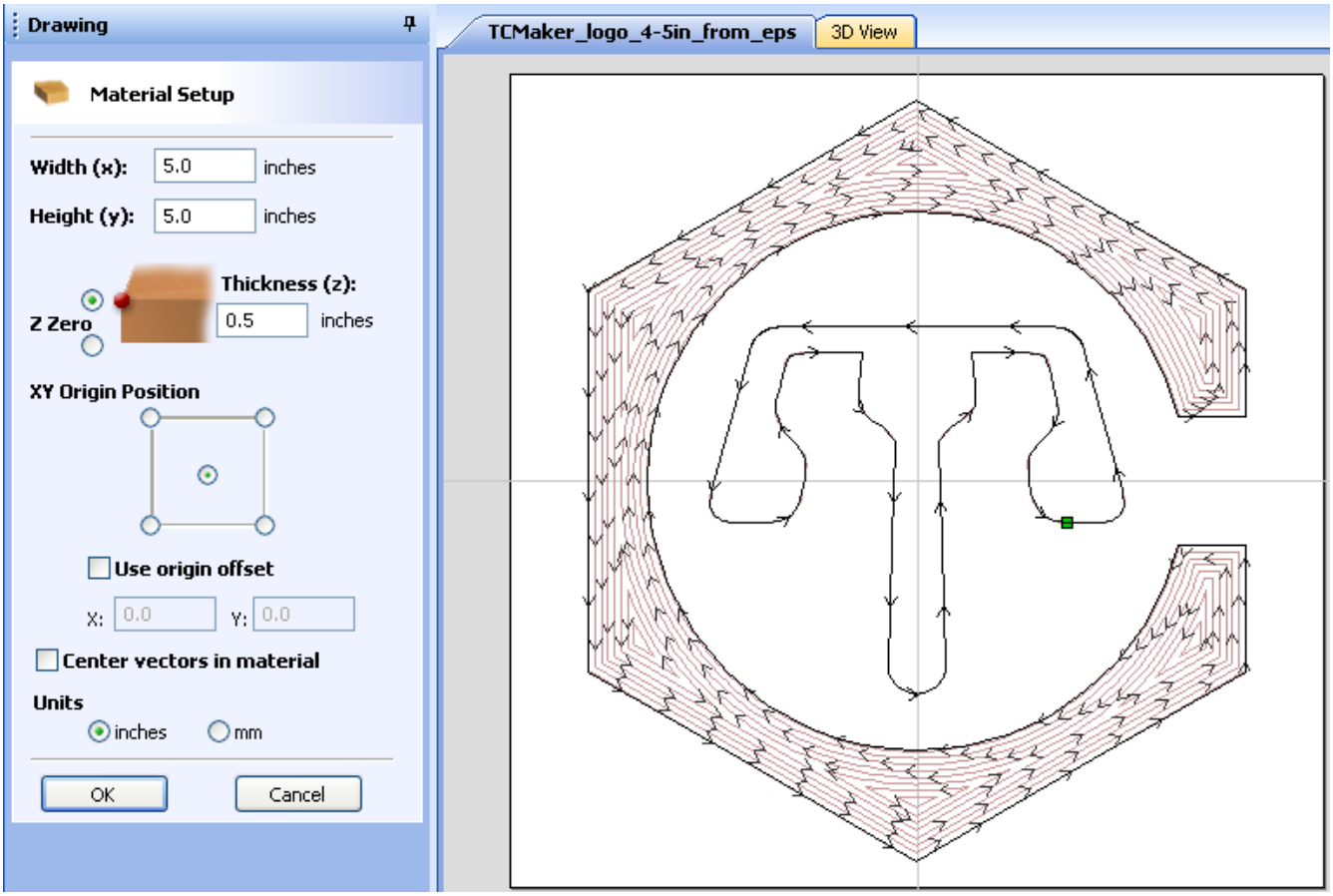
CNC Router - Operation Guide Mach3 – 4 x 4 Router
02/01/2013

Material selection
Figure out how you will secure the work piece first, make sure you make allowances and leave sufficient clearance for clamping the work securely, remember the collet nut is much bigger than the bit also the router and Z axis tool support itself needs to clear the clamps.

