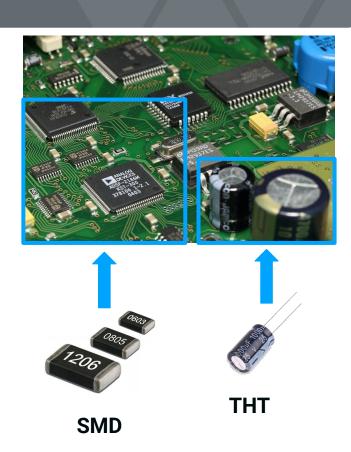
## **Workshop IV**

# PCB Design with KiCad

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#### **Terminology**

- Printed circuit board (PCB) multiple layers of copper sheets with insulator between them
- Surface mount device (SMD) this device does not go through the board, is soldered on one side
- Through hole technology (THT) this device has legs that go through the board and are soldered on those legs



### **Terminology (Cont'd)**

Component - a physical device that will be placed in the circuits, e.g. a resistor



Symbol - a graphic in the schematic that represents a component, e.g.



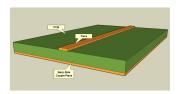
**Resistor Symbol** 

 Footprint - a map of the physical connections for a given components on the PCB, e.g.

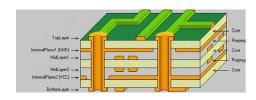


#### **Terminology (Cont'd)**

- Trace the PCB analog of a wire, a uniform piece of copper that connects components
- Via a hole with copper inside of it, allows different layers to be connected
- Net the Analog to a Node, a connection between one or more components, usually is named or labelled
- Fills the solid copper areas usually connected to ground



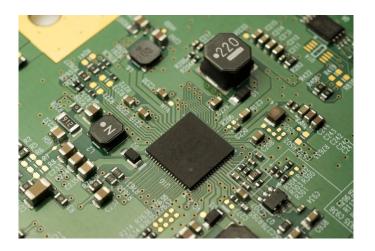
**PCB Trace** 



**PCB Via** 

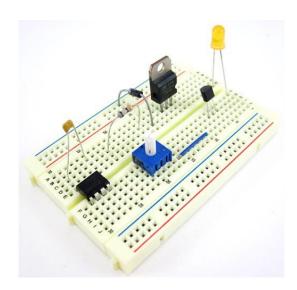
#### **Pros of Prototyping PCBs**

- Allows for much more complex designs vs breadboarding or on a perfboard
- Allows you to have much more reliable and stable connections between parts
- Much more compact
- Much easier to debug



### **Cons of Prototyping PCBs**

- Design is set in stone
- Can take more time to design and build than breadboarding
- Can be more expensive
- Requires more knowledge
- Requires a third-party for manufacturing



SECTION I

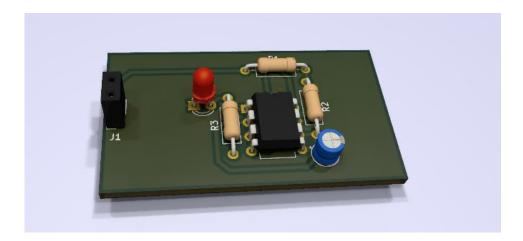
# **Getting Started**

#### **Design Process**

- 1. **Identify the components** and **circuit diagrams** you will use
- 2. Schematic capture
- 3. Component placement and routing (PCB Layout)
- 4. Verification
- 5. **Generate** the **manufacturing files**
- 6. **Fabricate** the **PCB**

#### **Workshop Objectives**

- We will be demonstrating the entire PCB design process in KiCAD
- The completed and assembled design will look something like this:



**555 Blinker Circuit** 

#### Creating a New Project

- Open KiCad 7.0 and either press
  Ctrl+N (\mathbb{H} + N for Mac) or go to the context menu and select File→Create New Project
- Name your project"ops\_project8\_lastname\_firstname.kicad\_pro"
- 3. You will see something like this:



