



ALTUMLIVE 2018: Designing for Adaptation

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**San
Diego**
10/4/18

Who I am

- Director of Hardware Engineering at Reach Labs
- Design phased arrays, power systems
- ~10 years of HW experience

What this is about

- How to design defensively and make it easy to modify your boards so you can skip re-spins
- "DFH" - Design for Hacking

What this isn't about

- How to rework
- How to debug/troubleshoot
- Design for manufacturing

Difficulty of rework

Don't get intimidated. You need:

- A stereo microscope
- Good soldering iron
- No coffee

or

- A good technician

Useful standards

IPC-7711/7721 - Rework, Modification, and Repair of Electronic Assemblies

IPC-A-600 - Acceptability of Printed Circuit Boards

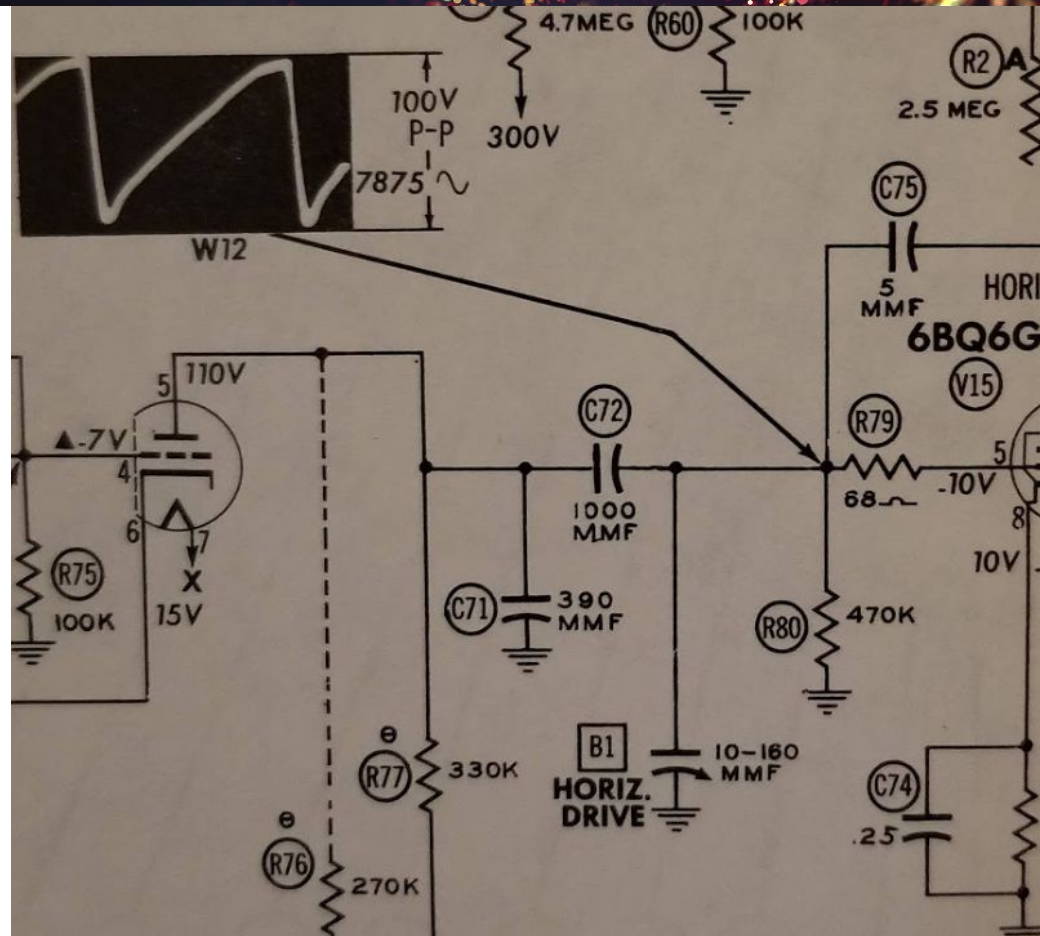
IPC J-STD-001-G - Requirements for Soldered Electrical and Electronic Assemblies

IPC-A-610E - Acceptability of Electronic Assemblies

Setting Up

Organization

- Comment and annotate schematics
- Label testpoints
- Describe correct behavior



High level techniques

- 1 Isolate subcircuits
- 2 Give yourself options
- 3 Make it easy to go between those options

