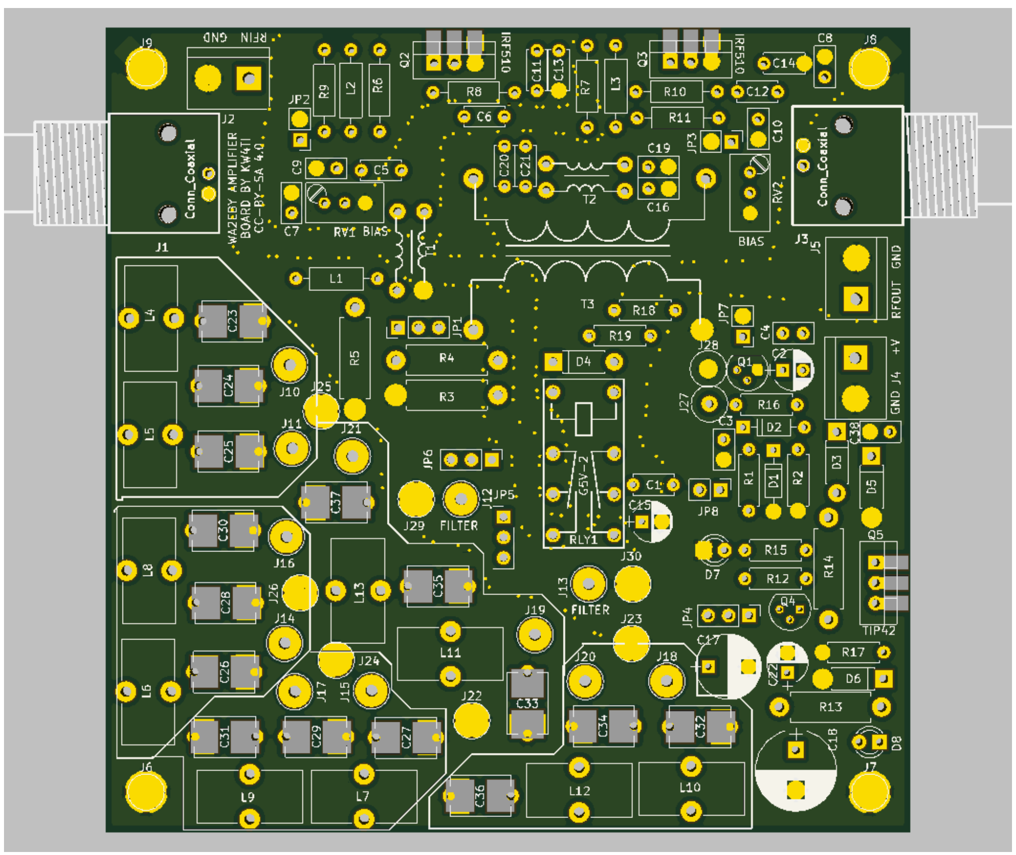
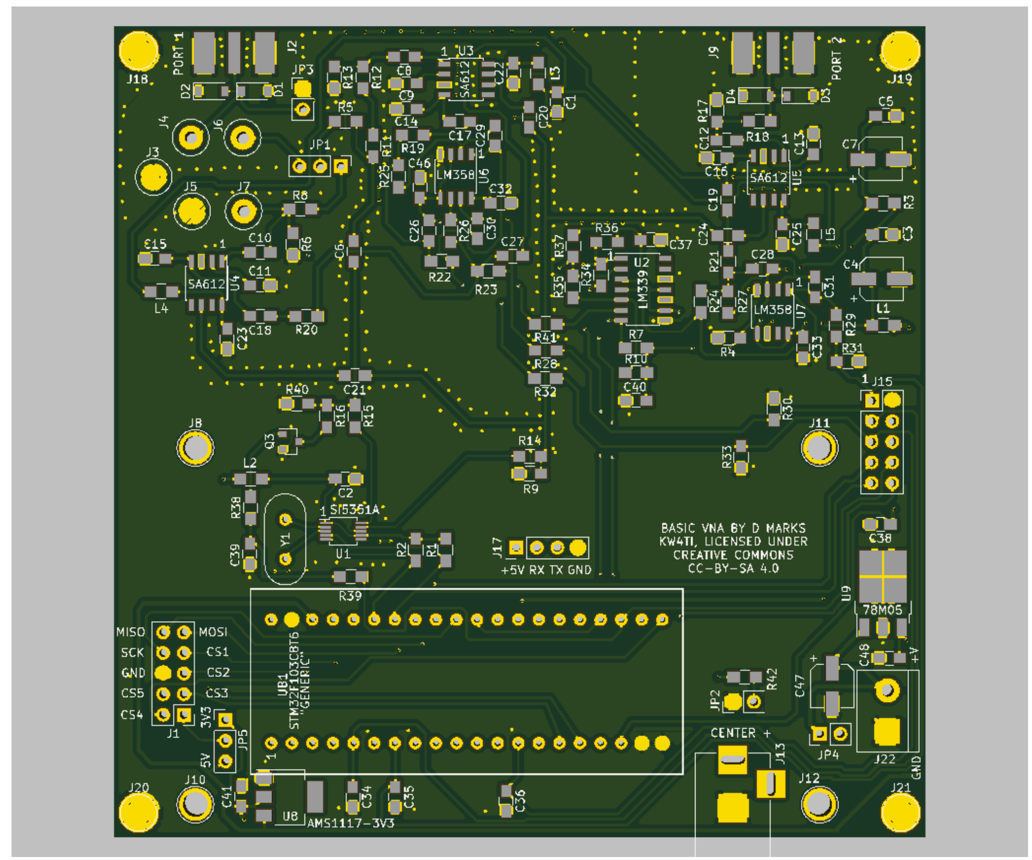
Open Source for Amateur Radio Projects
Including Kicad PCB design

By Daniel Marks, KW4TI

Raleigh Amateur Radio Society (rars.org)

September 10, 2019





What is “Open Source”?

It is a way to license software so that it remains “free.”

Free as in “beer,” you get free beer, you drink free beer, you don’t pay for it. Isn’t that great?

Free as in “libre,” the rights you receive as a software user, and guarantees as a developer.

- As a developer, your contributions to a free software project stay free (not made proprietary).
- As a user, your rights to use the software are irrevocable if you abide by the license.
- The source code is provided.
- As a developer, your software is provided with no warranty, and you are not liable for any damages.

The licenses help developers and users cooperate.

Open Source in amateur radio:

It makes software and hardware tools available that help and encourage participation and enjoyment of the hobby.

(Highly incomplete list) examples of software:

- Fl-digi: amateur digital modes, (PSK31, etc.)
- WSJT-X (FT8, JT65, etc.)
- LOG4OM, cqrlog (logging software).
- Dire Wolf terminal node controller software
- CHIRP (program your transceiver).
- NEC2 (antenna field solver) – 4NEC is non open source but free front-end
- Kicad (PCB design software).
- Qucs (SPICE-based graphical circuit simulator)

Open Source Hardware in amateur radio:

Briefly, this means freely available schematics, PCBs, and firmware for hardware devices. Examples:

- uBitx/BITX 40 QRP transceiver
- mcHF transceiver
- EU1KY Antenna Analyzer
- W8TEE Arduino Antenna Analyzer
- Haasoscope USB digital oscilloscope
- HPSDR (High Performance Software Defined Radio) project (https://openhpsdr.org/)
- HackRF One software defined radio
- LimeSDR software defined radio

My own projects I will present today….

Developing your own ideas!

Subpart A—General Provisions

§97.1 Basis and purpose.

The rules and regulations in this part are designed to provide an amateur radio service having a fundamental purpose as expressed in the following principles:

(a) Recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.

(b) Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

(c) Encouragement and improvement of the amateur service through rules which provide for advancing skills in both the communication and technical phases of the art.

(d) Expansion of the existing reservoir within the amateur radio service of trained operators, technicians, and electronics experts.

(e) Continuation and extension of the amateur's unique ability to enhance international goodwill.

The tools of hardware and software development have never been as easy to use, cheaper, or more available as they are today. There are resources today that previous generations of hams could only dream about.

Did the Internet kill ham radio?

Quite the opposite. It provides the means for hams across the world to collaborate on projects. The benefits of these projects can be shared by all because the rights to the work are guaranteed by

Open Source Licenses.

But 21st century ham radio is going to be very different. Examples:

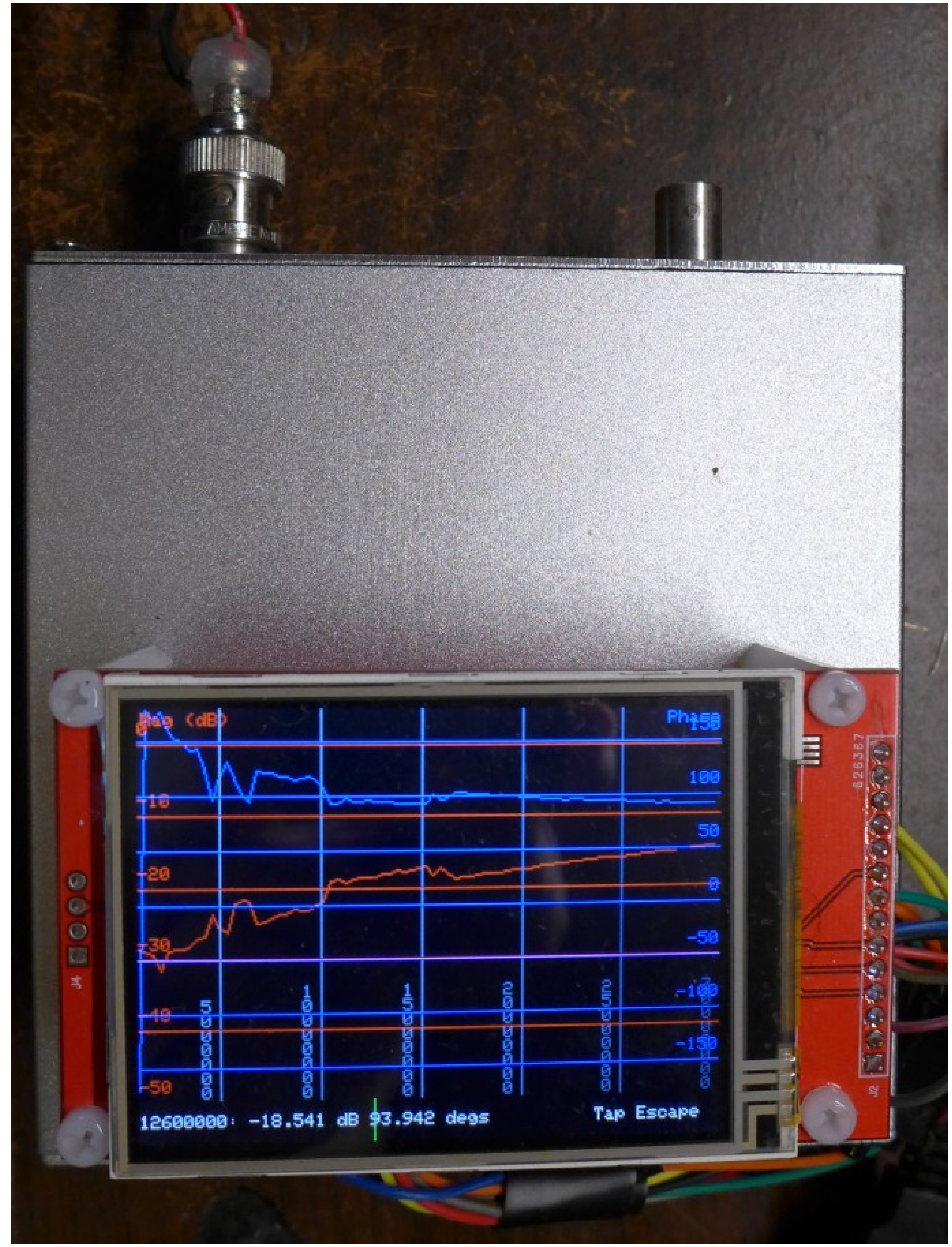
Complex digital modulation. (e.g. FT8/JT65)
Smart Antennas. (e.g. phased array antennas)
MIMO. Multiple input, multiple output antenna arrays.

Examples from my open source projects: a Vector Network Analyzer

A VNA is a device for measuring the reflections and transmissions from radio frequency components, for example, antennas and filters.

It can be used as an antenna analyzer, or to check the impedance of a balun, or the transmission of diplexer.

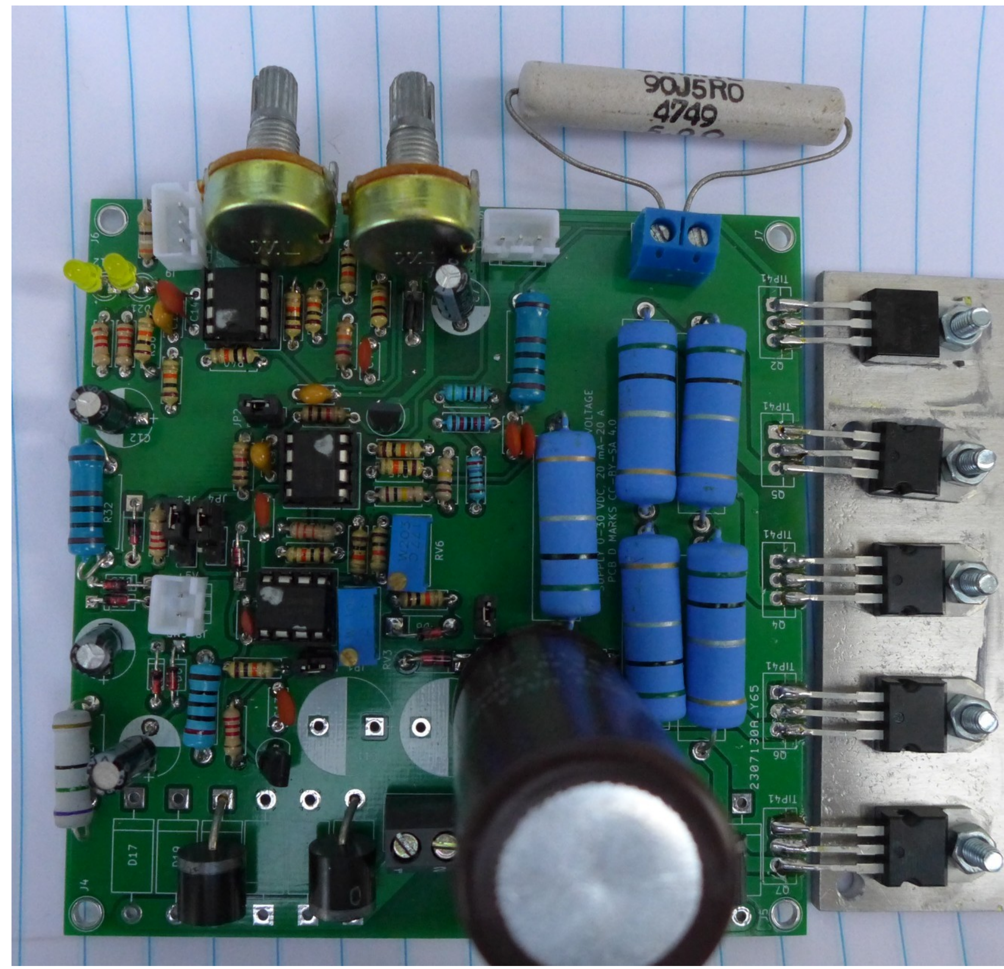
Can be built for under $50 in parts!



Examples from my open source projects: a linear power supply

This power supply allows one to make a new benchtop power supply from old, broken power linear power supply parts such as transformers, capacitors, and pass transistors.

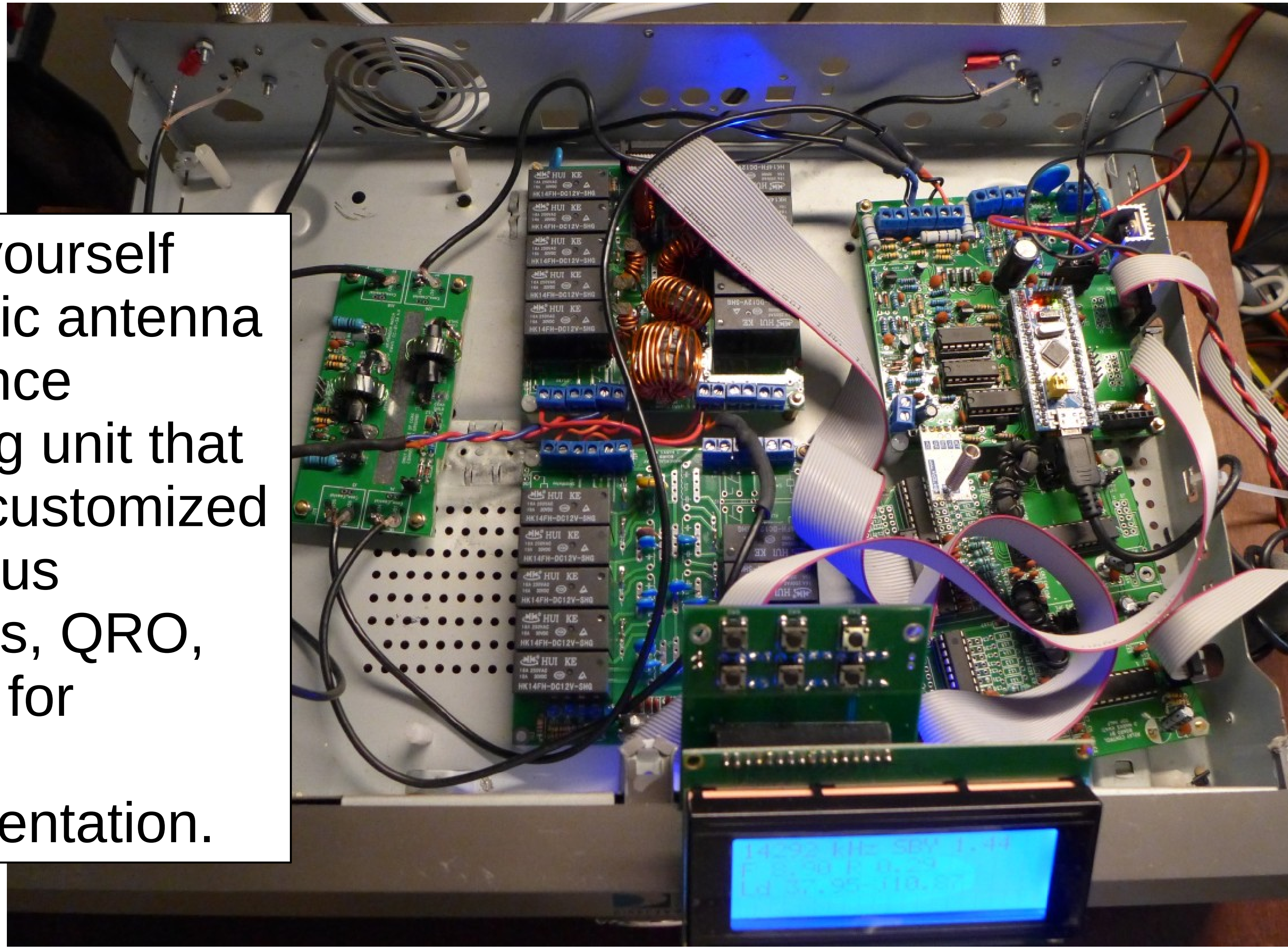
This power supply has constant voltage and current capability and external control.



Examples from my open source projects: a Theremin

A microcontroller based Theremin, which is a musical instrument that can be played by moving one's hands near the instrument's antennas. Makes spooky sounds like in sci-fi movies.

Examples from my open source projects: an automatic antenna impedance matching unit



A do-it-yourself automatic antenna impedance matching unit that can be customized for various purposes, QRO, QRP, or for antenna experimentation.

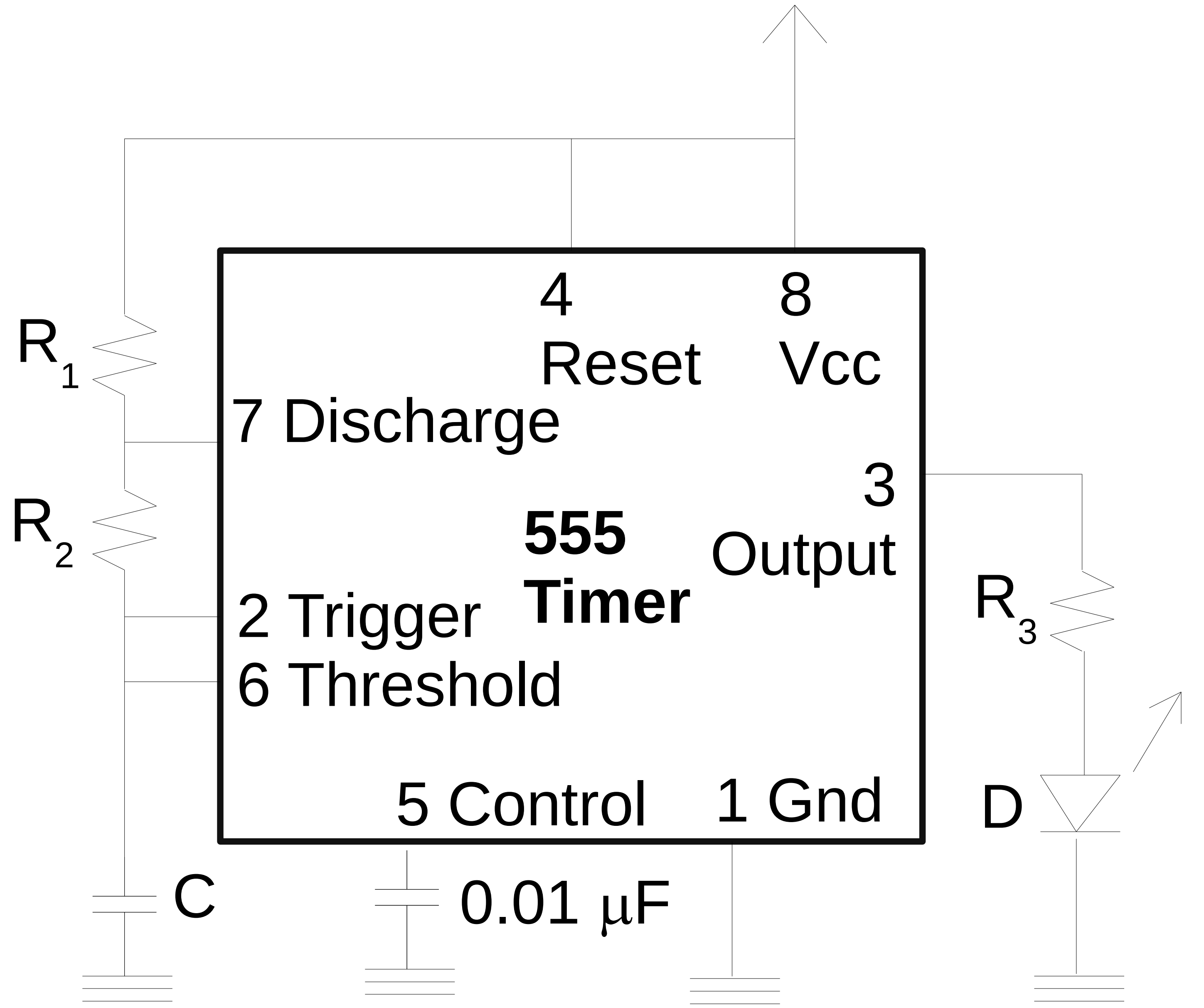
New PCB manufacturing services make obtaining custom PCBs for your project very cheap!

PCB manufacturers such as JLCPCB, Seeedstudio, and PCBway can manufacture two-layer PCBs up to 10-by-10 cm for $5 or even less!