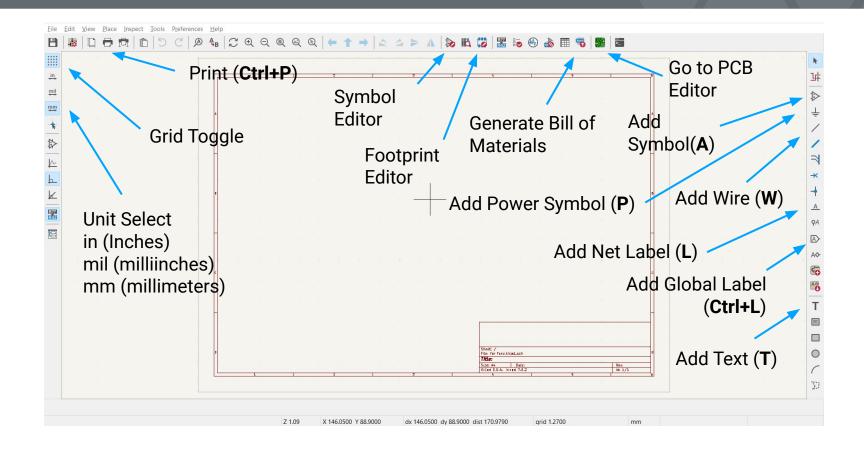
**SECTION II** 

# **Schematic Capture**

#### **Schematic Design Process**

- 1. Create and place all symbols
- 2. **Assign footprints** to symbols
- 3. Wire the symbols as desired
- 4. Flag all pins that should not be connected
- 5. **Label pins and nets** as needed

#### **Schematic Editor**



### **Important Shortcuts**

M - Move an Object

R - Rotate an Object

X - Mirror an Object horizontally

Y - Mirror an object vertically

W - Add Wire

**B** - Add Bus

**Z** - Add Bus Entry

**E** - Edit Properties

D - Open Datasheet

**G** - Drag (Interactive Move)

A - Add Symbol

P - Add Power Symbol

Ctrl/₩**+**D - Duplicate

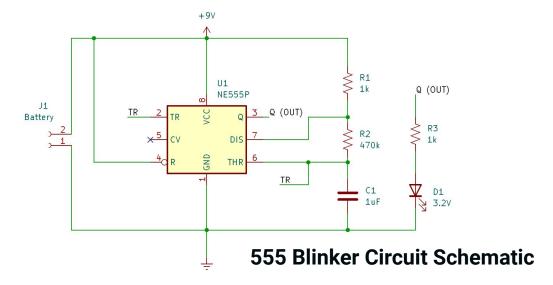
L - Add Label

H - Add Hierarchical Label

Ctrl/#+L - Add Global Label

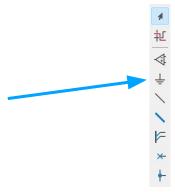
#### Creating a Schematic

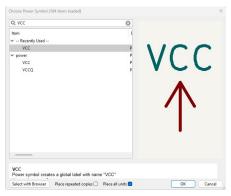
- Objective Create a basic blinking LED circuit with an attached battery (using components from prior projects)
- What the completed schematic will look like:

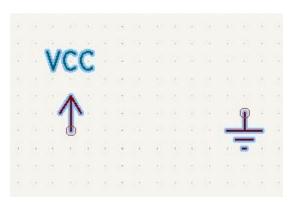


### **Adding Power Symbols**

- Open up Power Symbol Selector by pressing P or navigating to the right toolbar and clicking the earth symbol
- 2. Search for Earth (US Ground Symbol) and VCC:
- 3. Add a VCC and GND Net
- 4. Place them anywhere in the schematic



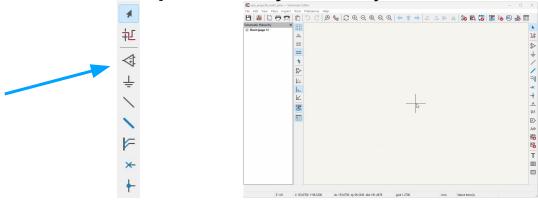


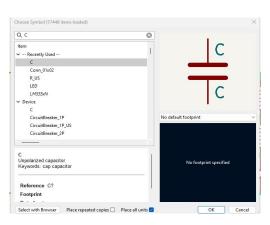


#### **Adding Symbols**

- 1. Press A or navigate to the right toolbar and click the "triangle" op amp symbol
- 2. Search in the box for symbols you need (ex. C for Capacitor)
- Add symbols for LED, R\_US (US Resistor Symbol), NE555P (555 Timer),
  C (Capacitor), and a Conn\_01x02\_Socket.