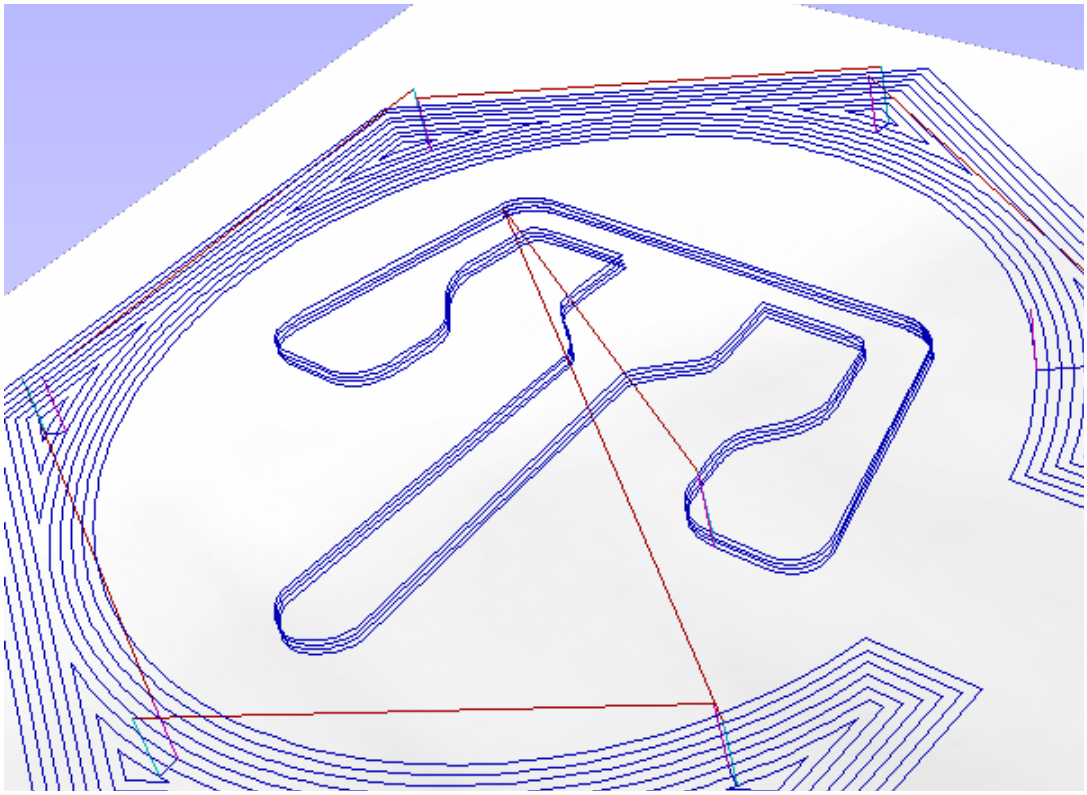
G-code creation
This is a huge topic, and I hope to put together a FAQ or something on it in the future. The images here are from Vectric Cut2D, which I own and can help you use to create code, but it can't live at the Hack Factory and it is moderately expensive. I'm experimenting with an Inkscape driven tool path creation method and it's looking promising, but has a steep learning curve and it is difficult to keep up with its chain of dependencies.

Set the origin in the center, or on a known reference point.
Note: You will almost always want to set Z=0 at the surface of the material, I.e. all cuts are at a -Z.

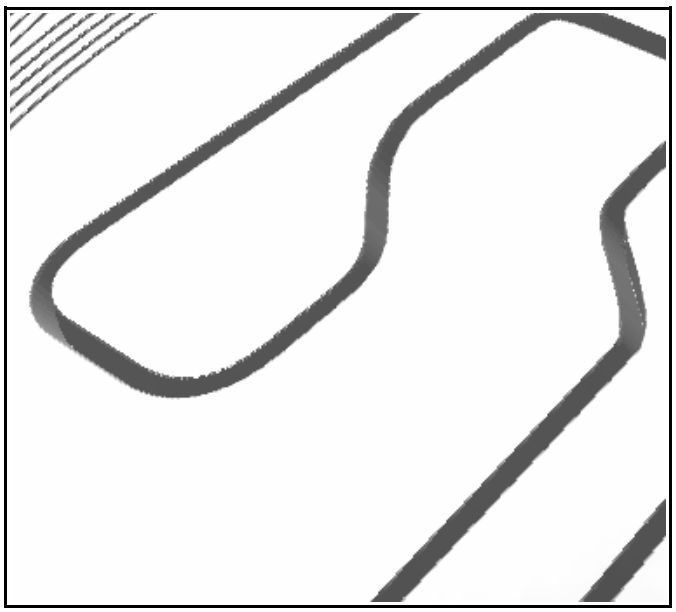


The image above is from Vectric Cut2D. The panel on the left sets the origin relative to the material you'll be using. The image on the right represents the tool paths as they relate to the material. The lines that cross in the center bisecting the material are the X and Y axis lines meeting at the origin. Though it is not toggled, the “Center vectors in material” feature was used to accomplish this. There are many means of generating g-code, most will have these basic features to allow you to set the origin in relation to the material. Also note that inches or mm must be checked, the g-code needs to be created in the correct units of measure, as the machine is set for one or the other when it is configured. (The router is in inches, if you have a drawing in metric units, convert the drawing first)

