

# HOW TO MAKE A CIRCUIT BOARD USING THE MODELA MILL AND CAD.PY

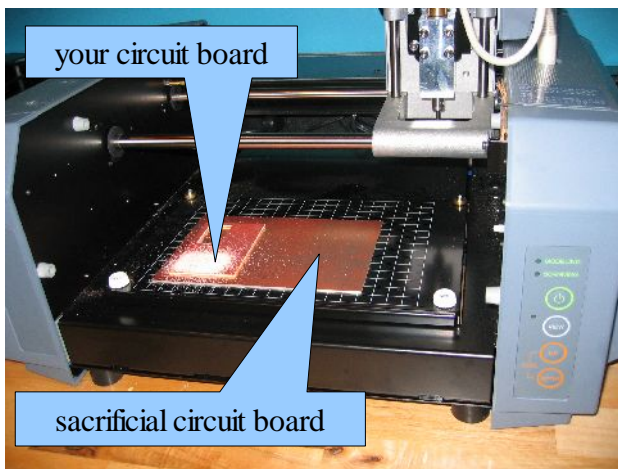
by R. Scott Zitek, Lorain County Community College

Version 1 - created on Aug-8-2007

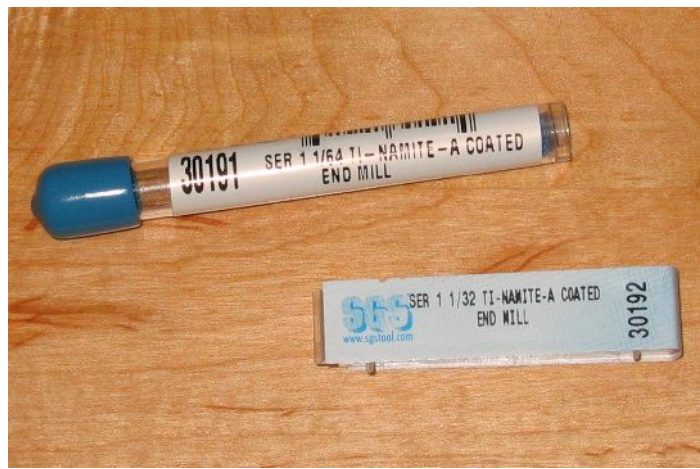
## WHAT WE ARE MAKING:

A small, one-sided, surface mount circuit board.

## WHAT YOU WILL NEED:



*Modela Mill*



*Tooling*

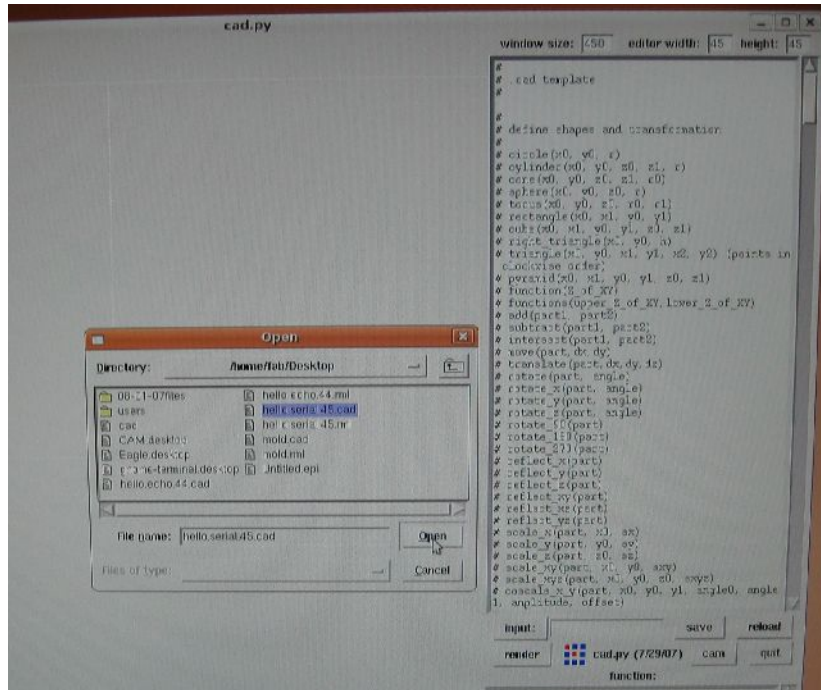
- Modela MDX-20 NC milling machine (or equivalent NC milling machine)
- 1/64 inch, 4 flute flat endmill for the milling the circuit traces\*\*
- 1/32 inch, flat endmill for the cutting the circuit board to size \*\*
- 2 inch x 3 inch piece of one-sided FR2 circuit board stock (copper coating over an epoxy/paper base)\*\*
- Larger piece of FR2 circuit board stock (approximately 6 inch x 4 inch) to be used as a sacrificial base layer – if not already present\*\*
- double sided tape
- CAD.py program
- CAD.py circuit file

\*\*See inventory list: <http://fab.cba.mit.edu/fab/inv.html>, Carbide Depot for end mills, and Crossley and Bradley for FR2.

## HOW TO DO IT:

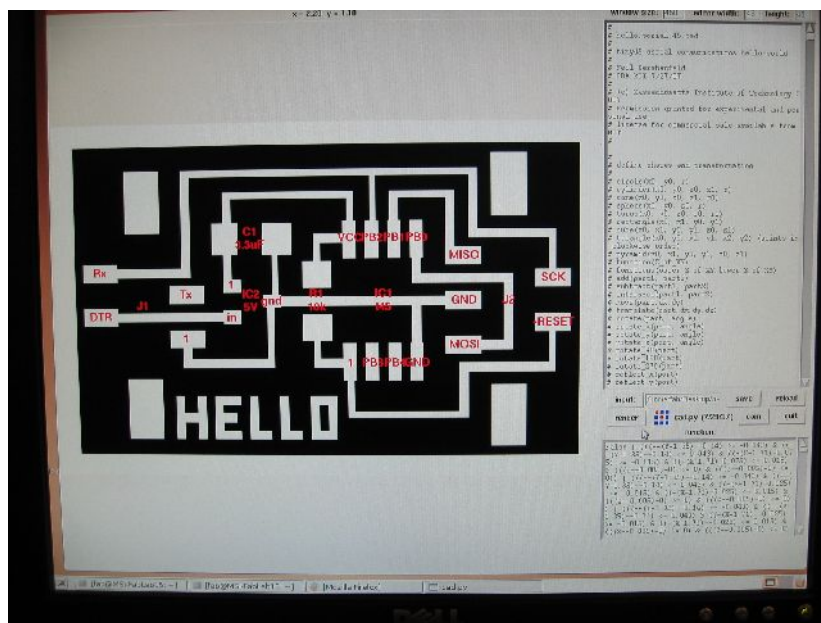
### Preparing the to cut the circuit with CAD.PY

- 1) Start CAD.PY (download for free from <http://fab.cba.mit.edu/fab>)
- 2) Click on the **input** button and then open the desired CAD.py circuit file. For this example, we will use **hello.serial.45.cad** (which can be found at <http://fab.cba.mit.edu/world/US/MSI/events/07.07.HTMAA/index.html>).



