

Notes on Usage

See <https://github.com/colinoflynn/colins-pcb-intro> for latest version of these slides.

See blog post at www.oflynn.com which links to YouTube video presentation(s) of these slides.

My text & photos are CC-SA Licensed – however many images used are *not*, so if presenting this I leave it up to you to replace them if required.

Intro to PCB Design

D1 Colin O'Flynn D2

WARNING ON THIS LECTURE

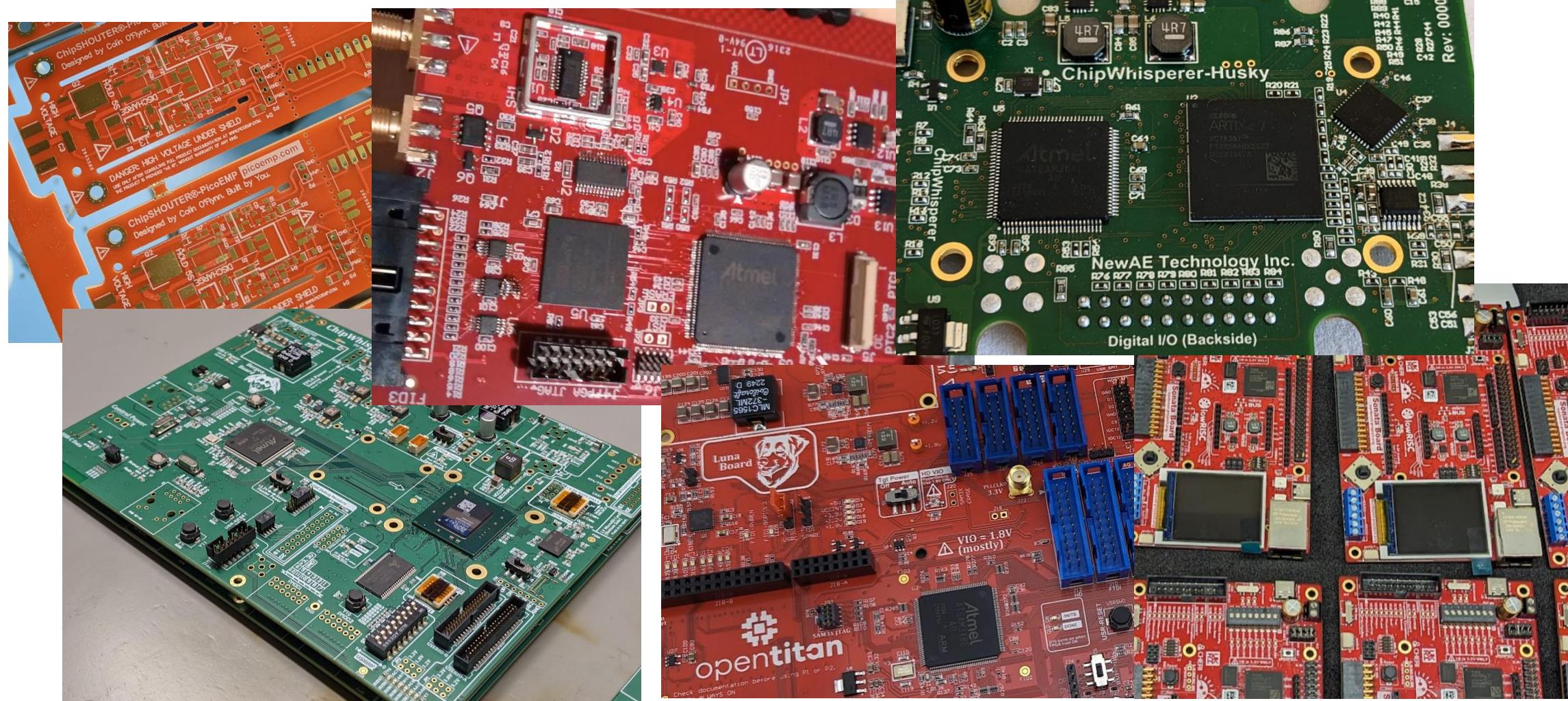
- This topic needs an entire course, maybe several. I'm giving you one lecture.
- Entering Ludacris speed...



Background to this Lecture

- My PCBs:
 - ~A few hundred designs over the years
 - Many open source, some very basic some more complex
 - Some prototype only, some higher volume (>5K)
 - 2 to 12 layers
 - Lots of small parts & high density (BGA).
 - I've written a few guides over the years on the topic... some of them referenced within here!
- Things I haven't done:
 - Heavily cost optimized (e.g., > 10K units or consumer electronics)
 - High-frequency RF (> 6 GHz)

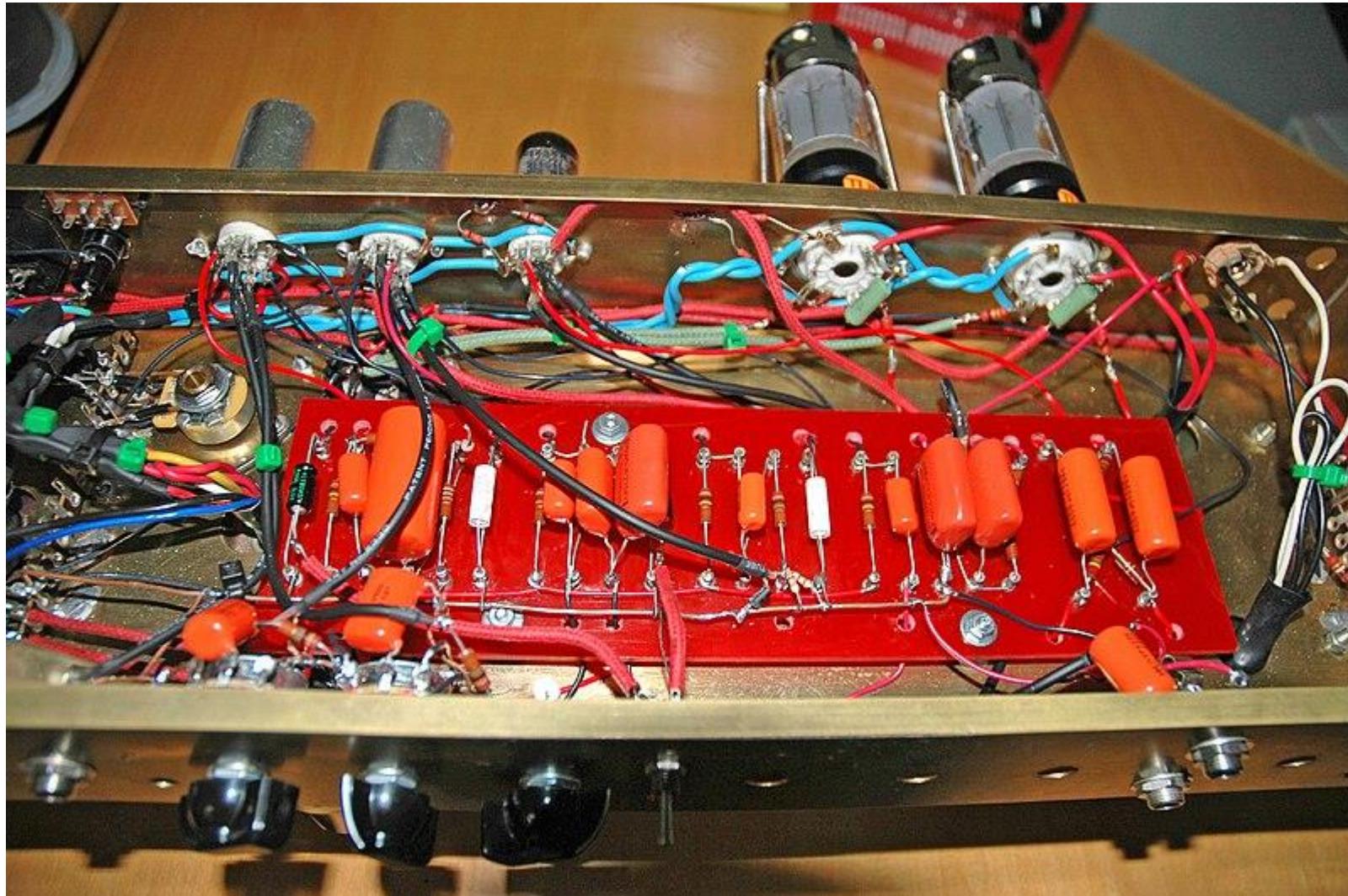
e.g., my PCBs over the years



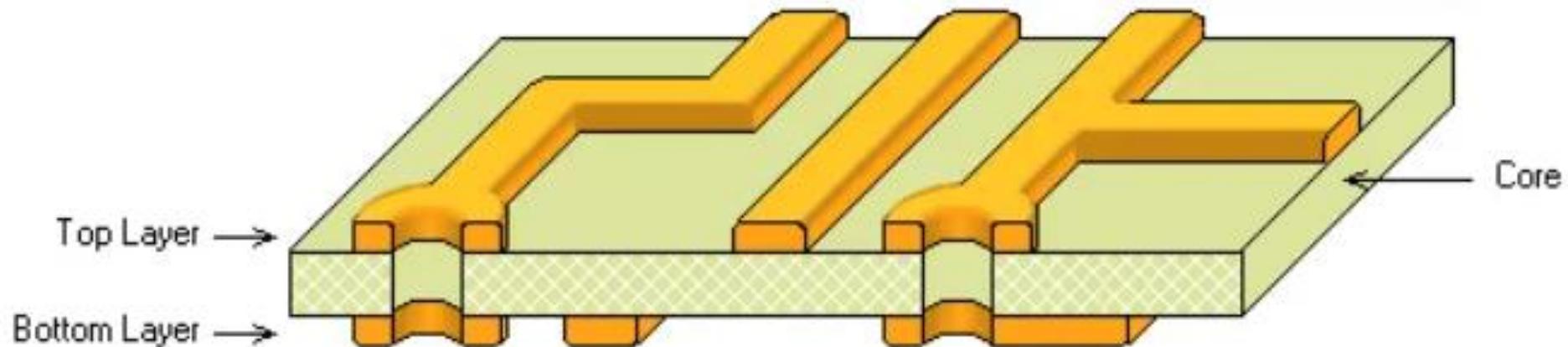
PCBs 101



PCBs 101



PCBs 101: Basic Board



A double-sided PCB, with conductive tracks on both top and bottom sides of the board.

<https://www.altium.com/documentation/altium-nexus/understanding-printed-circuit-board-makeup?version=4#single-sided-board>

Old PCBs!



RadioShack®

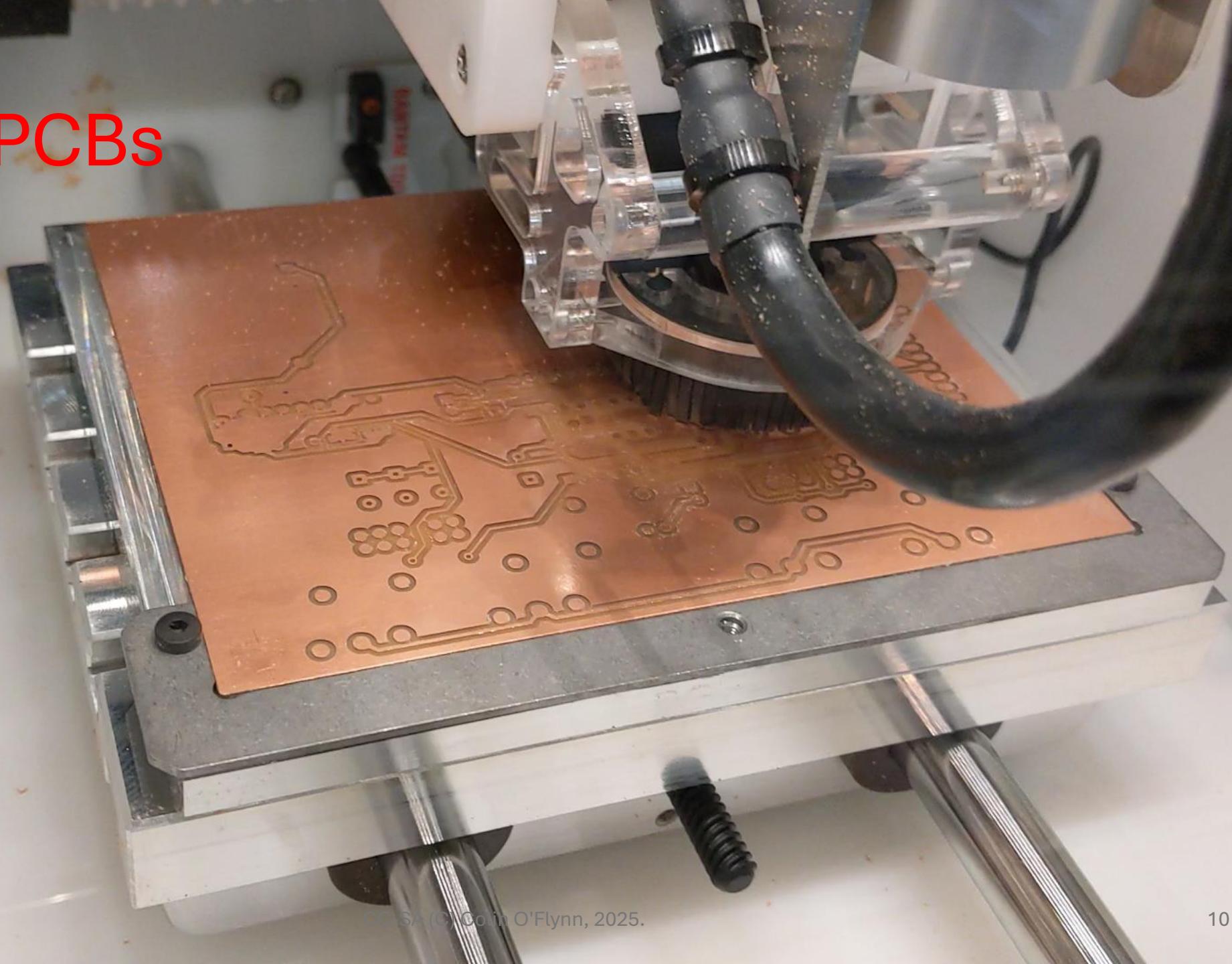
2025-01-15



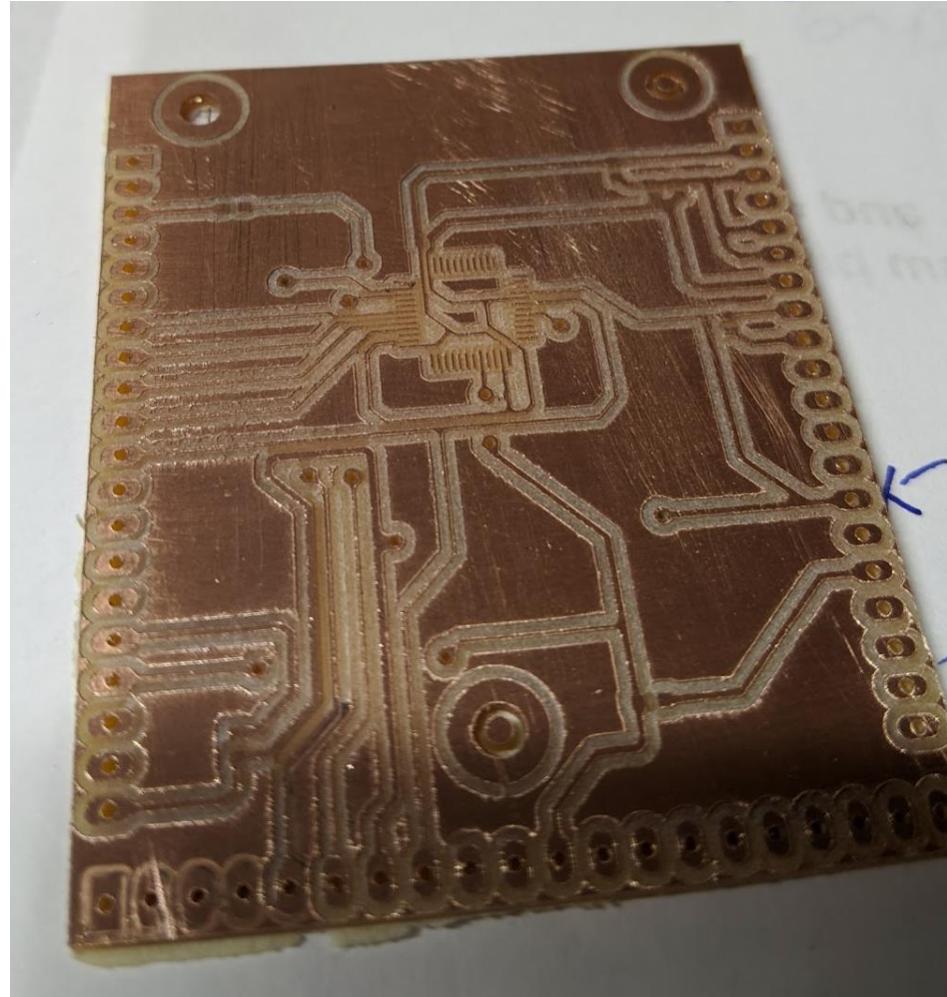
<https://www.youtube.com/watch?v=URGfZukAs98>

CC-SA (C) Colin O'Flynn, 2025.

Milled PCBs



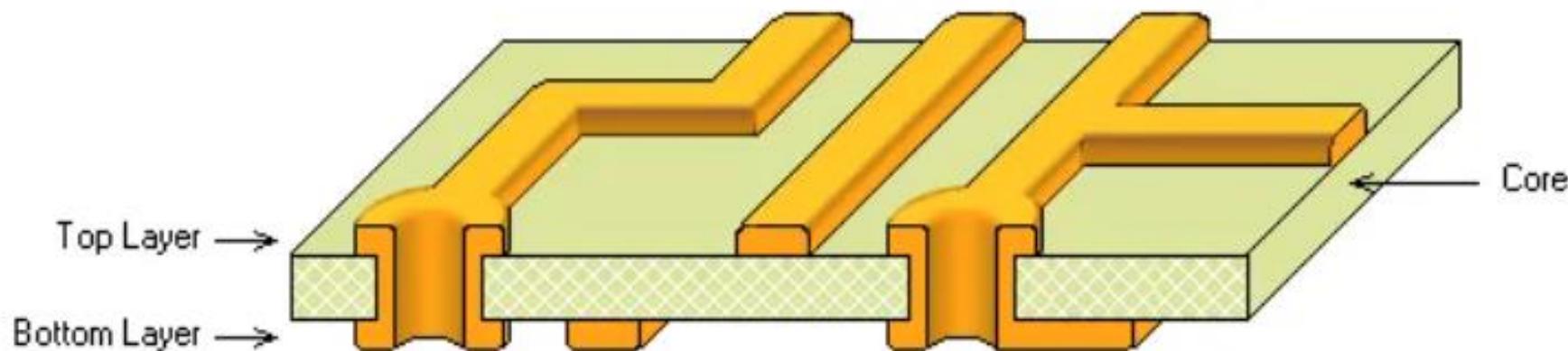
Another simple milled PCB example:



Golden Rule of PCB Design

*Design your board for how you plan on
getting it made and built.*

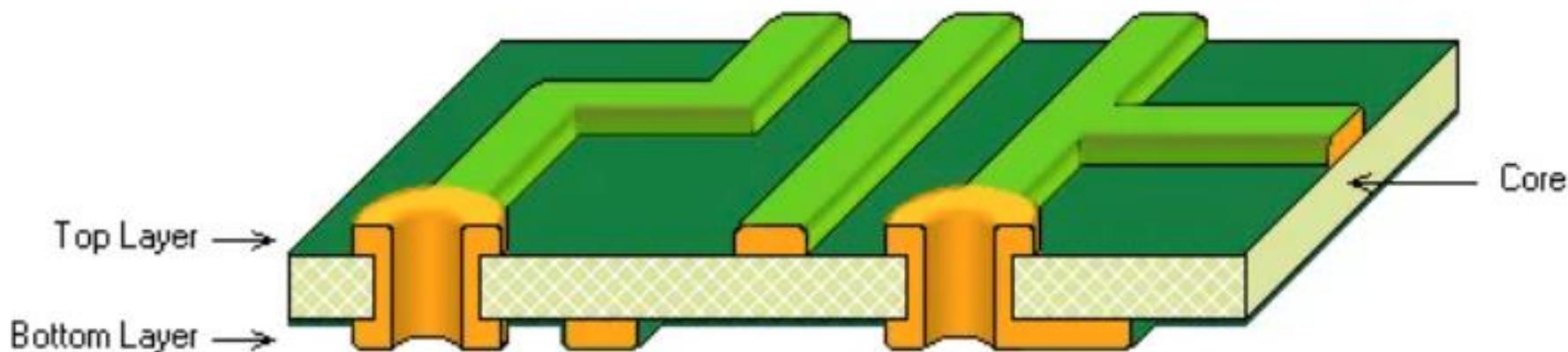
PCBs 101: PTH (Plated Through Holes)



A double-sided PCB with Plated Through Holes.

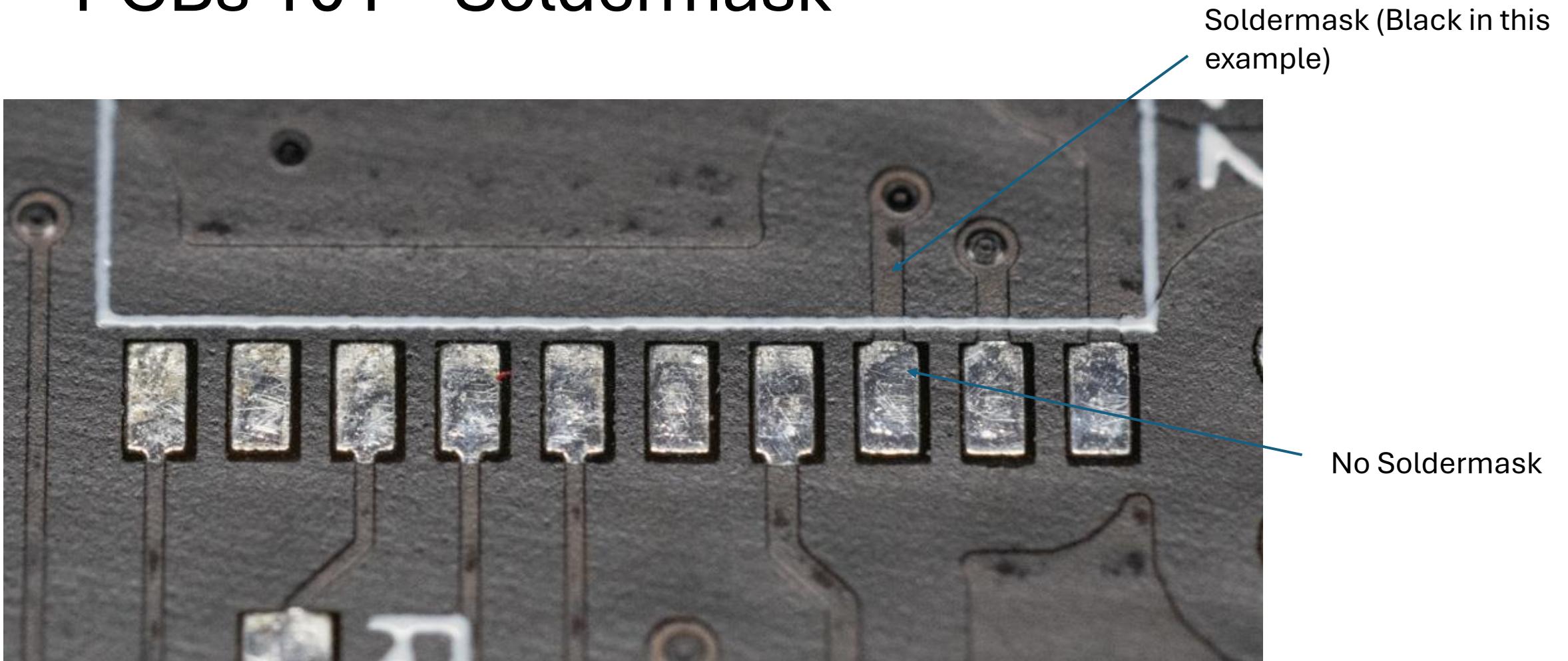
<https://www.altium.com/documentation/altium-nexus/understanding-printed-circuit-board-makeup?version=4#single-sided-board>

PCBs 101 - Basics



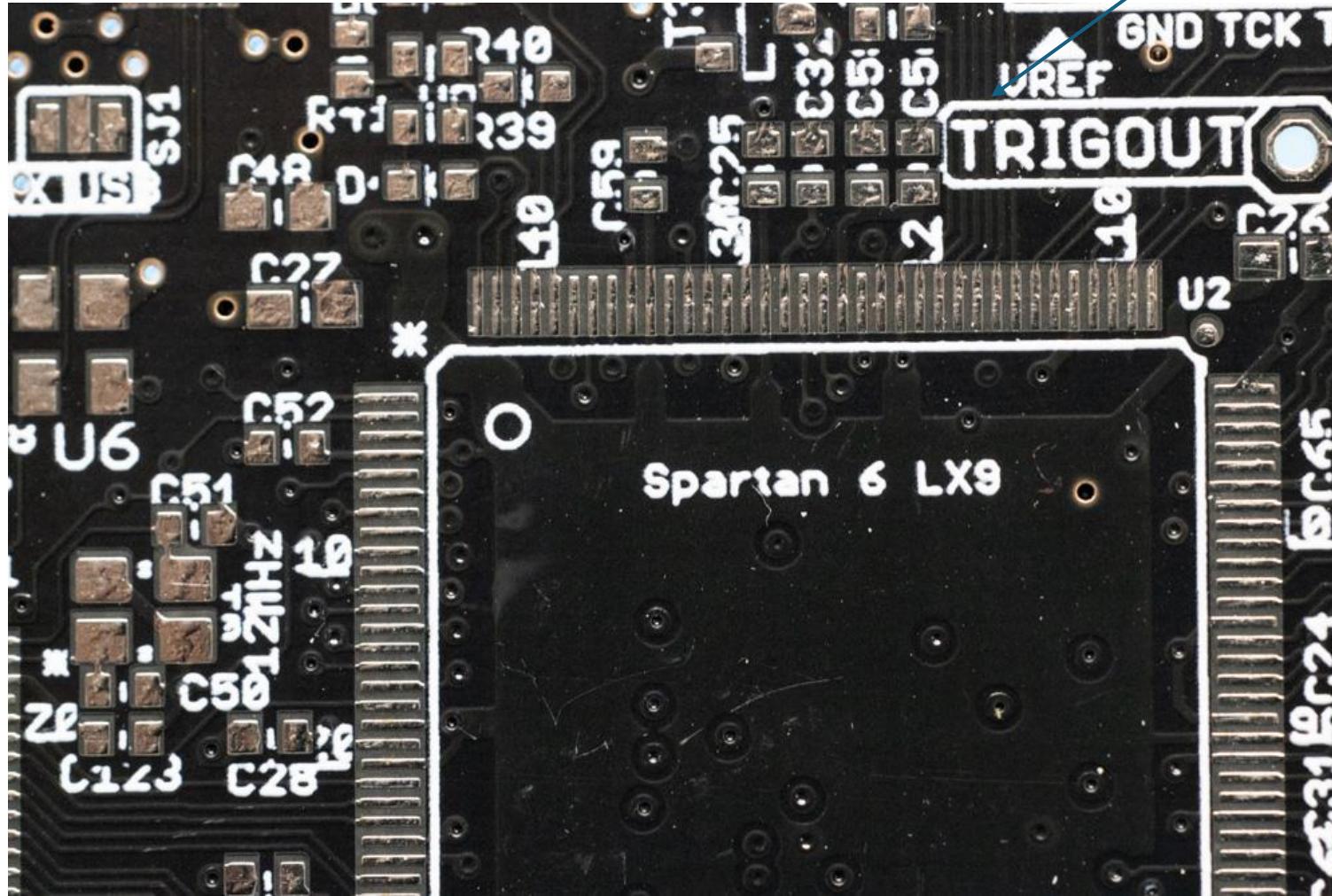
A double-sided PCB with plated through holes and solder mask.

PCBs 101 – Soldermask

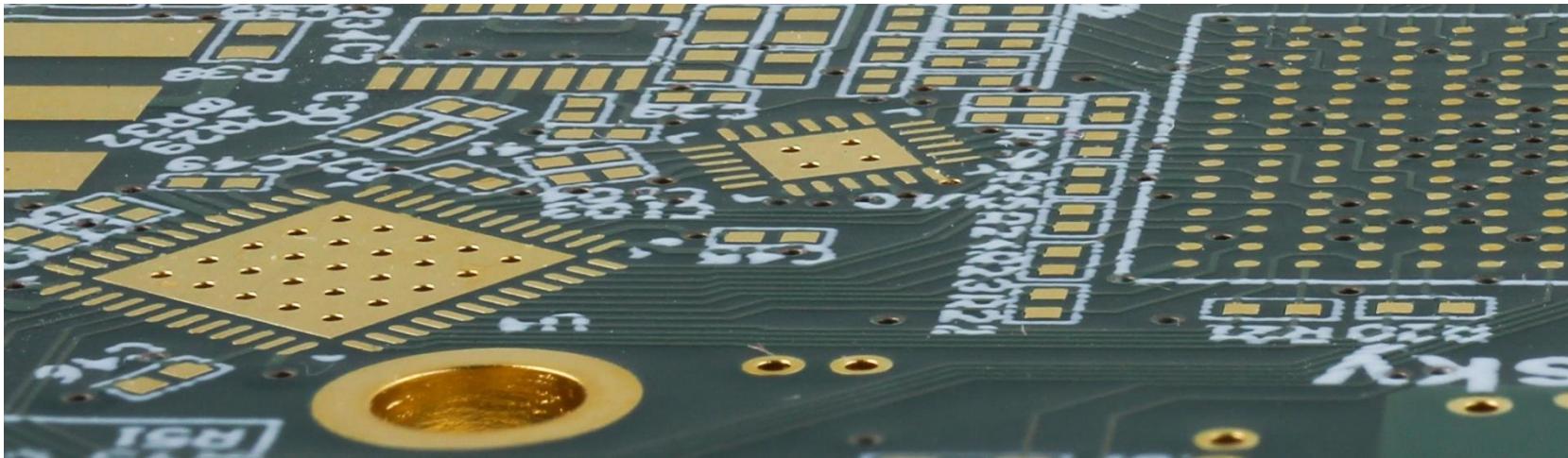


Silkscreen (White)

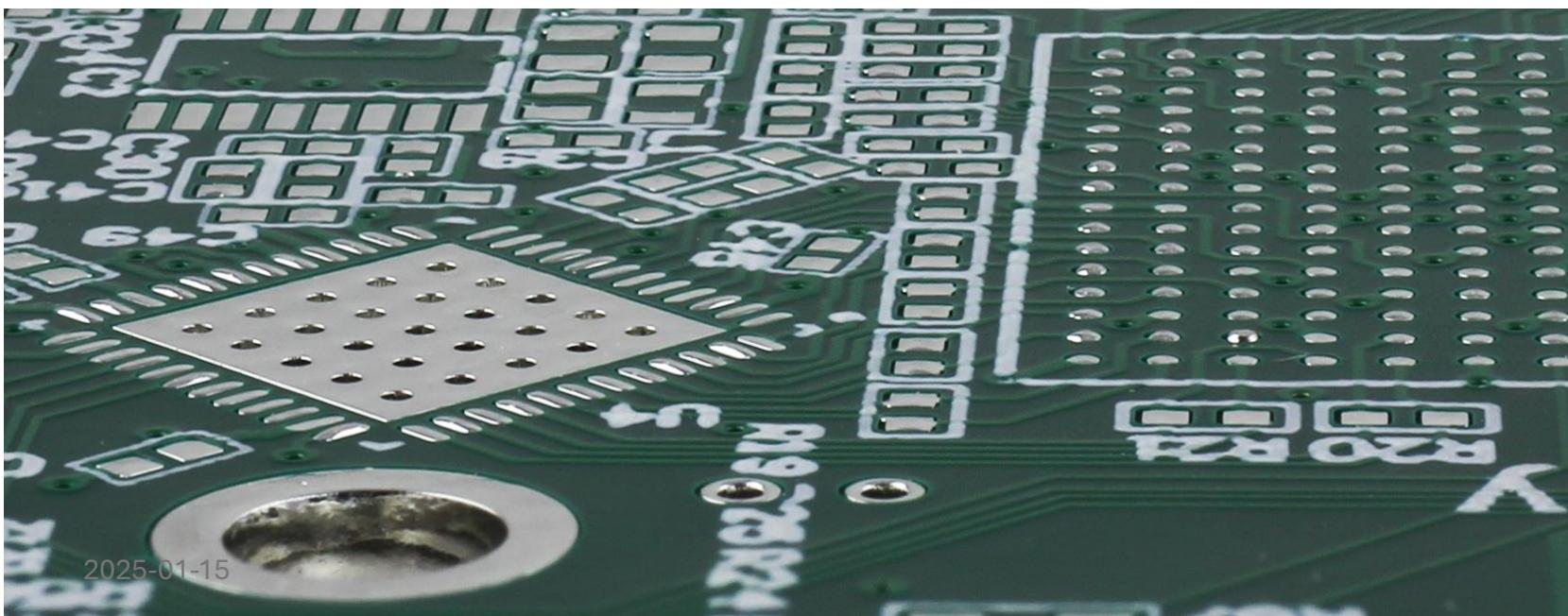
PCBs 101 – Silkscreen



PCBs 101 - Finish



ENIG



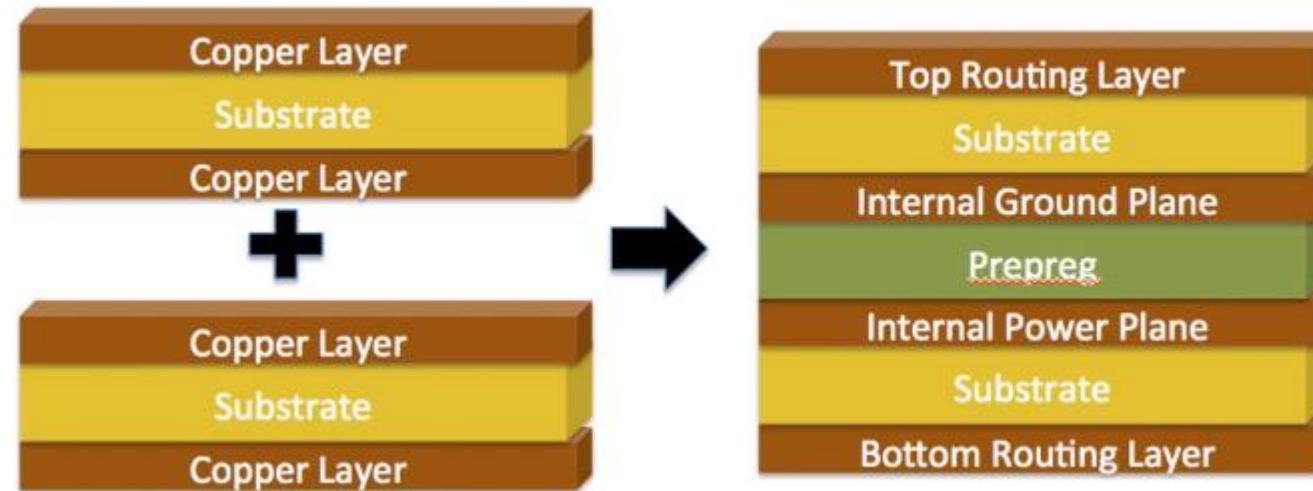
HASL

PCBs 101 – More Layers

Side-View of Multilayer Stackup (4 Layers)



Multi-Layer Lamination Process

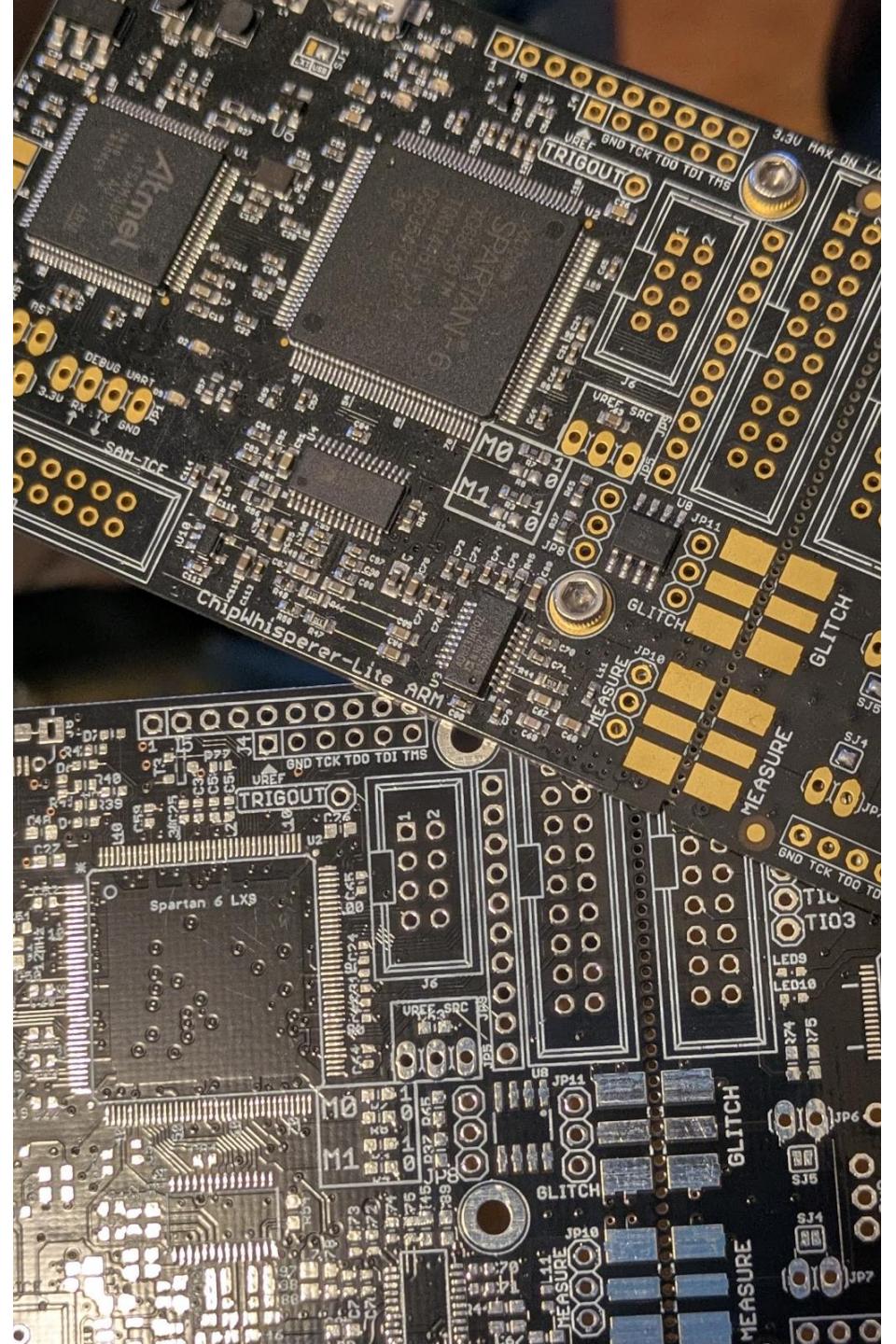


<https://morepcb.com/pcb-prepreg/>

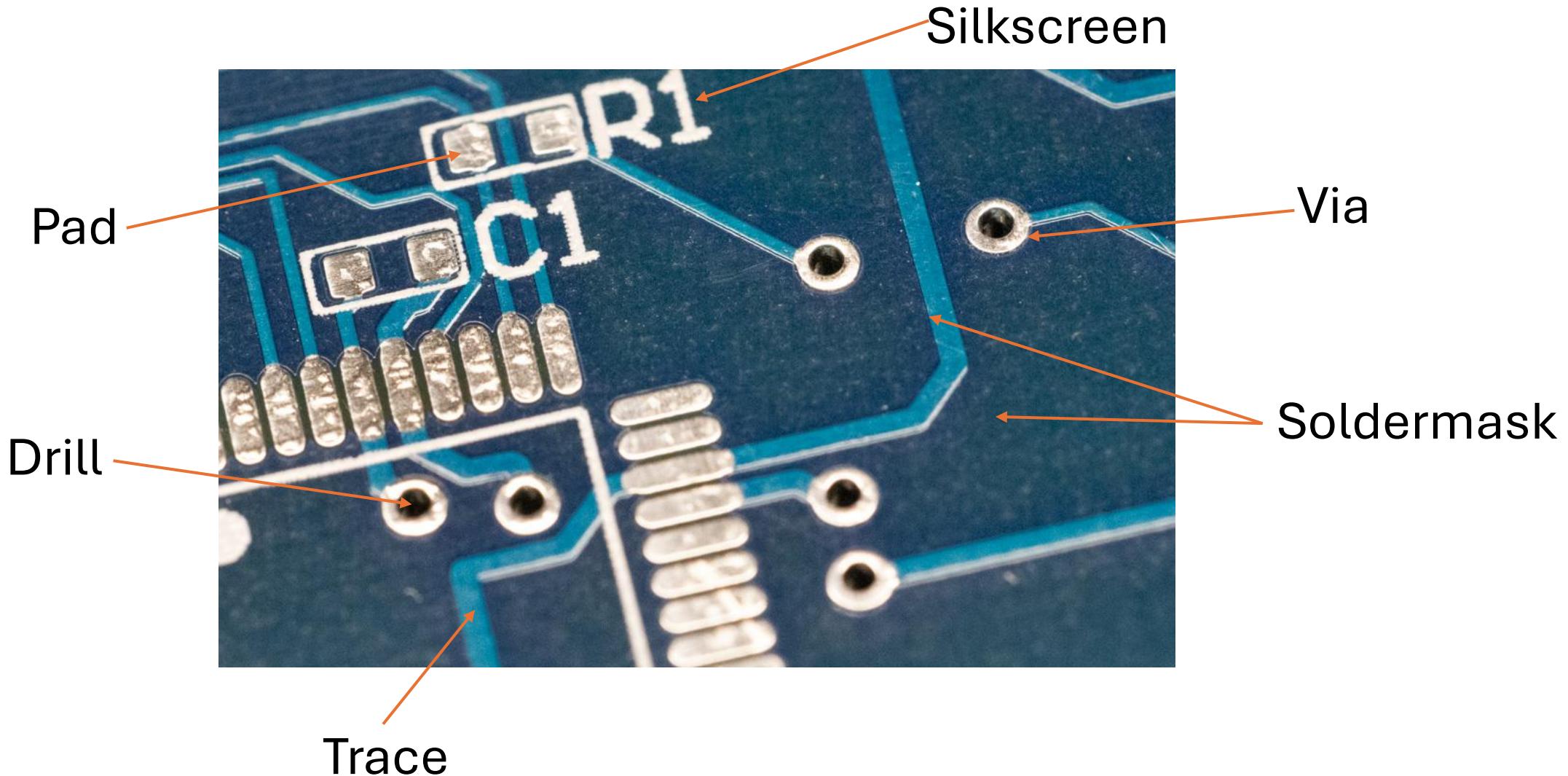
Terminology

PCB-A = Printed Circuit Board Assembly

PCB = Printed Circuit Board



Terminology – Cont'd



PCB: Design Software?



