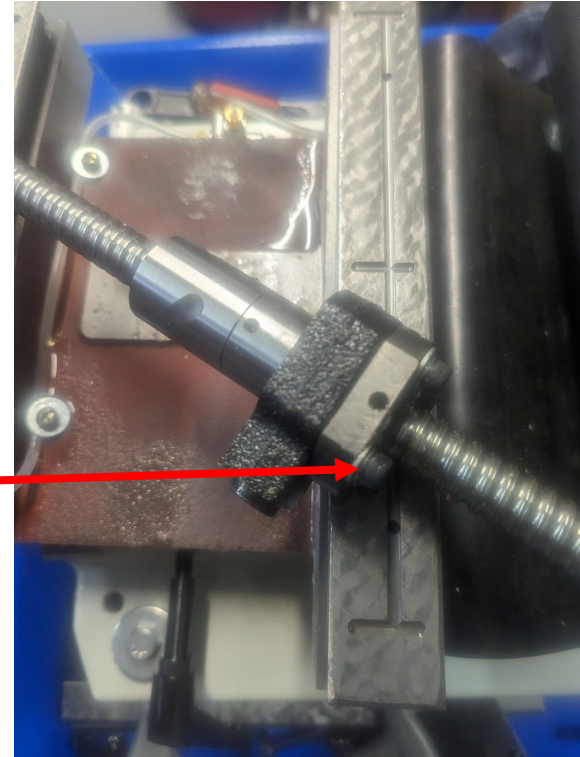
Keep the ballscrew clean. It is pre-oiled by the manufacturer and wrapped in plastic.

*Green slides are background information*



# Installing Y axis ballscrew

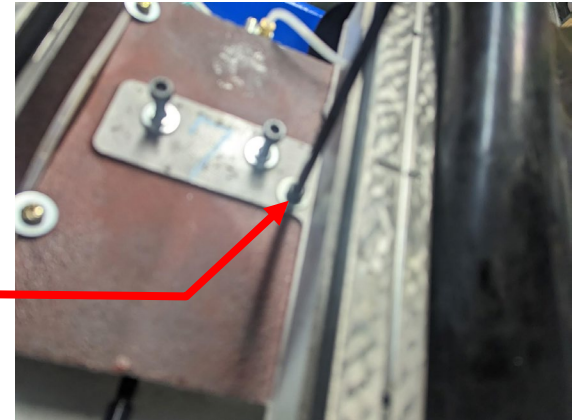
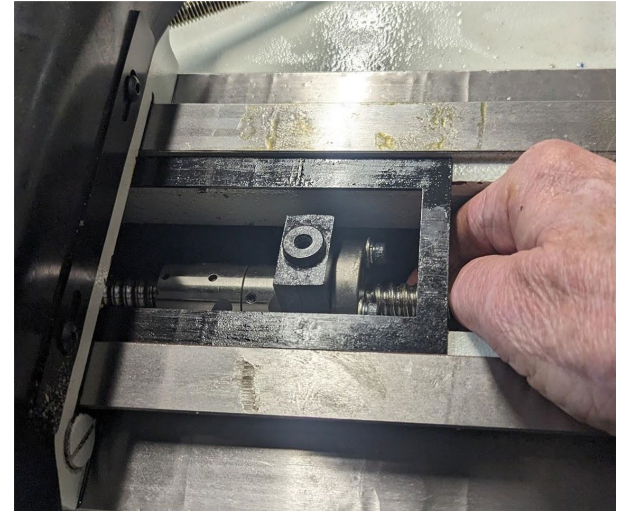
- The saddle should be in place on the base slides.
- The Y screw is the shortest.
- The Y nut casting is the shortest.
- Slide the ballnut through the Y axis casting and secure it with four M5 x25 screws, washers and lock washers.





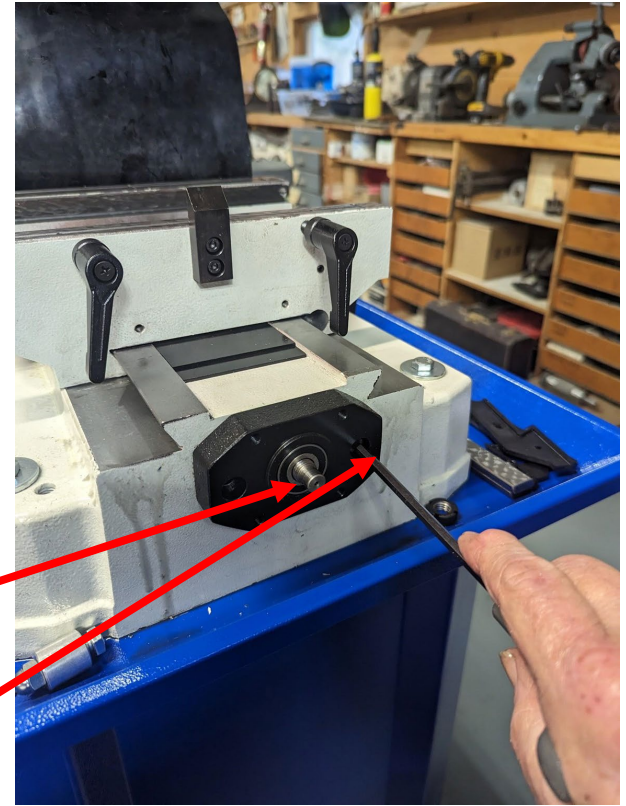
## Installing Y axis ballscrew (2)

- Slide the ballscrew assembly under the saddle with the threaded end toward the front of the mill.
- Be sure the sliding dust cover is in place and the nut goes through the opening.
- Extend the end of the screw through the hole in the front.
- Hold the nut mount up and slide it into the hole in the saddle casting.
- Fix it with the M6-1x25 bolt down through the saddle.



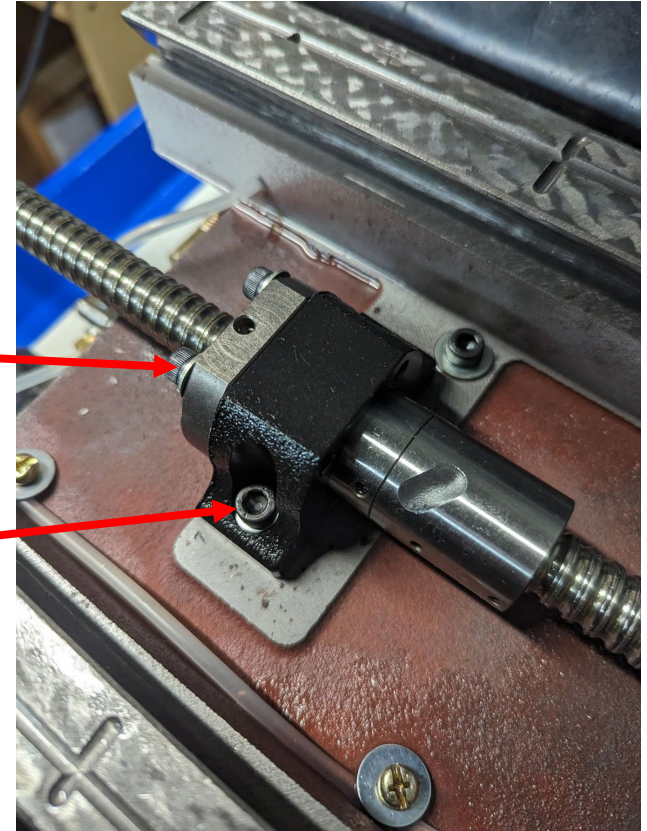
## Installing Y axis ballscrew (3)

- Place two 7201 ball bearings into the Y axis bearing casting
- **Note the bearings must be placed with the part numbers facing together**
- Slip the bearing casting over the end of the ballscrew.
- Apply the locknut to the end of the shaft and tighten fully. It may be necessary to hold the ballscrew with a plier. Hold it at the extreme end where the nut will not travel, and use something to provide a cushion for the jaws of the pliers.
- Bolt the casting to the front of the base.




# Installing the X axis ballscrew

- Slip the ballnut into its casting and fix with four M5x25 screws, washers and lock washers.
- The threaded end should be to the left side when facing the machine.
- Place the screw on the saddle. Fix with two M6-1.0x20 screws.



## Installing the X axis ballscrew (2)

- Place two 7201 ball bearings in the Xbearing casting. Note the numbers on the bearings must face each other.
- Slip the bearings onto the left end of the X ballscrew. 
- Place a locknut on the end of the ballscrew and tighten it fully.
- Clean the table sliding surfaces and rub on a thin film of Way oil.



## Installing the X axis ballscrew (3)

- Carefully align the dovetails and slide the table onto the saddle.
- Wipe Way oil on the gib strip and slide it into place.  
Note one end is thinner, it goes into the slot first.
- Replace the gib adjusting screw and tighten it down to the gib.
- Check that the table slides without binding or wobble.
- Hold the X axis bearing up and slide the table to it.
- Fix the bearing block to the table with two M6-1.0x16 screws.



# Installing the Z axis ballscrew

- Slide the Z axis ball nut into the bearing casting.
- Fix it to the casting with 4 m5-1x25 screws washers and lock washers.
- Slip the ballscrew into the top of the column casting.
- Align the nut castings with the hole in the head slide.
- Fix it with one M8 x35 screw.



# Stepper Motors

Each axis will be driven by a stepper motor.

A stepper motor does not run continuously like a normal motor, It only makes a small step each time it is pulsed.

An electronic driver box is needed to send the proper pulses to the motor.

Simple steppers are 'Open Loop', that is, there is no feedback from the motor. A step is requested but the controller does not know if the movement was complete.

If some mechanical overload occurred the motor will 'miss steps'

We are using 'closed loop' steppers. They have an encoder on the shaft so the electronics can tell if the step was actually made.

If an overload occurs an error signal will be sent back to the computer.

*Green slides are background information*

## Motors (2)

- Stepper motors make 200 steps for one revolution.
- Drivers can be designed to divide steps into 'micro steps' for smoother operation.
- Drivers have 'dip switches' to set the number of micro steps.
- We will use 8 micro steps on X and Y and 16 micro steps on Z.

*Green slides are background information*



## Motors (3)

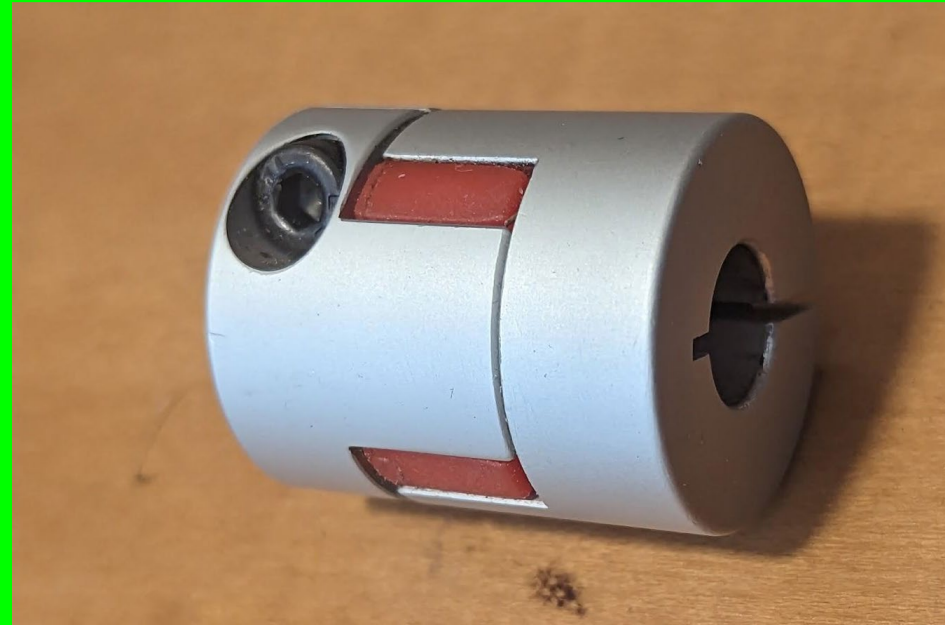
- Stepper motors are offered in many sizes, based on the torque it can produce.
- We are using motors on X and Y that produce a torque of 439 oz-in.
- On Z our motor is 1128 oz-in.
- Motor sizes are standardized by NEMA.
- We are using NEMA 23 on X and Y and NEMA 34 on Z

*In general, more torque means a motor can push(accelerate) a load faster.*

## Motors (4)

Motors must be connected to the ballscrews with a coupling

Couplings are designed to tolerate small misalignment of the axes, but still not have any backlash or slip.



# End Restraint

The table is moved by the ballnut fixed to it.

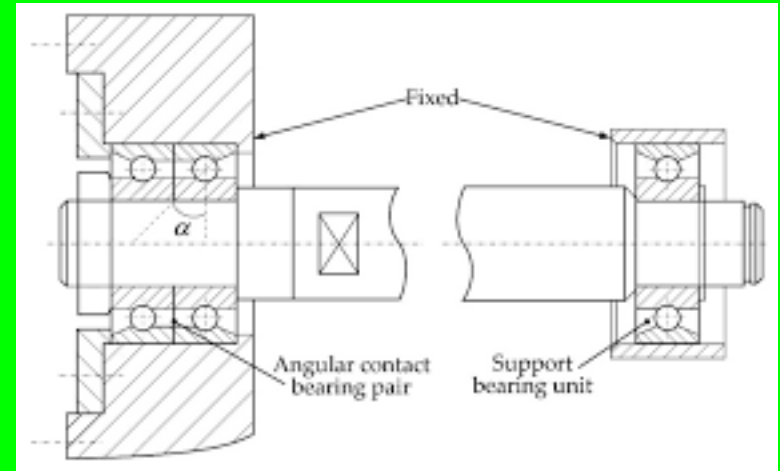
One end of the ballscrew must be restrained from linear movement

But the ballscrew must freely rotate.

This is accomplished by a pair of angular contact ball bearings

They must be mounted back-to-back so there is linear restraint in each direction.

The nut must be tight enough to prevent end play but still allow rotation.

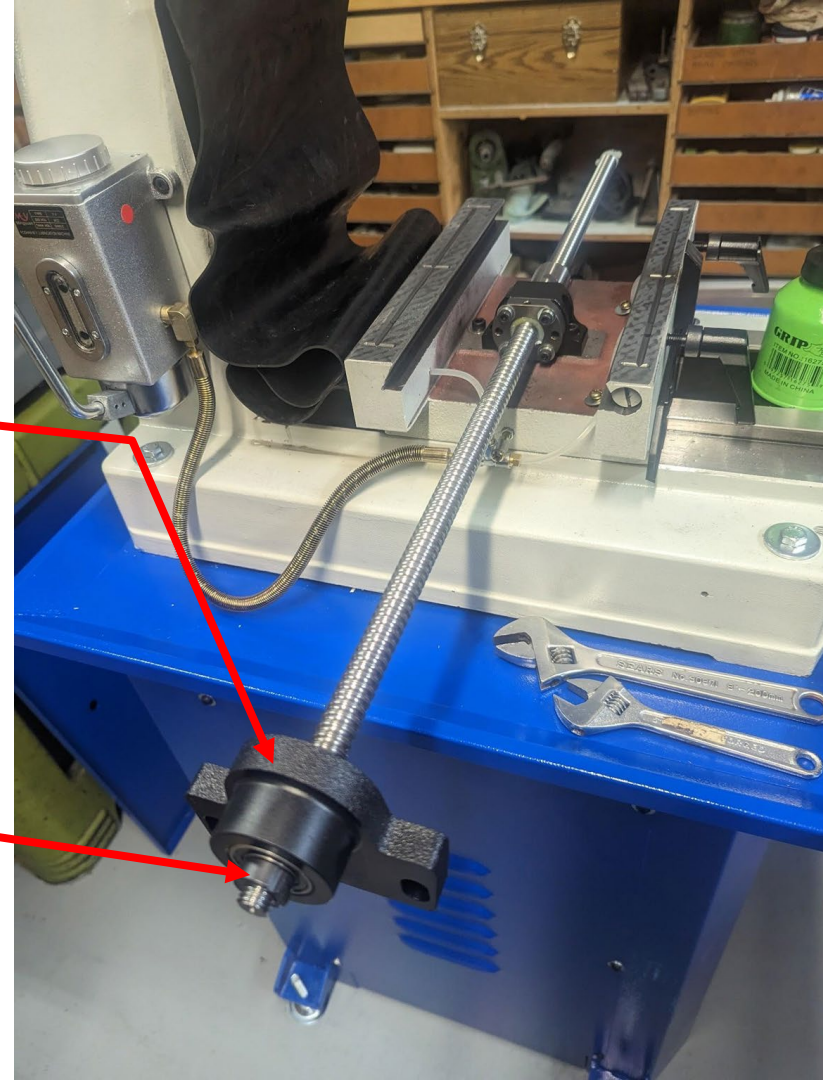


# Installing the X axis motor

The X axis has a bearing mount casting at the left end of the table.

The casting contains two angular ball bearings back to back.

A locknut restrains the bearings and provides pre-load to them. The pre-load should be just enough to prevent end play. Too much pre-load will prematurely wear the bearings.



## Installing the X axis motor (2)

At the right end of the ball screw install a coupling.

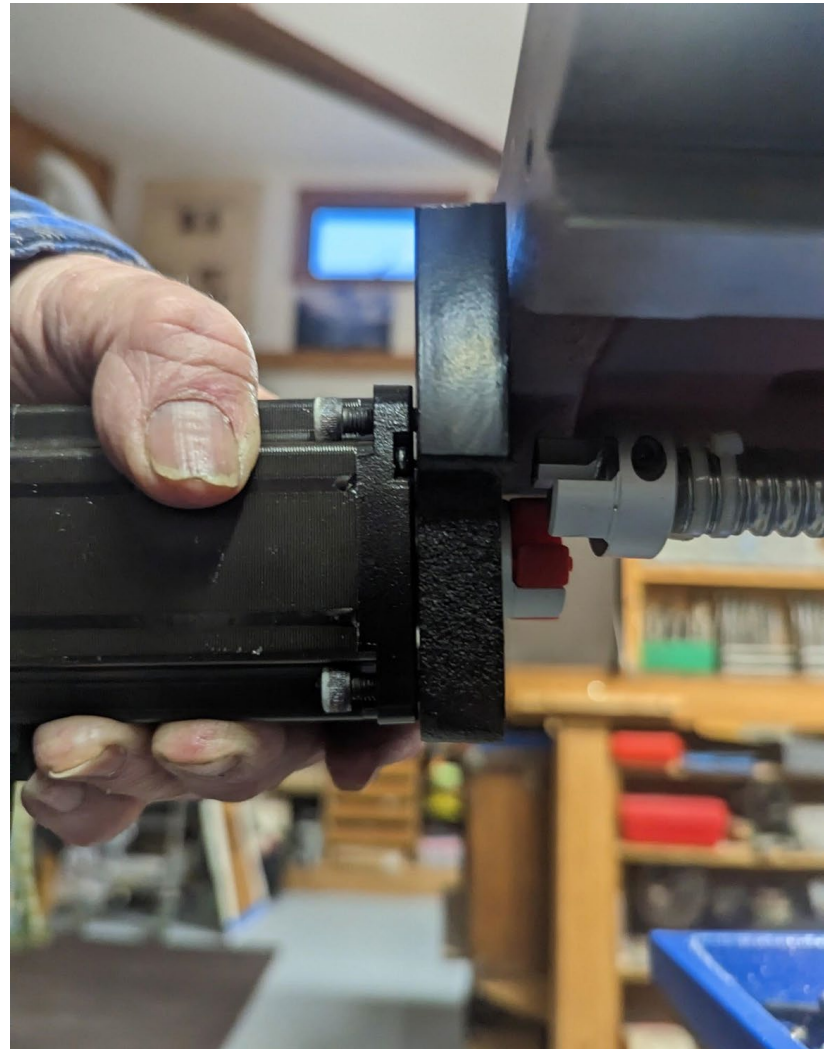
Align the dovetails and slide the table on.

Mount the casting to the table with 2 M5-1 screws

Slip the motor shaft into the coupling

Align the base of the motor with the casting

Bolt the motor on with 4 M5-1 screws.



# Installing the Y motor

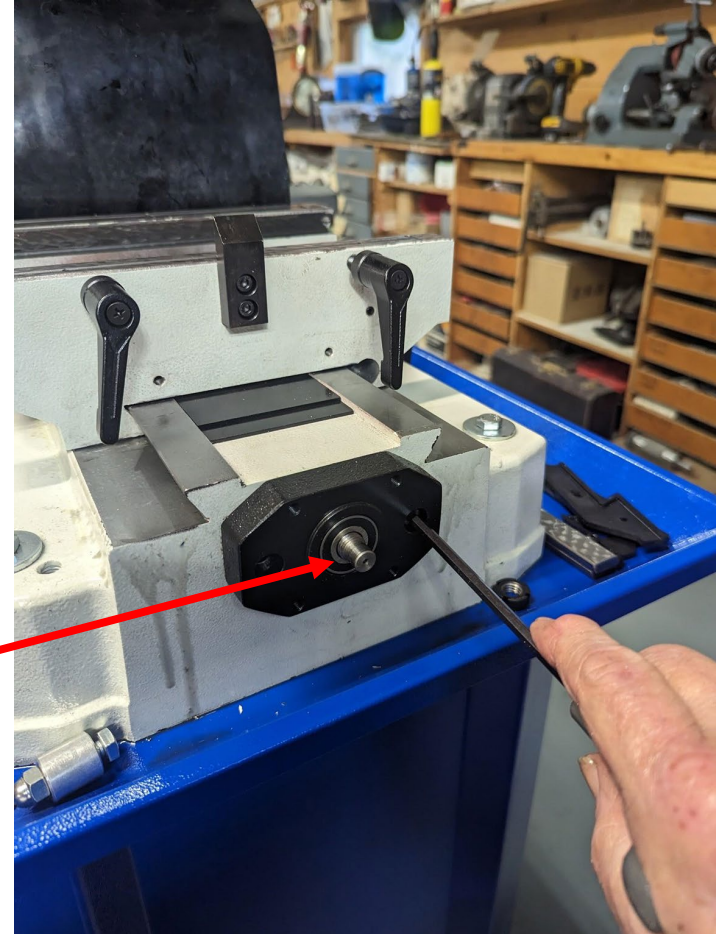
The Y ball screw has a bearing and motor mount casting on the front of the machine.

Place two ball bearings into the casting so that the part numbers face each other..

Slide the casting onto the ball screw.

Fix the casting to the front of the base casting.

Place the locknut on the screw end and tighten it to pre-load the bearings.





## Installing the Y motor (2)

Place a coupling on the shaft.