High level techniques

1

Isolate subcircuits

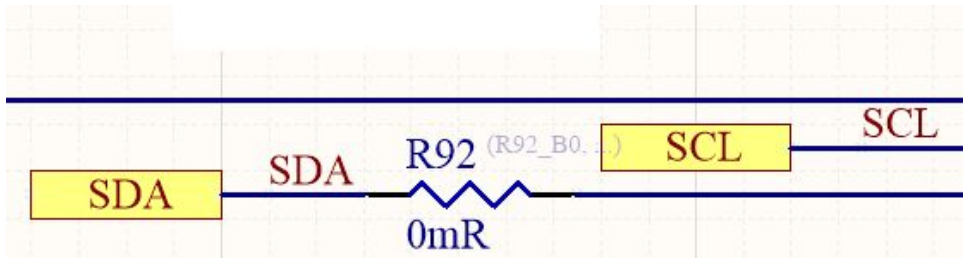
Isolate subcircuits

Why it's a good idea:

- Allows you to use pieces of multiple designs together
- With multiple boards, you can do A/B testing of modifications
- Plus easier to debug, characterize, verify

Isolate subcircuits

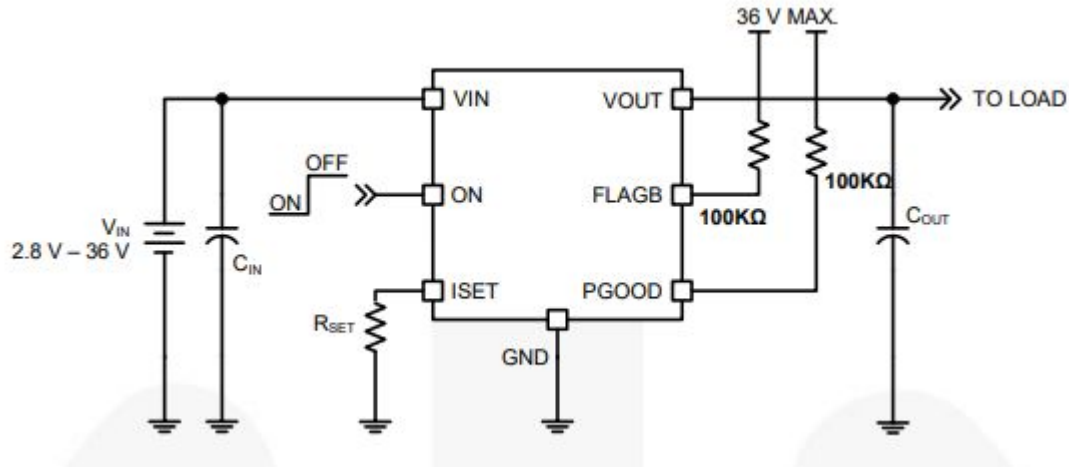
Series resistors



Note: 0 ohm resistors can actually be as high as 50 mOhm. Pick a precision small value to get a resistor closer to 0 ohms.

Isolate subcircuits

Load Switches

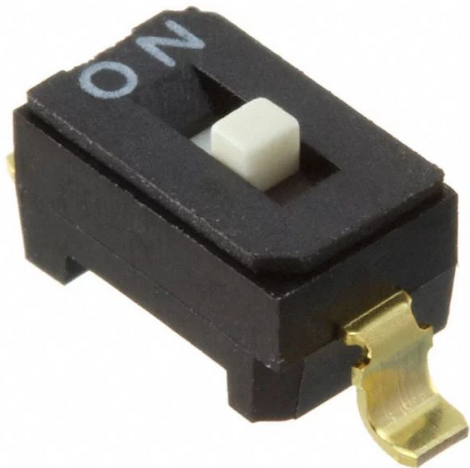


Load switches allow digitally controlled/selective isolation, plus bonus debugging signals

Isolate subcircuits

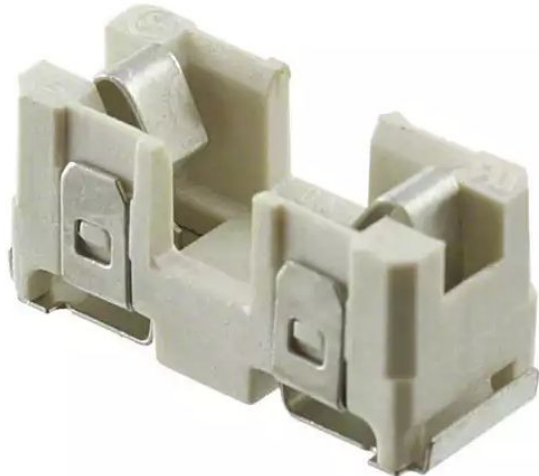
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Jumpers



Use a removable fuse as a jumper!