Make your initial files have slow and shallow cuts. (shallow would be ½ the bit diameter as a rule of thumb)



Above is a 3D representation of the toolpaths, note the multiple stacked lines on the “T”. These indicate multiple shallow passes will be made to obtain the desired depth. As seen in the 3D rendering of the cut below.



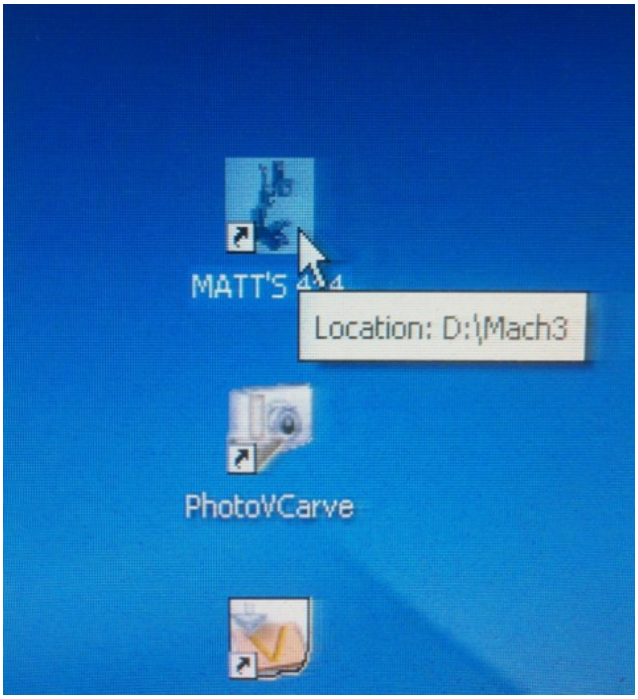
Clearance height should account for screw heads, clamps, other work piece features.

(discuss these, use of a known square edge or just in the center of a large piece, if you don't care, and everything is being cut)

Starting the System:
The 4 x 4 CNC Router is running Mach3 which is a Windows based control system. The first step is to turn the PC and monitor on, if they are not.

The Login information is: Matt Rymer - Hackfactory1

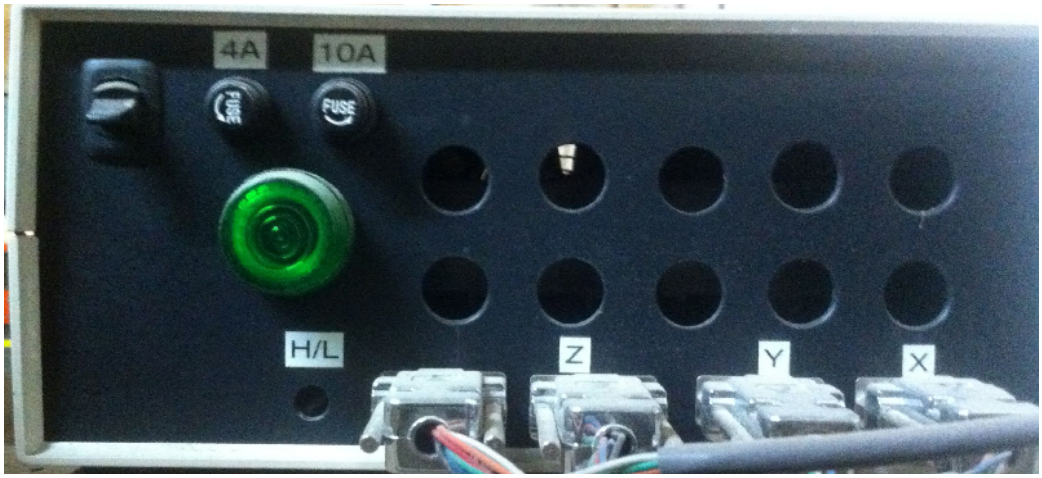
Start Mach3 with the “MATT'S 4x4” icon on the desktop