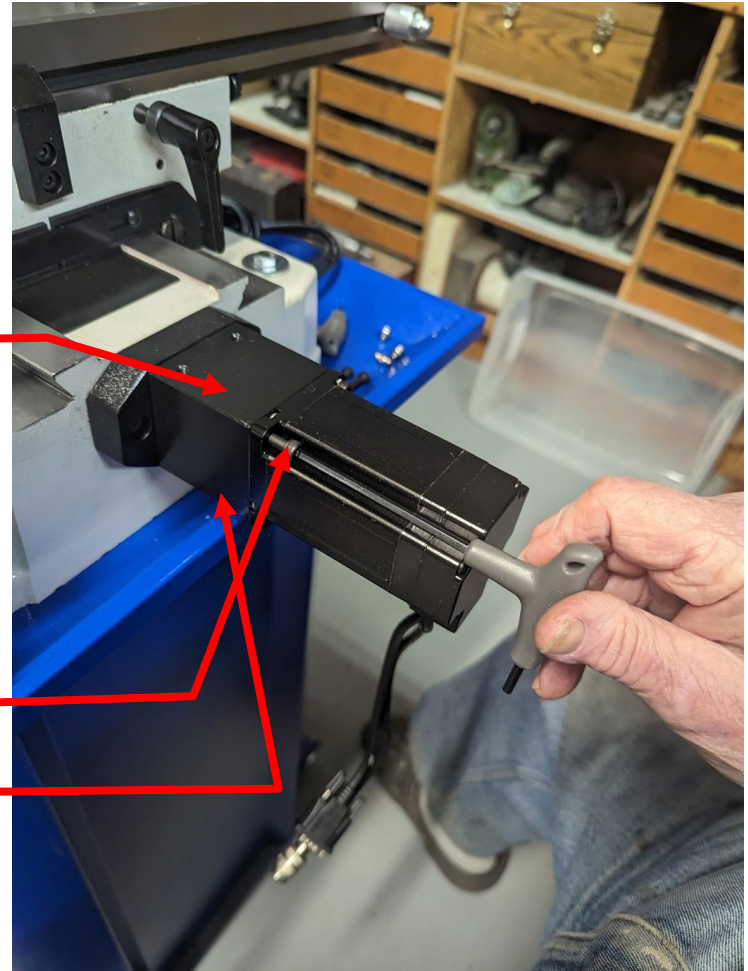
The Y axis motor casting surrounds the coupling on 3 sides.

Hold the casting with the slot down.

Slide the motor shaft through the casting and into the coupling.

Mount the motor with 4 M5-1 bolts through the motor flange and the casting.

Tighten the coupling through the slot.



# Installing the Z axis motor

Slide the head mount up until the ball screw end is at the top of the column.

Place two ball bearings into the Z mount casting.

Slide the bearings onto the shaft end.

Place the lock nut on the end of the screw and tighten it to pre-load the bearings.

Adjust the head mount until the motor mount casting is on the top of the column.





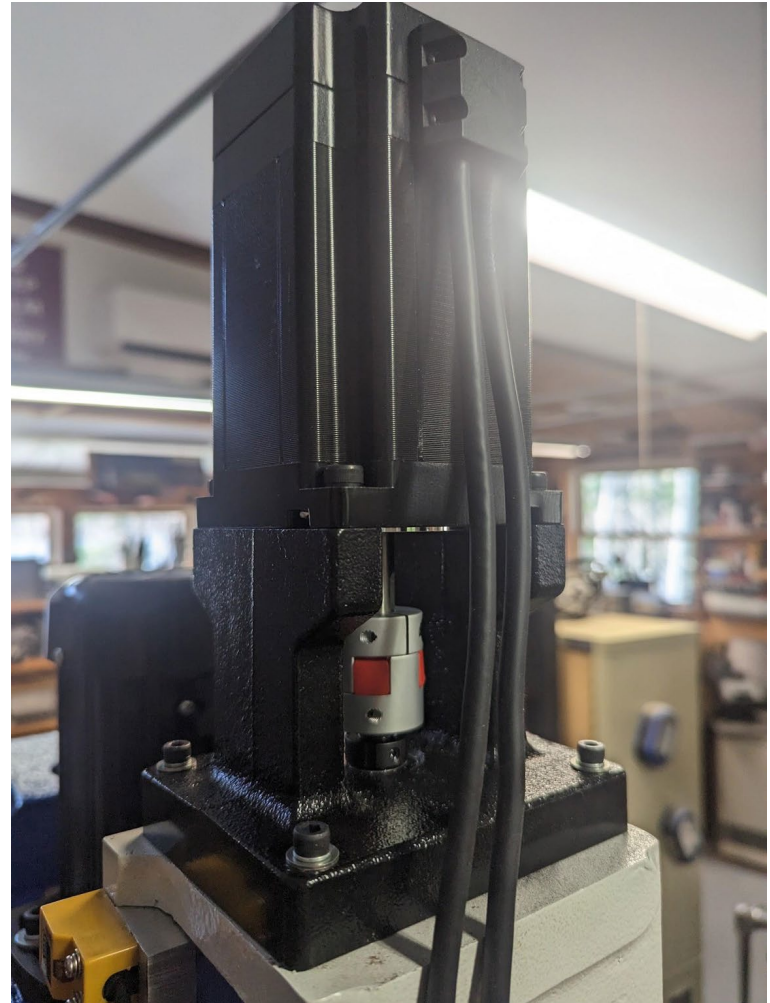
## Installing the Z axis motor (2)

Place a coupling on the end of the screw.

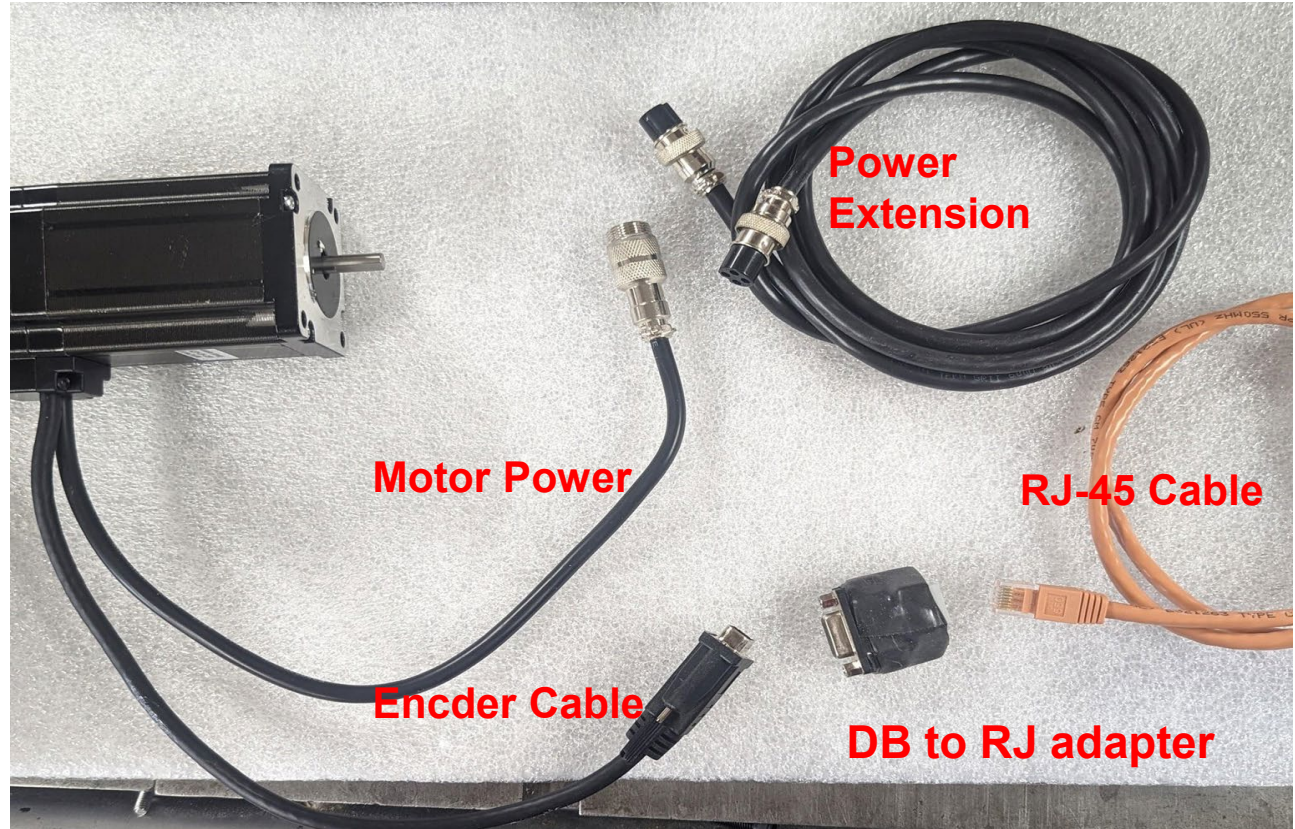
Place the Z motor on top of the casting and slip the shaft into the coupling.

Tighten the coupling.

Flx the motor with 4 M5-1 screws.



# Motor Cables



# Motor Cables

Connect a motor extension cable to each motor

Connect the extension cable to the control box

Connect a DB to RJ adapter to each motor encoder cable. Be sure to tighten the strain relief screws.

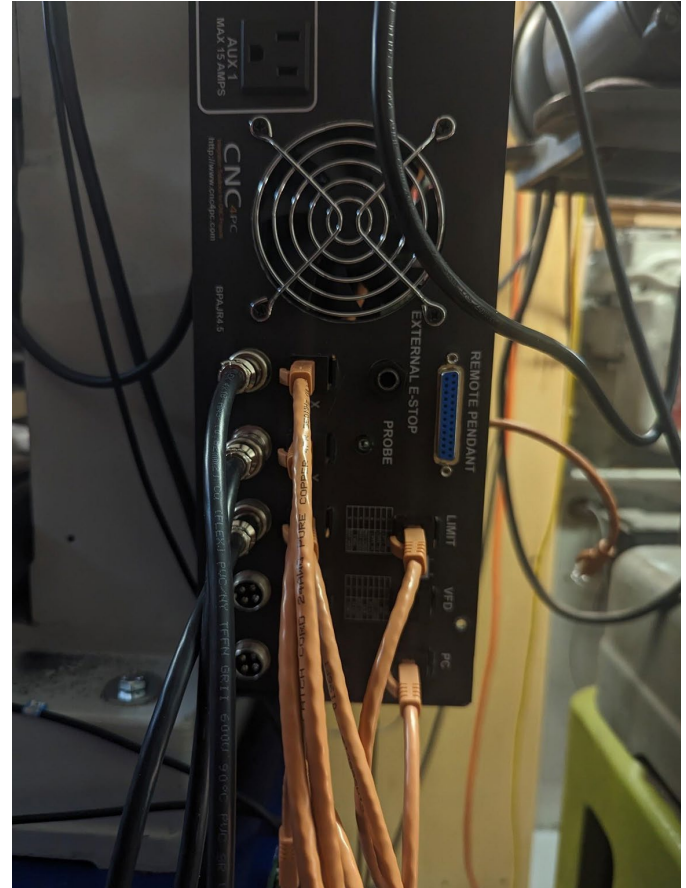
Connect an RJ45 cable to each adapter

Connect the RJ encoder cable to the control box.

# Arrange the motor cables neatly.

Be sure the X axis cable has enough slack to allow its full motion.

Use wire ties or cable clamps to tie cables neatly along the machine.





# Switches

Control systems often need to know the position of mechanical components.

Switches can Detect end points or reference points.

Proximity (“Prox”) switches are active magnetic devices that respond to ferrous(iron).

We will use Prox switches in this conversion.



*Green slides are background information*

# Home Switches

When the control software is started it has no way of knowing the tool location relative to the table.

Each axis is equipped with a proximity switch at the extreme home (Positive) end of its travel. (***remember we refer to the motion of the tool, not the table***)

A Prox switch can detect when a ferrous metal comes close to it. No actual contact is needed.

A 'Reference' operation must be done each time the software is started. This moves the axis to its positive limit of travel. This is called "Homing the Machine".

*Green slides are background information*

# Limit Switches

Operator error or program errors may drive an axis past its maximum limit of travel.

Such a move could do damage to the machine.

To prevent damage a Limit Switch is installed at the ends of travel.

The limit switch will signal to the software this end condition.

On the positive end of travel we can use the same switch as the Home switch.

A switch at Z negative is not used because any tool will hit before the limit can be reached

*Green slides are background information*



# Switch Cabling.

All five limit/home switches are supplied connected to one block.

This block has an RJ45 jack for an extension cable to the control box.

Be sure to uncoil all the switches before attaching them to the machine to remove twists from the cable.

*Green slides are background information*

# X axis home and limit switches.

The Switches are mounted at the ends of the saddle casting.

Hold the switch in position aligned with the upper edge of the saddle and it's right or left edge.

Mark the switch mounting holes. Center punch each hole location.

Drill a hole for an M3-.05 tap, tap each hole.

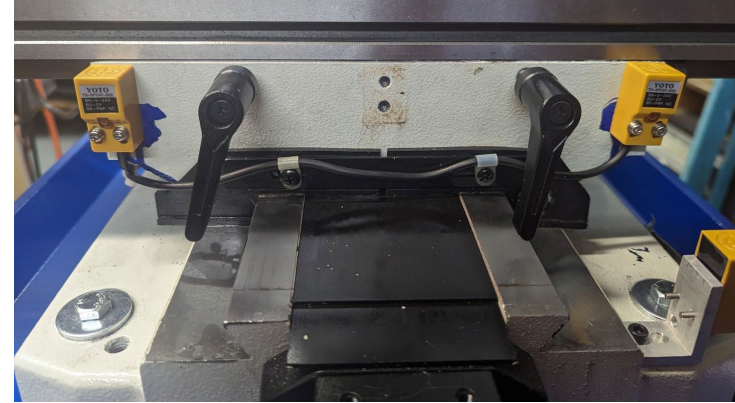


## X axis home and limit switches. (2)

Mount the switch to the casting with the M3-.5 screws provided with the switches.

Adjust the switch to be just under ( $1/16''$ ) the table edge.

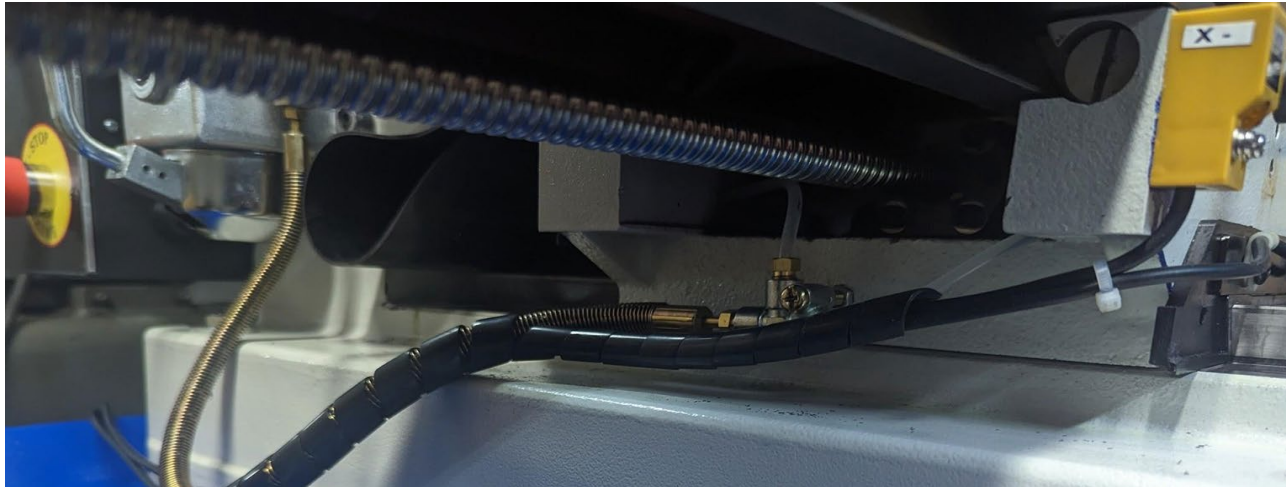
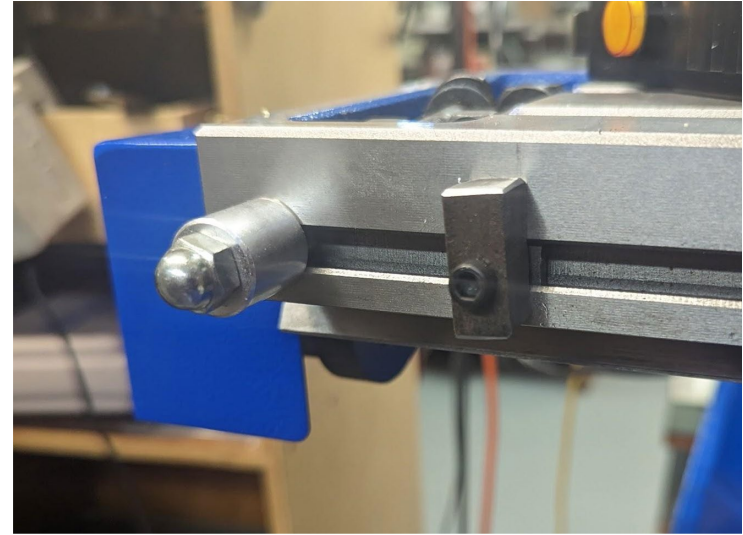
Remove the table stops and the center fixed stop.



## X axis home and limit switches (3)

Fix the steel blocks to the table front slot at each end.

Route the switch leads under the table and wrap them to the oil line.



# Y axis switches

The Y axis switches are mounted to the base casting on the left side under the table.

An aluminum angle bracket is provided for the mount.

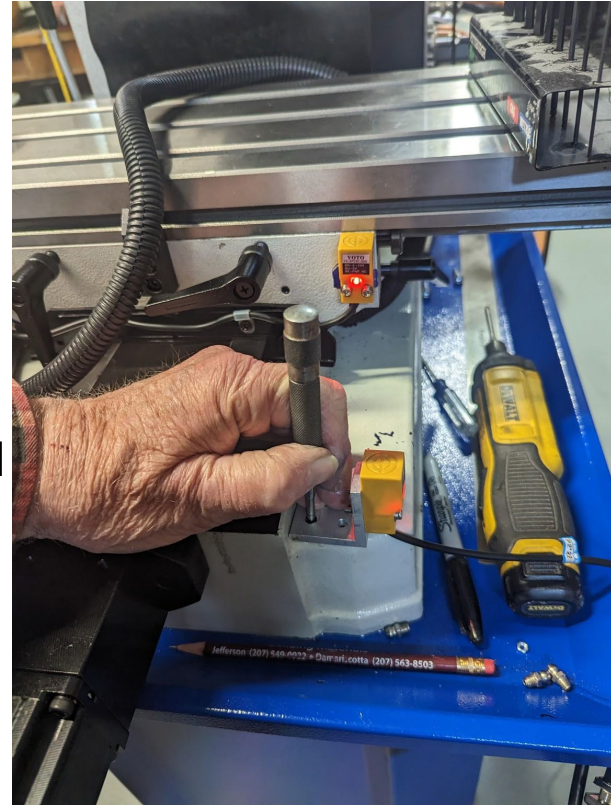
## Y axis switches (2)

Position the bracket at the end of travel with its back edge against the base casting raised area.

Drill a hole and tap it M5-1

Mount the Y+ switch to the angle bracket and the bracket to the base.

Check to see that the switch is adjusted to clear the saddle casting by about 1/16 Inch





## Y axis switches (3)

The rear switch is mounted like the front.

Position it to align with the saddle closest to the column.





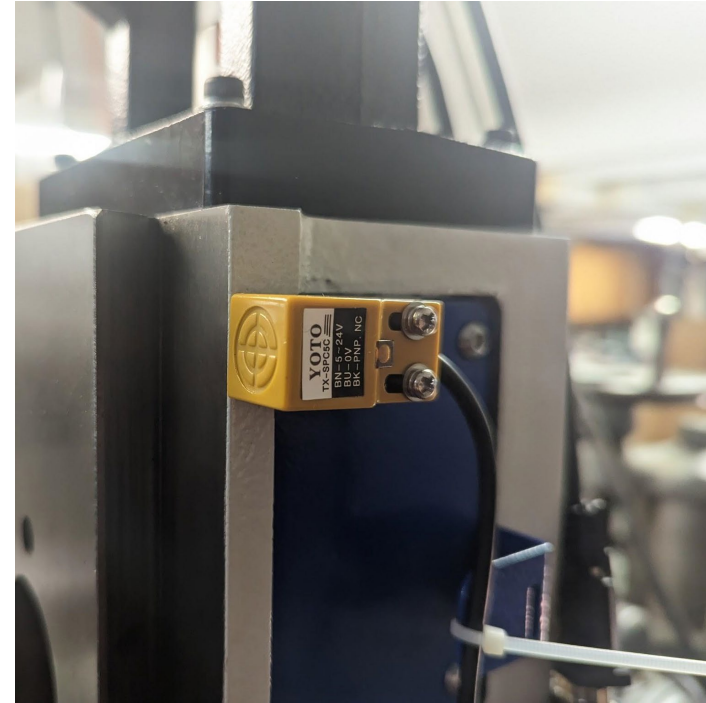
# Z axis switch

Z axis has only a single switch for Z home

We repurpose a screw that holds the cover plate from the removed Z axis crank.

An aluminum spacer block is held into the casting corner with one M5-1.0 screw.

The spacer block has tapped holes to hold the switch.

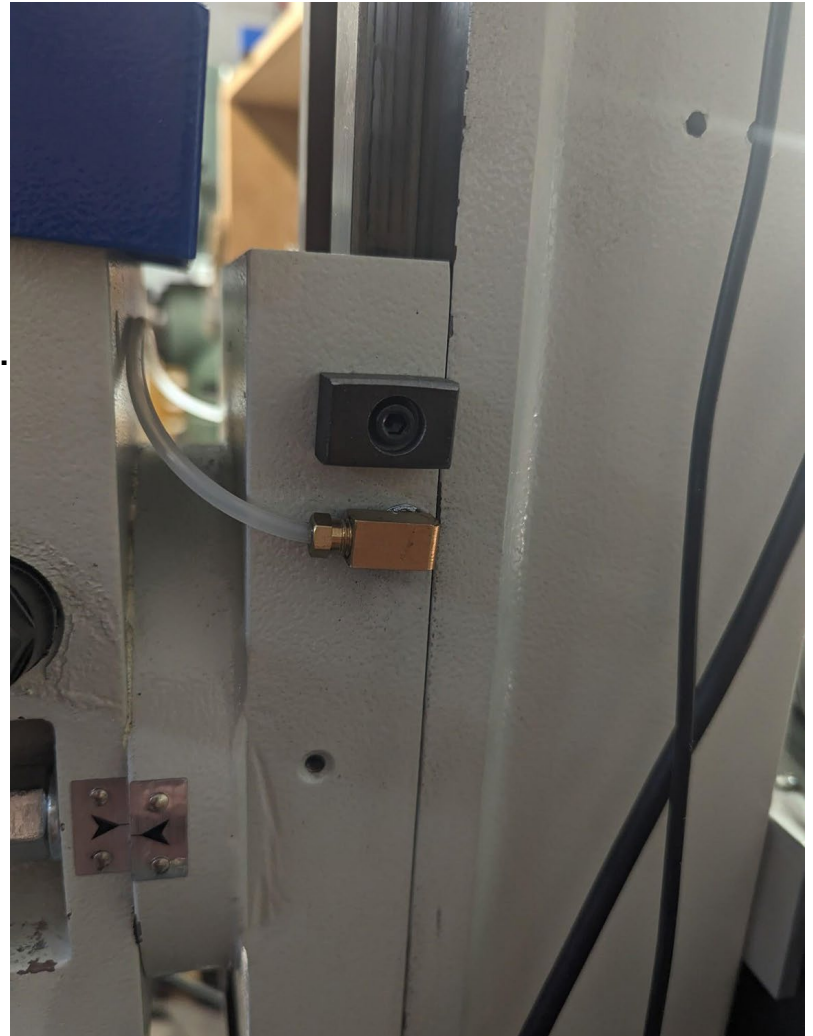


## Z axis switch (2)

Steel block is provided for the Z axis switch.