4. Press **OK**, then **place the symbol** anywhere





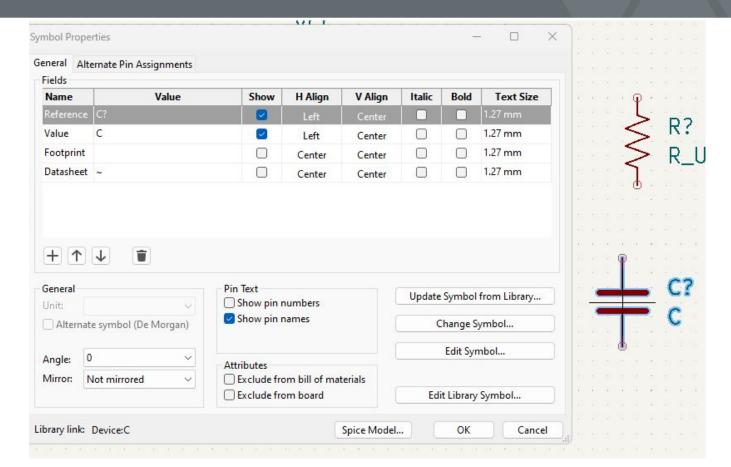
### **Editing Component Values**

- We want to set the value of the component... this can either be the name of the component, value (resistance, capacitance, etc...) or a part number.
- 2. Hover over a symbol and **right mouse click on the symbol** then **click Properties** in the popup OR press **E** to edit its properties:
- 3. We will **set the value** to the desired quantity (1k, 100nF, etc.)

The **value scheme** is as follows:

- a. {base value} {scale} {unit}
- b. **Scale** (Power of 10): p: -12, n: -9, u: -6, m: -3, k: 3, M: 6, G: 9
- c. **Unit**: Capacitors: F, Inductors: H, Resistors: None

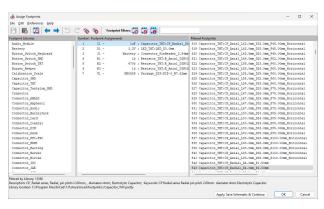
## **Editing Component Values (Window)**



#### **Assigning Component Footprints**

- Resistors, capacitors, inductors, and other components can come in many different packages (SMD, THT, etc.)
- We want to assign the symbols a certain footprint so that we can match up a physical component that we have in the lab
- We will use the **Run Footprint Assignment** tool by pressing





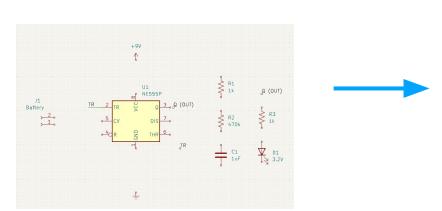
### **Assigning Component Footprints (Cont'd)**

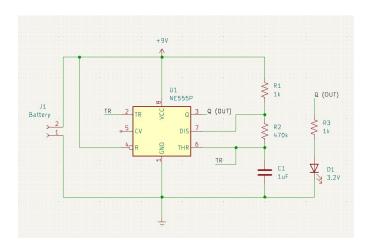
- For the resistors, we will search the Resistor\_THT library for R\_Axial\_DIN0207\_L6.3mm\_D2.5mm\_P7.62mm\_Horizontal
- For the capacitor, we will search the Capacitor\_THT library for CP\_Radial\_D4.0mm\_P2.00mm
- For the LED, we will search the LED\_THT library for LED\_D3.00mm
- We are going to use the Connector\_PinHeader\_2.54mm library to find
  PinHeader\_1x02\_P2.54mm\_Vertical