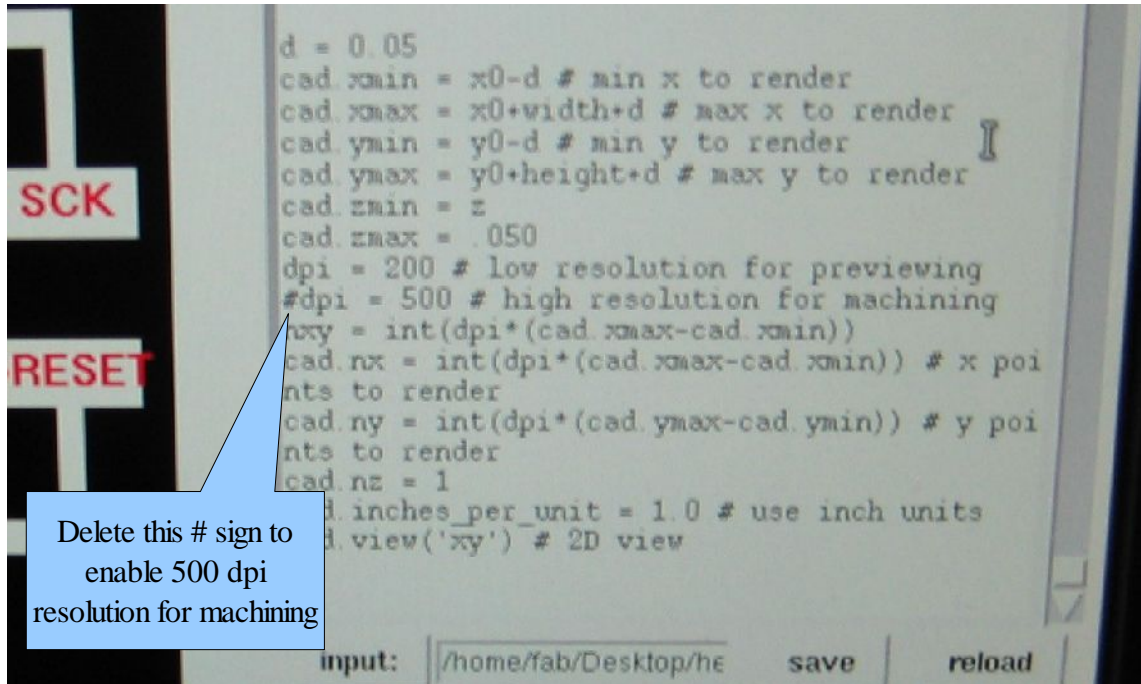
*Open (circuit file) dialog box*

- 3) The circuit should appear in the CAD.PY preview window. Click on the **cam** button.



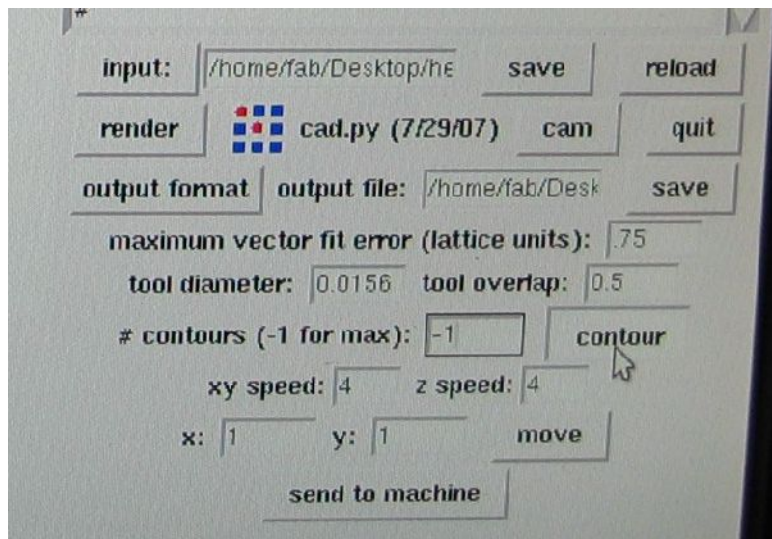
*Circuit in CAD.PY*

- 4) Scroll down to just about the end of the circuit file program. Find the line of the program “#dpi = 500 # high resolution for machining”. The text following a # sign is consider to be a comment in the program. Delete the # sign so that this line will be enabled when the program is executed.



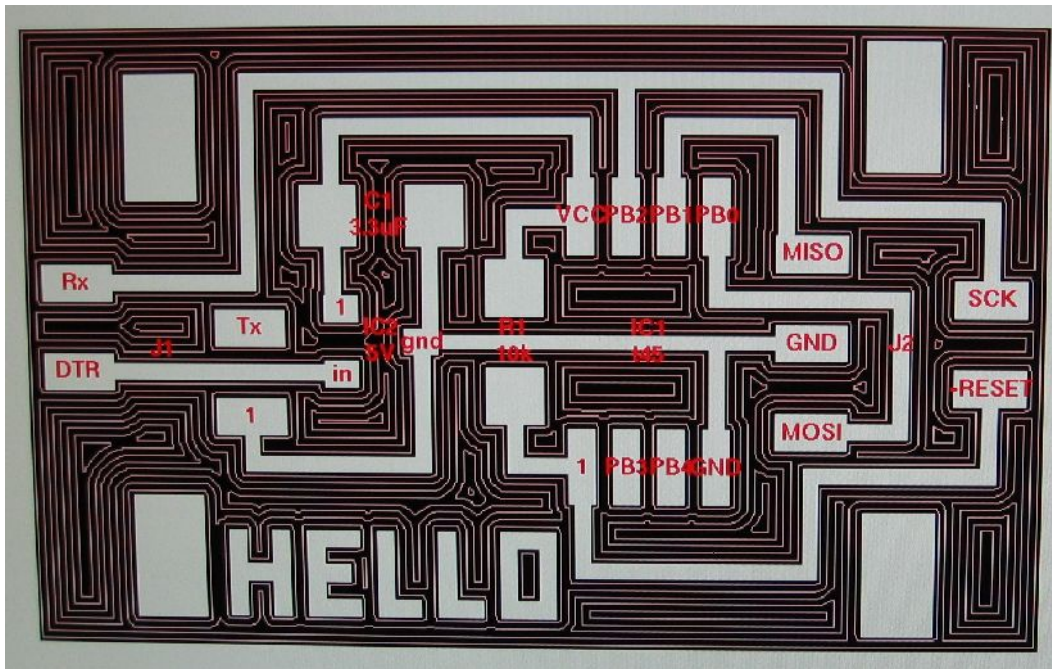
*Editing the circuit program*

- 5) Click on the **output format** button and select **.rml (Modela)**.
- 6) Configure CAD.PY as follows for circuit cutting (also documented in the circuit program):
- tool diameter = 0.0156 (1/64 inch endmill)
  - xy speed = 4
  - z speed = 4
  - # contours = -1 (maximum)

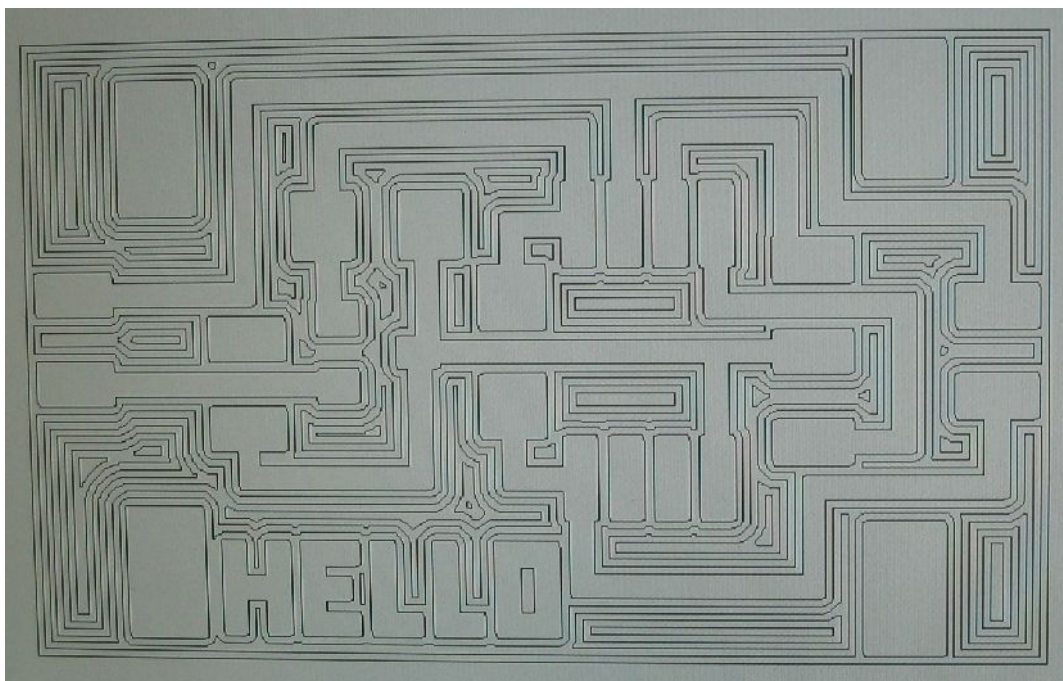


*Circuit cutting settings*

- 7) Click on the **contour** button. CAD.PY should render the tool paths needed to machine off all the copper not needed for circuit.