Locate it on the head just above the oil fitting.

Drill and tap a hole and mount the block.



# Spindle Control

The Spindle is powered by BLDC (Brushless DC) motor.

Motor driver can be controlled by CNC computer

Control requires Two relays, FORWARD and REVERSE

A 0-10Volt signal controls motor speed. This signal is generated by a PWM (Pulse Width Modulation) from the control.

*Green slides are background information*

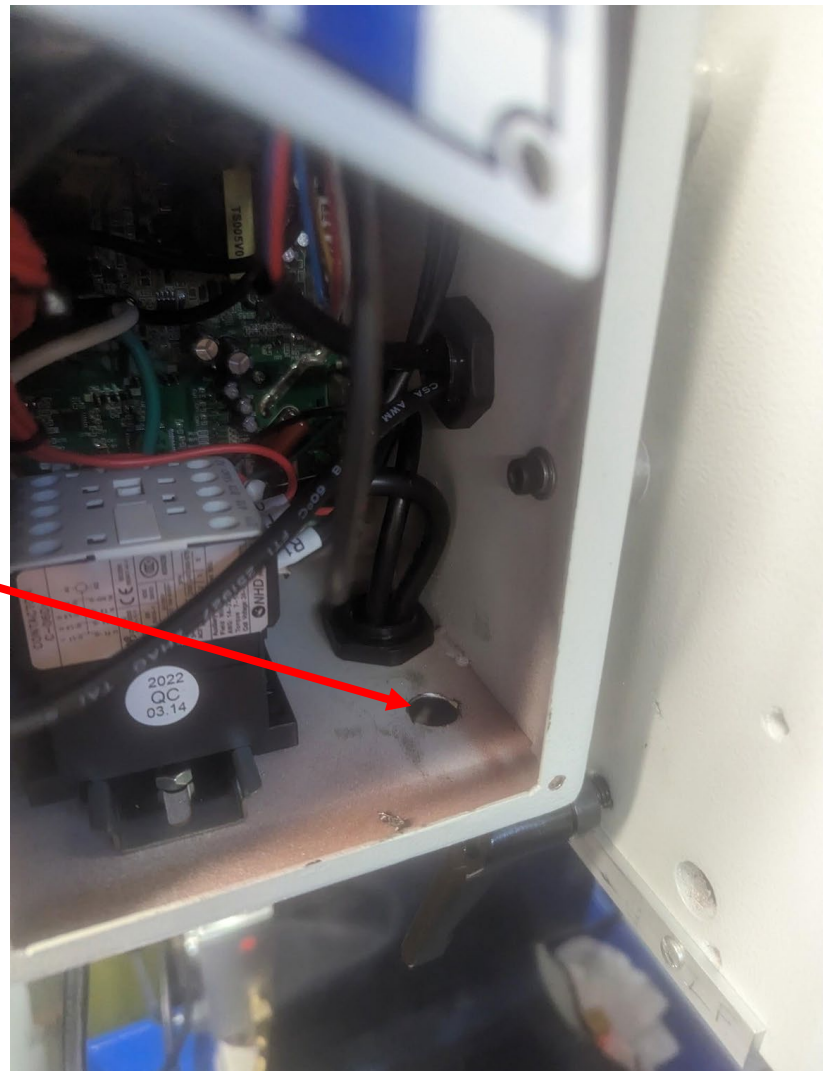
# Spindle Control

Remove front cover of Spindle control box

**CAUTION: Be sure to unplug the box.**

Drill  $\frac{1}{2}$ " hole in bottom of box

Use a step drill to make a neat hole.



## Spindle Control (2)

A cable is supplied with an RJ45 jack on one end and nothing on the other.

Insert end of wire through strain relief.

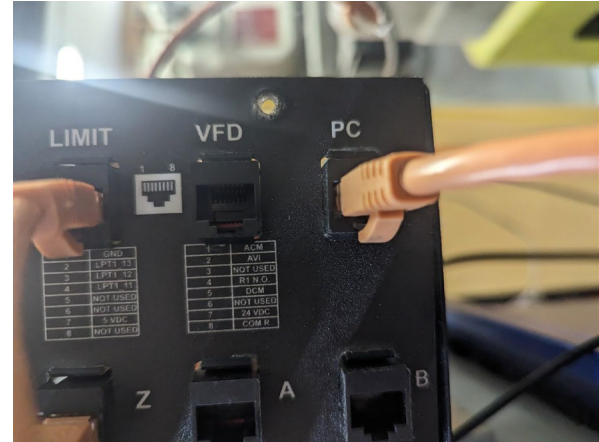
Tighten the nut to apply compression to the wire.

Insert strain relief into hole in box.

Place nut on to capture the wire.

Crimp ferrules onto wire ends.

Plug the RJ45 jack into the VFD jack on the back of the control box.

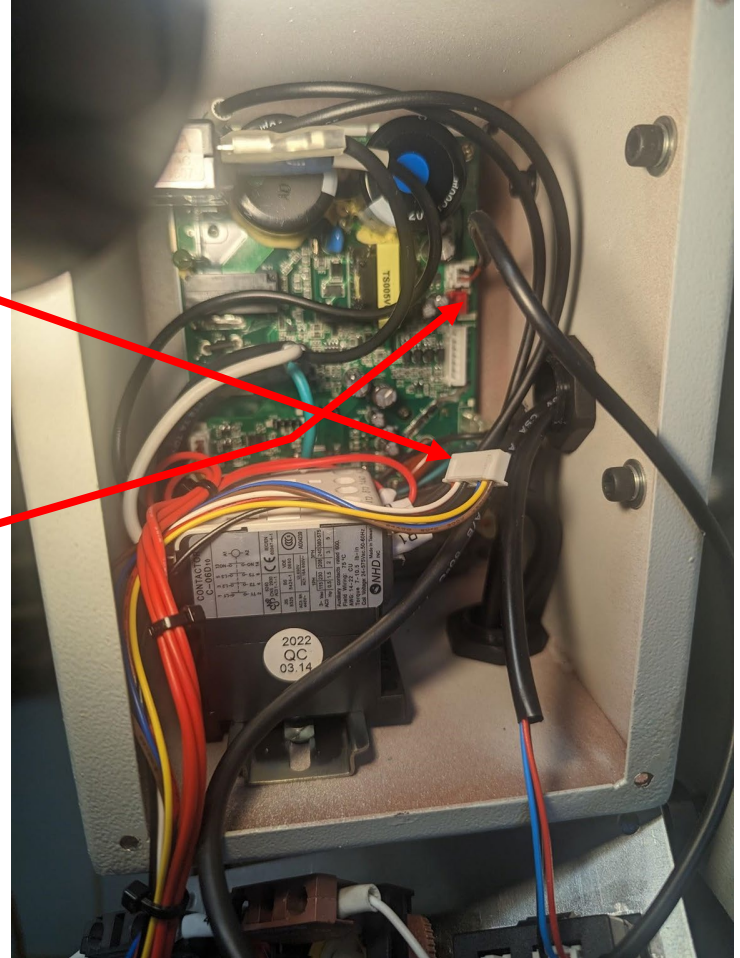


## Spindle Control (3)

Remove the 7 pin connector from the main control board

Replace the connector with the connector from the small speed control board.

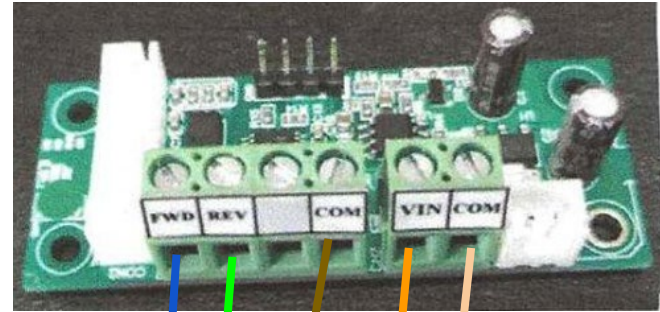
Plug in the two wire power connector from the speed control board.





# Spindle Control

Connect the 5 wires from the strain relief connector to the speed control board.



Forward-Blue

Reverse-Green

Common- Brown

Control Voltage Orange

Common Voltage - White\Orange



# Leftover parts

PM supplies sheet metal covers for the X and Y motors.

But these are made for open loop steppers.

Closed loop steppers are longer, so the covers don't fit.

The Mill will work fine without them.



# SOFTWARE

Mach4



# Mach4

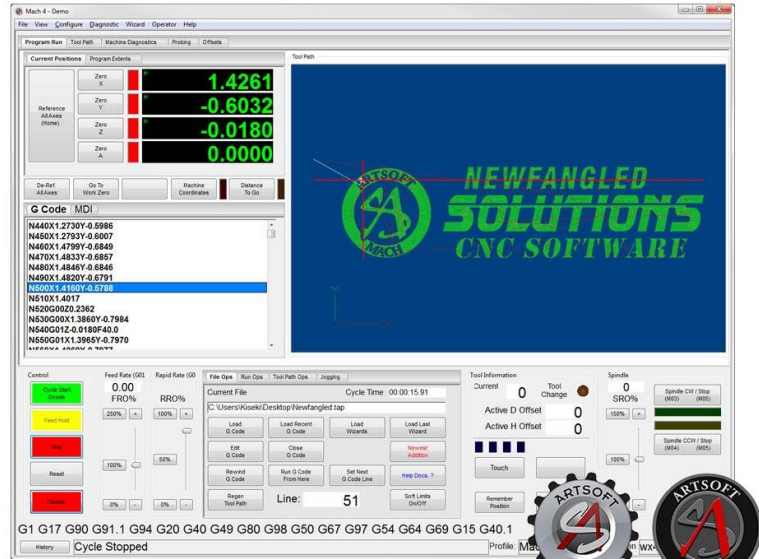
## Graphical interface to control machine

# Interpret G code

Mill, lathe, router, plasma cutter, laser cutter.

## Calculate trajectory of tool

## Communicate moves to motion control.

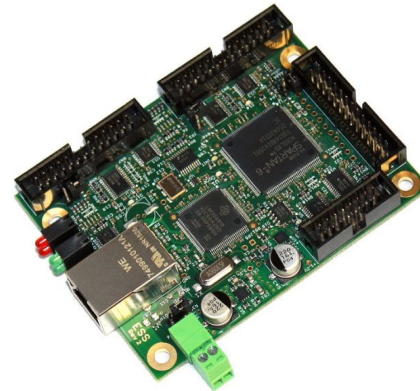


# Motion control

*Warp9 Tech Design, Inc.*

Ethernet Smoothstepper

Converts commands from Mach4  
into stepper motor pulses.



# Set up PC

Mach4 requires a PC running Windows 10 or 11. Use common windows setup, no extra software is needed, or desired, this PC should only be used as a machine control.

Install Mach4 from memory stick, Or download file from downloads tab at <https://machsupport.com>

Also requires a plugin from Warp9 tech on the memory stick or Download from <https://warp9td.com>

# Documents

Mach4 provides many manuals when installed

`C:\Mach4Hobby\Docs`

The ESS has many pages of on-line documentation

`https://Warp9td.com`

This document is a simplified guide to the installation.

If questions arise see the above sources.

# Mach4 Profile

A PC can be setup to run several different machines.

Each machine has a separate configuration appropriate to that machine.

The configuration is saved in a folder `C:\Mach4Hobby\Profiles`

When installing Mach4 you will be asked for a profile. Create a meaningful name.

In the sample screens here we used `MyMill` as profile name.

DO NOT use one of the system profile names, it will be overwritten if you upgrade the software.



# Optional profile

We have provided a profile suitable for the PM728.

We called it MyProfile.

A copy is on the memory stick.

Copy the file from the stick and put it in the profile folder.

`C:\Mach4Hobby\Profiles`

All of the following configuration steps are completed in this profile.

## Profile (2)

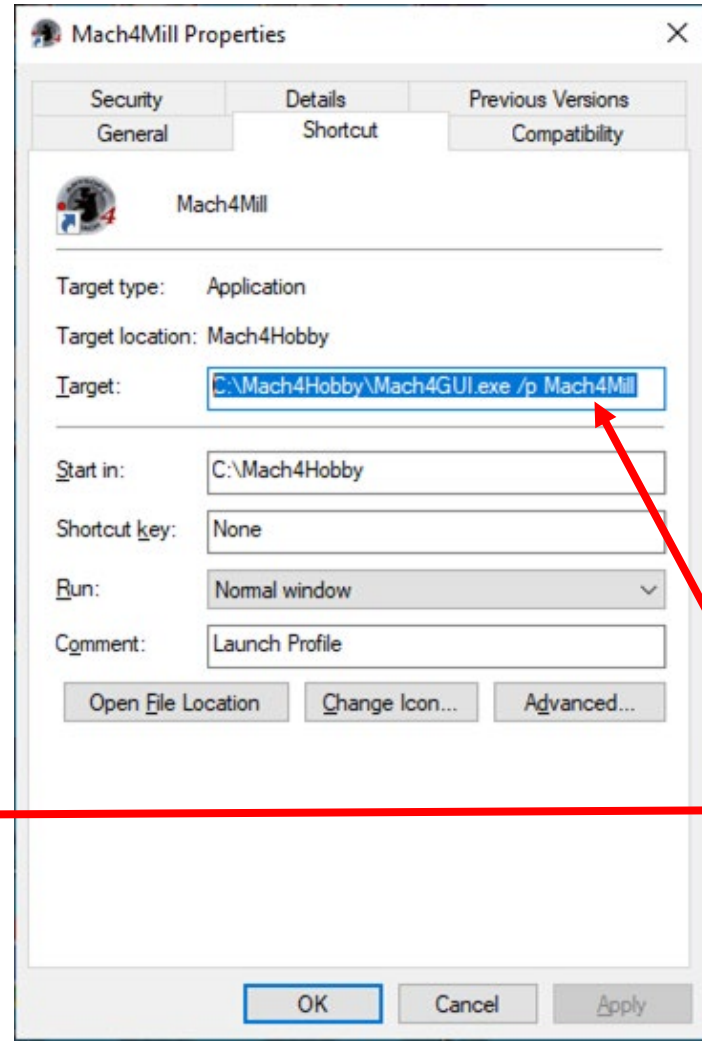
The Mach4 install will create some desktop icons.

Right click on the icon for Mill.

Select Properties

The Target line will have the start command for Mach4, followed by the profile name. Edit this to the name you have given your profile.

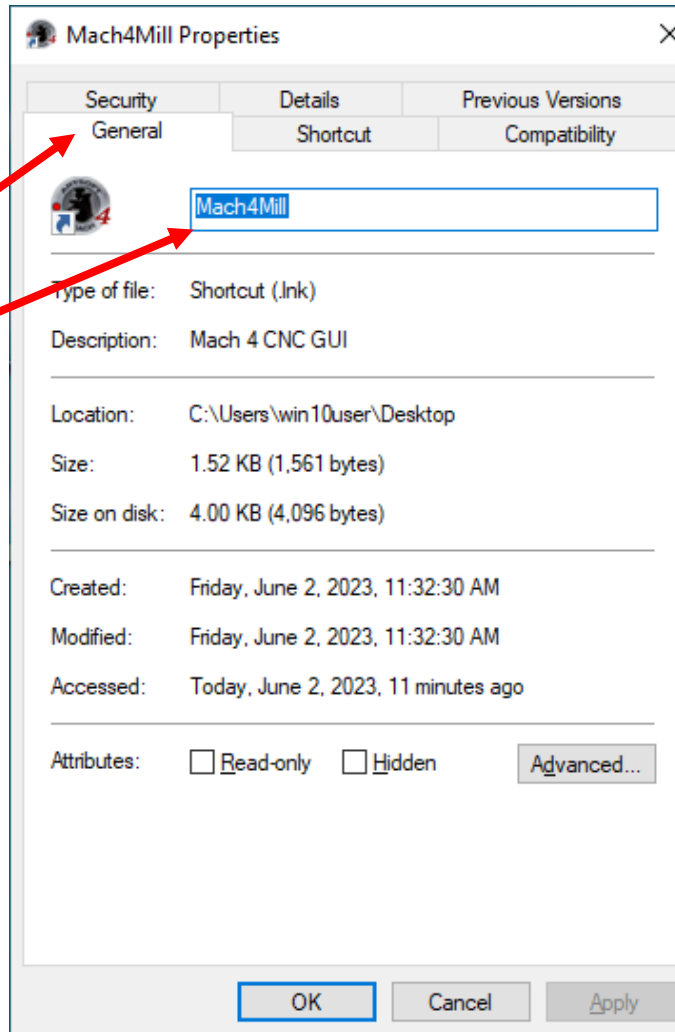
You can now start Mach4 with a double click



## Profile (3)

Change to the General tab

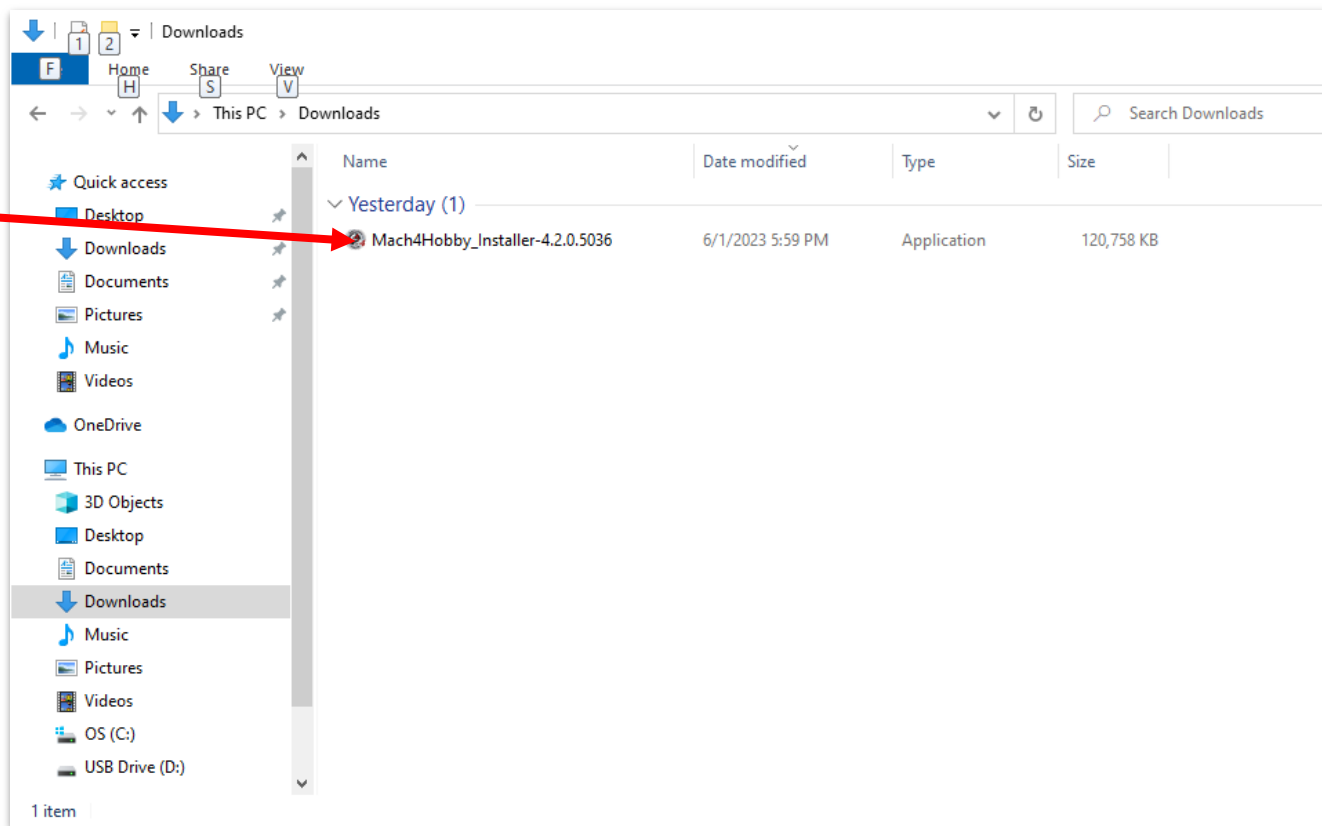
Replace the name with  
your profile name.



# Mach4 Install

Find the install file.

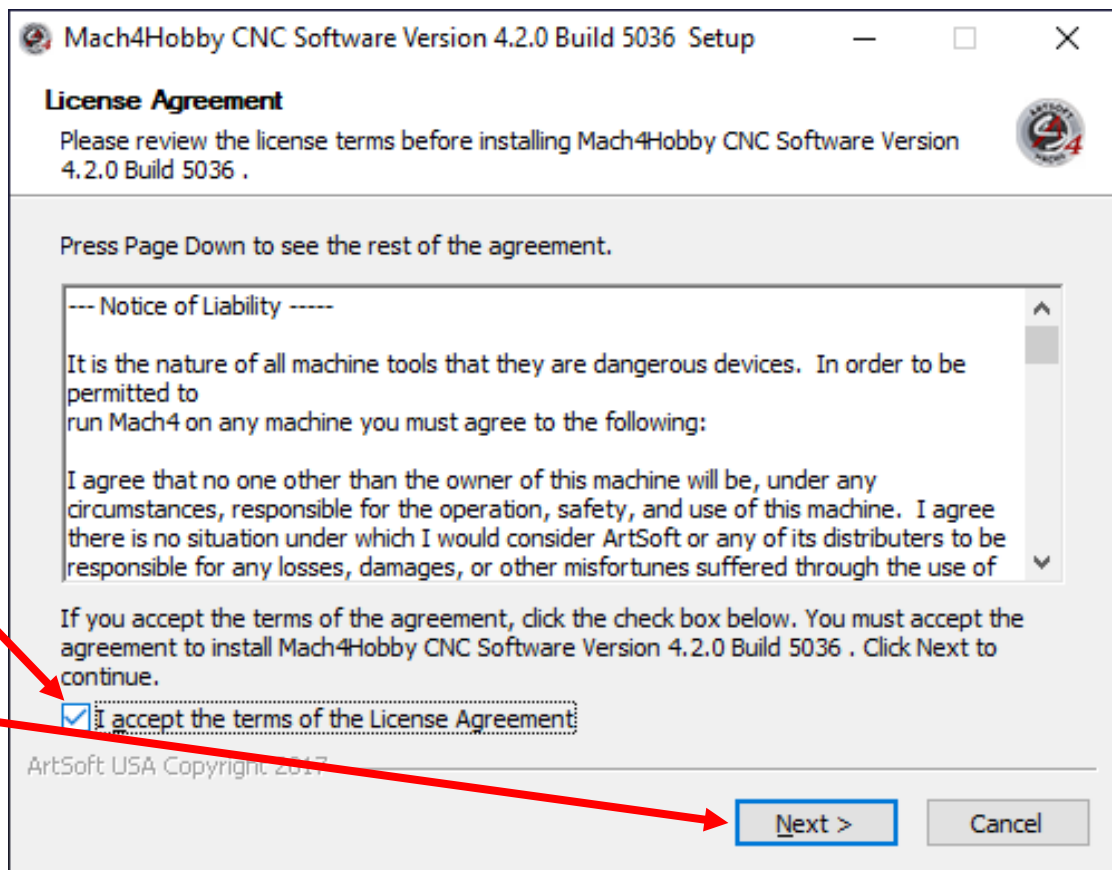
Double click it.