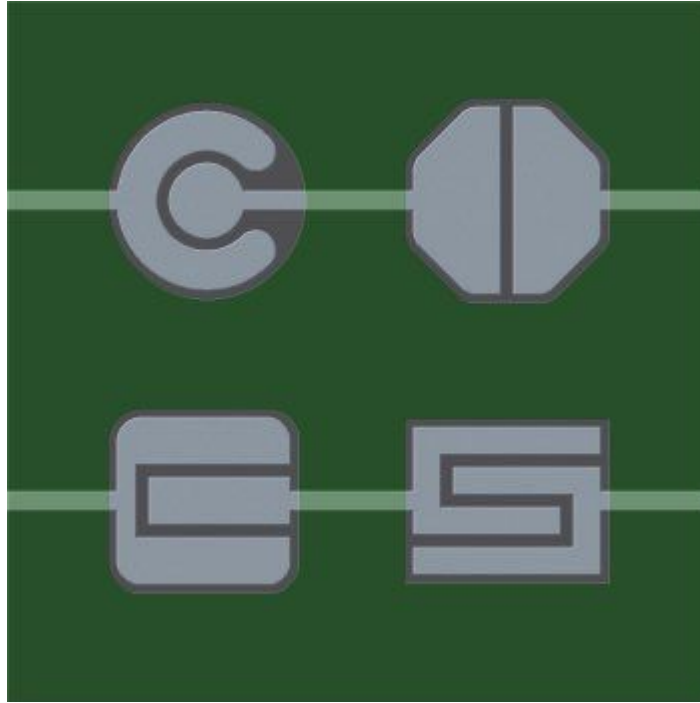
486-1991-ND



Isolate subcircuits

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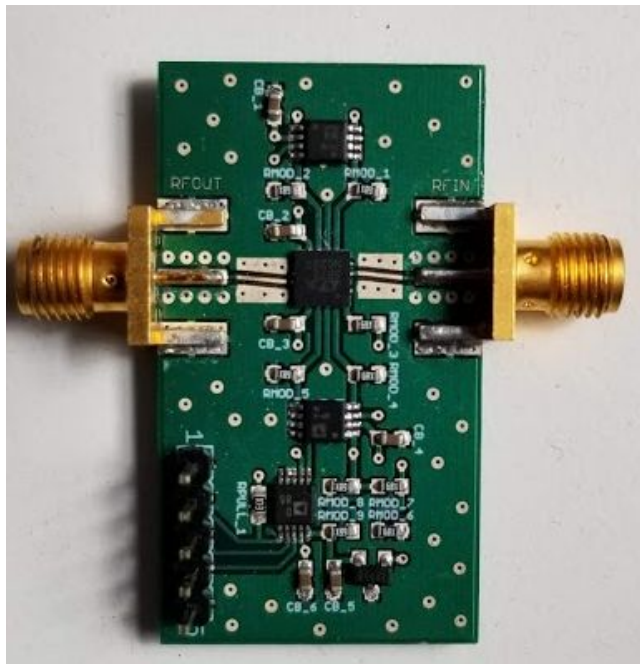
Jumpers



From Victor Laynez, @roteno

Isolate subcircuits

Connectors



Watch out for big current loops in power lines. Will wreck EMC. Also watch out for loss in RF lines.