Part 1: PCB Design Basics

PCB Design Units

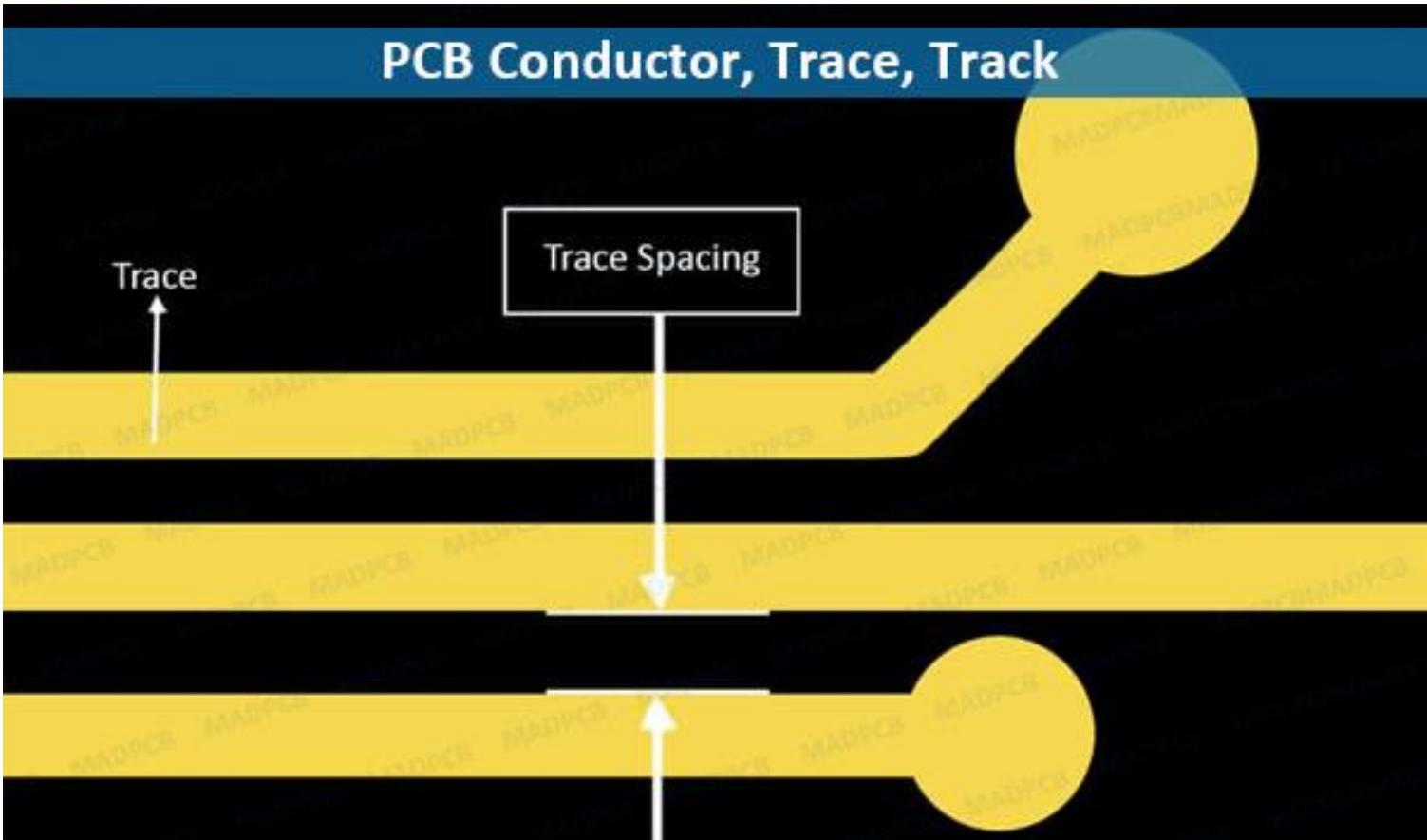
- Units are normally in *mils* or *mms*.

$$1 \text{ mil} = 0.001 \text{ inch} = 0.0254 \text{ mm}$$

WARNING: This is unique to PCB design. It's not a frequently used unit in mechanical design & may be misinterpreted as something else.

In mechanical design “thou” would be used. Especially outside North America where mm would be more common.

Trace & Space



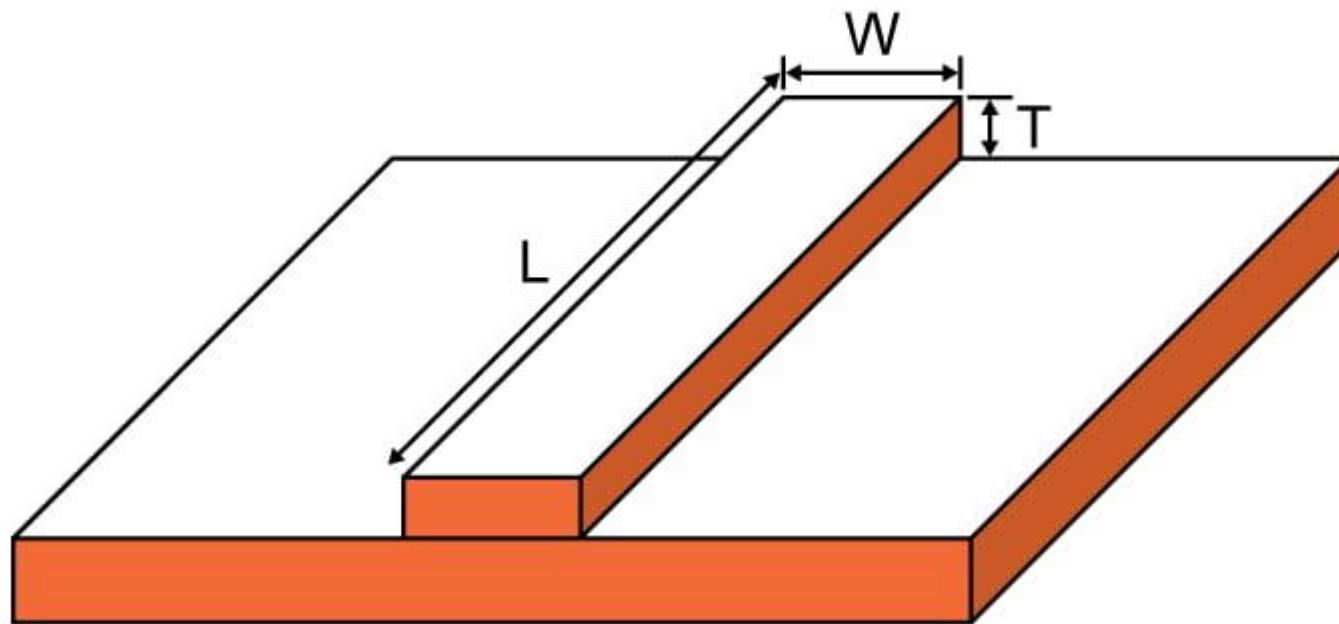
<https://madpcb.com/glossary/conductor/>

Trace & Space == \$\$

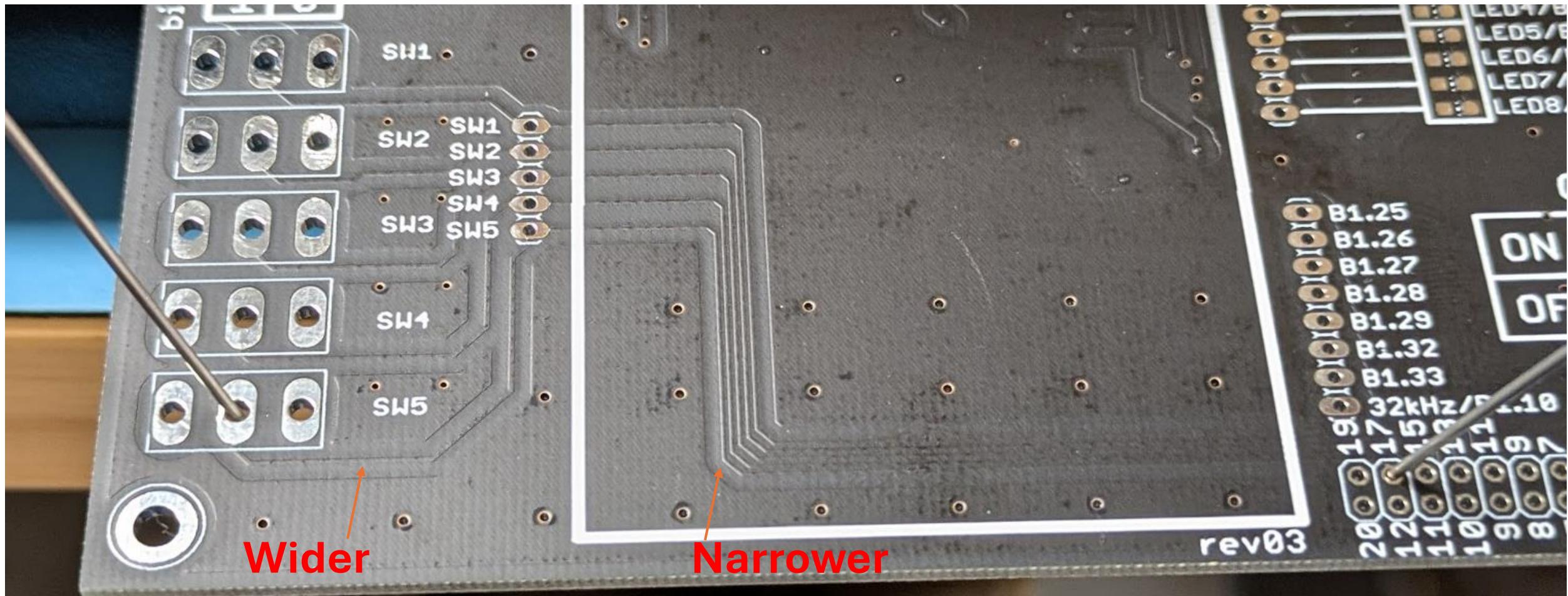
- Trace & Space of 8 mil (0.2mm) or higher can be produced anywhere.
- Trace & Space of 6 mil (0.15 mm) is *mostly* available.
- Trace & Space of 5 mil (0.127 mm) is now common on lower-cost boards, but not universal (OSHPark 2-layer PCBs are 6-mil)
- Trace & Space of 4 mil is higher-tech.

Accurate as of 2025 – this has been stable for some time, and little indication we are getting towards “normal” 4 mil trace/space usage.

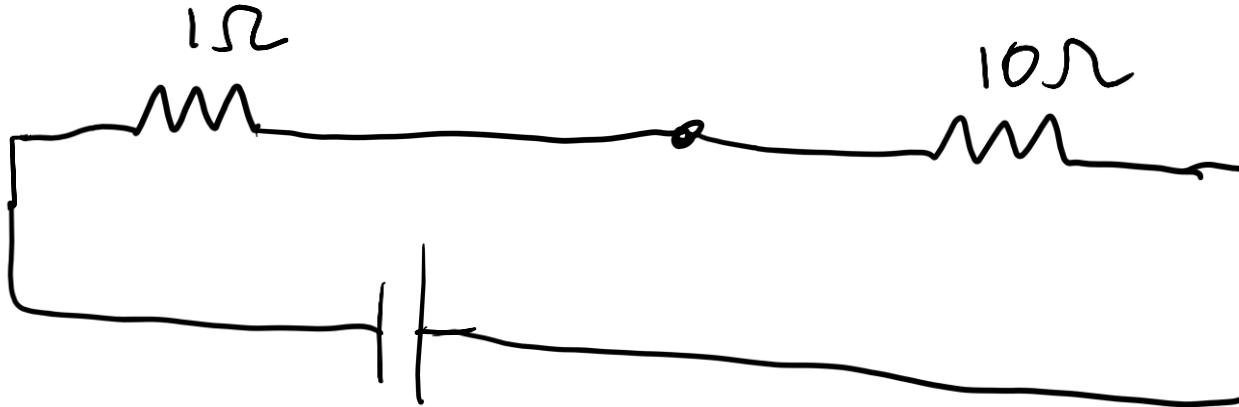
PCB Trace = Resistance & Inductor

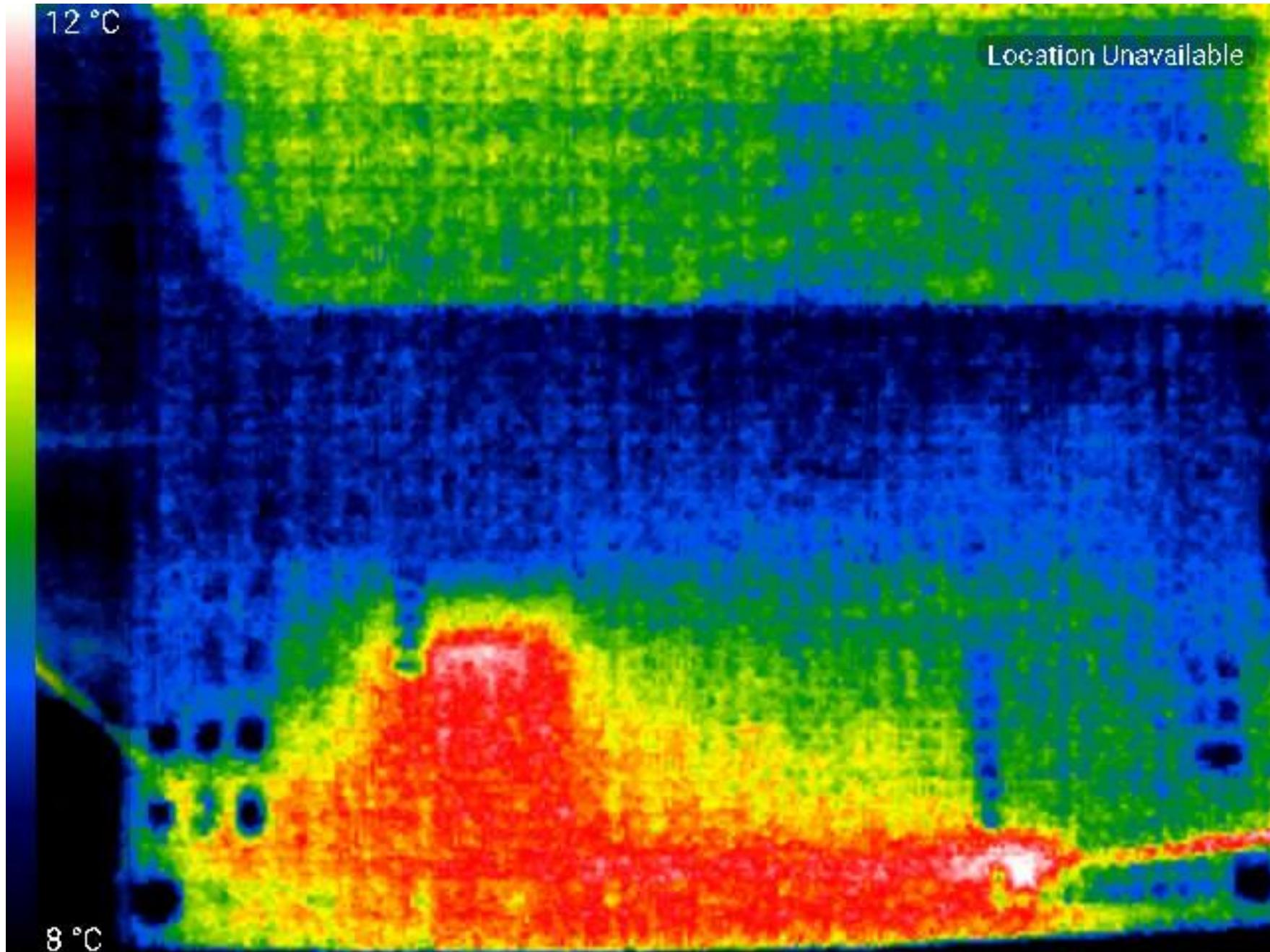


e.g., comparing two PCB traces passing 2A:



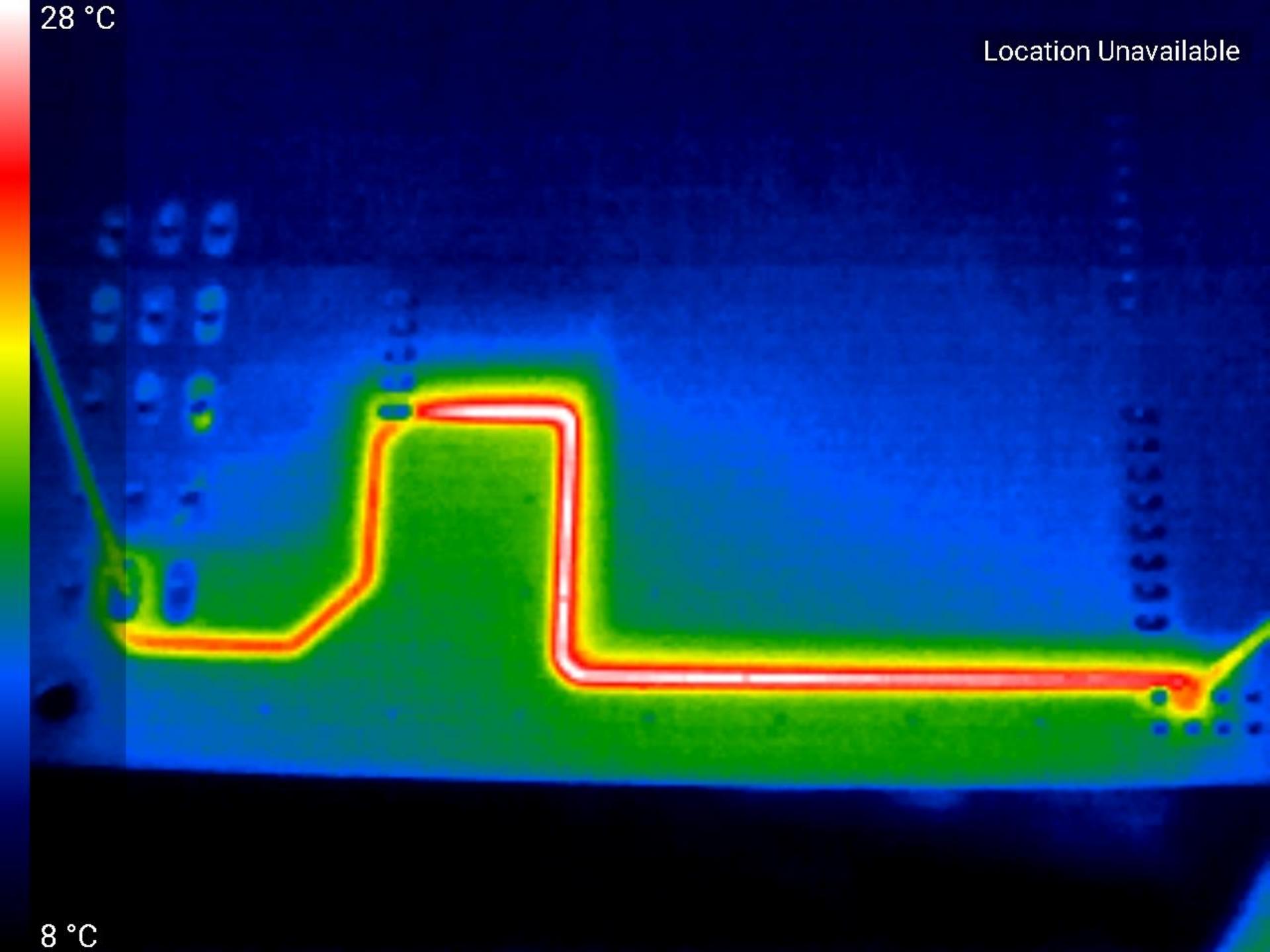
Circuit Equivalent:





28 °C

Location Unavailable



Good Starting Trace Settings

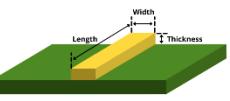
- Trace & Space of 8 mil (0.2mm) or higher can be produced anywhere.
- Trace & Space of 6 mil (0.15 mm) is *mostly* available.
- Trace & Space of 5 mil (0.127 mm) is now common on lower-cost boards, but not universal (OSHPark 2-layer PCBs are 6-mil).
- *NOTE: The lower limit of trace & space won't be as reliable for a process as going above that limit. Always good practice to keep as large a trace & space as your design allows.*

Trace & Space Defaults

- Use 10 mil (0.25mm) trace & space is a good initial setting.
- Widen power traces to ~20 mils (~0.5mm) or more.
 - You'll see in Group Project 1 how to calculate temperature rise of a trace.

Trace Width, Current Capacity and Temperature Rise Calculator

Input



Ambient Temperature (°C): 25 °C
Conductor Thickness (oz): 1 oz
Temperature rise above Ambient (°C): 4.9844 °C
Conductor Width (mils): 20 mils
Maximum Current Capacity (A): A
Maximum Temperature (°C): 293044 °C

Output

Conductor Length (inches): 1 inches
Resistance at Ambient Temperature (mΩ): 26.371 mΩ
Jacket loss at high temperature (mΩ): 26.793 mΩ
Voltage drop at Max Current Capacity (mV): 24.785 mV
Power loss at Max Current (mW): 26.793 mW

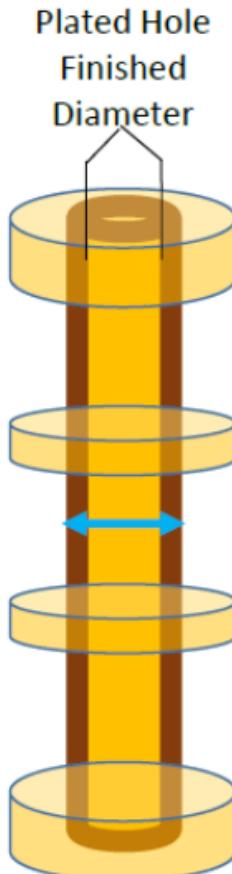
Select the Layer: External
www.protoexpress.com

Play Demo Video

Disclaimer: No representations or warranties of any kind are expressed or implied, about the completeness, accuracy, or reliability of these tools. Stereo Circuits, in no event, will be liable to any user of these tools for any loss or damages, including without limitation, indirect or consequential damages arising out of or associated with the use of these tools.

<https://www.protoexpress.com/tools/trace-width-and-current-capacity-calculator/>

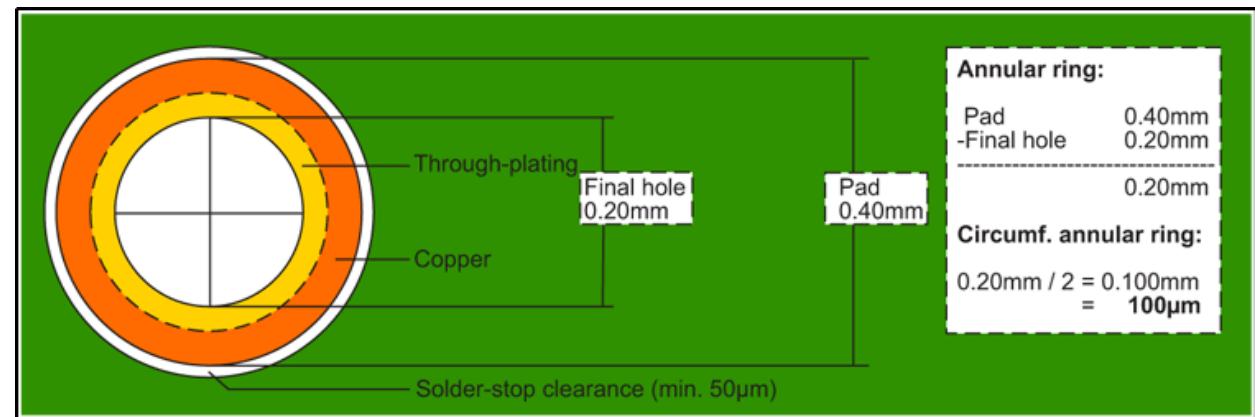
Via & Drill



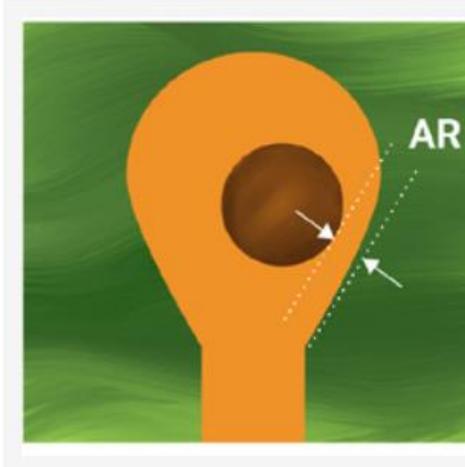
The difference between the drill diameter and the finished hole can be between .004"-.007" depending on the finish.

You are normally specifying the **finished hole size**.

PCB manufacturer will take care of selecting a drill to get you the required finished hole size you specify in the design software.

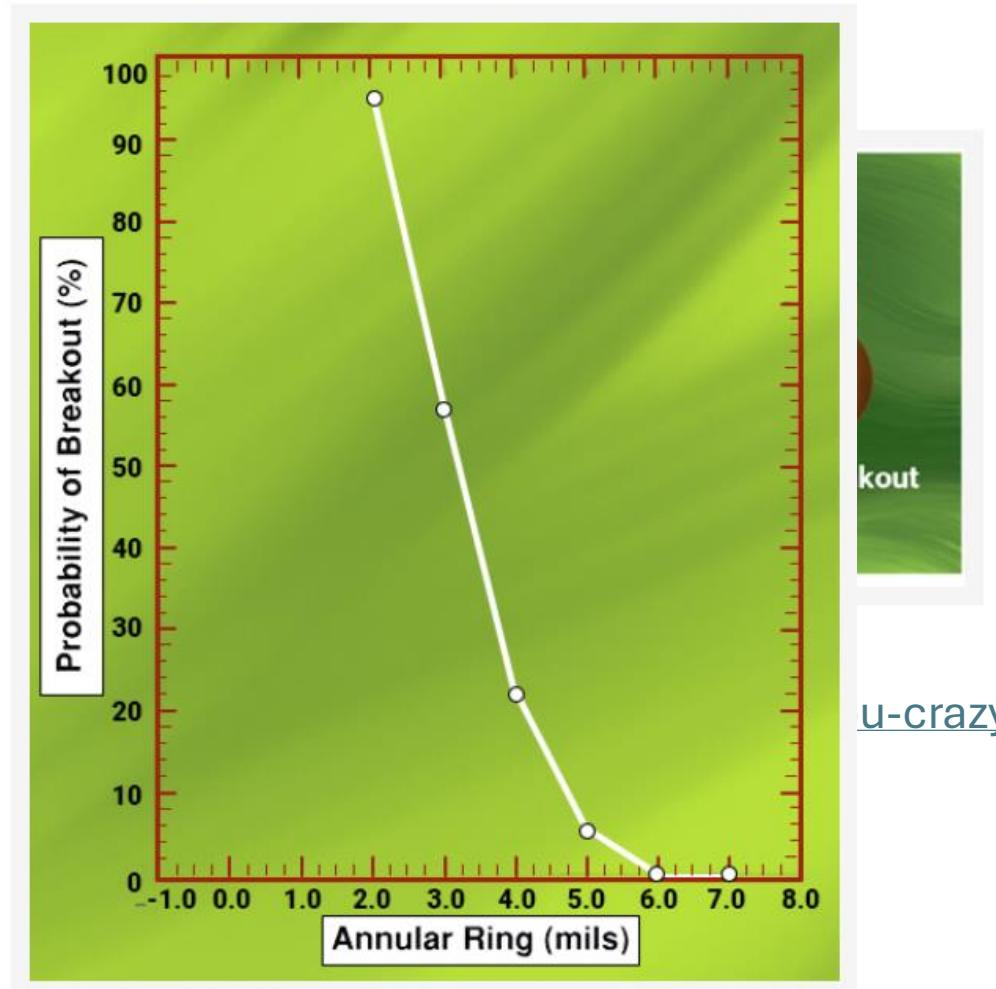


Annular Ring



Annular ring breakout occurs when the inner

<https://www.protoexpress>

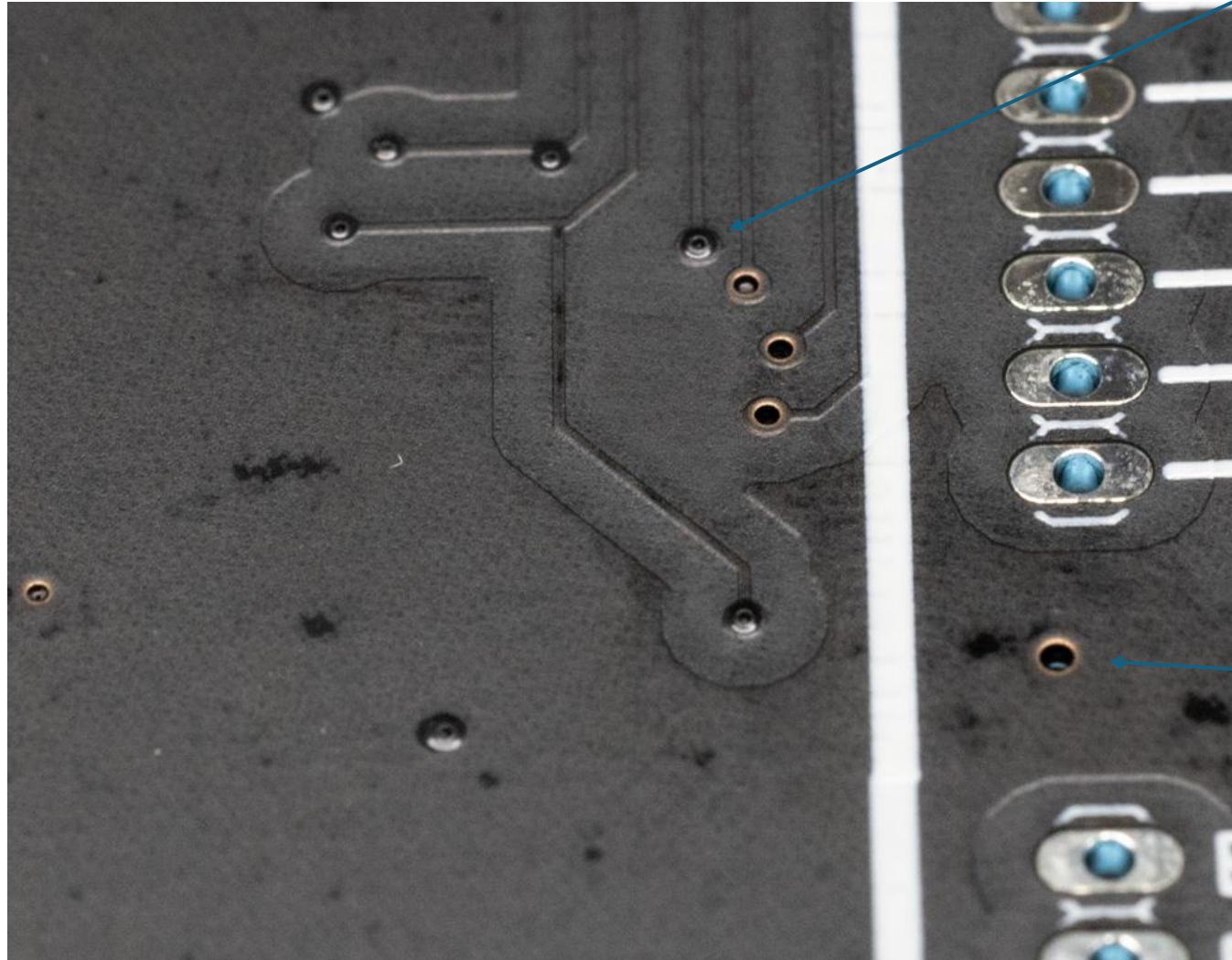


kout

[u-crazy](#)

The probability of breakout reduces when the annular ring width is higher.

Via Tenting



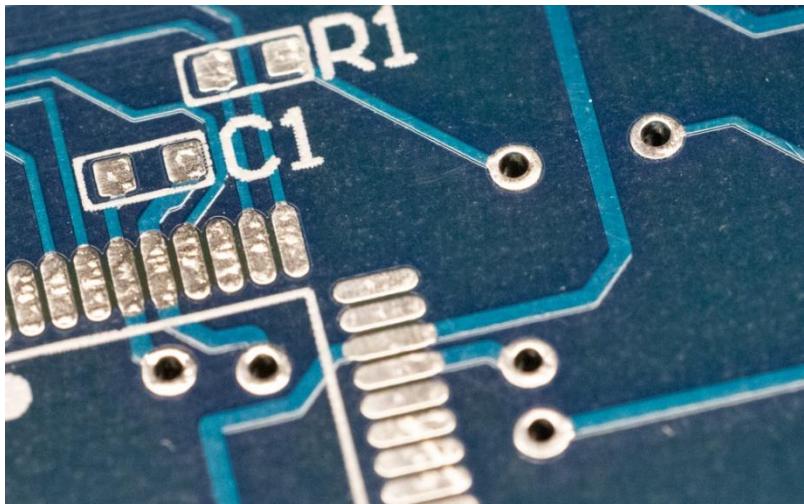
Tented Via (hole has slight raise)

If soldermask covers the vias they are tented.

Note depending on the drill hole sometimes the soldermask doesn't cover the hole.

Tented Via
(Hole is clear)

Untented Vias



Untented vias are exposed as here.

Why tent vias?

- Reduces risk of shorts or solder bridges.
- Looks cleaner.
 - *NOTE: Silkscreen cannot go over untented vias.*

Why untent vias?

- Can use vias as *test points*.
- Easier to modify PCB.