# Mach4 Install

Check to accept license terms

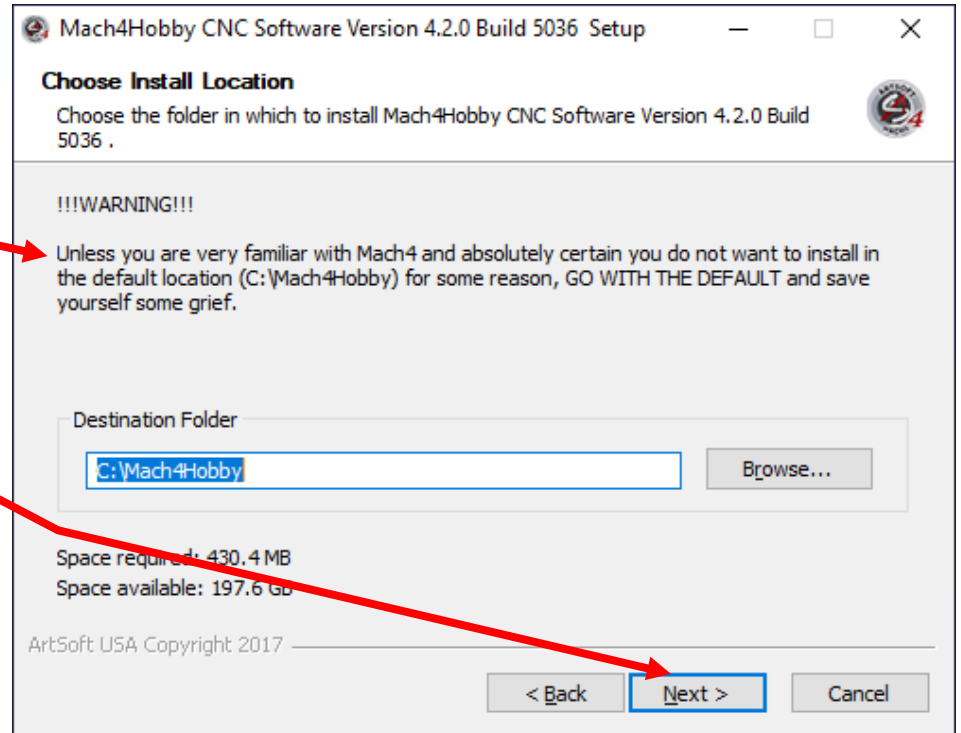
Click Next



# Mach4 Install

Observe the warning message!

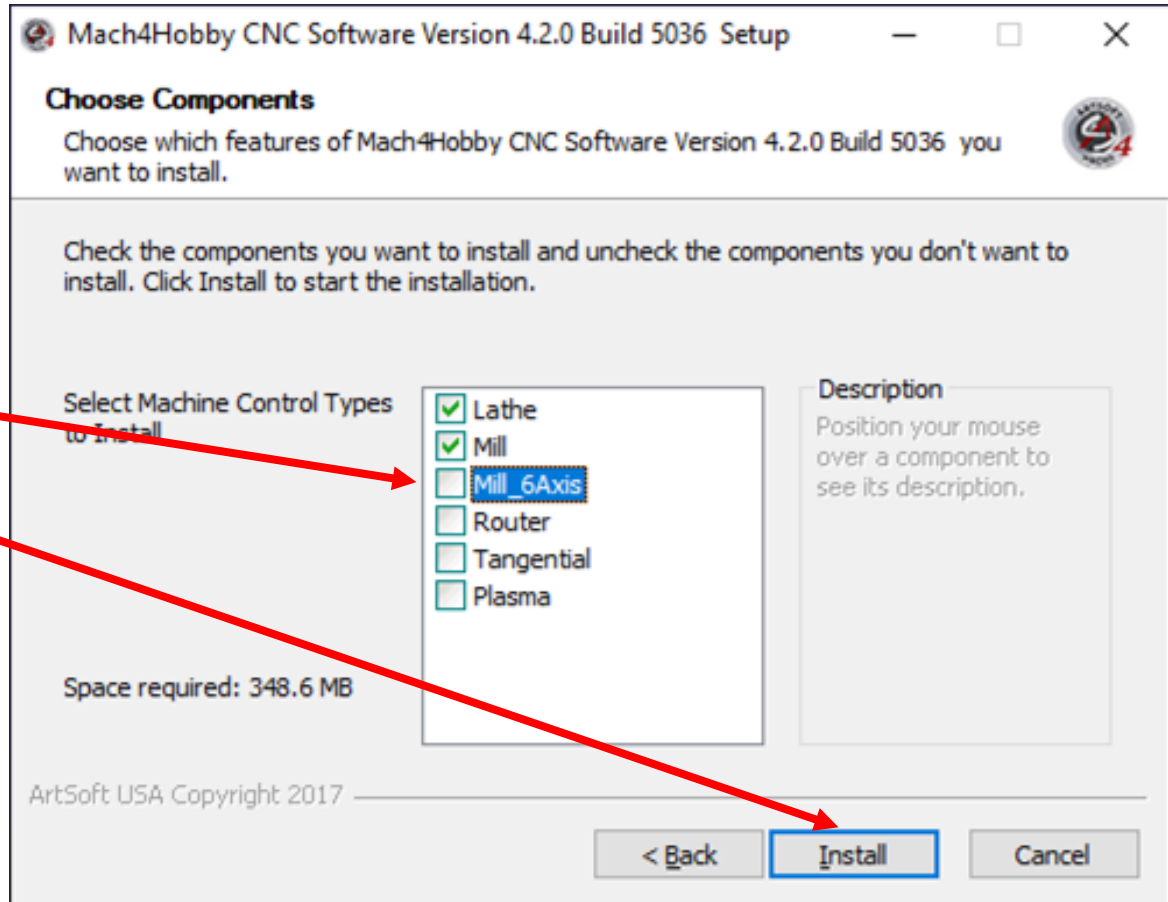
Click Next



# Mach4 Install

UnCheck type of machines you are not using.

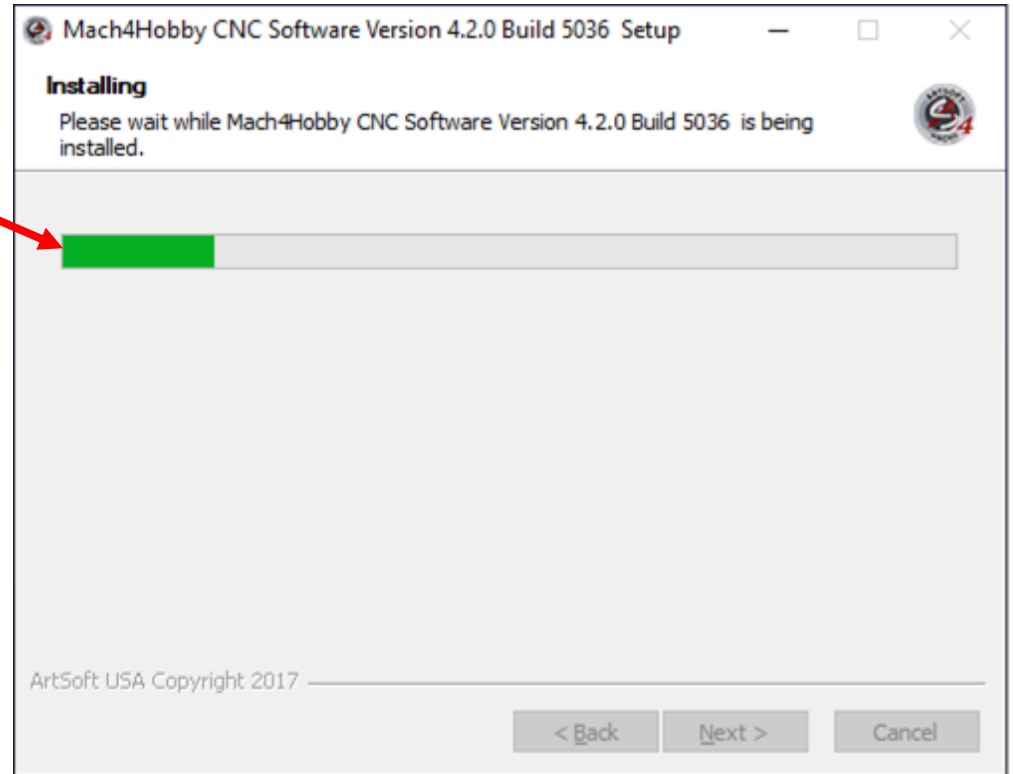
Click Install





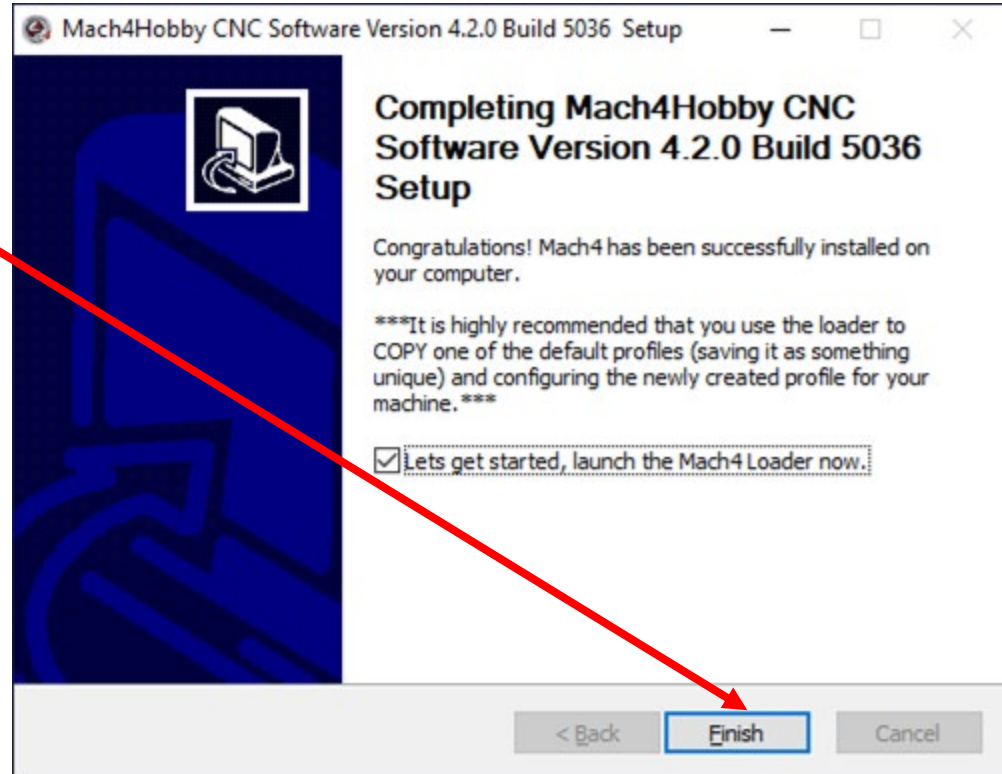
# Mach4 Install

Wait for progress bar



# Mach4 Install

Click Finish

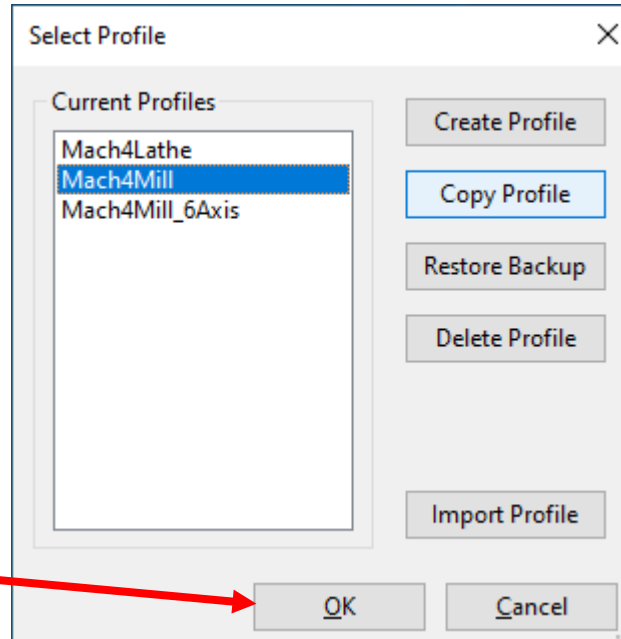


# Mach4 Install

Mach4 will start and show the profile select screen.

Select Your profile then Copy

Click OK



# Screen Set

Mach4 has a built in screen editor

You may use it to modify any part of a screen

You may add or remove buttons.

You may change colors or type fonts.

You may add controls.

Screens can be fully customized, but start with one of the pre-built screens

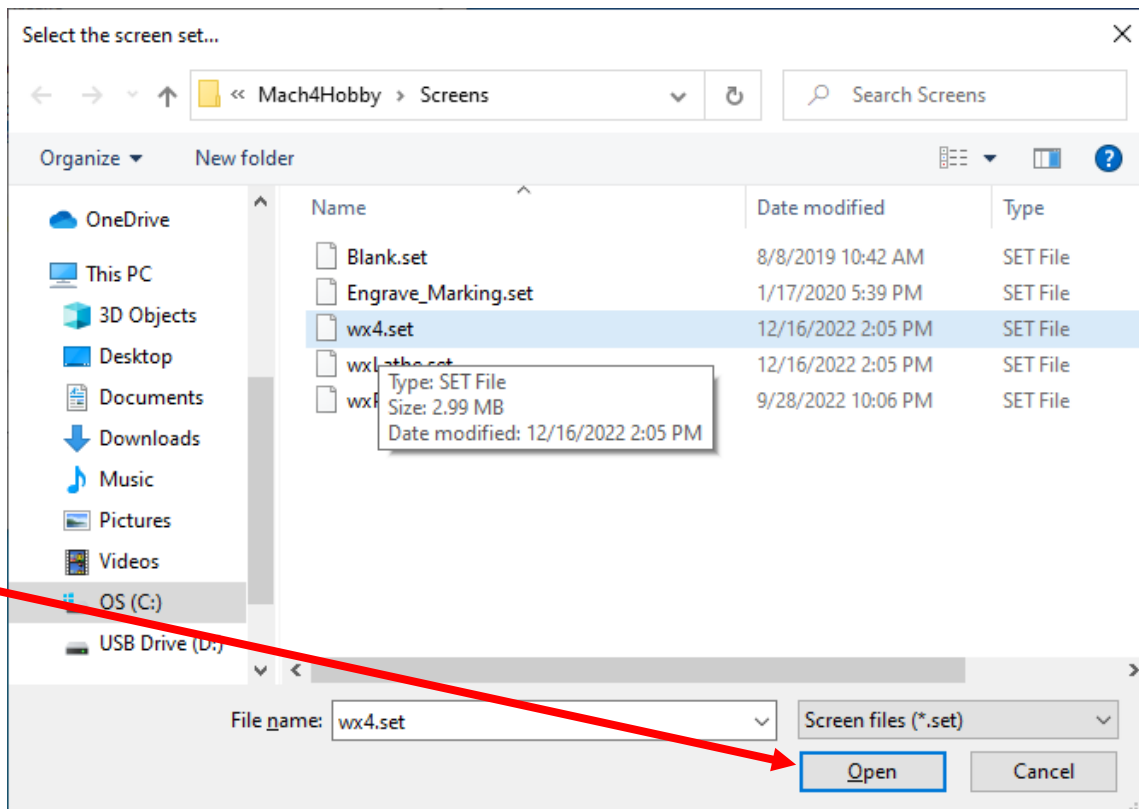
You may switch screens at any time during operation.

# Mach4 Install

Copy profile will ask for screen choice.

Select wx4.set for mill

Click OK



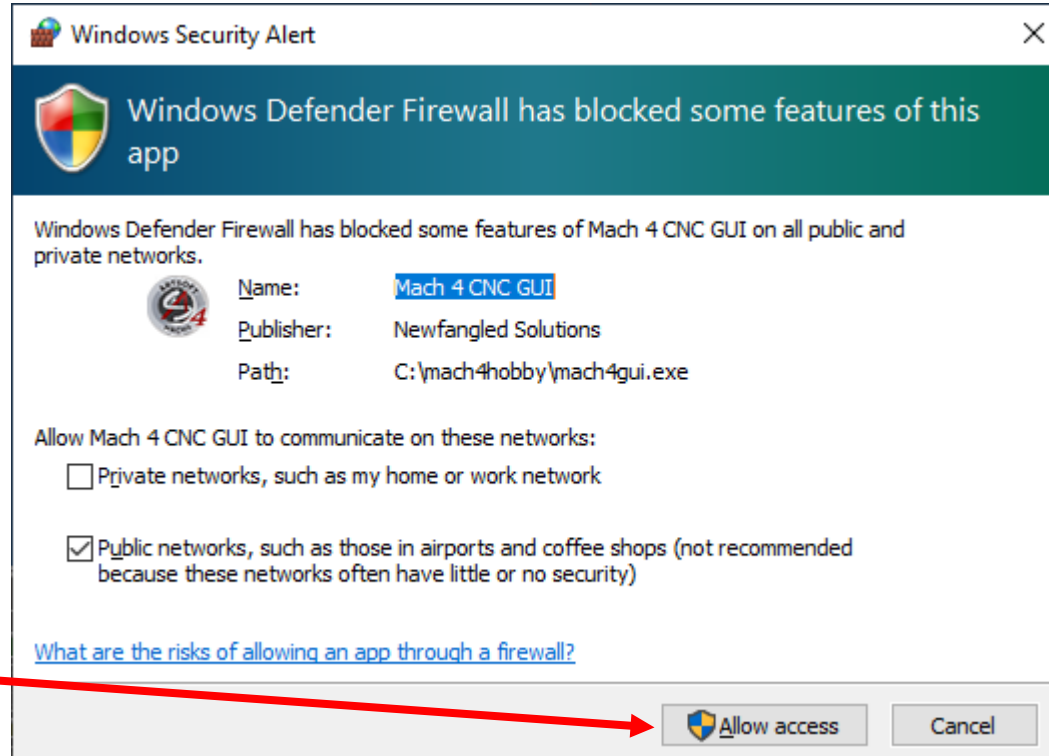
# Mach4 Install

As Mach4 Starts it will try to use some internal network functions.

Windows will show this block warning.

This will only happen on the first time start up.

Allow access

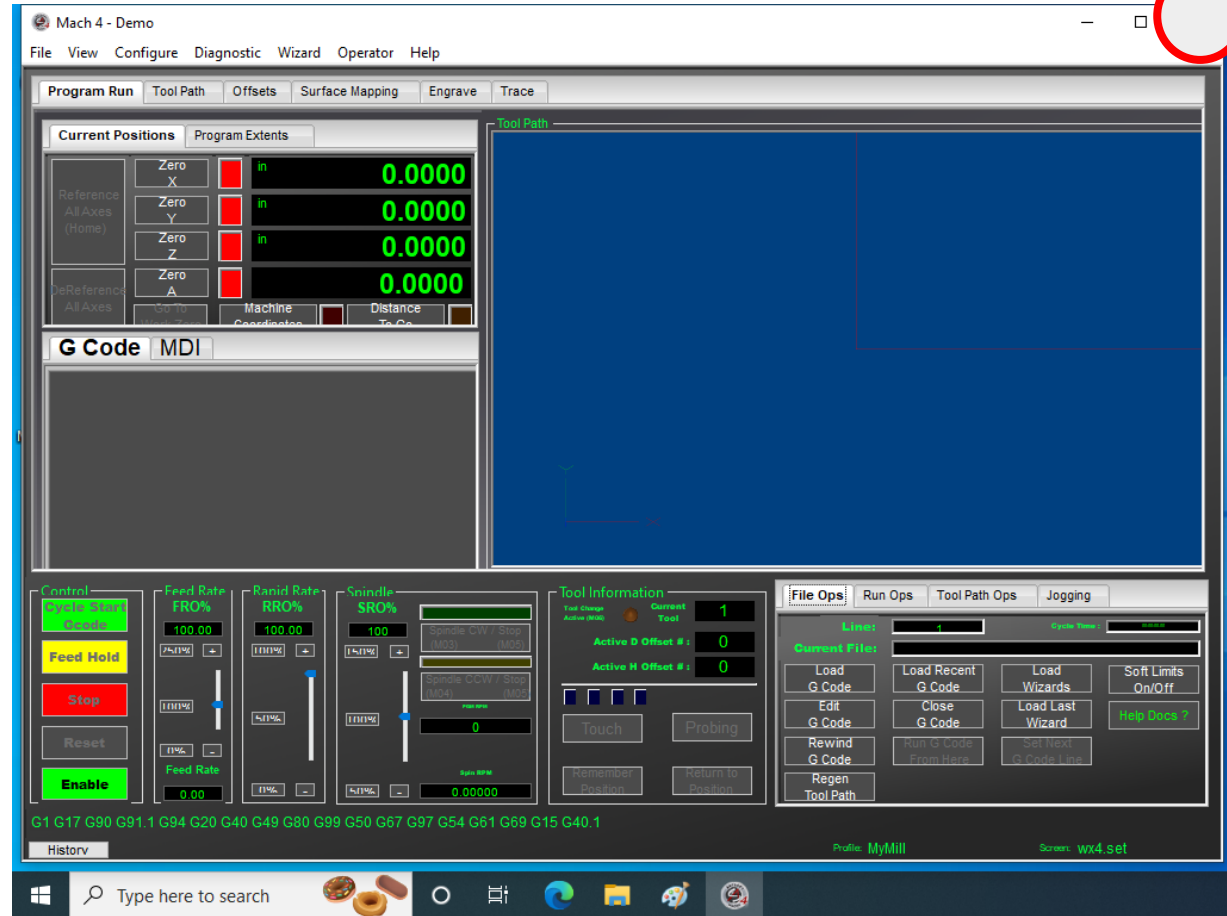


# Mach4 Install

SUCCESS! Mach4  
is installed.

Before we can run  
we need to install a  
plugin for motion  
control.