#### **Adding Wires**

- After setting the footprint of one symbol, we can copy it and change the pasted component's value
- 2. **Do not connect symbols directly into pins**; use wires to connect pins instead
- 3. Add a wire (**W**) to connect two pins

Here we have some wire laid:



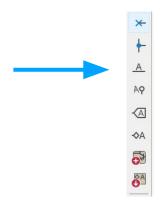


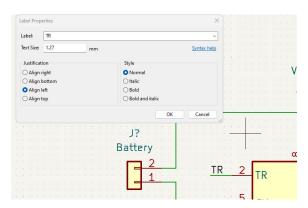
#### **Adding Connections with Labels**

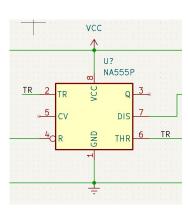
Why use labels instead of wires?

- You can't connect two pins due to wires/components in the way
- For clarity and cleanliness (advised to label most if not all nets/nodes)

**How to add a label**: Press **L** and put it in a stretch of wire. Then, name it an intuitive name and repeat wherever else you want to connect that point to

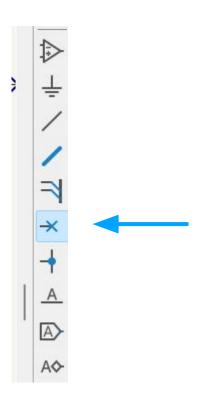






### **Adding Not-Connected Flags**

- Add the no-connection markers for all of the unused pins to complete the schematic
  - Indicates to the PCB editor and to other people that the pin is not meant to be connected to anything
- How to add a Not-Connected Flags: Press Q or click on the → icon you can find on the right of the schematic editor



#### **Schematic Verification**

Before our Schematic is finished, we have 2 last steps we need to do:

#### 1. Electronics rules check

- Make sure to run the Electronics Rules Check (ERC) under Inspect
- The only error you should receive is "Error: Input Power pin not driven by any Output Power pins." as we have not connected a specific Input Power Pin

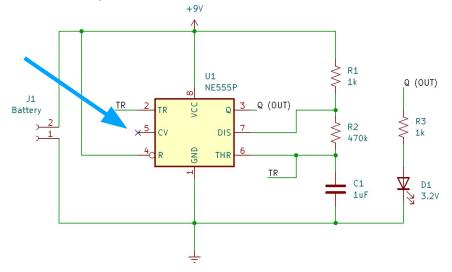
#### 2. Annotate the schematic

 We want to annotate our schematic as well by selecting **Annotate** under **Tools**

### Finishing the Schematic

After the no-connect markers are added, the annotation is done, and the ERC run, **the** schematic is complete!

It does not have to look exactly the same, as long as connections are the same...



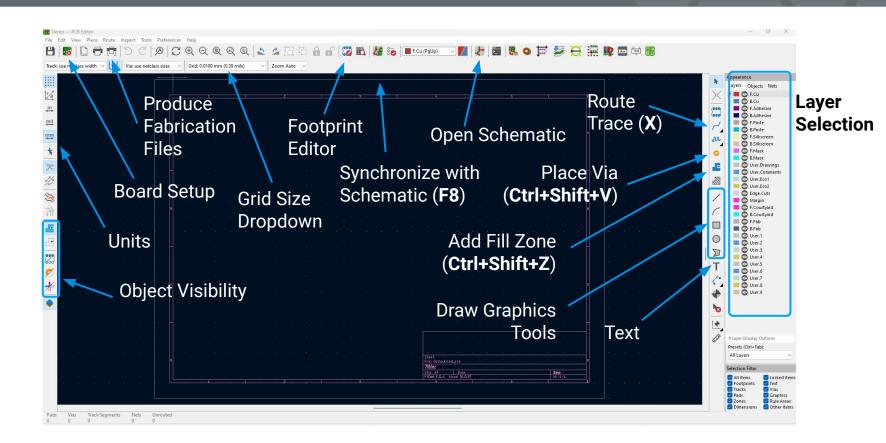
**SECTION III** 

PCB Design

#### **PCB Design Process**

- 1. Define board outline
- 2. Place components
- 3. Place traces and vias
- 4. Add any necessary fills