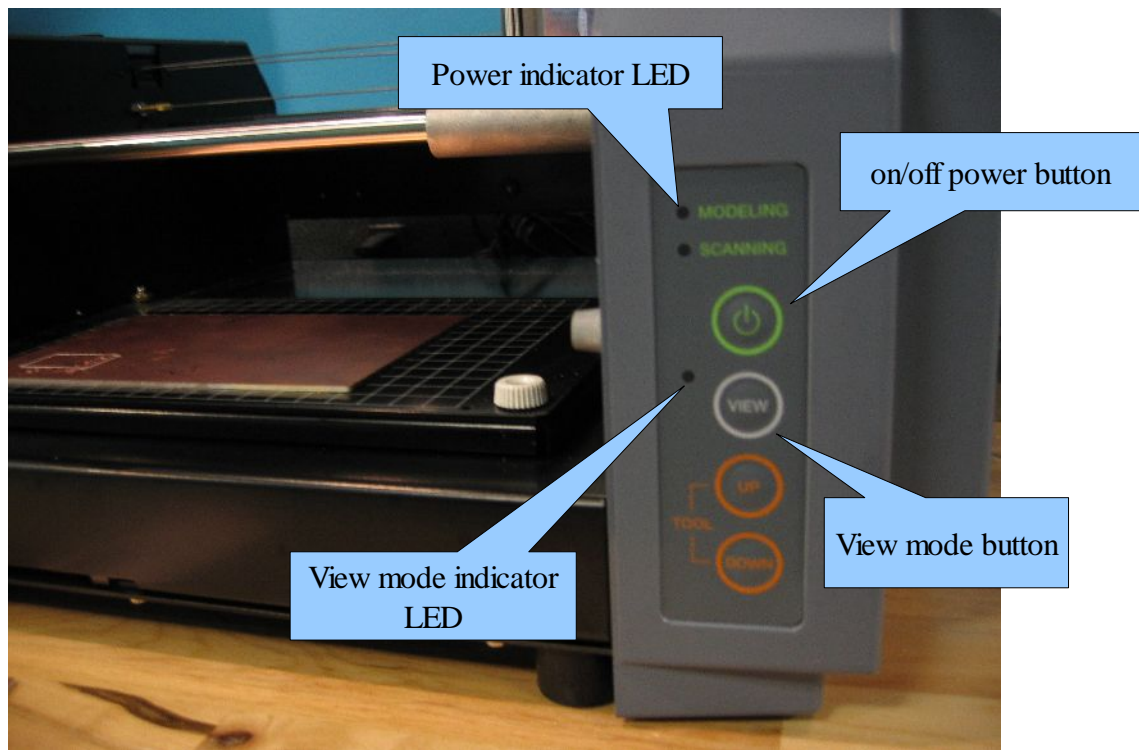
*Circuit after performing contour with setting of -1*



*Same circuit showing just the tool paths*

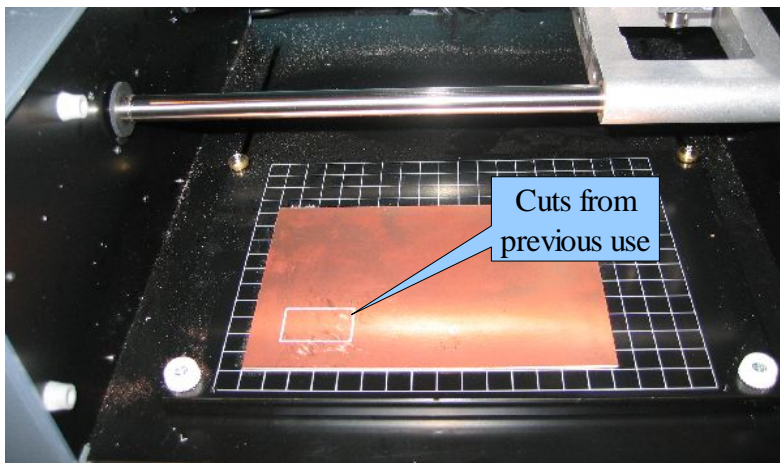
## Preparing the Modela Mill and circuit board for cutting.

- 1) Turn on the Modela mill by pressing the green **on/off** power button located on the front of the machine. The small green LED located to the left of the word MODELING should be illuminated.



*Modela control panel*

- 2) If the View mode indicator LED is not illuminated, press the **VIEW** mode button to put the machine into View mode. When in view mode, the tool will move to the far right side of the machine and the material bed will move to the front of the machine. View mode is useful for loading and unloading stock. When in View mode, the View mode indicator LED will be illuminated.
- 3) If not already present, mount a large piece of FR2 circuit board stock (approximately 6 inch x 4 inch) to the material bed of the mill. This piece will serve as a sacrificial base layer when cutting out your circuit board.



*Mounting location for sacrificial base layer*

### Notes:

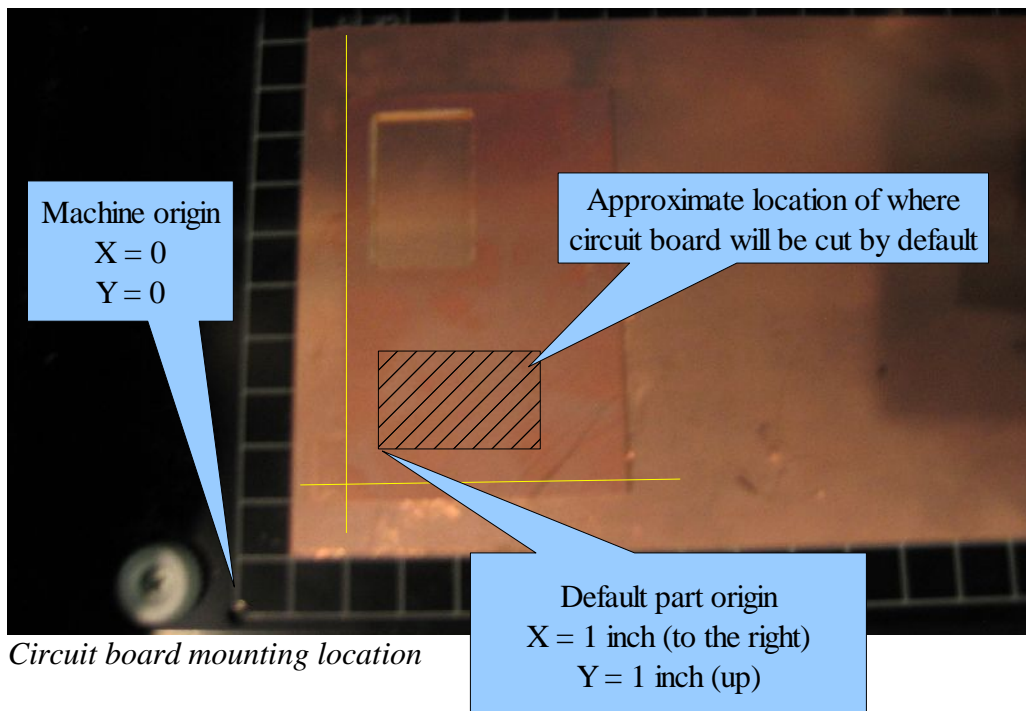
- 1) Attach with several strips of double-sided tape.
- 2) Do not overlap tape.
- 3) Mount 1 square over and 1 square up (as shown in example diagram)

- 4) Take a piece of one-sided FR2 circuit board stock approximately 2 inch x 3 inch and turn it upside down so that the cooper is face side down. Put pieces of double sided tape on the back of the copper board. The area where you will be milling needs to be solidly attached to the surface of the Modela bed, so be sure to put lots of tape, close together on the back, but not overlapping at all.



*Preparing the circuit board for machining*

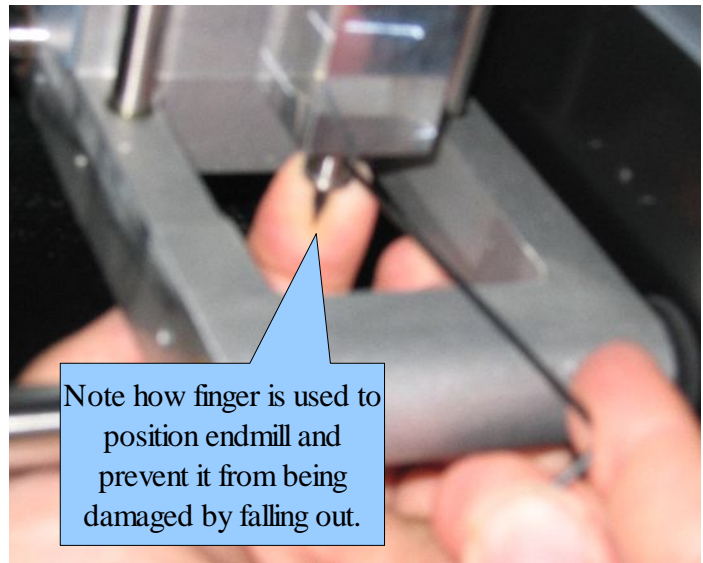
- 5) The material bed on the Modela has a grid of cm sized squares. Place your material 2 blocks over and 2 blocks up to accommodate the default starting point of 1 inch over and 1 inch up. Now using a piece of cloth or your shirtsleeve firmly adhere the board to the bed by pressing down and rubbing back and forth over the copper board. Don't do this with your fingers as the oil from your skin can affect the conductivity of the copper traces, so try not to get too much finger oil on the board.



