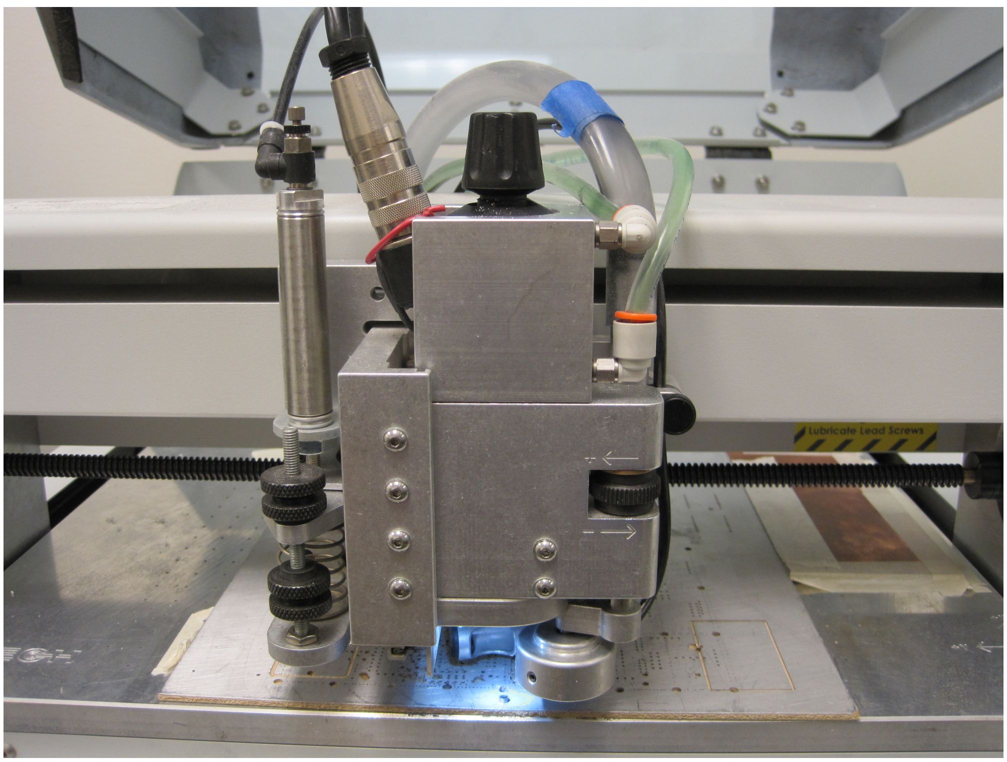
PCB Mill

This page is intended to be an all-inclusive guide to getting your PCB made and assembled on the OEDK's PCB milling machine. If you learn a better or faster way of doing any of the things listed here (or believe there should another section) feel free to add it in so that others can benefit from your knowledge.

On this page:



Capabilities

The PCB mill is great way to prototype PCBs because it is able to:

- Isolate small traces (up to 10mils) on a copper clad board
- Automatically drill required holes in correct position
- 2 Layer Boards

Limitations

Unfortunately the PCB Mill has a few limitations. It can not do:

- Solder Masks (The green part of an official PCB that keeps solder from running from 1 pad to the next) See (isolating traces) for an explanation on how to prevent solder run.
- SilkScreen (The white text on official PCBs that works to inform the user of the PCB)
- Vias (Connections from 1 layer to another layer) (See [Making Vias] for possible workarounds)
- Plated Through holes (Needs simple explanation)
- Anything More than 2 Layers (4,6,etc...)

Location

Machine

The PCB Mill is located in the OEDK Room #131 (Solder Lab) along with the [electronic components], Stereo Microscope, and Solder Oven

Parts

The parts for the PCB MIll can be checkout from [Carlos Amaro]. They include:

- A copper clad board
- Carbide End Mills (Various Sizes)
- Carbide Drill Bits (Various Sizes)

Preparing Design Files for PCB Mill

The software for the PCB Mill accpets standard Gerber files for traces and features as well as NC Drill Files for the holes that need to made

Which Side is Up

If you are making a really simple PCB then you might be tempted to just put all the traces on the "Top" layer of the PCB, however think really hard before you do this. The pads of the component you are going to use will be replicated on both sides of the board (assuming you take into consideration dealing with a copper clad --- BUT the traces only connect to 1 of the pads -- specifically the pad on the layer that the traces were drawn on.