Typical Via Sizes

Good generic one:

- 20 mill drill (0.5 mm) & 40 mil (1.0 mm) diameter pad

Smallest size for low-cost:

- 12 mil drill (0.3mm) & 24 mil (0.6 mm) diameter pad
(Now commonly 8 mil (0.2 mm) drill is available)

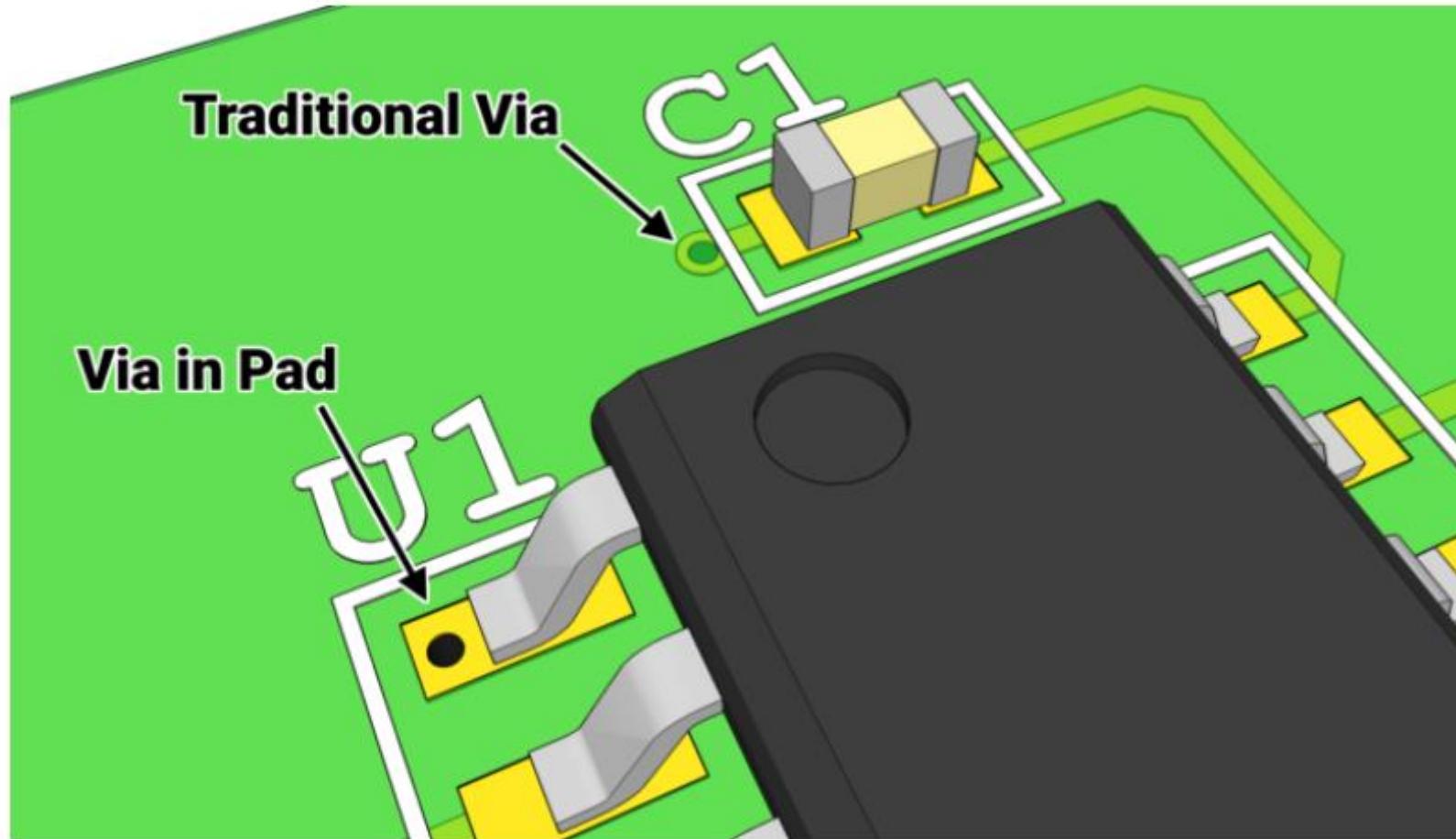
For higher power increase size & add several in parallel.

NOTE: We commonly call the hole size the “drill”, even though the actual drill size is different. We rarely know the actual “drill”. Just be aware these are different!

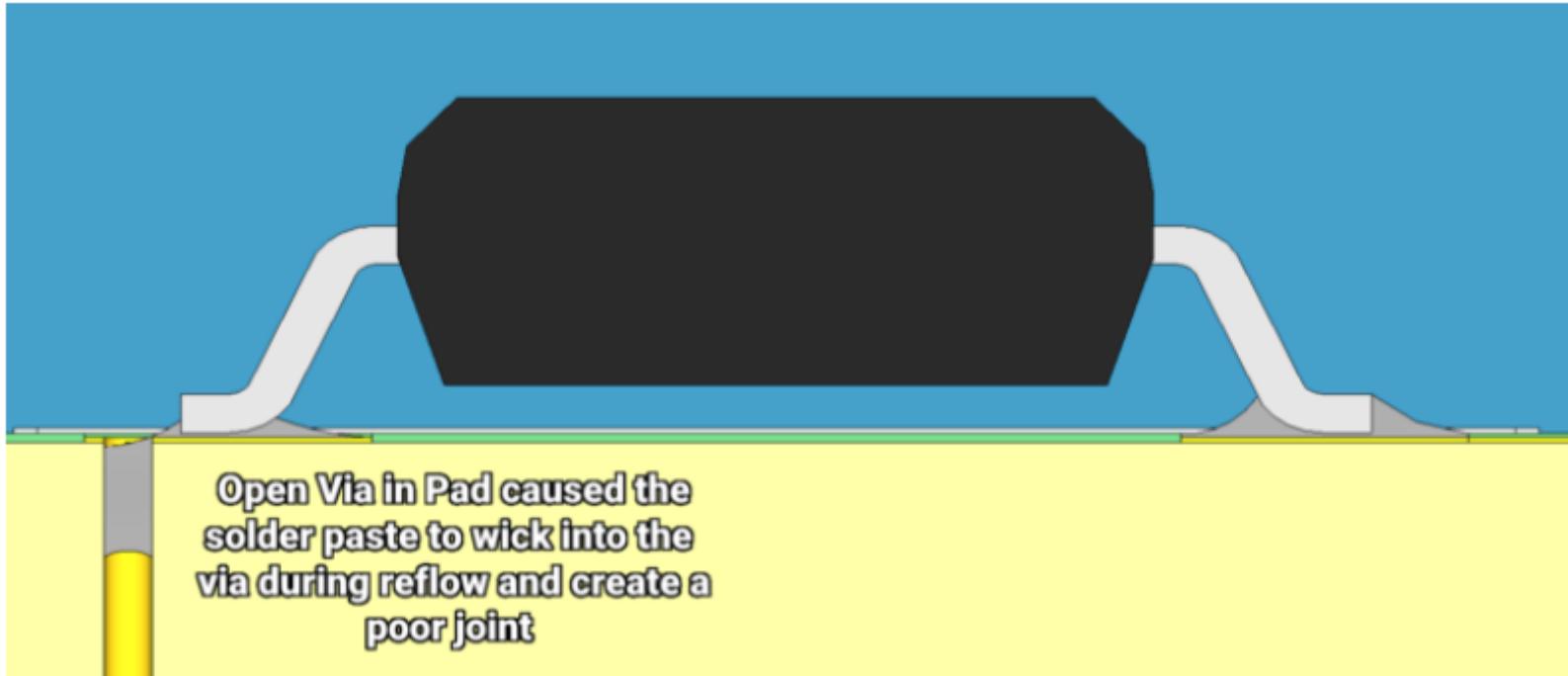
When Designing your PCB:

- Check default trace & space settings + via sizes – ensure it matches your process!
 - **It's a LOT more work to fix this later.**

Via in Pad

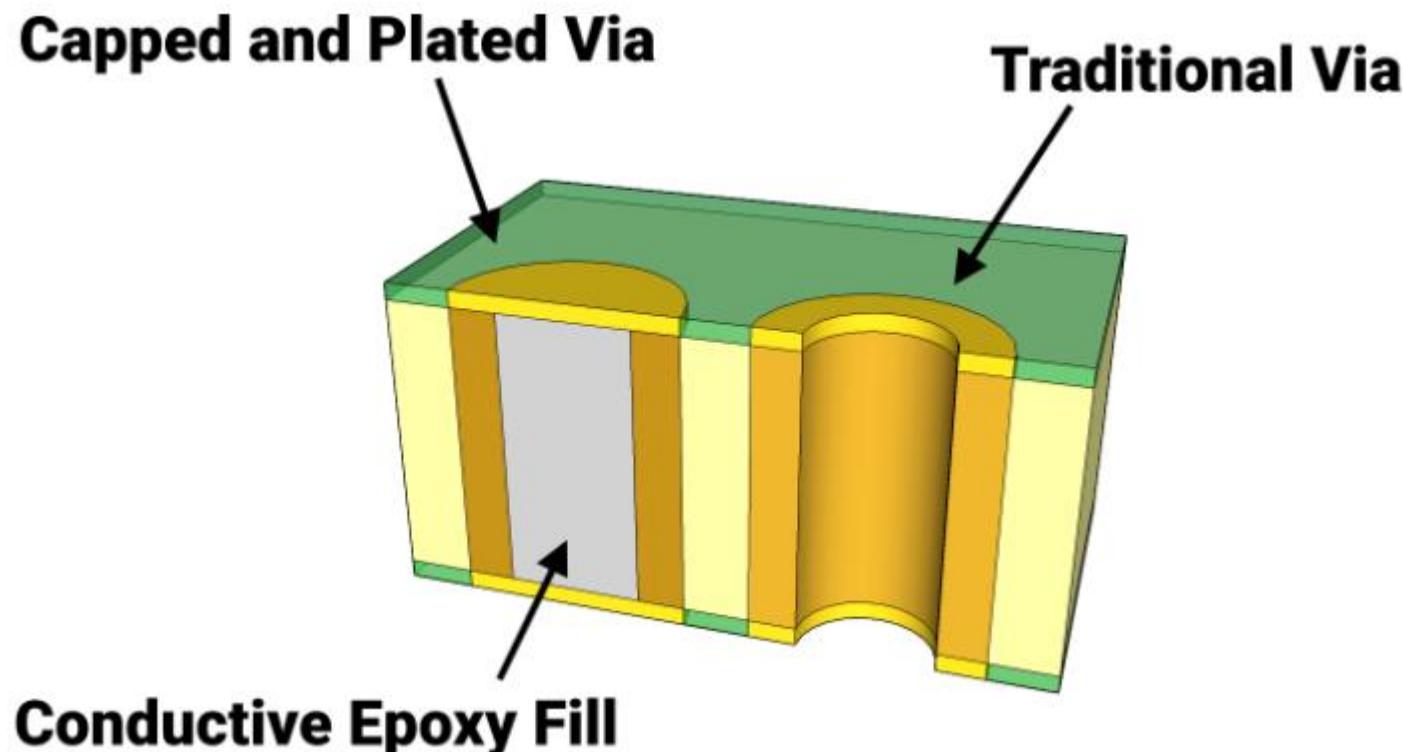


Via in Pad



Via in Pad Process

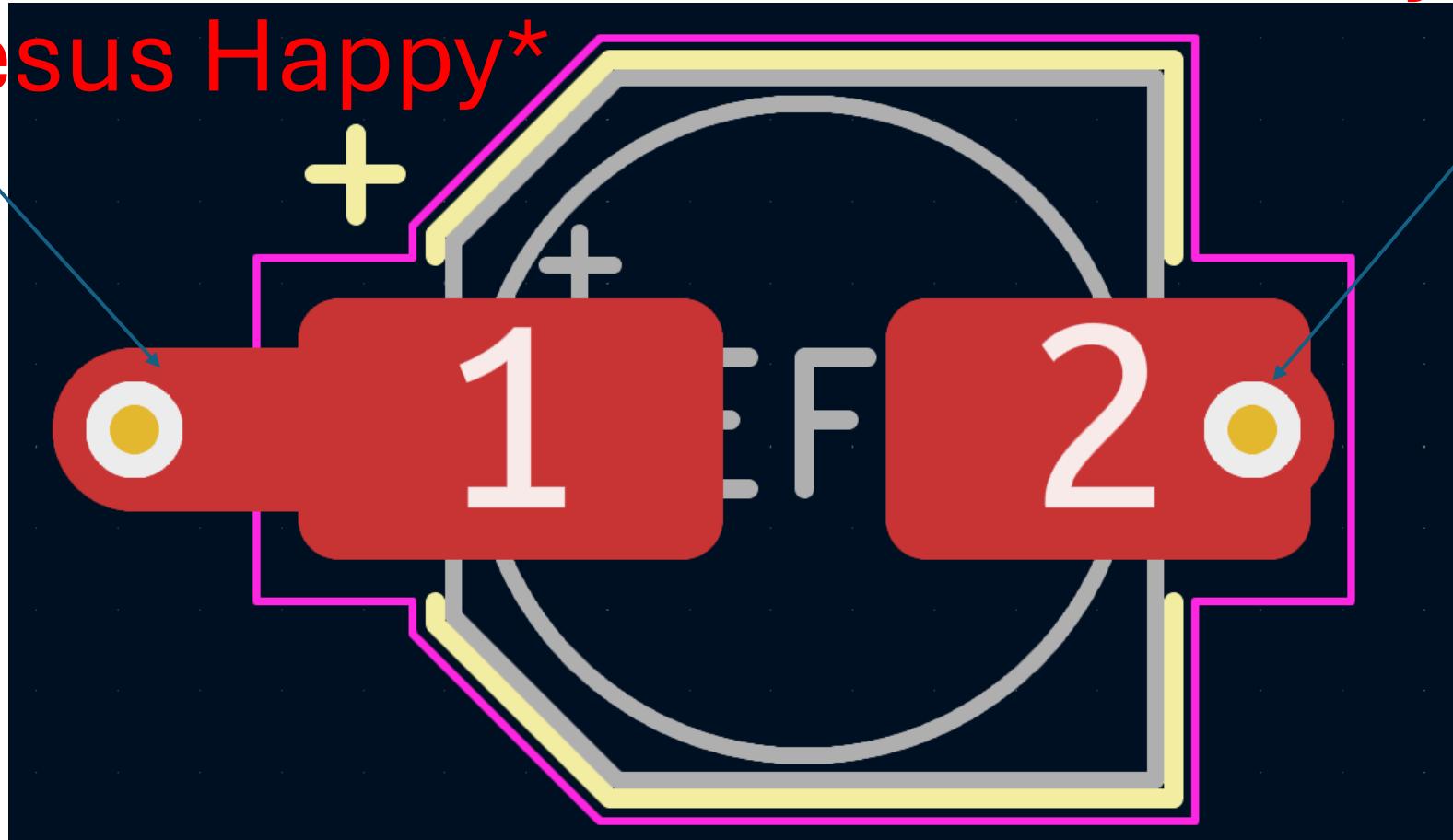
\$\$\$



Do This NOT That:

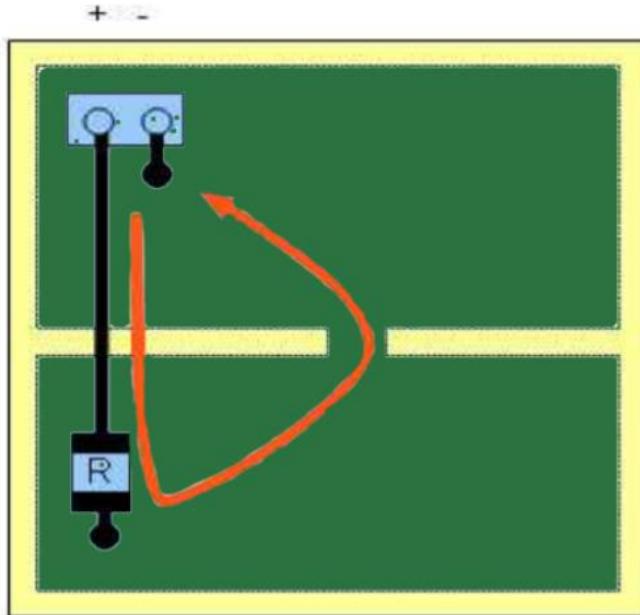
Baby Jesus Sad

Baby Jesus Happy*

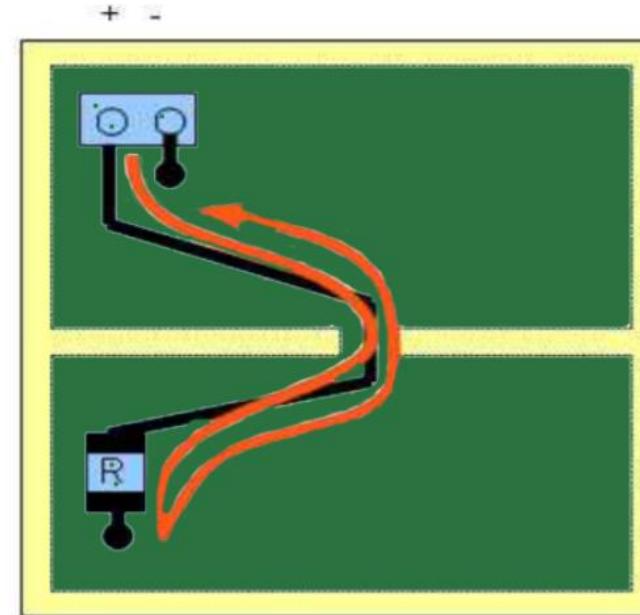


*Very pedantic people may point out there should be multiple vias to reduce inductance if this is for power

Route to avoid current loops



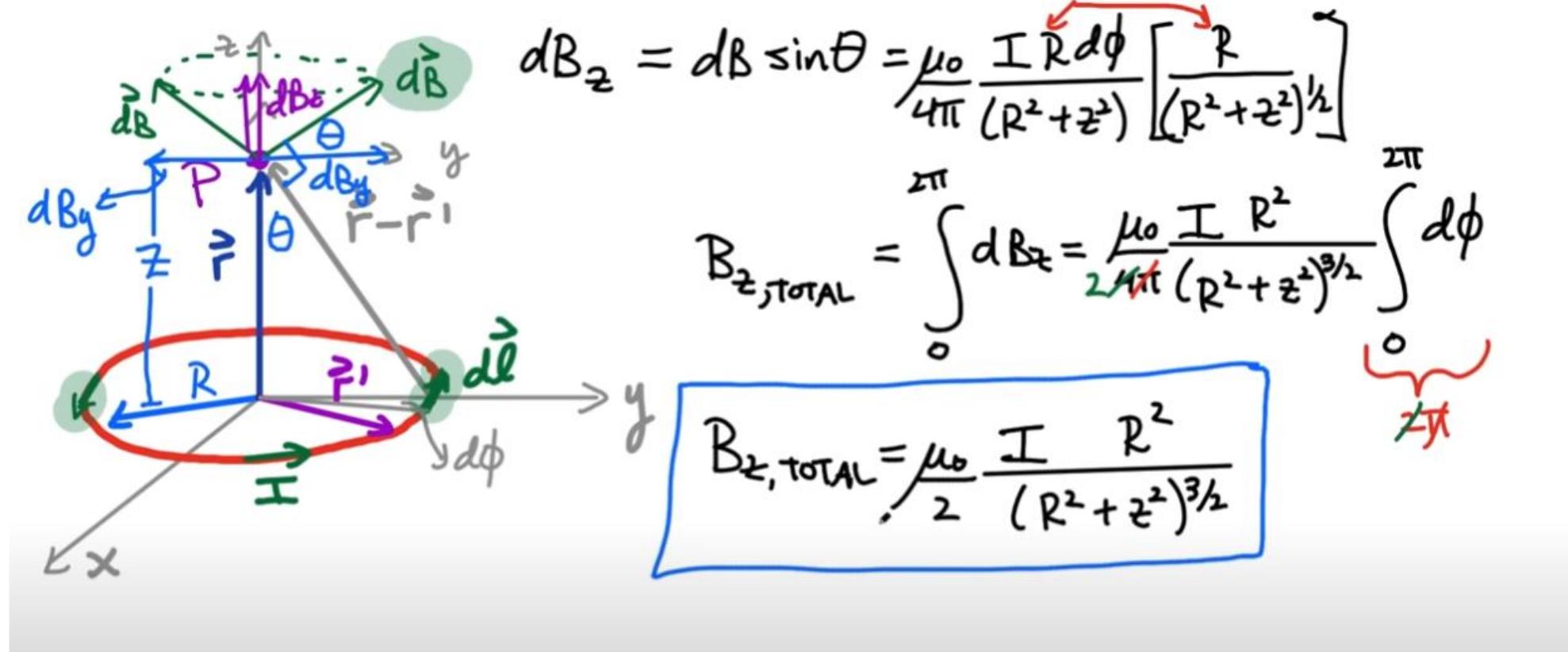
Large current loop area :
Strong radiated field



Small current loop area :
Low radiated field

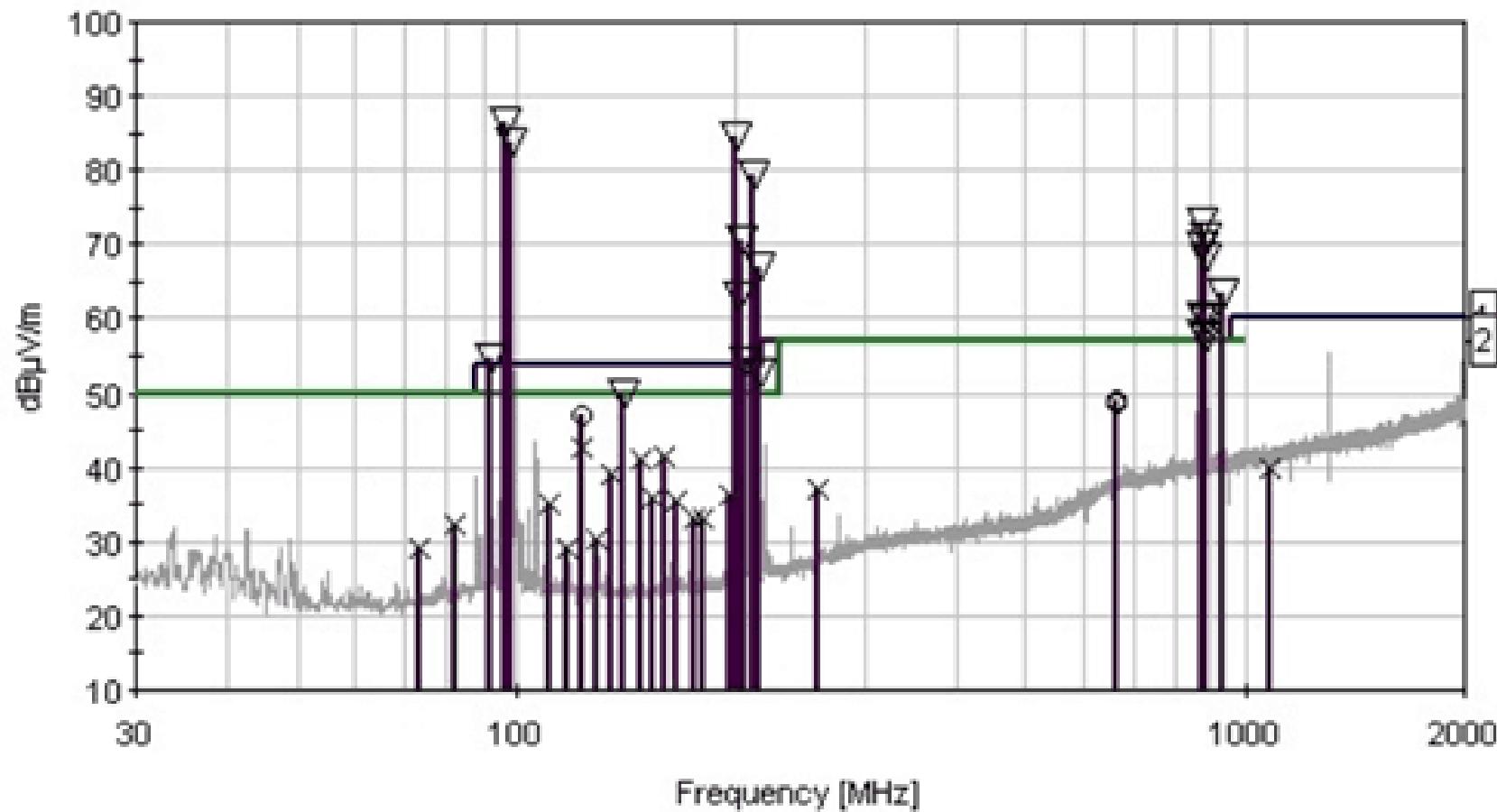
<https://www.protoexpress.com/blog/best-high-speed-pcb-routing-practices/>

Remember: Your Fields / EM Courses!



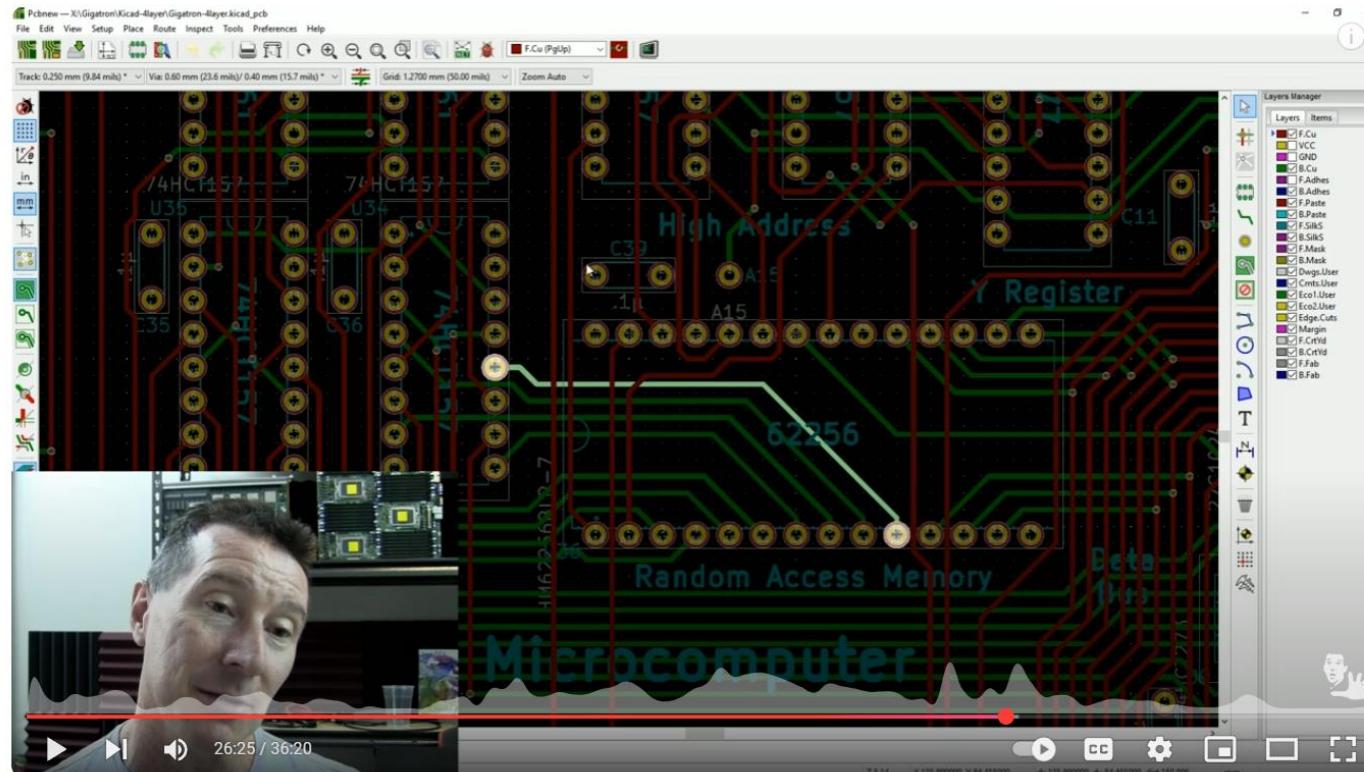
<https://www.youtube.com/watch?v=nydLMuGB61E&t=13m10s>

EMC Compliance



<https://emcfastpass.com/emc-testing-beginners-guide/emissions/>

2-Layer PCB vs 4-Layer PCB



EEVblog #1176 - 2 Layer vs 4 Layer PCB EMC TESTED!



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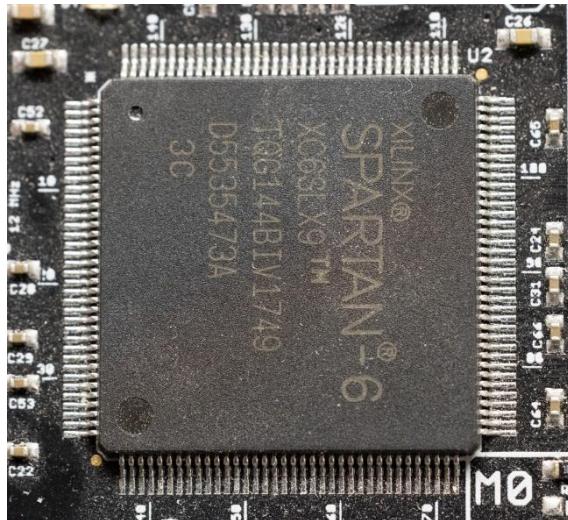
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Save

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<https://www.youtube.com/watch?v=crsQLuUTyQ>

Footprints



Choose Footprint (13945 items loaded)

▼ TQFP

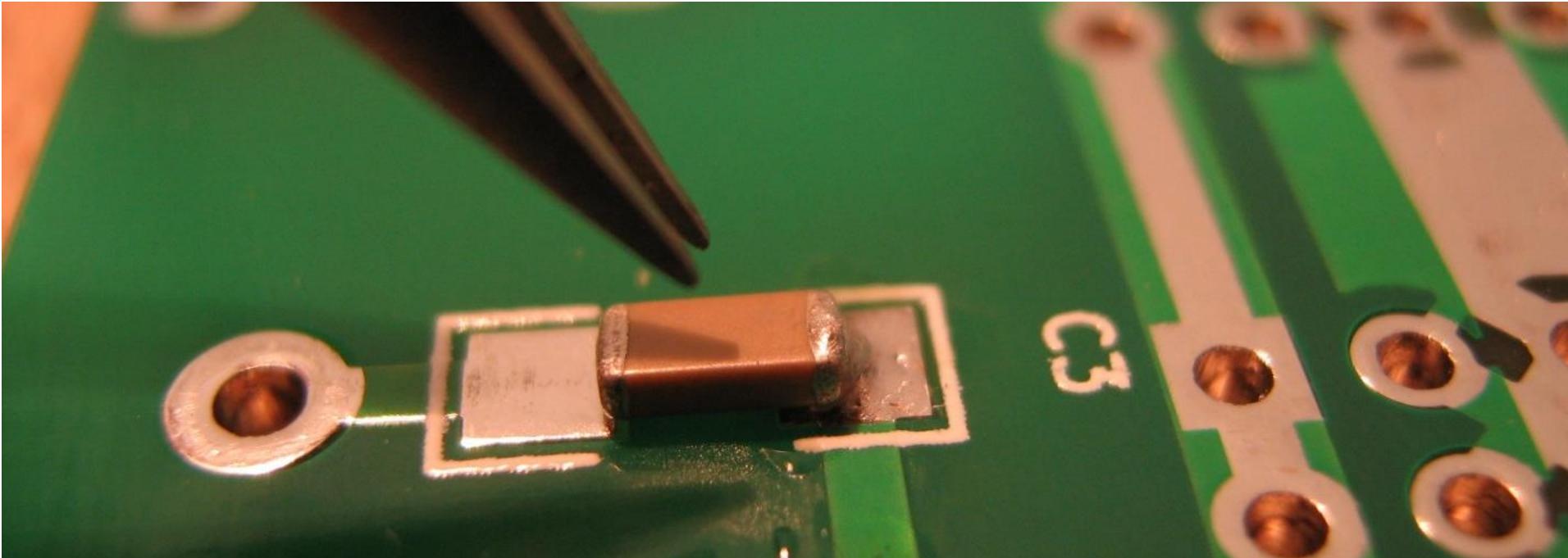
Item	Description
Package_QFP	Quad Flat Package (QFP)
TQFP-48-1EP_7x7...m_EP4.11x4.11mm	TQFP, 48 Pin (https://www.lumissil.com/assets/pdf/...cad-footprint-generator ipc_gullwing.pdf)
TQFP-48-1EP_7x7...P0.5mm_EP5x5mm	TQFP, 48 Pin (https://www.trinamic.com/fileadmin/...cad-footprint-generator ipc_gullwing.pdf)
TQFP-48-1EP_7x7...5mm_ThermalVias	TQFP, 48 Pin (https://www.trinamic.com/fileadmin/...cad-footprint-generator ipc_gullwing.pdf)
TQFP-48_7x7mm_P0.5mm	TQFP, 48 Pin (http://www.microchip.com/downloads/cad-footprint-generator ipc_gullwing.pdf)
TQFP-52-1EP_10x...5mm_EP6.5x6.5mm	TQFP, 52 Pin (http://www.analog.com/media/en/pack...h kicad-footprint-generator ipc_gullwing.pdf)
TQFP-52-1EP_10x...5mm_ThermalVias	TQFP, 52 Pin (http://www.analog.com/media/en/pack...h kicad-footprint-generator ipc_gullwing.pdf)
TQFP-64_10x10mm_P0.5mm	TQFP, 64 Pin (http://www.microsemi.com/index.php?...ad-footprint-generator ipc_gullwing.pdf)
TQFP-100-1EP_1...P0.5mm_EP5x5mm	TQFP, 100 Pin (https://www.analog.com/media/en/p...ad-footprint-generator ipc_gullwing.pdf)
TQFP-100-1EP_14...5mm_ThermalVias	TQFP, 100 Pin (https://www.analog.com/media/en/p...ad-footprint-generator ipc_gullwing.pdf)
TQFP-100_14x14mm_P0.5mm	TQFP, 100 Pin (http://www.microsemi.com/index.ph...cad-footprint-generator ipc_gullwing.pdf)
TQFP-144_20x20mm_P0.5mm	TQFP, 144 Pin (http://www.microsemi.com/index.ph...cad-footprint-generator ipc_gullwing.pdf)
TQFP-176_24x24mm_P0.5mm	TQFP, 176 Pin (http://www.microsemi.com/index.ph...cad-footprint-generator ipc_gullwing.pdf)
TQFP-64_7x7mm_P0.4mm	TQFP64 7x7, 0.4mm CASE 932BH (see ON Semiconductor 932BH.PDF)
TQFP-120_14x14mm_P0.4mm	TQFP120 14x14 / TQFP120 CASE 932AZ (see ON Semiconductor 932AZ.PDF)
TQFP-128_14x14mm_P0.4mm	TQFP128 14x14 / TQFP128 CASE 932BB (see ON Semiconductor 932BB.PDF)
TQFP-32_7x7mm_P0.8mm	32-Lead Plastic Thin Quad Flatpack (PT) - 7x7x1.0 ... Microchip Packaging Specification
TQFP-44-1EP_10x...8mm_EP4.5x4.5mm	44-Lead Plastic Thin Quad Flatpack (MW) - 10x10x1...Microchip Packaging Specification
TQFP-44_10x10mm_P0.8mm	44-Lead Plastic Thin Quad Flatpack (PT) - 10x10x1... Microchip Packaging Specification
TQFP-48-1EP_7x7...5mm_EP3.5x3.5mm	48-Lead Thin Quad Flatpack (PT) - 7x7x1.0 mm Body...icrochip Packaging Specification

TQFP-144_20x20mm_P0.5mm
TQFP, 144 Pin (http://www.microsemi.com/index.php?option=com_docman&task=doc_download&gid=131095), generated with kicad-footprint-generator ipc_gullwing_generator.py

Footprints: Standard

- Standard footprints designed for production soldering, using solder paste process.
- But what if you are doing just a few boards...

Footprints: Hand Soldering



<https://www.davidhaillant.com/smd-soldering/>

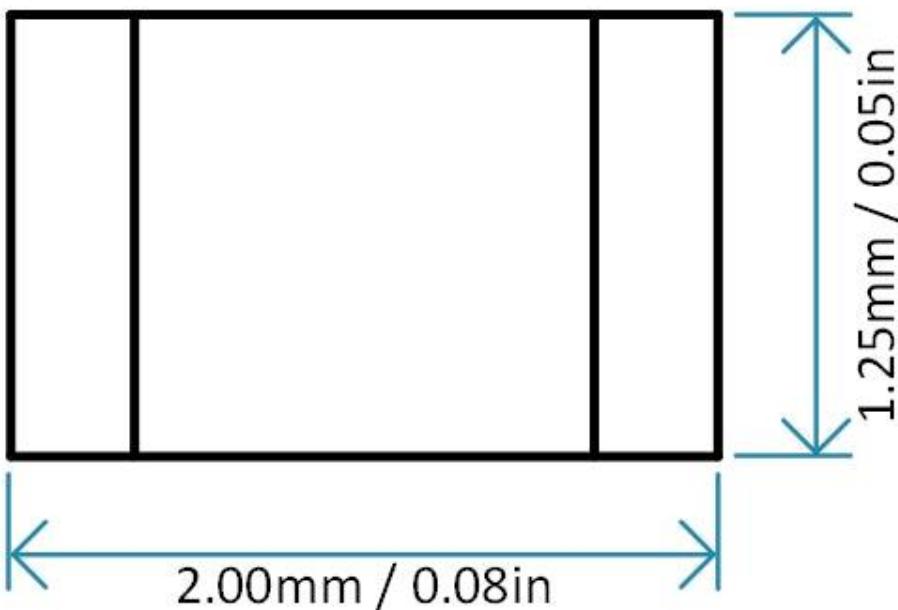
SMD vs. Through Hole

Surface mount parts can be more difficult to solder, but once you get used to it you may prefer them!

Lots of automated & semi-automated methods you can use for soldering, a few examples in these slides...

SMD Footprint Sizes

0805 SMD Size



0805 (Inch) = 2012 (Metric)

Suggest to use 0805 sizes as a minimum to get started.

In industry, most designs are 0603 where space is not a constraint, 0402 is “normal” where some space constraints.

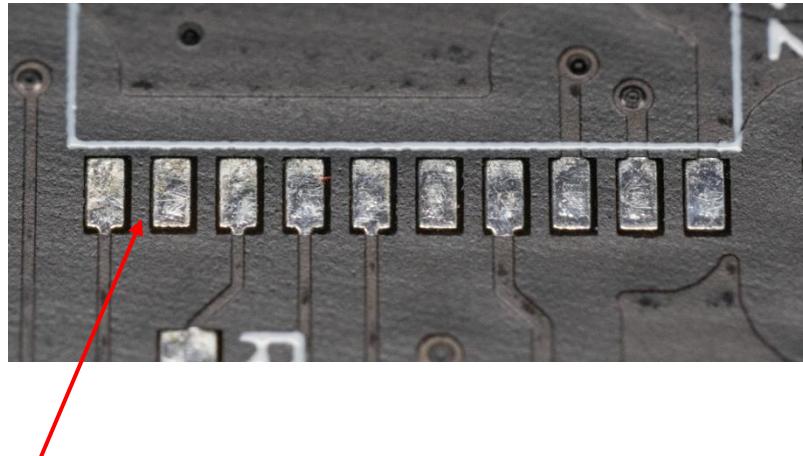
0201 and smaller are used for space constrained.

NOTE: As size goes down power handling capacity, voltage ratings, etc *tend* to go down. Very little downside to large packages.

Checking Footprints!