Isolate subcircuits

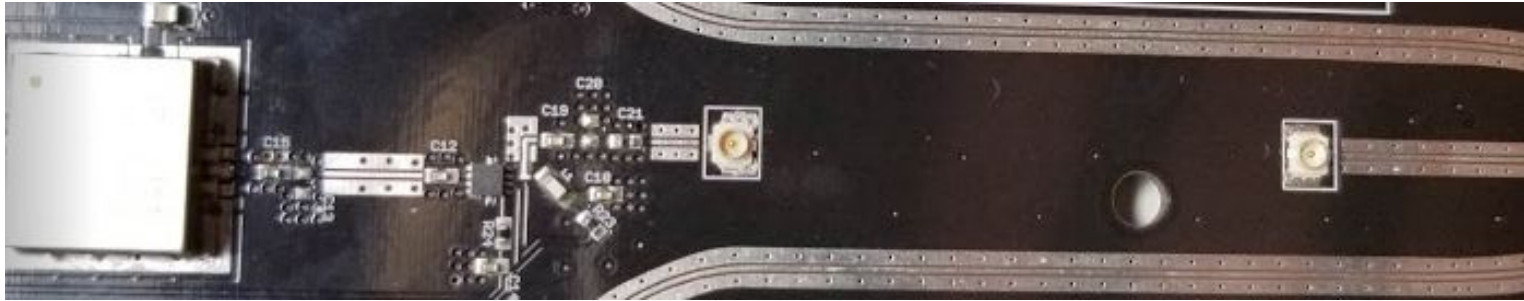
Connectors



Example from TI Launchpad

Isolate subcircuits

Connectors



RF jumper/isolation

High level techniques

- 2 Give yourself options

Give yourself options



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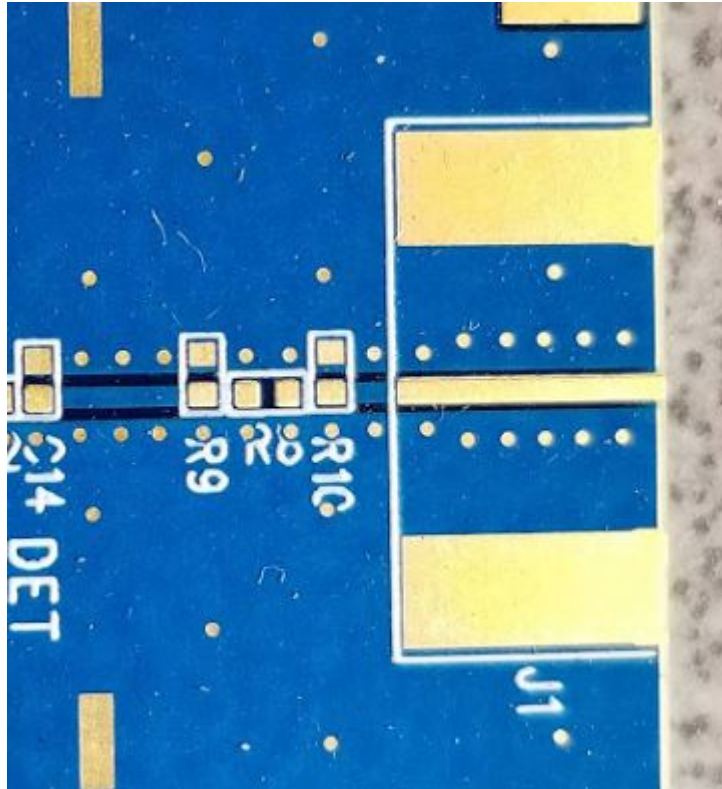
DNP is your best friend

- Costs nothing
- Easiest rework option you have
- DNP all over the place!