[Some Pictures and Examples]

Dealing with a Copper Clad

Unlike a PCB order from a normal [PCB house] PCBs on the PCB Mill are made by isolating the desired trace from the plate of copper (known as the "copper clad"). This can cause problems because according to your design there is only a thin trace of copper between any 2 points amongst a sea of essentially nothing (more specifically nothing conductive that would get in the way). With the isolation method that the PCB Mill uses, you have to make sure that your layout program of choice knows that there is copper everywhere else. Otherwise components will end up shorted together.

> Always mill BOTH sides of the PCB layout. Even if you have only 1 signal layer. If you leave the "other" side of the copper un-milled, the leads of your components will be shorted together by the large, unisolated copper plane that is on the back. ALWAYS isolate the pads on the reverse side of your PCB....it may not look like the leads will short but they inevitably come into contact with the un-milled copper plane.

Dealing with no Plated Through Holes

In a normal PCB from a PCB House PCBs will have plated through holes. That means that every drill is plated with copper so that the pad on the top is physically and electrically connected to the pad on the bottom. This means that you can run a trace to the top pad or the bottom pad without any consideration. With the PCB milling machine the top and bottom pads ARE NOT connected. So lets say you have a normal through-hole resistor. It needs 2 holes for it to connect correctly, the drill will pass through the top layer of copper then the FR4 fiberglass material between the copper layers and finally through the last layer of copper. The pads are then isolated on either side of the

Exporting from Eagle CAD

Exporting From OrCad/Cadence/Allegro PCB

Tips and Tricks

Setup

Setup Checklist

- Do you have at least an hour to kill?
- Is there a decently fresh aluminum sacrificial board in place
- Is your copper clad sufficiently large
- Does your copper clad have the alignment/holding holes drilled
- Do you have the required tools (drills, end mills, router bits)
- Is the drill usable
- Is the endmill usable
- Are the table vacuum holes drilled into the sacrificial board
- Are you feeling lucky enough to use windows XP?

Drill Depth

⚠ Always drill FIRST then mill. Doing it the other way around may result in the drill pulling up an etched trace and destroying the work of the milling process (especially for thin traces)

The easiest way to verify the correct drill depth is to

1. insert the drill into the collet all the way up the collar (the little brightly colored plastic ring that should be on all the drills, should have the drill size marked on the same ring in white).
2. Use the jog function of the mill to move the head so that the drill bit itself is just to the left of the copper clad board but the foot of the head is still squarely on the copper clad.
3. Use your hand (NOT the head down command in the jog window) to gently lower the head until you either reach the bottom of the head stroke or the drill touches the material.
4. If the drill touches the back of the mill before the head bottoms out on the copper clad you need to:
5. adjust the Up/Down adjustment ring on the head until the drill just barely grazes the aluminum sacrificial board.
6. Now adjust the lower limit of the head so it will go down just a little a more into the sacrificial board. Ideally you want the conical section at the top of the drill head to be fully embedded into the sacrificial board so that only the uniform section of the drill goes through the copper clad.

Once you believe that you have set the drill depth correctly:

1. Jog the drill head to a spare spot on the copper clad
2. Turn on the drill spindle to reasonable speed and then
3. Activate the "head down" command in the jog window
4. Inspect the hole to insure that it has fully and cleanly penetrated the entire copper clad, but has not gone too far (more than 1/4 of the way) into the sacrificial board.

Go ahead and run through all the drills that you need to do on the entire board. Since the drill bit collars are guaranteed to all be at the same height, you do not need to readjust the drill depth for every new hole size you have to drill.

ⓘ If you ever switch to a mill bit or carbide router or for ANY reason adjust the drill depth you will need to run through the drill depth procedure before drilling another (set) of holes.

If your drill does not have a collar (AKA you got it from ELEC 342 or the likes...grrr....) then you will have to re-adjust the drill depth for every drill that you use or insert all the drills all the way to bottom of the drill collet (or get the bits from the OEDK).

Mill Depth

⚠ Always mill the traces AFTER you drill the holes, doing it the other way may result in the drill pulling up an etched trace and destroying the work of the milling process.

The easiest way to set or verify the correct mill depth is to insert the mill all the way into the collet. Be careful with the end mill as jogging the head while the end mill is too low, **will result in snapping the end mill on the edge of the copper clad**. The end mills are extremely delicate.