Stop Mach4 with  
the X



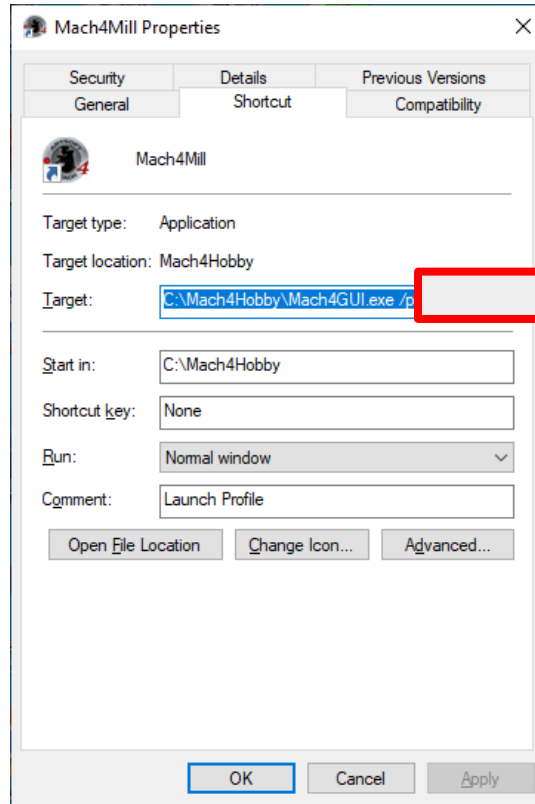


# Mach4 Install

Mach4 will build a screen icon for each machine type you selected.

Convert one of them to be your profile.

Right click on the icon and select Properties



Change the profile name to the profile you created.

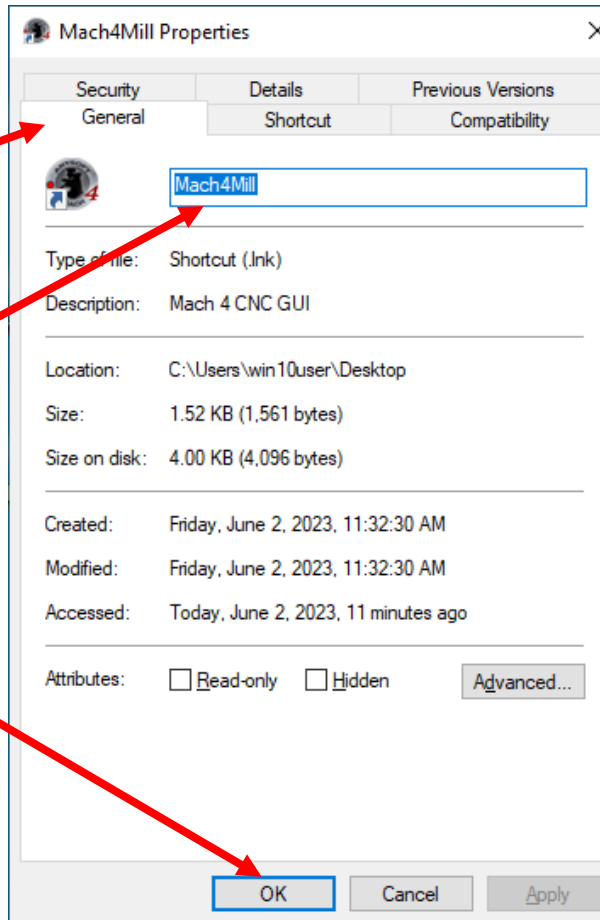
# Mach4 Install

Change to the  
General tab

Change the name to  
your profile name

Click OK

The desktop icon will  
now start Mach4 with  
your custom profile.



# ESS- Ethernet Smooth Stepper

The motion control- ESS- requires a software driver, called a plugin.

It is supplied on the memory stick with this system.

To check for a newer version look at <https://warp9td.com/>

Download the .zip file **ESS\_Mach4\_v####.zip**

### indicates the version number.

Open the .zip file and copy the two files

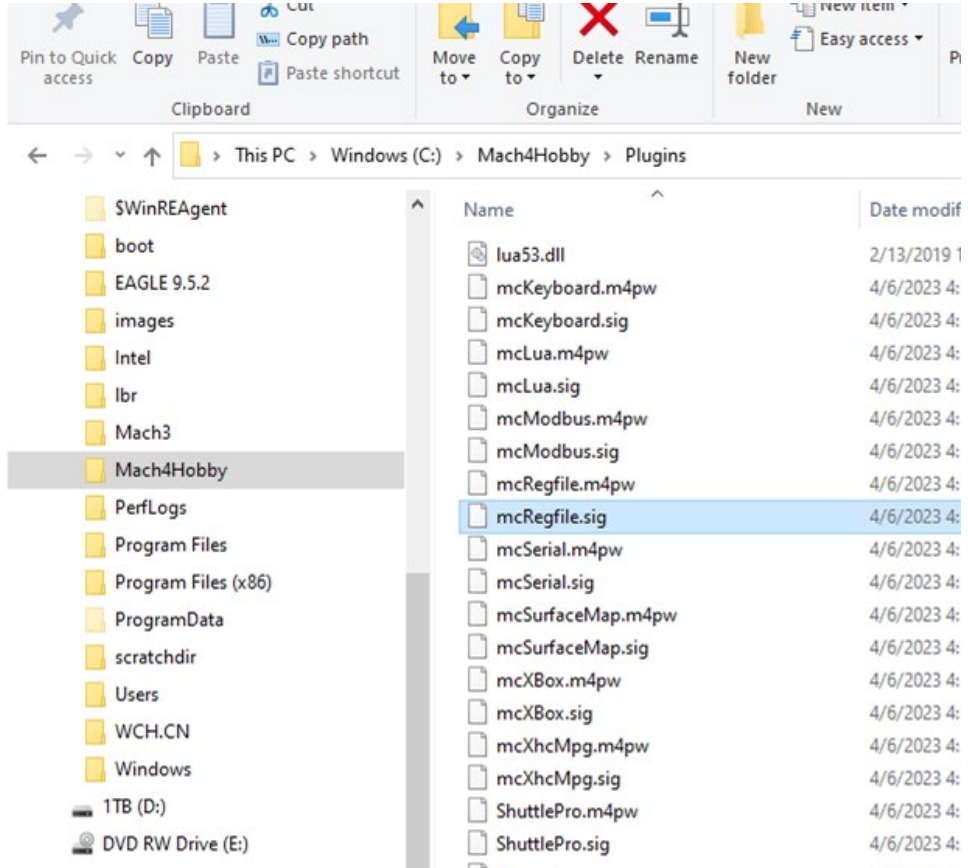
# ESS plugin install

Using File Explorer navigate to  
c:\Mach4Hobby\Plugins

Paste the two files into this  
folder

Warp9Mach4.sig

Warp9Mach4.m4pw

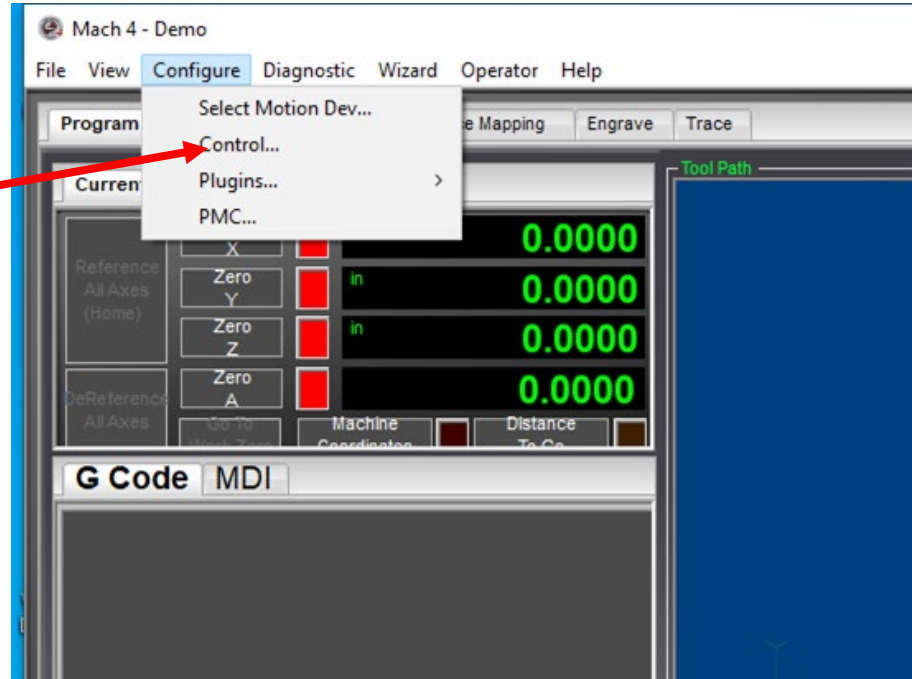


# Mach4 Install

Double click your profile Mach4 icon

When Mach4 starts select the *configure* menu bar item

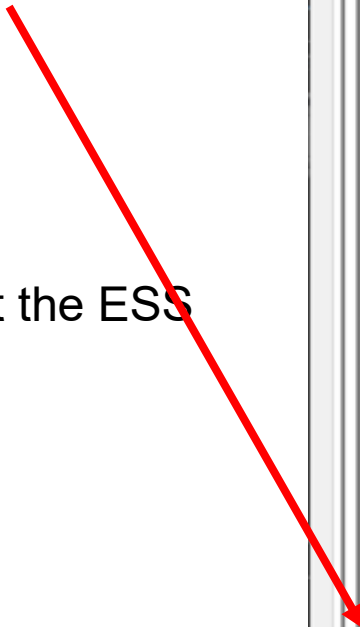
Select Control



## Select the ESS plugin

Click OK

Restart Mach4 to start the ESS plugin.



# Mach4 Install

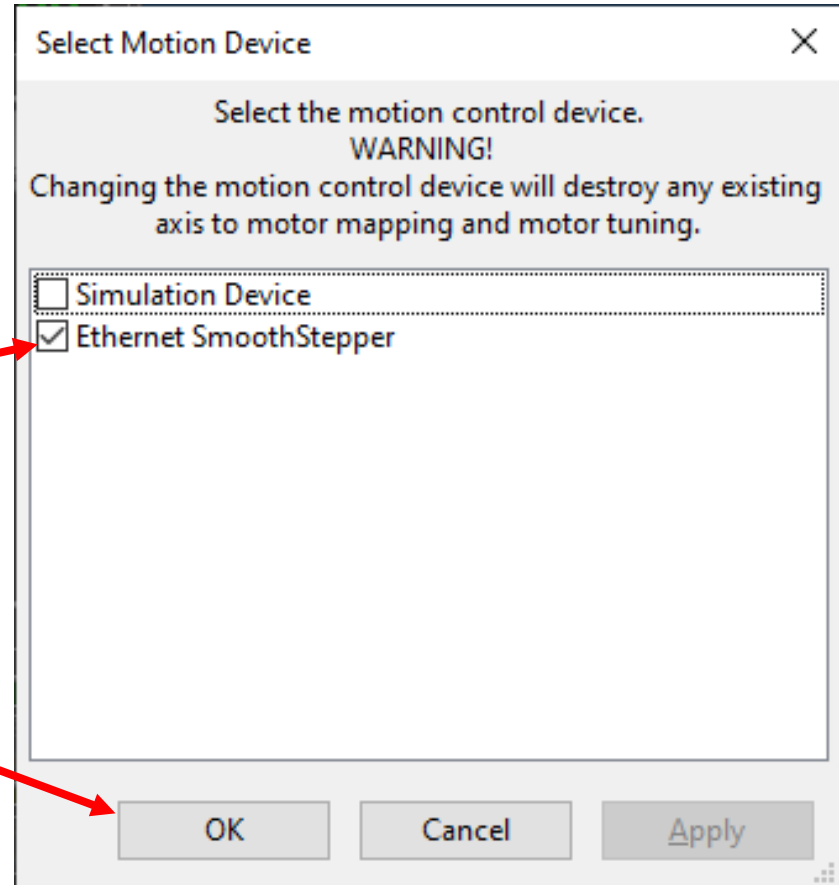
When Mach4 starts select  
Configure

Select motion device

Choose ESS

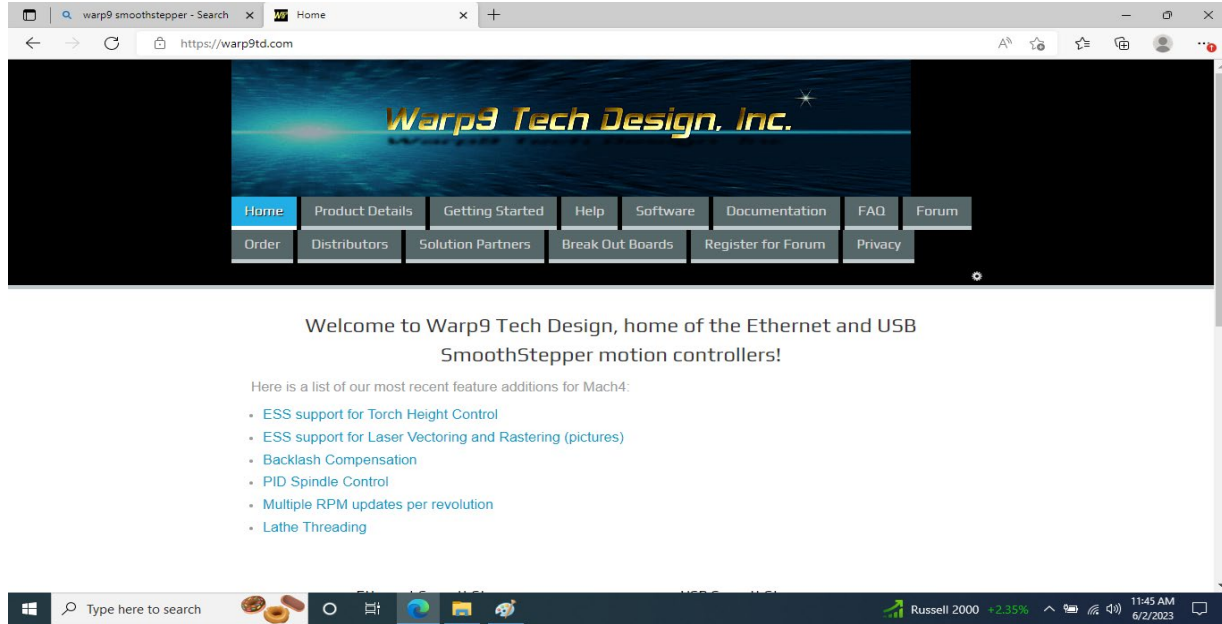
Click OK

Shutdown Mach4





# ESS setup



Browse to <https://warp9td.com>

Follow the directions to download the SCU application. There is also a great amount of background on setting up the ESS

# ESS setup

The screenshot shows a web browser window with the URL <https://warp9td.com/index.php/sw>. The website header features the company logo "Warp9 Tech Design, Inc." in a stylized yellow font against a dark blue background with a starburst effect. Below the logo is a navigation menu with two rows of buttons. The first row includes "Home", "Product Details", "Getting Started", "Help", "Software" (highlighted in blue), "Documentation", "FAQ", and "Forum". The second row includes "Order", "Distributors", "Solution Partners", "Break Out Boards", "Register for Forum", and "Privacy".

Below the navigation menu, the main content area is titled "Current Software Page". Under this title, a section asks "Which piece of software are you looking for:" followed by a bulleted list of software options:

- [SCU \(System Configuration Utility\) for ESS \(Ethernet SmoothStepper\)](#)
- [Mach4 Plugin for ESS \(Ethernet SmoothStepper\)](#)
- [Mach3 Plugin for ESS \(Ethernet SmoothStepper\)](#)
- [Configurator for ESS \(Ethernet SmoothStepper\)](#)
- [Windows Driver for USS \(USB SmoothStepper\)](#)
- [Mach4 Plugin for USS \(USB SmoothStepper\)](#)
- [Mach3 Plugin for USS \(USB SmoothStepper\)](#)

The bottom of the image shows a Windows taskbar with the search bar, task view button, and several application icons. The system tray on the right displays the temperature as 83°F, weather as Sunny, and the time as 11:46 AM on 6/2/2023.

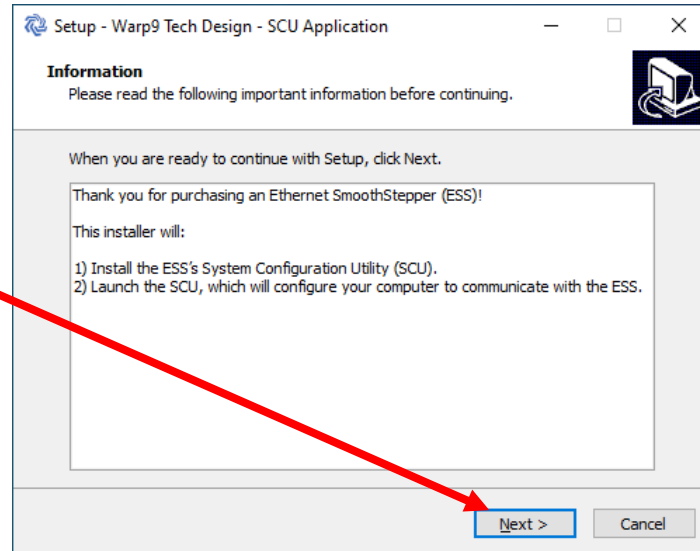
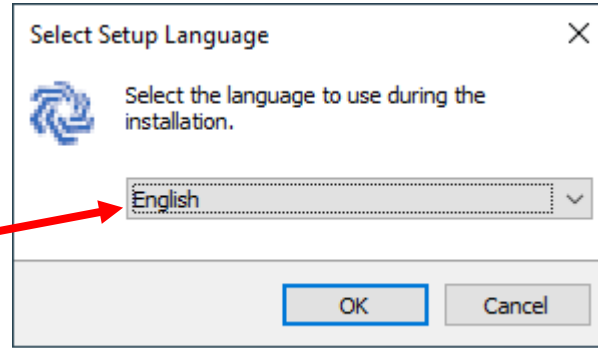
Select the SCU