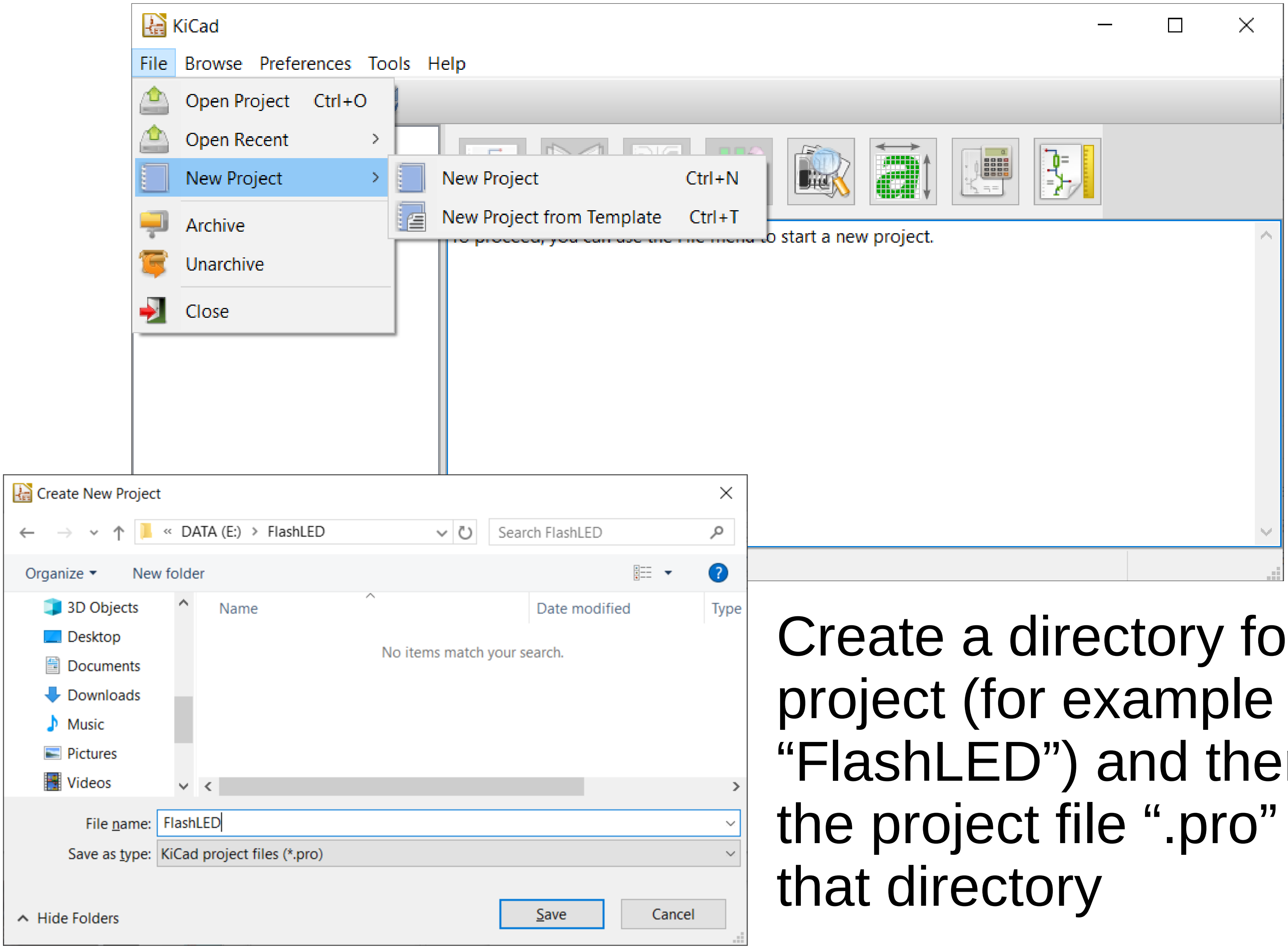
This can take the chore of handwiring together electronic components on a breadboard, and make it much easier and neater. They can also populate boards for you as well.

Today, I’m going to walk you through how to create a PCB with Kicad and submit it to one of these services.

Simple Kicad project: 555 LED flasher circuit

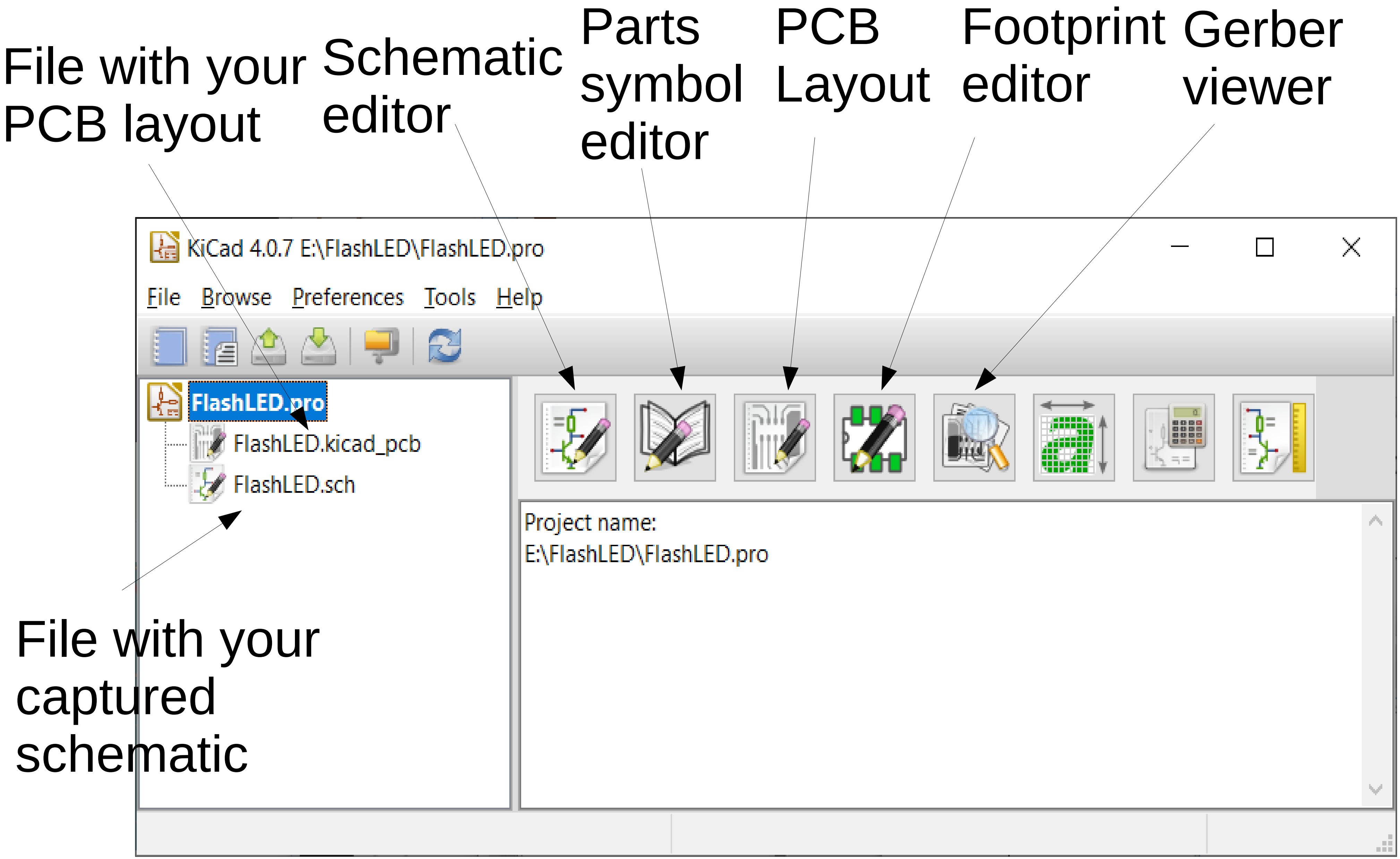


Starting a project



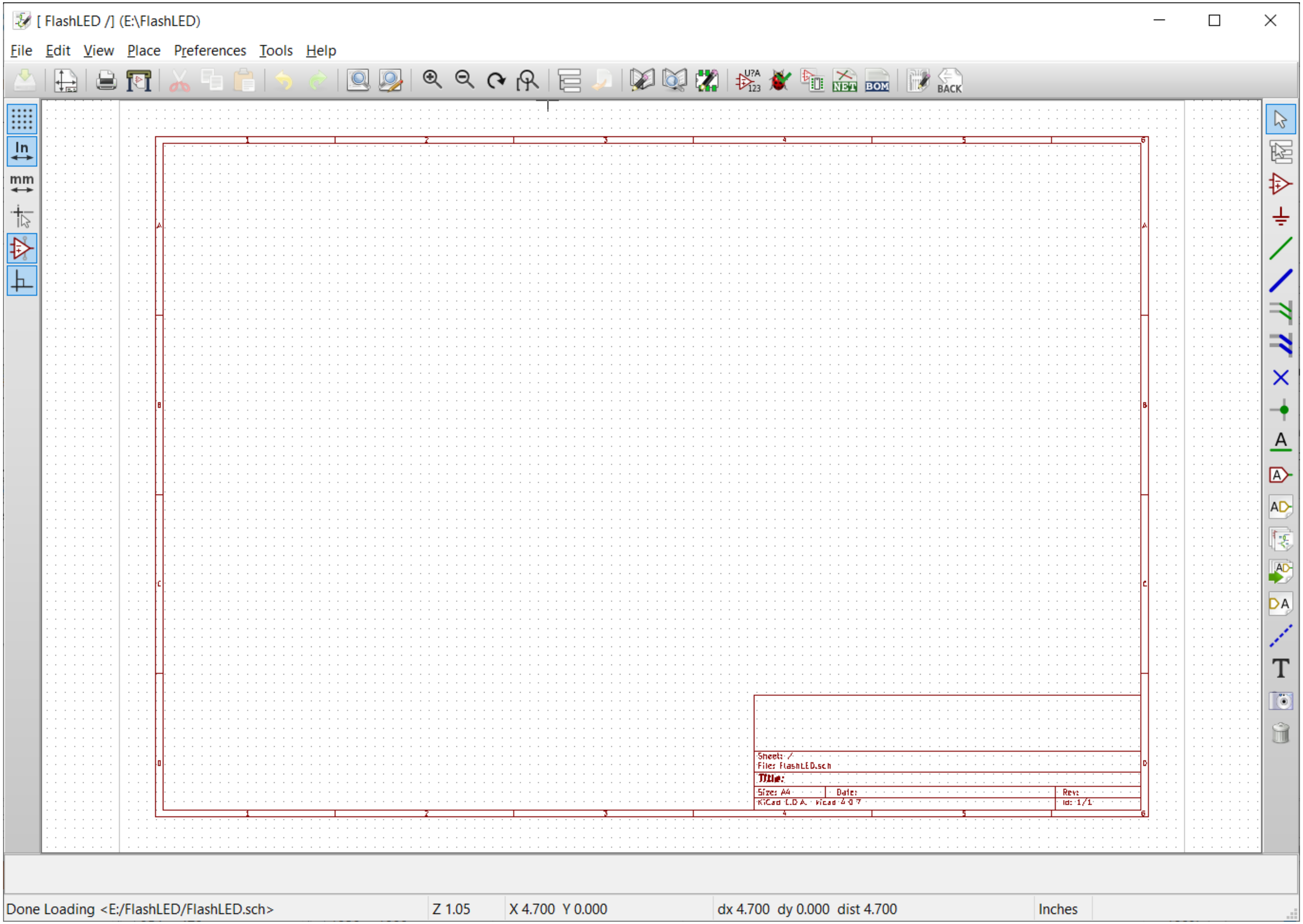
Create a directory for your project (for example “FlashLED”) and then place the project file “.pro” into that directory

The project is started. Now what?

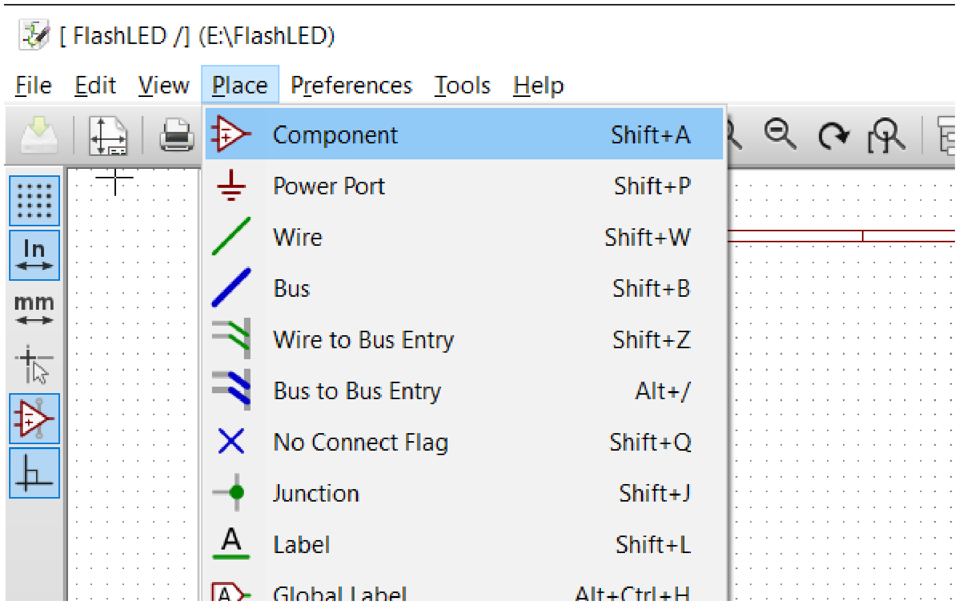


First: capture schematic (schematic editor)

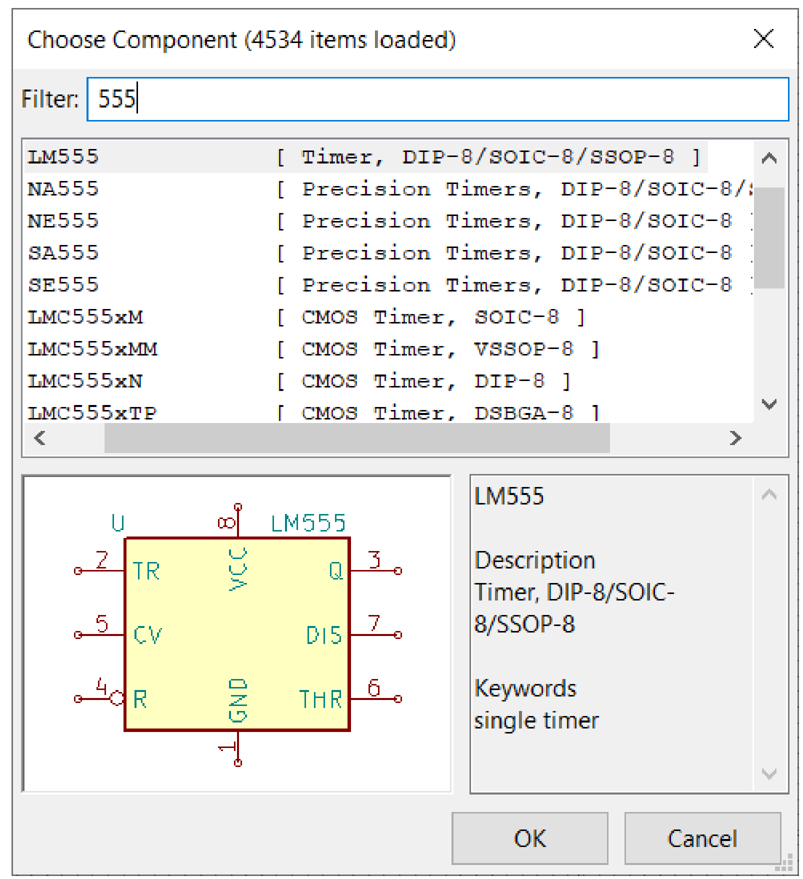
Empty schematic. Lets add some parts!



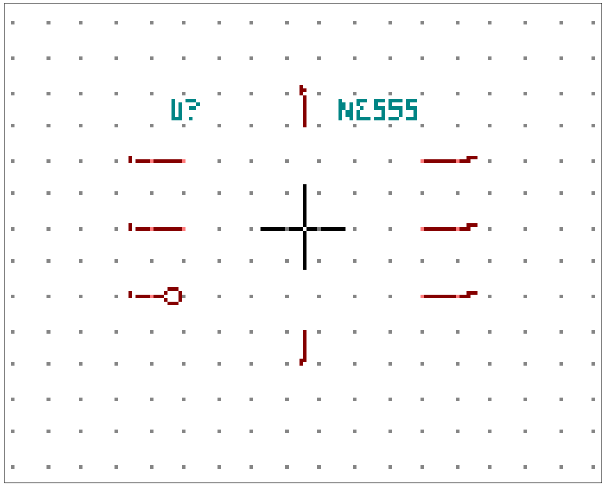
Place a component



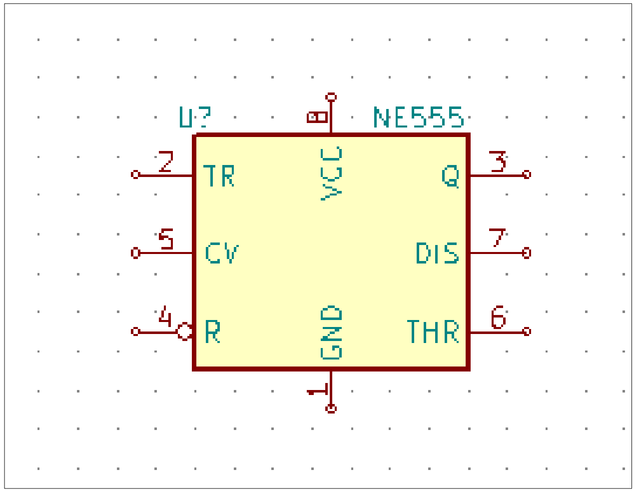
Then click on the location on the schematic you want the component placed with the crosshairs.



Type “555” to search the loaded libraries. Kicad lists the components with part numbers that match the search term.



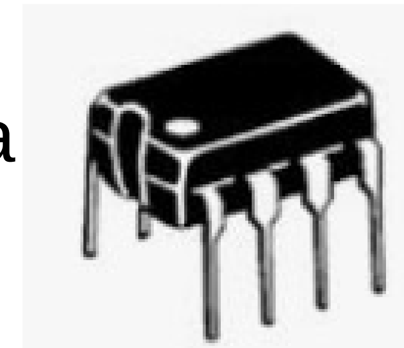
Move the part with the mouse cursor and click where the part should be placed.

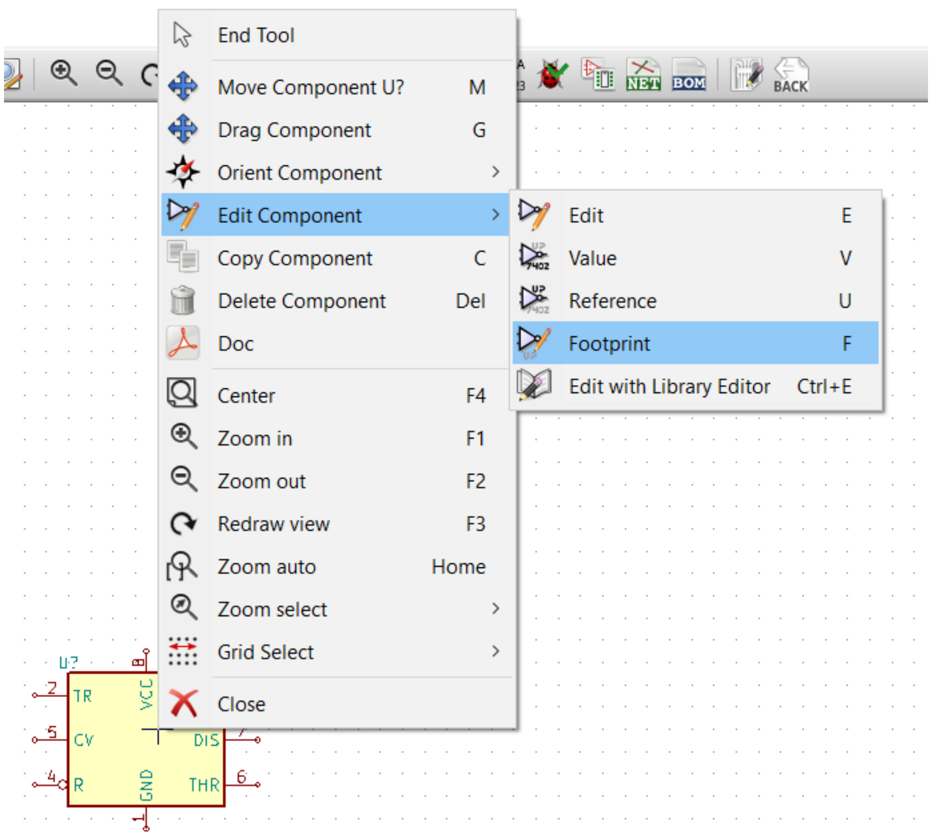


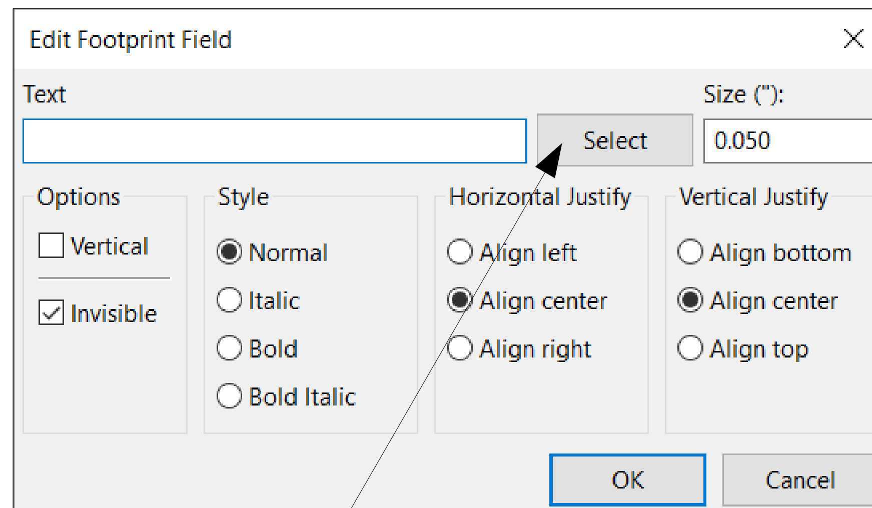
Now the part is placed.