- 6) Using the allen wrench provided, install the 1/64 inch, 4 flute flat endmill used for the milling the circuit traces. Be careful when handling endmills because they can be very sharp. Also be careful not to damage the tip of the endmill by allowing it to fall out of the collet. Be careful not to push the endmill into the collet too far. For now, the endmill should be mounted with about 1/2 inch extending below the spindle collet. There are two set screws on opposite sides of the collet. Do not over-tighten these set screws, they only need to be snug.

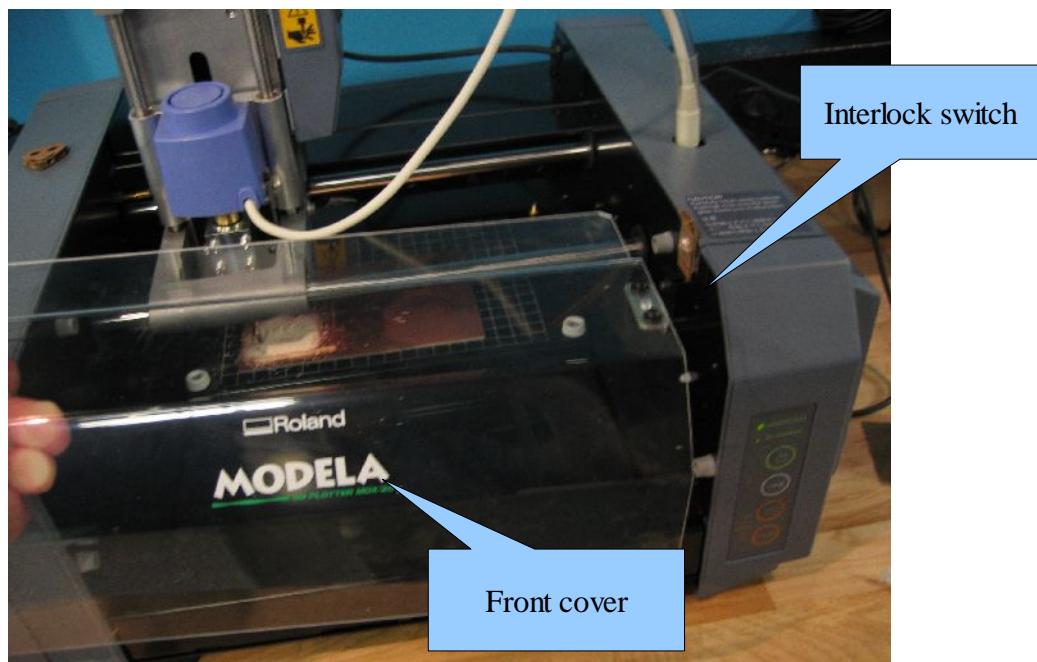


*Allen wrench*



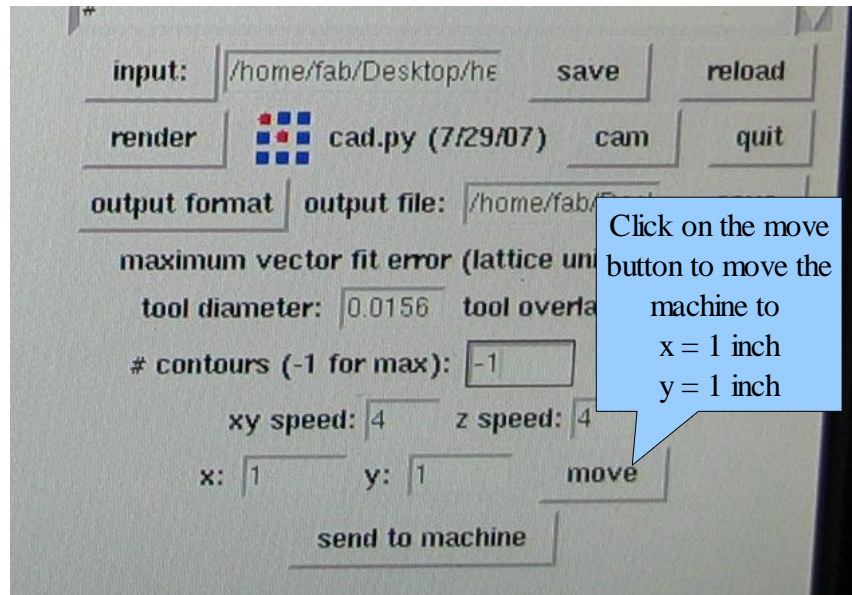
*Installation of endmill*

- 7) Press the View button on the front of the Modela to exit View mode. If the front cover for the machine is installed correctly (or the interlock has been over-ridden), the machine should move to its last position. If the machine looks like it may crash, press the **View** button to stop it.



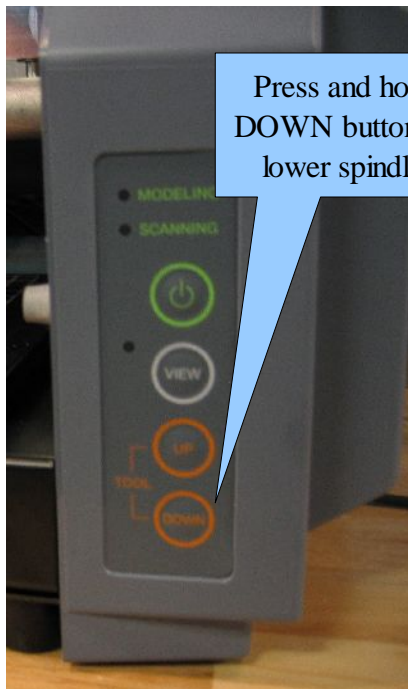
*Modela front cover*

- 8) We now need to move the machine to define the top surface of the circuit board. To move the machine above your part we will use the CAD.PY program. Make sure that CAD.PY is configured for x: 1 and y:1 as shown below. Click on the **move** button. The machine should move the tool so that it is located above your circuit board.

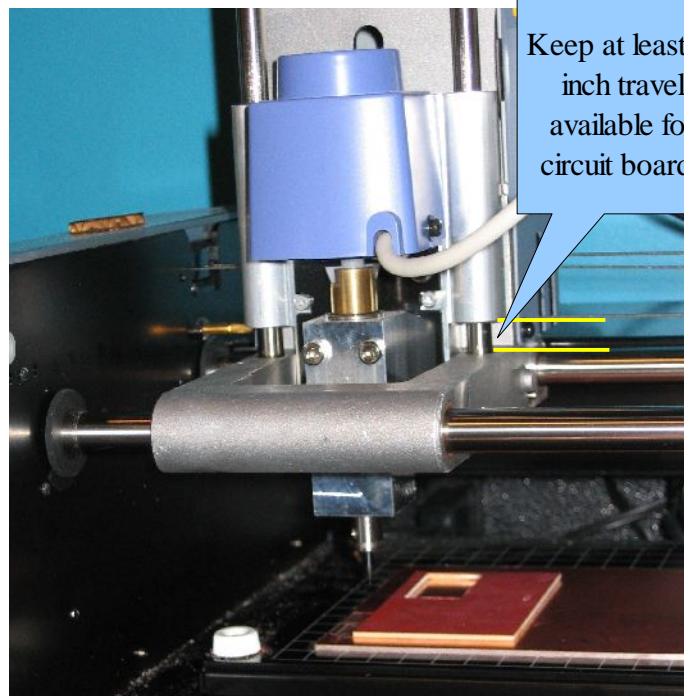


*move button in CAD.PY*

- 9) Being careful not to crash the tool or the spindle, lower the spindle until it is about  $\frac{1}{2}$  inch from the bottom of its travel. This is done by pressing and holding the tool **DOWN** button located on the front of the machine. This will also cause the spindle to rotate. To stop movement, just release the DOWN button.