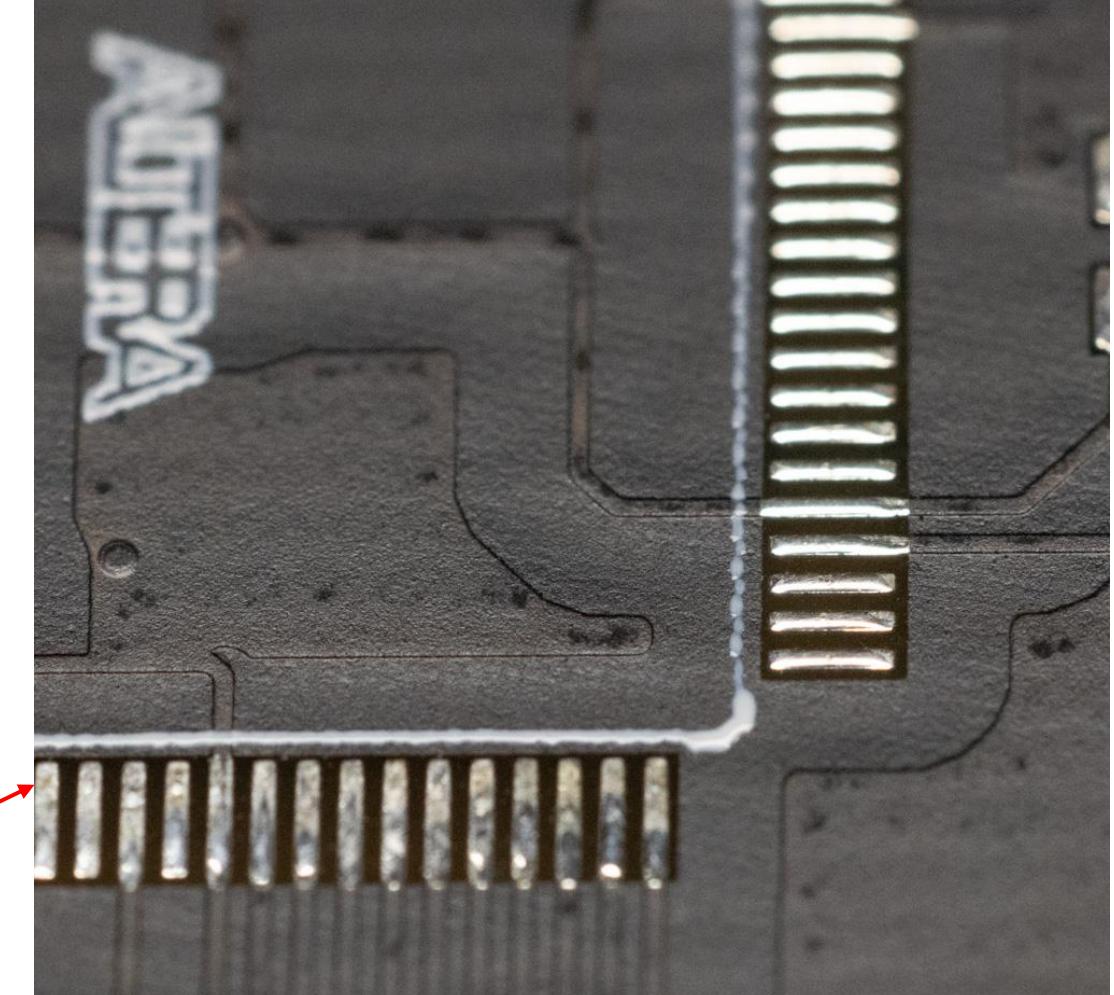
- Footprints may have errors. Good practice to always check them against datasheet.
- Also good idea to order parts early & test them on a printed copy of the PCB to ensure things “fit” as you expect.

Soldermask Bridges / Dams

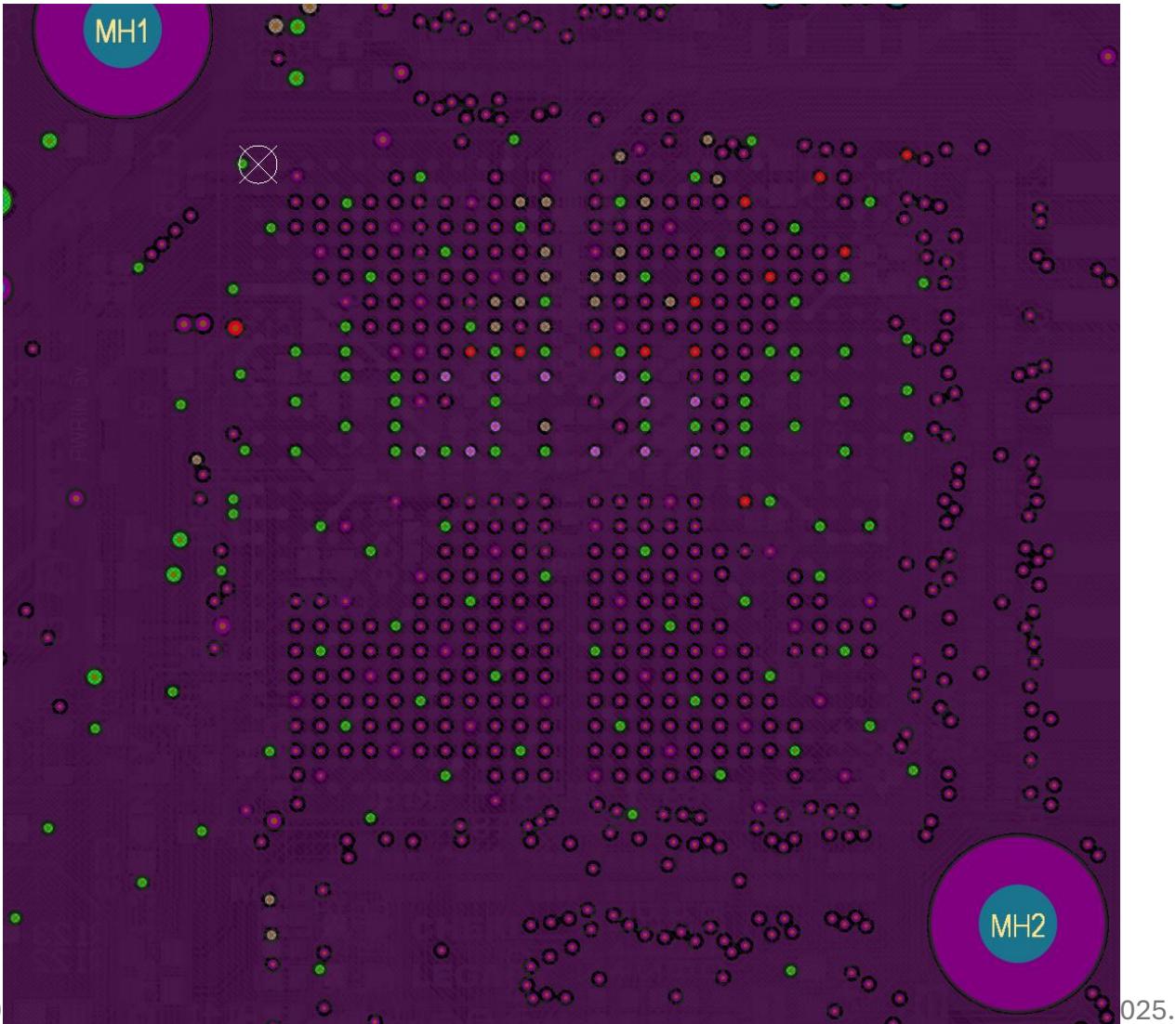


Soldermask between pins (wide pitch part)

Soldermask removed between pads – gap would be too small for soldermask process.



Planes & Pours

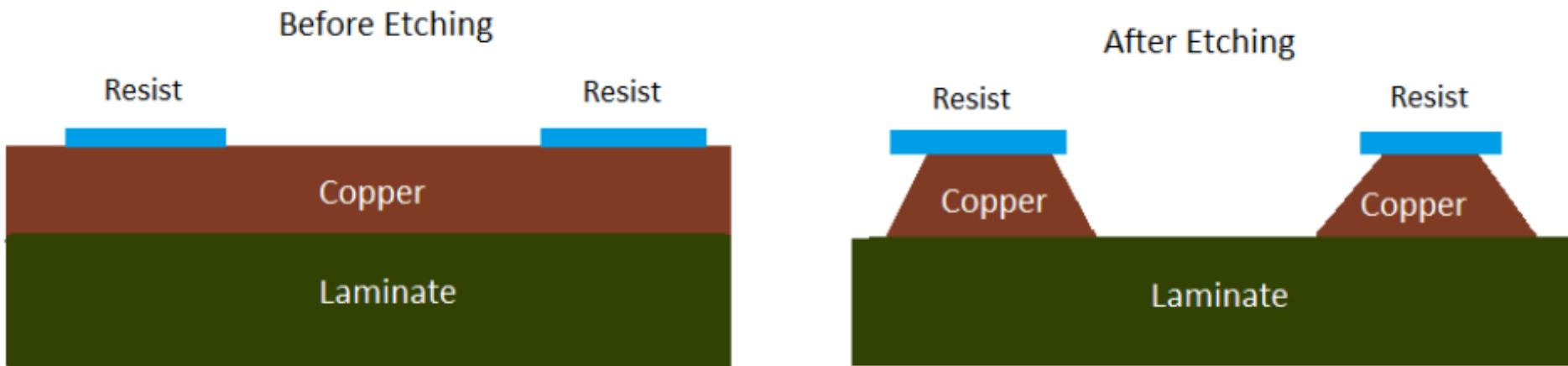


Let's assume you've got the design already (we'll see how you can make a design later).

And go onto...

Part 2: Ordering & Submission

Manufacturing Process



<https://www.protoexpress.com/kb/pcb-manufacturing-overview/>

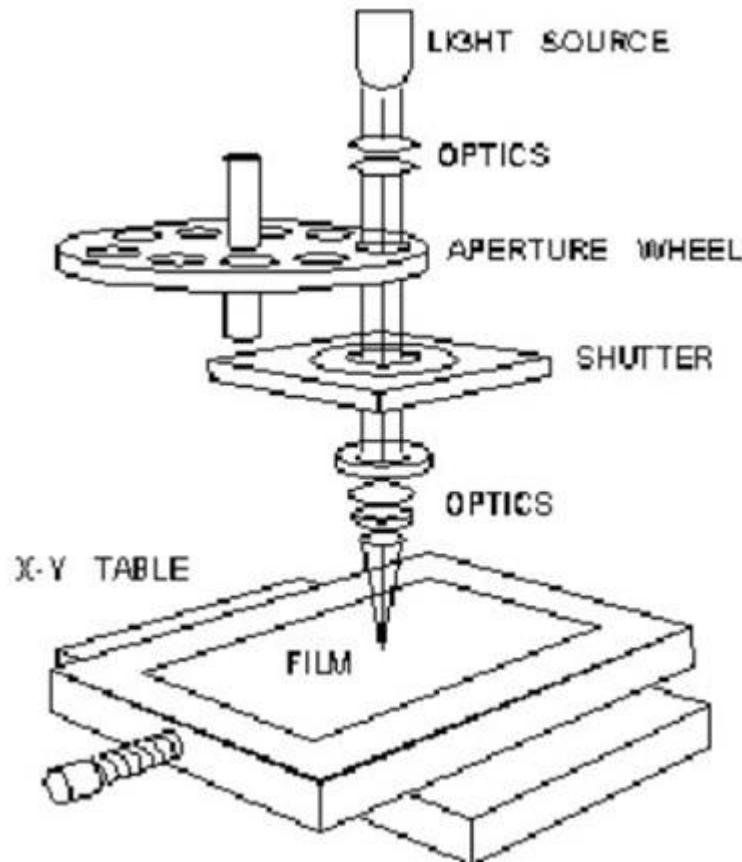
DRC / DFM Checks

- Design Rule Check (DRC) part of Design For Manufacturability (DFM)
- DRC is critical.
 - Causes delays or broken PCBs.

File Formats

- You are mostly going to deal with “Gerbers” & “NC Drill”.
- There are more “recent” file formats that you may come across in industry which have much better control on information.
- You may also share a netlist with the fab which is used for electrical test (E-Test).

Gerber & NC-Drill



These file formats are old (1960's), and have a lot of terminology that reflect how the PCBs were made (see left) using a *photoplotter*.

<https://www.eurocircuits.com/gerber-past-present-and-future/>

Gerber & NC-Drill

- The Gerber files (RS-274-D) contained the traces.
 - Encoded as selecting an aperture & moving it around. Still the case.
- The NC Drill (NC = Numeric Control) contained the drills for vias & holes.
 - Sometimes called *Excellon* after a brand name.
- You may need to specify your file parameters such as:
 - Units (mm vs inch)
 - “Precision” (how many decimal places are used)

README File

Very common to include a “README.txt” file which has details:

- Board parameters (size)
- File information
- Contact information (maybe?)

NOTE: Be careful to avoid OVERSPECIFYING things that you are specifying in the ordering process.

e.g., Minimal README File

```
2-Layer PCB

Soldermask: Blue
Silkscreen: White

Finish: HASL/ENIG

Individual PCB Size: 52.3mm x 64.6mm

Board Files:

.GTO - Top Silkscreen
.GTS - Top Soldermask
.GTL - Top Copper
.GBL - Bottom Copper
.GBS - Bottom Soldermask
.GBO - Bottom Silkscreen
.GM1 - Outline
.NCDRILL - Drill Files

Other Files:

.GTP - Top Paste (used for stencil)
.GBP - Bottom Paste (NOT USED)
```

e.g., More detailed README File:

```
-----  
GENERAL  
-----  
Board Size: 200 x 150mm  
Finish: ENIG  
Soldermask: Red  
Silkscreen: White  
Board Thickness: 1.6mm  
  
Min drill = 0.2mm  
Space/Trace = 5mil  
  
PCB STACKUP:  
-----  
.GTO Top Silkscreen  
.GTS Top Soldermask  
.GTL TOP COPPER (LAYER 1)  
.GP1 PLANE 1 (INVERTED)(LAYER 2)  
.G1 INNER 1 (LAYER 3)  
.G2 INNER 2 (LAYER 4)  
.GP2 PLANE 2 (INVERTED)(LAYER 5)  
.G3 INNER 3 (LAYER 6)  
.GP3 PLANE 3 (INVERTED)(LAYER 7)  
.GBL BOTTOM COPPER (LAYER 8)  
.GTS Bottom Soldermask  
.GBO Bottom Silkscreen  
  
Layer count marked in PCB files at bottom left. Should read 1-2-3-4-5-6-7-8 in order!  
  
ADDITIONAL FILES:  
-----  
.NCDRILL - NC Drill (slot and round)  
.GTP Top Stencil  
.GBP Bottom Stencil  
.GM1 Milling Layer  
  
BOARD CONSTRUCTION  
-----  
Standard board stackup spacing for 8-layer 0.062" PCB ok.  
  
Currently the design is based on this stack-up, but almost  
any 8-layer stackup will work for this version.  
  
ENIG Surface Finish  
Layer 1: 1 Oz Copper (1.4 mil)  
Prepreg - 2.95 mil (1080)  
Prepreg - 2.95 mil (1080)  
Layer 2: 1 Oz Copper (1.4 mil)  
Core - 9 mil  
Layer 3: 1 Oz Copper (1.4 mil)  
Prepreg - 7.3 mil (7628)  
Layer 4: 1 Oz Copper (1.4 mil)  
Core - 5.1 mil  
Layer 5: 1 Oz Copper  
Prepreg - 7.3 mil (7628)  
Layer 6: 1 Oz Copper (1.4 mil)  
Core - 9 mil  
Layer 7: 1 Oz Copper (1.4 mil)  
Prepreg - 2.95 mil (1080)  
Prepreg - 2.95 mil (1080)  
Layer 8: 1 Oz Copper (1.4 mil)  
ENIG Surface Finish  
  
E-TEST  
-----  
PCBs must be 100% electrically tested. Can provide netlist in preferred format on request.
```

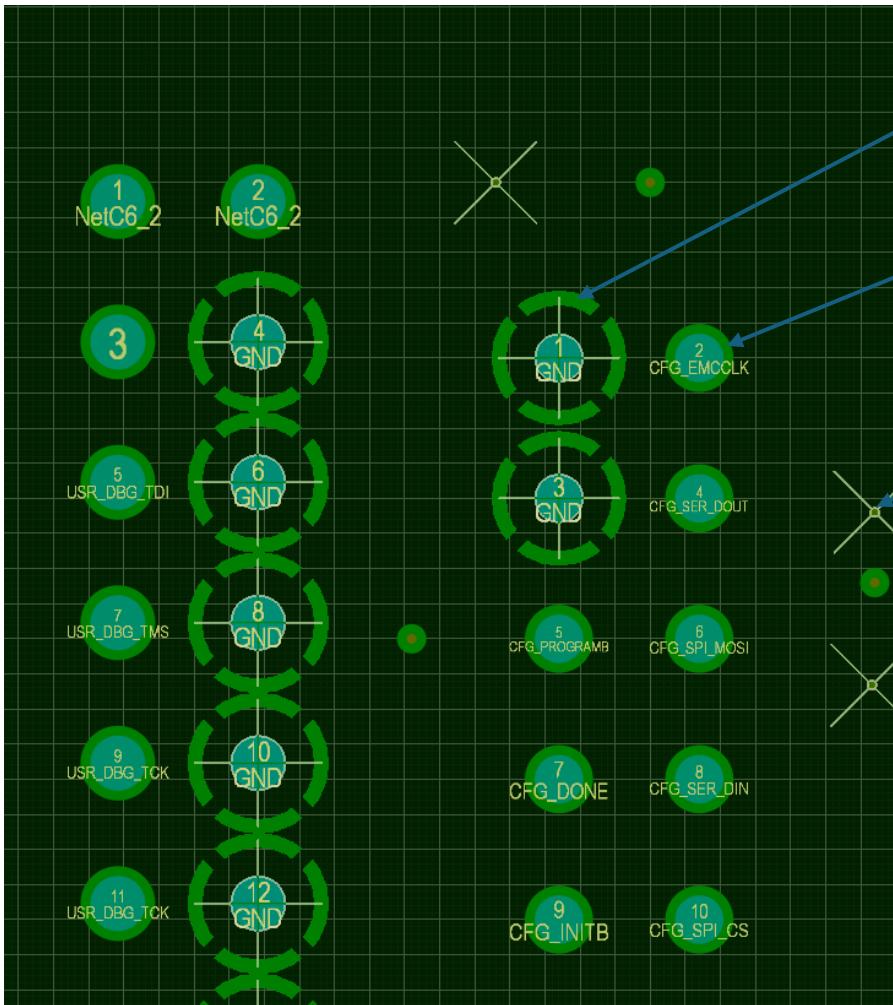
Design Technology

8 Layers

Physical stackup details

E-Test Requirement

Sidenote: Inverted Layers?



The green here marks where there *isn't* copper on this layer (inverted).

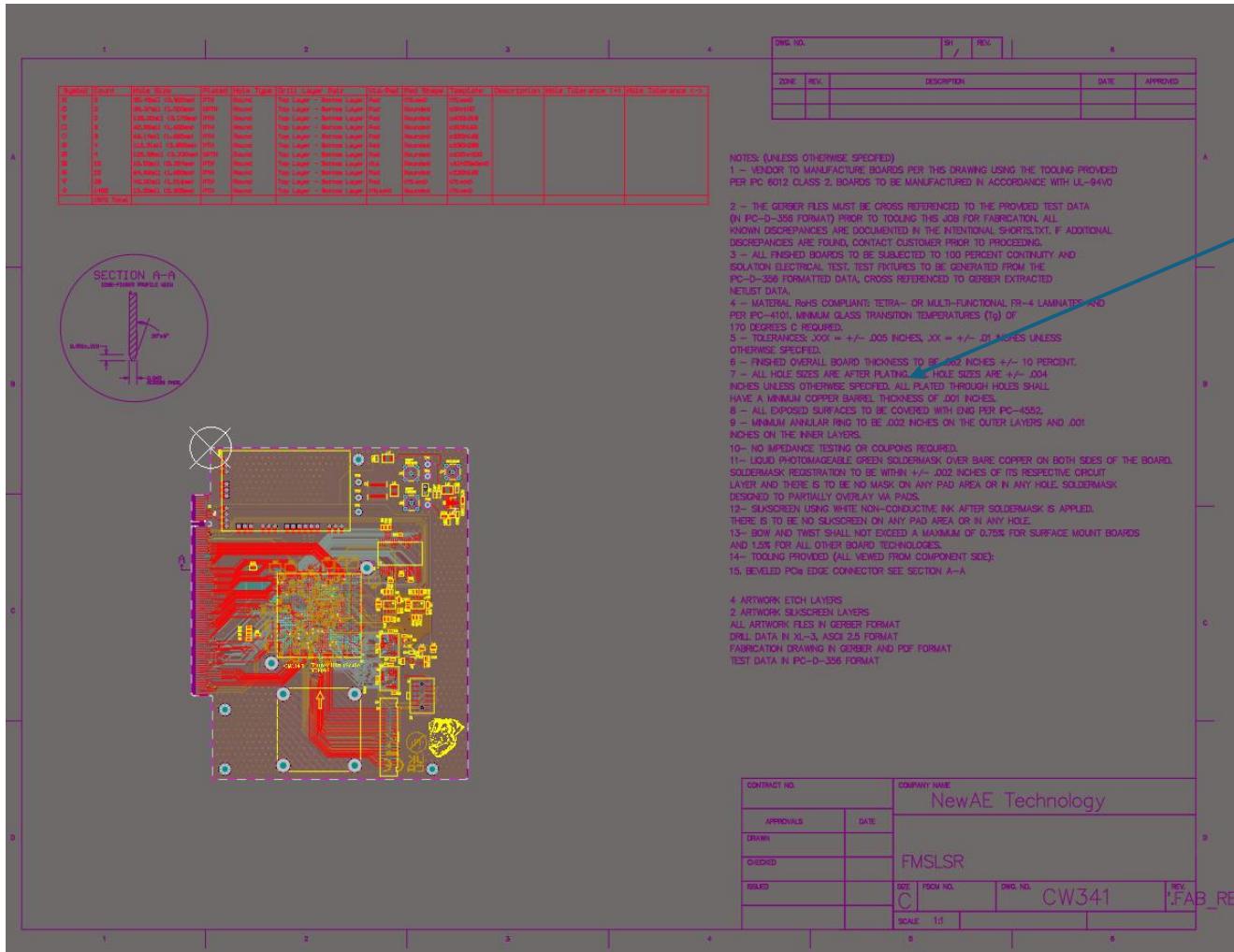
Hole isolated from the plane

Via connected to the plane

Plane layers are often *inverted* since they are mostly copper. This helps visualize them and keep file sizes lower.

Normally the fabs will pick up on this, but good to specify.

Manufacturing Drawing



Various details of the board manufacturing requirements.

PCB Fabs of Interest

- (China) JLCPCB: Currently most popular overseas fab
- (China) PCBWay: Access to higher-end processes than JLCPCB, more expensive/less user friendly.
 - WARNING: Chinese New Year / Spring Festival happens shortly, PCB fabs shut down...
- (EU) EuroCircuits: Good website, good prices & speed
- (USA) OSHPark: Slower due to shipping here, but great service & very “maker-friendly”.

Quoting via JLCPCB

The screenshot shows the JLCPCB quoting interface. At the top, there is a blue button labeled "Add gerber file" with an upward arrow icon. Below it, a message says "Only accept zip or rar, Max 50 MB, View example >". To the right, a link says "All uploads are secure and confidential." Further down, there are links for "Instructions For Ordering" and "Log in to view your upload history".

Base Material: FR-4 (selected), Flex, Aluminum, Copper Core, Rogers, PTFE Teflon.

Layers: 1, 2 (selected), 4, High Precision PCB, 6, 8, 10, 12, 14, 15, More.

Dimensions: 100 * 100 mm (mm selected).

PCB Qty: 5.

Product Type: Industrial/Consumer electronics (selected), Aerospace, Medical.

PCB Specifications:

- Different Design:** 1 (selected), 2, 3, 4, [empty input field].
- Delivery Format:** Single PCB (selected), Panel by Customer, Panel by JLCPCB.
- PCB Thickness:** 0.4mm, 0.6mm, 0.8mm, 1.0mm, 1.2mm, 1.6mm (selected), 2.0mm.
- PCB Color:** Green (selected), Purple, Red, Yellow, Blue, White, Black.
- Silkscreen:** White.
- Surface Finish:** HASL(with lead) (selected), LeadFree HASL, ENIG.

Upload a .zip file

Layers should be autodetected.

Outline should be autodetected.

Get **more than 5** if all group members get one & to have lots of spare for soldering.

1.6mm (0.062") is normal thickness.

Green may be fastest...

Select Lead-Free or ENIG

README File for Generic Ordering

2-Layer PCB

Soldermask: Blue
Silkscreen: White

Finish: HASL/ENIG

Individual PCB Size: 52.3mm x 64.6mm

2-Layer PCB

Soldermask: *
Silkscreen: White

Finish: HASL/ENIG

Individual PCB Size: 52.3mm x 64.6mm

If I plan on selecting soldermask via JLCPCB interface, don't specify one here! Chance I forget to update the file which may cause them to hold the job while they confirm what I actually want.

.GTL - Top Copper
.GBL - Bottom Copper
.GBS - Bottom Soldermask
.GBO - Bottom Silkscreen
.GM1 - Outline
.NCDRILL - Drill Files

Other Files:

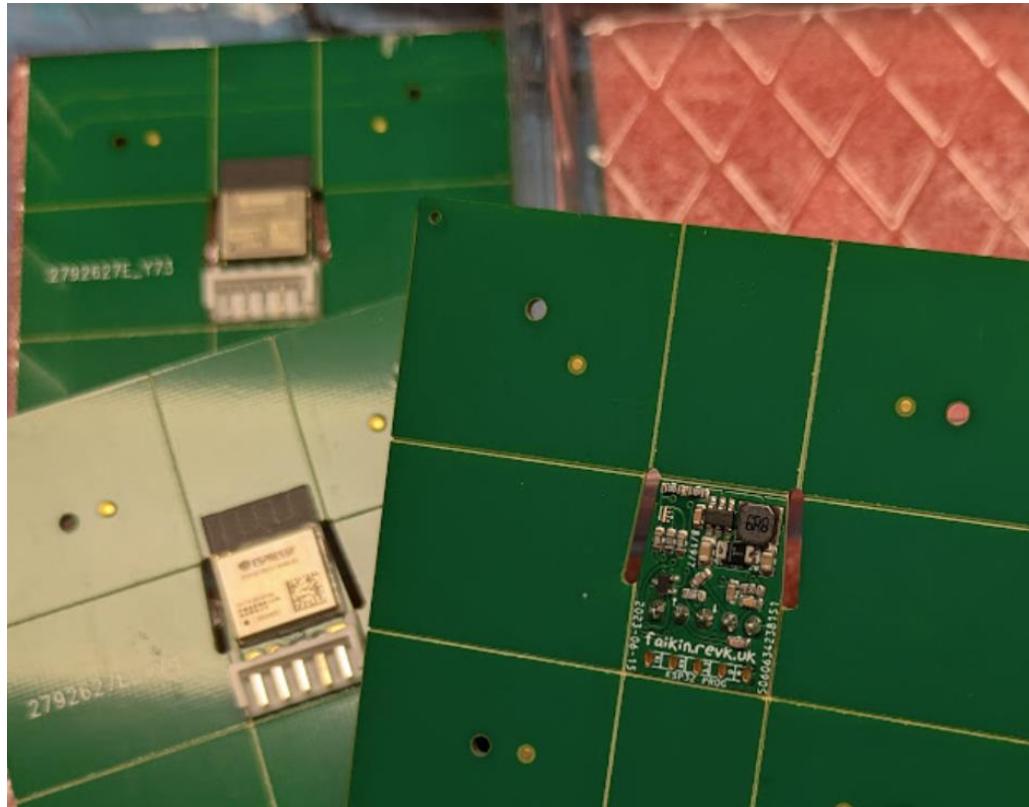
.GTP - Top Paste (used for stencil)
.GBP - Bottom Paste (NOT USED)

.GBL - Bottom Copper
.GBS - Bottom Soldermask
.GBO - Bottom Silkscreen
.GM1 - Outline
.NCDRILL - Drill Files

Other Files:

.GTP - Top Paste (used for stencil)
.GBP - Bottom Paste (NOT USED)

Ordering Full Assemblies



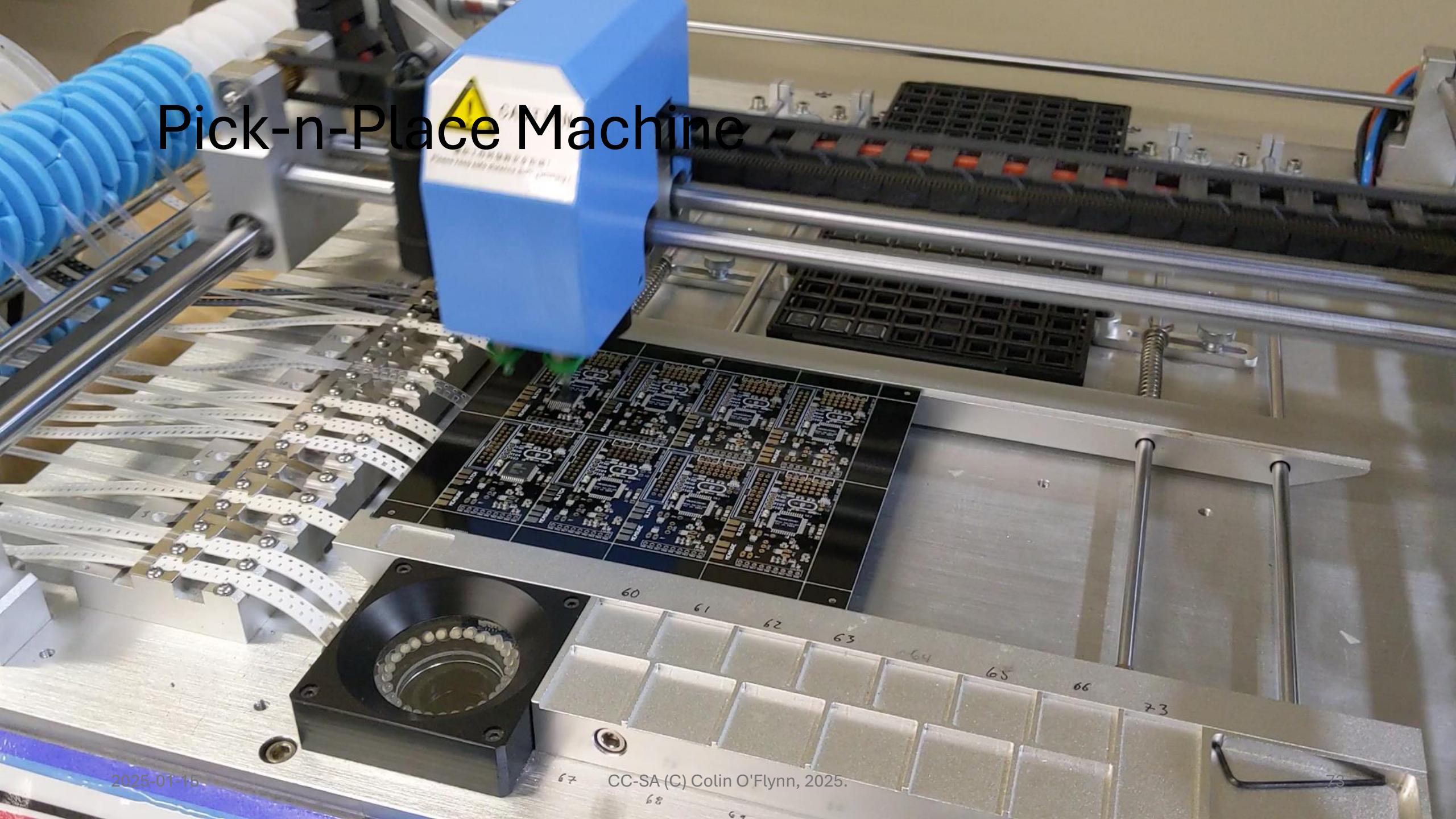
JLPCB can be used for even ordering simple pre-built boards like the one to the left.

Bill of Material (BOM)

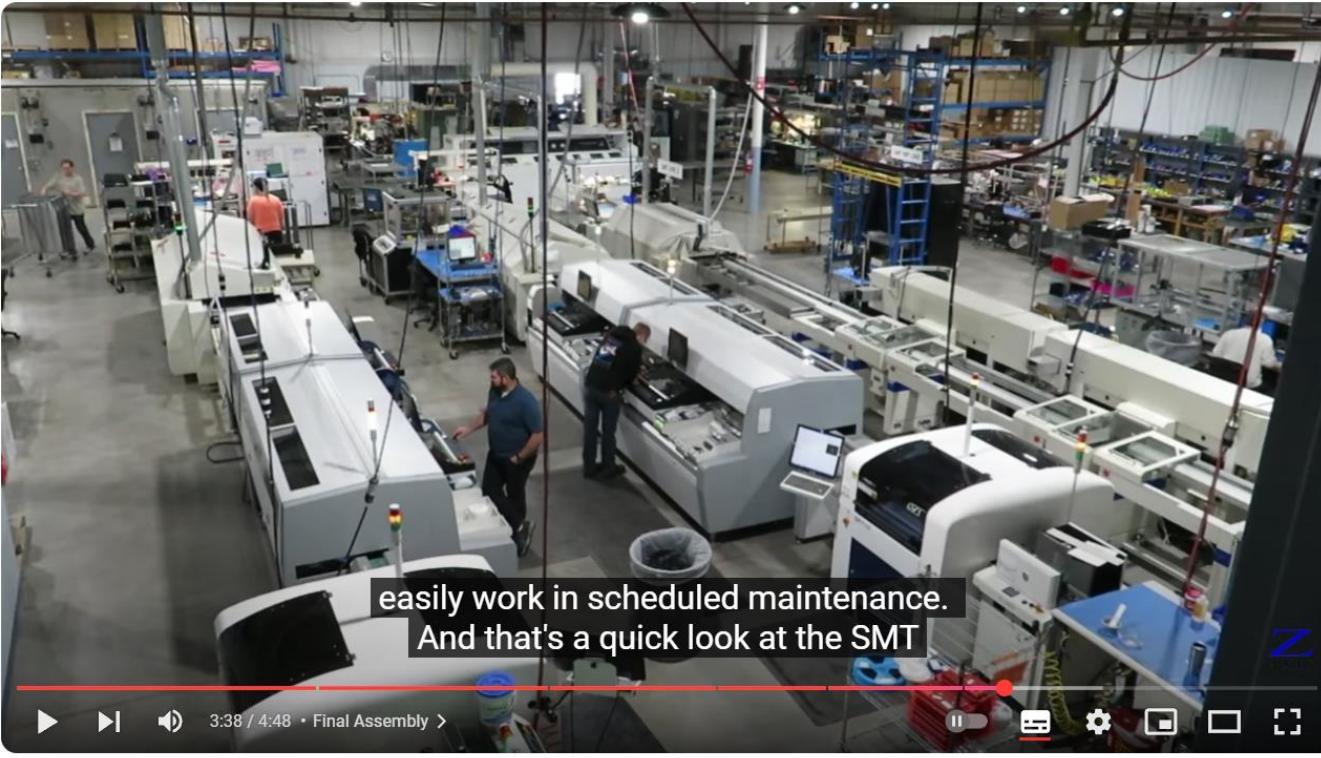
- BOM is a critical file that contains your parts.
- You can maintain this separately OR export it from your design files (preferred).
- For JLCPCB they have a special format they want! But generally may look like this:

A	B	C	D	E	F	G	H	I
Quantity	Designator	Description	DNM?	Manufacturer 1	Manufacture Part Number 1	Manufacture 1 Part	Manufacture 1	Manufacture 1
1	47	C1, C2, C3, C4, C7, C8, C100n, 0402		TDK	CGA2B3X7R1V104K050BB			
3	4	C5, C6, C15, C17	18p, 0402	Murata	GRM1555C1H180JA01D			
4	1	C12	1u, 0603, 50V	Samsung	CL10A105KB8NNNC			

Pick-n-Place Machine



e.g., Full Production Line



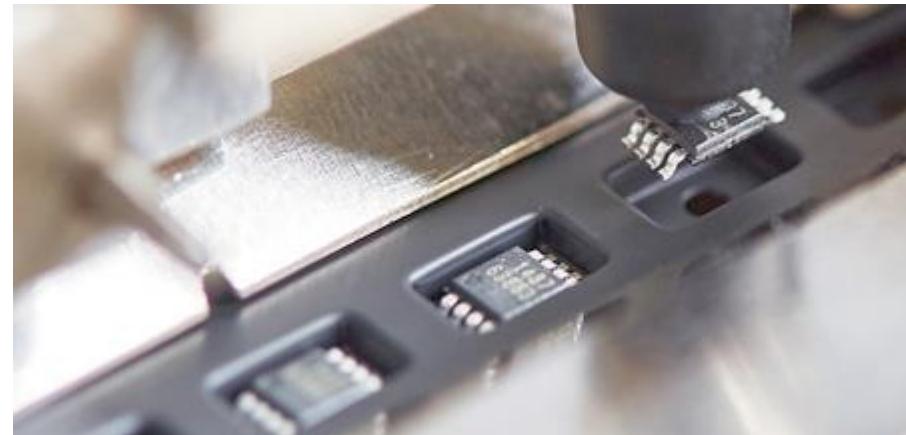
- <https://www.youtube.com/watch?v=9uet6TNtUXI>

PNP / CPL File Format

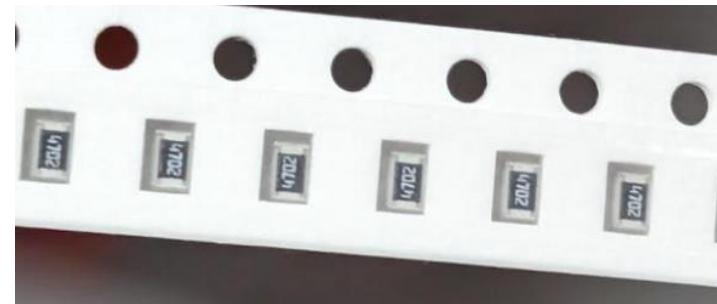
- Manufacturers may need specific format – see documentation for your software.