Assign a footprint

The footprint tells Kicad how to place the pads so that the selected part can be soldered into the board. For example, the NE555 chip has a DIP-8 package. To select the footprint, right-click on the part and then



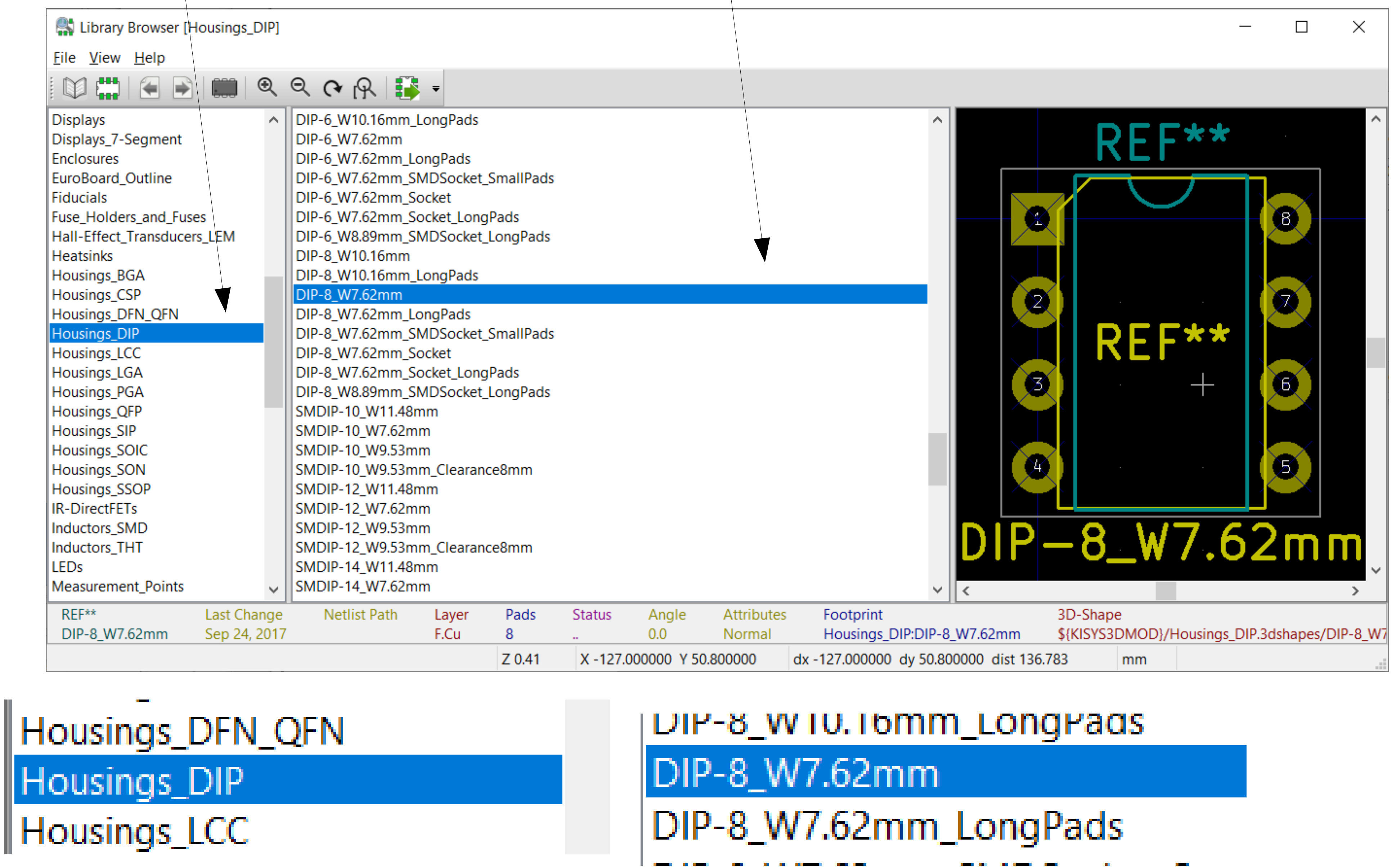




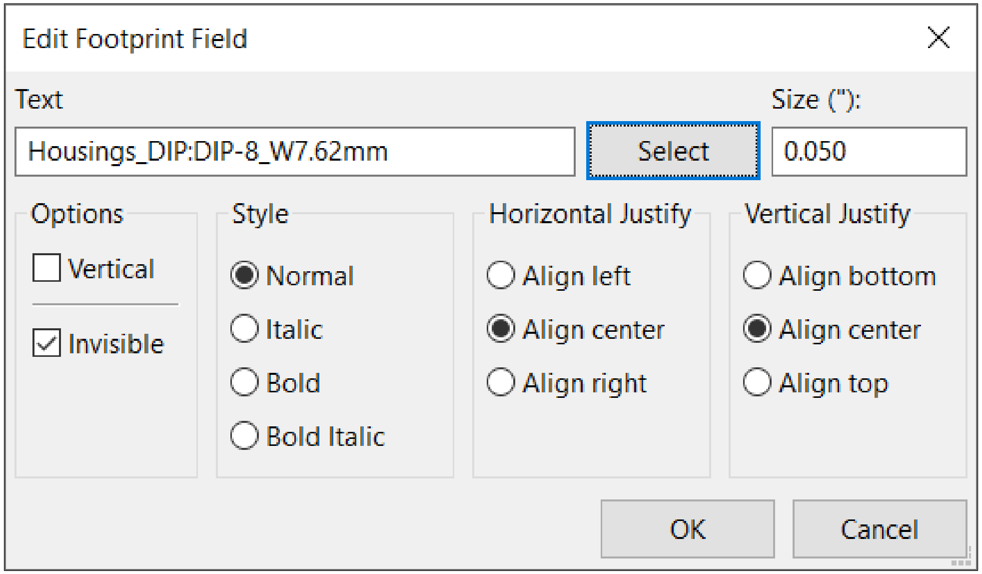
Click Select to choose the footprint

Library with footprint

Selected footprint in library



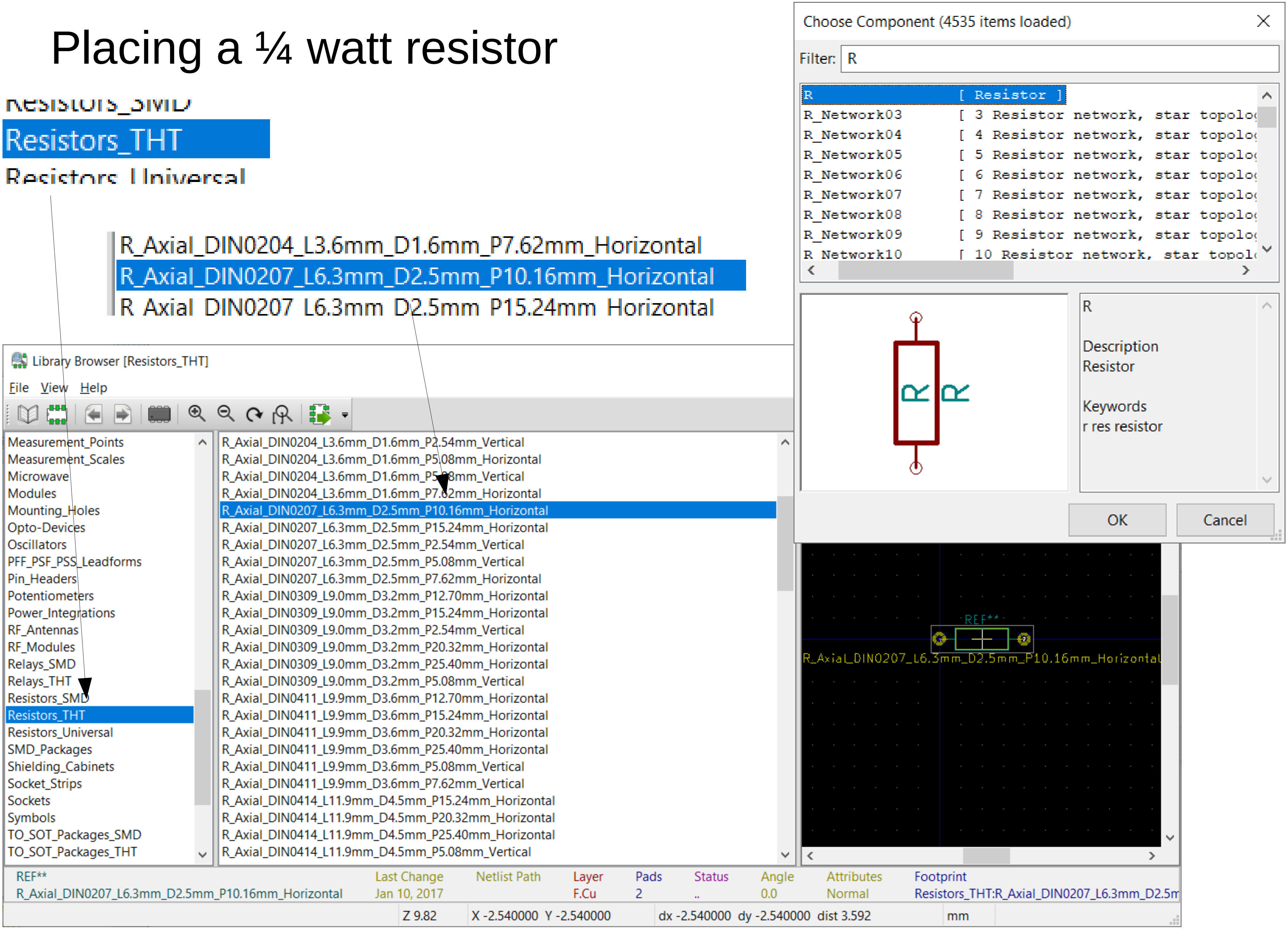
Footprint field now shows selected footprint



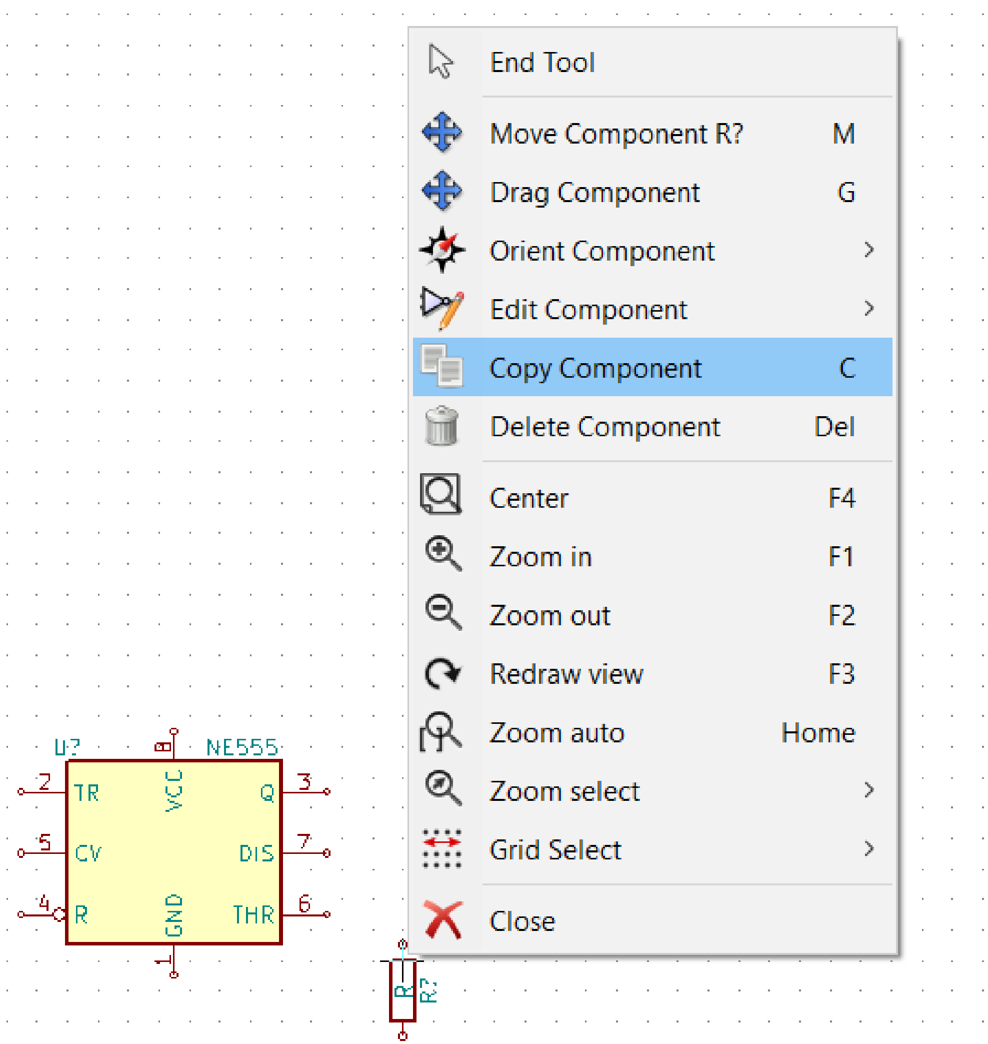
Click ok

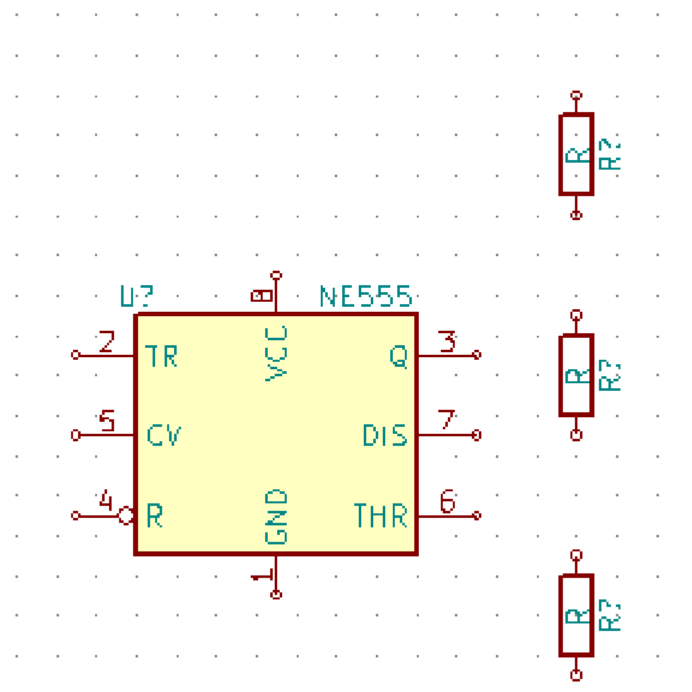
Now you've placed your first part!

Placing a ¼ watt resistor



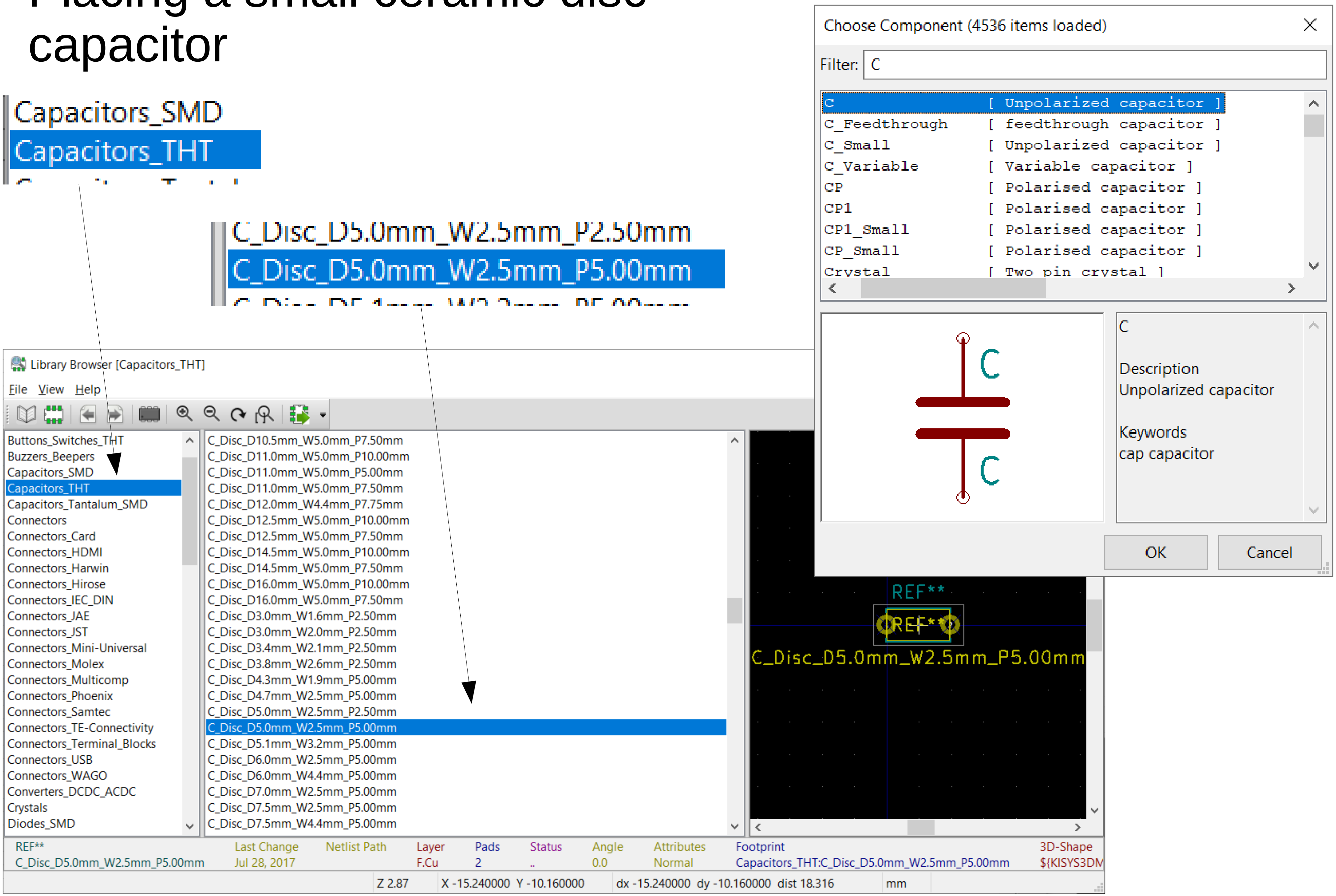
Now if we want two more resistors of the same type, we can just copy the one resistor twice



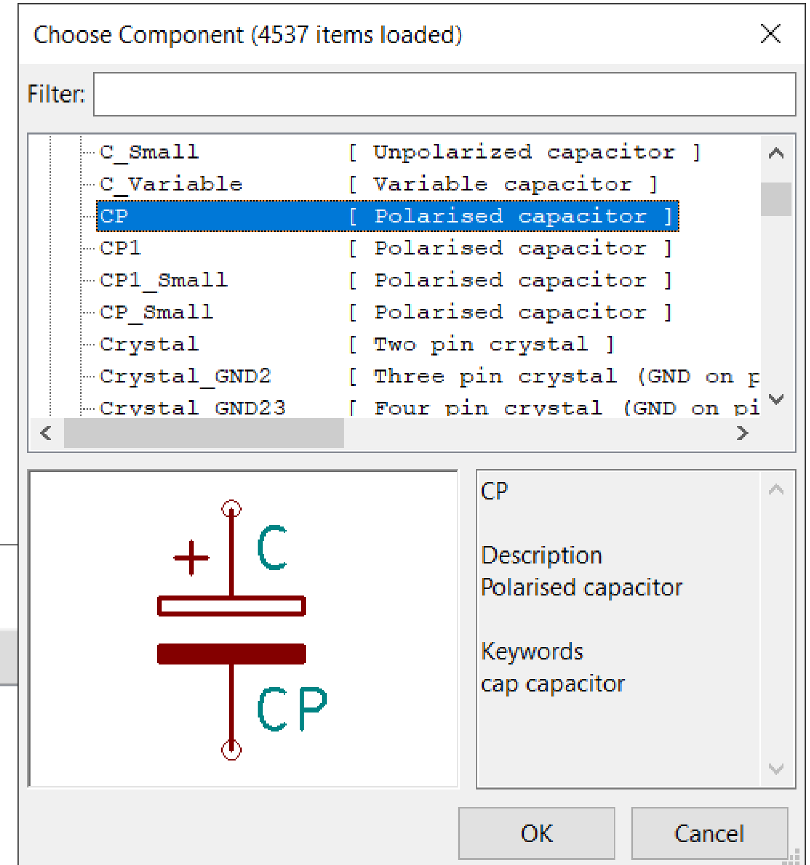


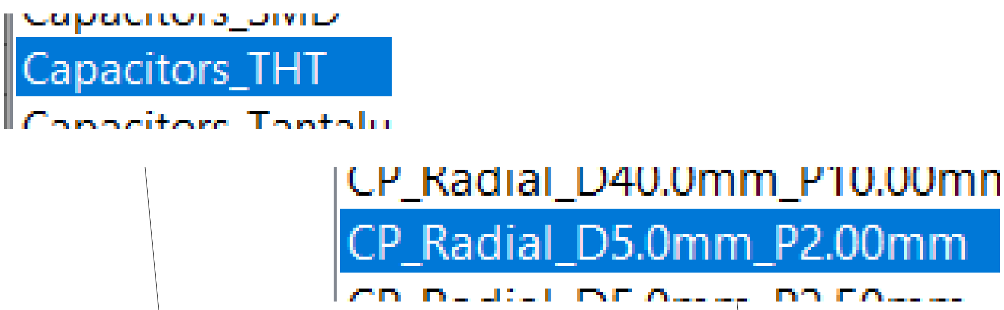
These all have the same ¼ watt package footprint we just selected.