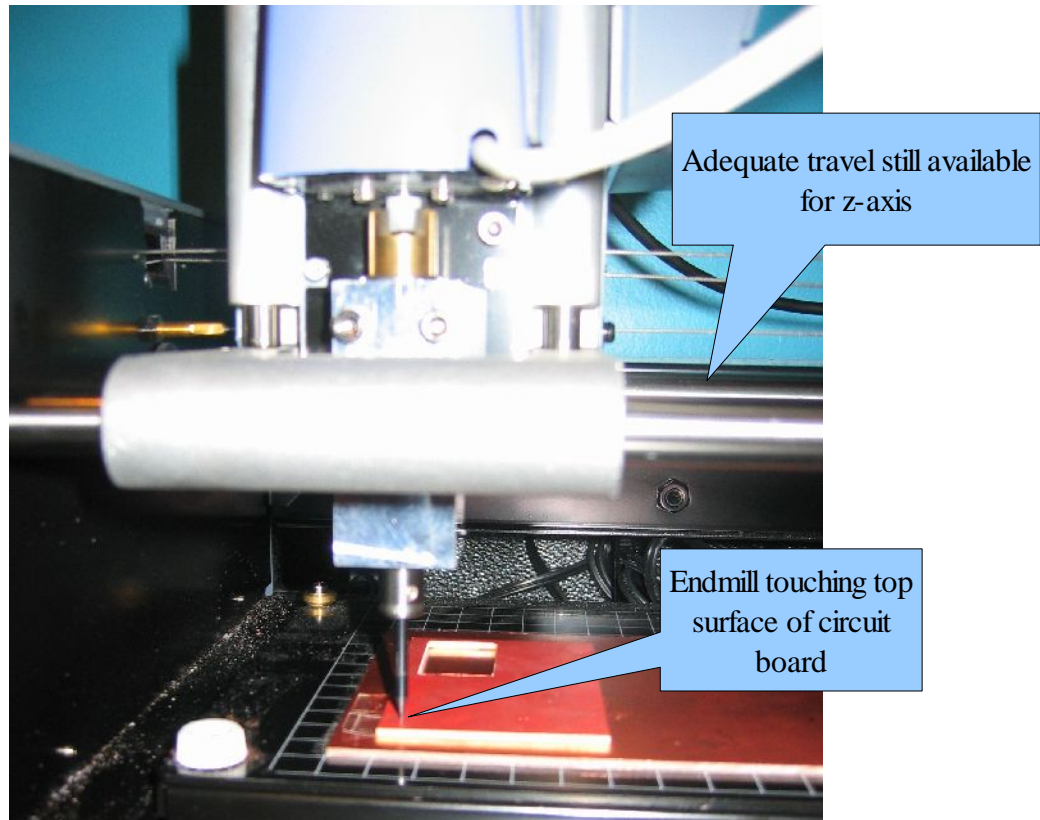


*Modela control panel*



*Setting the spindle height*

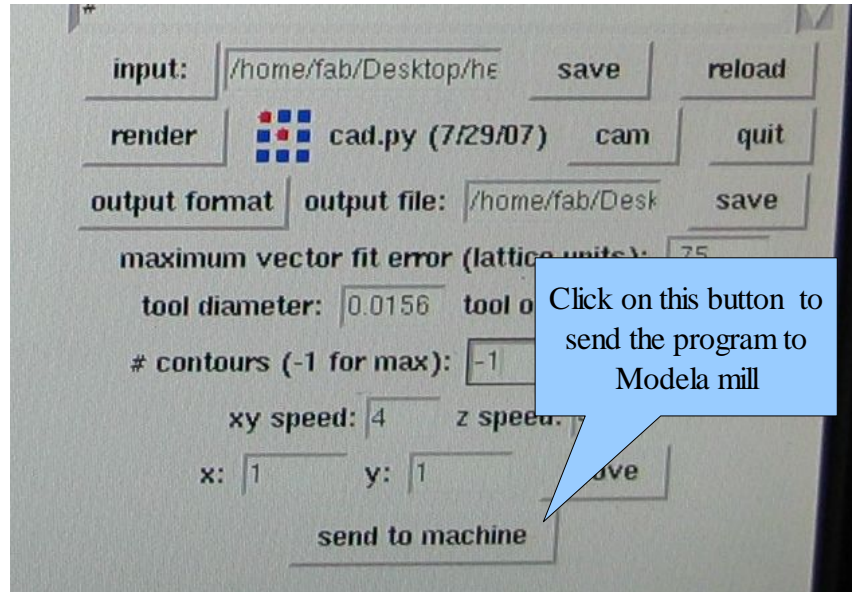
- 10) Once the spindle is in position and the spindle has stopped rotating, grasp the endmill gently with your fingers. Use the provided allen wrench to loosen the two set screws that hold the endmill in the spindle and careful allow the endmill to slowly drop down until it touches the top surface of the circuit board. Tighten the set screws to hold the endmill in this position. Do not over-tighten these set screws, they only need to be snug.



*Spindle height and tool set properly for a circuit board*

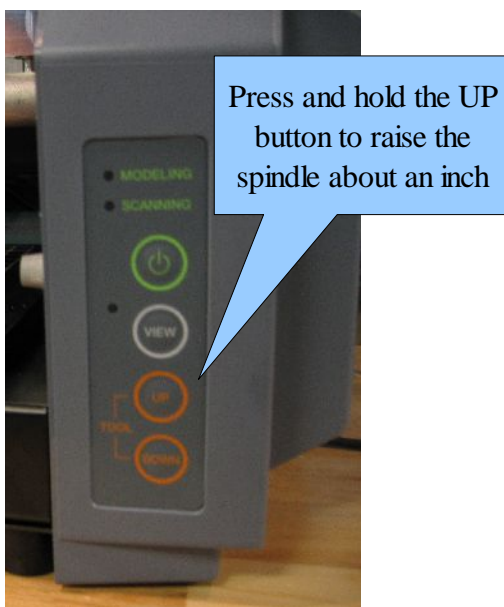
## Milling the circuit board traces.

- 1) Once the circuit board is mounted in the mill, the correct tool is installed, and the top surface of the part has been defined, cutting the actual program is easy. Just click on the send to machine button in CAD.PY. If the front cover for the machine is installed correctly (or the interlock has been overridden), the machine should start cutting the circuit board. If at any time the machine looks like it may crash, press the View button to stop it.



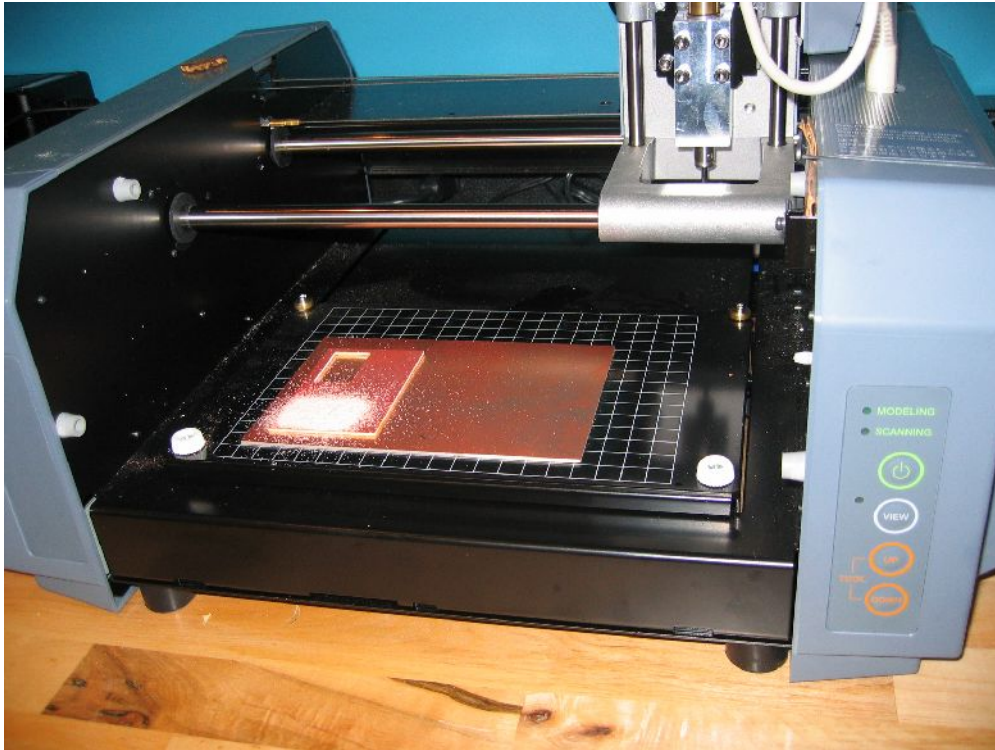
*CAD.PY send to machine button*

- 2) It should take the mill about 11 minutes to run the program. It will take longer for larger circuits. CAD.PY will display an estimated cutting time once the send to machine button has been clicked on.
- 3) When the program is completed, the machine will stop. Hold down the tool UP button until the spindle raises about an inch (this will make it safer to configure the next tool).