A	B	C	D	E	F	G	H	I	J	K
13	Designator	Comment	Layer	Footprint	Center-X(n)	Center-Y(n)	Rotation	Description		
14	U9	PHA-13LN	TopLayer	PHA13LN	101.8434	-23.2142	90	Integrated Circuit		
15	R26	51R	TopLayer	RESC1608	98.0186	-28.8798	0	51R res, 0603, 1%, 1/10W		
16	R25	1k5	TopLayer	RESC1608	105.7656	-22.1116	90	1k5 res, 0603, 1%, 1/10W		
17	L9	5n1	TopLayer	IND_0603	101.2952	-28.8036	0	FIXED IND 5.1nH		
18	L8	LQH32DN	TopLayer	INDC3225	99.314	-17.78	180	15uH, 300mA, 1210 Inductor		
19	L7	LQH32DN	TopLayer	INDC3225	74.3458	-4.5466	0	Ferrite Bead, 1K@100MHz, 2A, 1210, 100mOhm		
20	J7	5-1814832	TopLayer	SMA_VERT	101.5492	-10.16	0	SMA, Vert		
21	C94	DNM	TopLayer	CAPC0603	99.822	-31.1912	270	DNM, 0603		
22	C91	2u2	TopLayer	CAPC0603	103.3526	-17.588	90	2u2, 0603		
23	C90	2u2	TopLayer	CAPC0603	103.632	-28.194	90	2u2, 0603		
24	C89	100n	TopLayer	CAPC0402	105.7656	-24.813	90	100n, 0402		
25	C88	10u	TopLayer	CAPC0603	69.6214	-4.6482	270	10u, 0603		
26	C87	1n	TopLayer	CAPC0603	94.0308	-19.7104	90	1n, 0603		
27	C86	10u	TopLayer	CAPC0603	95.7072	-19.685	90	10u, 0603		
28	SJ1	NC	TopLayer	SJ_3S_NC1	17.7799	-50.419	180	Solder Jumper, NC		
29	MH6	4-40 MH, T	TopLayer	MOUNT_#2	6	-110	0	Machine screw 4-40 Mounting Hole		
30	MH4	4-40 MH, T	TopLayer	MOUNT_#2	6	-135	0	Machine screw 4-40 Mounting Hole		
31	MH2	4-40 MH, T	TopLayer	MOUNT_#2	93	-135	0	Machine screw 4-40 Mounting Hole		
32	MH1	4-40 MH, T	TopLayer	MOUNT_#2	62	-5	0	Machine screw 4-40 Mounting Hole		
33	J6	40-pin. 1.2	TopLayer	SHF-120-0	74.803	-121.539	270			

Tape & Reel



<https://www.reelservice.com/blog/2018/09/18/the-a-z-glossary-of-tape-reel-part-1-a-h/>



<https://electronics.stackexchange.com/questions/694163/smd-resistor-rotation-on-tape-and-reel>

PNP Gotchas

- The rotation of the parts needs to be relative to the part position in the “tape”.
- This is **especially important with diodes (LEDs)** where it won’t be obvious if the part is backwards.
 - You will often supply documentation to confirm the anode or cathode of each diode.
- Some workflows let you do this automatically (JLCPCB, MacroFab, etc).
 - Always check – it may have something simple like a “pin 1” indicator for LEDs, **go check if Pin 1 means anode or cathode & that your files agree!!**

JLCPCB Assembly Service

- <https://cart.jlcpcb.com/quote?fromDemo=yes>

JLCPCB Parts (LCSC)

The screenshot shows the LCSC Electronics website. At the top, there's a search bar with the placeholder "Part #/ Keyword" and a magnifying glass icon. Below it, a navigation bar includes links for "Log In", "Register", "Account & Orders", and a shopping cart icon. The main banner features the text "Expert in PCB & PCBA Since 2006" and "Register Now & Get Coupons Up to \$125 (PCB, PCBA, Parts, etc)". It highlights services like "1-32 Layers PCBs from \$2", "100+ PCB Assembly Lines", "560,000+ Parts in Stock", and "24 Hours Fastest Build Time". A large image of a blue printed circuit board (PCB) with various electronic components is displayed. Below the banner, there are sections for "POPULAR PRODUCTS" featuring items like SS54, H11LIS(TA), UTP1306S, 11FB-05NL, CL05BI04KB54PNC, and EEC0252B3-000C-A99. Each product has a thumbnail image, a "HOT" badge, a price, and a manufacturer name. To the right of the products, there's a link to "SEE MORE POPULAR PRODUCTS". On the left side of the page, there's a sidebar with a "All Products" dropdown menu containing categories such as Capacitors, Connectors, Crystals, Oscillators, Resonators, Diodes, Embedded Processors & Controllers, Filters, Inductors, Coils, Chokes, Interface, IoT/Communication Modules, Optoelectronics, Power Management (PMIC), Resistors, Sensors, Switches, Transistors/Thyristors, Deals, and a "View All Products" link. The main content area also includes sections for "Upload a Parts List to Check Pricing & Availability", "RFQ", "IAF Quality & Security Management System Certificate", and "560,000 Parts in Stock".

Use special suppliers where possible with JLCPCB – many parts are not available in each others markets.

Finding Replacement Parts

The screenshot shows a search interface for replacement parts. At the top, there is a header with part numbers (R132, R133, R134, ...), value (560Ω±1%), package (0402_R), and other details (0402WGF5600TCE, C25126, 62.5mW Thick Film Resistors 50V ±100ppm/°C ...). Below the header are three navigation tabs: Part Info, Search Part (which is active), and Attribute. A search bar contains the query "560 ohm resistor" and a "search" button. There are also checkboxes for "Basic Parts Only" and "In Stock". The main area displays a table of search results:

Part	Package	Lib Type	Unit Price	JLCPCB Stock	Idle Parts Stock	My Part	
1206W4F5600T5E 250mW Thick Film Resistors 200V ...	1206	Extended	\$0.0029	2945	4180	0	Select
2010W2J0561T4S 500mW Thick Film Resistors 200V ...	2010	Extended	\$0.0192	3	0	0	Inventory shortage
A09-561JP 8 ±5% 560Ω 125mW ±100ppm/°C S...	SIP-9-2.54mm	Extended	\$0.0879	6438	0	0	Select
0402WGF5600TCE 62.5mW Thick Film Resistors 50V ±...	0402	Extended	\$0.0006	5	0	0	Inventory shortage
0402WGJ0561TCE 62.5mW Thick Film Resistors 50V ±...	0402	Extended	\$0.0004	13896	4000	0	Select

At the bottom, a message says "Please carefully check the packages of selected parts before proceeding." and shows a page navigation with "1536102 items in total" and pages 1 through 307221.

NOTE: The search isn't that good. Here I tried a few variations (560 resistor, 560 ohm resistor, 560R resistor). Check carefully on hover-over that it looks reasonable & package size is what I need (0402), then click the item to see all details.

560 0402

search

 Basic Parts Only In Stock

Part	Package	Lib Type	Unit Price	JLCPCB Stock	Idle Parts Stock	My Part	
 0402CG560J500NT 50V 56pF C0G ±5% 0402 Multilayer...	0402	Extended	\$0.0010	257050	0	0	<button>Select</button>
 0402WGF5600TCE 62.5mW Thick Film Resistors 50V ±...	0402	Extended	\$0.0006	5	0	0	Inventory shortage
 0402WGF560JTCE 62.5mW Thick Film Resistors 50V ±...	0402	Extended	\$0.0005	73555	33	0	<button>Select</button>
 0402WGJ0560TCE 62.5mW Thick Film Resistors 50V ±...	0402	Extended	\$0.0004	418	0	0	<button>Select</button>
 0402WGF5602TCE 62.5mW Thick Film Resistors 50V ±...	0402	Extended 	\$0.0005	393300	18085	0	<button>Select</button>

62.5mW Thick Film Resistors 50V ±100ppm/°C ±1% 56kΩ
0402 Chip Resistor - Surface Mount ROHS

19569 items in total

[<](#) [1](#) [2](#) [3](#) [4](#) [5](#) [6](#) ... [3914](#) [>](#)

E.g., here “560 0402” is coming up with 5.6K, 56R, 56k, etc

SIDE BAR: Suffixes as Multipliers

Very common to use R as “ohms”, then drop it for higher values. The suffix also becomes the decimal place:

$$560R = 560\Omega$$

$$560k = 560k\Omega$$

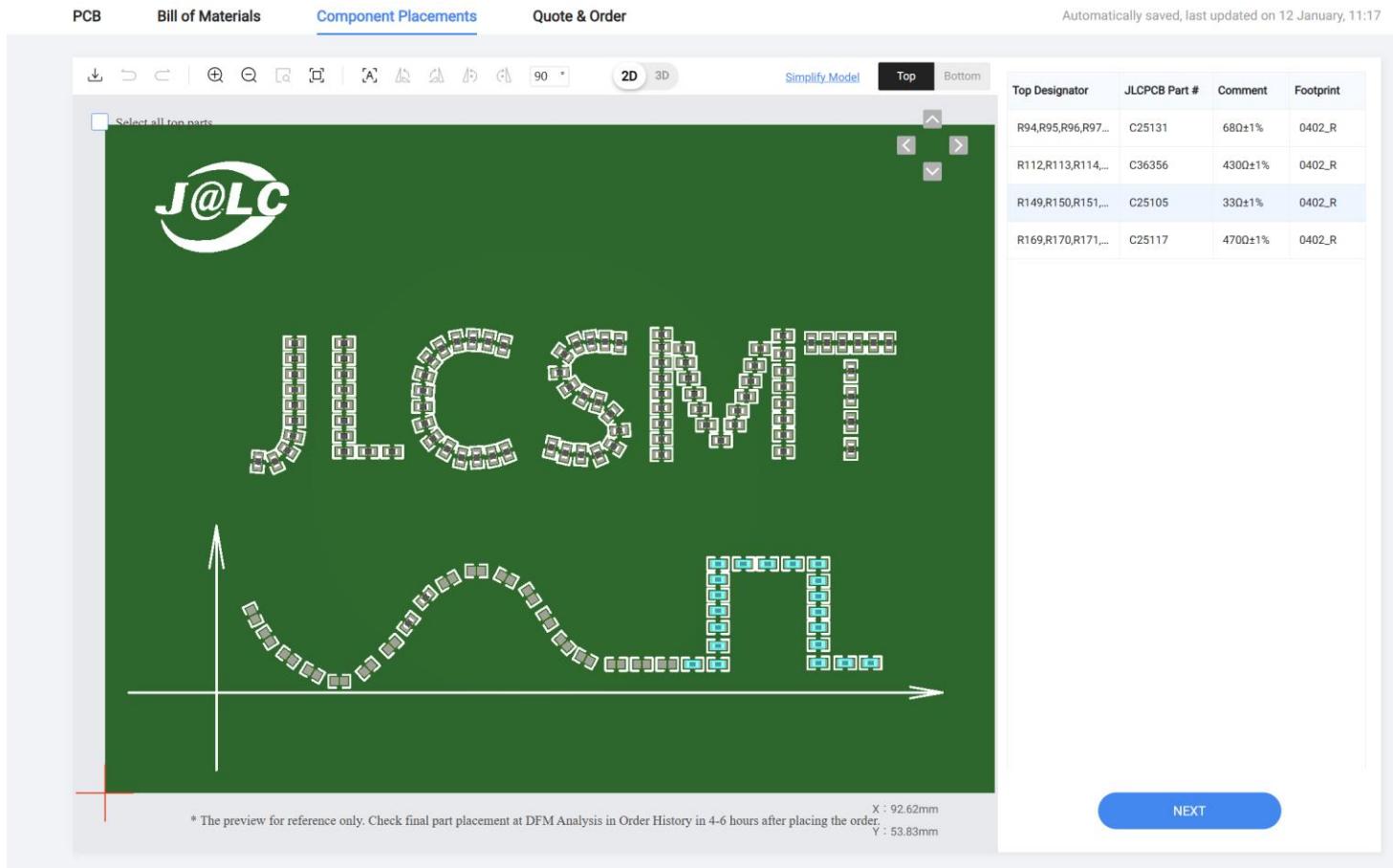
$$5k6 = 5.6k\Omega$$

For capacitors, common to use n or u:

$$100n = 100nF$$

$$2u2 = 2.2\mu F$$

Placement Preview



Fixing Orientation

component is placed correctly.

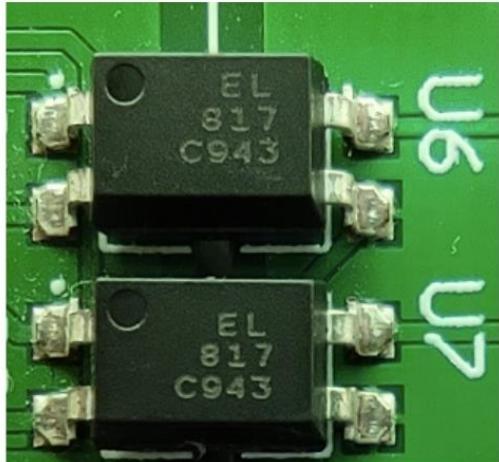


Figure 1. The dots on PCB and components

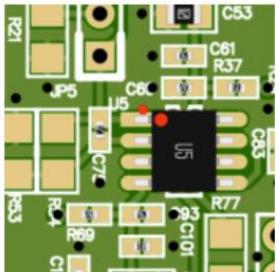


Figure 2. The red dots

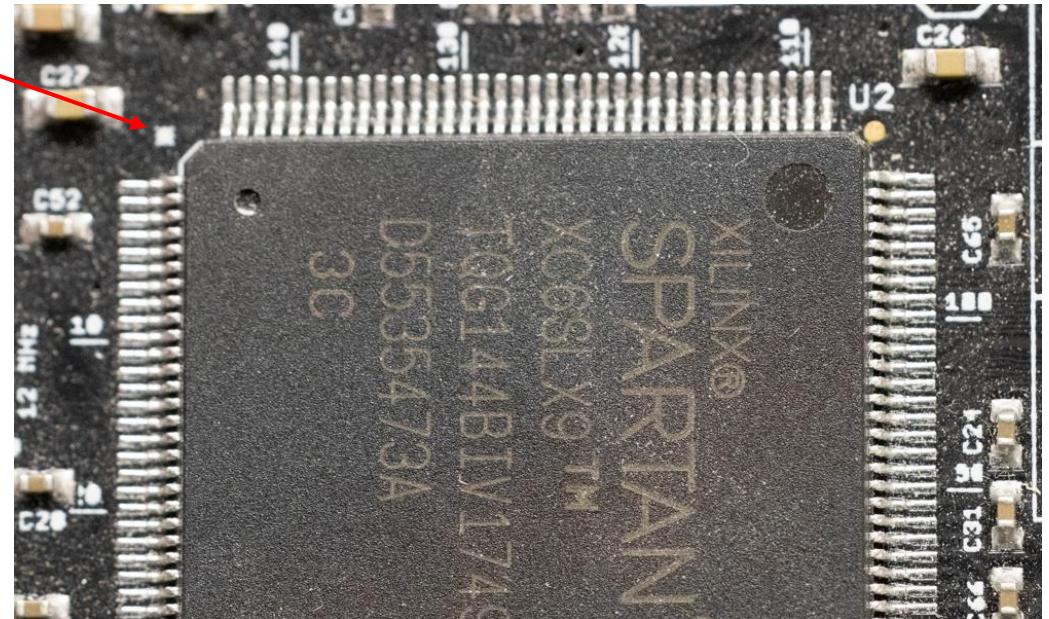
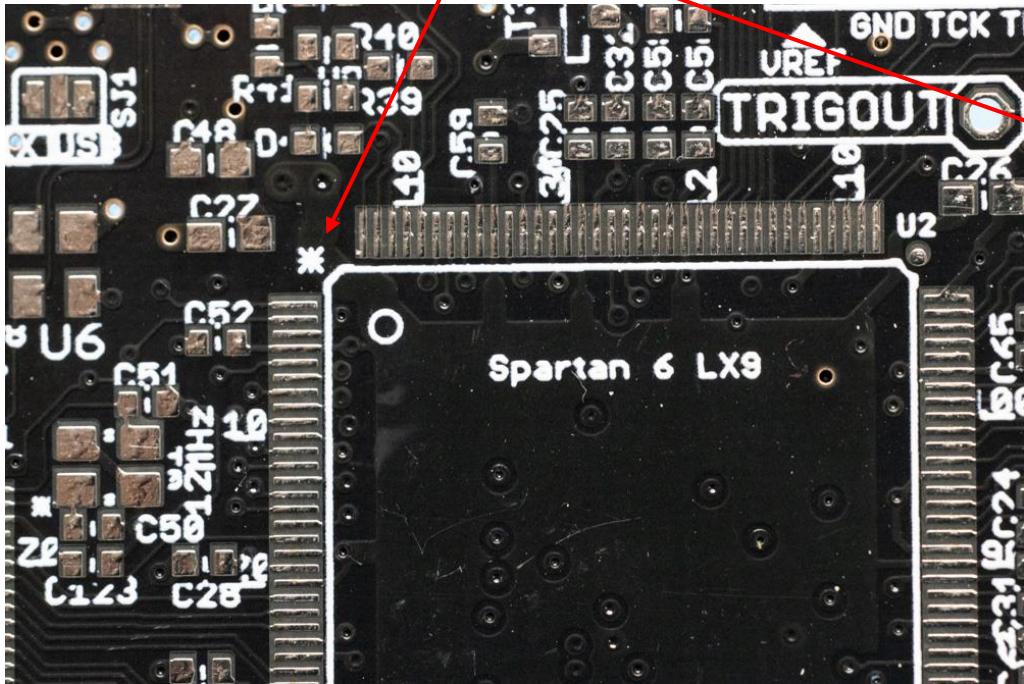
See <https://jlpcb.com/help/article/pcb-assembly-faqs-part-2> if using this service.

They rely on silkscreen markings to confirm polarity/rotation.

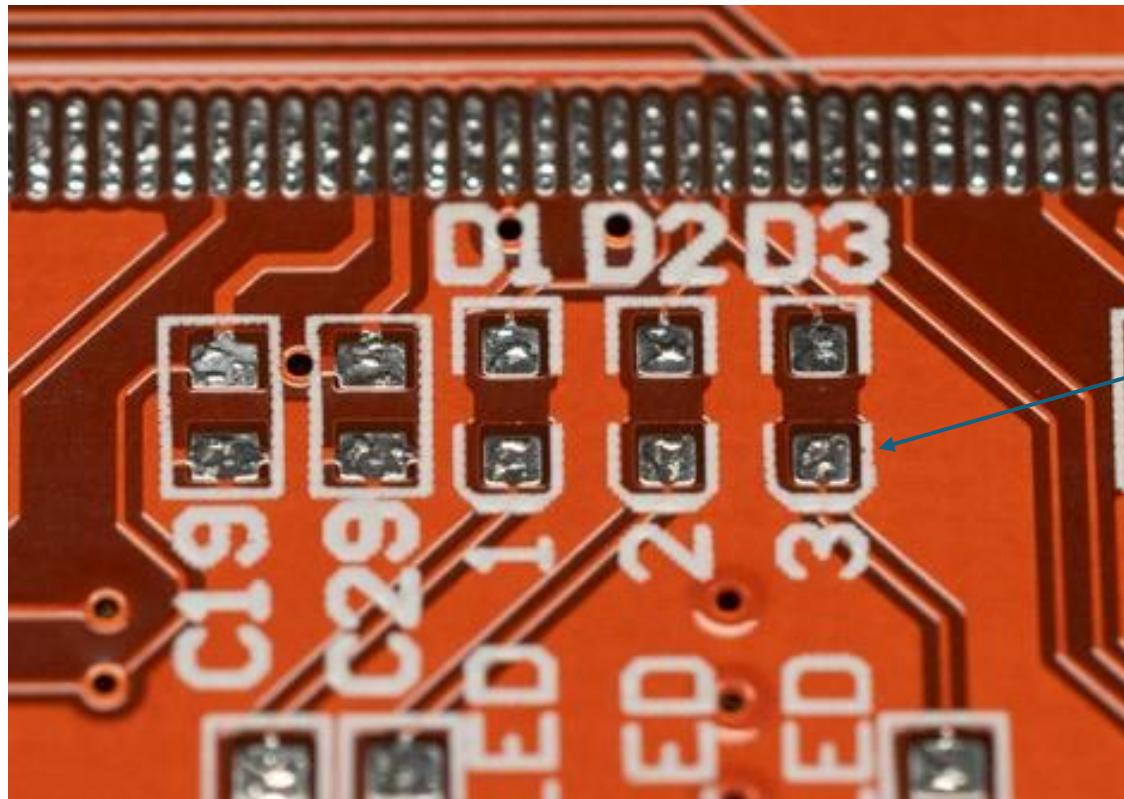
The previewer may be wrong, this will get fixed later and you will need to confirm it.

Sidebar: Pin 1, Anodes/Cathode Markings

Pin 1 marking is visible with part mounted.



Sidebar: Pin 1, Anodes/Cathode Markings

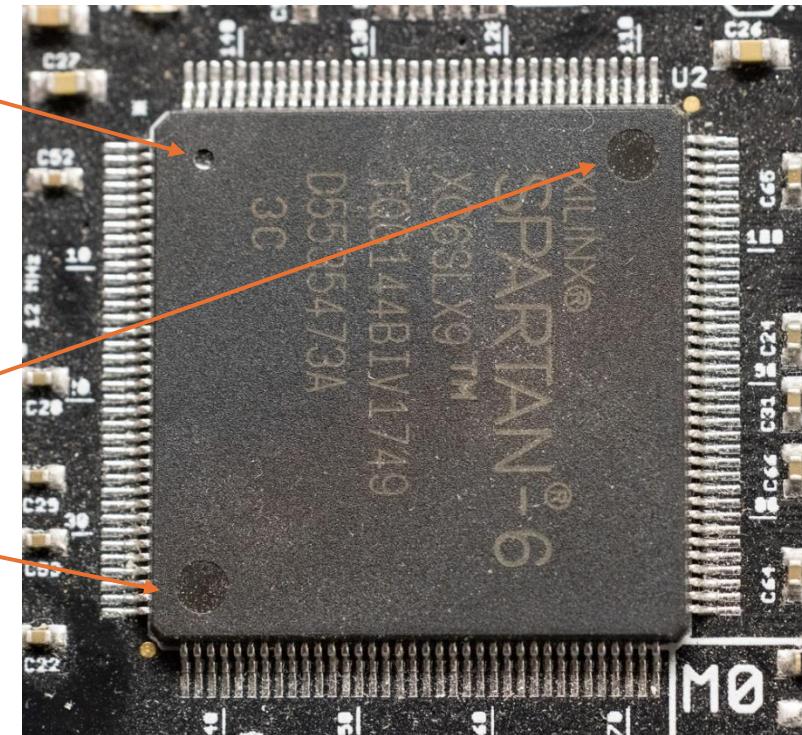


What does this polygon mean?

Be sure to document if anode or cathode!!

Sidebar on Sidebar: IC Ejection Marks

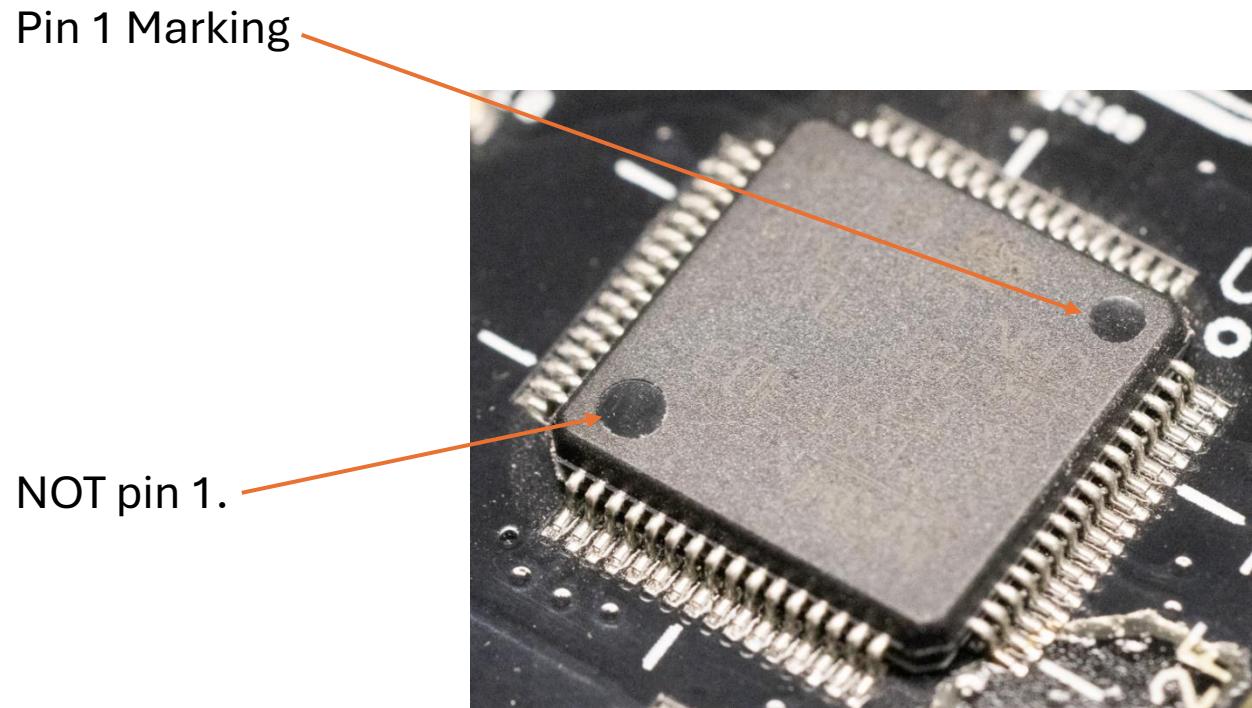
Pin 1 Marking



NOT pin markings.

These are from moulding
process.

Sidebar on Sidebar: IC Ejection Marks



Ejector marks are much shallower. Look carefully!

Part 3: KiCAD Introduction

Getting / Installing KiCad

Download

Select your operating system



Windows



macOS



Linux/Other



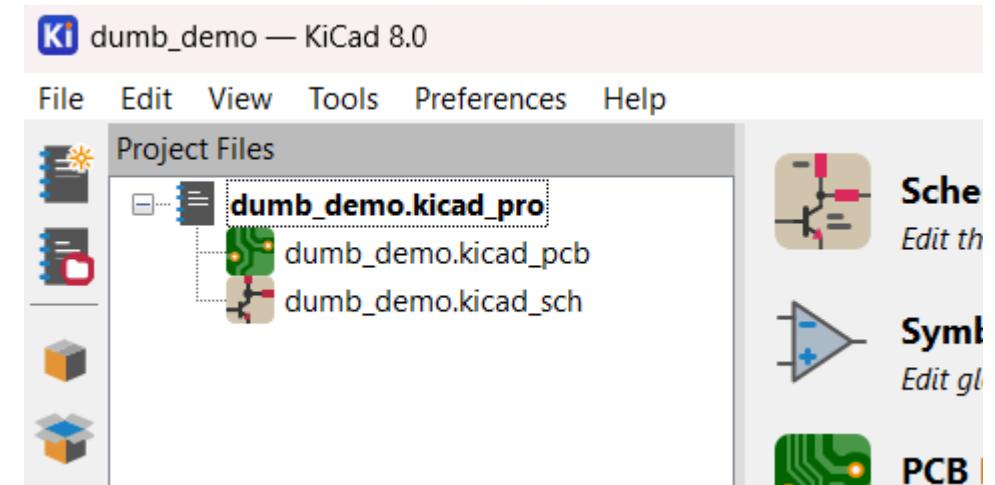
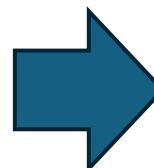
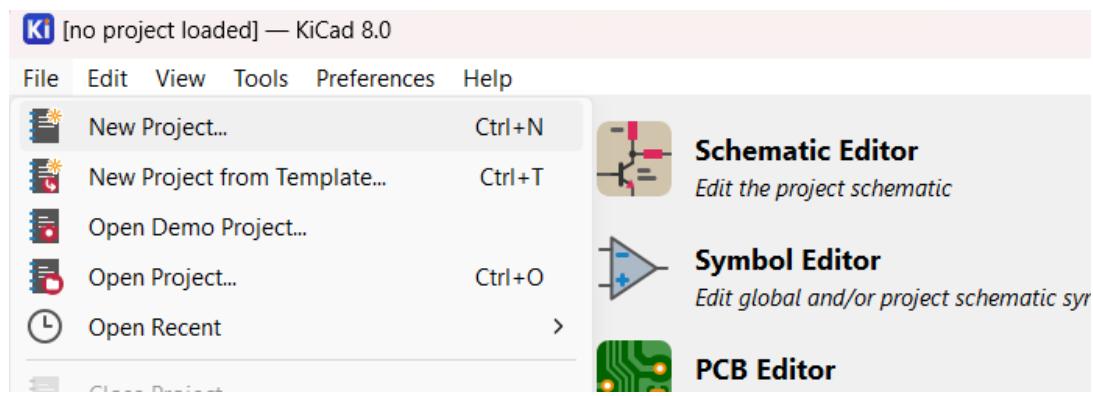
Docker

Obtaining the KiCad source code

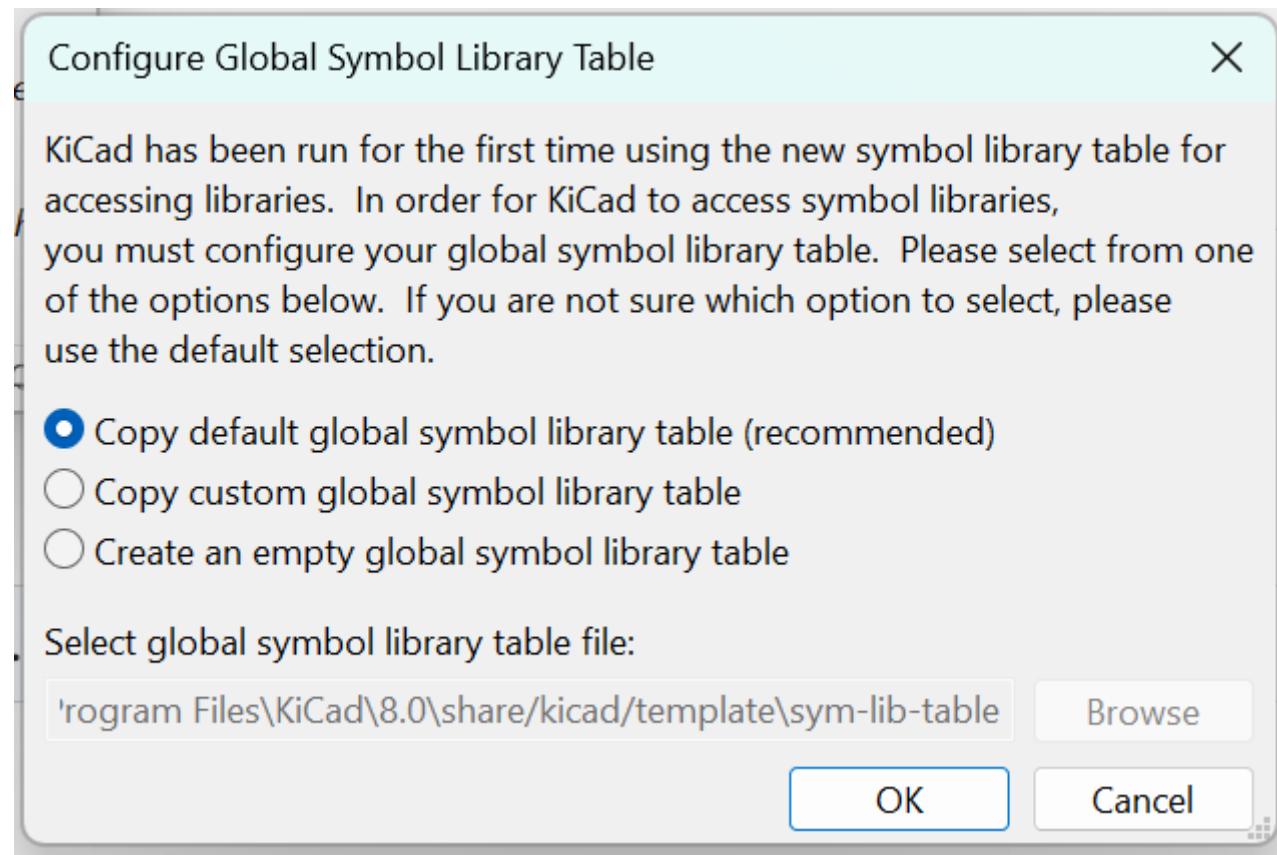
See the [install from source code](#) page for instructions.

<https://www.kicad.org/download/>

Starting a Simple Project



First Time: Defaults should be OK!



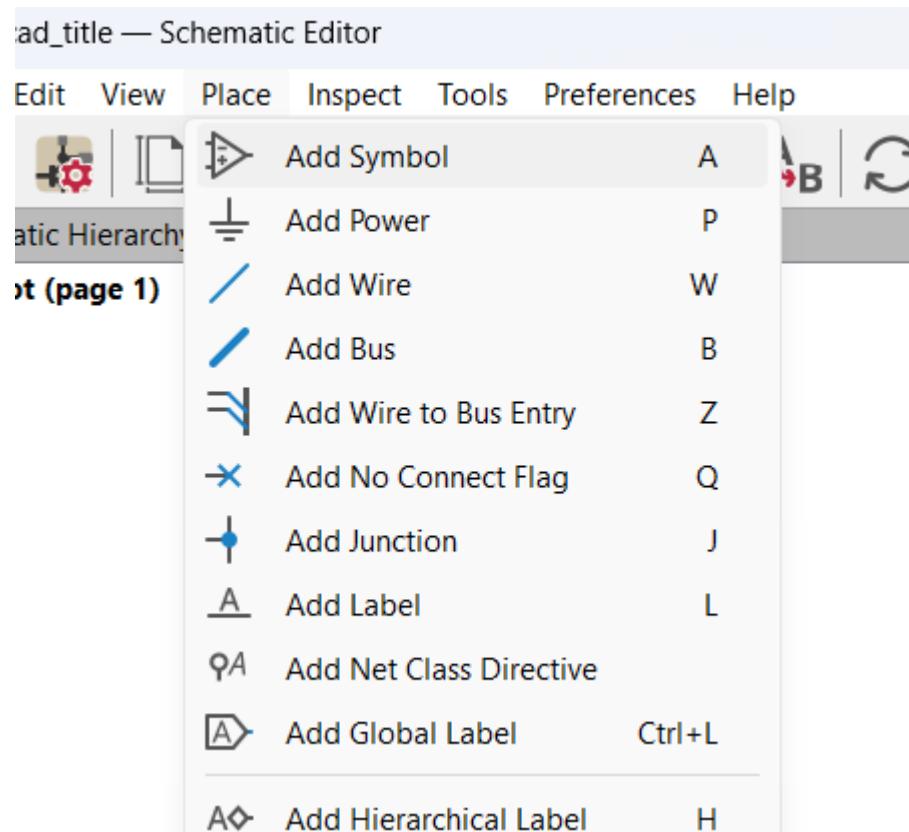
Project: Keep It Simple!

- Make a simple first project (See Group Assignment).
- Keep a single sheet to avoid learning about hierarchy for now.

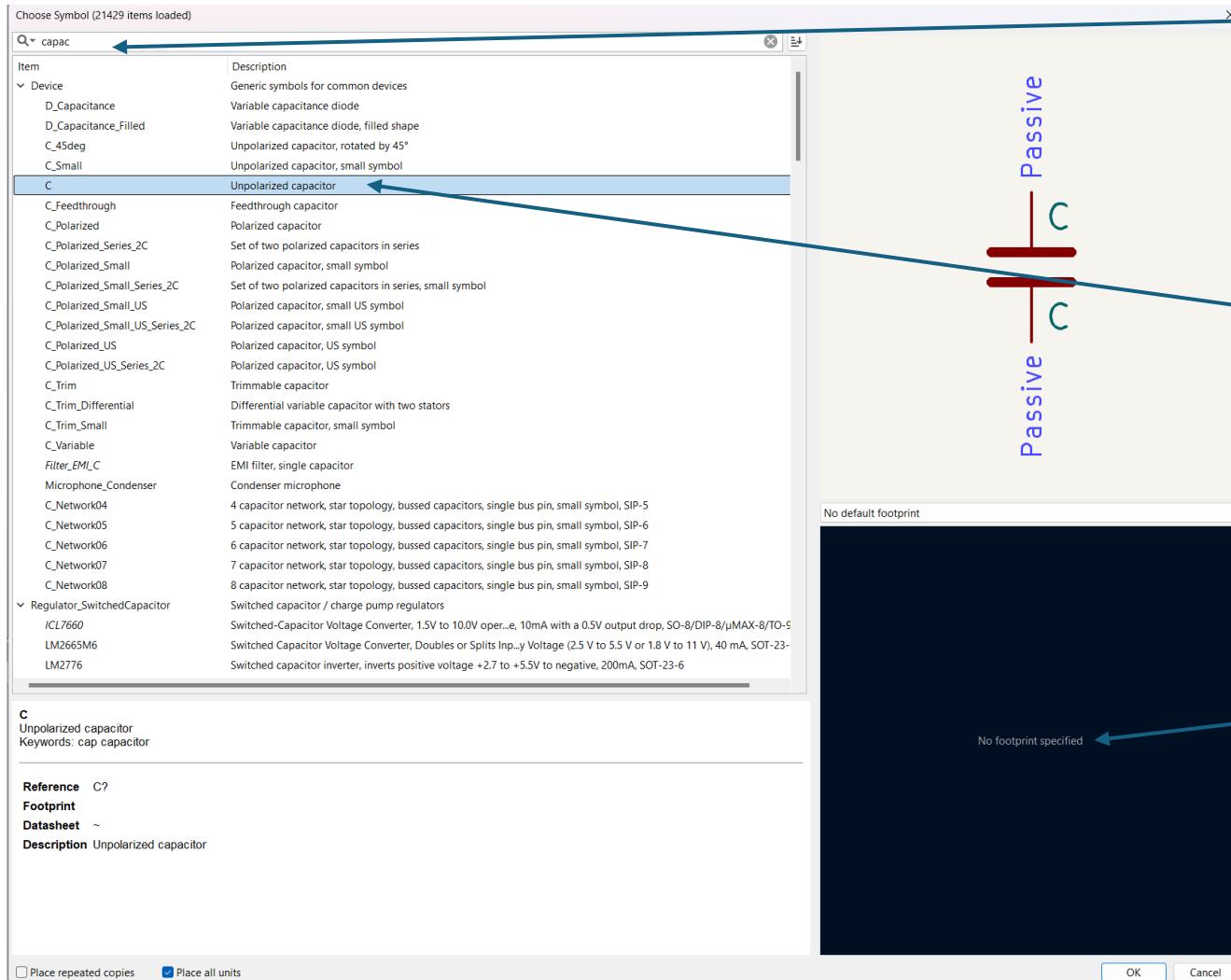
Symbols & Footprints

- Symbol *libraries* hold the symbols used on the schematic.
- Similar *libraries* hold the footprints we'll use to design the PCB.

Schematic Entry



Schematic Entry



Search for “Capacitor”

Click on the Symbol

This is a generic symbol with no footprint. We'll need to specify one!

Schematic Entry

Choose Symbol (21431 items loaded)

Search: opamp

Item	Description
Simulation_SPICE	Symbols specialized for SPICE circuit simulation (including ngspice).
OPAMP	Operational amplifier, single, node sequence=1+ 2- 3:OUT 4:V+ 5:V-
Device	Generic symbols for common devices
Opamp_Dual	Dual operational amplifier
Opamp_Qquad	Quad operational amplifier
Amplifier_Operational	General operational amplifiers
AD8021AR	Operational Amplifier, 4.5-24V single/dual supply, low noise, high speed, SOIC-8
AD8021ARM	Operational Amplifier, 4.5-24V single/dual supply, low noise, high speed, MSOP-8
ADA4898-1YRDZ	High Voltage, Low Noise, Low Distortion, Unity-Gain Stable, High Speed Op Amp, SOIC-8
ADA4898-2	Dual High Voltage, Low Noise, Low Distortion, Unity-Gain Stable, High Speed Op Amp, SOIC-8-1EP
LMH6609MA	900MHz Voltage Feedback Op Amp, SOIC-8
LMH6609MF	900MHz Voltage Feedback Op Amp, SOT-23-5
LMH6611	Single Supply, 345 MHz, Rail-to-Rail Output, Amplifier, TSOT-23-6
LMH6702MA	1.7 GHz Ultra-Low Distortion Wideband Op Amp, SOIC-8
LMH6702MF	1.7 GHz Ultra-Low Distortion Wideband Op Amp, SOT-23-5
> LMH6733	1.0 GHz GBW Triple Operational Amplifier, 3..12V single supply or +1.5V..6V dual supply , SSOP-16
LT6230xS6	215 MHz, Rail-to-Rail Output, Amplifier, TSOT-23-6
MCP6L01Rx-xOT	Single, 1 MHz, 85µA, Rail-to-Rail input and output, SOT-23-5
MCP6L01Ux-xOT	Single, 1 MHz, 85µA, Rail-to-Rail input and output, SOT-23-5
MCP6L01x-xLT	Single, 1 MHz, Rail-to-Rail input and output, SC-70-5
MCP6L01x-xOT	Single, 1 MHz, 85µA, Rail-to-Rail input and output, SOT-23-5
> MCP6L02x-xMS	Dual, 1 MHz, 85µA, Rail-to-Rail input and output, MSOP-8
> MCP6L02x-xSN	Dual, 1 MHz, 85µA, Rail-to-Rail input and output SOIC-8
> MCP6L04x-xST	Quad, 1 MHz, 85µA, Rail-to-Rail input and output, TSSOP-14
> MCP6L04x-xSL	Quad, 1 MHz, 85µA, Rail-to-Rail input and output, SOIC-14
NCS20071SN	Single, 2.8V/µs, Rail-to-Rail Output, TSOP-553
NCS20071XV	Single, 2.8V/µs, Rail-to-Rail Output, SOT-553
OPA569DWP	Rail-to-Rail I/O, 2A, Power Amplifier, SO-20
OPA690xD	Single Low-Power, 500 MHz GBW, $\pm 2.5V$ to $\pm 5V$ Dual Supply...oltage-Feedback Operational Amplifier with Disable, SO
OPA690xDBV	Single Low-Power, 500 MHz GBW, $\pm 2.5V$ to $\pm 5V$ Dual Supply...ge-Feedback Operational Amplifier with Disable, SOT-23

LMH6609MA

Derived from OPA333xxD (Single 1.8V, microPower, CMOS Operational Amplifiers, Zero-Drift Series, SOIC-8)
900MHz Voltage Feedback Op Amp, SOIC-8
Keywords: opamp single wideband unity-gain stable

Reference U7
Footprint Package_SO:SOIC-8_3.9x4.9mm_P1.27mm
Datasheet <http://www.ti.com/lit/ds/symlink/lmh6609.pdf>
Description 900MHz Voltage Feedback Op Amp, SOIC-8

HINT: Selecting Parts

- If selecting parts (like op-amps, microcontrollers, etc) try to stick with parts that are in the library, saves you from making footprints.
- Decide on what you are comfortable soldering. If DIY stick with through hole or large SMD. If using JLCPCB Assembly stick with SMD (they prefer SMD to through hole).