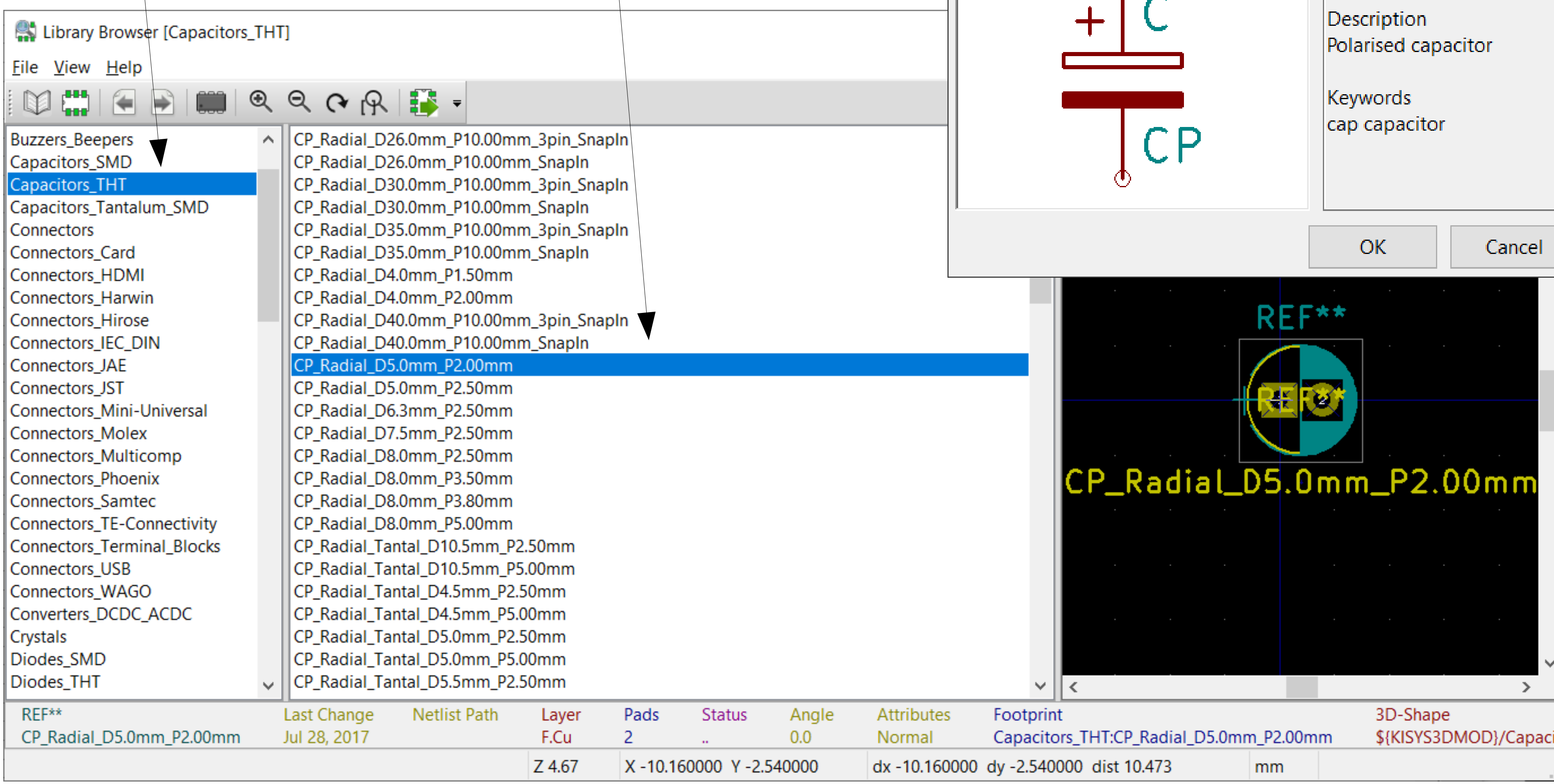
Placing a small ceramic disc capacitor



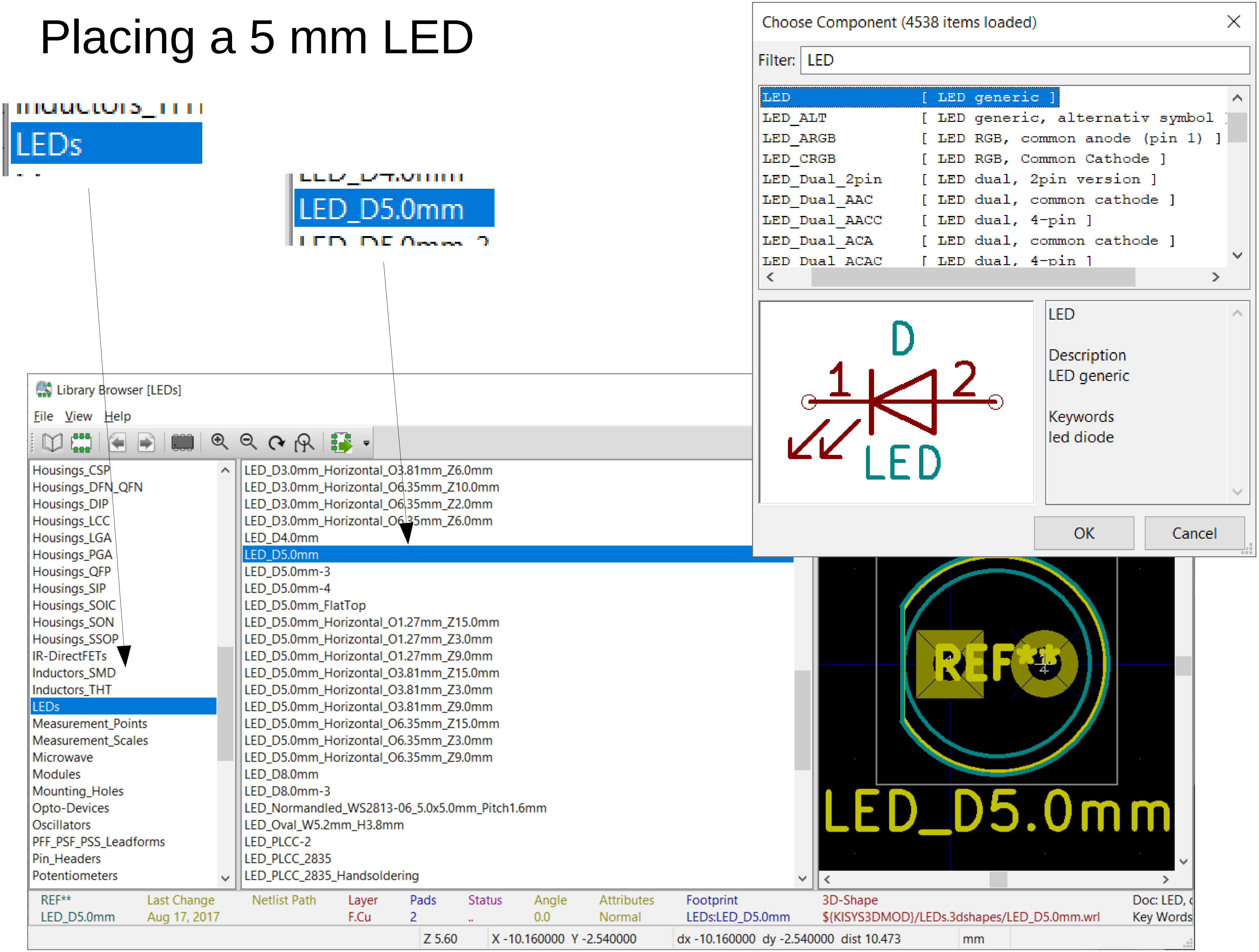
Placing a radial polarized capacitor



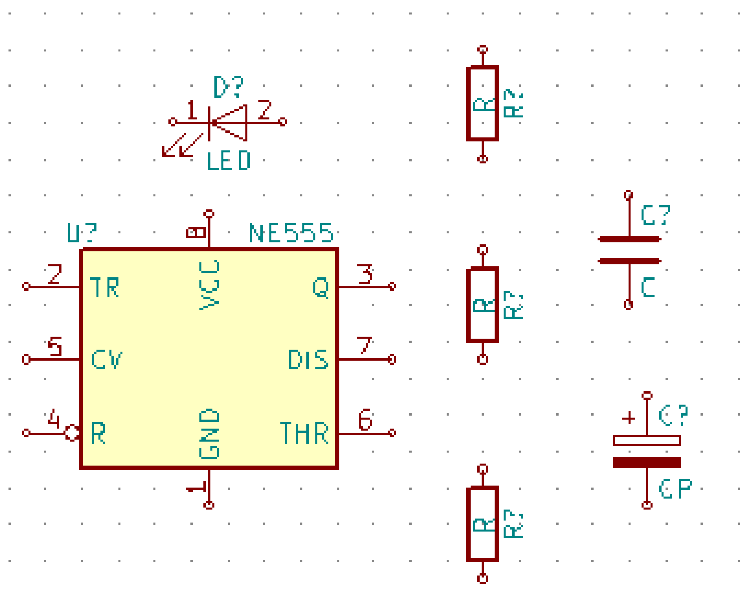




Placing a 5 mm LED



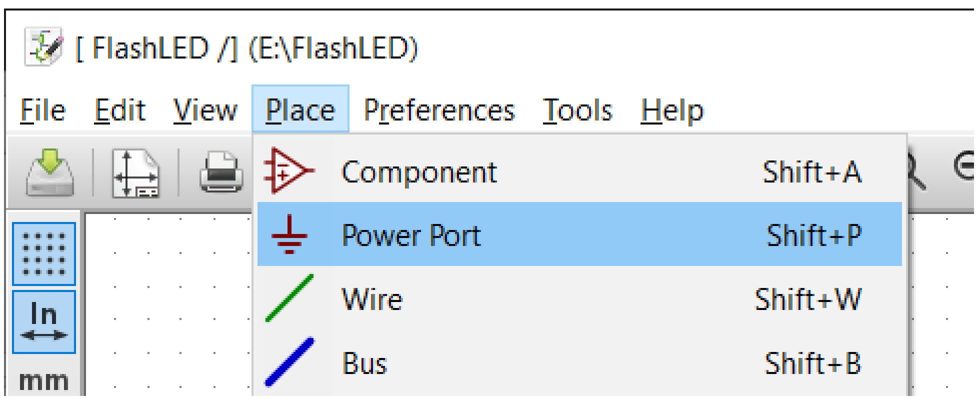
What we have so far...



What else do we need?

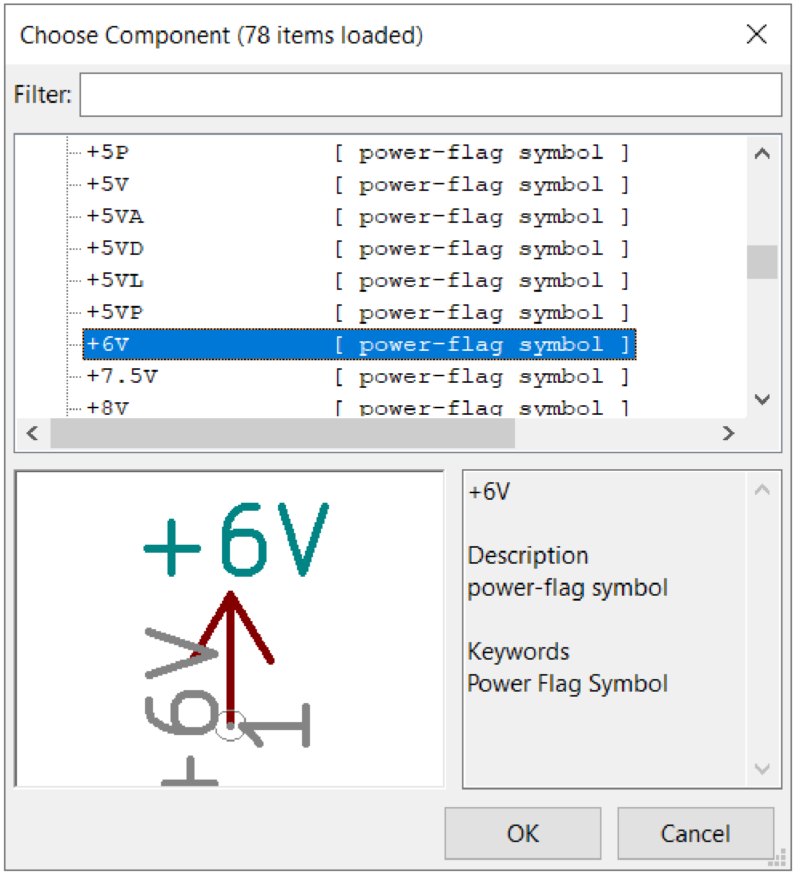
POWER!

To do this we need power ports.

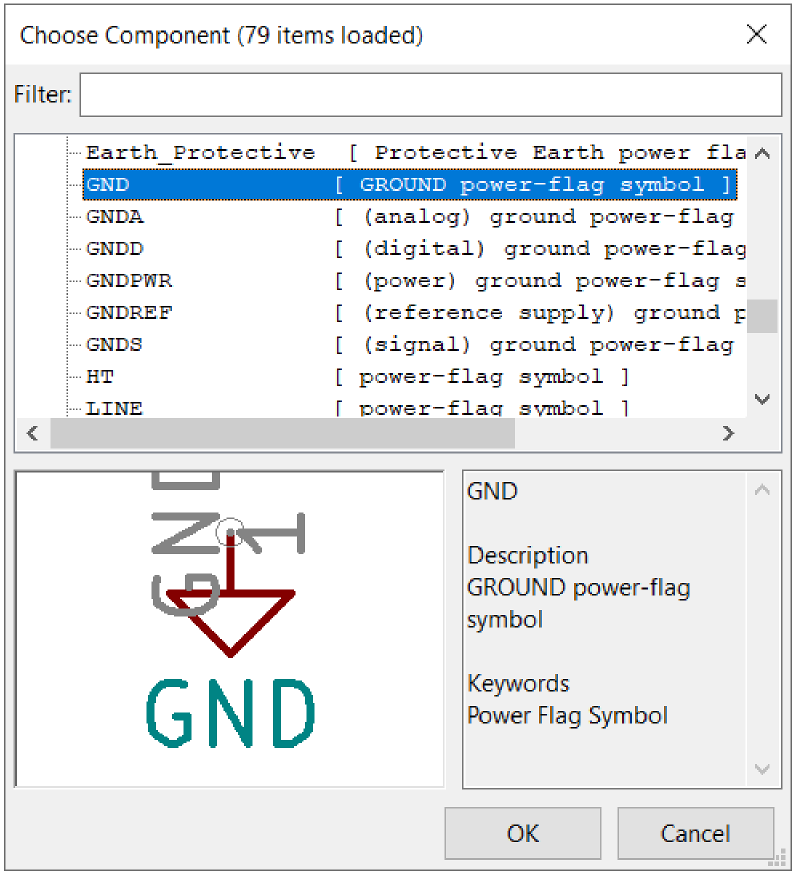


We choose the place power port menu item.

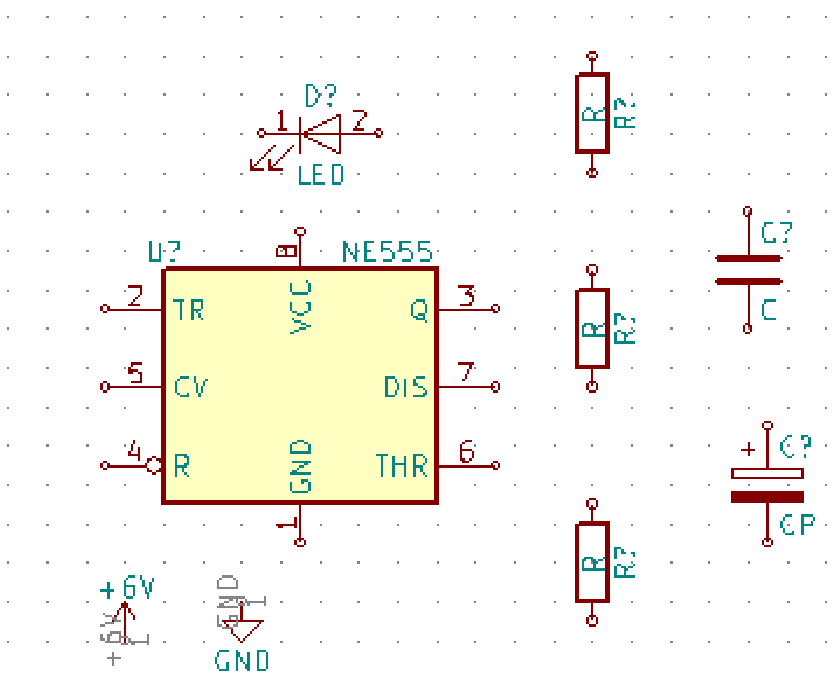
We can expand the list of power ports and select 6 volts, for example, for the positive voltage.



Then we can place a second power port for ground.



Now we have power ports. Finally, we need a way to connect external wires to the power port, so we place screw terminals.

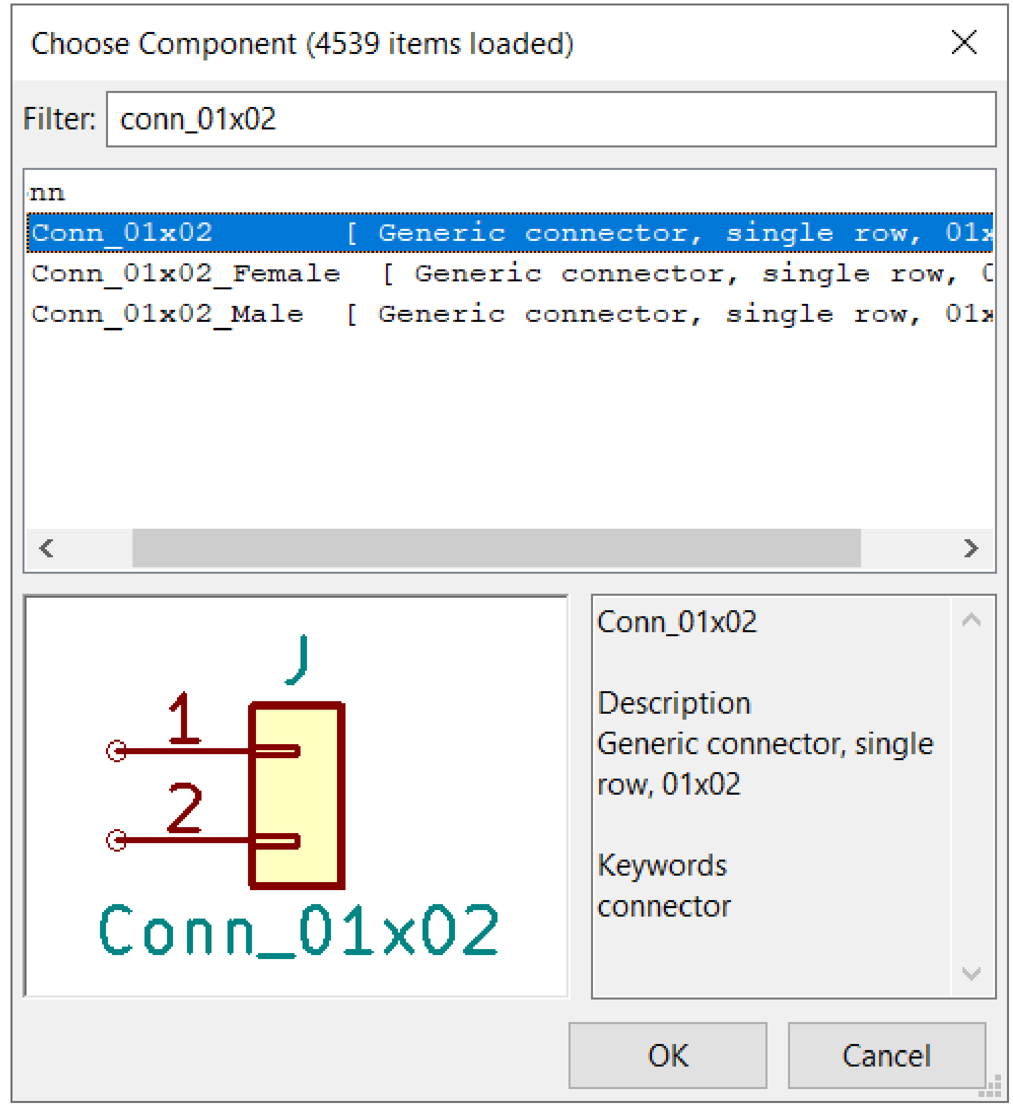


Connectors_TE-Connectivity
Connectors_Terminal_Blocks
Connectors_USB

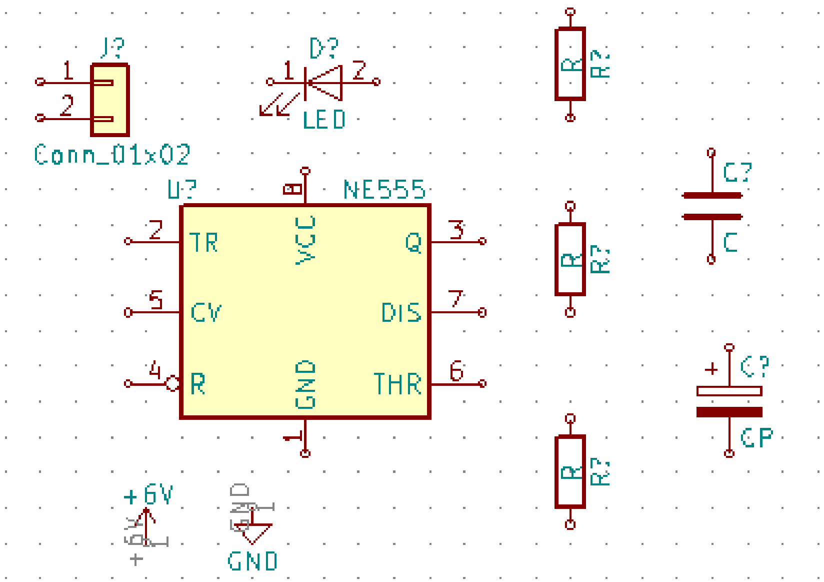
TerminalBlock_bornier-2_P5.08mm

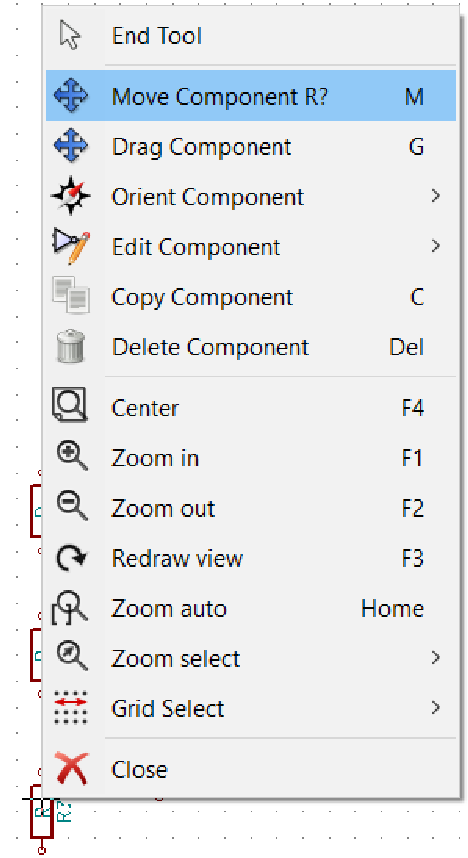
Footprint for standard 2/10" spacing screw terminals.

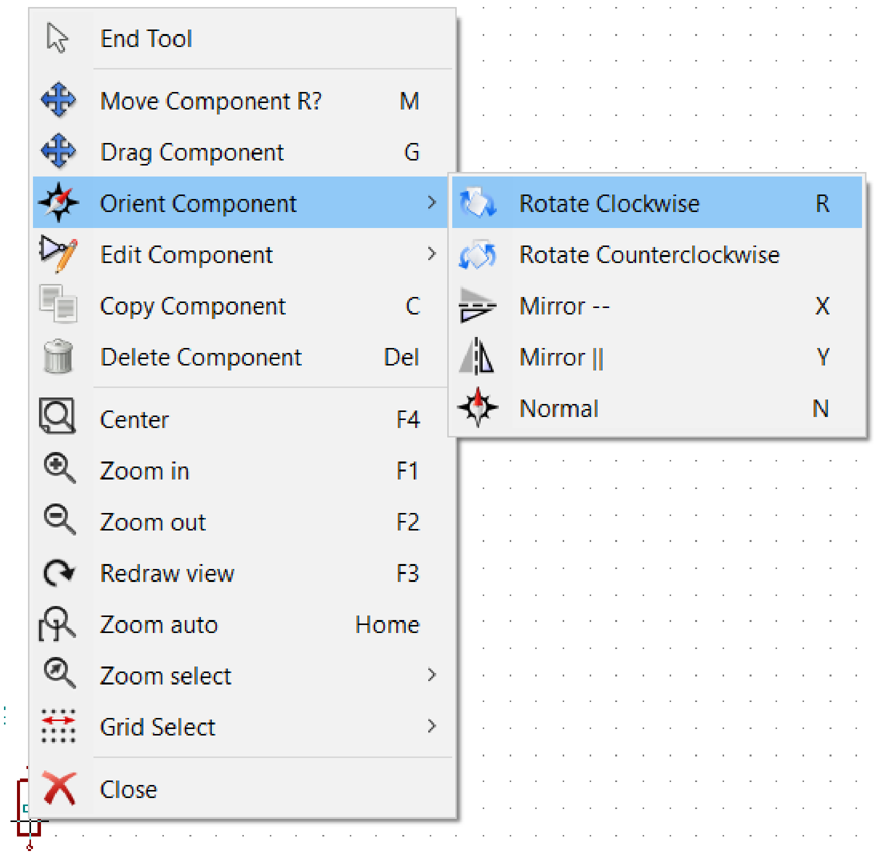
Placing a two terminal connector



Wiring it all up

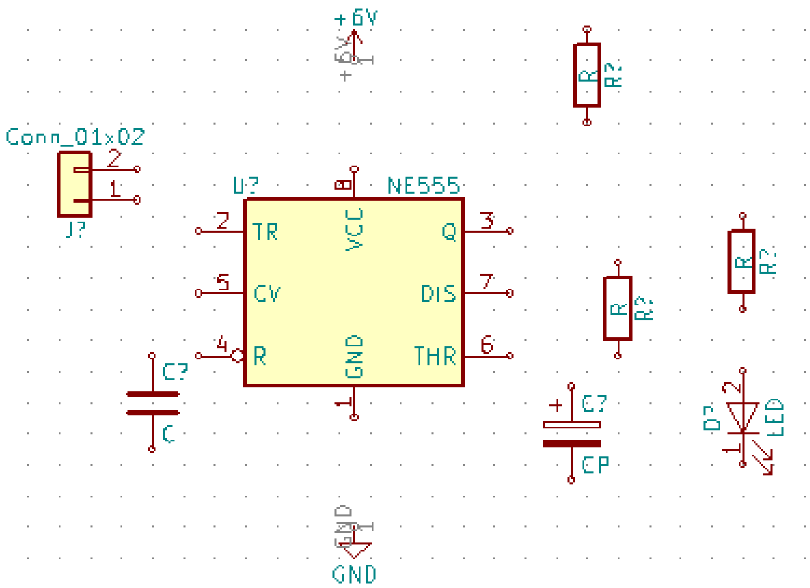


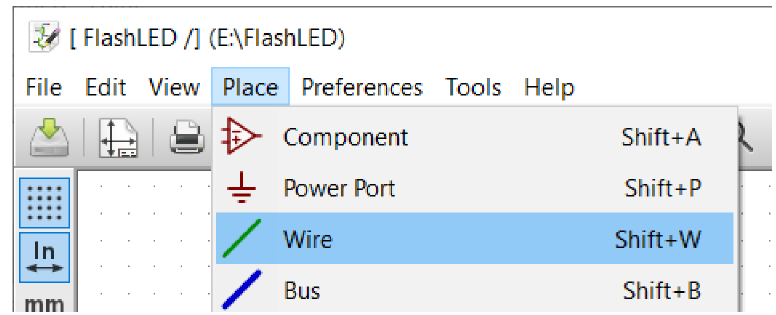




First move and rotate the components into the approximate right places. Right click on part and select move or rotate component.

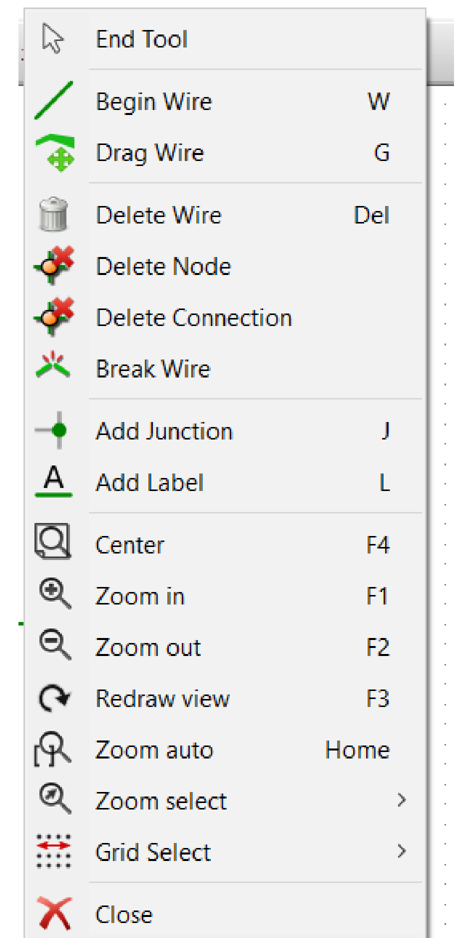
Now we can draw wires between the components



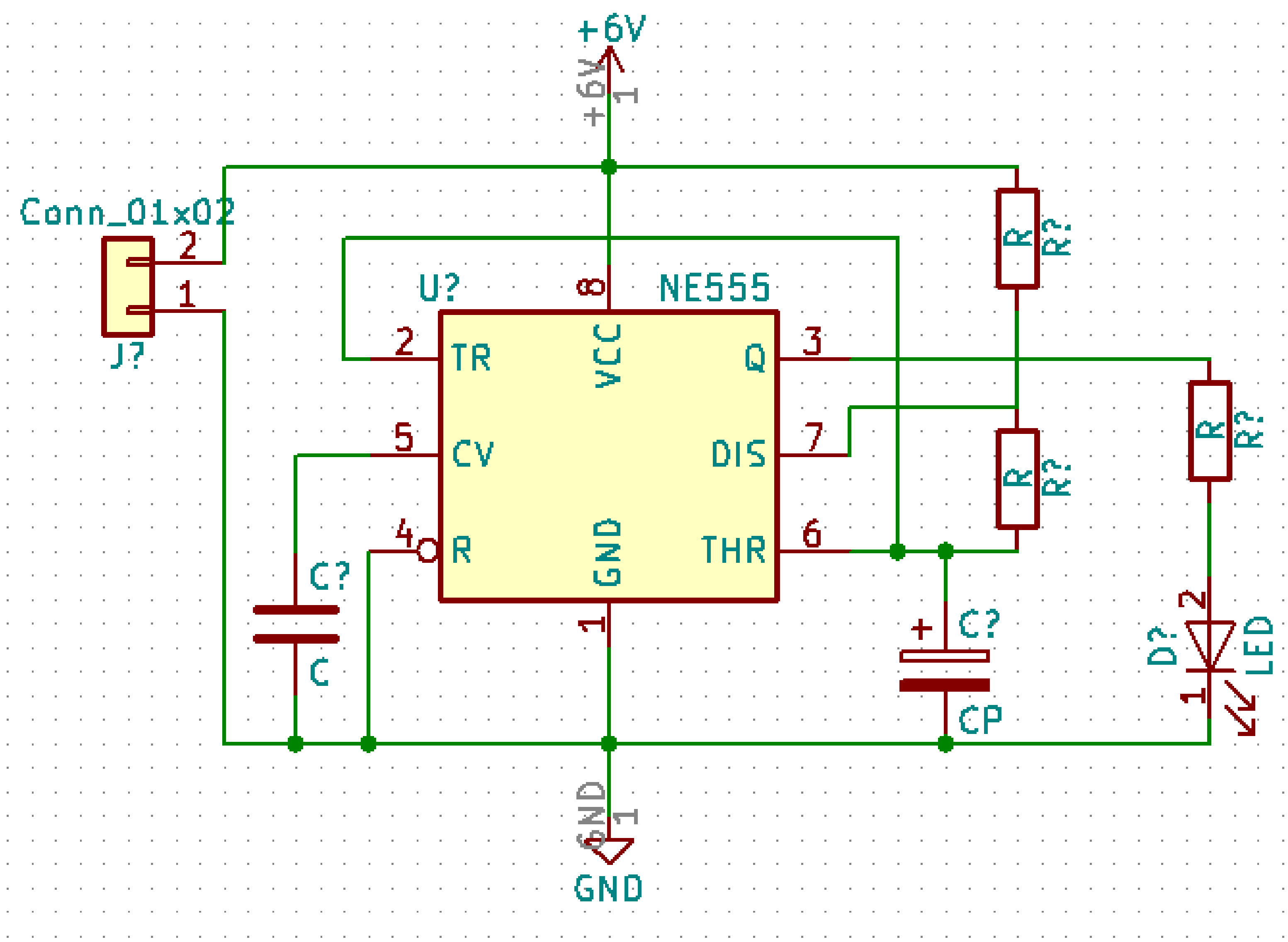


Click where you want wires to begin or end. You can placed bends in wires by clicking on points you want the wire to bend at.