# SCU setup

Start the SCU

Select Language

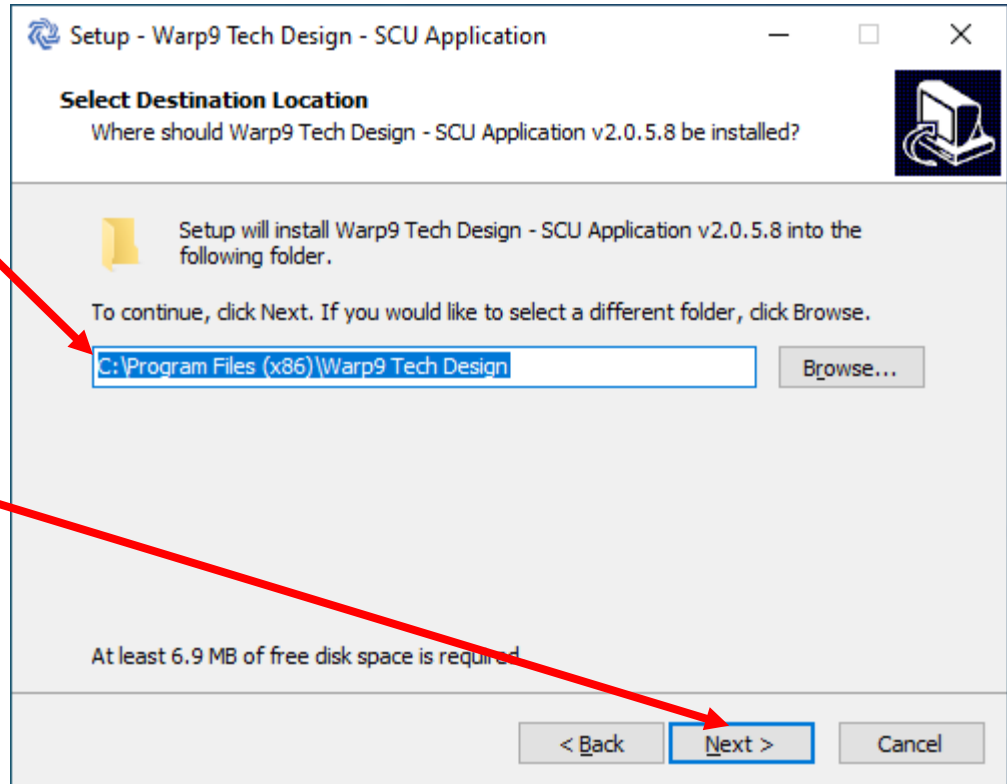
Select NEXT



# ESS setup

Use the suggested folder

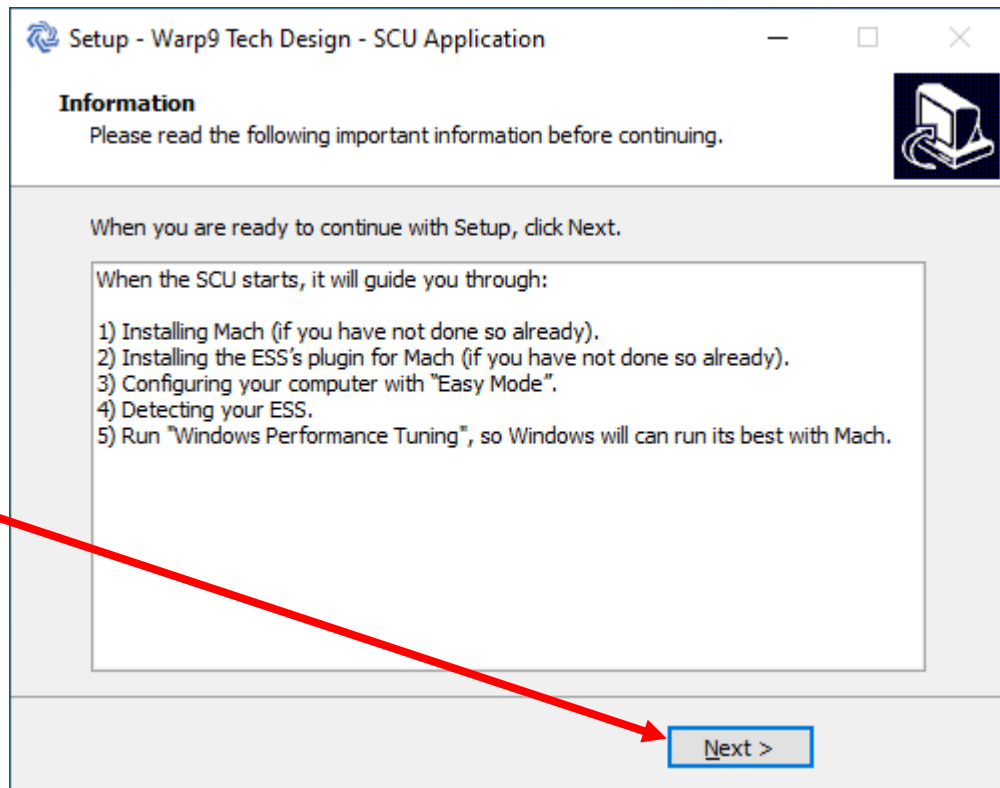
Select Next to install



# ESS Setup

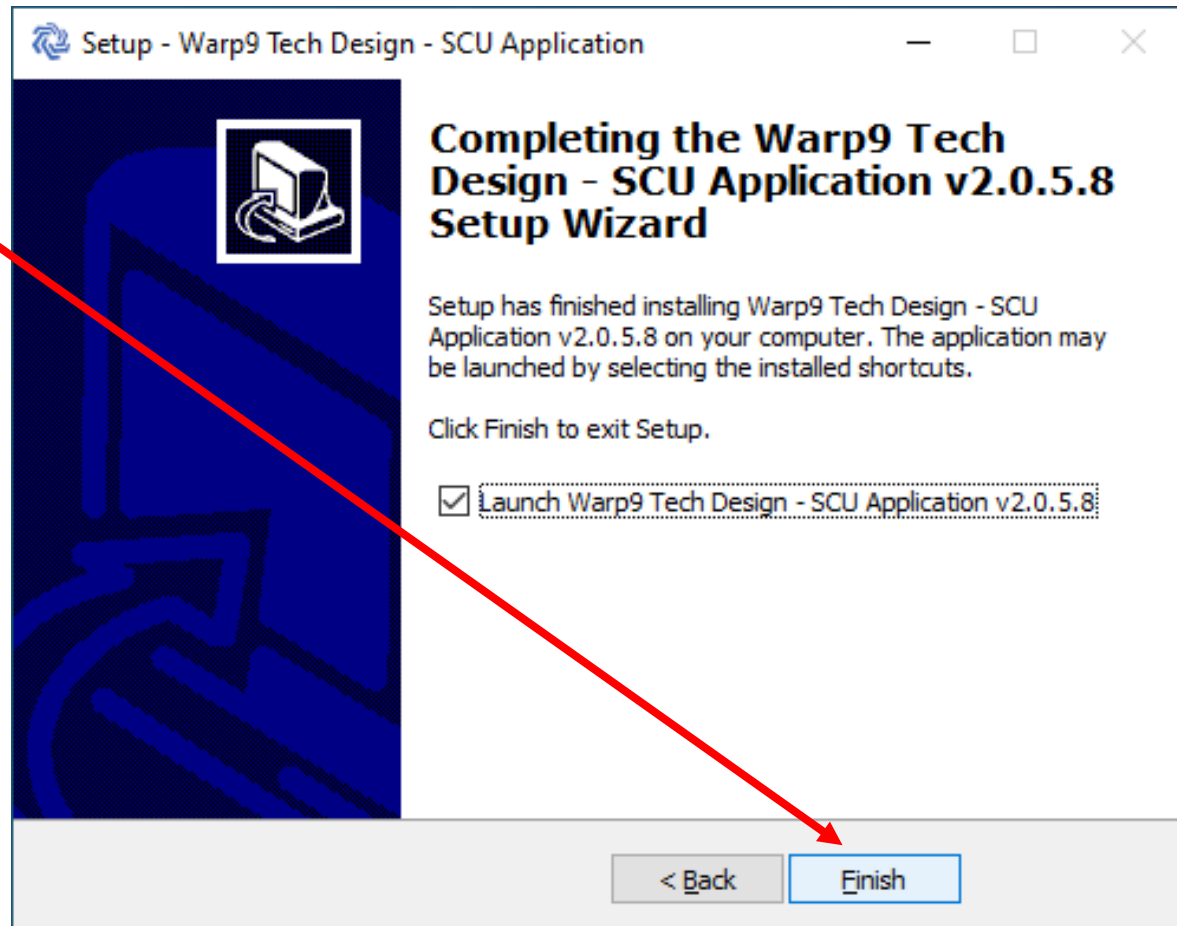
Note the instructions.

Select Next

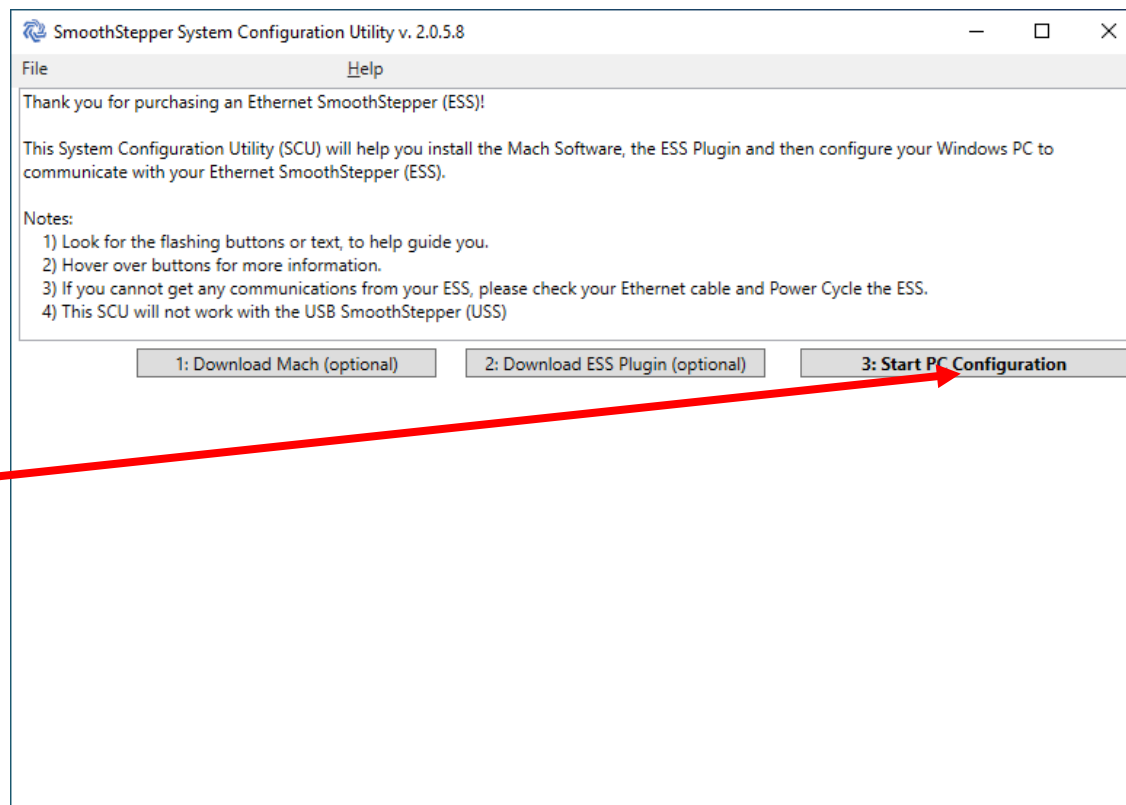


# ESS Setup

Select Finish



# ESS Setup

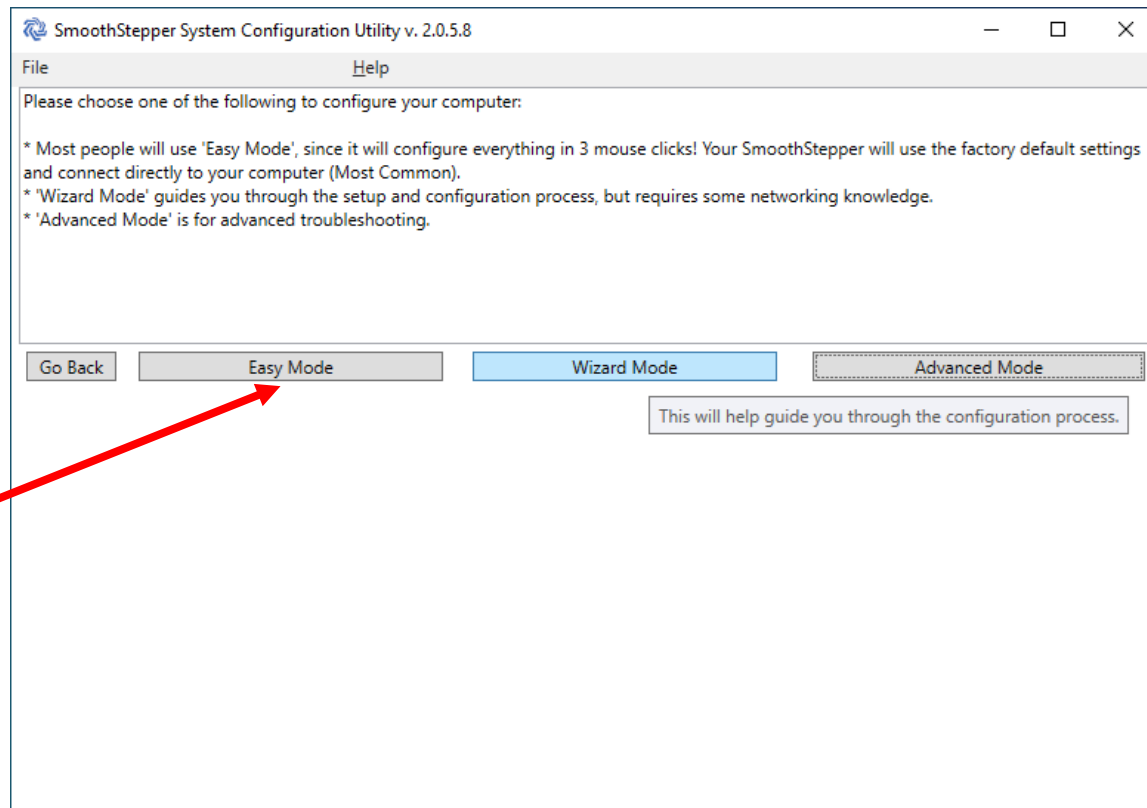


Use option 3



# ESS Setup

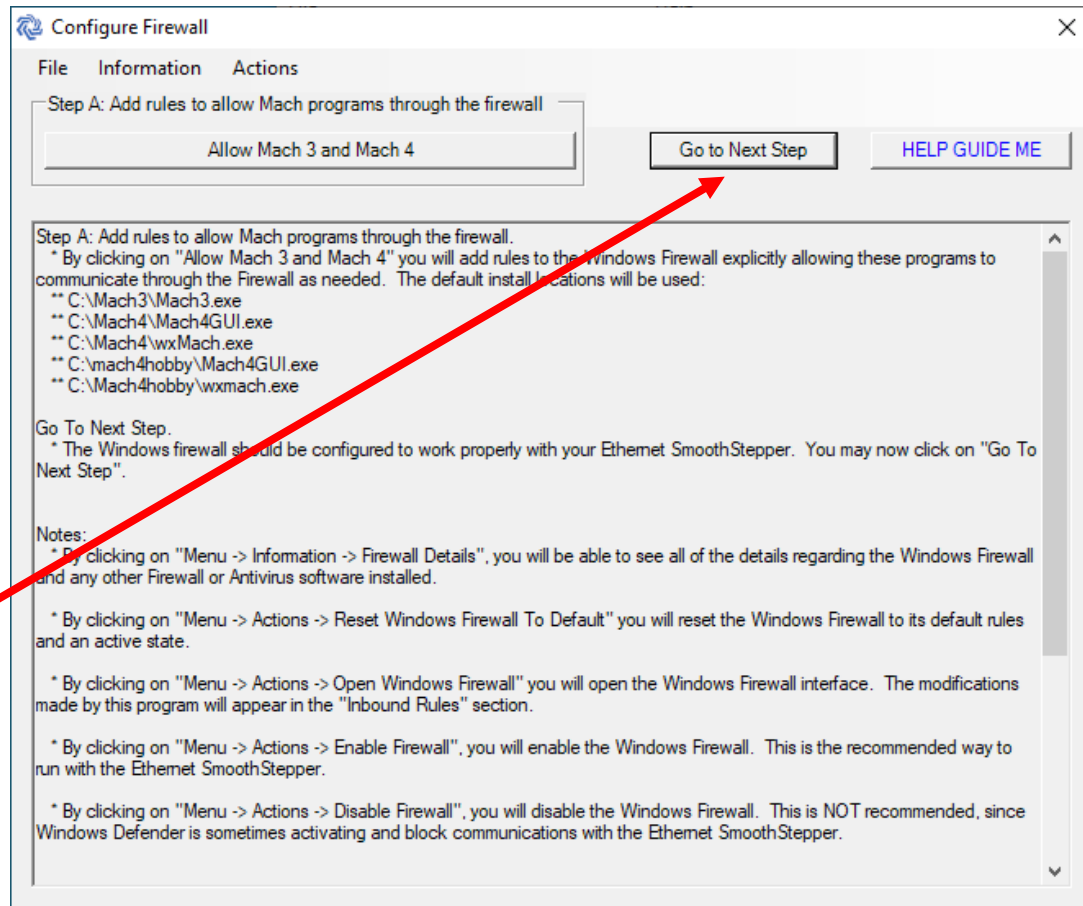
Select Easy Mode



# ESS Setup

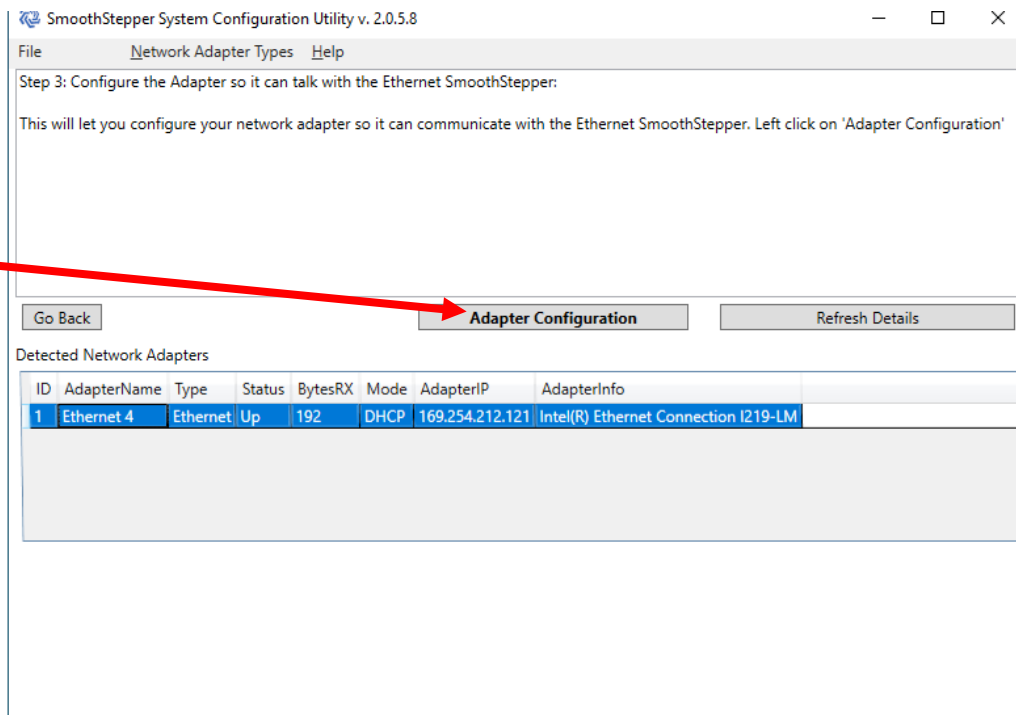
The SCU will show several changes it makes to the firewall settings.

Go to the next step



# ESS Setup

## Select Adapter Configuration



# ESS Setup

Select Recommended settings

We strongly advise that you use the 'Recommended ESS Configuration'. These settings will automatically work with the default factory address of the SmoothStepper.

'Set Configuration Manually' should only be used by experienced users, or to set your adapter to custom settings.

Recommended ESS Configuration

Set Configuration Manually

Go to Next Step

This will set your network adapter to the recommended settings to communicate with the ESS.

Apply settings

Configure Adapter Wizard

By pressing 'Apply Settings Now' these settings will be applied to your network adapter, which should then be able to communicate with your Ethernet SmoothStepper.

Note: Your Ethernet SmoothStepper is set to an IP address of 10.9.9.9. You DO NOT want to have the Network Adapter's IP address set to that value. However we are setting the Gateway to 10.9.9.9, which will let the network interface show if it is connected to the Ethernet SmoothStepper.

Go Back

Apply Settings Now

Go to Next Step

Adapter Name Ethernet 1

Adapter IP 10.9.9.2

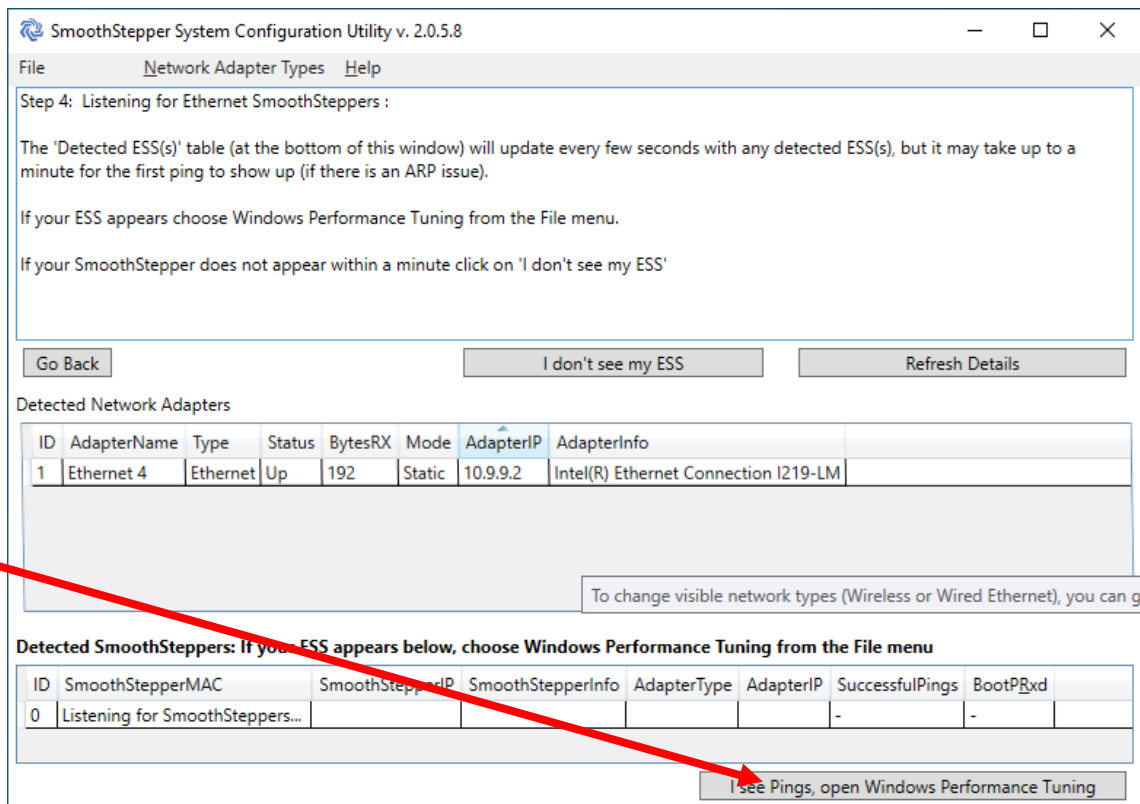
Adapter Subnet 255.255.255.0

Adapter Gateway 10.9.9.9

Go to next step

# ESS Setup

Select Windows  
Performance Tuning

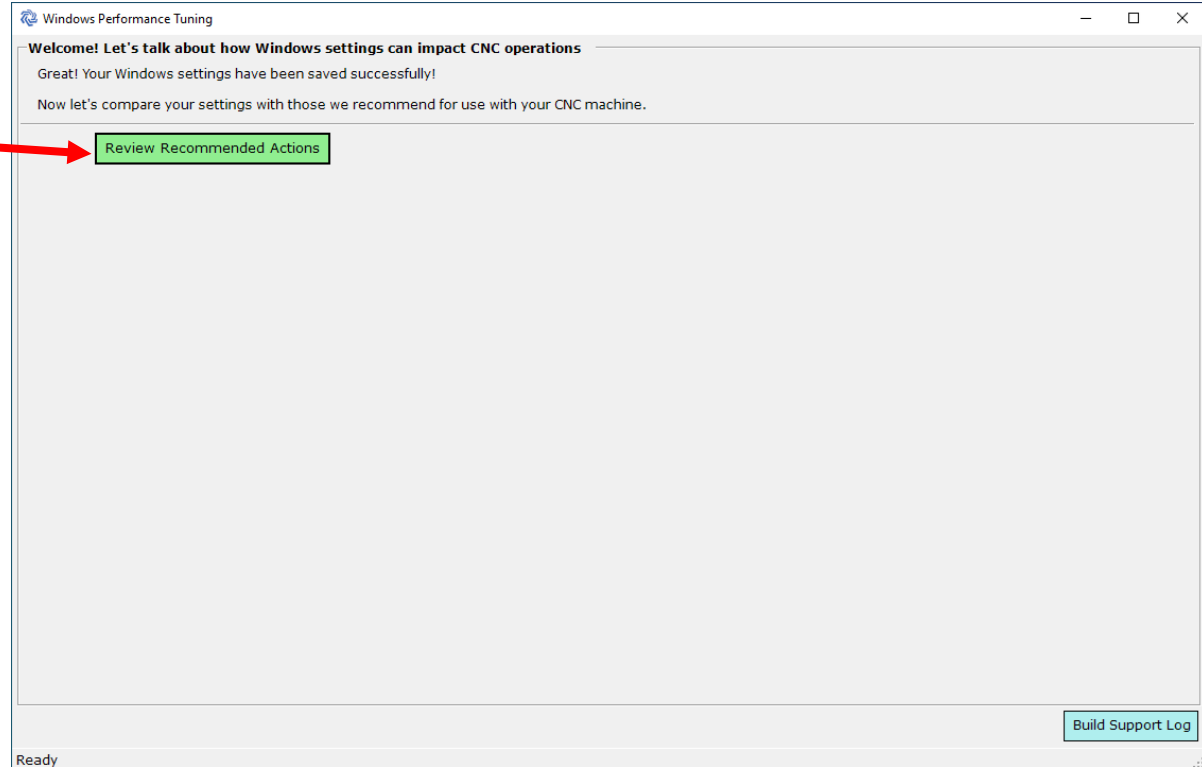


# ESS Setup

Continue to choose  
default settings

You may see variations  
from this series of  
screens. Just accept all  
defaults until SCU is  
finished.

Read the docs on the  
warp9td.com site for  
further detail.



# Machine Configuration

The ESS has 3 ports of 17 pins.

Most pins can be assigned as input or output.

The system has several control signals which are connected to an ESS pin

We must associate each signal with the correct pin.

All this data is stored in the Machine.ini file within your Profile.

There is a Machine.ini file on the memory stick supplied with this system.

You may simply copy it from the stick to replace the current file in your Profile.



# Active Low

All signals in this system are digital, binary.

That means they may be a HIGH (typically +5V) or LOW (typically ground)

The system needs to know when the signal is TRUE, or ACTIVE

Active High means the signal is TRUE when it is HIGH

Active Low means the signal is TRUE when it is LOW.