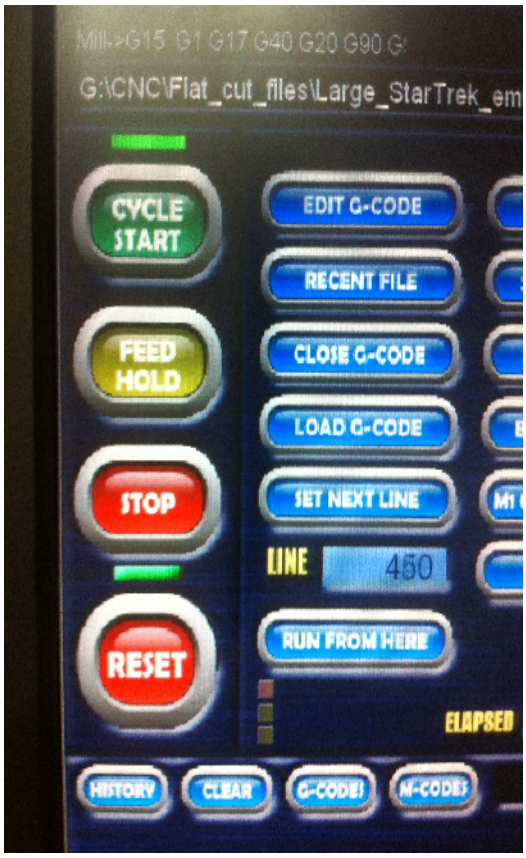
If you are not using the large 4 x 4 CNC, please refer to the “CNC Router Guide for 2013”

This is the default Mach3 screen, and where we will discussing settings in this guide.

Then power up the control box. On the back right edge of the 4 x 4 Router, the power switch is the toggle switch on the upper left as seen below.

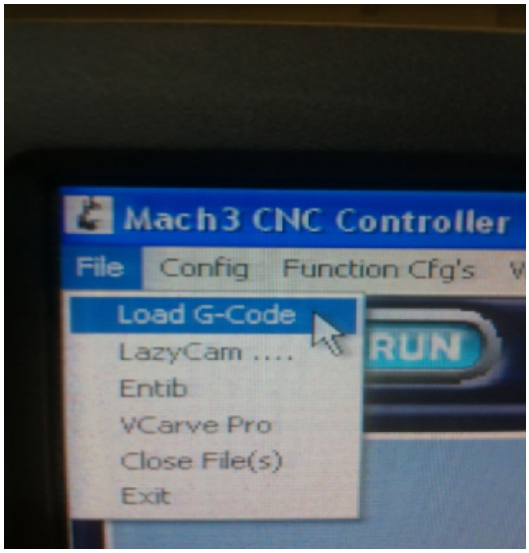


Within Mach3, when you first start up, you need to toggle the reset button. You can use the on screen reset button or the reset button on the pendent. Reset serves as the E-Stop for this system.