If you right-click on a wire, you can remove the connection.

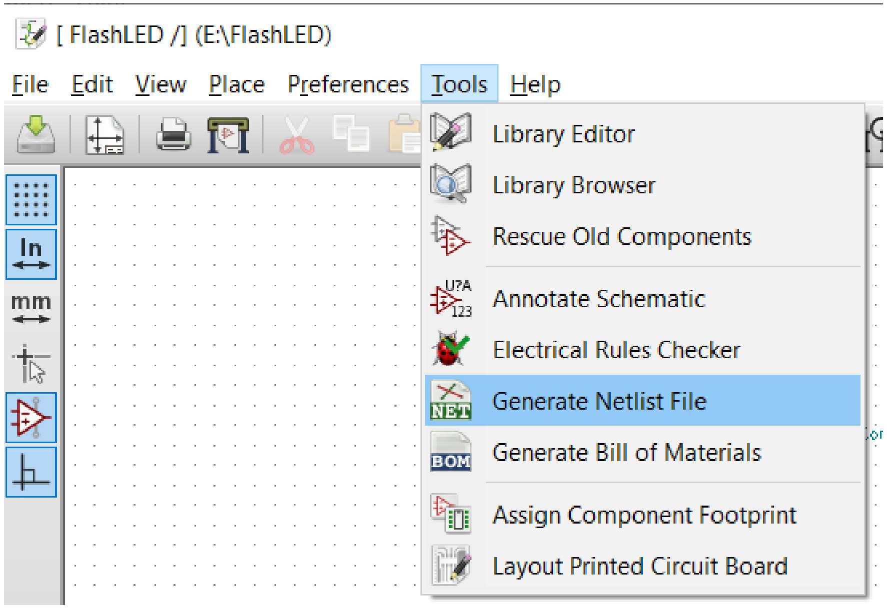


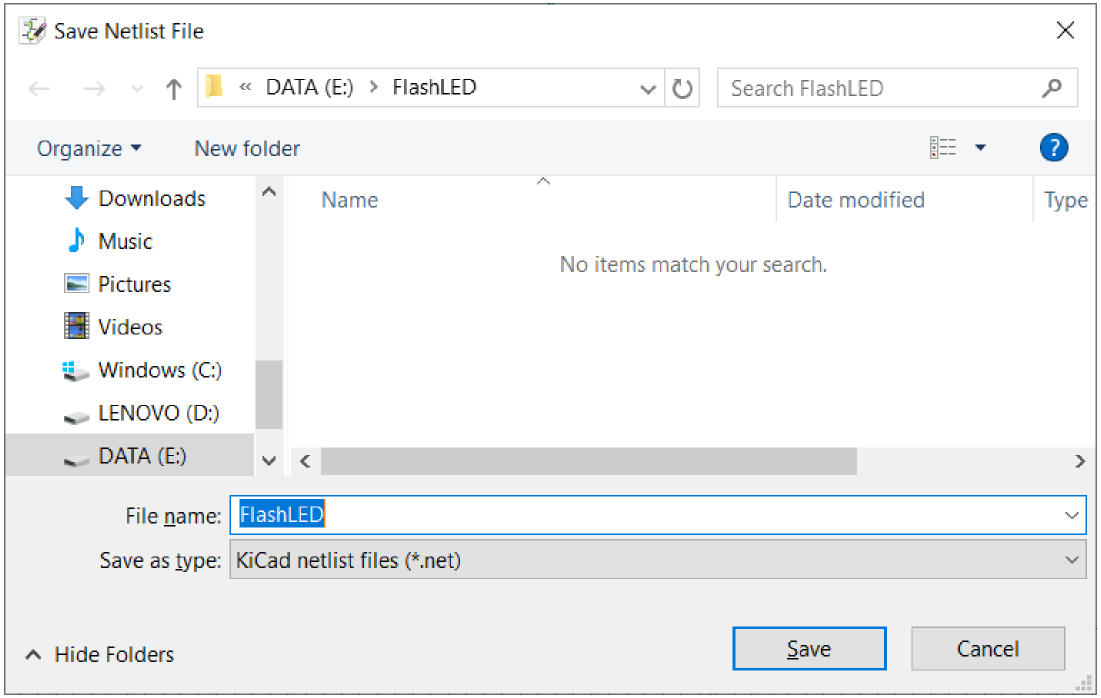
Schematic capture is complete!



Schematic capture is complete!

Now we export a netlist, which provides the PCB layout editor the description of the schematic.

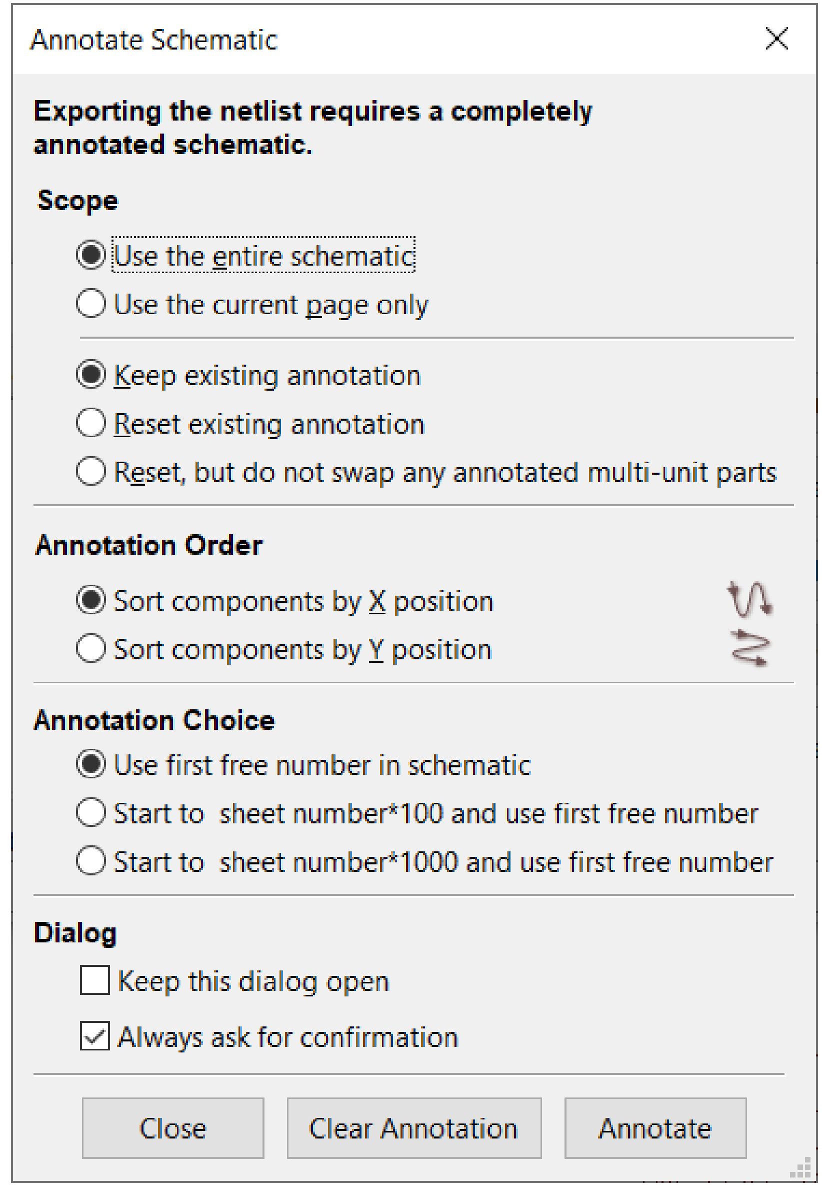




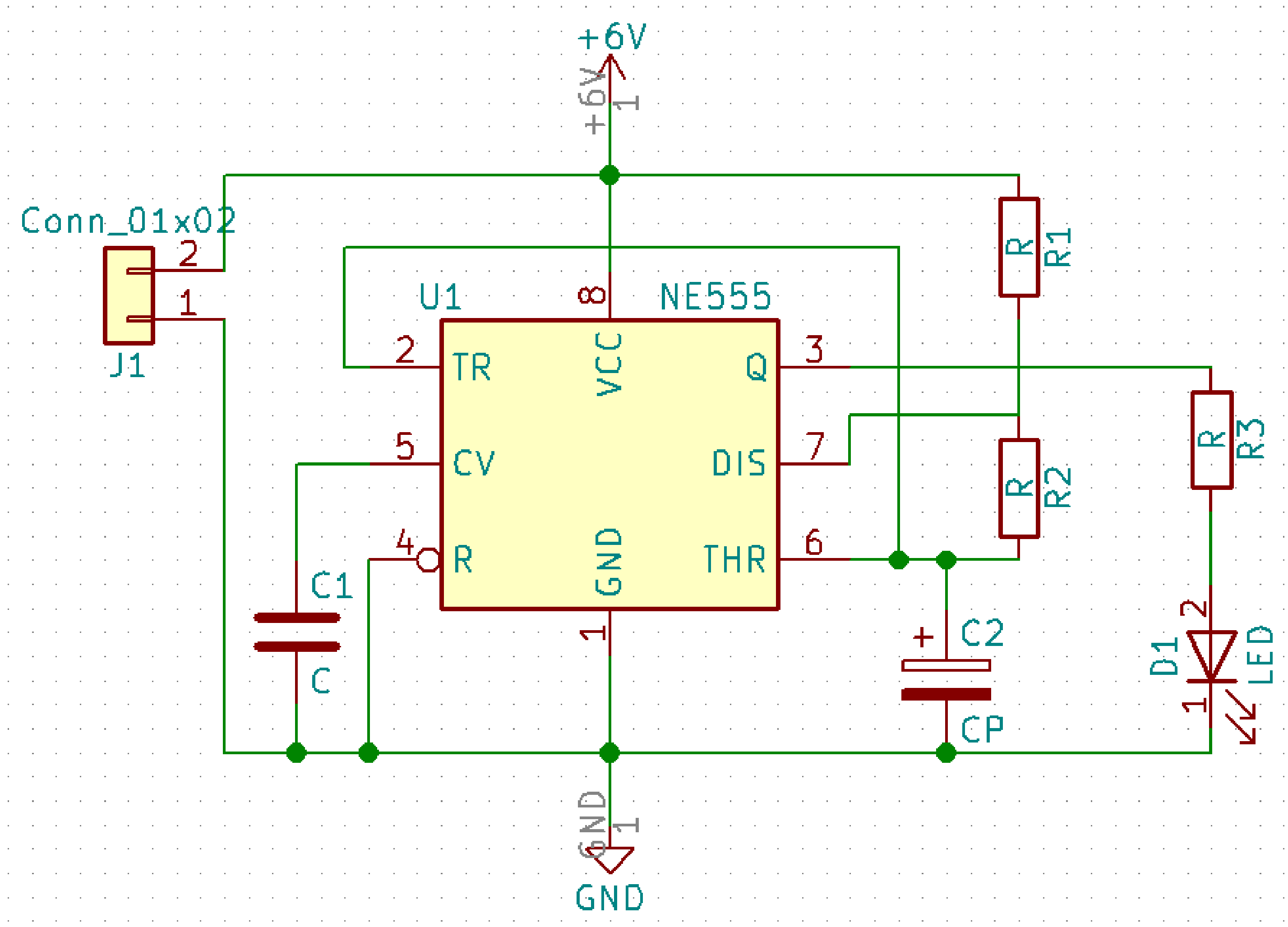
We select the name of the netlist file to save to (usually the default).

Annotating the schematic references

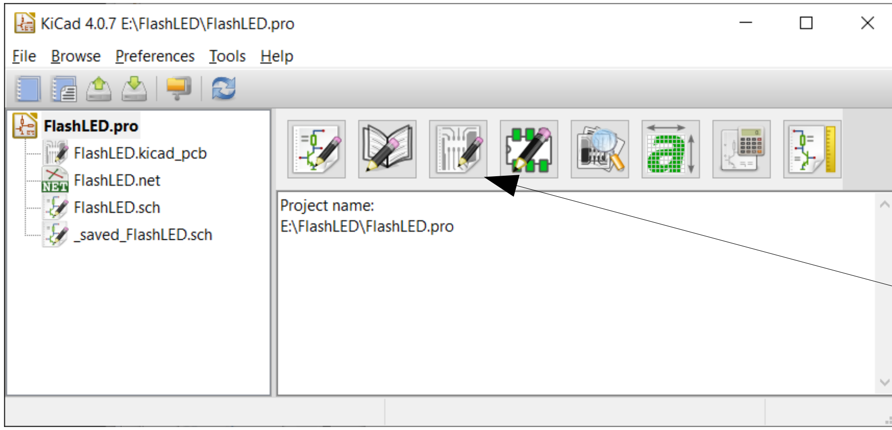
Since we didn't specify what the part references were (for example R1, R2, R3 for the three resistors), and these are required for the PCB editor, Kicad will automatically annotate the references. These may be assigned manually if desired as well when you create the part.



Now the references are added to the schematic.

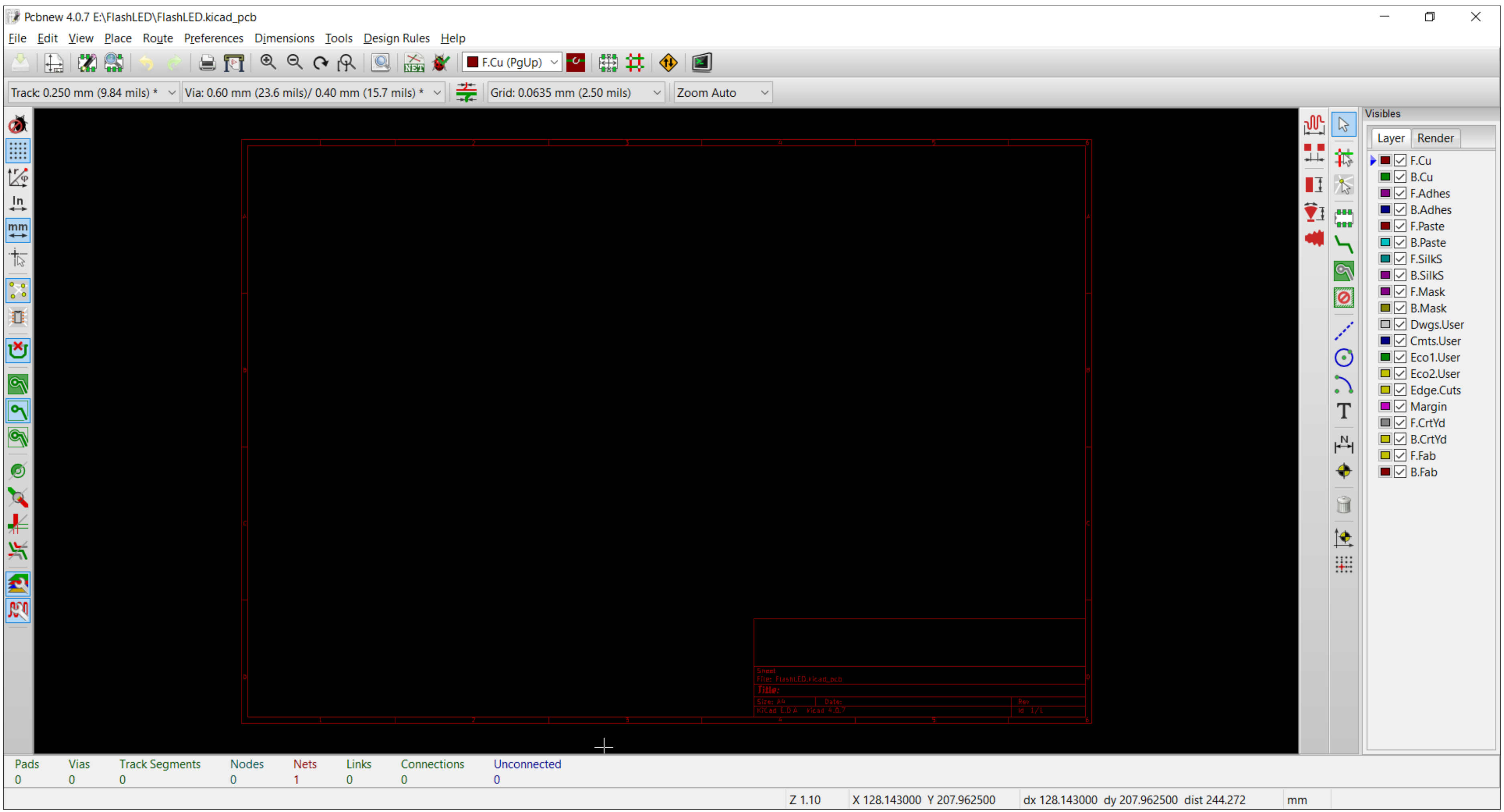


On with laying out the PCB!

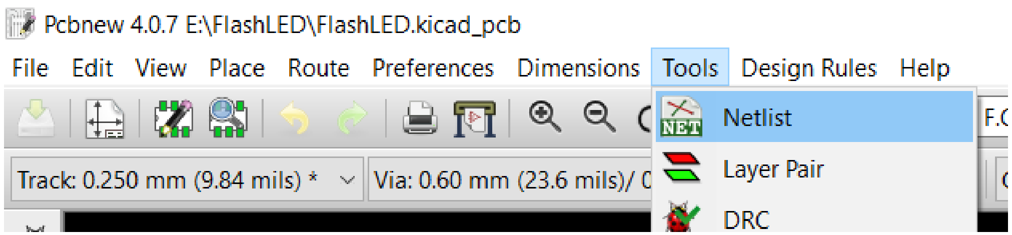


PCB
Layout

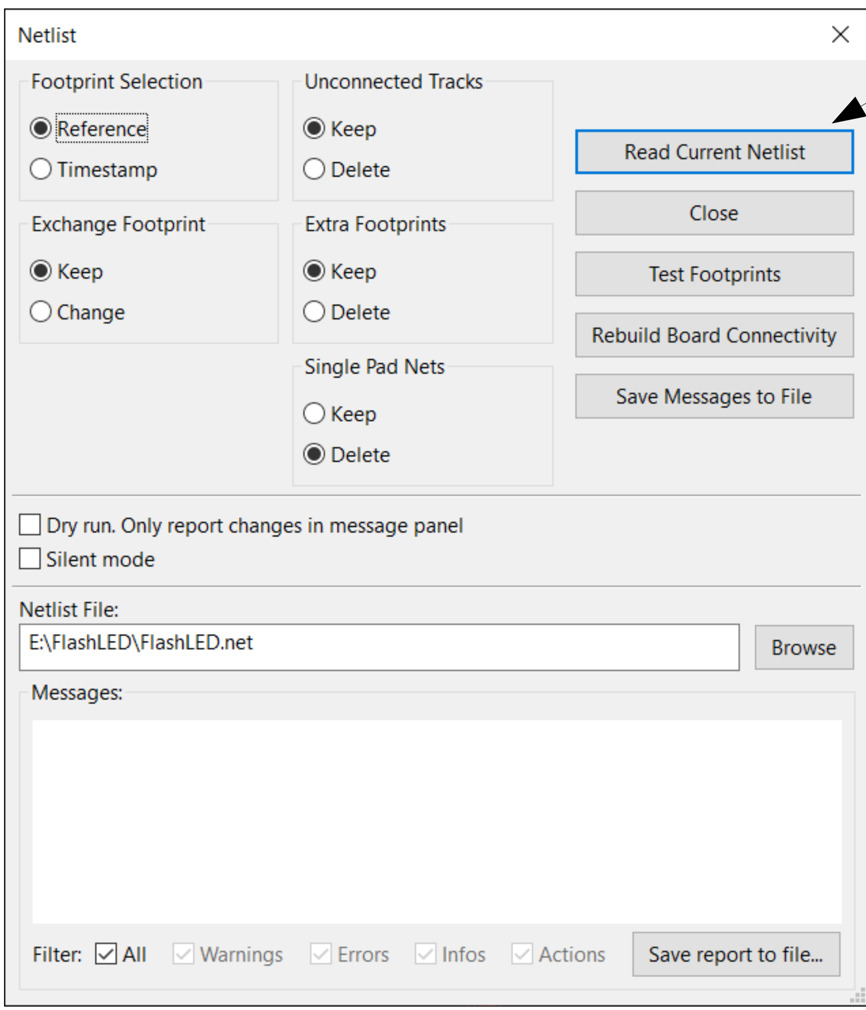
PCB Editor

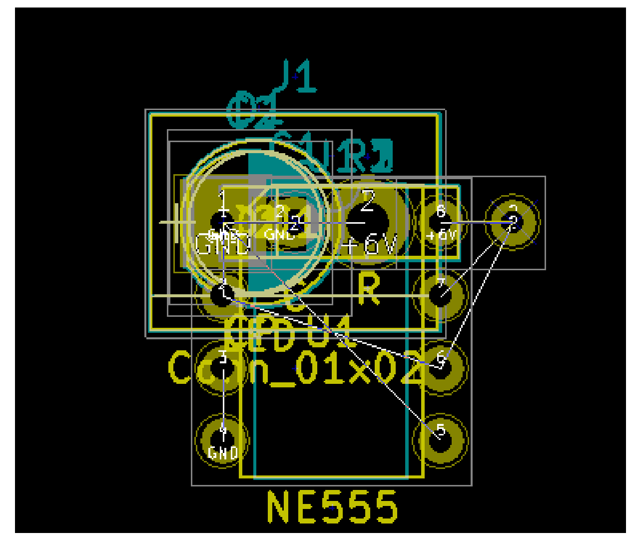


Importing the netlist into the PCB editor



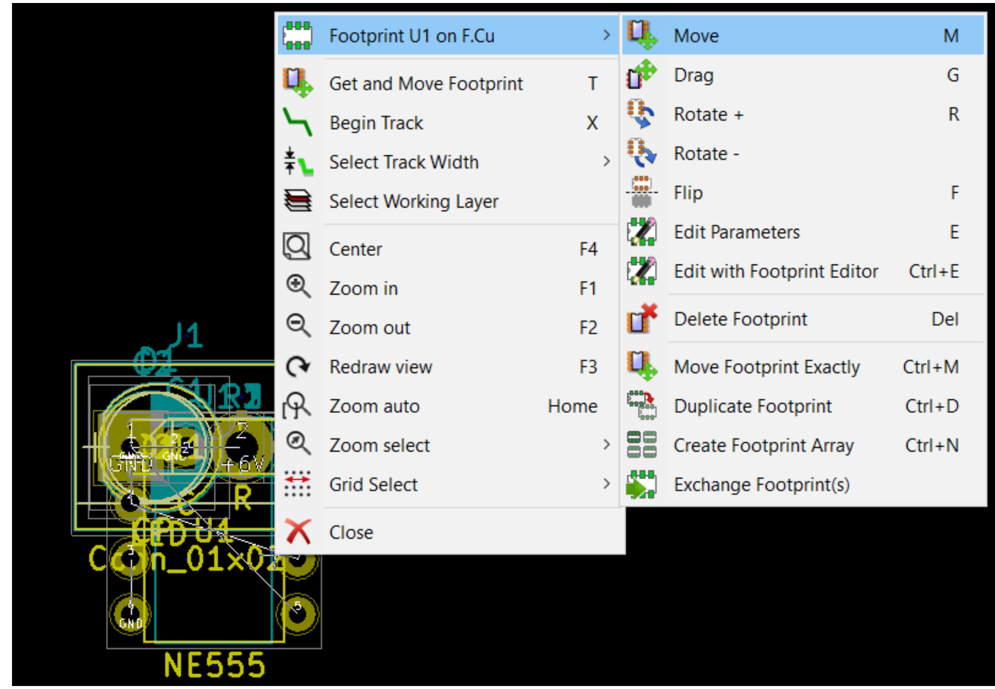
Click Read Current Netlist



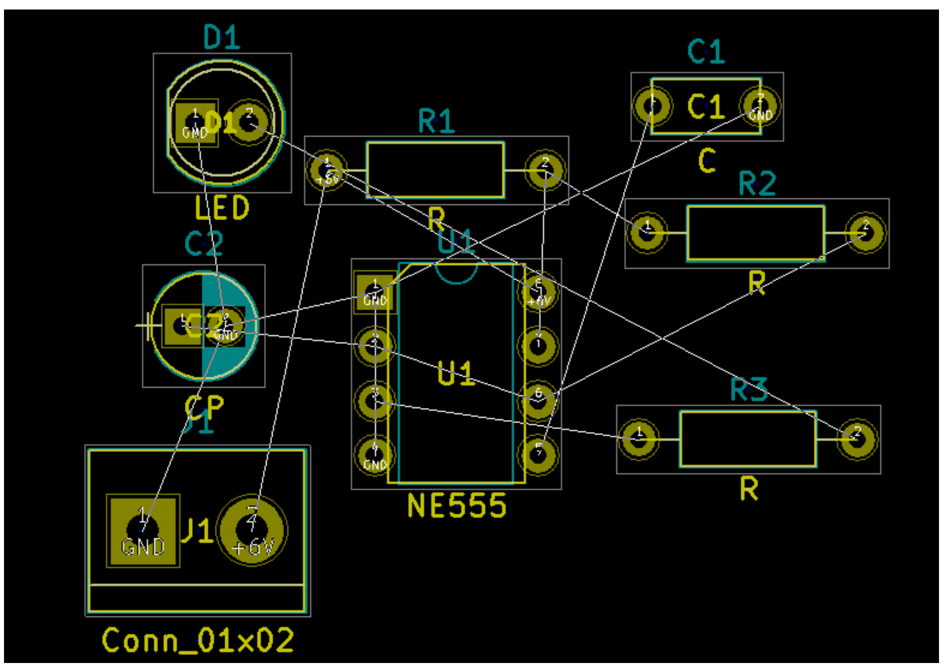


All of the components are imported, and lines drawn between the pins to be connected.