There is no right or wrong, here, you just must use whichever choice the system designer chose.

# Machine Configuration

If you want to fully understand the wiring of your machine use the following screens to config the ESS pins.

The general process is to assign alias names to the pins in the ESS config and assign the alias names to the correct functions in Mach4.

The following screens conform to the tabs of the ESS Config screens.

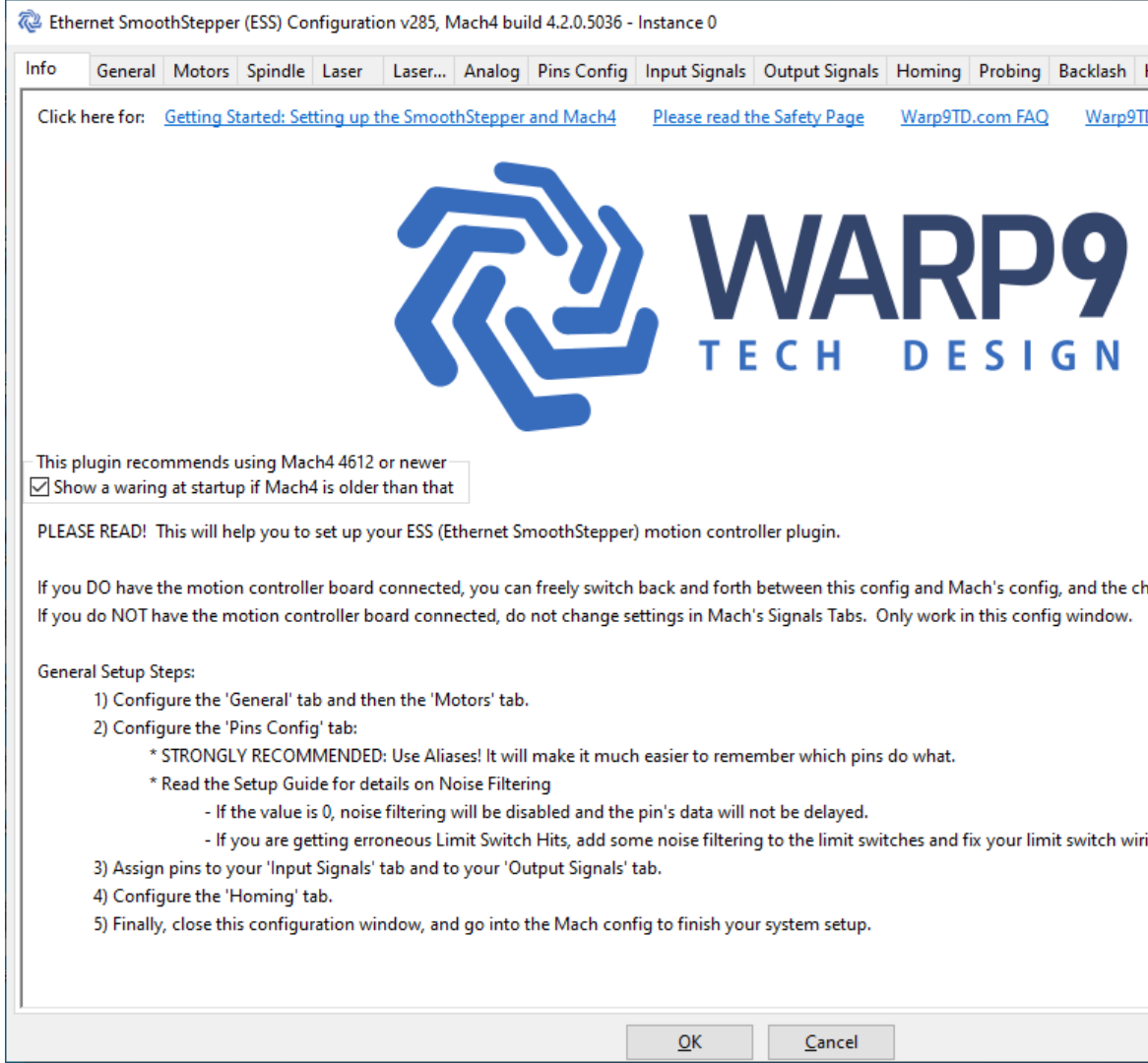
# Machine Configuration

From the main Mach4  
screen menu bar

Select Configure-  
>Plugins->ESS

Info screen will open

Work across the tabs



# ESS config, tab General

On the General tab leave all the settings as is.

Ethernet SmoothStepper (ESS) Configuration v285, Mach4 build 4.2.0.5036 - Instance 0

Info General Motors Spindle Laser Laser... Analog Pins Config Input Signals Output Signals Homing Probing Backlash HC

1) IP Address of the SmoothStepper: 10.9.9.9

2) Buffer Size (seconds, max of 0.5): 0.1800

3) Plugin Frequency (Hz): 40

4) Velocity FIFO Buffer Ran Out of Data: ☒ Show Hardware Velocity FIFO Ran Dry Msgs

5) Disable & EStop: ☒ Charge Pump Runs In EStop, ☒ Disable Expansion Port In Disable

6) Advanced Logging: ☐ Enable Advanced Logging

7) When a Feed Hold Event turns an Output Pin: ☒ OFF, prompt the operator before turning the output pin ON again, ☒ ON, prompt the operator before turning the output pin OFF again

1) The motion controller's IP address will be 10.9.9.9 unless it was modified with the configurator.

2) Buffer Size defaults to 0.18. A smaller buffer size is more responsive to Feed Hold commands, but is more sensitive to the Velocity FIFO running out of data if your computer bogs down. Increase the buffer size to prevent the Velocity FIFO from running out of data. If you have received 'Velocity FIFO Ran Out of Data' messages, you should restart Mach4 after modifying the buffer size.

3) The plugin frequency is typically left at 40 Hz. Higher frequencies will let Mach respond to events faster, but will also force your PC to work harder to keep up (which is harder for slower computers to do).

4) This lets you choose to watch the Velocity FIFO, to make sure it does not Run Out of Data. We recommend you leave this checked. Running out of data may cause lost steps, and may indicate your PC is doing other tasks instead of servicing Mach4.

If you get these messages regularly, take these actions so critical data can make it to the motion controller in time:

- \* Increase your Buffer Size (above).
- \* Disconnect your PC from the internet and shut off WiFi.
- \* Shut down all other programs on your PC.
- \* Decrease your plugin Frequency to 30Hz or 20 Hz (above).
- \* Visit Warp9TD.com and look at our FAQ Windows page to see how to optimize your PC further.
- \* If your PC has less than 3 GB RAM (XP), 4GB RAM (Win7) or 8 GB RAM (Win10) you may want to increase your PC's RAM.

OK Cancel

# ESS config tab Motors

We are using  
Step/Dir motors  
on all positions.

w9 Ethernet SmoothStepper (ESS) Configuration - v260

Info General **Motors** Spindle Laser Pins Config Input Signals Output Signals Homing Probing Ba

Axis Motors Settings: Step/Dir, Quadrature or CW/CCW

	Mode	Reported Feed Rate Smoothing (Sec)
<b>Motor 0</b>	Step/Dir	0.100
<b>Motor 1</b>	Step/Dir	0.100
<b>Motor 2</b>	Step/Dir	0.100
<b>Motor 3</b>	Step/Dir	0.100
<b>Motor 4</b>	Step/Dir	0.100
<b>Motor 5</b>	Step/Dir	0.100

☐ Enable AntiClunk Mode for Servo Motors

- 1) In the 'Output Signals' Tab, assign Aliases or Pins for each Motor used.
- 2) In Mach Config -> Motors, set up the parameters for each Motor used.
- 3) In Mach Config -> Axis Mapping, Enable your axes and assign Motors as Masters and/or slaves.

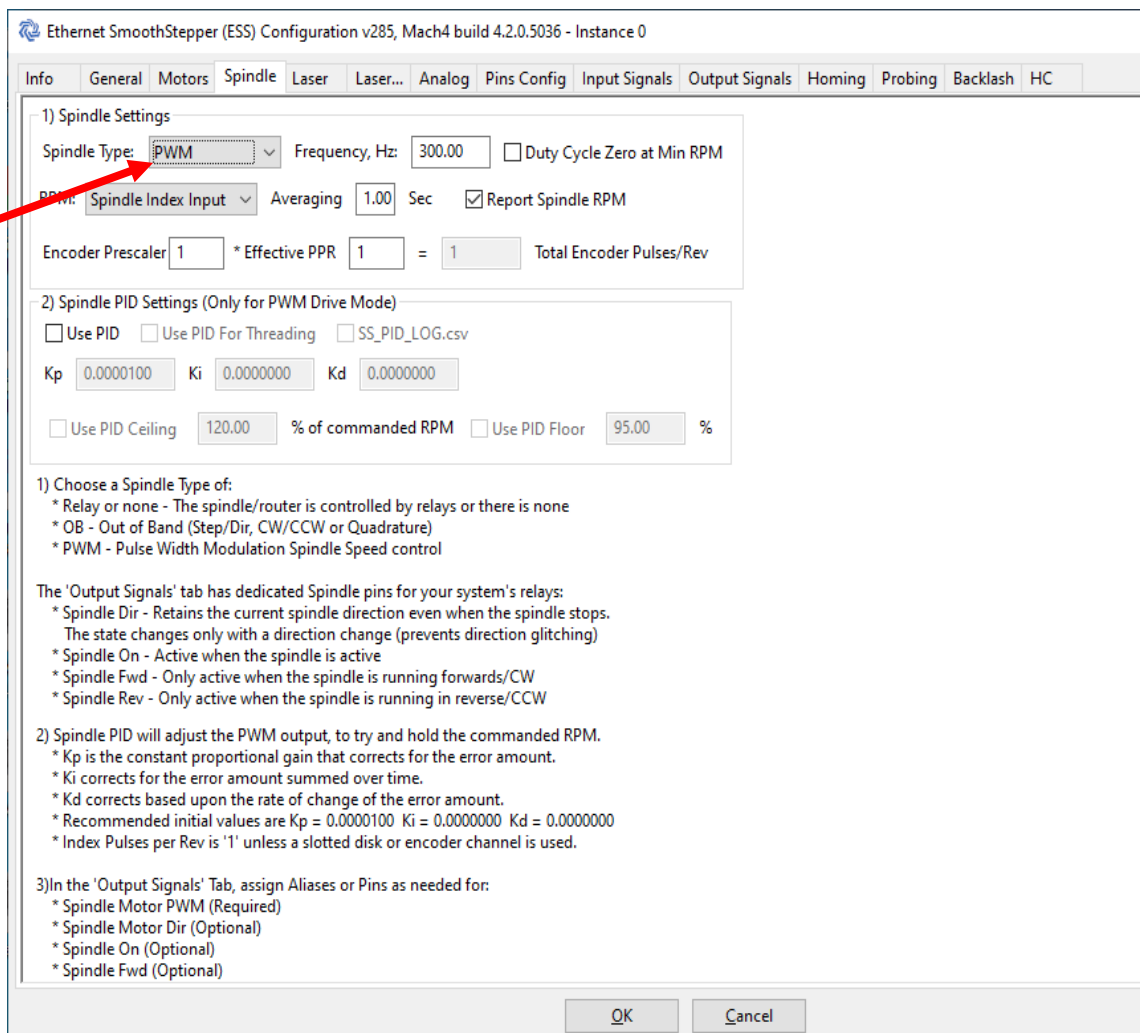
# ESS config tab Spindle

We use a PWM signal to control spindle RPM.

We do not have a spindle index signal.

Bar will remain highlighted.

Do not use PID terms.



# ESS config tab Pins

Scroll down on the Pins tab to see the Port 2 assignments.

Enter alias names for these pins.

Ethernet SmoothStepper (ESS) Configuration v285, Mach4 build 4.2.0.5036 - Instance 0

Info General Motors Spindle Laser Laser... Analog Pins Config Input Signals Output Signals Homing Probing Backlash HC

1) Set the pins Active High (Red Arrow Up) or Active Low (Green Arrow Down).  
2) Give the Pins you are using an Alias: {P#-#} DESCRIPTION (This is the {Port#-Pin#} for the pin and a description of it). This makes it MUCH EASIER to identify which pins do what in the Input and Output signal tabs.  
3) Assign Noise Filtering, in us, for each input pin, if needed (see the 'Info' tab for more details).  
4) A Feed Hold or Stop (Stop, EStop, Disabled or Limit) event can set the Output state to 'Force ON', 'Force OFF', or 'No Change'. 'No Change' means that the output is controlled by Mach4. With 'Force ON' and 'Force OFF' the ESS will force that desired state.  
5) Pins are always enabled, only Signals can be enabled or disabled. Connect pins as needed on the Input and Output signal tabs.

Port 2 Pins 2-9 Direction Port 3 Pins 2-9 Direction  
☒ Inputs ☐ Outputs ☒ Inputs ☐ Outputs

This is the tooltip text...

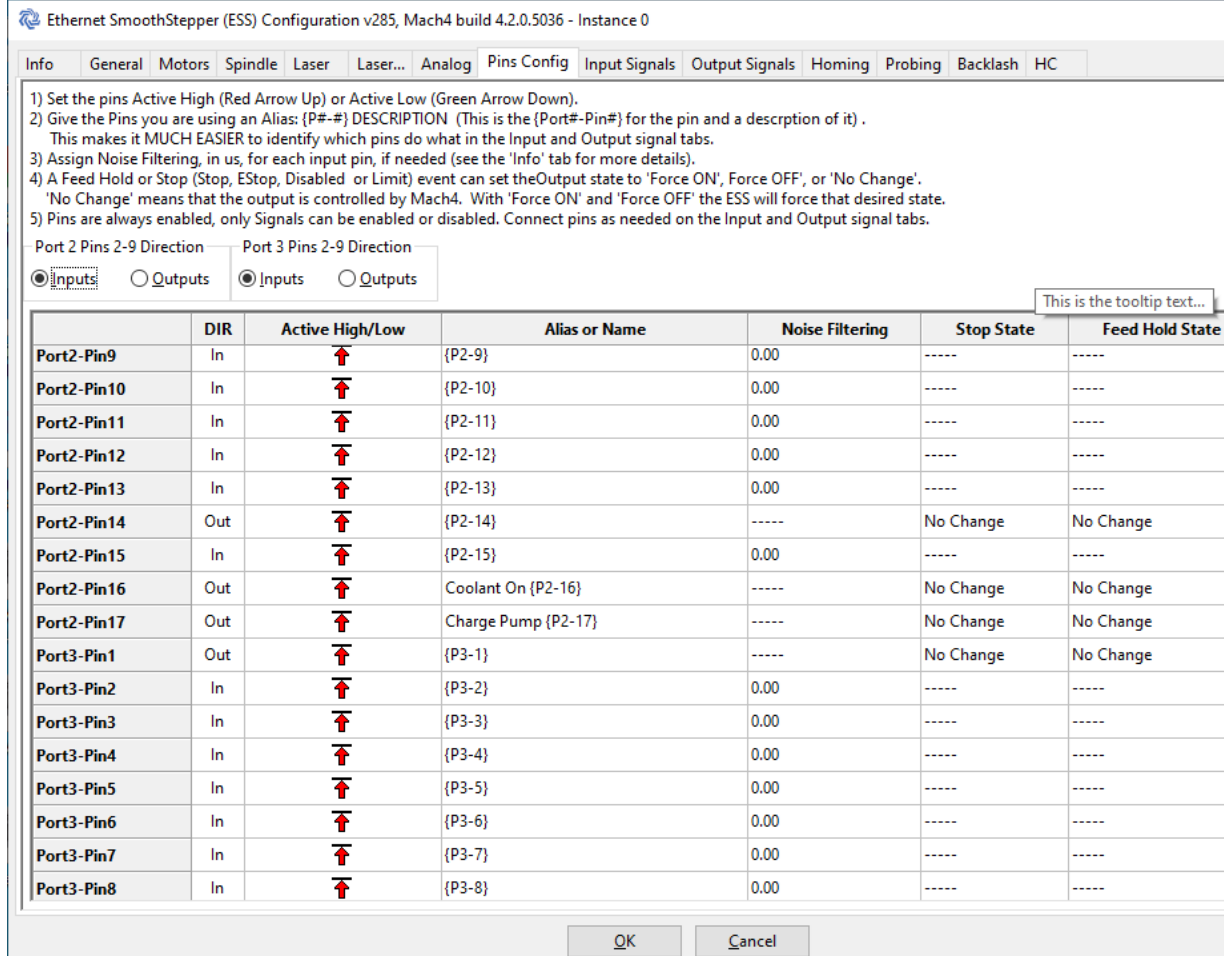
	DIR	Active High/Low	Alias or Name	Noise Filtering	Stop State	Feed
Port1-Pin1	Out	↑	Motor 4 Step {P1-1}	-----	No Change	No Change
Port1-Pin2	Out	↑	Motor 0 Step {P1-2}	-----	No Change	No Change
Port1-Pin3	Out	↑	Motor 0 Dir {P1-3}	-----	No Change	No Change
Port1-Pin4	Out	↑	Motor 1 Step {P1-4}	-----	No Change	No Change
Port1-Pin5	Out	↑	Motor 1 Dir {P1-5}	-----	No Change	No Change
Port1-Pin6	Out	↑	Motor 2 Step {P1-6}	-----	No Change	No Change
Port1-Pin7	Out	↑	Motor 2 Dir {P1-7}	-----	No Change	No Change
Port1-Pin8	Out	↑	Motor 3 Step {P1-8}	-----	No Change	No Change
Port1-Pin9	Out	↑	Motor 3 Dir {P1-9}	-----	No Change	No Change
Port1-Pin10	In	↓	E-Stop {P1-10}	0.00	-----	-----
Port1-Pin11	In	↓	Motor 0 ++ {P1-11}	0.00	-----	-----
Port1-Pin12	In	↓	Motor 1 ++ {P1-12}	0.00	-----	-----
Port1-Pin13	In	↓	Motor 2 ++ {P1-13}	0.00	-----	-----
Port1-Pin14	Out	↑	Spindle PWM {P1-14}	-----	No Change	No Change
Port1-Pin15	In	↓	Probe {P1-15}	0.00	-----	-----
Port1-Pin16	Out	↑	Spindle Rev {P1-16}	-----	No Change	No Change
Port1-Pin17	Out	↑	Motor 4 Dir {P1-17}	-----	No Change	No Change

OK Cancel

# ESS config tab Pins

This system does not include a coolant pump.

Charge Pump is a safety feature, commonly known as a watchdog timer. If Mach4 should crash the control logic will shutdown all motion.


























# ESS config tab Inputs

The only input signals are from the limit switches and the E-stop button.

Ethernet SmoothStepper (ESS) Configuration v285, Mach4 build 4.2.0.5036 - Instance 0

Info General Motors Spindle Laser Laser... Analog Pins Config **Input Signals** Output Signals Homing Probing Backlash HC

1) When you enable an input signal here, it will automatically be enabled and mapped into Mach.  
2) An Input Pin (or Alias) may be assigned to multiple Input Signals.

	Enable	Mach Mapping	Mapped Pin
E-Stop		ESS	E-Stop {P1-10}
Motor 0 Home		ESS	Motor 0 ++ {P1-11}
Motor 1 Home		ESS	Motor 1 ++ {P1-12}
Motor 2 Home		ESS	Motor 2 ++ {P1-13}
Motor 3 Home			
Motor 4 Home			
Motor 5 Home			
Motor 0 ++ Limit			
Motor 1 ++ Limit			
Motor 2 ++ Limit			
Motor 3 ++ Limit			
Motor 4 ++ Limit			
Motor 5 ++ Limit			
Motor 0 -- Limit			
Motor 1 -- Limit			
Motor 2 -- Limit			
Motor 3 -- Limit			
Motor 4 -- Limit			
Motor 5 -- Limit			
Motor 0 Index		ESS-only	
Motor 1 Index		ESS-only	

OK Cancel

# ESS config tab Outputs

These outputs drive the motors.

Ethernet SmoothStepper (ESS) Configuration v285, Mach4 build 4.2.0.5036 - Instance 0

Info General Motors Spindle Laser Laser... Analog Pins Config Input Signals **Output Signals** Homing Probing Backlash H

1) An Output Pin (or Alias) may only be assigned to a single Output Signal.  
2) An Output Signal may have up to 3 Output Pins (or Aliases) assigned to it:  
\* When enabled in this window, only 'Mapped Pin1' will be enabled and mapped into Mach.  
\* 'Mapped Pin2' and 'Mapped Pin3' will still receive the same Output Signal as 'Mapped Pin1', but will not be referenced in Mach.

	Enable	Mach Mapping	Pin1 Mapping	Pin2 Mapping	
Motor 0 Step		ESS-only	Motor 0 Step {P1-2}		
Motor 0 Dir		ESS-only	Motor 0 Dir {P1-3}		
Motor 1 Step		ESS-only	Motor 1 Step {P1-4}		
Motor 1 Dir		ESS-only	Motor 1 Dir {P1-5}		
Motor 2 Step		ESS-only	Motor 2 Step {P1-6}		
Motor 2 Dir		ESS-only	Motor 2 Dir {P1-7}		
Motor 3 Step		ESS-only	Motor 3 Step {P1-8}		
Motor 3 Dir		ESS-only	Motor 3 Dir {P1-9}		
Motor 4 Step		ESS-only	Motor 4 Step {P1-1}		
Motor 4 Dir		ESS-only	Motor 4 Dir {P1-17}		
Motor 5 Step		ESS-only			
Motor 5 Dir		ESS-only			
Motor 0 Enable		ESS			
Motor 1 Enable		ESS			
Motor 2 Enable		ESS			
Motor 3 Enable		ESS			
Motor 4 Enable		ESS			
Motor 5 Enable		ESS			
ESS, XY Feed Rate PWM		ESS-only			
ESS, Z Feed Rate PWM		ESS-only			

OK Cancel

# ESS config tab Outputs 2

Spindle and charge pump outputs.

Ethernet SmoothStepper (ESS) Configuration v285, Mach4 build 4.2.0.5036 - Instance 0

Info General Motors Spindle Laser Laser... Analog Pins Config Input Signals **Output Signals** Homing Probing Backlash

1) An Output Pin (or Alias) may only be assigned to a single Output Signal.  
2) An Output Signal may have up to 3 Output Pins (or Aliases) assigned to it:  
\* When enabled in this window, only 'Mapped Pin1' will be enabled and mapped into Mach.  
\* 'Mapped Pin2' and 'Mapped Pin3' will still receive the same Output Signal as 'Mapped Pin1', but will not be referenced in Mach.