Give yourself options

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DNP Filters

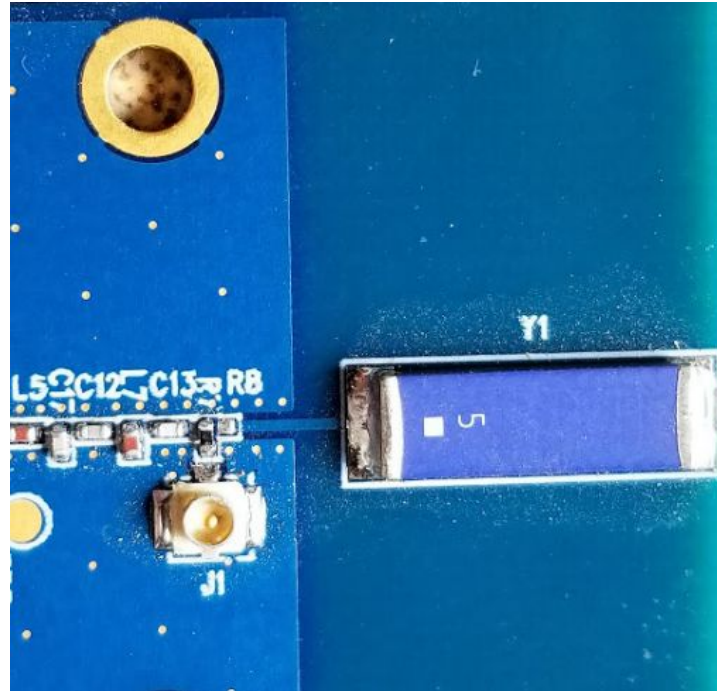


Classic example: pi/T network

Give yourself options

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DNP RF Connectors

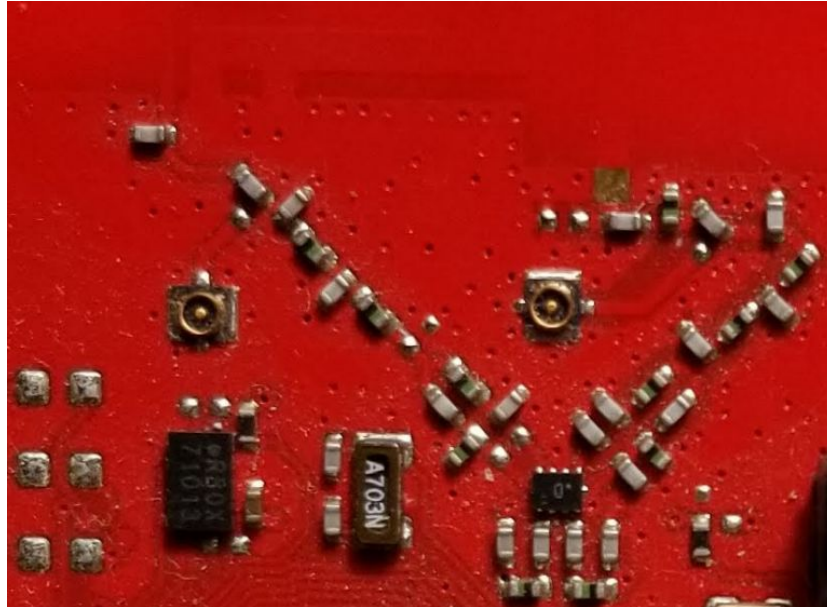


U.FL connector to measure before antenna

Give yourself options

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DNP RF Connectors



Another example from the TI board with a smaller connector before PCB antennas

Give yourself options

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DNP RF Connectors

BTW, tiny RF connectors are super confusing.

U.FL = IPEX = IPX = AMC = MHF = UMCC

If it's not one of those, it won't fit and you won't realize it until the moment you try to plug it in.

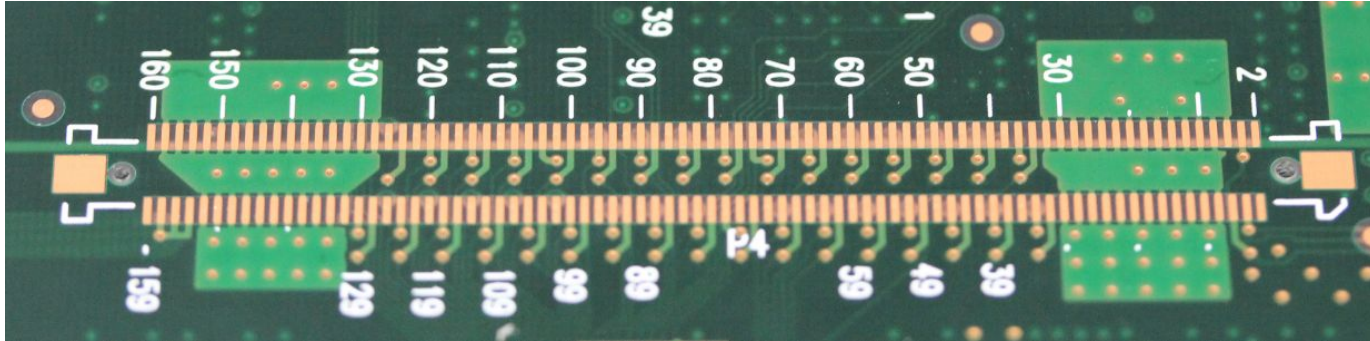
U.FL $\neq$ E.FL $\neq$ W.FL $\neq$ lots of other tiny, similar looking connectors

*Don't forget, these only work up to 6 GHz. If you're higher than that, you need a different (bigger, more expensive) connector.