Moving the components



Lets move the parts so they're not on top of each other so we can better see what we're doing.



Kicad shows us how the parts are to be connected, but these are not wires. This is called the "ratsnest."

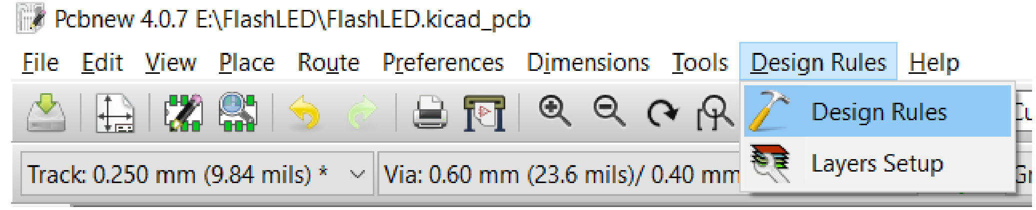
Design rules

We have to decide aspects such as

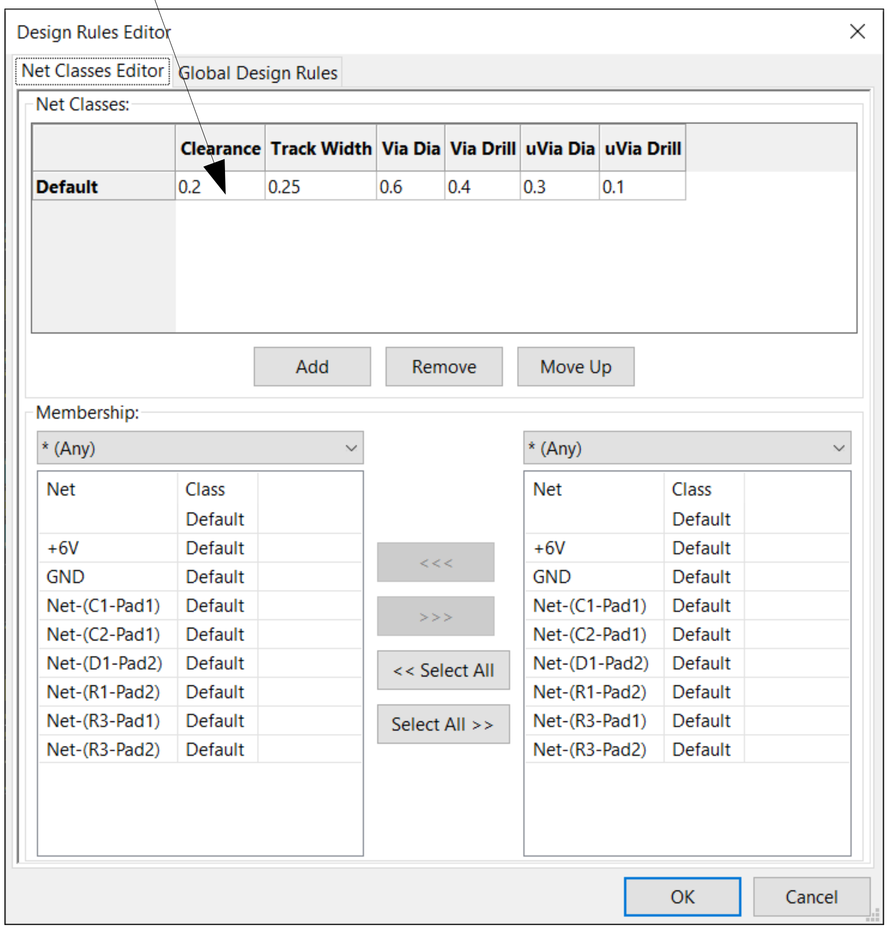
- How wide or narrow will the traces be between the components?
- How close are the traces allowed to be?
- How big or small are vias allowed to be?

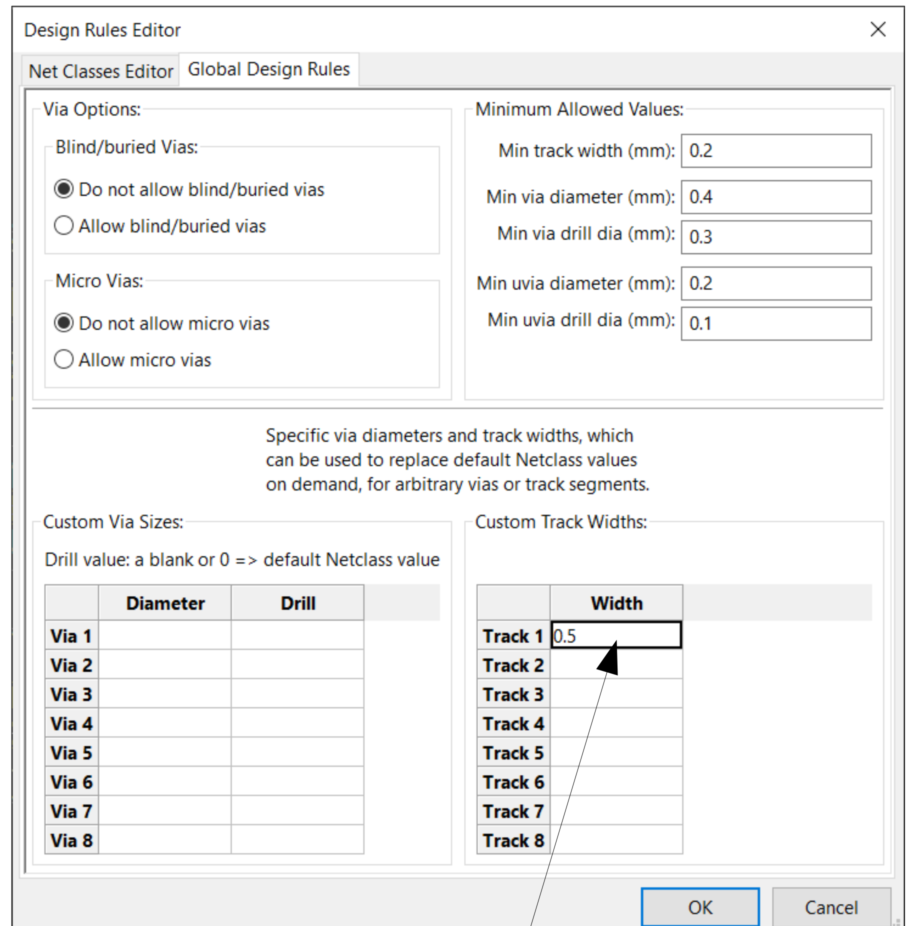
These are often determined by the manufacturer of your PCB. If you want very small features, this costs more. Most hobbyist projects do not require very challenging or expensive design rules.

Setting the design rules



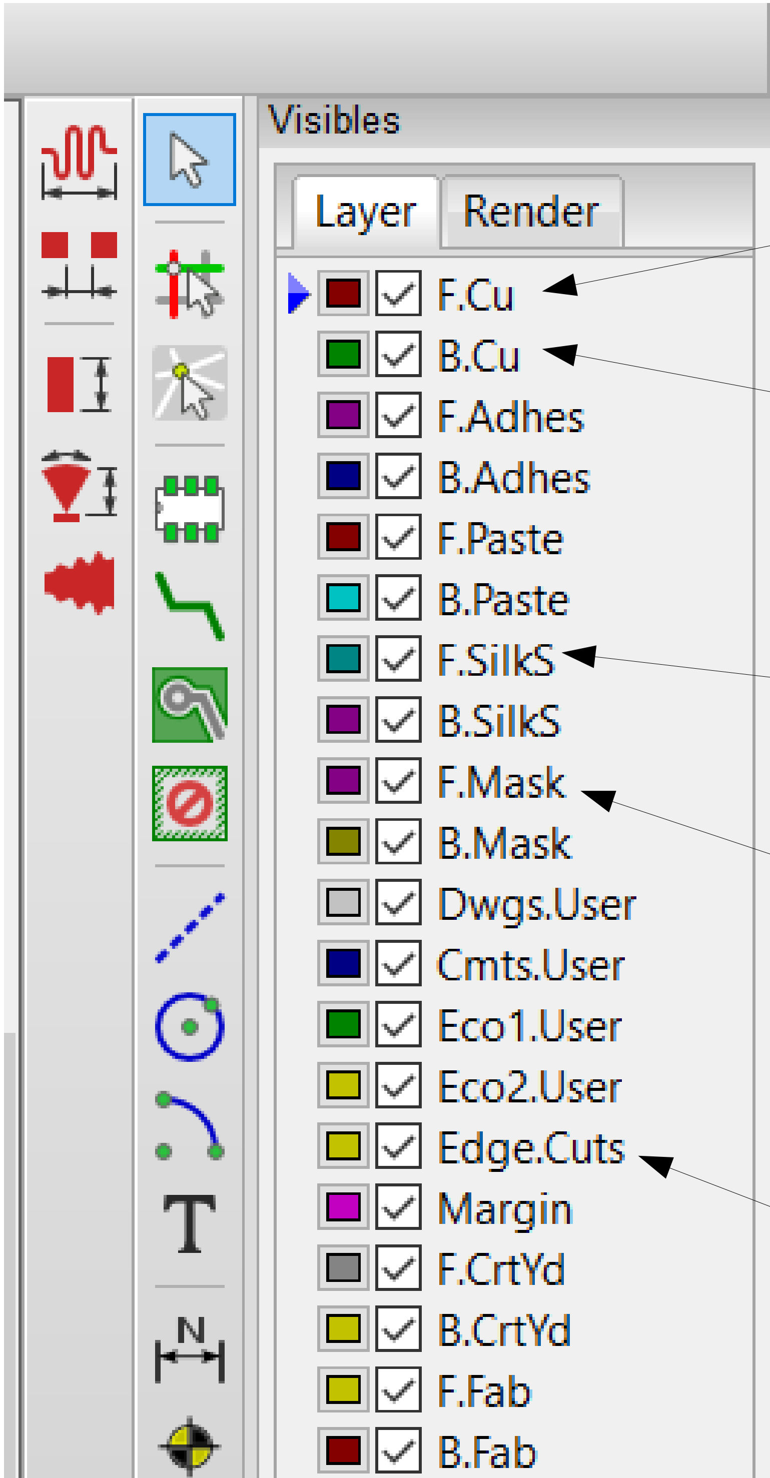
These rules determine via sizes and minimum feature sizes and widths.





These are the widths of the tracks that can be placed. 0.5 mm is placed here.

Commonly used board Layers



Front copper layer (where traces go on the front of the board)

Back copper layer (where traces go on the back of the board)

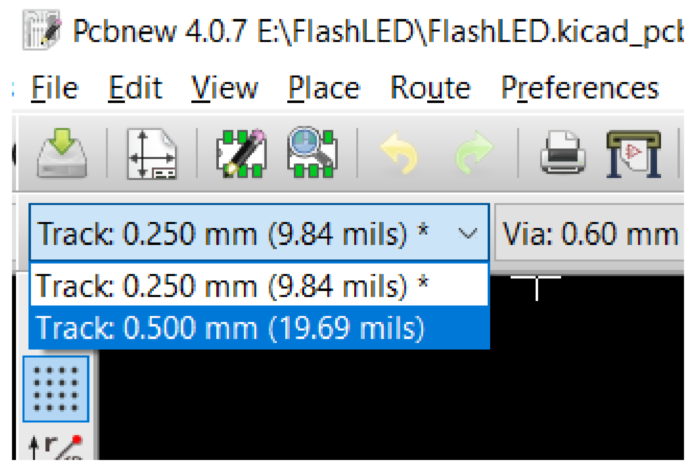
Front silkscreening layer, so you can annotate your PCB

Front and back solder mask.

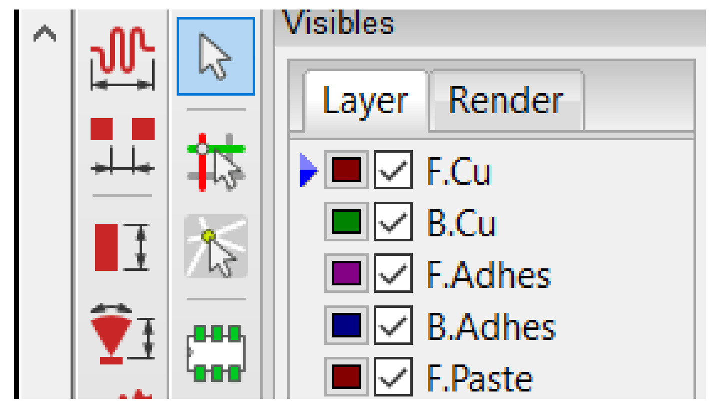
Edge Cuts (not used by all manufacturers), denotes the boundaries of your PCB (usually a rectangle)

Drawing the traces between components

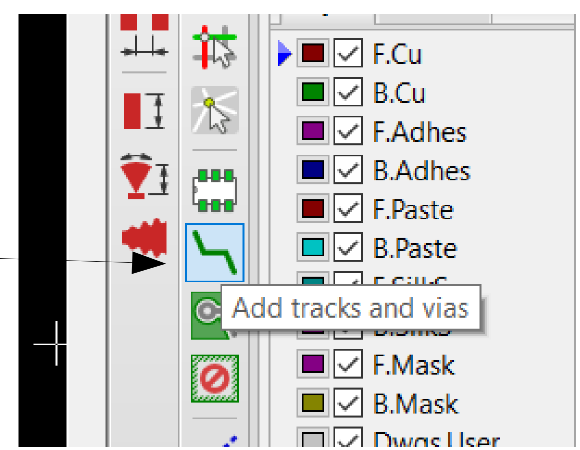
We move and rotate the components into position.
To draw a trace between two pads, we first select the trace size:



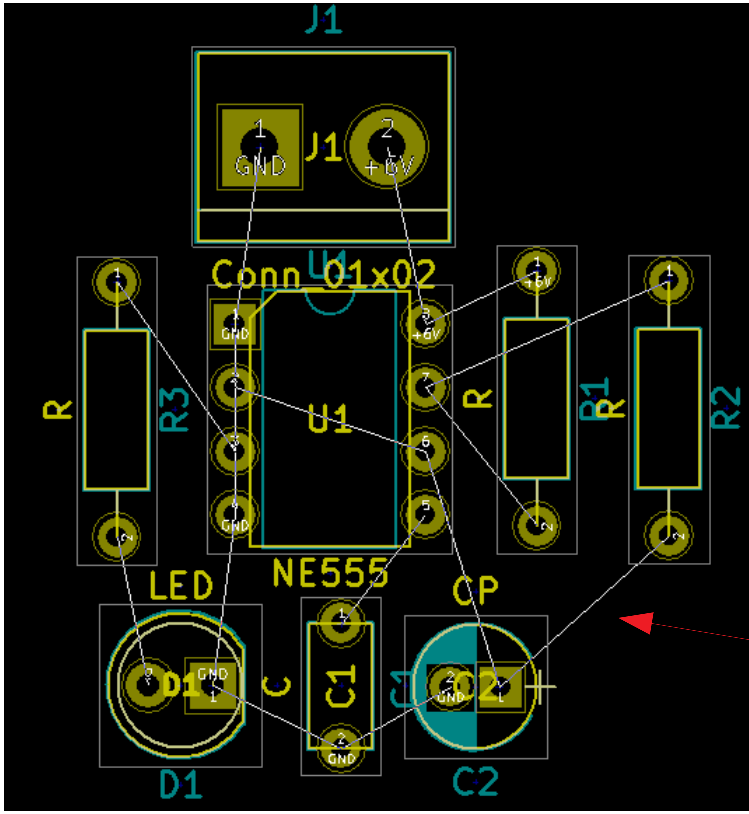
Select the layer the trace goes on by clicking on the layer name. The arrow appears next to the selected layer.



Then we select the draw track tool.



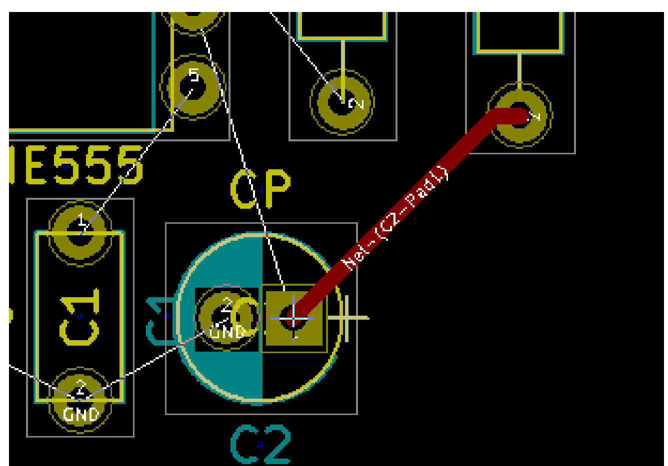
Connecting the components



The ratsnest tells us which components to connect. Kicad will not allow us to make connections not in the ratsnest, as these are not compatible with the schematic.

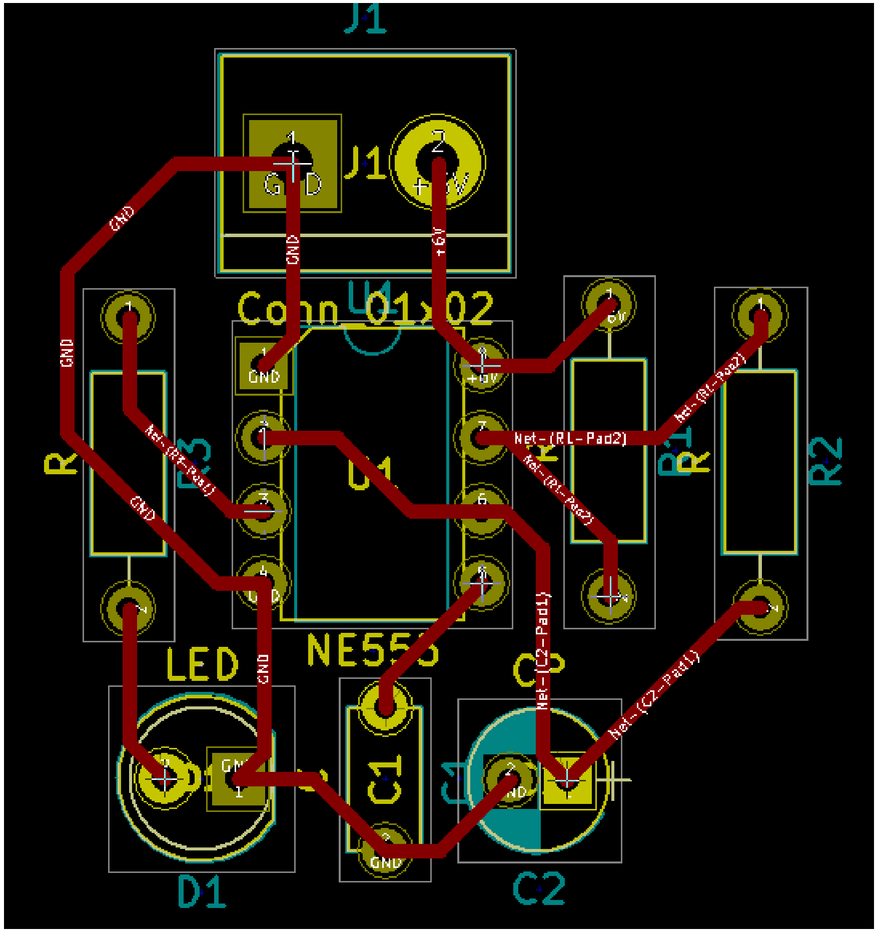
Pick this connection

Click on one of the ends of the ratsnest, and guide the trace to the other end, and click the other end.



The ratsnest line is replaced by a trace with the color given by the layer.

Filling in all of the traces

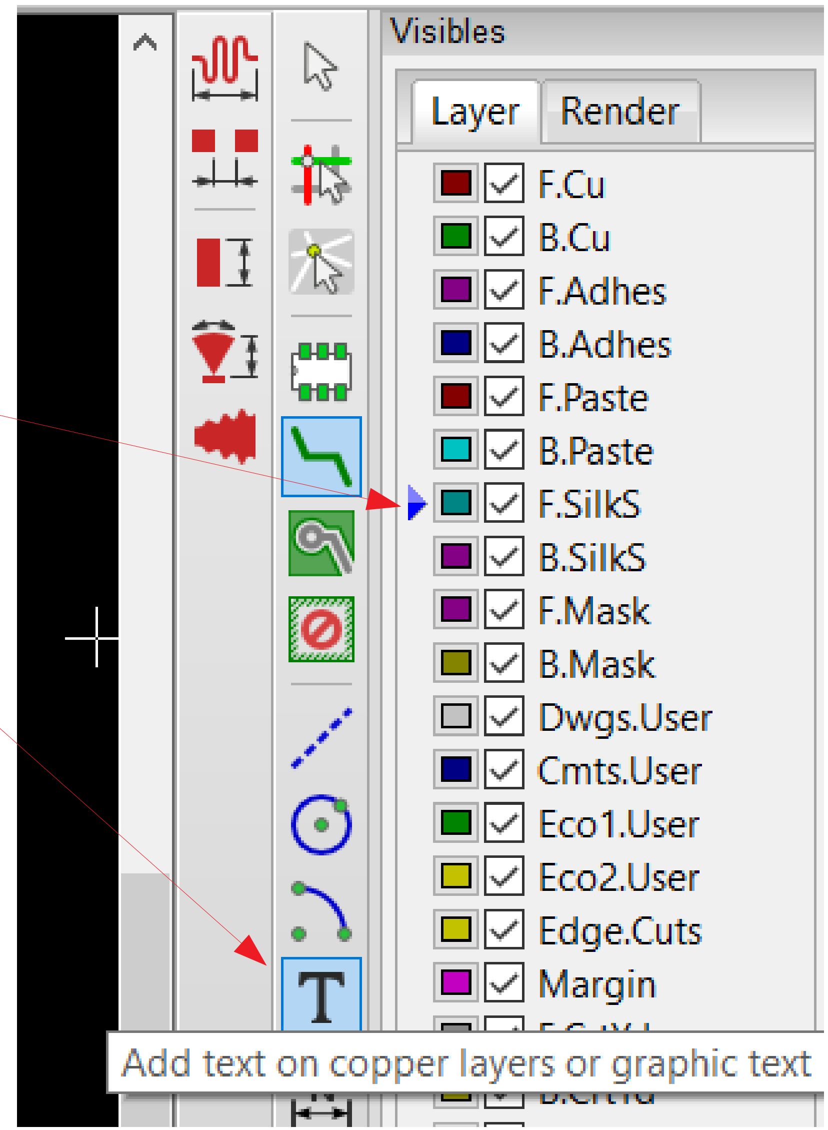


Each trace is labeled by its “net name” which describes which pads it connects.