#### **PCB Editor**



#### **Important Shortcuts**

- R Rotate an Object
- X Create a Trace
- V Switch Layers (Between Top and Bottom Copper), Adds Via if routing a trace
- M Move an Object on its own
- **E** Edit Properties
- F Flip (Moves Component from the Top to Bottom or Vice Versa)
- D Drag (Interactive move)

#### **PCB Layers**

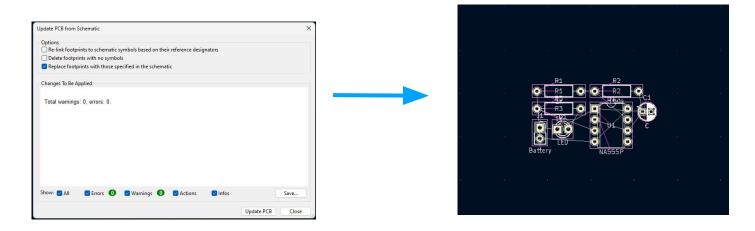
- F/B.Cu Top/Bottom Copper layer, where the traces, vias, and fills are
- F/B.Courtyard Defines the area around parts which there can not be other parts on the Copper layers
- F/B.Silkscreen Graphics that are on top of the solder masks, usually white, usually for text
- Edge.Cuts Board Outline

### PCB Layers (Cont'd)

- F/B.Mask Solder Mask on the Top/Bottom (Where we want to have an opening for the copper, e.g. for pads)
- F/B.Fab Shows the component name and value for components on the Top/Bottom (For Manufacturing)
- F/B.Adhesive Placement Adhesive mapping for the Top/Bottom (Not Important for us)
- User.Drawings/Comments Layers to add dimensions or comments for documentation

#### **Exporting the Schematic to the PCB**

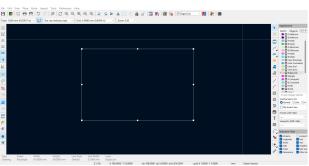
- To add the footprints to the PCB editor, press F8 or click this icon on the top toolbar
- 2. Once the dialog pops up: Press **Update PCB**, watch for errors, then press **Close** You will see some footprints appear on the PCB like this:



#### **Creating Board Outline**

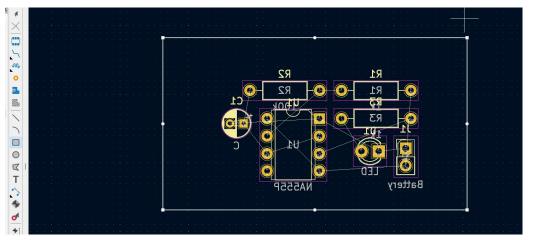
- 1. Select the **Edge.Cuts** layer by clicking on it; it will be gray once you highlight it
- 2. **Create a closed graphical shape** in the Edge.Cuts layer (usually a rectangle)
  - Layer represents the outline/cut-out of the board (any closed shape of any size will do)
  - b. It is recommended you create a rectangle or other simple shape:





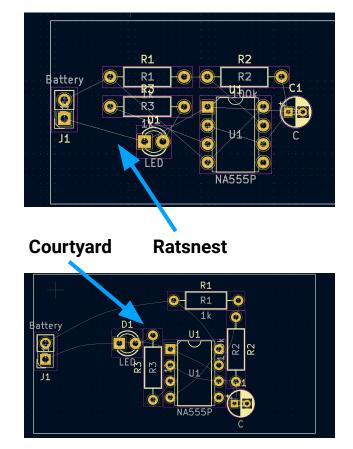
### **Creating Board Outline (Cont'd)**

- Here is a simple rectangle using the rectangle drawing tool; I made sure to leave plenty of space to move footprints/traces around
- You can make it any shape using the arc, line, or polygon tools, as long as it is closed



#### **Moving Components to Place**

- Move the components so that they can be connected using traces and vias
  - Note: We have two layers of copper and we can use either of them to connect pins
- There will be little lines or curves connecting one or more pins, which are called ratsnest
  - Indicates which pins need to be connected to one another
- Stay in the outline and not overlap the pink boxes on the outside of the footprints called the courtyards