Adding Power

Choose Power Symbol (104 items loaded)

Filter

Item	Description
-24V	Power symbol creates a global label with name "-24V"
-36V	Power symbol creates a global label with name "-36V"
-48V	Power symbol creates a global label with name "-48V"
-BATT	Power symbol creates a global label with name "-BATT"
-VDC	Power symbol creates a global label with name "-VDC"
-VSW	Power symbol creates a global label with name "-VSW"
AC	Power symbol creates a global label with name "AC"
Earth	Power symbol creates a global label with name "Earth"
Earth_Clean	Power symbol creates a global label with name "Earth_Clean"
Earth_Protective	Power symbol creates a global label with name "Earth_Protective"
GND	Power symbol creates a global label with name "GND" , ground
GND1	Power symbol creates a global label with name "GND1" , ground
GND2	Power symbol creates a global label with name "GND2" , ground
GND3	Power symbol creates a global label with name "GND3" , ground
GNDA	Power symbol creates a global label with name "GNDA" , analog ground
GNDD	Power symbol creates a global label with name "GNDD" , digital ground
GNDPWR	Power symbol creates a global label with name "GNDPWR" , global ground

GND
Power symbol creates a global label with name "GND" , ground
Keywords: global power

Reference #PWR?
Footprint
Datasheet

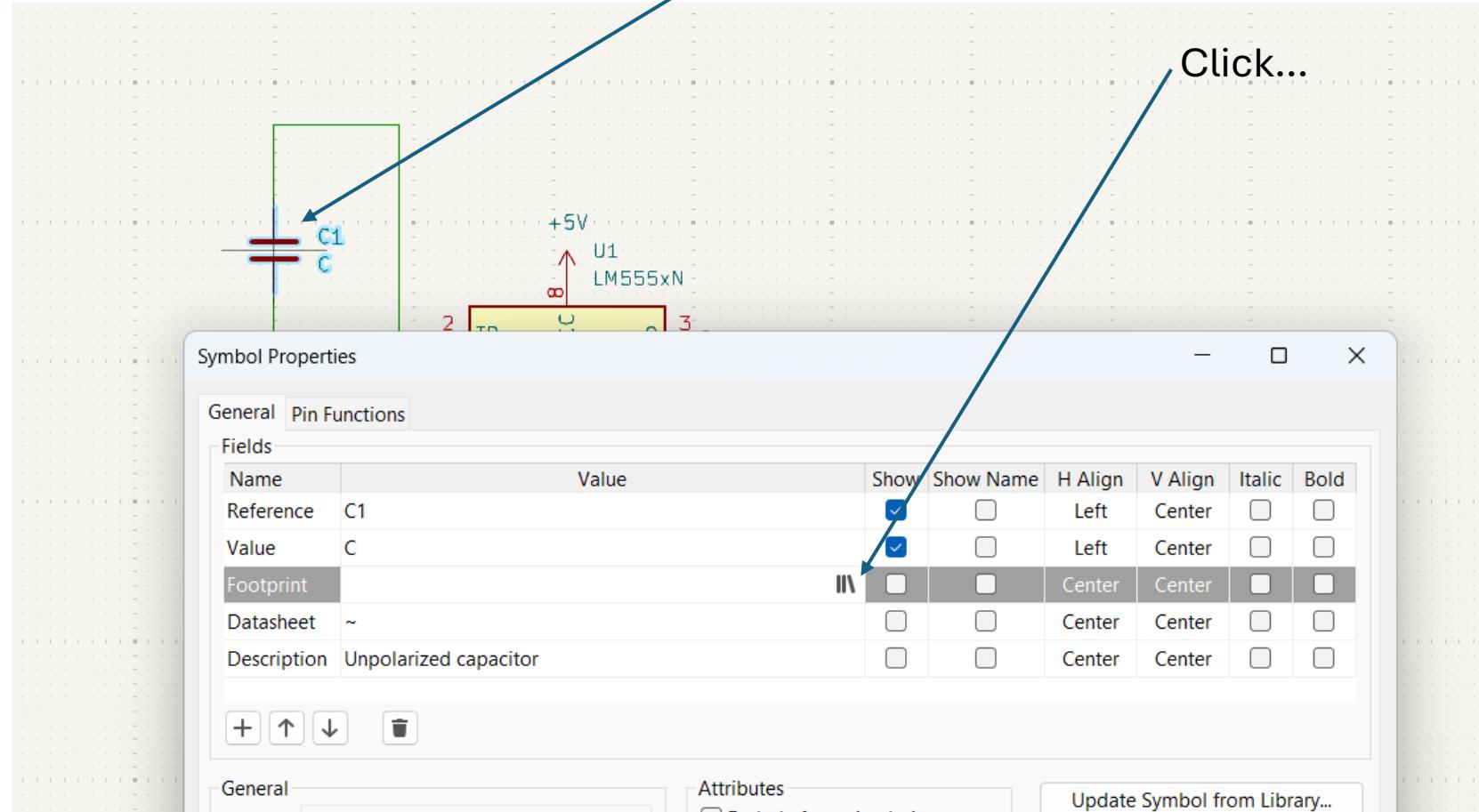


The same name gets connected together, actual name doesn't matter.

But make sure you use the same name for e.g., all your 3.3V nets!

Assigning Footprints

Double-click...



Assigning Footprints

The screenshot shows the 'Footprint Chooser' dialog box from the Kicad software. The title bar says 'Koot (page 1)'. Below it, a message says 'Footprint Chooser (13943 items loaded)'. A 'Filter' button is present. The main area is a table with two columns: 'Item' and 'Description'. The 'Item' column lists various footprint categories and specific components, each preceded by a disclosure triangle. The 'Description' column provides a brief description of each item.

Item	Description
-- Recently Used --	
> AFBR-59F2Z	
> Audio_Module	Audio Module footprints
> Battery	Battery and battery holder footprints
> Button_Switch_Keyboard	Buttons and switches for keyboard applications
> Button_Switch_SMD	Buttons and switches, surface mount
> Button_Switch_THT	Buttons and switches, through hole
> Buzzer_Beeper	Audio signalling devices
> Calibration_Scale	Scales and grids intended for calibration and measurement
✓ Capacitor_SMD	Capacitor, surface mount
CP_Elec_3x5.3	SMT capacitor, aluminium electrolytic, 3x5.3, Cornell Dubilier Electronics
CP_Elec_3x5.4	SMD capacitor, aluminum electrolytic, Nichicon, 3.0x5.4mm
CP_Flec_4x3	SMD capacitor, aluminum electrolytic, Nichicon, 4.0x3mm

Assigning Footprints

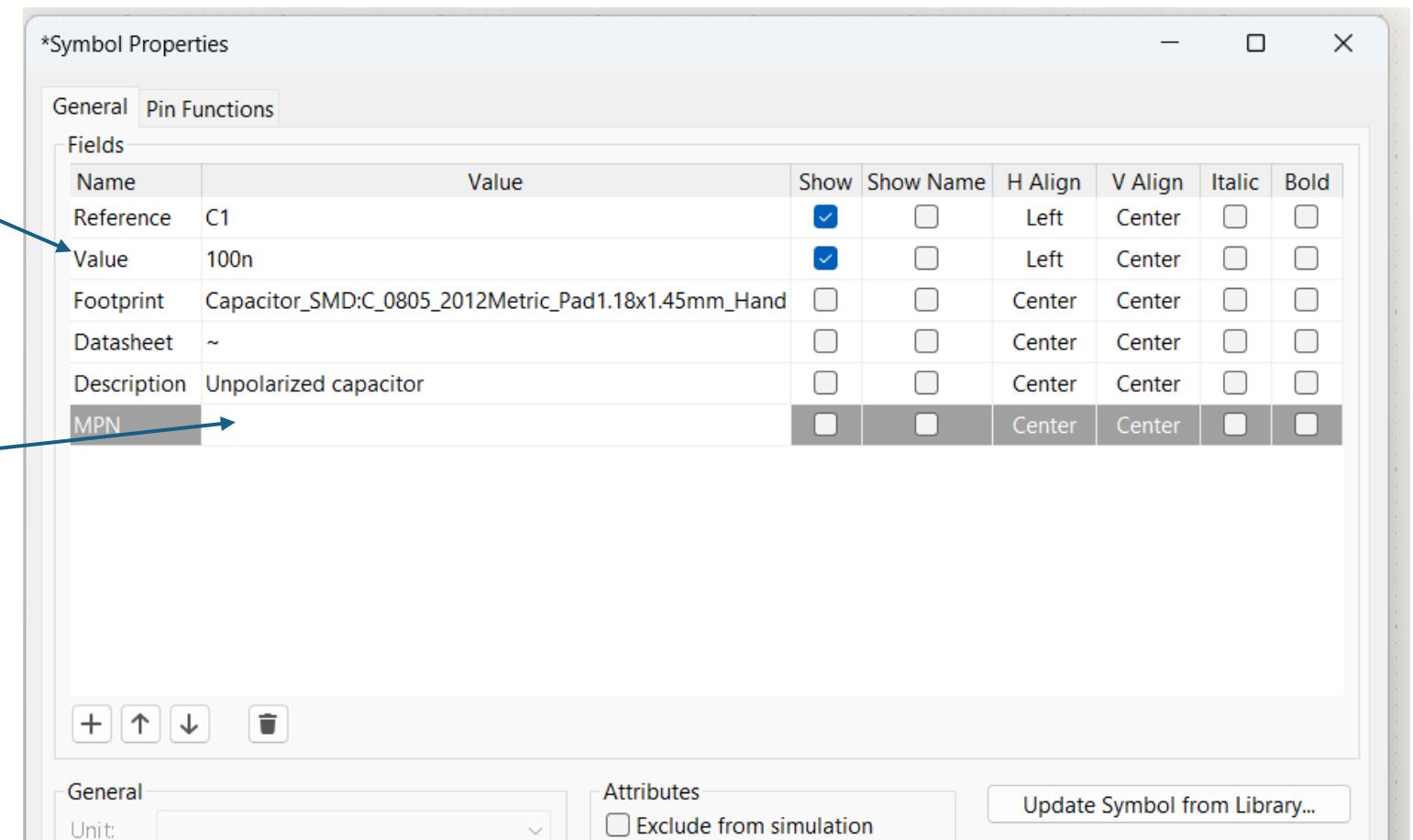
C_0805_2012Metric	Capacitor SMD 0805 (2012 Metric), square (rectangular sharing), generated with kicad-footprint-generator
C_0805_2012Metric_45mm_HandSolder	Capacitor SMD 0805 (2012 Metric), square (rectangular sharing), generated with kicad-footprint-generator
C_01005_0402Metric	Capacitor SMD 01005 (0402 Metric), square (rectangular sharing), generated with kicad-footprint-generator

WARNING: You can assign incompatible footprints. Check carefully what anode/cathode marks to with diodes, and parts like transistors that may have different pinouts available.

Assigning Part Numbers?

Assign value here

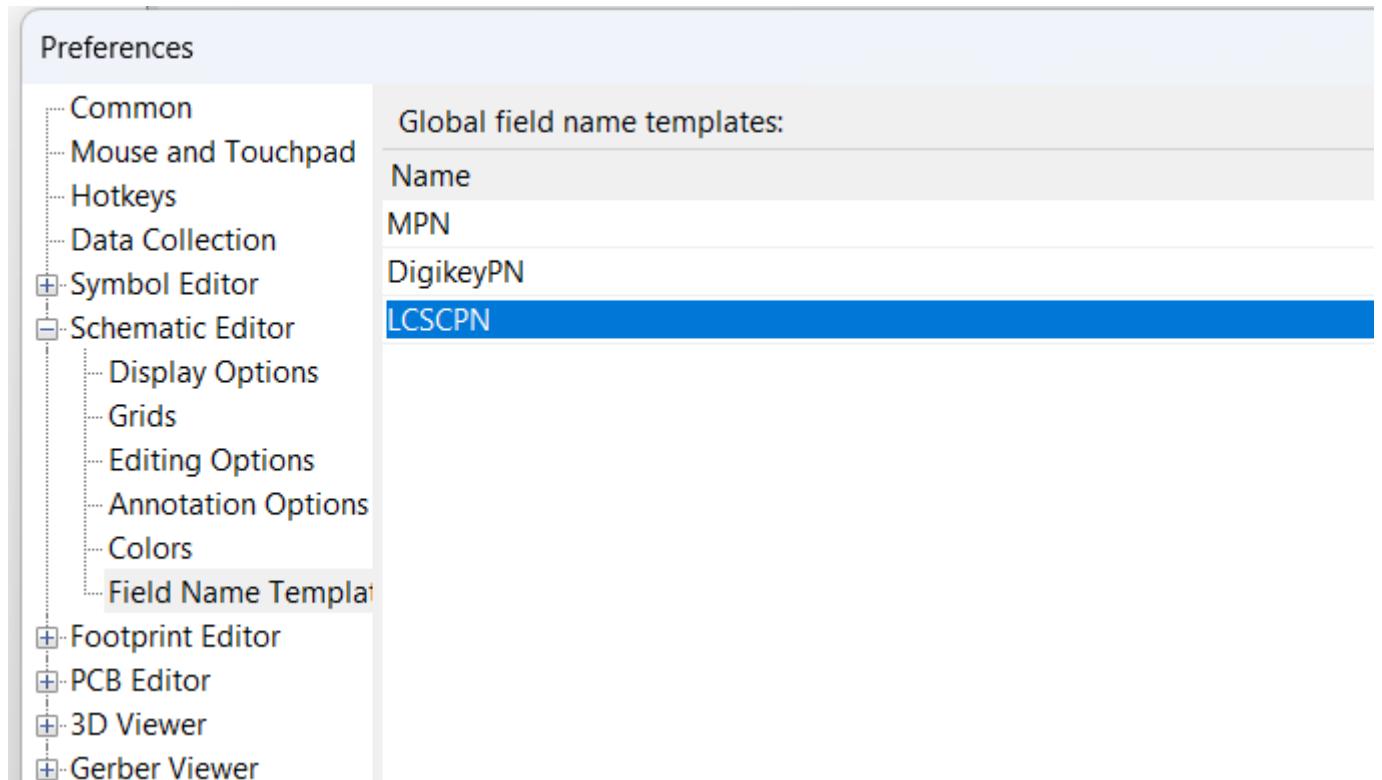
I can add other *fields* to specify specific part numbers.



Hint: Adjusting your Default Template

Set up some defaults if you want them to always be on your symbols!

Saves you from remembering all the fields...



Finding Parts on Digikey / Mouser

DigiKey

resistor

Upload a List

Search

Login or REGISTER

Products Manufacturers Resources Request a Quote

FREE SHIPPING on Order

Showing 2,286,874 Results for "resistor"

Filters

Search Within

In Stock RoHS Compliant

[+ More Filters](#)

Categories

Anti-Static, ESD, Clean Room Products

Top Results

	Chip Resistor - Surface Mount Resistors 995,529 Items		Through Hole Resistors Resistors 508,248 Items
	Chassis Mount Resistors Resistors 25,494 Items		Resistor Networks, Arrays Resistors 36,047 Items
	Trimmer Potentiometers Potentiometers, Variable Resistors 10,077 Items		Resistor Kits Kits 5,655 Items

Typical Resistor Search

<Live Demo, backup slides >

Chip Resistor - Surface Mount

Search Within



Results: **995.529**

Stocking Options

- In Stock
- Normally Stocking
- New Product

Environmental Options

- RoHS Compliant
- Non-RoHS Compliant

Media

- Datasheet
- Photo
- EDA/CAD Models

Marketplace Product

- Exclude

Apply All**92 Results**

SEARCH ENTRY

APPLIED FILTERS [Remove All](#)resistor XTolerance X ▼Package / Case X ▼Resistance X ▼Stocking Options X ▼

Filter by highly available and/or lower price. Good enough!

Showing 1 - 25 ▾ of 92

Sort By: Featured ▼

	Mfr Part #	Quantity Available ▼	Price ▼	Series	Package	Product Status	Resistance	Tolerance	Power (Watts)
<input type="checkbox"/>	  RMCF0805FT10K0 RES 10K OHM 1% 1/8W 0805 Stackpole Electronics Inc	1,380,730 In Stock 2,800,000 Factory ②	1 : \$0.16000 Cut Tape (CT) 5,000 : \$0.00703 Tape & Reel (TR)	RMCF	Tape & Reel (TR) ② Cut Tape (CT) ② Digi-Reel® ②	Active	10 kOhms	±1%	0.125W, 1/8W ②
<input type="checkbox"/>	  RK73H2ATTD1002F RES 10K OHM 1% 1/4W 0805 KOA Speer Electronics, Inc.	520,328 In Stock	1 : \$0.16000 Cut Tape (CT) 5,000 : \$0.01078 Tape & Reel (TR)	RK73H	Tape & Reel (TR) ② Cut Tape (CT) ② Digi-Reel® ②	Active	10 kOhms	±1%	0.25W, 1/4W ②

Resistor Quick Ref

- Check power handling capacity. If powering bright/large LEDs do calculation of power loss in resistor, keep that at < 50% of rated.
 - Watch for heating effects – through hole resistors may be preferred here!
- 1% & 5% resistors are the same price with smaller resistors. Tend to just order 1%...
- Don't get too caught up on anything else for now.

Typical Capacitor Search

The screenshot shows the DigiKey website's search results page for the query "capacitor". The top navigation bar includes the DigiKey logo, a search bar with "capacitor", an "Upload a List" button, a magnifying glass icon, and a Canadian flag icon. To the right are "Login or REGISTER" links and a "FREE SHIPPING on" banner. Below the header, it says "Showing 1,264,383 Results for 'capacitor'".

Filters:

- Search Within: Q
- In Stock
- RoHS Compliant
- + More Filters

Categories:

- Capacitors
- Circuit Protection
- Connectors, Interconnects
- Crystals, Oscillators, Resonators
- Development Boards, Kits, Programmers
- Discrete Semiconductor Products

Search Within: Results: 545,003

Top Results:

- Ceramic Capacitors** Capacitors 845,663 items
- Aluminum Electrolytic Capacitors** Capacitors 108,055 items
- Film Capacitors** Capacitors 159,685 items
- Aluminum - Polymer Capacitors** Capacitors 9,747 items
- Tantalum Capacitors** Capacitors 101,004 items
- Electric Double Layer Capacitors (EDLC), Supercapacitors** Capacitors 2,644 items
- Mica and PTFE Capacitors** Capacitors 8,806 items
- Tantalum - Polymer Capacitors** Capacitors 12,691 items
- Thin Film Capacitors** Capacitors Kits

Refinement Options:

Capacitance	Tolerance	Voltage - Rated	Temperature Coefficient	Operating Temperature	Features
Min <input type="text"/> 0.091 µF	Max <input type="text"/> 0.094 µF	Search Filter <input type="text"/> ±1%	Search Filter <input type="text"/> 6V	Search Filter <input type="text"/> -55°C ~ 100°C	Search Filter <input type="text"/> Bonding Mountable
Max <input type="text"/> 0.099 µF	Search Filter <input type="text"/> ±2%	Search Filter <input type="text"/> 6.3V	Search Filter <input type="text"/> A	Search Filter <input type="text"/> -55°C ~ 105°C	Bonding Mountable, Gold Flash
0.1 µF <input type="button" value="Clear"/>	Search Filter <input type="text"/> ±2.5%	Search Filter <input type="text"/> 10V	Search Filter <input type="text"/> B	Search Filter <input type="text"/> -55°C ~ 125°C	Bonding Mountable, Single Lay
100 nF	Search Filter <input type="text"/> ±5%	Search Filter <input type="text"/> 16V	Search Filter <input type="text"/> BC	Search Filter <input type="text"/> -55°C ~ 150°C	Bypass Capacitor, Decoupling
0.11 µF	Search Filter <input type="text"/> ±6%	Search Filter <input type="text"/> 20V	Search Filter <input type="text"/> BD	Search Filter <input type="text"/> -55°C ~ 160°C	Controlled ESR
0.12 µF	Search Filter <input type="text"/> ±10%	Search Filter <input type="text"/> 25V	Search Filter <input type="text"/> BE	Search Filter <input type="text"/> -55°C ~ 175°C	Controlled ESR, Low ESL (Reve
0.13 µF	Search Filter <input type="text"/> ±15%	Search Filter <input type="text"/> 35V	Search Filter <input type="text"/> BF	Search Filter <input type="text"/> -55°C ~ 200°C	DC Annex H, Humidity 3B Anne
0.14 µF	Search Filter <input type="text"/> ±20%	Search Filter <input type="text"/> 50V	Search Filter <input type="text"/> BG	Search Filter <input type="text"/> -55°C ~ 250°C	DC Annex H, Humidity 3B Anne
<input type="button" value="Clear"/>	Search Filter <input type="text"/> Clear	Search Filter <input type="text"/> 63V	Search Filter <input type="text"/> BJ	Search Filter <input type="text"/> -55°C ~ 260°C	DC Annex H, Humidity 3B Anne
		Search Filter <input type="text"/> Clear	Search Filter <input type="text"/> CJ	Search Filter <input type="text"/> ESD, RFI, EMI	

Stocking Options:

- In Stock
- Normally Stocking
- New Product

Environmental Options:

- RoHS Compliant
- Non-RoHS Compliant

Media:

- Datasheet
- Photo
- EDA/CAD Models

Marketplace Product:

- Exclude

Apply All

2,067 of 845,663 Results

Package / Case:

- Search Filter 0603 (1608 Metric)
- 0612 (1632 Metric)
- 0704 (1810 Metric)
- 0709 (1823 Metric)
- 0805 (2012 Metric)**
- 01005 (0402 Metric)
- 1005 (2512 Metric)
- 1111 (2828 Metric)
- 1205 (2016 Metric)

Size / Dimension:

- Search Filter 0.002" L x 0.010" W (0.05mm x 0.25mm)
- 0.010" L x 0.005" W (0.25mm x 0.13mm)
- 0.010" L x 0.010" W (0.25mm x 0.25mm)
- 0.012" L x 0.010" W (0.30mm x 0.25mm)
- 0.012" L x 0.012" W (0.31mm x 0.31mm)**
- 0.015" L x 0.012" W (0.38mm x 0.30mm)
- 0.015" L x 0.015" W (0.38mm x 0.38mm)
- 0.016" L x 0.008" W (0.40mm x 0.20mm)
- 0.016" L x 0.008" W (0.41mm x 0.20mm)
- 0.016" L x 0.010" W (0.40mm x 0.25mm)

Capacitor Biasing Effect

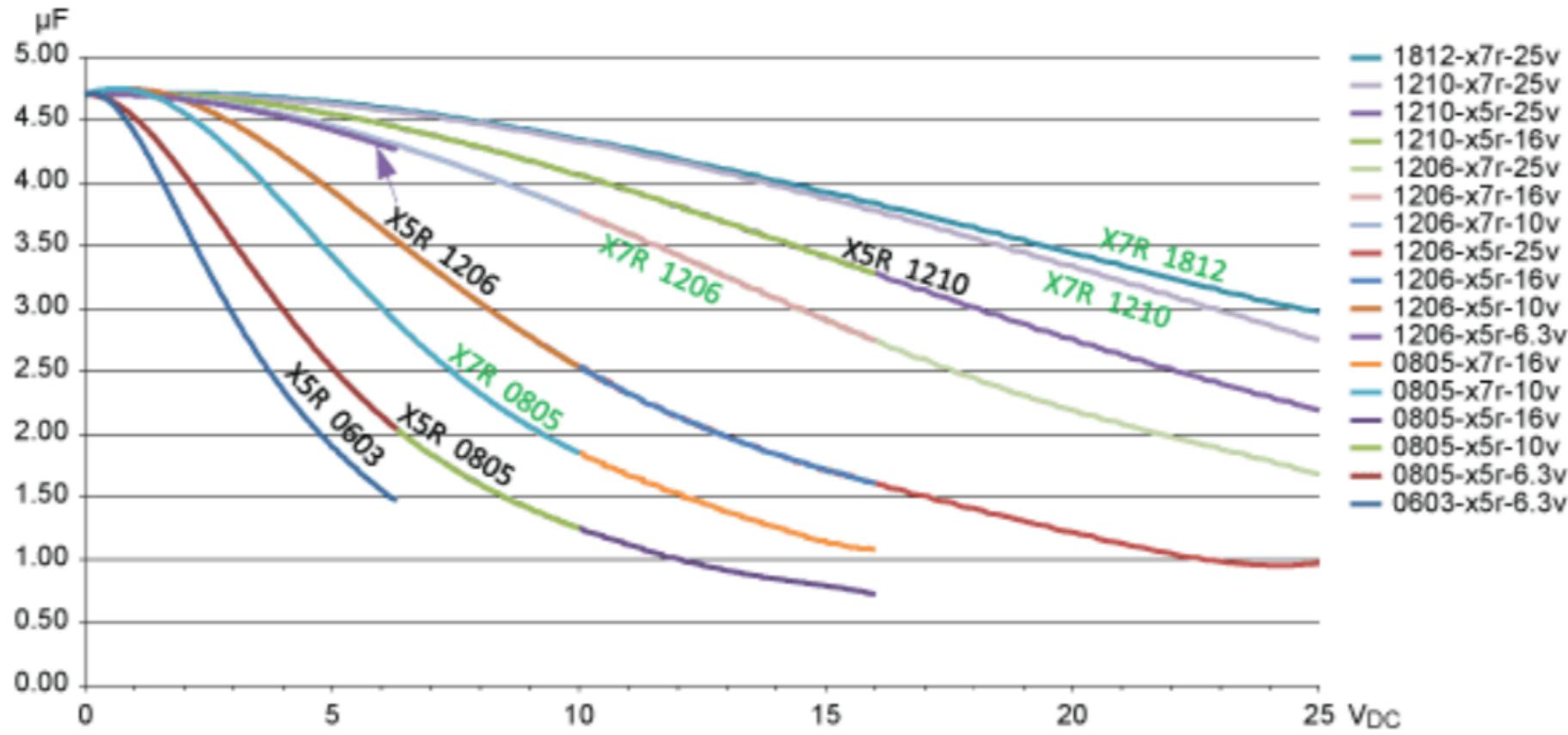


Figure 1. Capacitance variation vs. DC voltage for select 4.7 μF capacitors.

	Mfr Part #	Quantity Available ⓘ	Price Price by Quantity	Series
]	    CC0805KRX7R9BB104 CAP CER 0.1UF 50V X7R 0805 YAGEO	3,664,640 In Stock	1 : \$0.12000 Cut Tape (CT) 4,000 : \$0.02673 Tape & Reel (TR)	CC
]	  CL21B104KBCNNNC CAP CER 0.1UF 50V X7R 0805 <i>Samsung Electro-Mechanics</i>	1,283,926 In Stock	1 : \$0.12000 Cut Tape (CT) 4,000 : \$0.00754 Tape & Reel (TR)	CL
]	  KGM21NR71H104KT CAP CER 0.1UF 50V X7R 0805 KYOCERA AVX	347,893 In Stock	1 : \$0.12000 Cut Tape (CT) 4,000 : \$0.01701 Tape & Reel (TR)	KGM - X7

Temperature Coefficient

Capacitor Quick-Ref

- Stick to ceramic caps unless you need higher values for e.g., filtering of input power.
 - **WARNING:** Some types, such as tantalum, are very sensitive to reverse polarity and over-voltage.
 - Don't rate only based on expected voltage! Consider biasing for ceramic caps.
 - BUT: If you set the voltage TOO high you will pay \$\$\$ or need too large a package.
- Capacitor tolerance is looser: $\pm 10\%$ is a good value.
 - For higher values larger tolerance swings are reasonable.
- X7R/X5R is a good temp coefficient to start with, but often not too important.
- For sensitive values (such as crystal capacitors) C0G or NP0 are more stable.

Typical LED Search

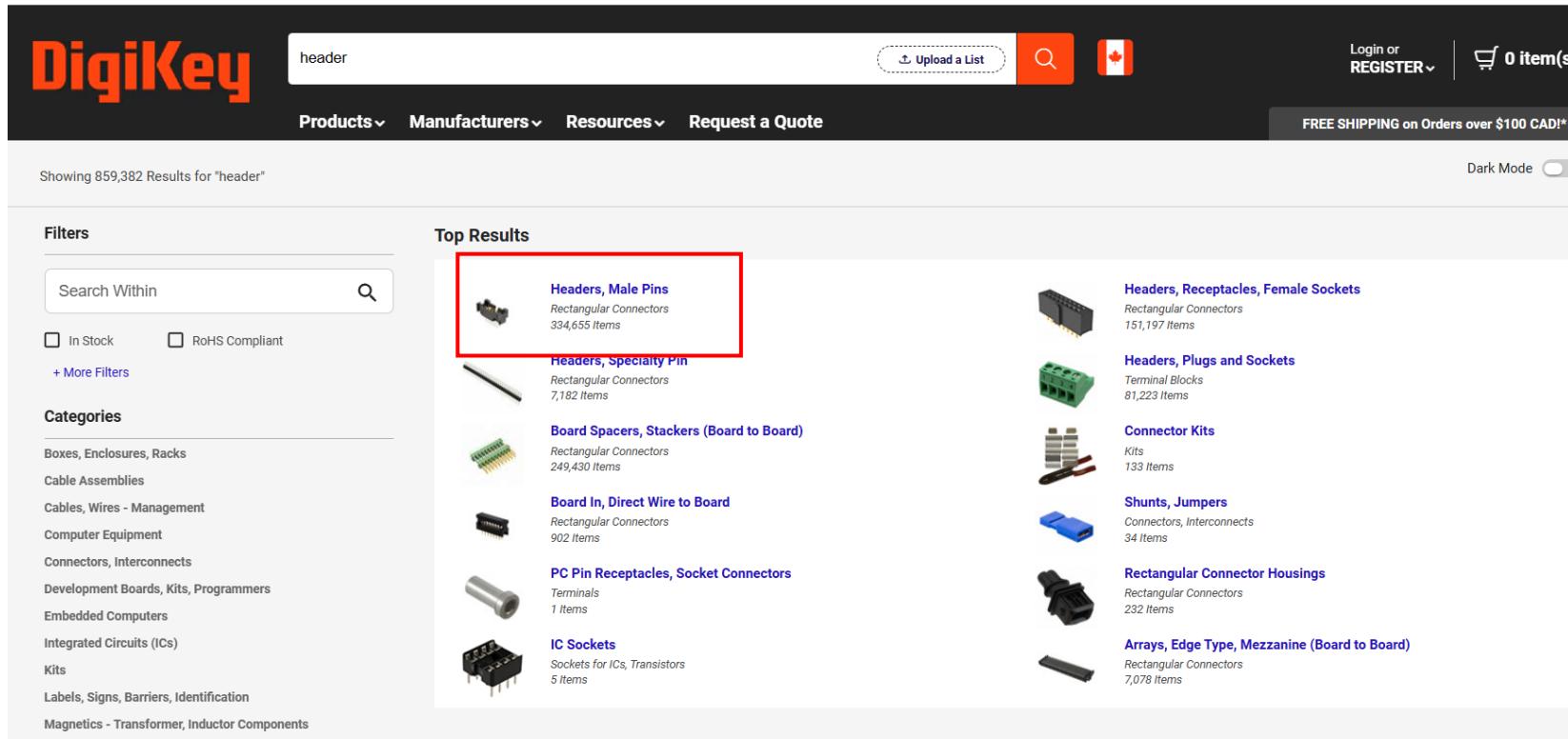
The screenshot shows a search interface for LED Indication - Discrete components. At the top, there are navigation links: Product Index > Optoelectronics > LED Indication - Discrete. On the right, there are Dark Mode and Share options. Below the header, the title "LED Indication - Discrete" is displayed, followed by a search bar with "Search Within" and a magnifying glass icon, and the results count "Results: 7,253". To the right of the search bar are three filter buttons: Filters (highlighted), Stacked, and Scrolling. The main area is a grid of search filters categorized into eight columns:

- Wavelength - Peak**: Includes a search filter and a list of wavelengths: 400nm, 420nm, 428nm, 430nm, 445nm, 450nm, 451nm, 452nm, 454nm.
- Features**: Includes a search filter and a list of features: Cycling, Cycling (Fast), Cycling (Slow), Flashing, IPX8, Wire Leads - 20cm, Wire Leads - 30cm.
- Grade**: Shows Automotive.
- Qualification**: Shows AEC-Q101, AEC-Q102.
- Package / Case**: Includes a search filter and a list of packages: 0602 (1605 Metric), 0603 (1608 Metric), 0604 (1510 Metric), 0605 (1513 Metric), 0605 (1613 Metric), 0606 (1616 Metric), 0805 (2012 Metric) (highlighted in blue), 0807 (2018 Metric), 1010 (2525 Metric), Clear.
- Supplier Device Package**: Includes a search filter and a list of packages: 1.8mm, 1.8mm Discrete LED, 1.8mm Miniplast, 1.8mm Round Subminiature, 2.0mm Round, 2mm, 3.0mm Round, 3mm, 3mm Round.
- Size / Dimension**: Includes a search filter and a list of dimensions: 0.60mm L x 0.30m, 0.65mm L x 0.35m, 0.65mm L x 0.38m, 0.65mm L x 0.65m, 0.69mm L x 0.69m, 0.80mm L x 0.80m, 0.83mm L x 0.83m, 0.95mm L x 0.95m, 1.00mm L x 0.50m.

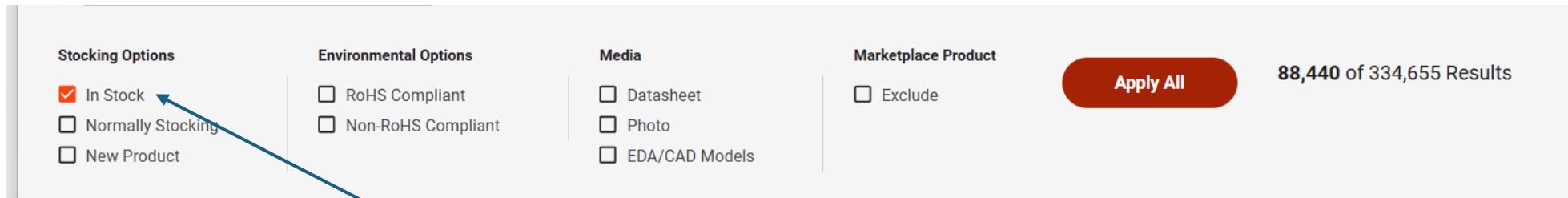
LED characteristics can vary a lot – maybe you don't want SMD? Do you want a super-bright LED?

Finding Connectors

- Connectors can be tricky to search for. Let's say I want some standard terminal headers:



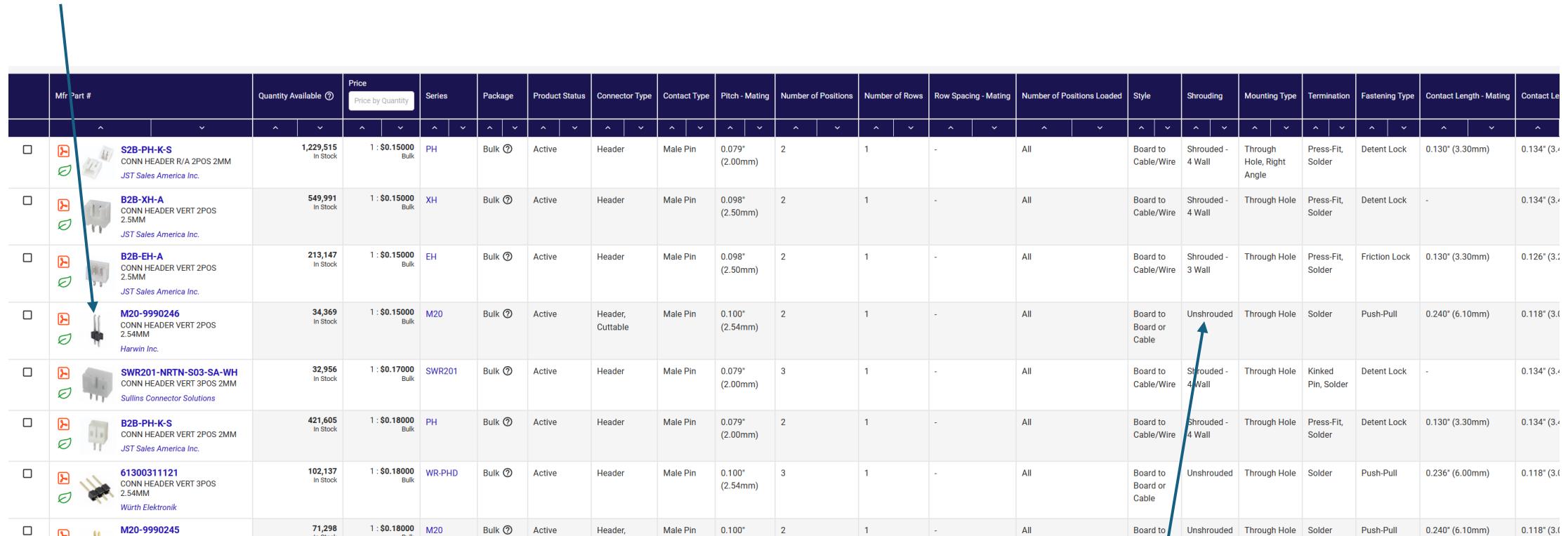
Finding Connectors



Always check “In Stock” first!