	Enable	Mach Mapping	Pin1 Mapping	Pin2 Mapping
Motor 2 Enable		ESS		
Motor 3 Enable		ESS		
Motor 4 Enable		ESS		
Motor 5 Enable		ESS		
ESS, XY Feed Rate PWM		ESS-only		
Laser PWM/XY Vel PWM/AOut1		ESS-only		
Spindle Motor PWM Or AOut 0		ESS-only	Spindle PWM {P1-14}	
Spindle Motor Dir		ESS-only	Spindle Rev {P1-16}	
Spindle On		ESS		
Spindle Fwd		ESS		
Spindle Rev		ESS		
Alarm		ESS		
Charge Pump		ESS-only	Charge Pump {P2-17}	
Coolant, Flood (M08, M09)		ESS	Coolant On {P2-16}	
Coolant, Mist (M07, M09)		ESS		
Current Hi/Low		ESS		
Cut Recovery		ESS		
Digitize Trigger		ESS		
Dist To Go		ESS		

OK Cancel

# ESS config tab Homing

The motors in this system do not have an index signal.

Home operations approach the switch at higher speed, then back off slowly to make accurate location.

Ethernet SmoothStepper (ESS) Configuration v285, Mach4 build 4.2.0.5036 - Instance 0

Info General Motors Spindle Laser Laser... Analog Pins Config Input Signals Output Signals **Homing** Probing Backlash HC

1) Homing is enabled for a Motor 'N', when the 'Input Signals' tab has:  
\* 'Motor N Home' Enabled with a green check.  
\* 'Motor N Home' has an assigned 'Mapped Pin'.

2) If you have encoders with an index pulse, you may enable homing to a motor's index pin by:  
\* Place a green check in 'Home to Motor's Index Pin'.  
\* Make sure that the index signal is enabled for that Motor.

	Home Pin (Automatically Populated from 'Input Signals' tab)	Approach Velocity (Units/Min)	Backoff Velocity (Units/Min)	Home To Motor's Index Pin	Rotational Axis Motor Index Pin (Automatically Populated from 'Input Signals' tab)
Motor 0	Motor 0 ++ {P1-11}	1.0	1.0	✗	
Motor 1	Motor 1 ++ {P1-12}	1.0	1.0	✗	
Motor 2	Motor 2 ++ {P1-13}	1.0	1.0	✗	
Motor 3		1.0	1.0	✗	
Motor 4		1.0	1.0	✗	
Motor 5		1.0	1.0	✗	

This number sets the velocity of the home move.  
20 is a reasonable value for the PM728

OK Cancel

# ESS config tab Backlash

We use ballscrews with near zero backlash.

Mach4 can compensate for backlash when it exists.

w9 Ethernet SmoothStepper (ESS) Configuration - v260

Info General Motors Spindle Laser Pins Config Input Signals Output Signals Homing Probing Backlash HC

1) Backlash Compensation Options

☒ Use Backlash Compensation ☐ Show Backlash Comp Messages in Log

	Enabled	Backlash Amount (Read Only)	Mach Velocity (Units/Min)	Mach Acceleration (Units/Sec^2)	Use Custom Values?	Custom Velocity (Units/Min)	Custom Acceleration (Units/Sec^2)
Motor 0		0.0000	501.0000	20.0000		10.0000	1.0000
Motor 1		0.0000	502.0000	20.0700		10.0000	1.0000
Motor 2		0.0000	125.0000	5.0200		10.0000	1.0000
Motor 3		0.0000	500.0000	20.0000		10.0000	1.0000
Motor 4		0.0000	15.0000	10.0000		10.0000	1.0000
Motor 5		0.0000	15.0000	10.0000		10.0000	1.0000

1) When 'Use Backlash Compensation' is enabled, the SmoothStepper will perform Backlash Compensation (B.C.). Fixing backlash through software is never as effective as removing backlash with better hardware.

\* The first column, 'Enabled', should be CHECKED if it is a normal motion axis, or if you want that motor's movements to affect B.C.

# Associating ESS and Mach4 connections.

We have now assigned a name to each signal connected to the ESS

Now we need to use these names to configure Mach4.

In the ESS we simply refer to motors 0-6.

Mach4 needs to associate a motor with an axis.

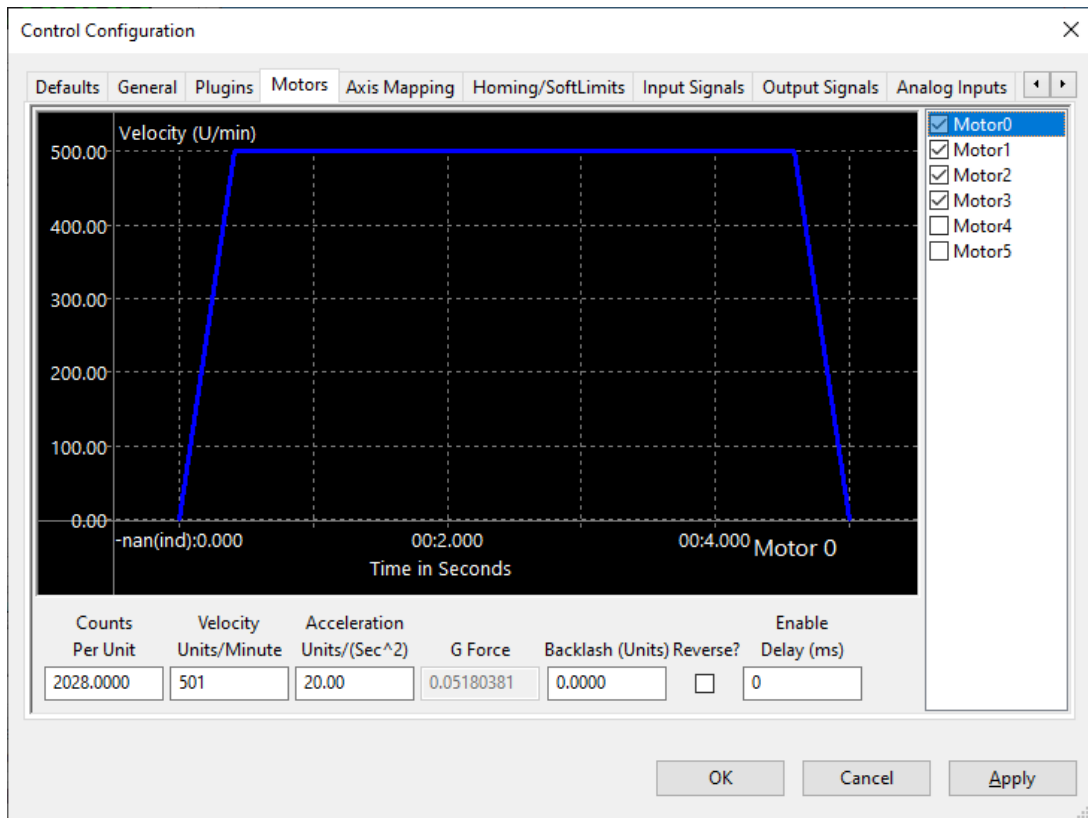
Select Configure->Control from Mach4 main screen.

# Configure Mach4 signals- Motors

Each motor must be configured for step per unit and speed.

The motors maximum velocity is set here.

Test these values carefully to be sure you are not pushing the machine too fast.



# Configure Mach4 signals- Motors

On the prototype machine we found these values

Axis	Step	Vel	Accel
X	2028	500	20
Y	2028	500	20
Z	8112	120	10

You should make accurate measurement by commanding a set distance and measuring the actual move.















# Configure Mach4 signals Axis Mapping

Enable each motor  
and associate the  
Axis with motor.

Note Mach4 supports slave motors when one motor is not powerful enough for an axis (large routers)

Control Configuration

Defaults General Plugins Motors **Axis Mapping** Homing/SoftLimits Input Signals Output Signals Analog Inputs

	Enabled	Master	Slave 1	Slave 2	Slave 3	Slave 4	Slave 5
X (0)		Motor0					
Y (1)		Motor1					
Z (2)		Motor2					
A (3)							
B (4)							
C (5)							
OB1 (6)							
OB2 (7)							
OB3 (8)							
OB4 (9)							
OB5 (10)							
OB6 (11)							

OK Cancel Apply

# Configure Mach4

Associate input pins  
with motors home  
position.

Control Configuration MyMill:0

Defaults General Plugins Motors Aux. Positions Axis Mapping Homing/SoftLimits **Input Signals** Output Signals

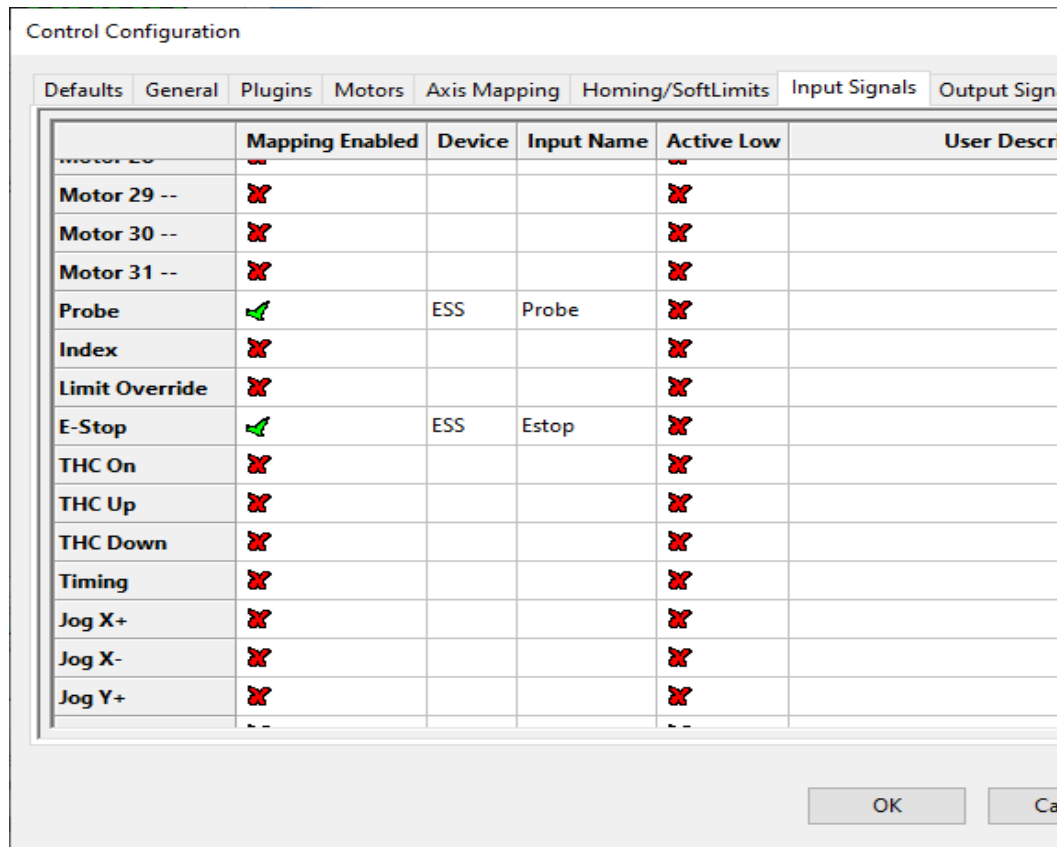
	Mapping Enabled	Device	Input Name	Active Low	Log Enabled	User Description
Input #58						
Input #59						
Input #60						
Input #61						
Input #62						
Input #63						
Motor 0 Home		ESS	Motor 0 ++ {P1-11}			
Motor 1 Home		ESS	Motor 1 ++ {P1-12}			
Motor 2 Home		ESS	Motor 2 ++ {P1-13}			
Motor 3 Home						
Motor 4 Home						
Motor 5 Home						
Motor 6 Home						
Motor 7 Home						
Motor 8 Home						

OK Cancel

# Configure Mach4 Inputs 2

Set the E stop  
signal.

Set the Probe  
(optional)



# Configure Mach4 Spindle

Set a Min and Max speed for each gear range of the mill.

This value must be set to 0

These two values must be set to 4000

The PM728 has two belt ranges.

Set MAX spindle RPM

Control Configuration

Input Signals Output Signals Analog Inputs Analog Outputs MPGs Tools Spindle Tool Path

	MinRPM	MaxRPM	Accel Time	Decel Time	FeedBack Ratio	Reversed
0	100.00	3000.00	2.00	2.00	0.00000	✗
1	0.00	0.00	0.00	0.00	0.00000	✗
2	0.00	0.00	0.00	0.00	0.00000	✗
3	0.00	0.00	0.00	0.00	0.00000	✗
4	0.00	0.00	0.00	0.00	0.00000	✗
5	0.00	0.00	0.00	0.00	0.00000	✗
6	0.00	0.00	0.00	0.00	0.00000	✗
7	0.00	0.00	0.00	0.00	0.00000	✗
8	0.00	0.00	0.00	0.00	0.00000	✗
9	0.00	0.00	0.00	0.00	0.00000	✗
10	0.00	0.00	0.00	0.00	0.00000	✗
11	0.00	0.00	0.00	0.00	0.00000	✗

Max Spindle Motor RPM: 4000.00 ☐ Wait on spindle to stabilize to 90 percent.

Spindle Override Delay: 25 (ms)

Step/Dir Spindle Axis: None (Axis must be enabled and mapped.) ☐ Enable Step/Dir Spindle rigid tapping.

OK Cancel Apply

# Configure Mach4

These values are appropriate for an automatic tool changer.

The screenshot shows the 'Control Configuration' dialog box with the 'Tools' tab selected. The dialog is organized into two columns of settings. The left column contains: 'Max Tools' (text box with '99'), 'Tool Change Type' (radio buttons for 'I on M6 line is next tool' and 'I on M6 line is tool to use.'), 'Tool Life Cancel Number' (text box with '100'), 'Tool Life Restart M Code' (text box with '0'), and 'Tool Life Type Default' (radio buttons for 'Cycle' and 'Time'). The right column contains: 'Tool Skip Group' (radio buttons for 'Current Group' and 'Specified'), 'Tool Exchange Reset Signal' (radio buttons for 'Clears specified group.' and 'Clears all groups.'), 'Life Count Override (time only)' (radio buttons for 'Disabled' and 'Enabled'), 'M99 Expired Condition' (radio buttons for 'TLCHB signal is not output.' and 'TLCHB signal is output.'), and 'TLCHB Signal' (radio buttons for 'Output for each tool.' and 'Output for the last tool in a group.'). At the bottom right are 'OK', 'Cancel', and 'App' buttons.

Control Configuration

Input Signals Output Signals Analog Inputs Analog Outputs MPG<sub>s</sub> Tools Spindle Tool Path

Max Tools  
99

Tool Change Type  
☒ I on M6 line is next tool  
☐ I on M6 line is tool to use.

Tool Life Cancel Number  
100

Tool Life Restart M Code  
0

Tool Life Type Default  
☒ Cycle  
☐ Time

Tool Skip Group  
☒ Current Group  
☐ Specified

Tool Exchange Reset Signal  
☒ Clears specified group.  
☐ Clears all groups.

Life Count Override (time only)  
☒ Disabled  
☐ Enabled

M99 Expired Condition  
☒ TLCHB signal is not output.  
☐ TLCHB signal is output.

TLCHB Signal  
☒ Output for each tool.  
☐ Output for the last tool in a group.

OK Cancel App

# Generating a Mach4 license key

Mach4 is licensed software.

A license is needed for each machine.

The license is keyed to the PC it is running on.

Each system in this project was provided with a registration code that is needed to activate a license.

# Generating a Mach4 license key

Click Help->About on the Mach4 menu bar

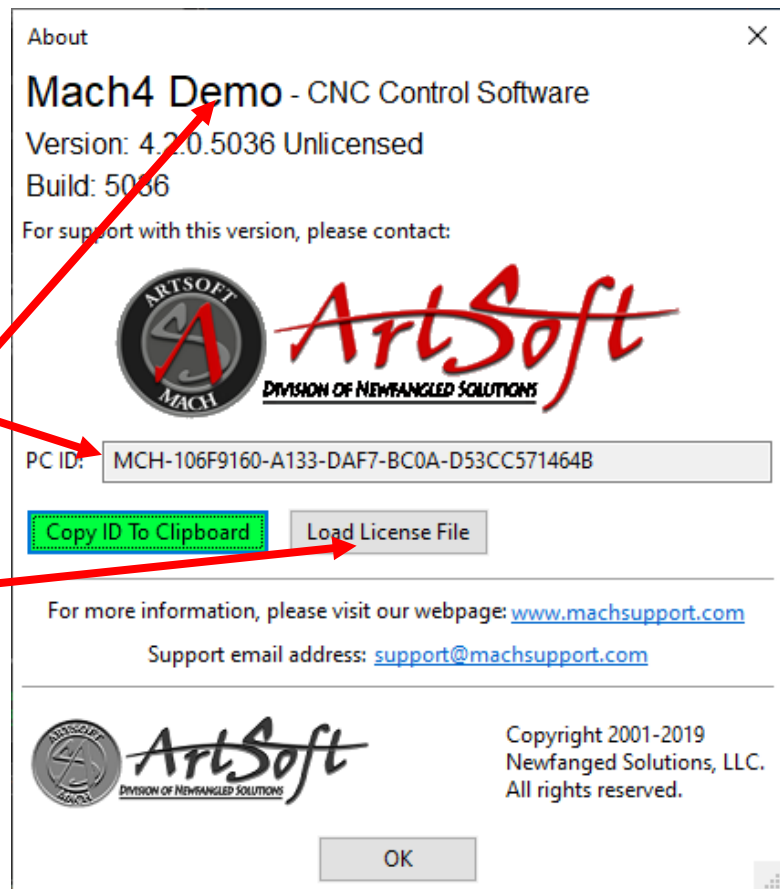
Copy this PC ID to clipboard.

On the Machsupport.com site paste the ID when asked.

A key file will be E-mailed to you.

Load it here.

DEMO will be changed after license is installed.



# Mach4 license

After the license key is successfully loaded Mach4 will change references to DEMO to your user ID.

There are some restrictions built into Mach4 DEMO that will be removed after the license is installed.

Certain changes to the PC, replacing hard drive or net card, will change the PC\_ID

This will require getting a new key from [Machsupport.com](http://Machsupport.com)



# Backup

Mach4 stores all configuration values and some current operation data in a file `C:\Mach4Hobby\Profiles\MyMill\Machine.ini`.

This file is saved during shutdown.

A copy is also stored in the folder `\Backups` in the Profile folder.

A revolving list of 20 backups are saved with a 2 digit number appended.

If you ever have a problem and want to go back to a previous version simply move the file from `\Backups` to replace the current `\Machine.ini`, removing the 2 digit number.

# Calibrating Spindle Speed

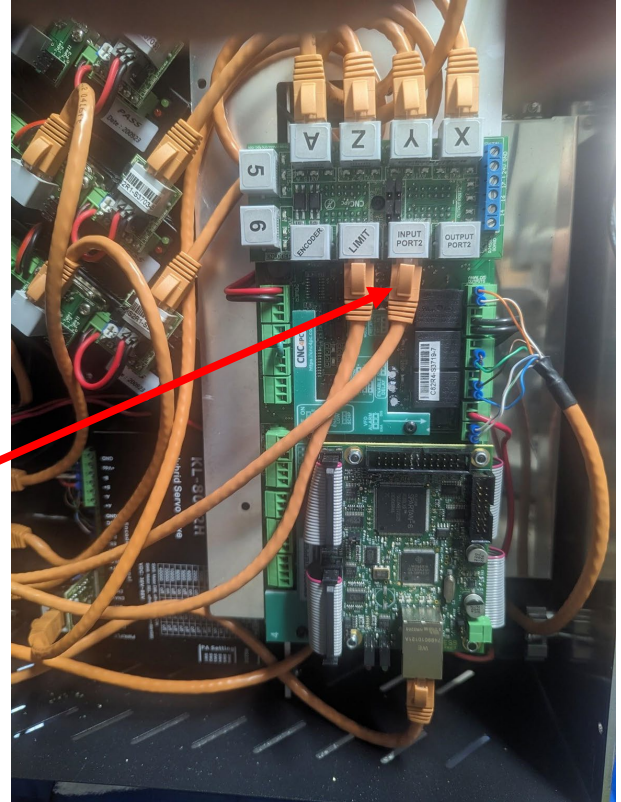
The spindle speed is controlled by a PWM signal generated by Mach4.

A circuit on the C82 control board converts this pulse stream to a varying DC voltage between 0 and +10 volts.

Use the MDI window to set the machine to run at its mid-speed, 2000 RPM

You can use the MDI command 'S2000 M3' to set the speed.

Adjust this pot to set the speed.



# Spindle Direction control

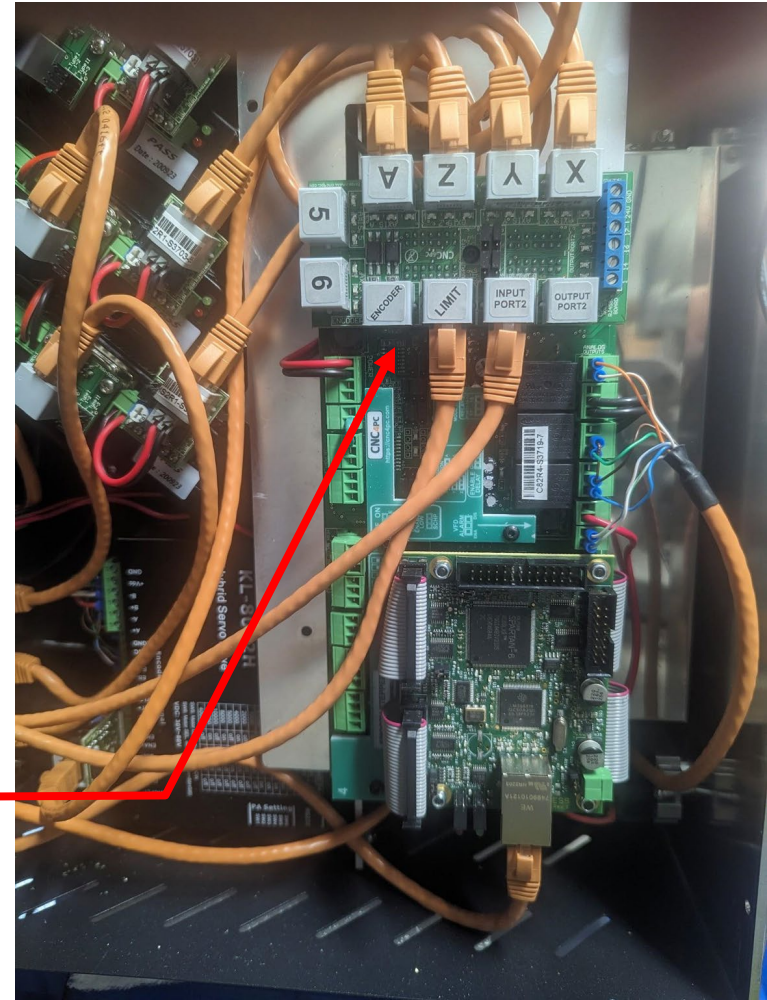
The C82 board has outputs for Forward and Reverse run of the spindle motor.

There are two common schemes for managing these signals, one commonly used in the US, another in Europe.

The C82 board has two jumpers to set this.

If set to INT the motor will only run in one direction.

For this control the jumpers should be set to the US position.



# Congratulations

You should now be ready to make parts with you new mill.

Good Luck!