We can add silkscreening

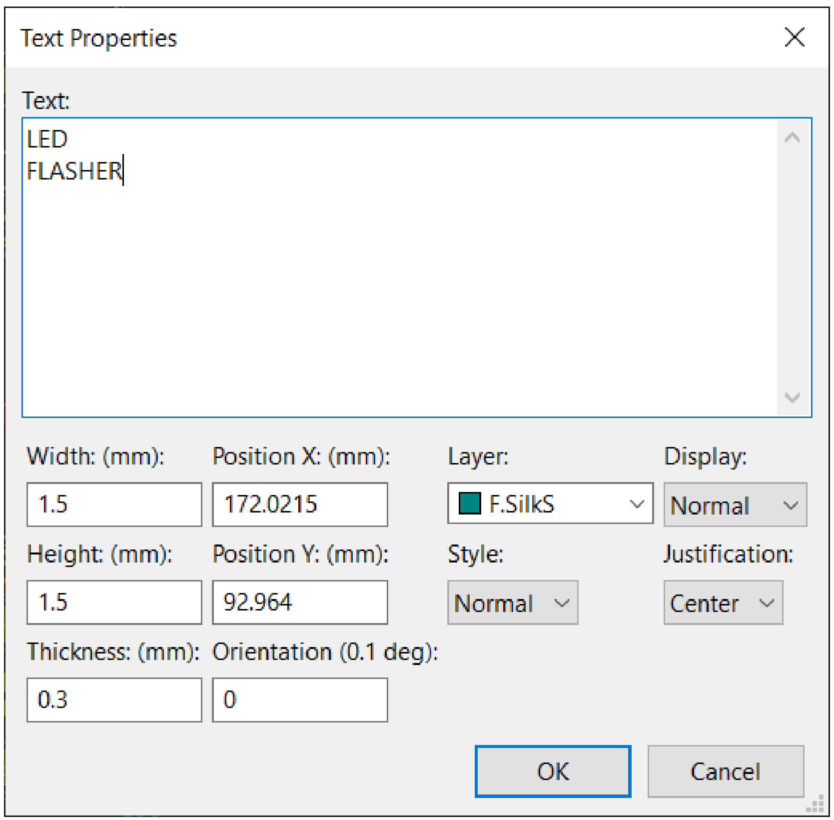
Select silkscreen layer

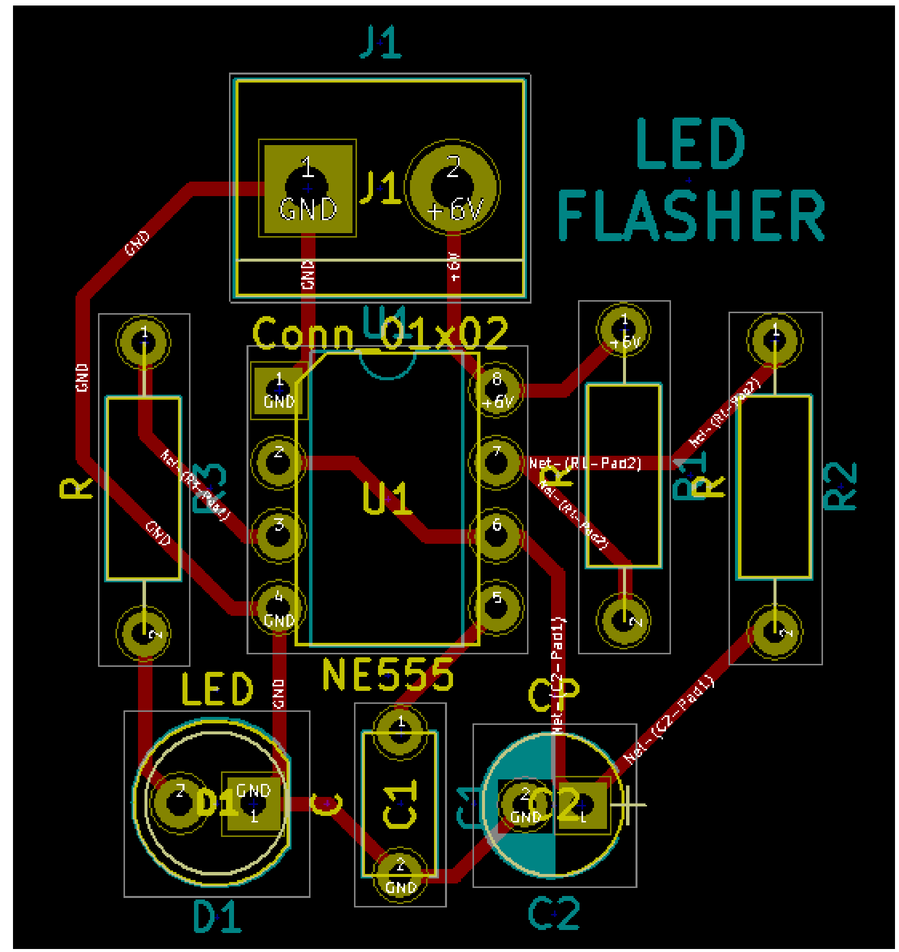
Text tool



Adding silkscreening

Click on the PCB where you want to add the silkscreening and then type the text into the box:

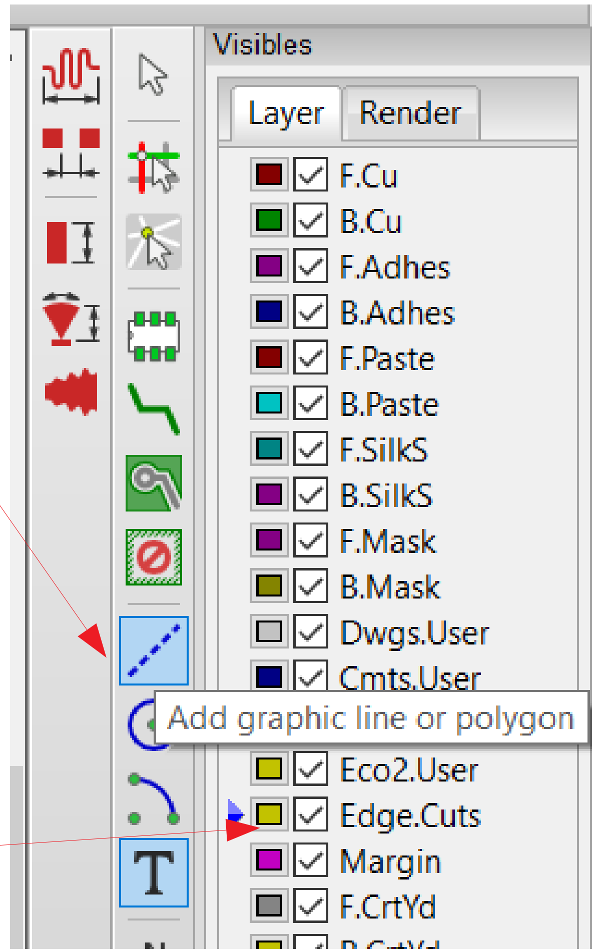


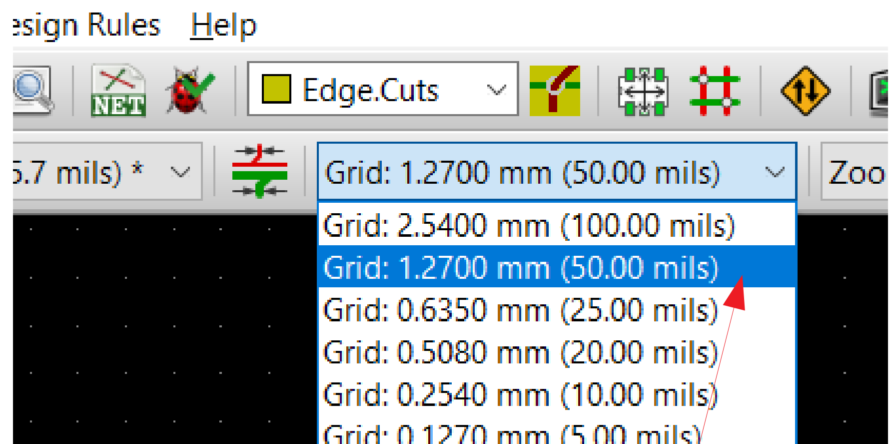


Drawing the board outline

Choose line tool

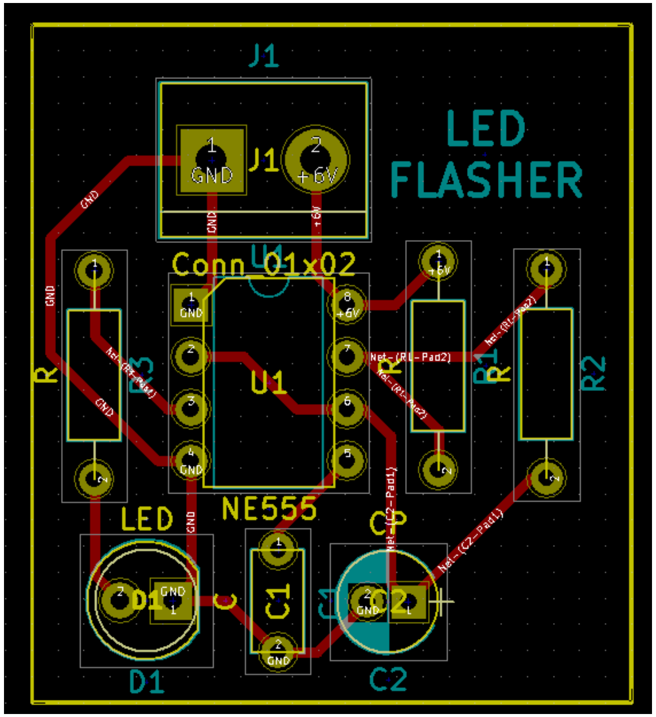
Select edge cuts layer



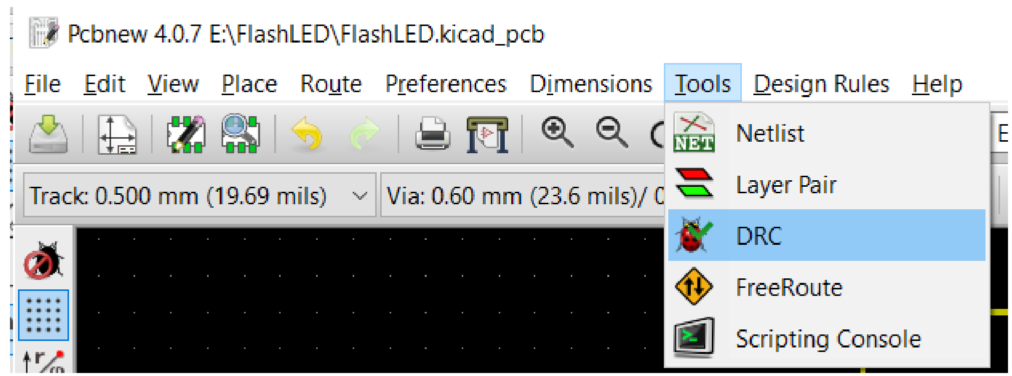


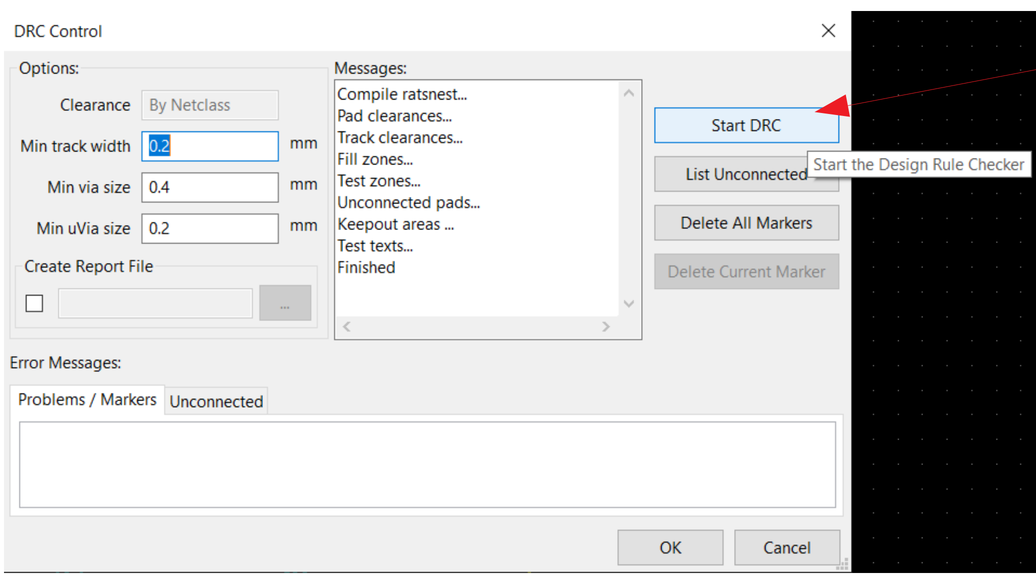
Select a coarse grid size to make it easier to draw a straight rectangle

With the board outline



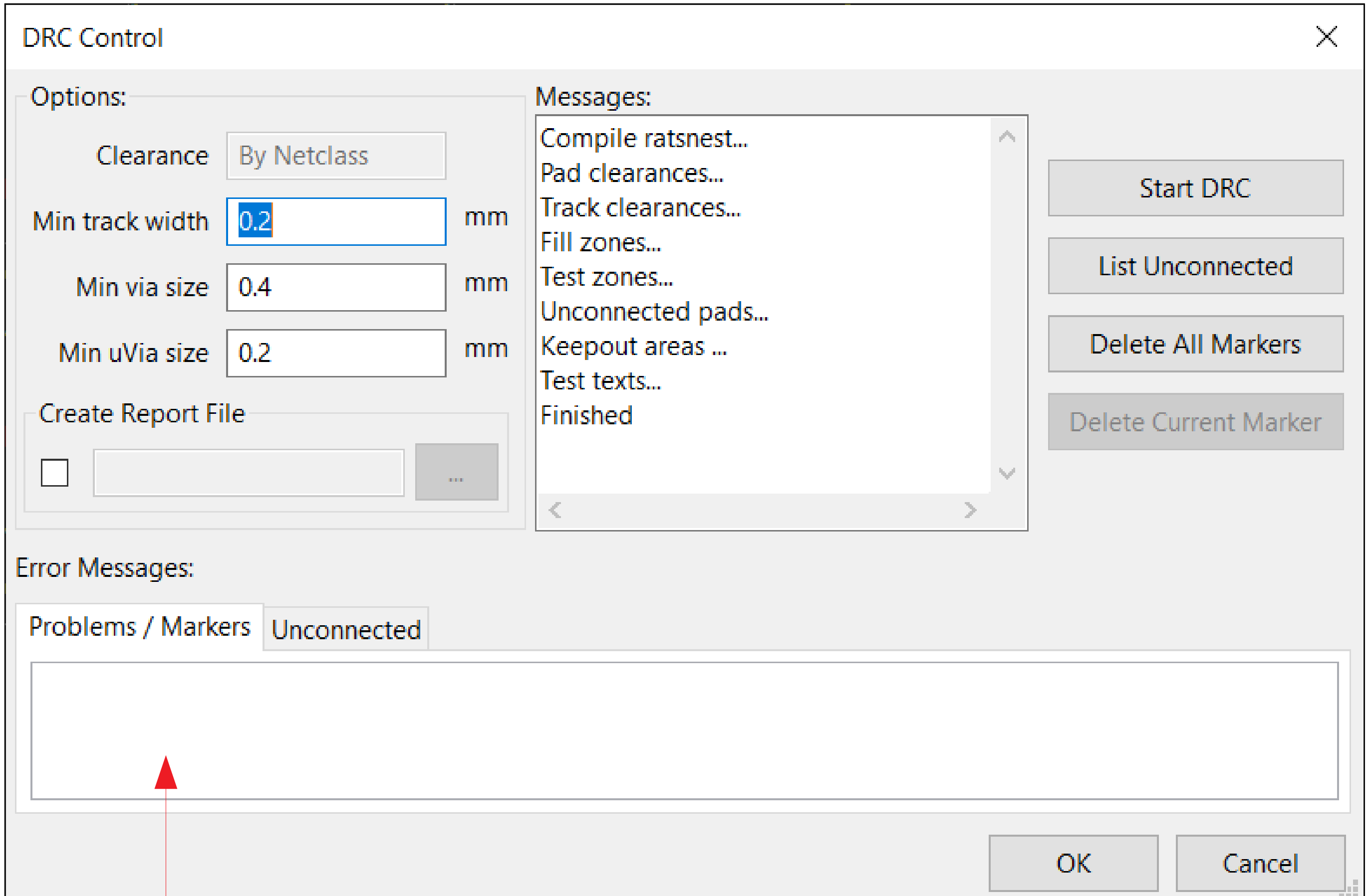
Now we do a design rules check to make sure everything is ok!





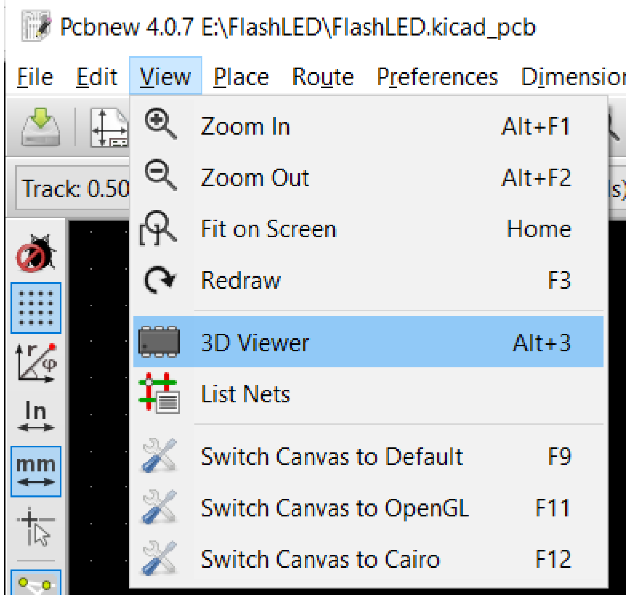
Do design rule check

Design rule check success!

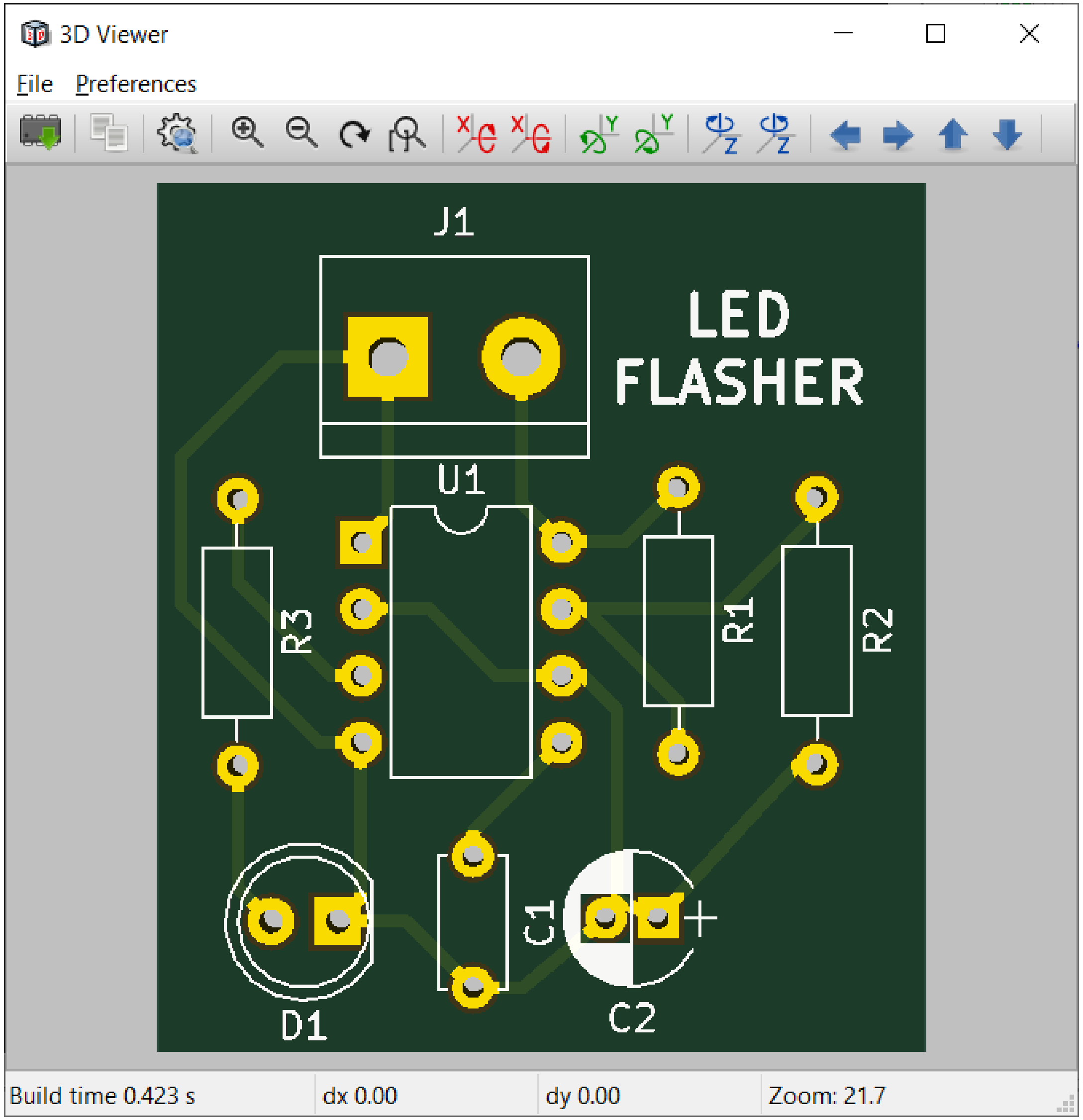


Problems can be parts are too close together or touching that should not be, too small width between traces, etc. If you click on the problem it takes you the location of the PCB.

What does my PCB look like?