Visual Clues

Look at photos – for example if I want normal unshrouded connectors, I can see this one is right:



	Mfr Part #	Quantity Available	Price Price by Quantity	Series	Package	Product Status	Connector Type	Contact Type	Pitch - Mating	Number of Positions	Number of Rows	Row Spacing - Mating	Number of Positions Loaded	Style	Shrouding	Mounting Type	Termination	Fastening Type	Contact Length - Mating	Contact Le
<input type="checkbox"/>	  S2B-PH-K-S CONN HEADER R/A 2POS 2MM JST Sales America Inc.	1,229,515 In Stock	1 : \$0.15000 Bulk	PH	Bulk 	Active	Header	Male Pin	0.079" (2.00mm)	2	1	-	All	Board to Cable/Wire	Shrouded - 4 Wall	Through Hole, Right Angle	Press-Fit, Solder	Detent Lock	0.130" (3.30mm)	0.134" (3.4
<input type="checkbox"/>	  B2B-XH-A CONN HEADER VERT 2POS 2.5MM JST Sales America Inc.	549,991 In Stock	1 : \$0.15000 Bulk	XH	Bulk 	Active	Header	Male Pin	0.098" (2.50mm)	2	1	-	All	Board to Cable/Wire	Shrouded - 4 Wall	Through Hole	Press-Fit, Solder	Detent Lock	-	0.134" (3.4
<input type="checkbox"/>	  B2B-EH-A CONN HEADER VERT 2POS 2.5MM JST Sales America Inc.	213,147 In Stock	1 : \$0.15000 Bulk	EH	Bulk 	Active	Header	Male Pin	0.098" (2.50mm)	2	1	-	All	Board to Cable/Wire	Shrouded - 3 Wall	Through Hole	Press-Fit, Solder	Friction Lock	0.130" (3.30mm)	0.126" (3.1
<input type="checkbox"/>	  M20-9990246 CONN HEADER VERT 2POS 2.54MM Harwin Inc.	34,369 In Stock	1 : \$0.15000 Bulk	M20	Bulk 	Active	Header, Cuttable	Male Pin	0.100" (2.54mm)	2	1	-	All	Board to Board or Cable	Unshrouded	Through Hole	Solder	Push-Pull	0.240" (6.10mm)	0.118" (3.0
<input type="checkbox"/>	  SWR201-NRTN-S03-SA-WH CONN HEADER VERT 3POS 2MM Sullins Connector Solutions	32,956 In Stock	1 : \$0.17000 Bulk	SWR201	Bulk 	Active	Header	Male Pin	0.079" (2.00mm)	3	1	-	All	Board to Cable/Wire	Shrouded - 4 Wall	Through Hole	Kinked Pin, Solder	Detent Lock	-	0.134" (3.4
<input type="checkbox"/>	  B2B-PH-K-S CONN HEADER VERT 2POS 2MM JST Sales America Inc.	421,605 In Stock	1 : \$0.18000 Bulk	PH	Bulk 	Active	Header	Male Pin	0.079" (2.00mm)	2	1	-	All	Board to Cable/Wire	Shrouded - 4 Wall	Through Hole	Press-Fit, Solder	Detent Lock	0.130" (3.30mm)	0.134" (3.4
<input type="checkbox"/>	  61300311121 CONN HEADER VERT 3POS 2.54MM Würth Elektronik	102,137 In Stock	1 : \$0.18000 Bulk	WR-PHD	Bulk 	Active	Header	Male Pin	0.100" (2.54mm)	3	1	-	All	Board to Board or Cable	Unshrouded	Through Hole	Solder	Push-Pull	0.236" (6.00mm)	0.118" (3.0
<input type="checkbox"/>	  M20-9990245 CONN HEADER VERT 2POS	71,298 In Stock	1 : \$0.18000 Bulk	M20	Bulk 	Active	Header, Cuttable	Male Pin	0.100"	2	1	-	All	Board to Board or Cable	Unshrouded	Through Hole	Solder	Push-Pull	0.240" (6.10mm)	0.118" (3.0

I know to search “Unshrouded” now...

Visual Clues

The screenshot shows a search interface with two main filter sections:

- Shrouding:** A dropdown menu with options: Shrouded, Shrouded - 1 Wall, Shrouded - 2 Wall, Shrouded - 3 Wall, Shrouded - 4 Wall, and Unshrouded. The "Unshrouded" option is highlighted with a blue background.
- Mounting:** A dropdown menu with options: Board Ed, Panel Mc, Stacking, Surface N, and Surface M.

On the left side of the interface, there is a vertical sidebar with the text "or Cable /Wire". At the bottom of the interface, there is a "Clear" button.

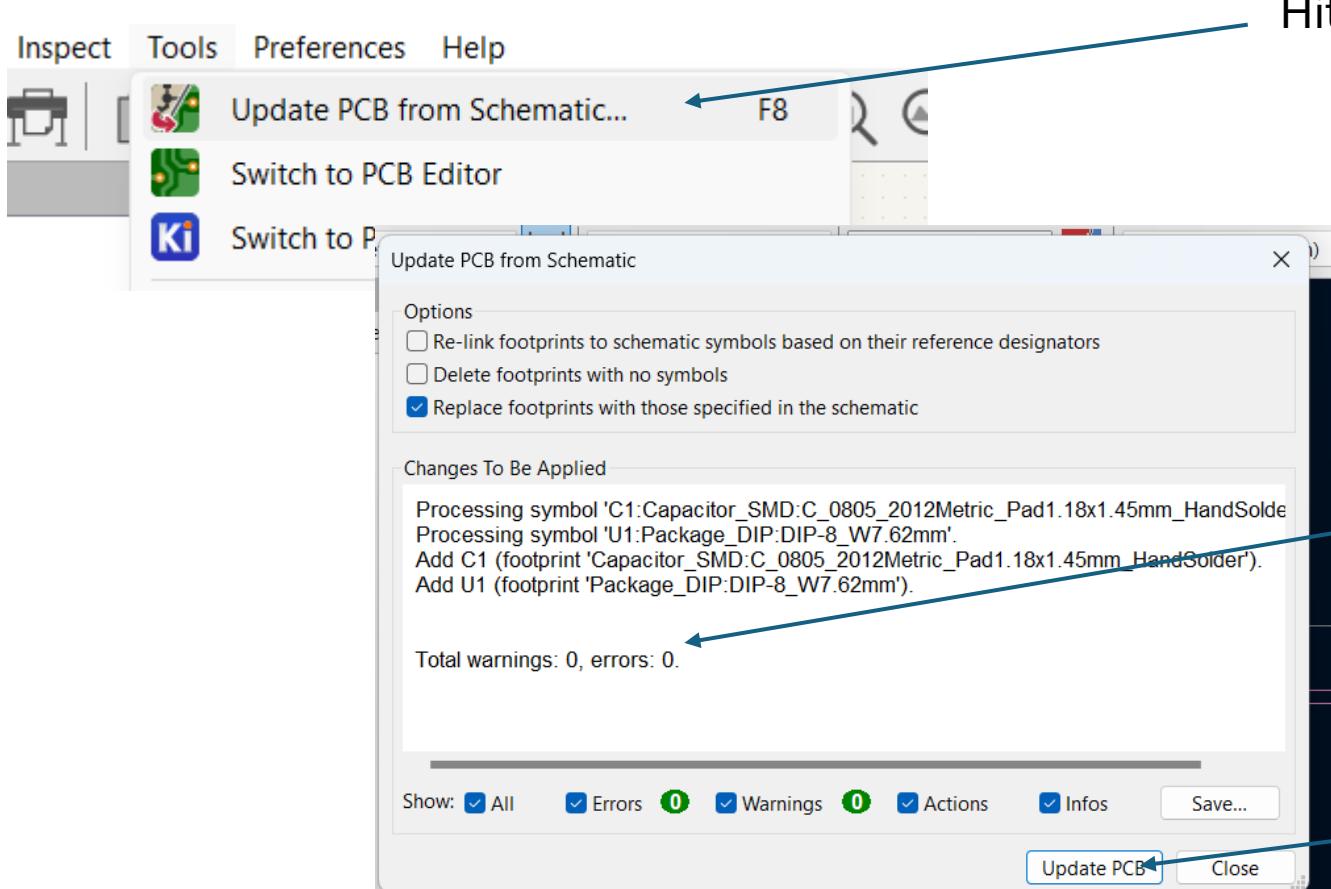
I can now select “Unshrouded” and hit “Apply All” to filter results again.

Mfr Part #	Quantity Available	Price	Series	Package
	In Stock	Price by Quantity		
M20-9990246 CONN HEADER VERT 2POS 2.54MM Harwin Inc.	34,369 In Stock	1 : \$0.15000 Bulk	M20	Bulk
61300311121 CONN HEADER VERT 3POS 2.54MM Würth Elektronik	102,137 In Stock	1 : \$0.18000 Bulk	WR-PHD	Bulk
M20-9990245 CONN HEADER VERT 2POS 2.54MM Harwin Inc.	71,298 In Stock	1 : \$0.18000 Bulk	M20	Bulk
61300211121 CONN HEADER VERT 2POS 2.54MM Würth Elektronik	31,339 In Stock	1 : \$0.18000 Bulk	WR-PHD	Bulk
M20-9990345 CONN HEADER VERT 3POS 2.54MM Harwin Inc.	83,942 In Stock	1 : \$0.23000 Bulk	M20	Bulk
M22-2010205 CONN HEADER VERT 2POS 2MM Harwin Inc.	21,205 In Stock	1 : \$0.23000 Bulk	M22	Bulk
77311-118-02LF CONN HEADER VERT 2POS 2.54MM Bergstik	12,083 In Stock	1 : \$0.24000 Bulk	BERGSTIK®	Bulk

Selecting Parts

- Selecting parts requires careful consideration of everything we need.
- Can be overwhelming at first! Take some time to look through. Use existing designs if you can find them as reference too.
- Let's assume we finished that...

Syncing to PCB



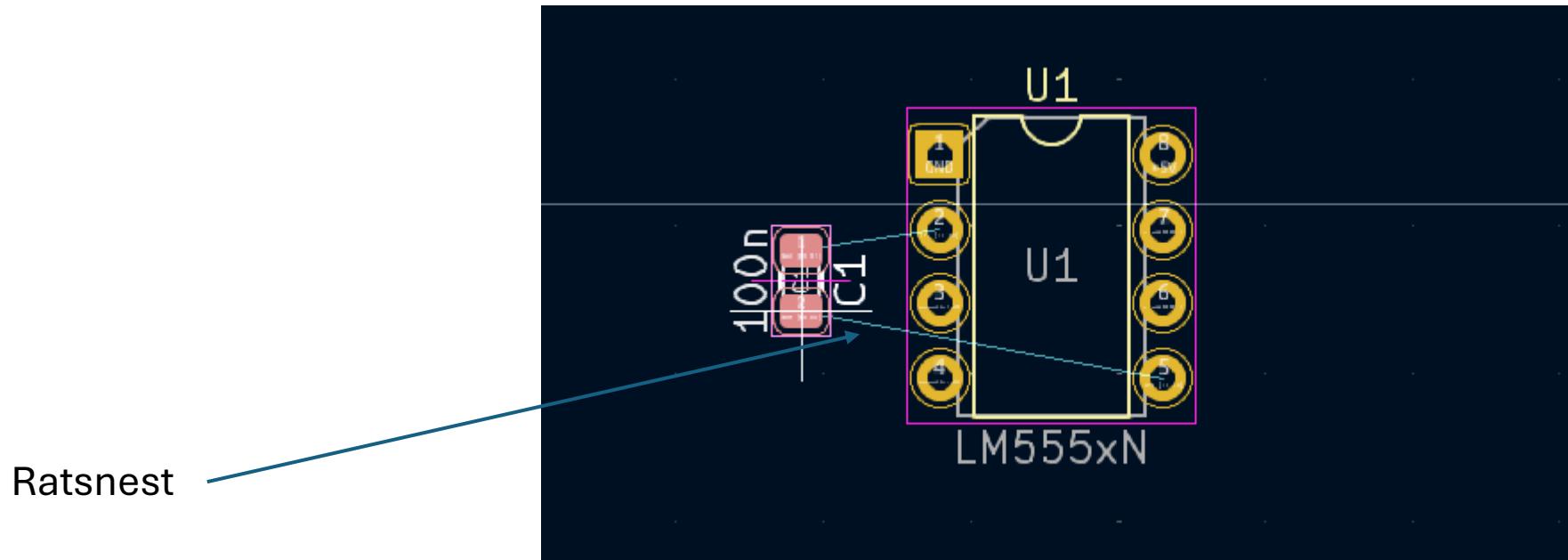
Hit this...

Read warnings or errors – might happen if you have the wrong footprint!

Hit this now.

Placing Parts

Click & drag parts (watch you get the *part* and not the text).
Hit 'r' to rotate while holding down button.

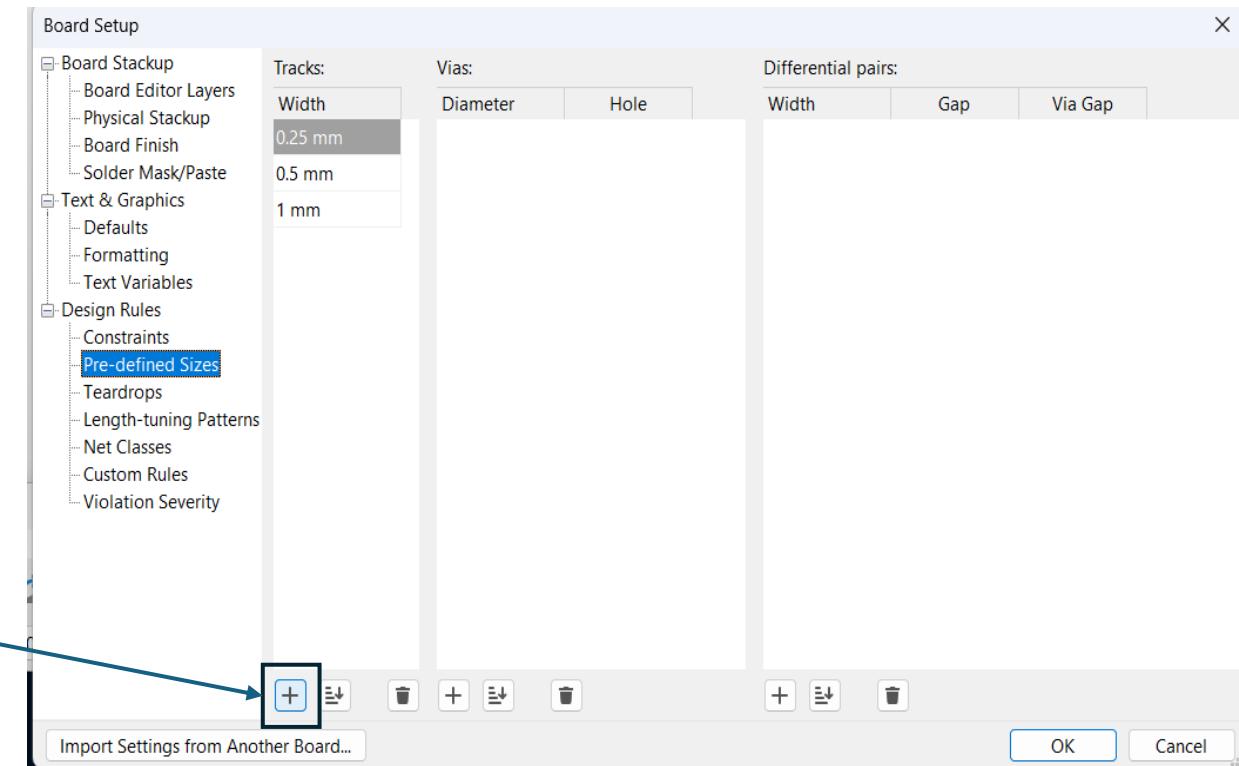
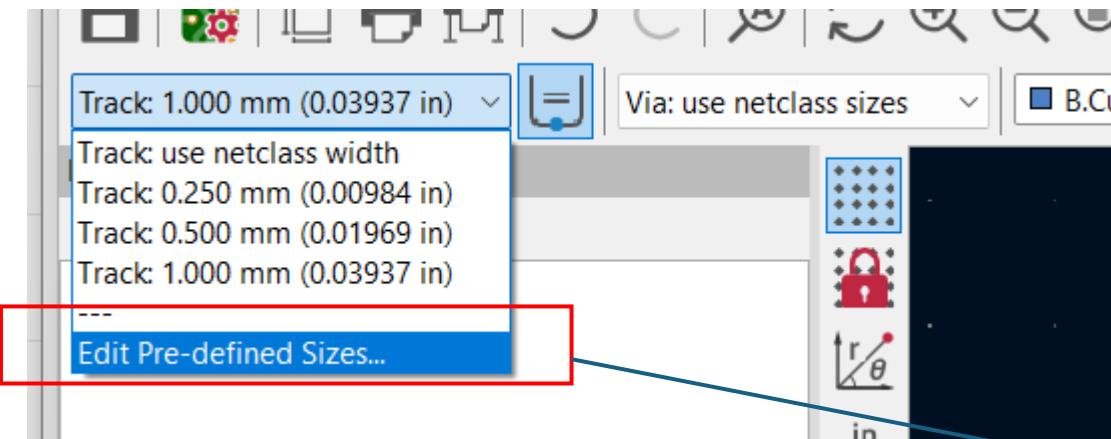


Placing Effort

Time spent improving placement will make your routing much easier.

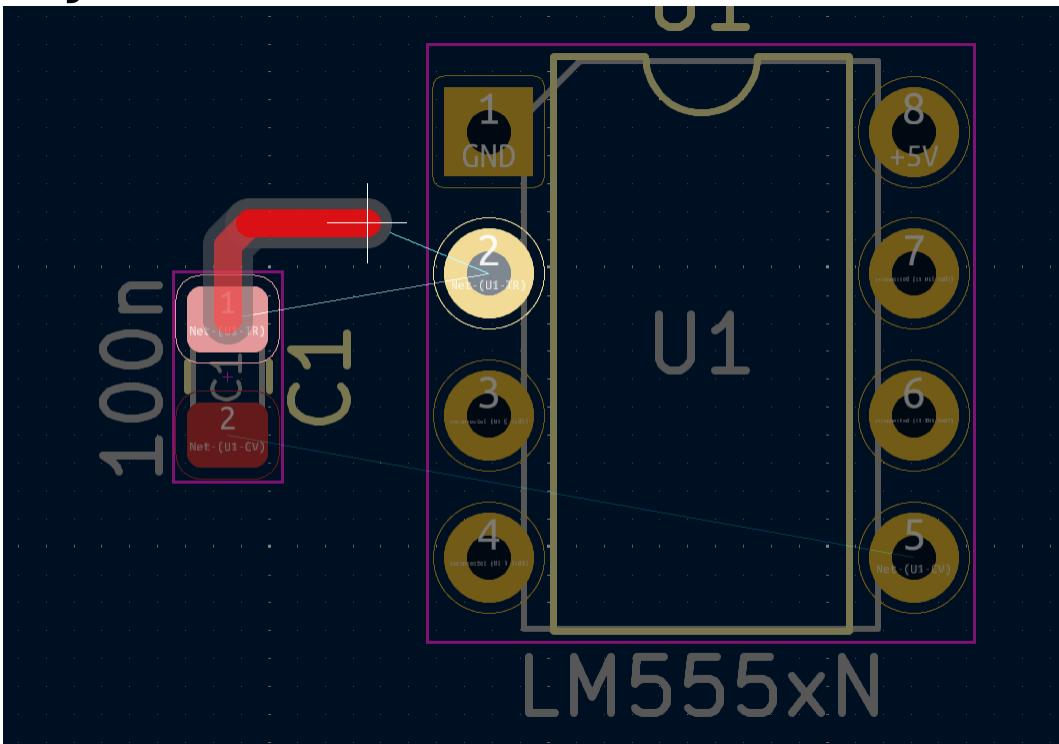
This can take some time to develop, since you need some experience routing to understand what makes sense.

Setting up Widths



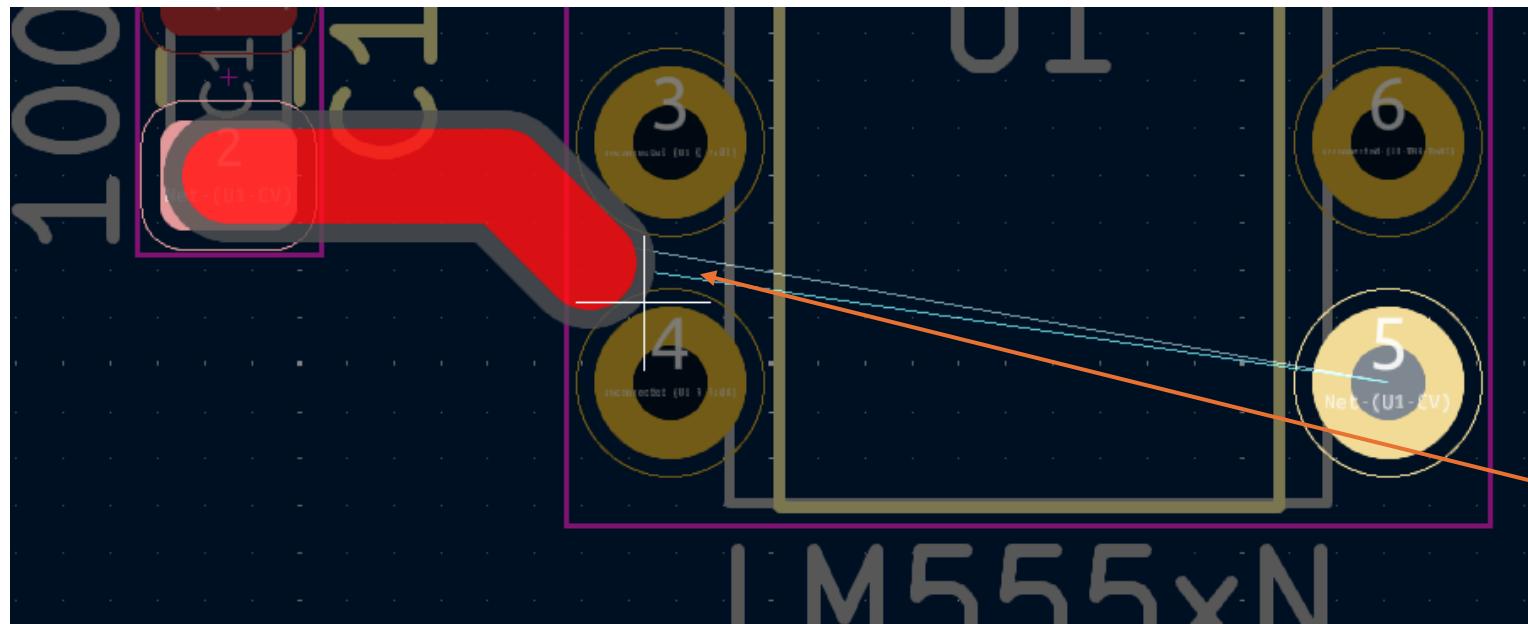
Routing

Press “x” to start routing. Click on a point and you see the ratsnest follow you:



Press w key to switch between defined trace widths (Shift-W goes backwards).

Online DRC



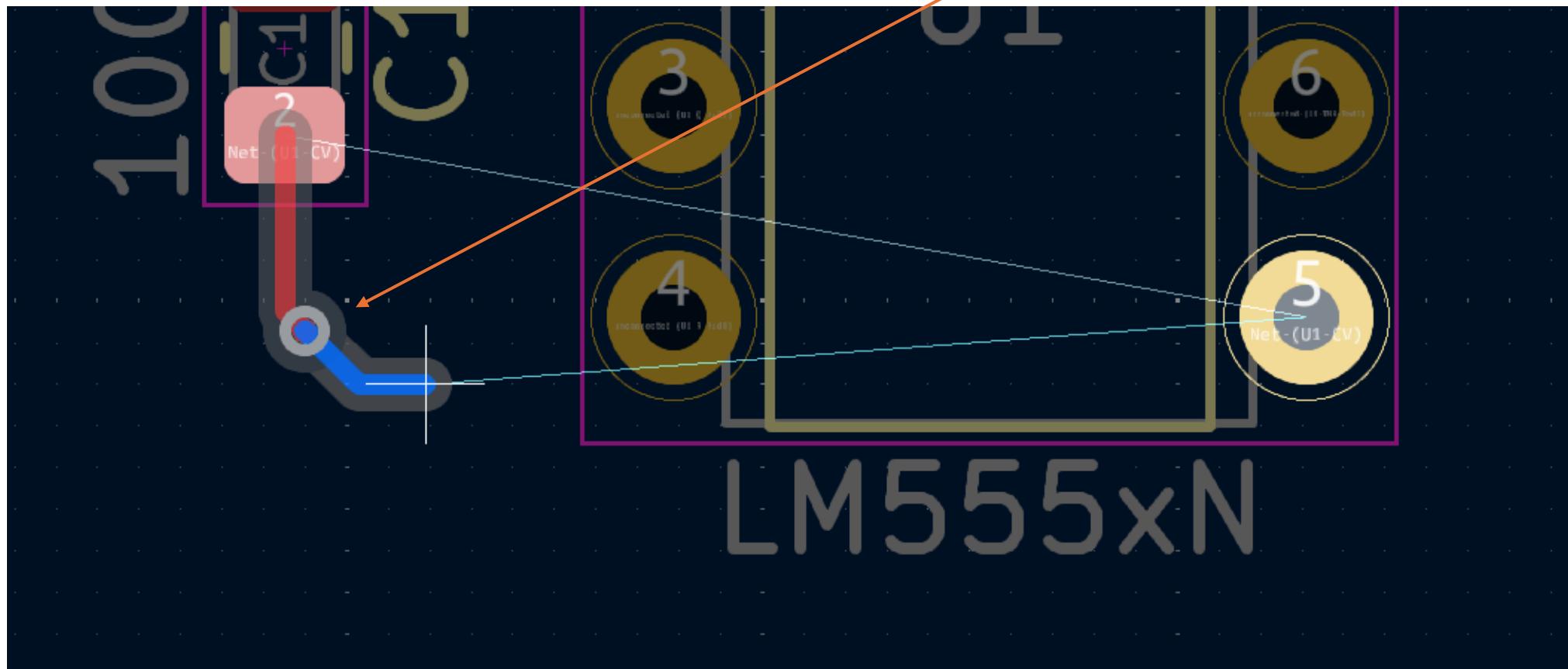
Online Design Rule Check enabled by default.

Prevents you from doing illegal things like routing trace too close for your design rules.

In this example I cannot drag it through here.

Switching Sides (Via)

Press 'v' button to place via.
Switches sides automatically!

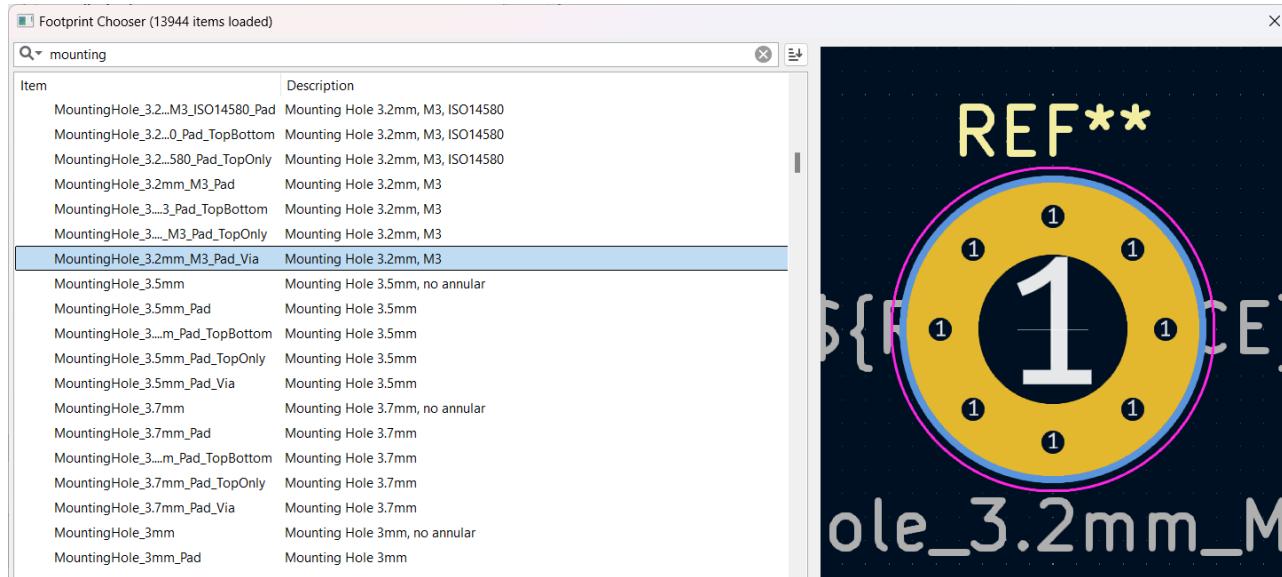


Autorouter??

- Autorouter sounds like it could be magic!
- Despite many peoples negativity they *can* work, but they require a *lot of effort defining what you want them to do*. In many circumstances not worthwhile.
 - E.g., you *inherently* know which traces are high current or sensitive. AutoRouter has no idea, you need to make a class, define the trace widths, etc.
- I've used them on some boards for tests, rarely pleased with results.

Check Mechanical Size & Add Mounting Holes

- Think about how you will mount this:
 - If fitting in breadboard, mount headers on 0.1" grid space
 - If bolting to something, make a convenient mounting hole

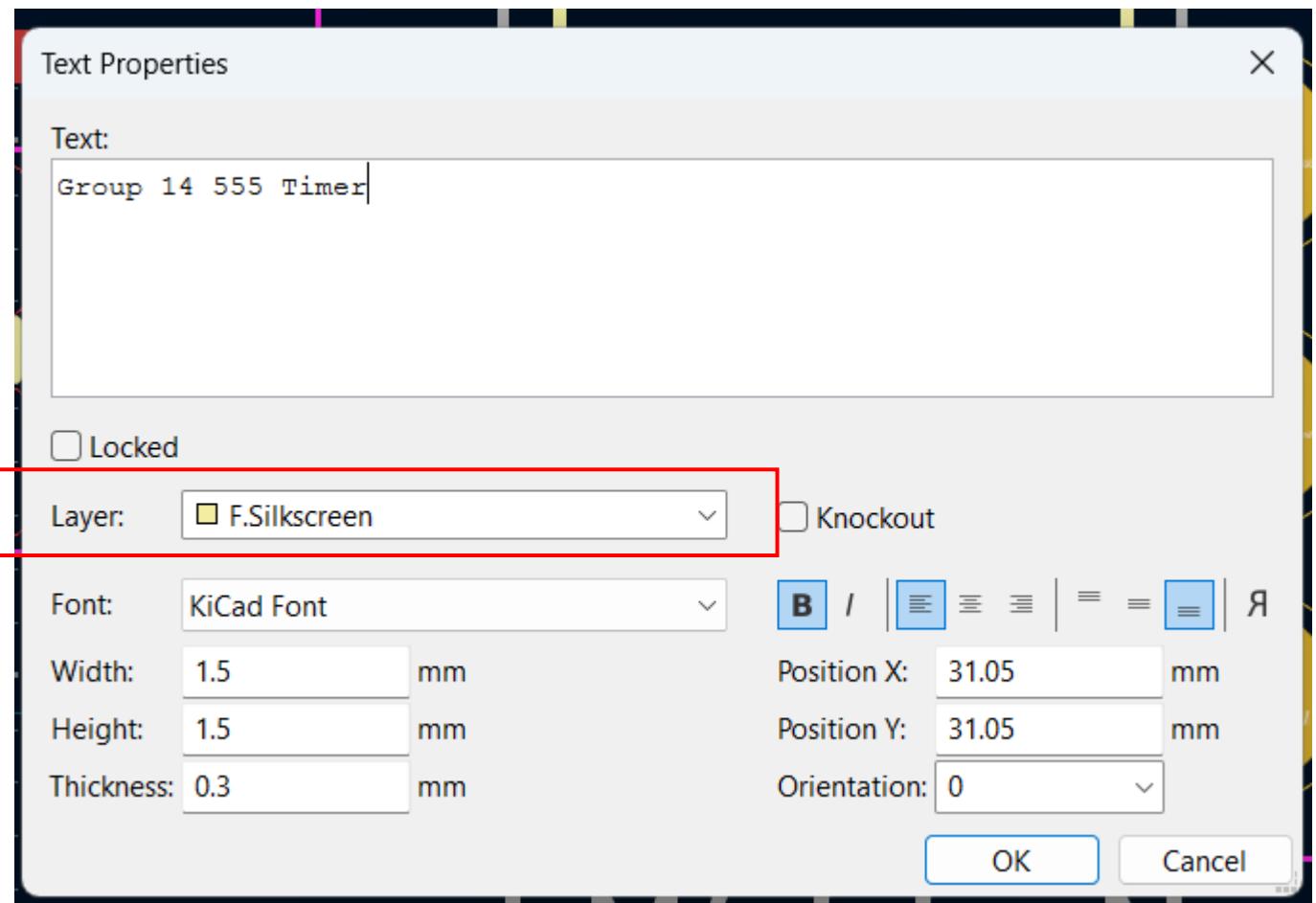


HINT: Add a “Mounting Hole” part on schematic and assign it a “Mounting Hole” footprint.

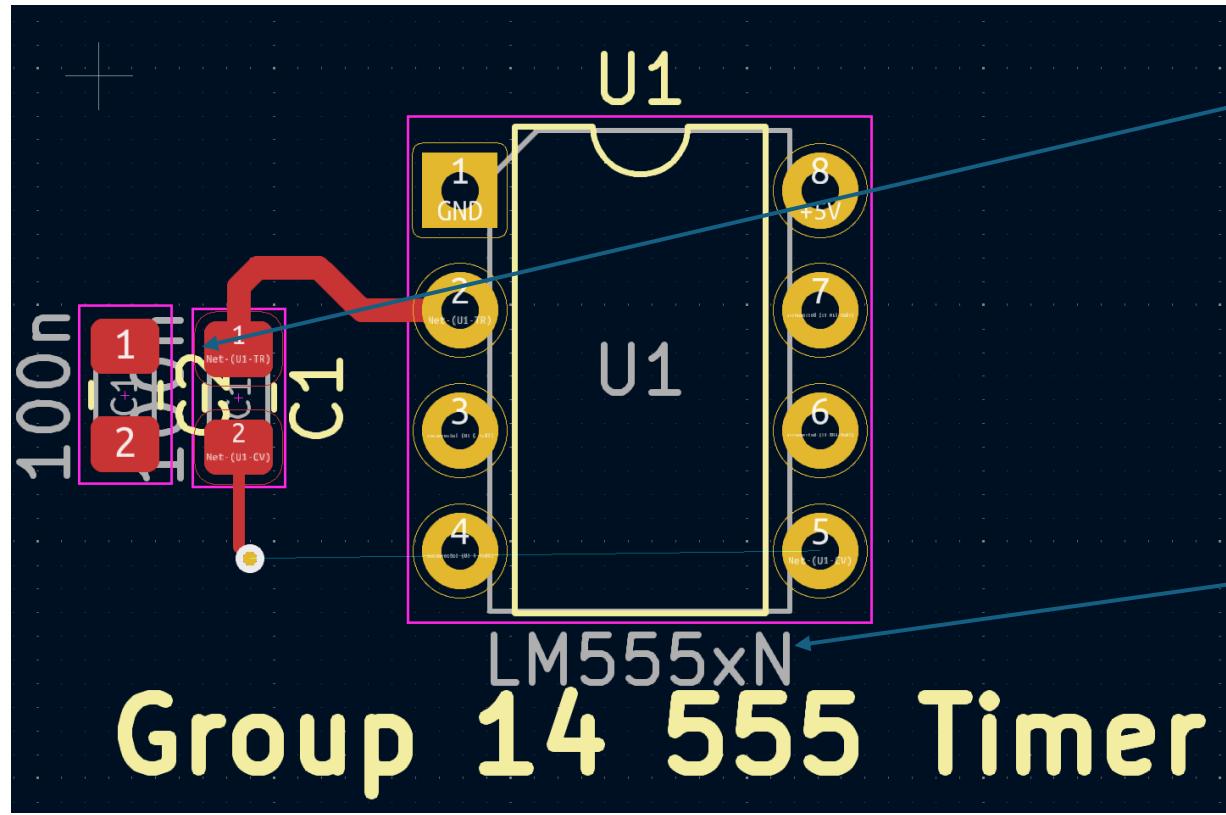
This will ensure it stays around and isn’t forgotten!

For mechanical strength some hole patterns have additional small vias within them.

Pretty Up Silkscreen



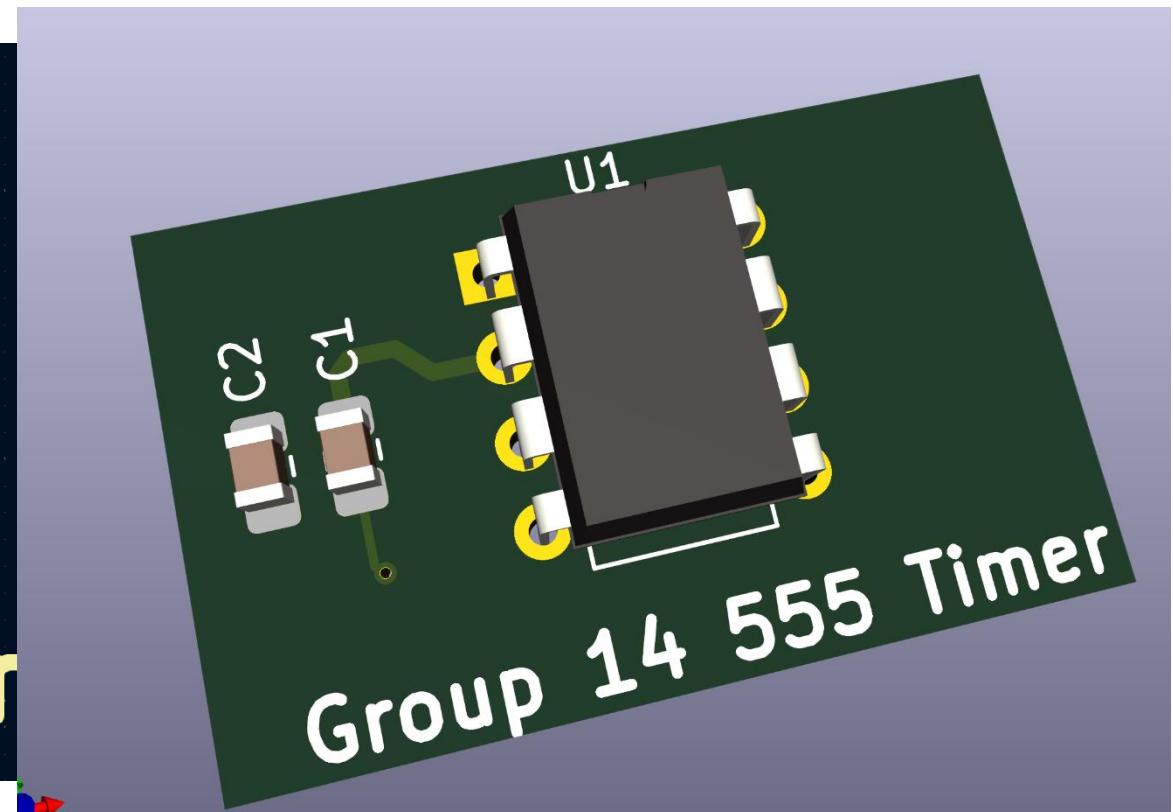
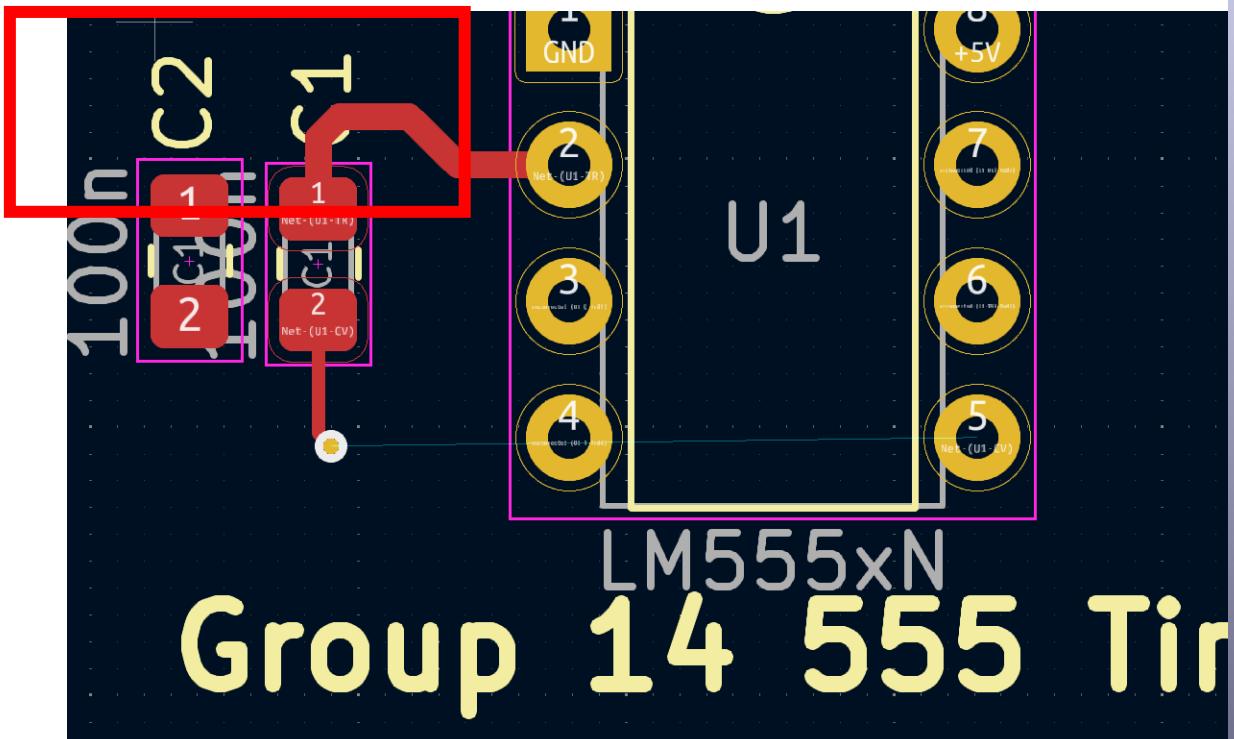
Pretty Up Silkscreen



Move the reference designators so it doesn't overlap the other component pads.