*Modela control panel*

4) Press the View button to enter view mode. Use the vacuum to clean up the copper shavings.



*Circuit traces cut*

## Preparing the to cut out the circuit board with CAD.PY

1) Using the CAD.PY to scroll down to just about the end of the circuit file program that was just used to mill out the circuit. Uncomment (remove the # sign from) the following two lines:

- #cad.function = pcb.interior
- #z = -.065

Uncomment these two lines

```
# uncomment to mill out board
#
# use 1/32 end-mill
# set tool diameter = .0312
# set xy, z speed = .5
# set # contours = 1
#
cad.function = pcb.interior
z = -.065

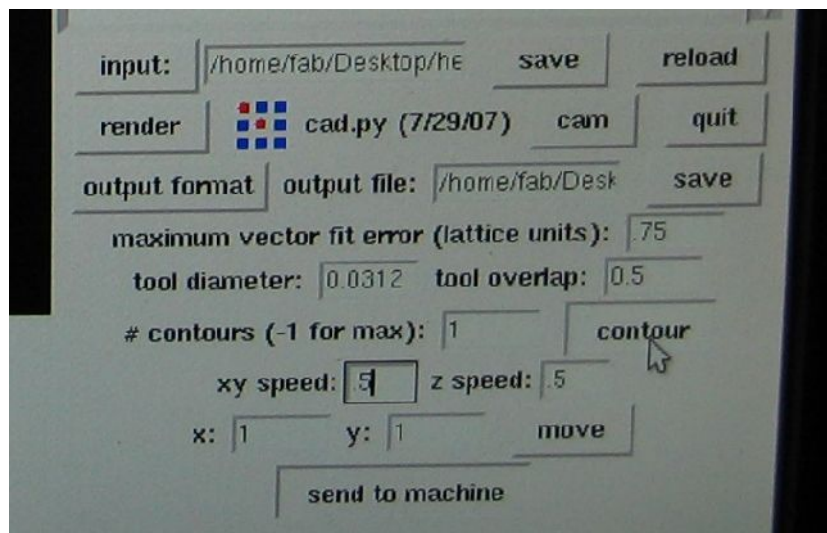
# define limits and parameters
#
d = 0.05
cad.xmin = x0-d # min x to render
cad.xmax = x0+width+d # max x to render
cad.ymin = y0-d # min y to render
cad.ymax = y0+height+d # max y to render
cad.zmin = z
cad.zmax = .050
dpi = 200 # low resolution for previewing
dpi = 500 # high resolution for machining
nxy = int(dpi*(cad.xmax-cad.xmin))
cad.nx = int(dpi*(cad.xmax-cad.xmin)) # x points to render
cad.ny = int(dpi*(cad.ymax-cad.ymin)) # y points to render
cad.nz = 1
cad.inches_per_unit = 1.0 # use inch units
cad.view('xy') # 2D view
```

Notice: the proper settings are documented in the program

*Editing the program to cut out circuit board*

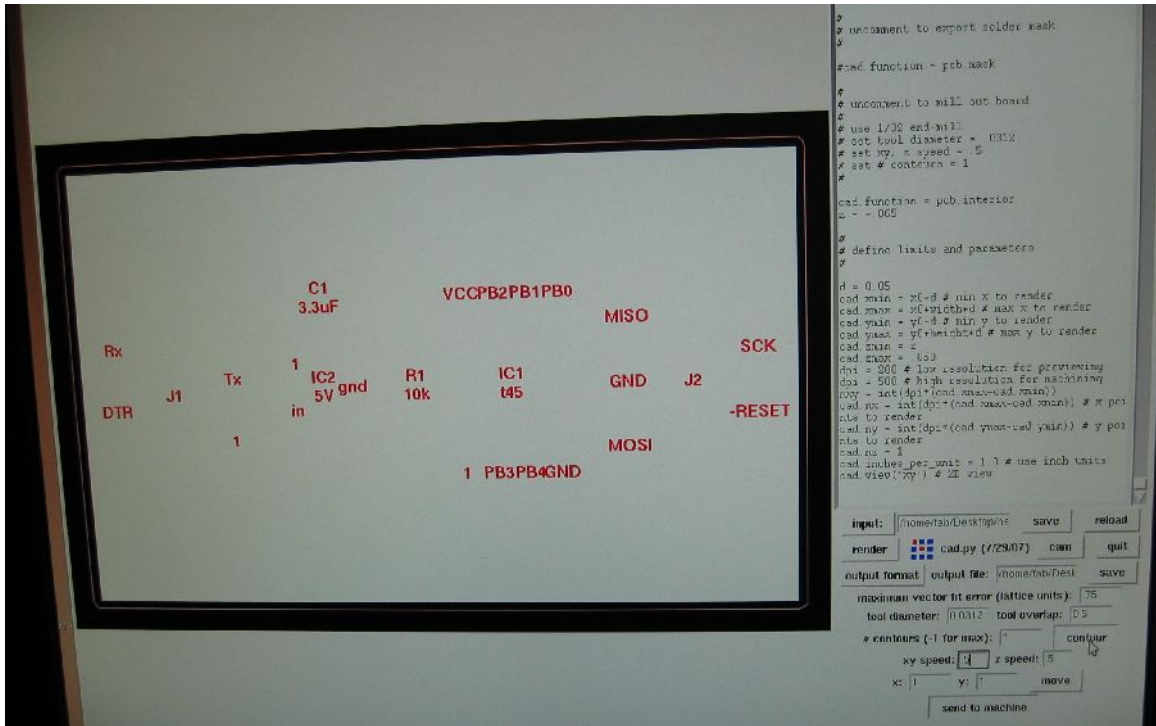
2) Configure CAD.PY as follows for cutting out the circuit board:

- tool diameter = 0.0312 (1/32 inch endmill)
- xy speed = 0.5
- z speed = 0.5
- # contours = 1 (one contour)

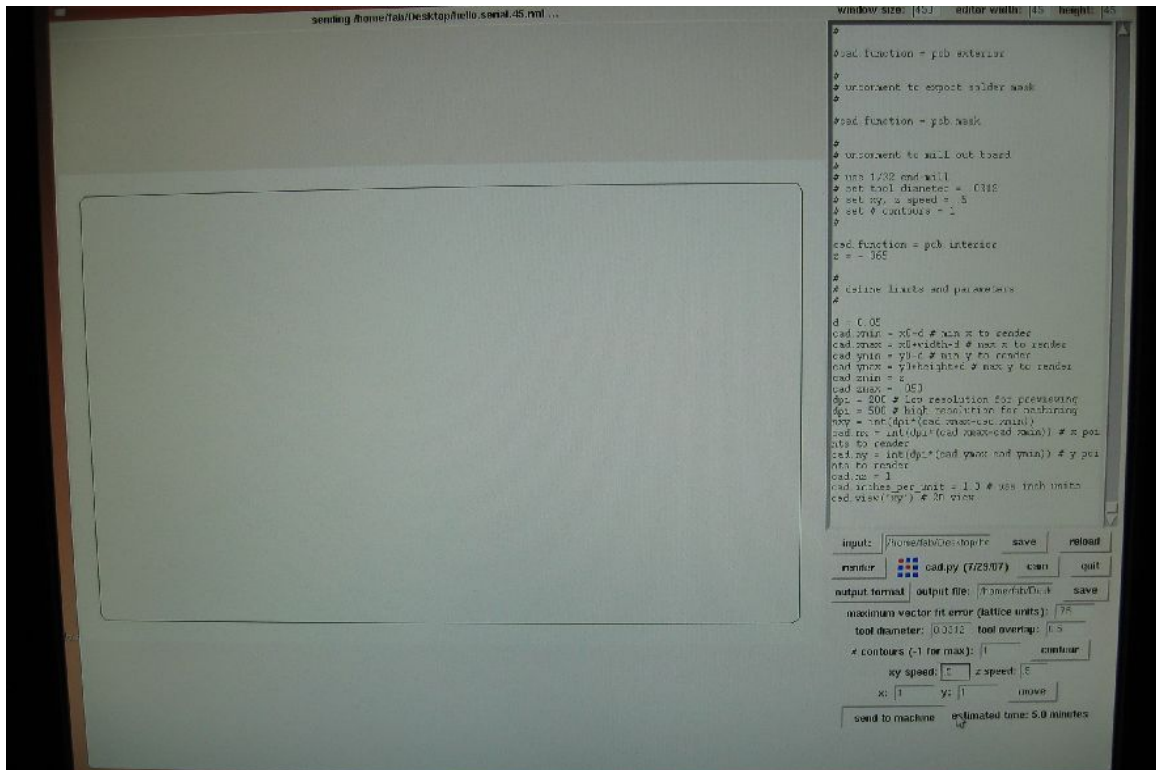


*Settings for cutting out circuit board*

- Click on the **contour** button. CAD.PY should render the tool path needed to cut out the circuit board.