1. Jog the head to a spare area on the copper clad and gently lower the head with your hand onto the copper clad.
2. Make sure both the tip of the end mill and the foot of the head are on the copper clad.
3. If the end mill touches the top of the copper clad before the head bottoms out, adjust the limit screw so that the head bottoms out before the end mill touches the top of the copper clad.
4. Spin up the drill head from the Jog window interface.
5. Toggle the "head down" to engage the endmill. The end mill should not be touching the top of the copper clad after the head goes down!
6. Once the foot has struck the top of the copper clad, begin lowering the limit screw until the end mill engages the copper layer. The pressure from the machine should keep the drill head at the lowest position allowed by the limit screw.
7. Once the end mill engages the copper you can jog the end mill around in a single direction with the arrow keys on the keyboard. NEVER engage copper clad or jog the end mill across the copper clad without the head being spun up. **This will immediately and permanently break the end mill**. They are very expensive...don't break them...please!
8. With the end mill engaged and a small jog in an arbitrary direction, you want to continue to lower the limit and jog the end mill a little until you can see the black/brown backing underneath the layer of copper.

9. Adjust the limit screw 3-4 clicks down (that is to say lower the end mill just a smidge more). This is because the copper clad is not always perfectly flat and the section you chose to test may be just a bit lower than other sections, if that is the case and you do not lower it just a smidge more you may end up with sections where the copper is not completely milled away.

Speed and Feed Rates

In order for the end mill to properly cut through the copper layer of the board the machine needs to know how fast (think inches in a the X direction per second) to move the end mill.

If the end mill is **moving too quickly** then the copper may appear "torn off" instead of cleanly milled away. This could lead to inadvertent shorts through the isolation layer between traces. It will also require considerably more effort to clean up after you are done milling the board.

The primary factor that effects the mill feed rate is the thickness of the copper that is on the copper clad. A thicker copper layer will provide lower resistance to an electrical resistance, but will take slightly longer to mill through (aka the feed rate needs to be slower).

The following feed rate table is a good starting point for settings, however you may need to adjust the values depending on how deeply you mill into the FR4. Always perform test mills and feel the edges of the cuts that the mill makes in order to judge for yourself if the feed rate is too fast.

> ⚠ No harm can come from setting the feed rate too slowly (it'll just take a little longer), but you can **permanently damage the machine, end mill, and PCB board if the feed is to HIGH.**

Completions

De-burring

Cleaning

The best way to clean a copper clad board after milling all the traces and drilling the holes is with de-ionized water and light abrasive such as a fiberglass scour or brush.

You should always clean the board after milling to reduce the number of copper shards left over by the milling and drilling process. While a good cleaning will not guarantee complete removal of artifacts such as copper shards, it certainly reduces the chance of such artifacts being present (especially smaller artifacts such as copper dust or fiberglass dust).

Beware that excessive cleaning will result excessive oxidation of the copper on the board. If you do not plan on soldering your components onto the board soon after you have cleaned the board, the fresh copper on the copper clad board will rapidly oxidize and make soldering harder if not nearly impossible. To mitigate the effects of oxidation on soldering effectiveness be sure to clean the board before soldering and use plenty of flux. While most solder has a inner resin flux core that is essential to soldering, you may find that the heavy oxidation that builds up on bare copper may require extra flux. Use a flux pen to apply a small amount of solder on the pad immediately prior to soldering *just that pad* do not apply flux to the entire board, it will dry up and move around on you and likely defeat the purpose.

Ultrasonic cleaners (such as the one in the machine shop) can be used for this purpose, but care must be taken that the bowl does not have random metal shavings or dust that have collected from cleaning machined items. These particulate may embed themselves in the isolation between traces and cause shorts. Always rinse the board after cleaning with the ultrasonic cleaner, failure to do so will result in a sticky mess and impossible soldering. This is because the cleaner uses a solution of water and industrial detergent, the detergent will leave a thin film behind that is intended to be rinsed away. Do not forget this step!

Inspecting For Shorts

Due to the imperfect nature of the PCB milling machine, once a board is finished milling and drilling there can often times be little bits of copper

Tools you will need:

1. Stereo Microscope
2. Digital Multimeter (DMM)
3. Xacto Knife
4. Dental Picks
5. Patience

What you're looking for:

1. Thin strands of copper that are fully attached at 1 end and touch another trace or plane (NEED PIC)
2. Thin strands of copper that are freely floating on the board but that have become embedded between traces in the isolation area.
3. Thin strands of copper that are inside drilled holes or are poking up from a drilled a hole
    a. These strands may appear benign because they are inside the hole, but they can become a problem once you insert your part into the hole and the copper gets either pushed out the other end or connects the bottom pad to the top pad... etc
4. Copper dust that has collected in the isolation area.
    a. This dust may not show up in a continuity inspection because the dust may not present a direct path between traces, however it does provide a low impedance air gap that could potentially shift into a full blown short.

Inspection For Ripped or Lifted Pads