Values are for our ref & won't get printed on silkscreen. We can turn this layer off if it starts to look too messy.

Pretty Up Silkscreen



Press Alt-3 (or view 3D viewer) to check what it will look like.

Add Outline

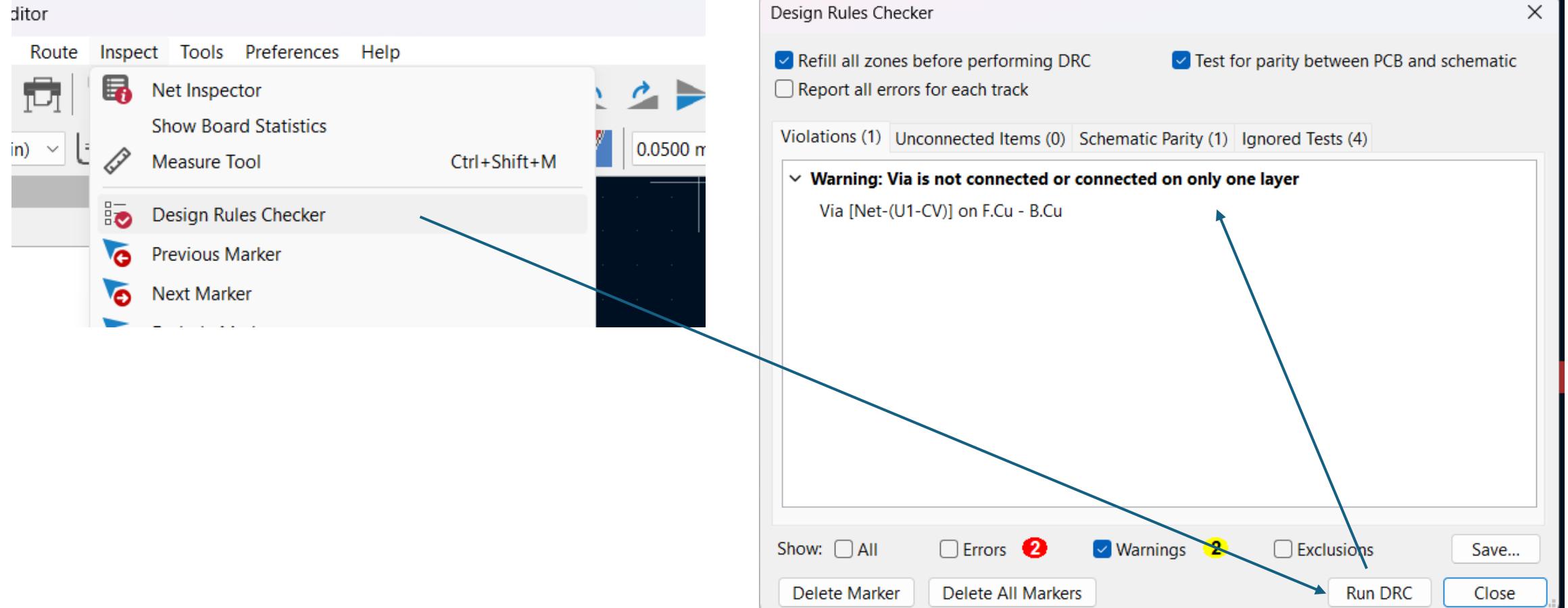
- Add a closed outline on the EdgeCuts layer



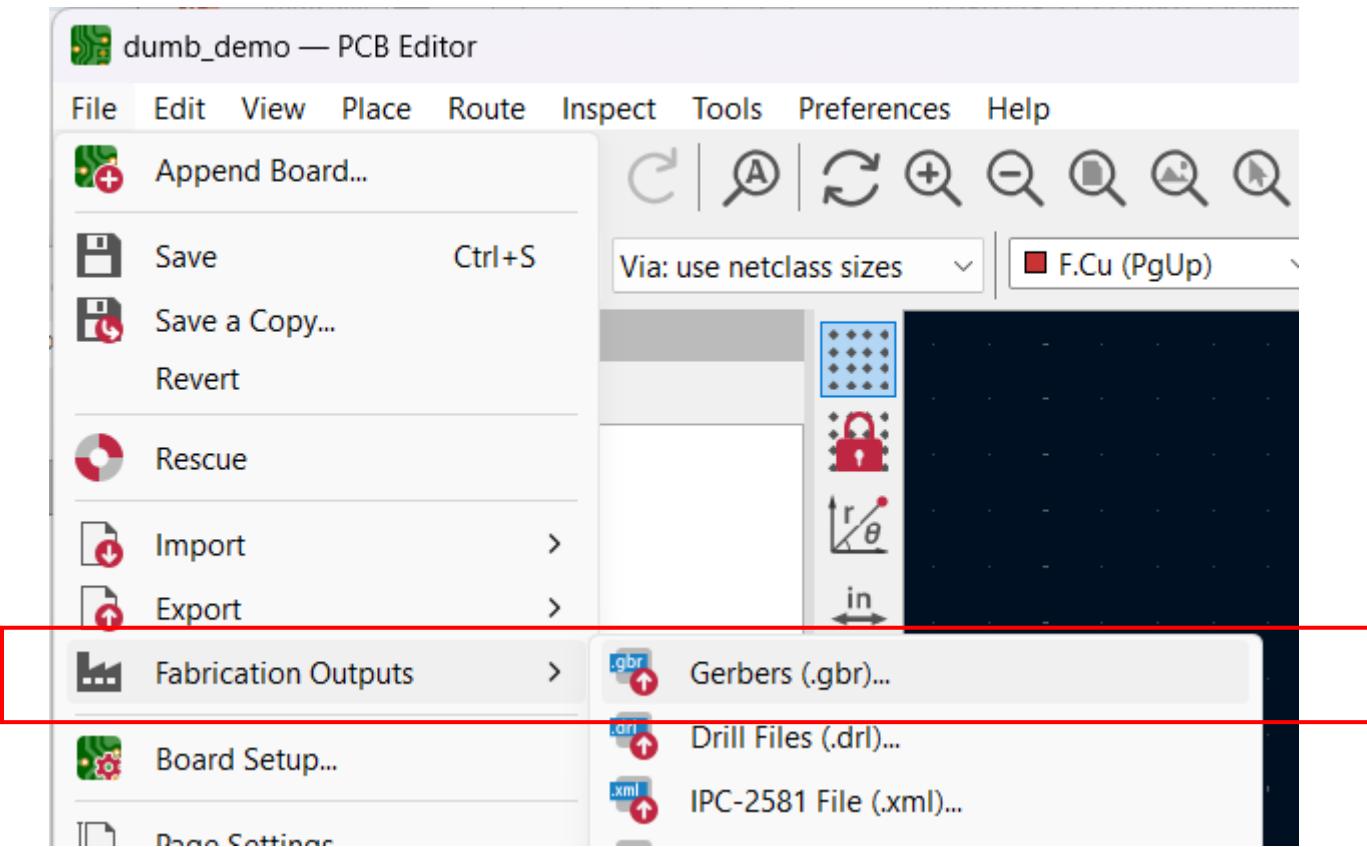
Ground Pours

- Consider adding ground pours.
- Make sure you have some vias to GND they will connect to!
- ...we're going beyond the time limit here, see many of the other great tutorials...

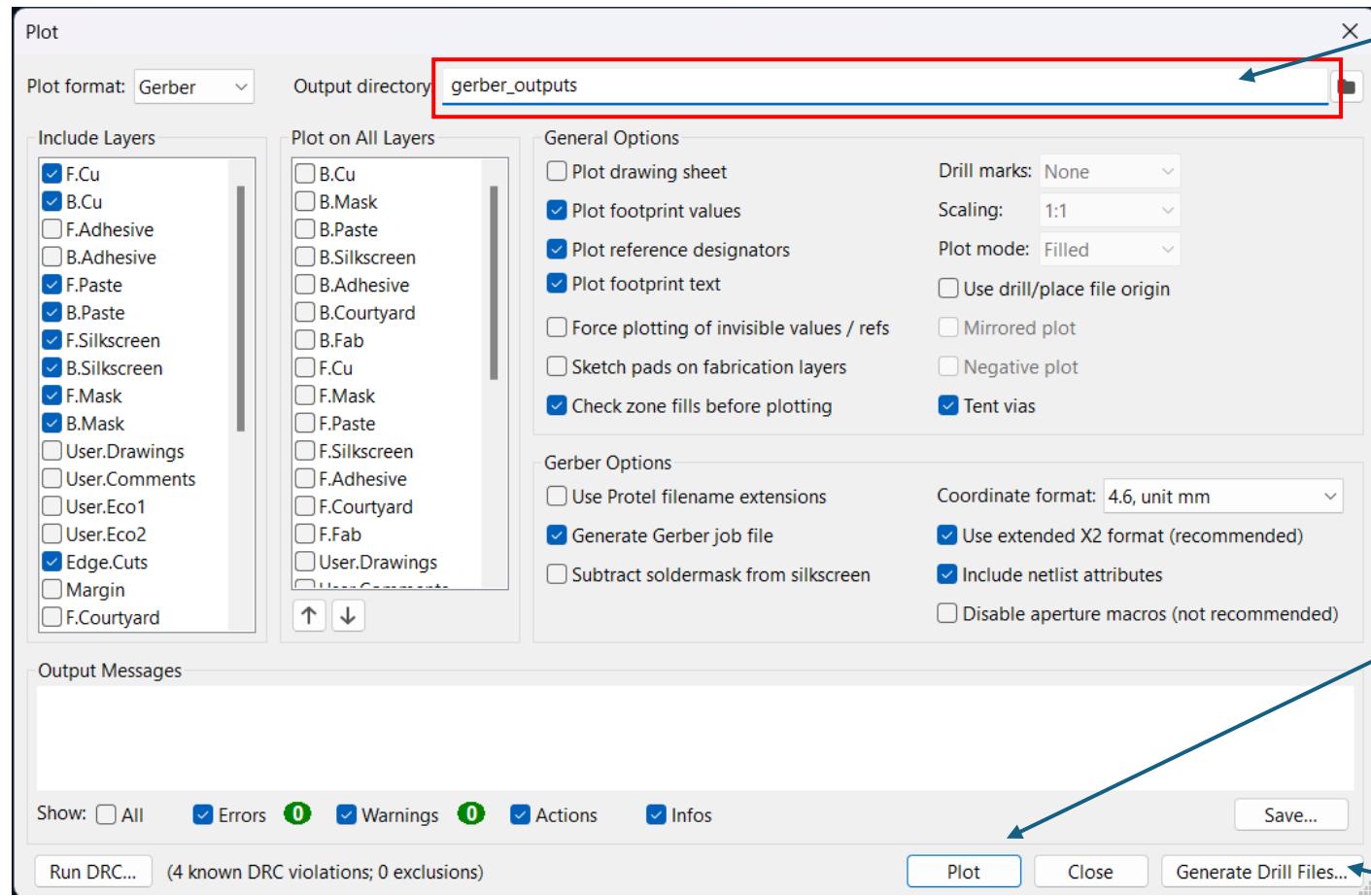
DRC Checks



Exporting Files



Exporting Files



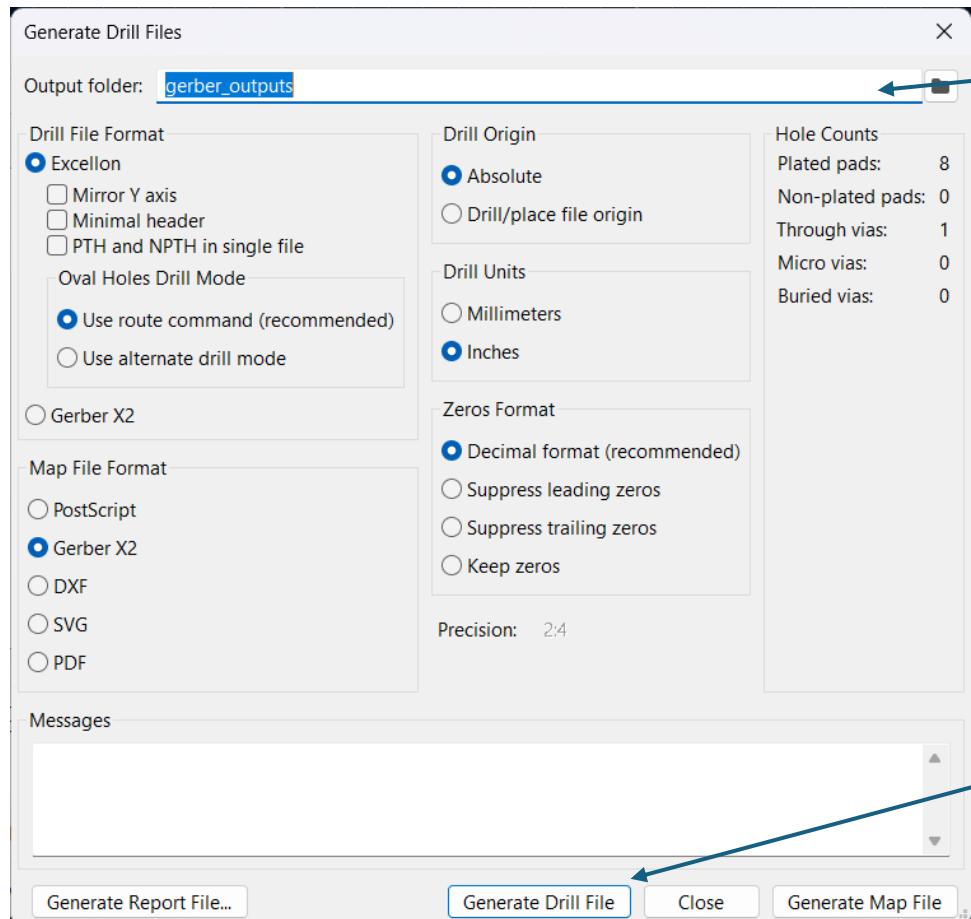
1. Put a folder here such as
“gerber_outputs”

This will keep all your files
together so you don't miss one!

2. Then press this button.

3. Then press this button.

Exporting Files Cont'd

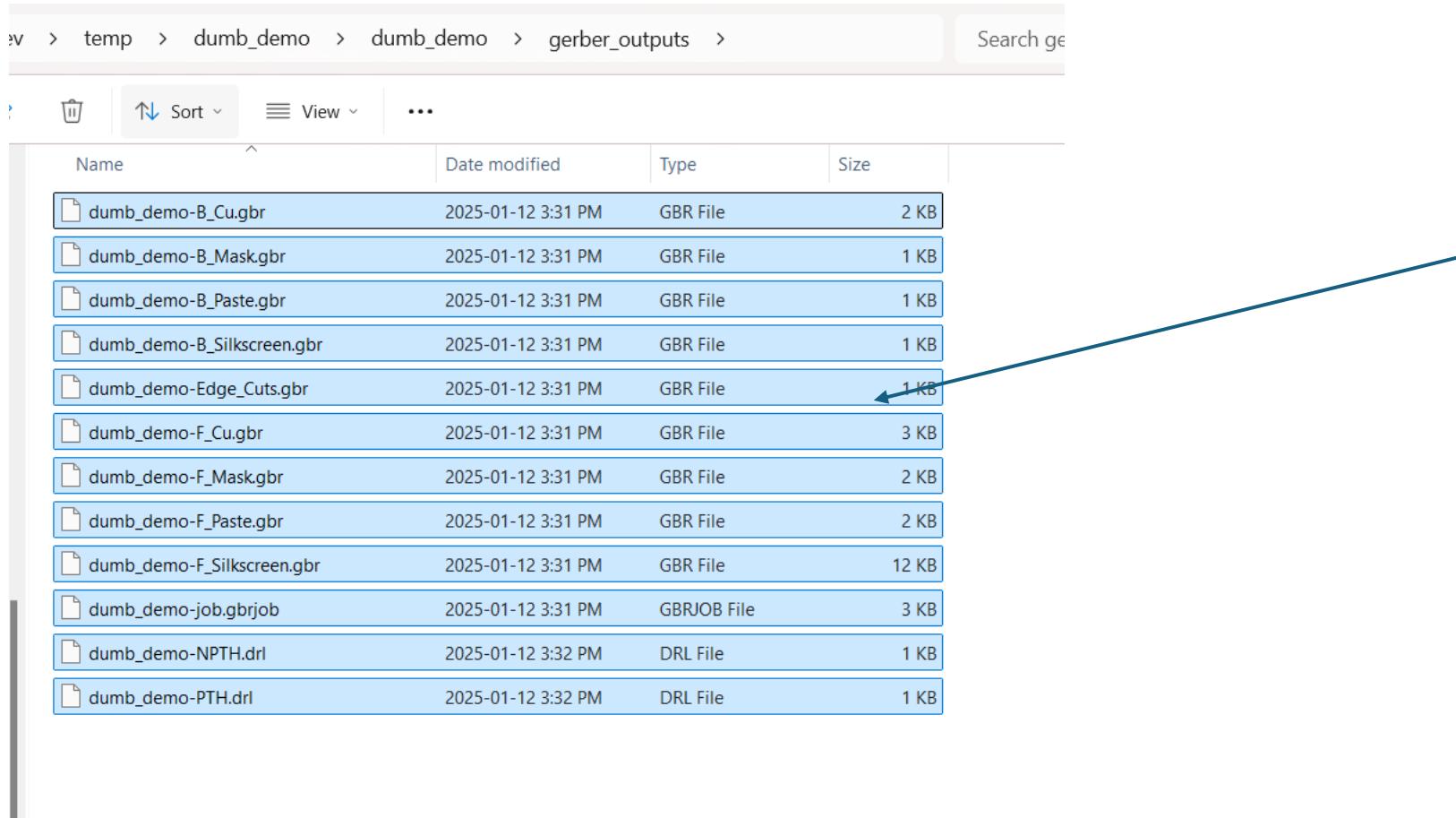


This should have been populated automatically. Same as gerbers!

2. Then press this button.

3. Then close everything.

Zipping Together



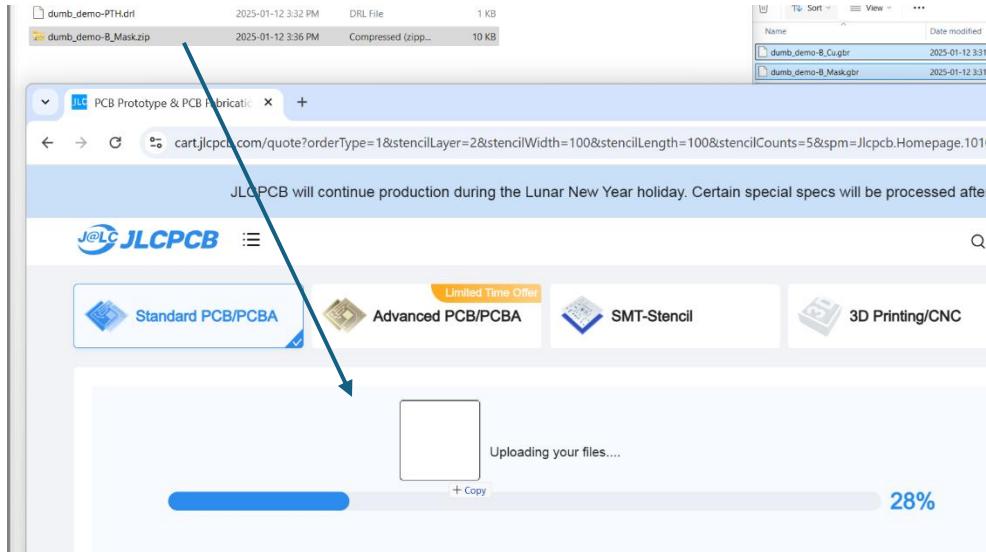
Name	Date modified	Type	Size
dumb_demo-B_Cu.gbr	2025-01-12 3:31 PM	GBR File	2 KB
dumb_demo-B_Mask.gbr	2025-01-12 3:31 PM	GBR File	1 KB
dumb_demo-B_Paste.gbr	2025-01-12 3:31 PM	GBR File	1 KB
dumb_demo-B_Silkscreen.gbr	2025-01-12 3:31 PM	GBR File	1 KB
dumb_demo-Edge_Cuts.gbr	2025-01-12 3:31 PM	GBR File	1 KB
dumb_demo-F_Cu.gbr	2025-01-12 3:31 PM	GBR File	3 KB
dumb_demo-F_Mask.gbr	2025-01-12 3:31 PM	GBR File	2 KB
dumb_demo-F_Paste.gbr	2025-01-12 3:31 PM	GBR File	2 KB
dumb_demo-F_Silkscreen.gbr	2025-01-12 3:31 PM	GBR File	12 KB
dumb_demo-job.gbrjob	2025-01-12 3:31 PM	GBRJOB File	3 KB
dumb_demo-NPTH.drl	2025-01-12 3:32 PM	DRL File	1 KB
dumb_demo-PTH.drl	2025-01-12 3:32 PM	DRL File	1 KB

Zip all the files.

Sanity check the
dates/times are within
a few mins of each
other.

(In case a file didn't export)

Testing



Drag your file here



(Example error: I didn't include a board outline in kicad so this is cut too close!)

Part 4: Prototype Bring-Up

Soldering 101

- Hopefully you have previous soldering experience!
- Modify your design based on your team(s) experience, OR plan on ordering preassembled boards.

SMD Soldering Guides

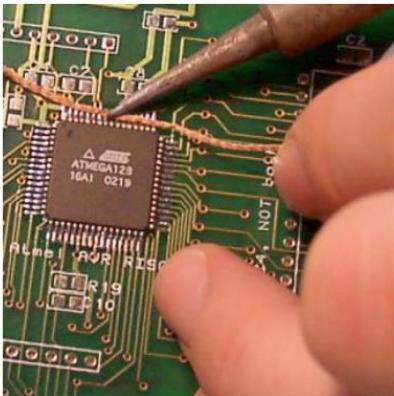
- Surface mount soldering is often done with *solder paste*.
- Can also do it with regular solder – use lots of flux if so!

Hand Soldering & Low-Cost

I've got a guide from 2003:

https://colinoflynn.com/wp-content/uploads/2025/01/smd_soldering.pdf

I'd just thought there is a chance you will remove solder bridges that you never know existed as they were too small to easily see.



8. Again inspect your joints!! Inspection is your friend in these SMD circuits. The optimum system would be a 20-30x stereo microscope, although they are very pricey. You may be able to get the "Intel QX3+ Microscope" to work for this though, as it can be used out of its stand (although it may be hard to focus in this mode) and connected to your computer for a nice

Solder Paste



Solder spheres & flux mixed together.

Often needs to be stored at low temp or the flux becomes too liquid & separates!

Available in tubes (left) and tubs.

Solder Paste Usage

- Best usage with a stencil (can order with PCB).
- But can also use a toothpick to “paint” on pads. If you are careful this will work with multi-package SMD well!

See the next three videos...

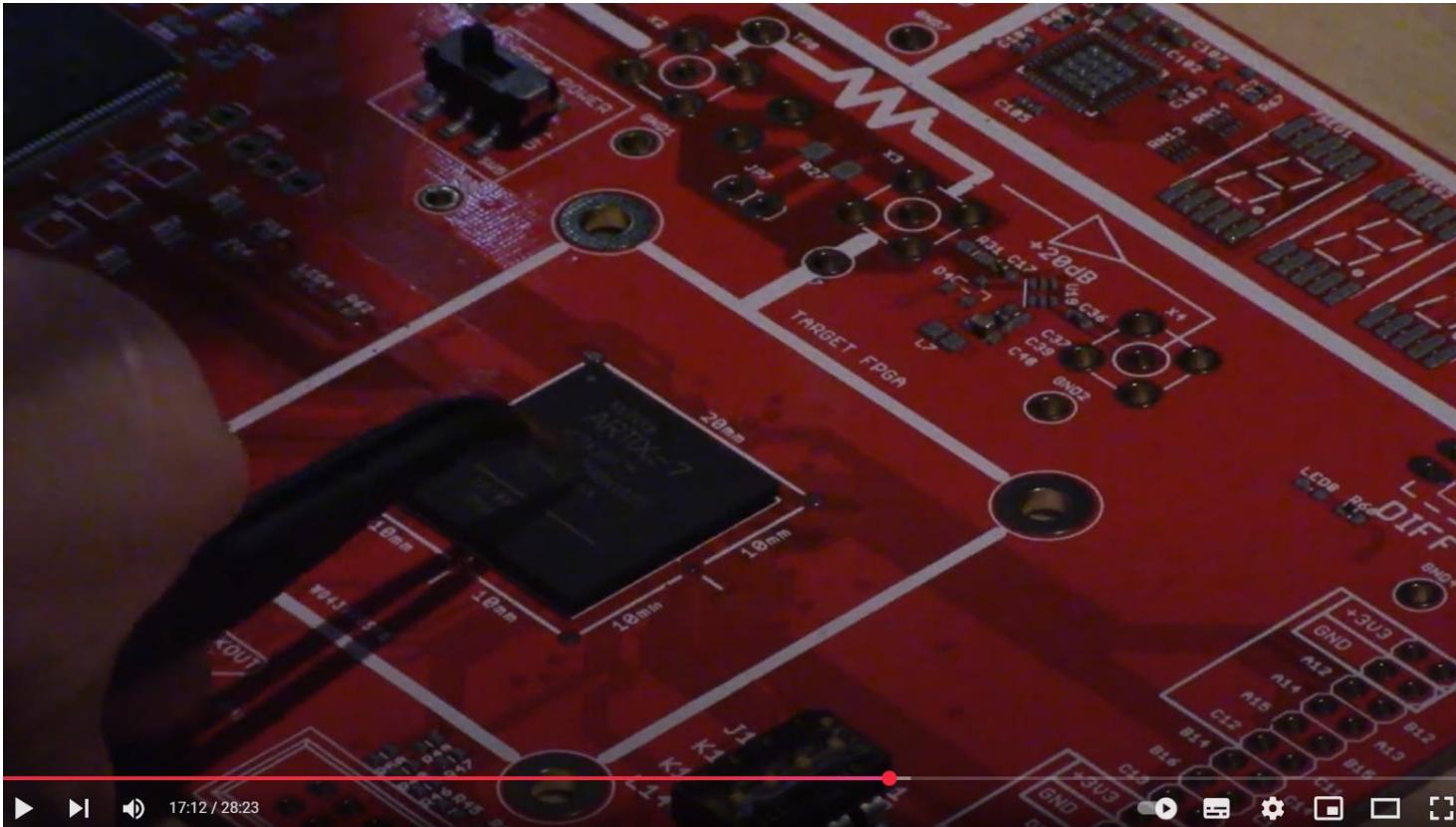
e.g., Hand Assembly Example



<https://www.youtube.com/watch?v=-DMYJmB4naA>

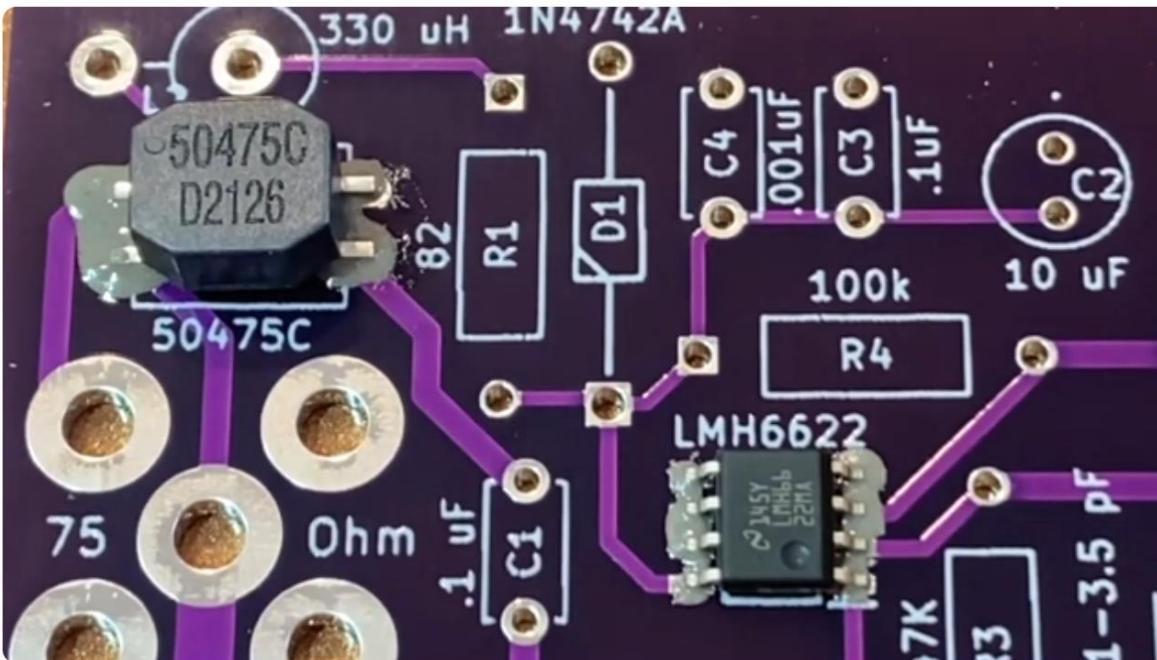
<https://colinoflynn.com/2015/10/low-cost-smd-soldering-setup/>

e.g., Hand Assembly Example screenshot



<https://www.youtube.com/watch?v=-DMYJmB4naA>

Soldering with a Skillet



Use an electric frying pan (skillet) to reflow solder paste



Subscribe

54 Share Download Clip ...

<https://www.youtube.com/watch?v=i8zzNZV8AlU&t=2s>

REMEMBER THE GOLDEN RULE

Design your board for how you plan on getting it made and built.

- *If you might use skillet assembly, keep all SMD parts on top side only!*

Bring-Up Best Practices

- If assembling your own board:
 - Assembly a smaller portion and test at a time.
 - E.g., I may build up the power supply section of a board first
- Use current limited power supplies if possible (if board doesn't need max current initially).
- Confirm as much as you can is working before doing “dangerous” things (like triggering a high-current mode).

Thermal Camera Checks

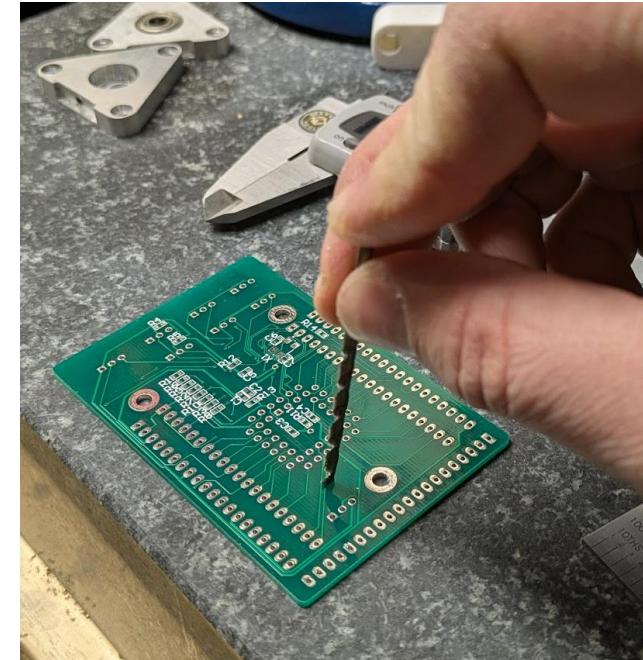
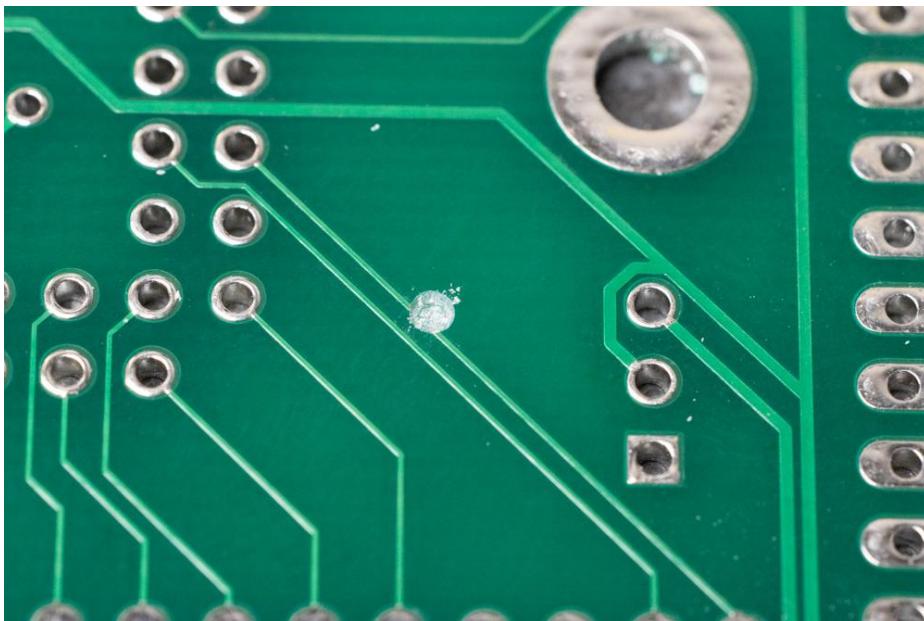
Use of a thermal camera can be helpful on important bring ups to watch for “hot spots” before you feel (or smell) them:



Bodging & Repairs

You may need to modify the PCB to fix things! Typical operations:

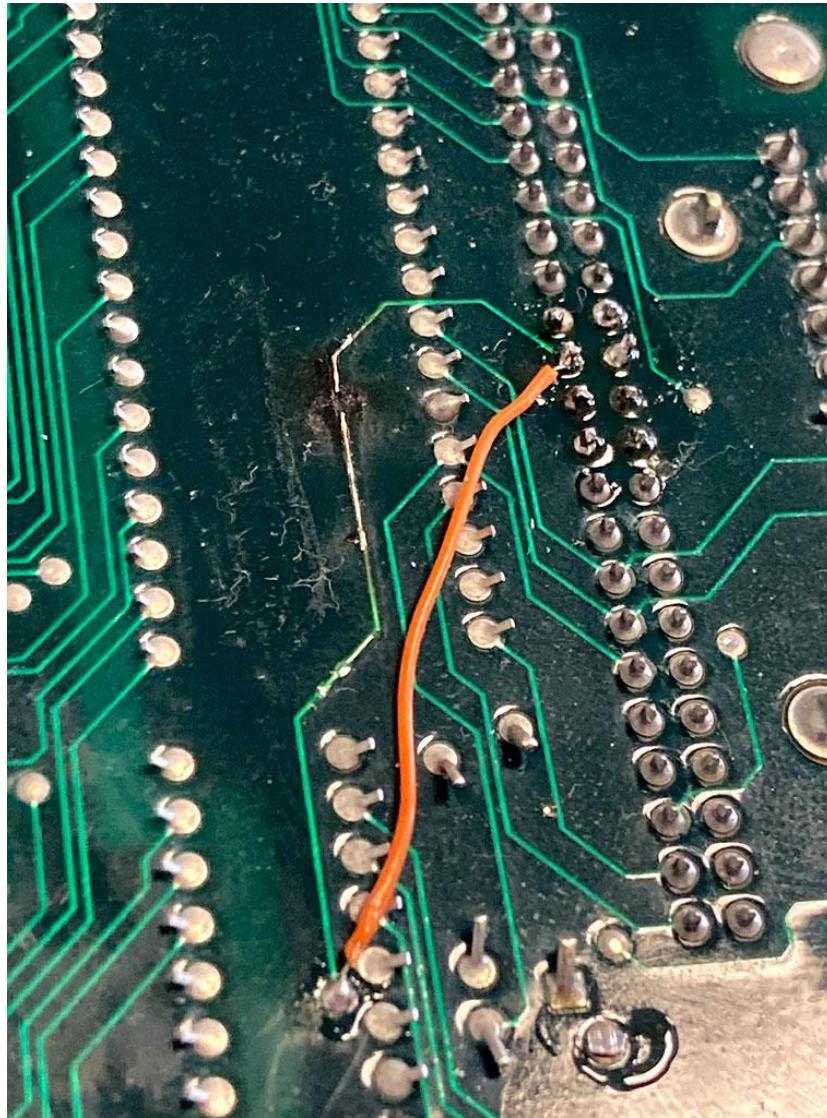
1. Cut a trace – easy to use a small drill bit for this (handheld):



Bodging & Repairs

2. Solder a *bodge wire* to fix a missing connection. Often used in combination with the drilling to re-route.

Or to repair (as in right)



<https://personal.garrettfuller.org/>

Further Learnings

That's it! There is tons (and tons) of information out there:

- Reference books
- YouTube (EEVBlog has a lot of videos on these topics)
- Forums

Don't get overwhelmed – make mistakes. Ignore some of the online overly pedantic advice. Have fun!