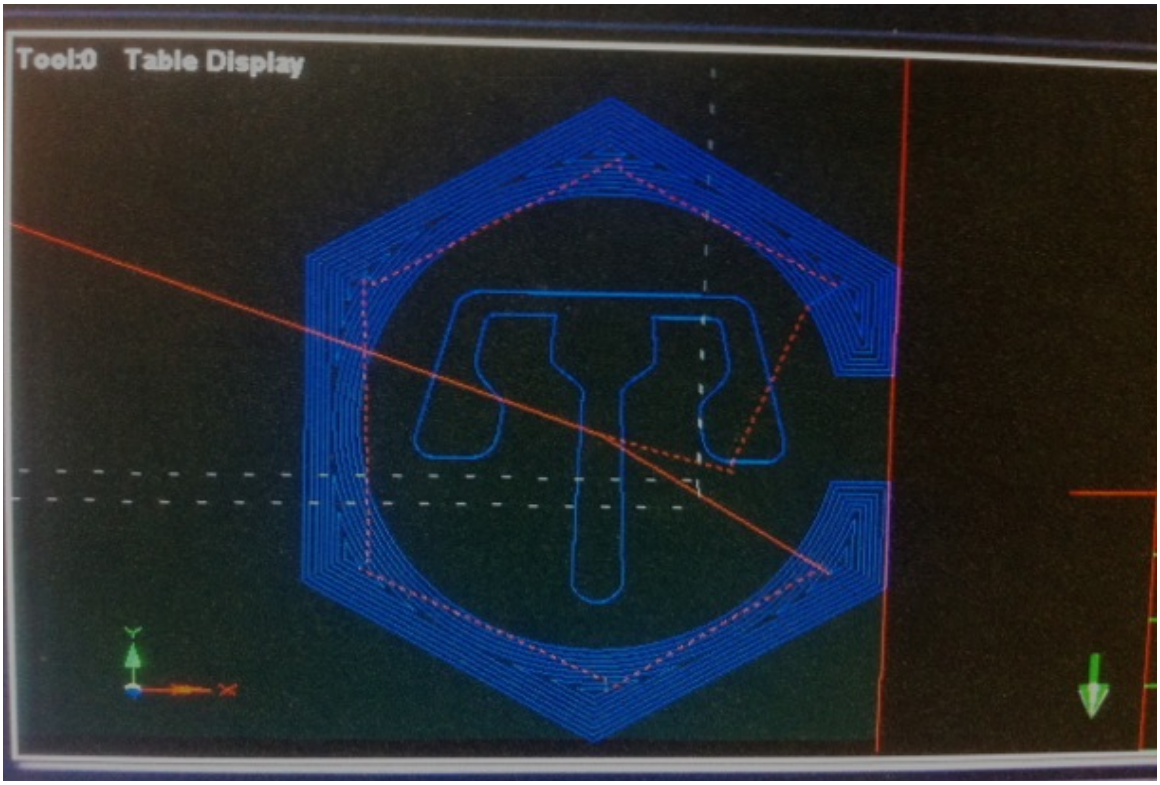


The System is now live.

Orienting the g-code file:
You can next either home the system or load your file and then home the system. I chose to load a file we'd all be familiar with next. Loading a new file is simply a matter of File - > Load Gcode File (select your file)



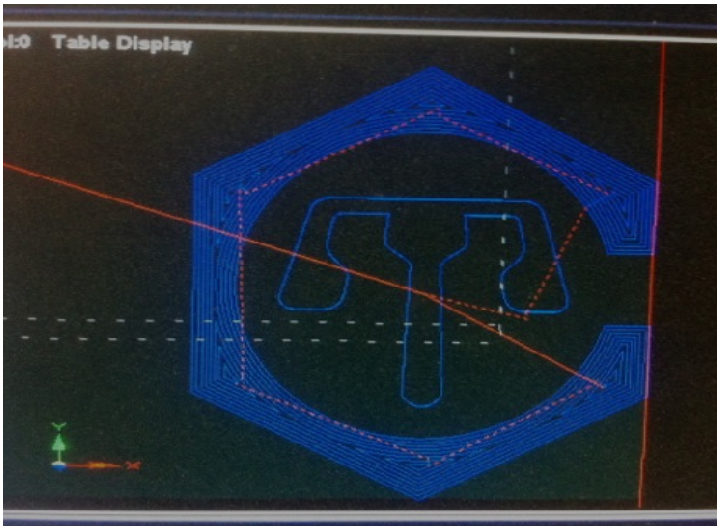
This is the newly loaded TC Maker g-code file



Manipulate the file image on screen within Mach using the mouse functions below.

Mouse buttons:
Left button is 3D pan.
Right is drag image around.Center wheel is Zoom.
Orienting the machine environment:

The system now needs to orient the tool to it's physical environment. Within Mach, the working envelope of the system is the cube outlined with dashed white lines. (they don't seem to track quite right to my mind, I'll investigate further) In order for Mach to understand the tools current location the system needs to be “homed”. This is currently a manual operation on the 4 x 4 router, but it's pretty easy. First lets understand how to move the router / tool via the pendent control and the keyboard keys.



Manually Jogging the tool to a given location:
Which is just a complicated way of saying manually putting the tool where you would like it. The pendent has a button for each axis which is held down to move the corresponding axis, the black ring on the controller is then turned either left or right to move the axis. The ring snaps back to its center stopped position when released, and is a proportional control further left or right is faster motion. The center dial is the fine feed for the axis.

Directionally:
X down to the left = move left | down to the right = move right
Y down to the left = move forward | down to the right = move back
Z down to the left = move down | down to the right = move up

Left and Right arrows move the X axis left and right,
Up and Down arrows move the Y axis backwards and forward.
(It's best to just make sure the bit is above all obstructions and then just play with the controller on the at low speed to get the hang of it.)