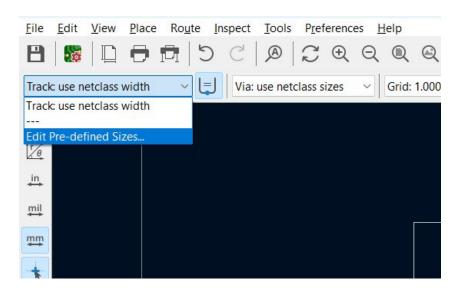


#### Setting Up Traces and Vias

- We want to set the size of vias and traces to adjust resistance
  - The wider the trace the less resistive it is, same with vias.
- We want to make traces that carry higher current to be wider
- For data signals the trace size doesn't matter very much as minimal current is carried
- For our units we will use "mils" which stands for mili-inches

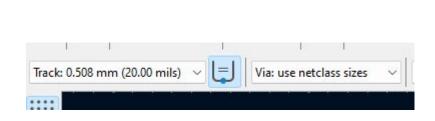
### **Setting Up Traces and Vias (Cont'd)**

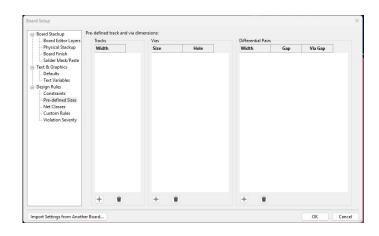
- We want click on the via size selection list or the track size collection list
  - From there we will click Edit predefined sizes



### **Setting Up Traces and Vias (Cont'd)**

- 2. Press + under the Vias table to add a via size of 30 mils
  - We want to make the via hole 20 mils
- 3. We want to add 2 track sizes: 30 mils and 40 mils
- 4. After, press **OK**





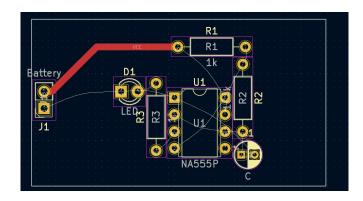
## **Routing Traces and Vias (Contd)**

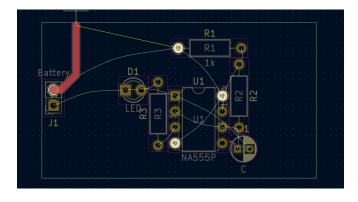
- 1. Now we have the track sizes and via sizes set we can start drawing traces. To place a track we need to select a track size from the drop down menu mentioned in the slide before:
  - a. 40 mils track, 30/20mils Via Size for all power/ground lines
  - b. 30 mils track, 30/20mils Via Size for all signal lines
- 2. **Deselect** this icon between the track size and via size dropdowns before routing



#### **Routing Traces and Vias (Contd)**

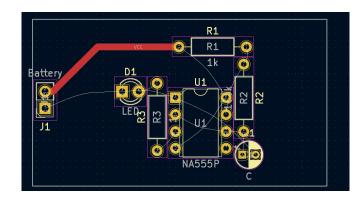
- Do not wire ground; we will do that later
- Click on the F.Cu layer in the selecter and start routing
  - To draw a track, press X while hovering over a pin
  - If you need to make a turn or pivot, click on that pivot point and route from there

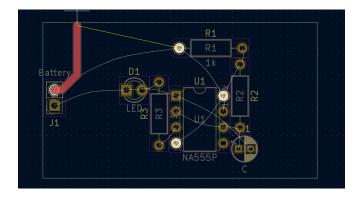




### Routing Traces and Vias (Contd)

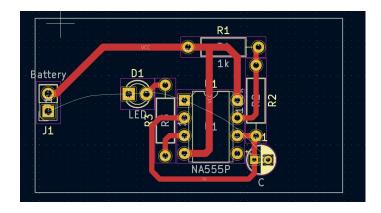
- If you can't route wires, press V while routing and you can use the other layer with a via
- When you draw the traces, the color will be blue, indicating you are on another copper layer
- To go back to the first layer, you will need to create another via, and the trace laying should now be red