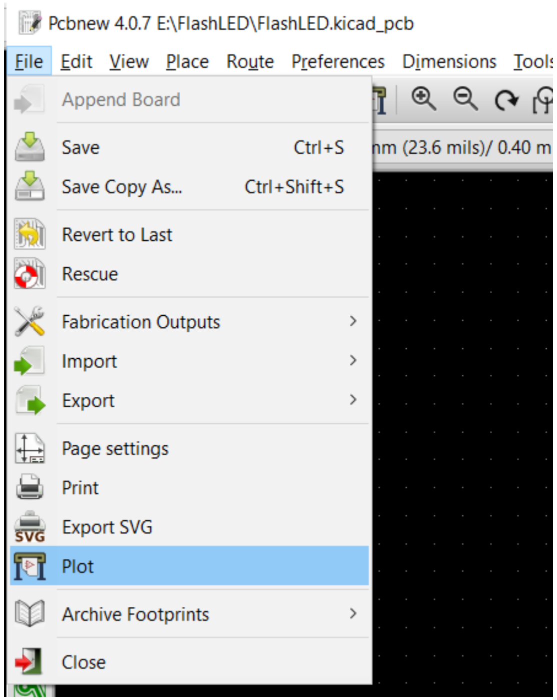
Use the 3-D viewer



Exporting the Gerber files

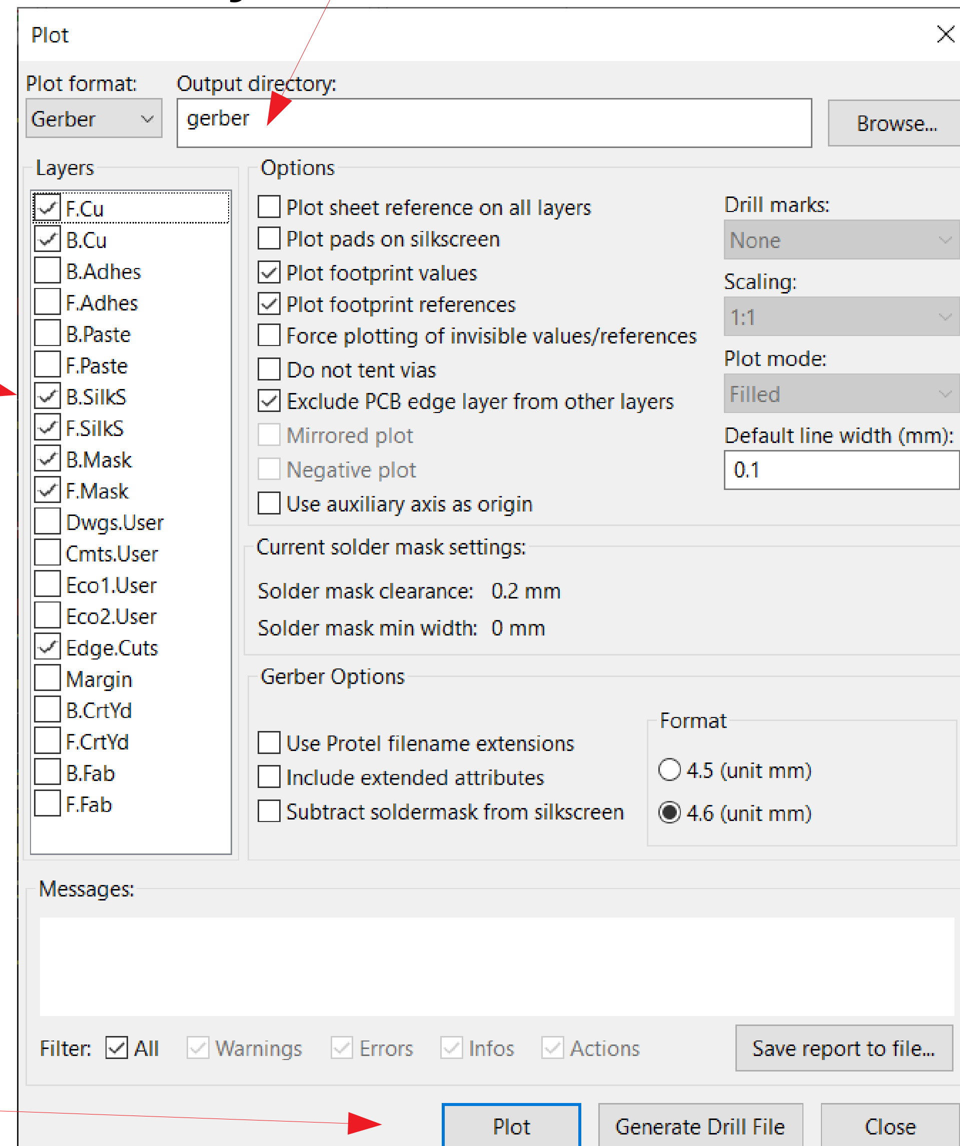
Gerber files are what you send the PCB manufacturer to make your PCB.

Enter “gerber” here so the files are in a separate directory.



Select plot from the menu

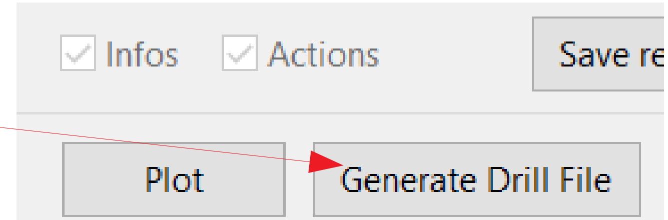
Check these layers, which are typically what is needed (unless you need a solder stencil as well)



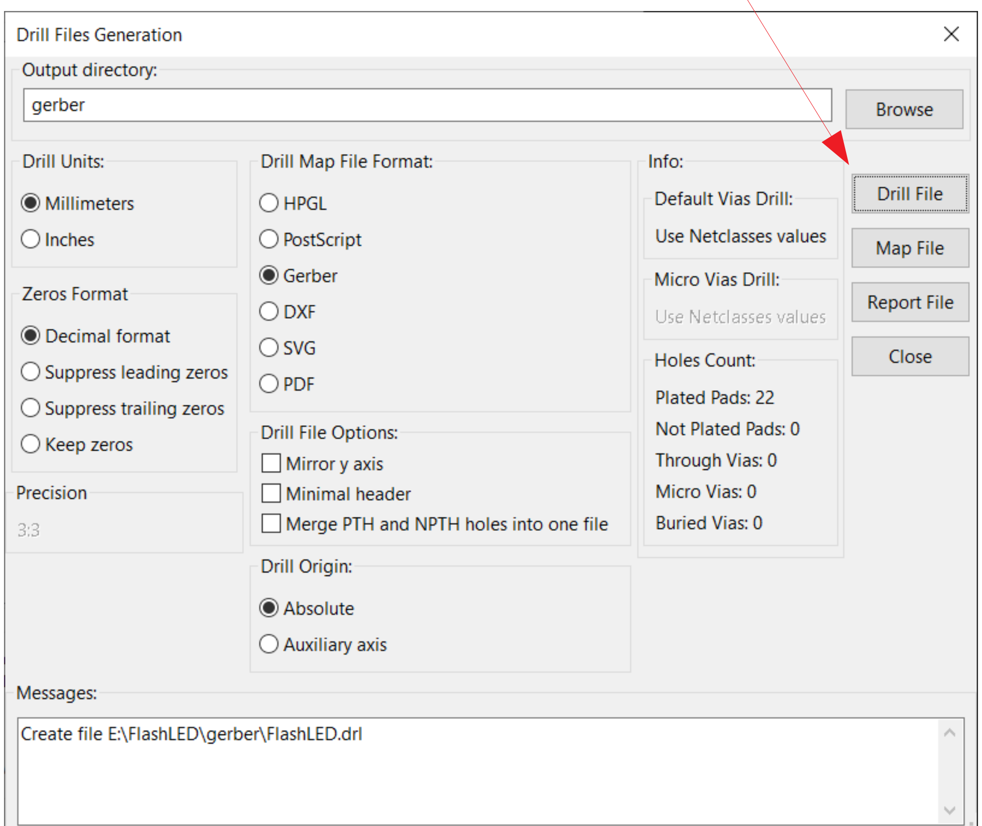
Click “plot” to generate the gerbers

Exporting the Excellon Drill Files

You also need files to indicate the holes to drill.



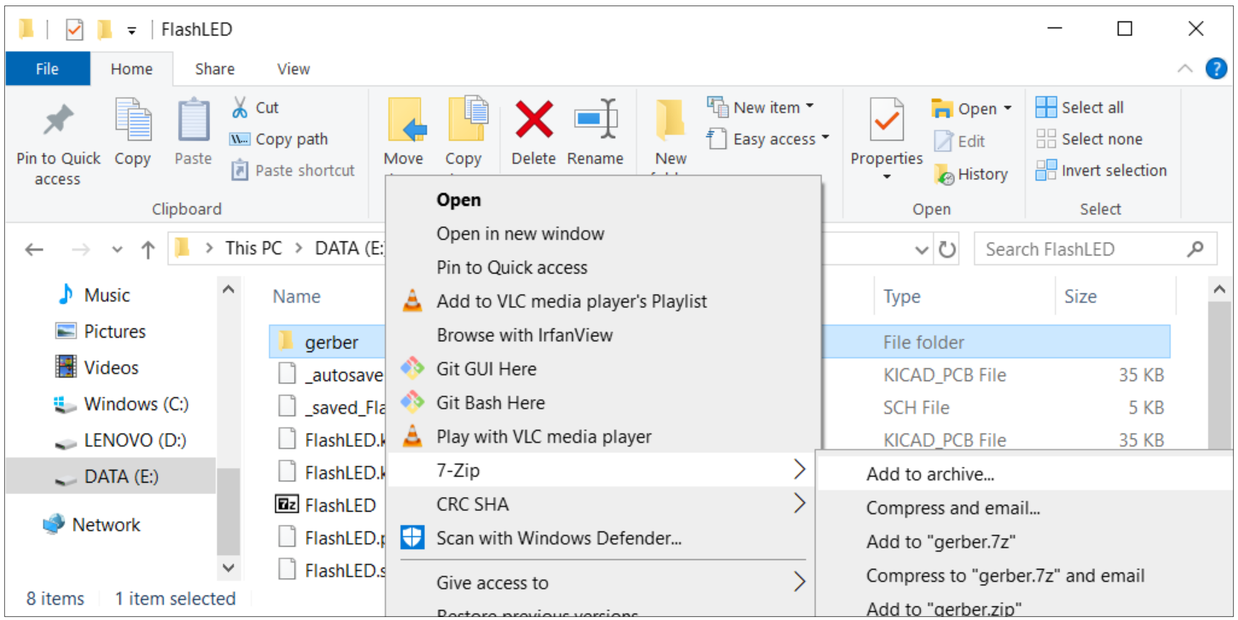
Click here to generate drill files.



The drill files go into the same directory as the gerber files.

Sending your job to be manufactured (example, JLCPCB)

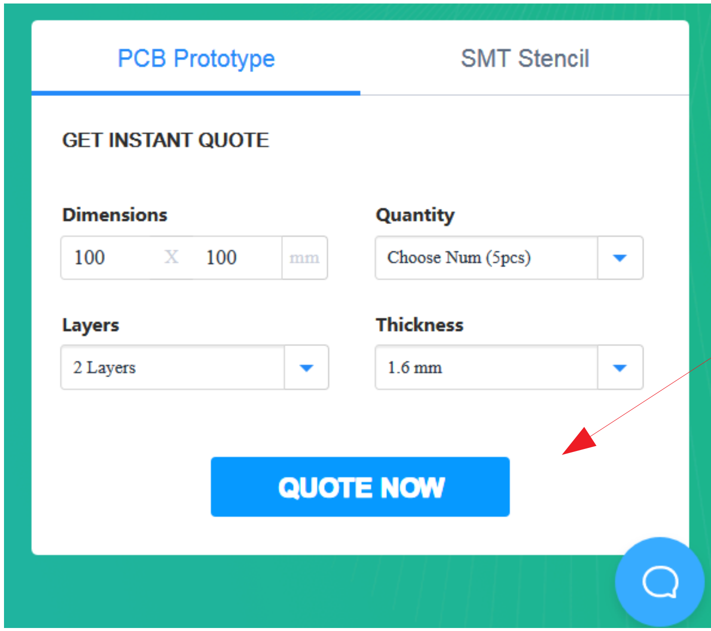
We zip up the gerber directory into a single file



Use your favorite zip program (I use 7-zip under Windows)

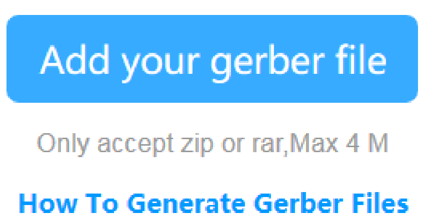
Now we have a zip file of the “gerber” directory.

Log onto JLCPCB website (`www.jlcpcb.com`)



Click "quote now."

Click "add your gerber file."

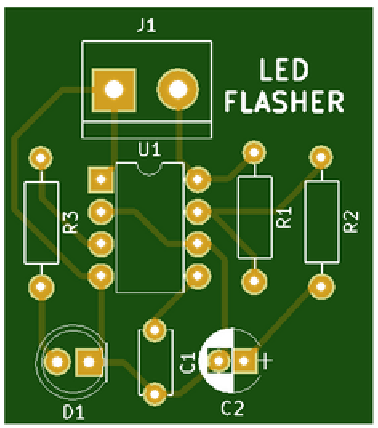


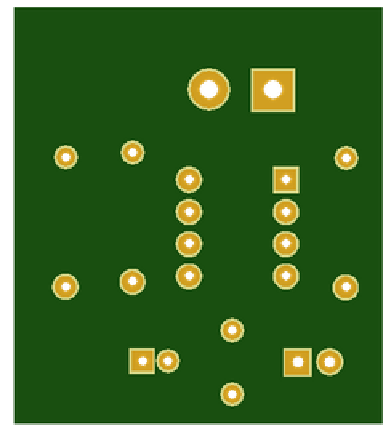
Find and upload
the gerber zip file.

And here it is, you can see the front and back of the PCB board in the on-line viewer.

Detected 2 layer board of 33x29mm(1.3x1.15 inches) .

Your upload has finished processing. Enter the project details below and we'll move on to checking all the individual layers to make sure that they're correct.





The gerber viewer is for reference purpose only and may differ from the actual PCB product.

Gerber Viewer

Use the “Gerber Viewer” link to check to make sure JLCPCB’s system is reading your gerber files correctly.

Finish filling out the form and complete the order.

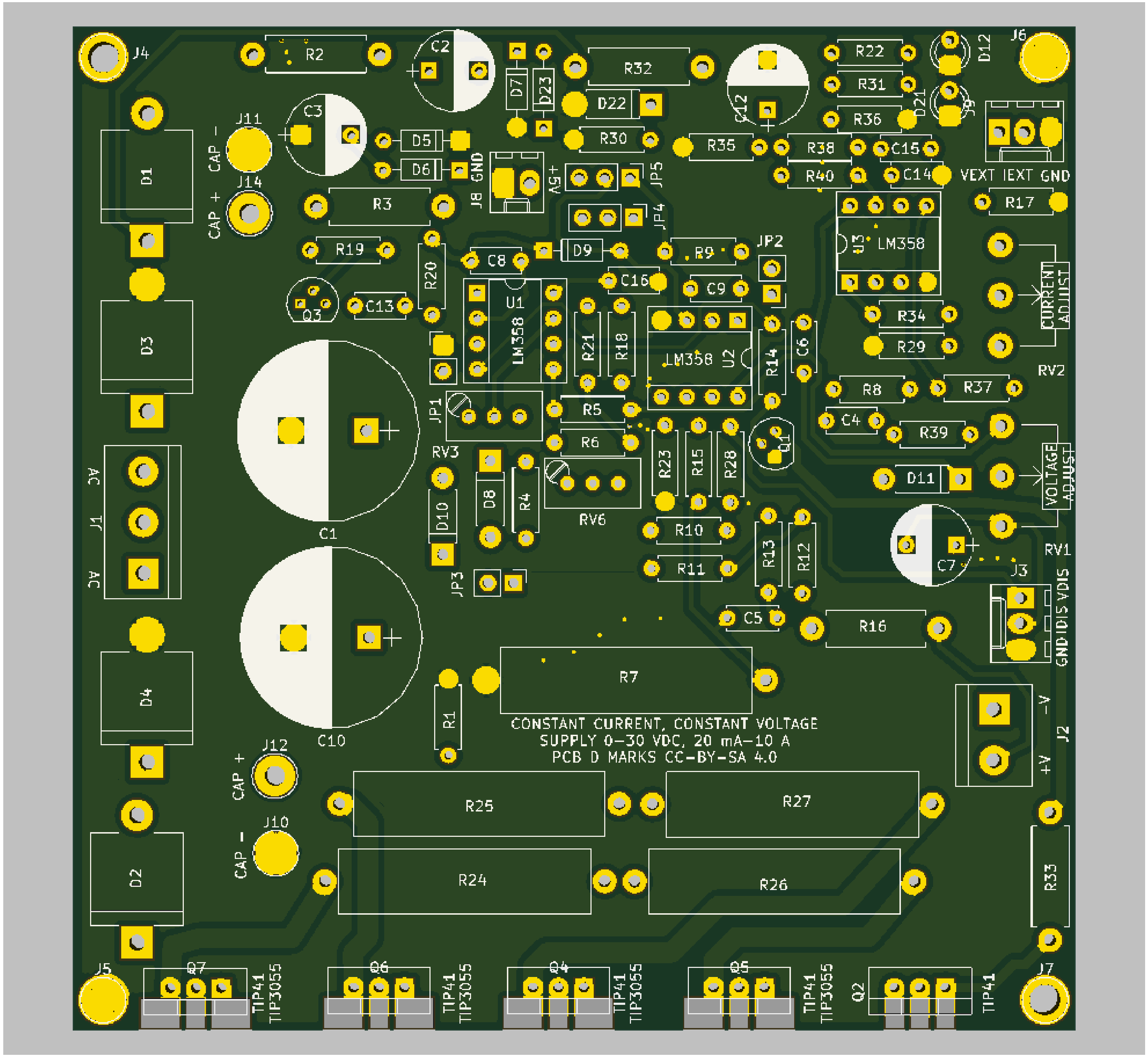
And that is an example on how to design a PCB with Kicad and have it made, start-to-finish!

Designing library symbols and footprints are important tasks, but not covered here.

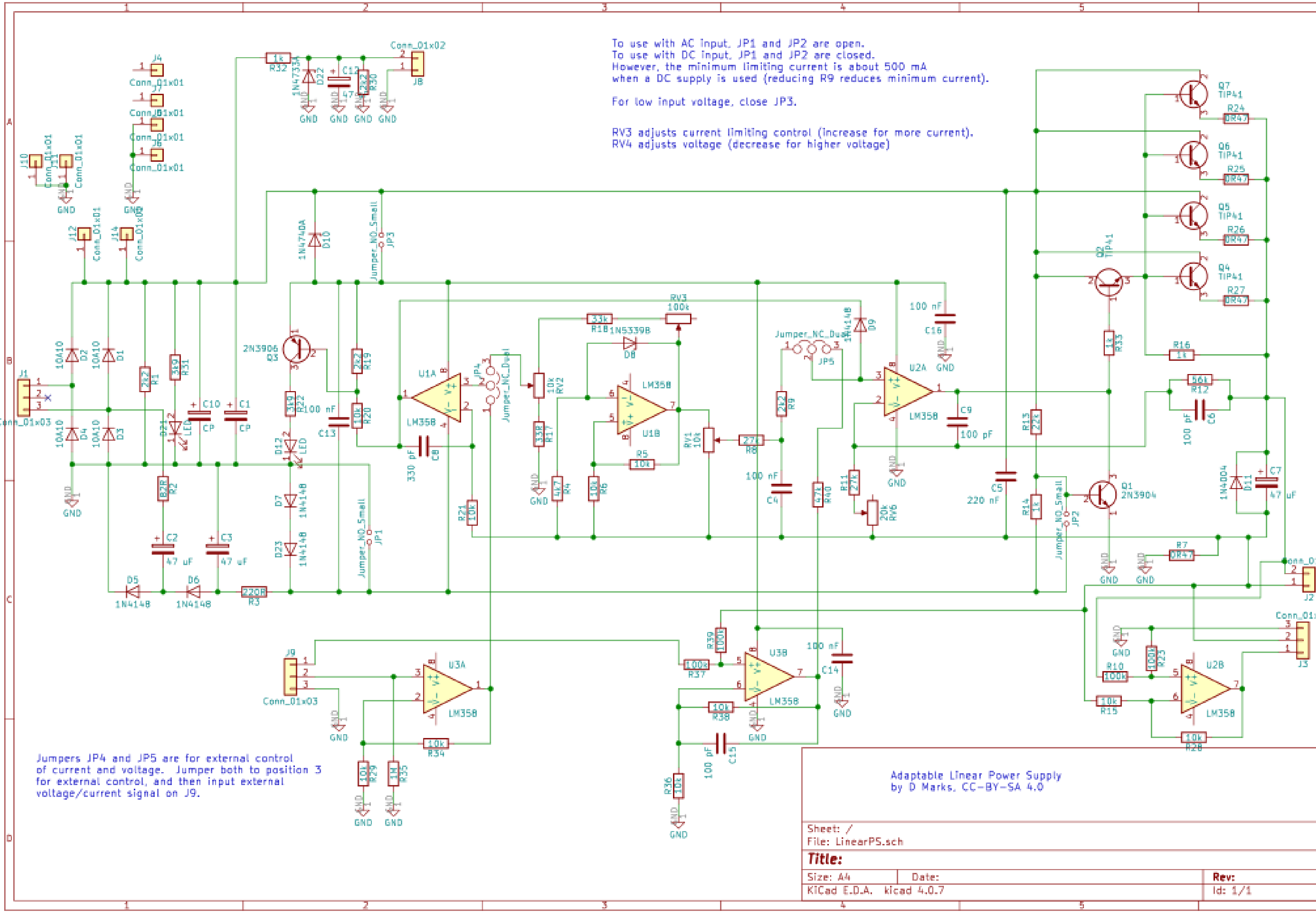
Also adding copper fills and vias are not covered in PCB layout, also important.

Some examples:

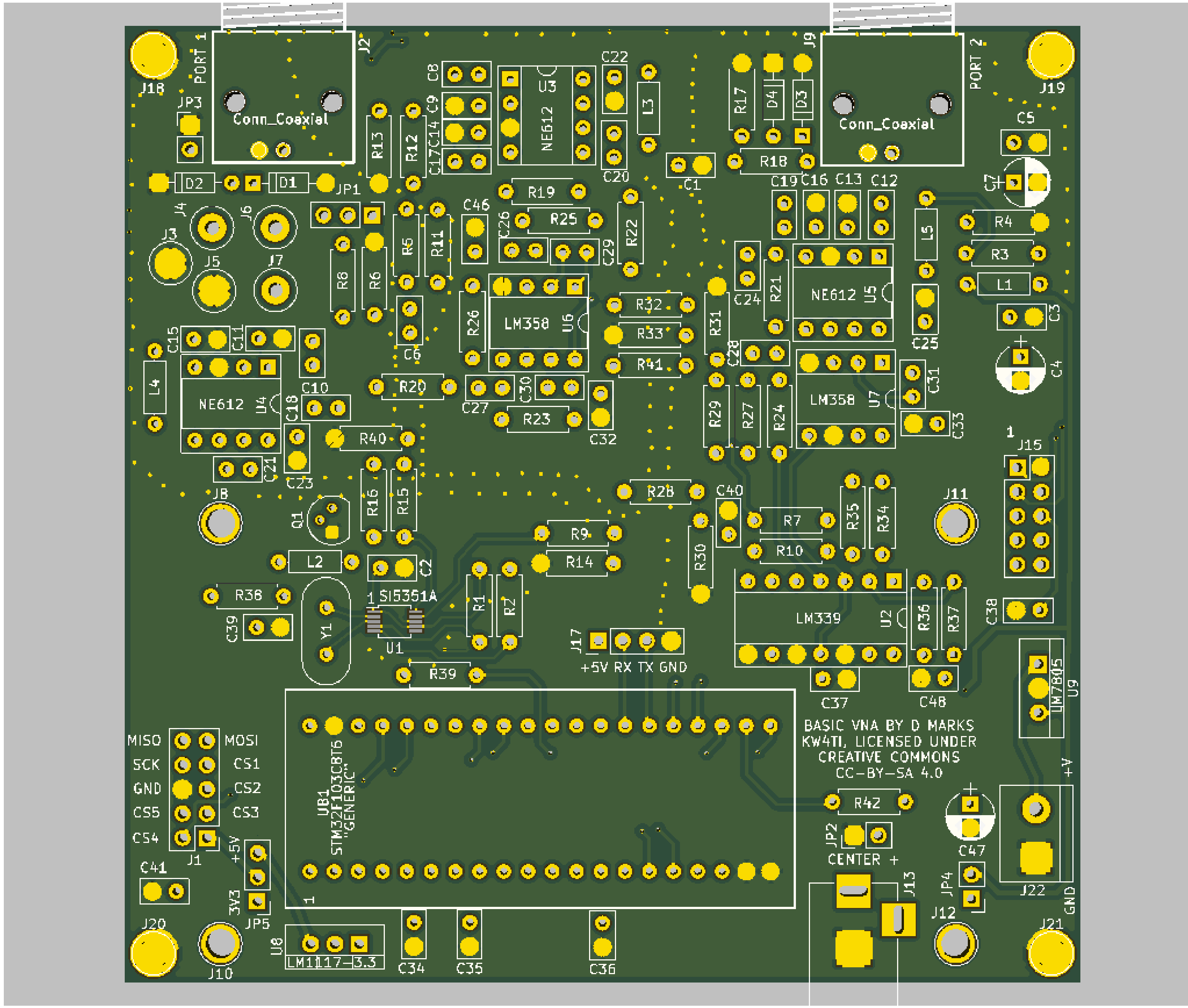
Power Supply PCB



Power Supply Schematic



Some examples: VNA PCB



Conclusions

Hams across the world work together on open source projects that are freely shared by all.

If you have an idea, go for it! Open-source tools like Kicad are out there to be used by people like you.

If you like a project, participate! Be a user, document something, make a instructional video, or even design a circuit or write some code.

Kicad is available at `www.kicad-pcb.org`

My projects are available on
`http://www.github.com/profdc9/`