Homing:
Now that we can drive the tool where we wish it is time to home the system. Again ensure that the Z axis is up so that the tool is clear of any obstructions when moving it. The destination is the left front edge of the table. Be careful when approaching the end of travel for any axis as the system has only soft limits, and they may not be correctly defined prior to homing! (in other words go slowly at the extremes of travel) The destination for homing is pictured below, the bit is centered over the front left corner of the table.

Once the tool is in the home position we need to tell Mach that, “this is home”
Prior to homing the system position indicators may look something like this.

Note that the red indicator above the “Machine Coords” button is light. Homing is to set the machine coordinates, and this button must be active / illuminated as shown above. Once the X and Y axis are positioned at the left front edge of the table. Bring the Z axis down to the height of the spoil board you will be using underneath your work piece, and click the “Ref All Home” button, all of the axis indicators should now read “0.000”.

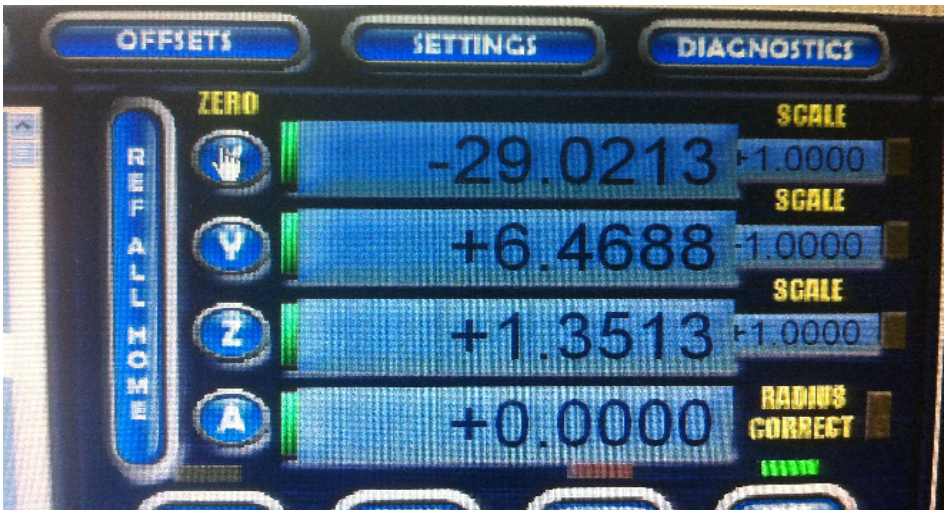
System Interface homing examples:
Next toggle the “Machine Coords” button so that the red light goes off, Mach is now homed, and the screen should look something like this. The axis indicators may not read zero at this time.

To clear the coordinate system offsets we will zero the X, Y, and Z axis here before moving the tool, this process will be repeated when we “touch off” on the work piece next.

To set each axis to zero simply click on the X, Y, and Z buttons under the ZERO header as seen above. Note the mouse is hovering over the Z ready to zero it.

Orienting the work piece to the machine environment (touching off):

The next step is to inform the system where the work piece is. This is known as “touching off”. It is OK if your piece is not secured at this point, it's best to orient the system, file and physical work piece first. You will then have a visual and verifiable representation of all tool travel, which is very helpful in setting up clamps, etc so that they will not interfere with the cutting process. Drive the router to where ever you have set the origin on your material, as described above in **Manually Jogging** above. In our example file the origin is set in the center of the piece, so roughly center the material on the machine bed (with a spoil board underneath!), and jog the router near to the materials center, and begin the “touching off” process.



We will begin by “touching off” the X-axis. To do so select the X-axis button under the zero column as we did just after homing.

(Note the new X and Y axis readings which indicate the tool has been jogged from its machine home position, remember the file origin is in the center of the TC Maker symbol.)

You can see in the image above that X-axis is now at 0 and the image is centered left to right on the tool. The tool is represented by the red X.

Next we will touch of the Y-axis in much the same way. select the Y-axis button under the zero column. For the Y-axis negative numbers are to the front, and positive numbers are to the back of the machine.

The X and Y axis are now both zeroed, and you can see that the red X is centered on the file, so the machine now understands that the current tool location is the center of your file. You can now ensure that your material is centered under the tool, and then we will discuss securing your work piece.

Securing the work piece:

Now that you can see the extents of the piece you will be cutting out, and the tool paths that will be traveled, you can clamp the work piece to the table.