# Finishing Routing

- Try and route all of the traces on one layer by making the path from one pin to the next as small as possible
  - The only unrouted net is ground
- Make sure that everything is routed correctly by cross-checking with the datasheets and schematic



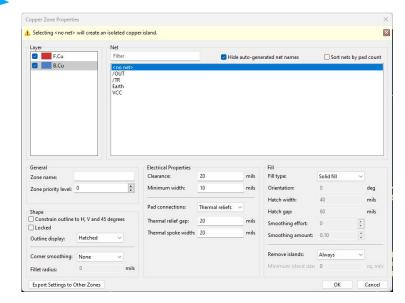
#### **Adding the Ground Fill**

- We have left ground unrouted so we can connect it with a fill
- A fill is just a large piece of copper that fills all of the gaps in the design and is connected to whatever nets it is assigned to
  - Fills are utilized to stabilize the ground, allow for better current conduction, as well as allow for more heat to be dissipated
- To add a fill we want to select this icon or use
  Ctrl+Shift+Z, we need to be on the F/B.Cu layers



## Adding the Ground Fill (Cont'd)

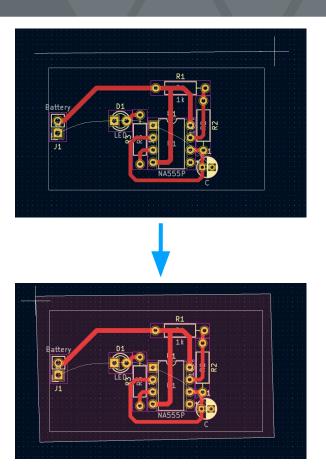
- Click a point outside of the border, you will get this menu
- 2. Select the **F.Cu** and **B.Cu** layers
- Select the **Earth** net as the assigned net
- 4. Don't touch the rest of the parameters and press **OK**
- 5. After this, we will move on to drawing the fill





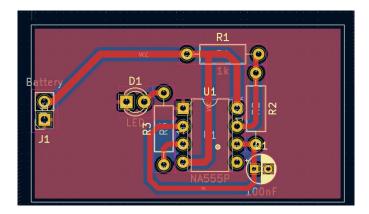
## Adding the Ground Fill (Cont'd)

- Once we have a fill started, draw its border
- Draw a shape outside of the perimeter enclosing the whole shape/PCB
- After adding all of the corners of the shape close the shape by connecting all four corners
- 4. Press **B** to make the fill real



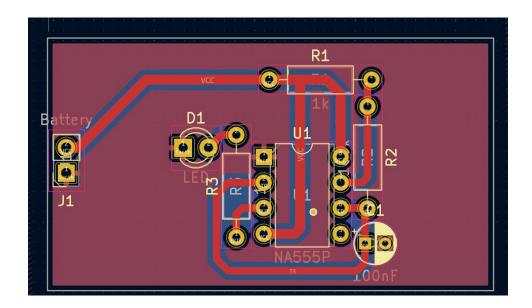
#### Finishing the PCB

- Once we have the fill all done there should be no more ratsnest
  - If there are any connections that need to be made, make them
- 2. We can place a via if there is a void in the fill to fix the void (press **B** after to refill)
- 3. There is an optional but very helpful step that follows this:



## Finishing the PCB (Cont'd)

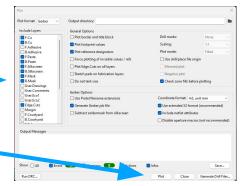
- 1. We need to move all of the silkscreen items so that they are easily visible
- 2. Select the Silkscreen layers and move the text so that it is visible, like this:

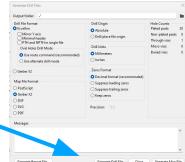


## **Exporting Manufacturing Files**

- Save the PCB with Ctrl/出+S
- 2. We want to press the **Plot** button
  - We will get this dialog
- 3. Select an output directory and press **Plot**
- 4. Press **Generate Drill File**
- 5. **Zip the folder** with the files
- 6. **Upload the zip** to a Fab







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