Single contour around the entire circuit board



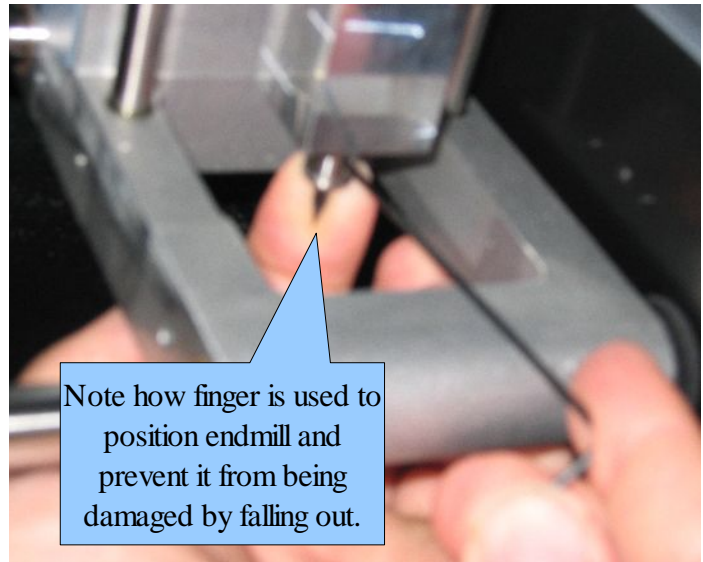
Same tool path without the background

## Installing the 1/32 inch endmill

- 1) The mill should still be in View mode.
- 2) Hold the 1/64 inch tool and the loosen the two setscrews that hold it in the spindle collet. Carefully pull the tool out and put it away for future use. Remember to be careful, these endmills are very sharp and will also be damaged if they are dropped.
- 3) Now install the 1/32 inch, 4 flute flat endmill used to cut all the way through the circuit board. Be careful not to push the endmill into the collet too far. For now, the endmill should be mounted with about 1/2 inch extending below the spindle collet. Temporarily tighten the two set screws. Do not over-tighten these set screws, they only need to be snug.

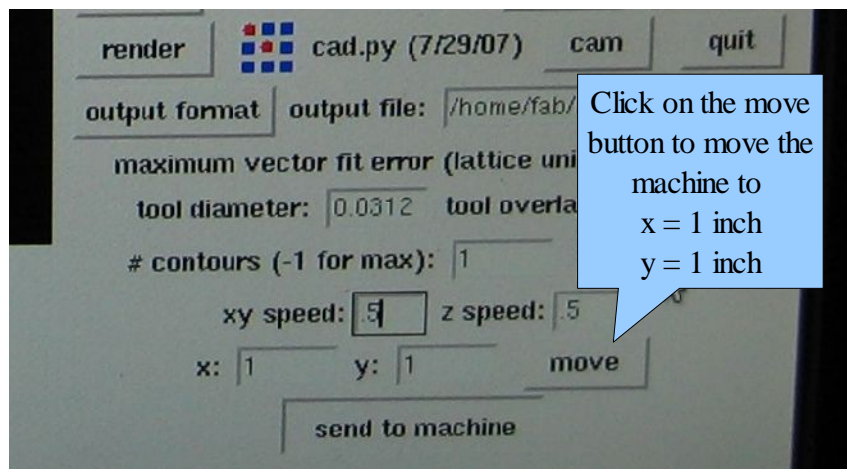


*Allen wrench*



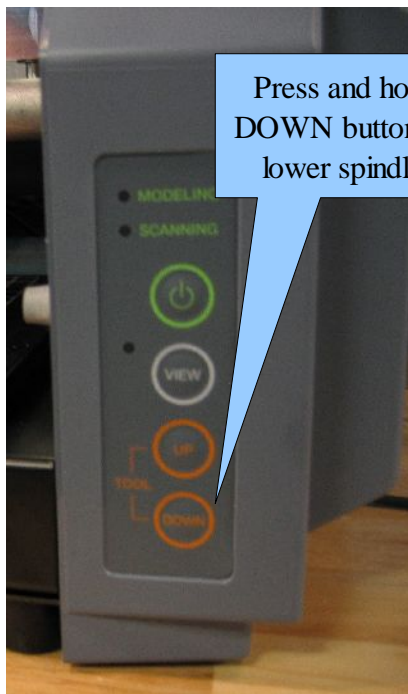
*Installation of endmill*

- 4) Press the View button on the front of the Modela to exit View mode. If the front cover for the machine is installed correctly (or the interlock has been over-ridden), the machine should move to its last position. If the machine looks like it may crash, press the **View** button to stop it.
- 5) We now need to move the machine to define the top surface of the circuit board with this new tool. Make sure that CAD.PY is configured for x: 1 and y:1 as shown below. Click on the **move** button. The machine should move the tool so that it is located above your circuit board.



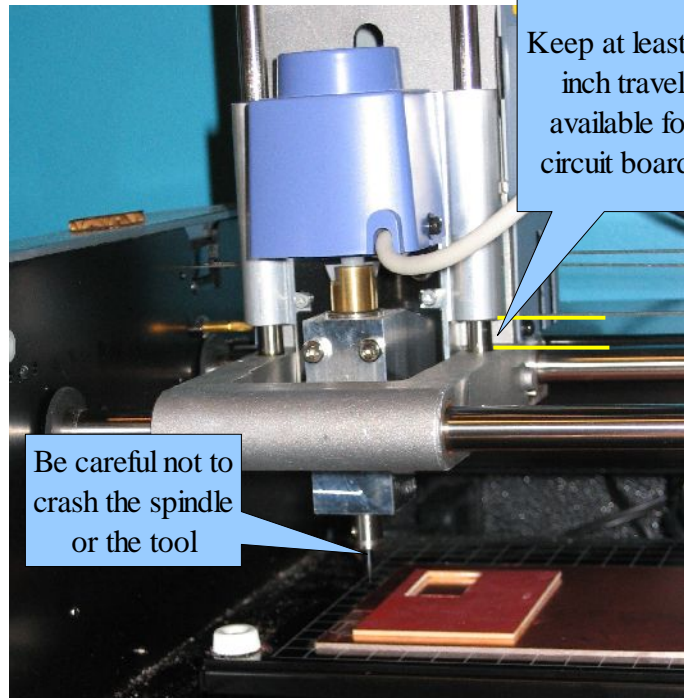
*move button in CAD.PY*

- 6) Being careful not to crash the tool or the spindle, lower the spindle until it is about  $\frac{1}{2}$  inch from the bottom of its travel. This is done by pressing and holding the tool **DOWN** button located on the front of the machine. This will also cause the spindle to rotate. To stop movement, just release the DOWN button.