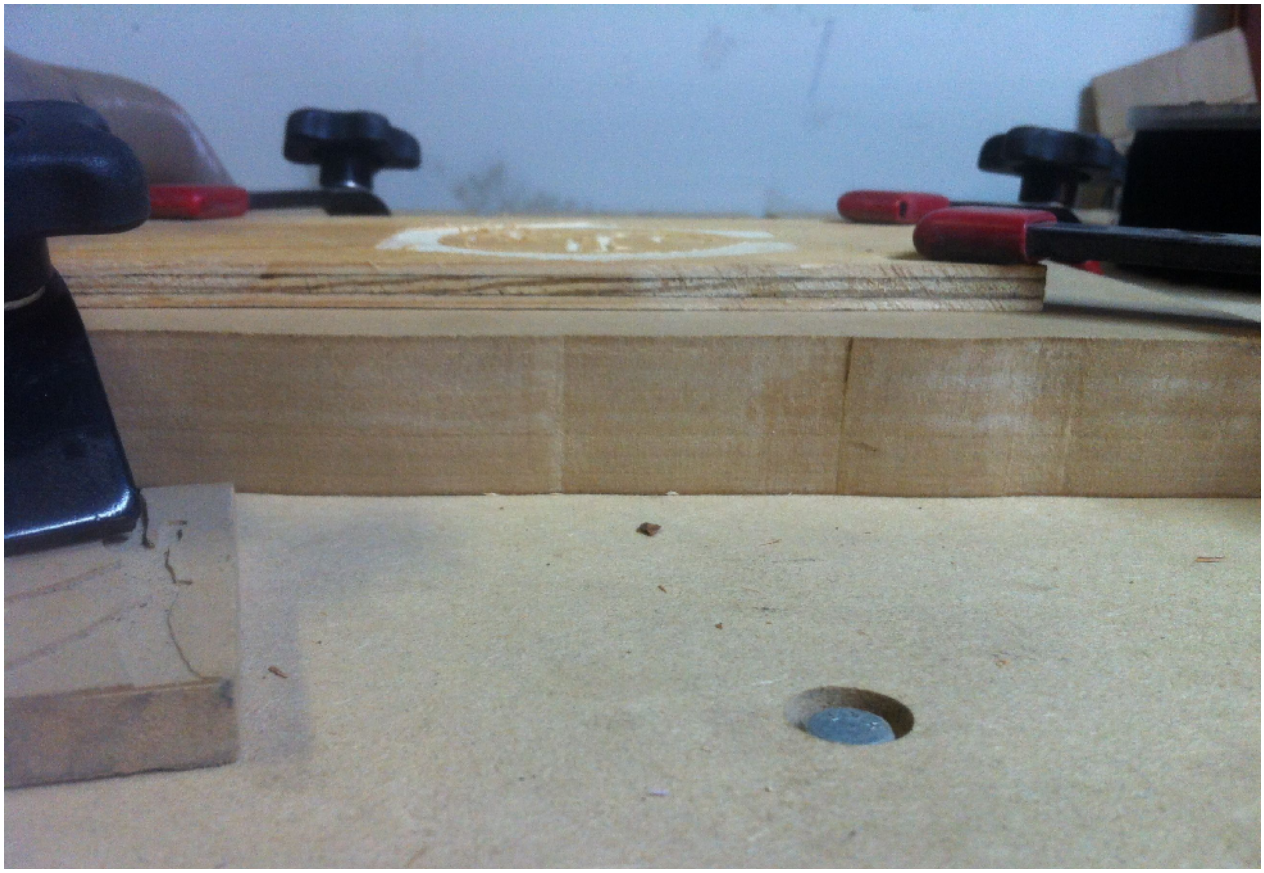
On the 4 x 4 Router you must use a spoil board under the piece you will be cutting. The table surface is not a spoil board and there should be no chance of accidentally cutting the table top!

Note the thick piece of MDF below the plywood into which the TC Maker logo is cut.

To secure both the work piece and the spoil board use the t-slot clamps, these slide into the t-slots on the table and then screw down. You may wish to block up the back of the clamp so you have a downward angle on the clamp as it holds the work piece. You need to be keenly aware how much the clamps protrude above the work piece surface, especially if the work piece is close in size to the file you are cutting. The router needs to fit around the clamps, and the Z axis on the 4 x 4 router is limited to about 3 total inches of travel.

This is a good perspective to see how much the clamp heads protrude, and where they are relative to the cut file. Once the work piece secured, you can drive to the extents of the tool paths with the controller or arrow keys and verify that the router body, collet nut, and bit will not run over any clamps etc.

Please ensure that the Z axis is at a safe height and take care to not collide with anything!
You may need to pan the image to keep a straight down perspective on the work piece as you go.



Mouse buttons:
Left button is 3D pan.
Right is Zoom.
Center is 2D pan.

Note: Cutting a part out from material that is the same or nearly the same size as the finished part is not an easy task, as room to hold the material with clamps does not exist, in such a case you may need to cut internal features such as holes first and then screw the part down before cutting it out, plan carefully, and review your plan before you start cutting! Buy extra material whenever possible.

Preparing to cut:
Cut Air first, before touching off Z on the work surface, it's a good idea to:
A: drive to the extremes of the tool paths and check clamp placement as mentioned above.
B: Cut air, which means

> Place the end of the tool about an inch above the work piece surface, and touch off the Z axis at 0, you can then run the program with the spindle off and verify that no tool paths with run into clamps, off the stock, etc.

Once you are satisfied that the piece is setup correctly, you can set the tool on top of the workpiece and touch off Z at 0 again, to begin the actual cut.

Powering up the Router motor.
The router is a Hitachi router, and it is has a speed adjustment dial on its side. Some materials, especially those that melt. (Foam, plastics, etc) will benefit from running at less then full speed, be aware that torque is lost as the speed is reduced. If cuts in wood are burning, it is likely that the tool is moving to slow, and increasing the feed rate is the best remedy, you may need to have more shallow cuts to accomplish the cuts.

The power switch for the router is on top of the router itself. Turning it on will run the dust collector too, ensure that the “dust shoe” is in place before turning on the router.

First cuts:

You and everyone near you have your safety glasses on right? Hearing protection is also highly recommended!
You may want to hear the router and bit make it's first few contacts, but the prolonged whine is hard on your hearing. The Hitachi is a 1 ¾ HP router, it isn't huge as routers go but it can easily snap 1/8” and 1/4” bits, cut through aluminum clamps, and generally ruin stuff in a hurry, human appendages included, do not become complacent while running the CNC router, and never leave the machine while it is cutting, if you need to leave the area, click the “Feed Hold” button to pause the job, power the router off and do the reverse when you return, please be safe!
You can control the speed of the tools movement in real time by adjusting the “Feed Rate” down to 50% and up to 200% of the rate set in the CAM software with which you created the tool paths and gcode file.

Start slow, which I consider 20-40 IPM much below that and wood will burn and the bits take excessive heat and wear rapidly. An exception to this would be very small bits, they are prone to snapping. You'll need to experiment depending on the material. In general the depth of cut, which is the amount that the tool takes in each pass should be the diameter of the bit at most and closer to the radius for small bits or when in doubt.

Appendix of sorts:

How to change a bit:

The collet wrenches live near the router, location may vary. This is actually not the 4 x 4s Hitachi router but it is a very similar process.

The small wrench goes up above the nut on the shaft of the spindle. It's hard to see, running the Z-axis up (carefully there's no limit switch) helps to see. Also bringing the router to the front of the table helps. I try and put something under the bit, especially for small or fragile bits, because it's hard to both loosen or tighten and hold the bit, pink foam scraps work well.

To remove the current bit.
Obviously a different router is pictured, but the technique is what is important, and it is the same. Place the small wrench above the nut on the spindle flats, and the large wrench on the like as pictured below.

Then pull the wrenches towards each other.

Collets and Bits:

Bits will be supplied for class, when you want to cut your own parts, you will be expected to provide your own bits, or may use the community router bits in the tool chest in the wood shop. (Check on availability of the size(s) and type(s) you need.

I have found that the Rotozip bits are good bits to learn on in soft materials like foam and Coroplast.. The Saber Cut version has a flatter bottom, more like an end mill. The standard points are more drill bit shaped. They need the 1/8” collet adaptor as pictured below. (that's a Saber cut)

The other collet adaptors are for other sub 1/4” shank bits, there should be 3 not sure where the third one has gone. The live in the little envelope with the collet wrenches.

Here's a few more bit types that are commonly used in CNC projects..

In the center are End Mills (these are High Helix Aluminum) ones, they work well on plastic too, not so much on wood. On the right are wood bits, the top one being a shallow, maybe 90 degree Vee bit.

Comments, corrections requests for further details gladly accepted, the guide like the router is a work in progress.

Pete