Press and hold  
DOWN button to  
lower spindle

*Modela control panel*

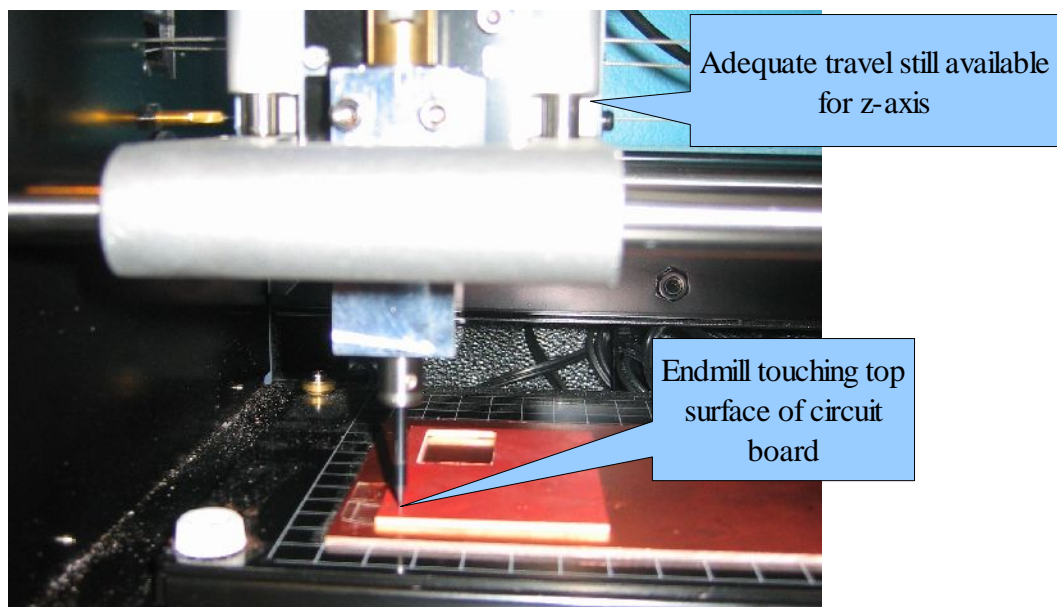


Keep at least  $\frac{1}{2}$   
inch travel  
available for  
circuit boards

Be careful not to  
crash the spindle  
or the tool

*Setting the spindle height*

- 7) Once the spindle is in position and the spindle has stopped rotating, grasp the endmill gently with your fingers. Use the provided allen wrench to loosen the two set screws that hold the endmill in the spindle and carefully allow the endmill to slowly drop down until it touches the top surface of the circuit board. Tighten the set screws to hold the endmill in this position. Do not over-tighten these set screws, they only need to be snug.



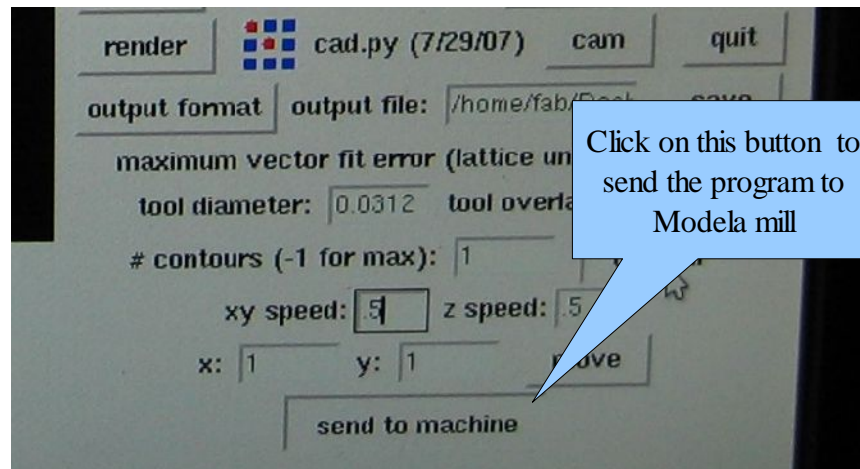
Adequate travel still available  
for z-axis

Endmill touching top  
surface of circuit  
board

*Spindle height and tool set properly for a circuit board*

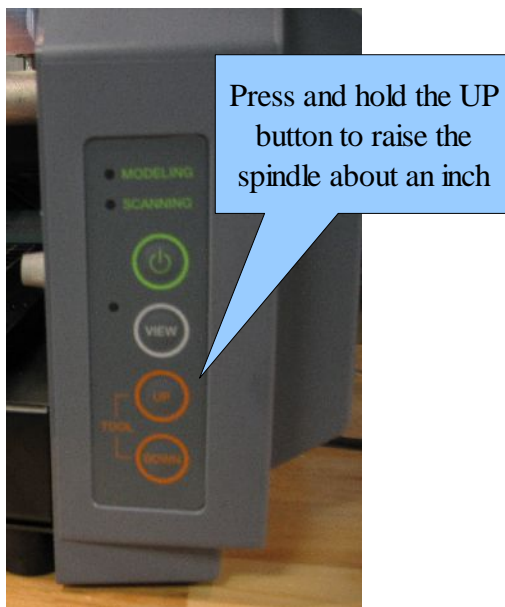
## Milling through the circuit board.

- 1) Once the circuit board is mounted in the mill, the correct tool is installed, and the top surface of the part has been defined, cutting the actual program is easy. Just click on the send to machine button in CAD.PY. If the front cover for the machine is installed correctly (or the interlock has been overridden), the machine should start cutting the circuit board. If at any time the machine looks like it may crash, press the View button to stop it.



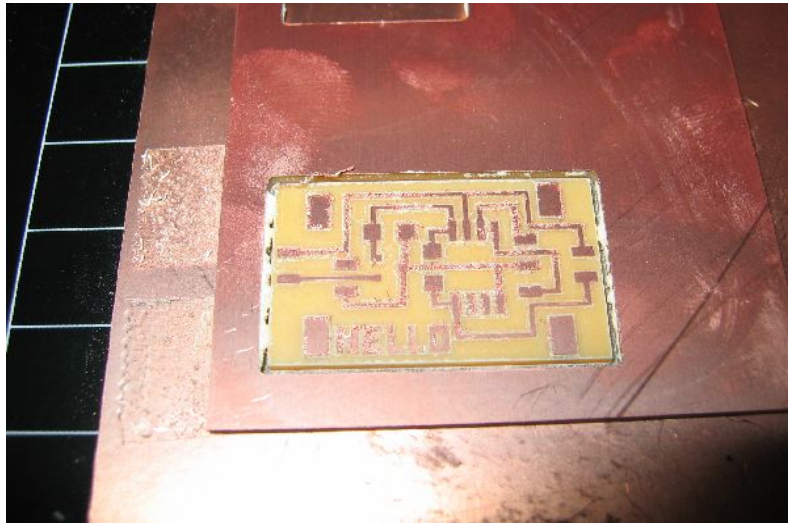
*send to machine button in CAD.PY*

- 2) It should take the mill about 5 minutes to run the program. It will take longer for larger circuits. CAD.PY will display an estimated cutting time once the send to machine button has been clicked on.
- 3) When the program is completed, the machine will stop. Hold down the tool UP button until the spindle raises about an inch (this will make it safer to configure the next tool).



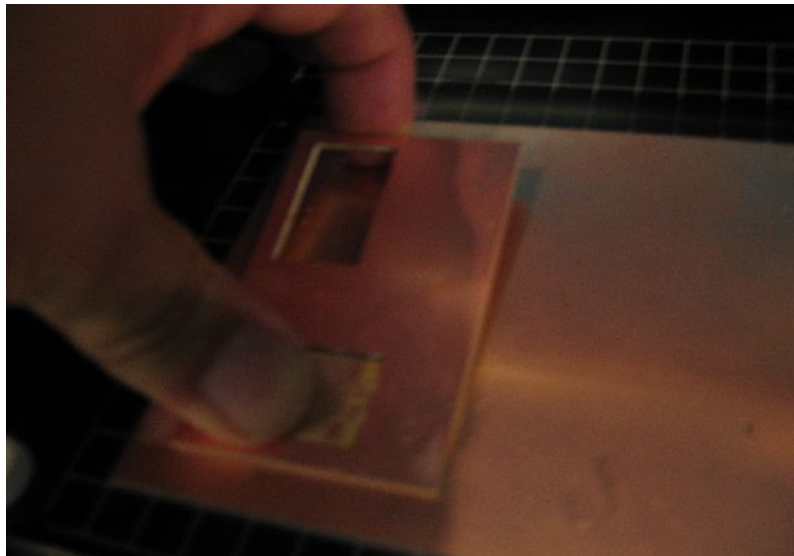
*Modela control panel*

- 4) Press the View button to enter view mode. Use the vacuum to clean up the copper shavings. It should look something like this:



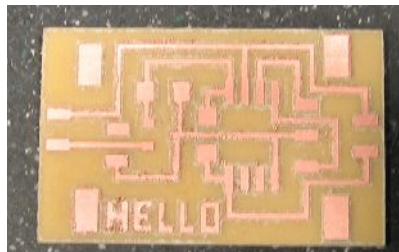
*Cut out circuit board*

- 5) Gently pry the circuit boards off of the sacrificial base layer.



*Removing the finished circuit board*

- 6) Carefully remove the used double-side tape from the back of the boards. Congratulations, you are now ready to solder on the electronic components.



*Completed circuit board*