Give yourself options

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DNP Debug Connectors



Give yourself options

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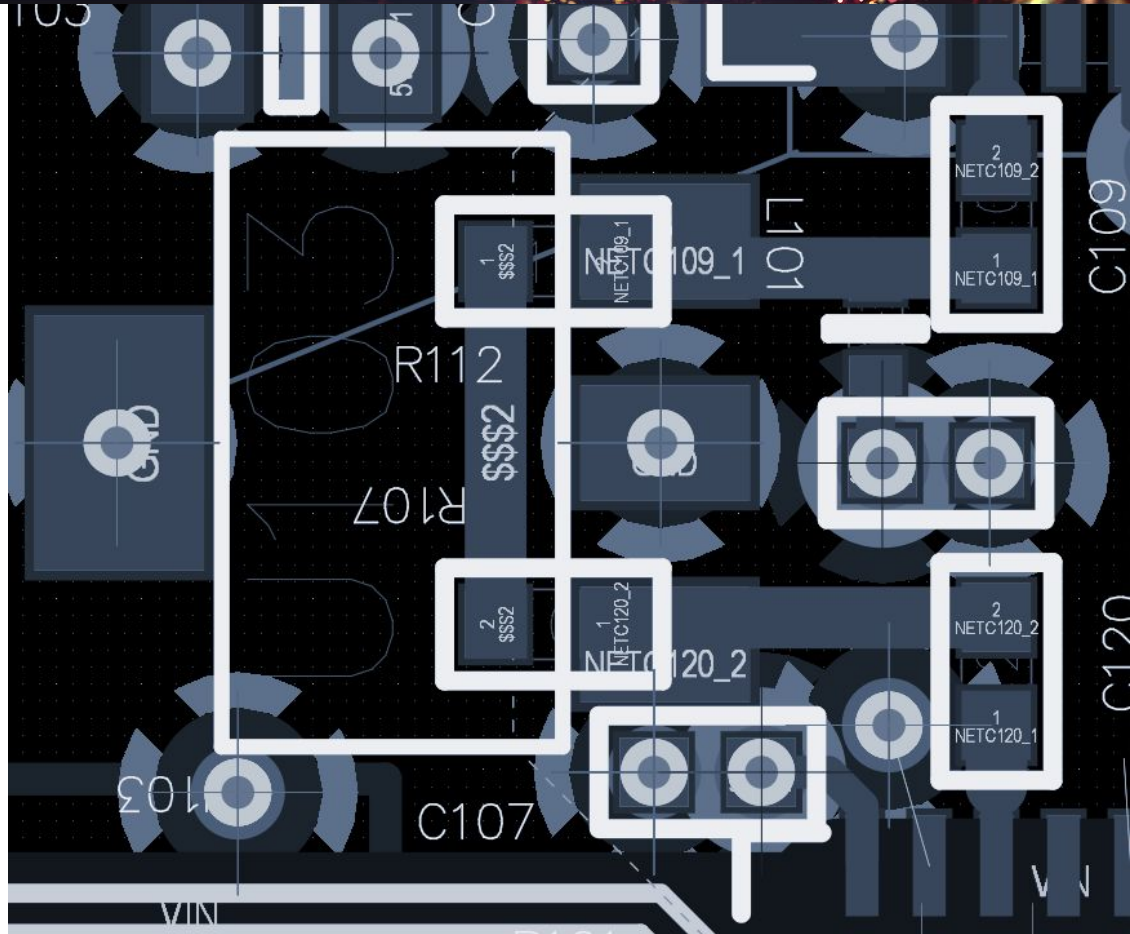
DNP Entire sub-circuits

- Use this to try different implementations of the same circuit
- Also useful if you want to make multiple versions of the same product

Give yourself options

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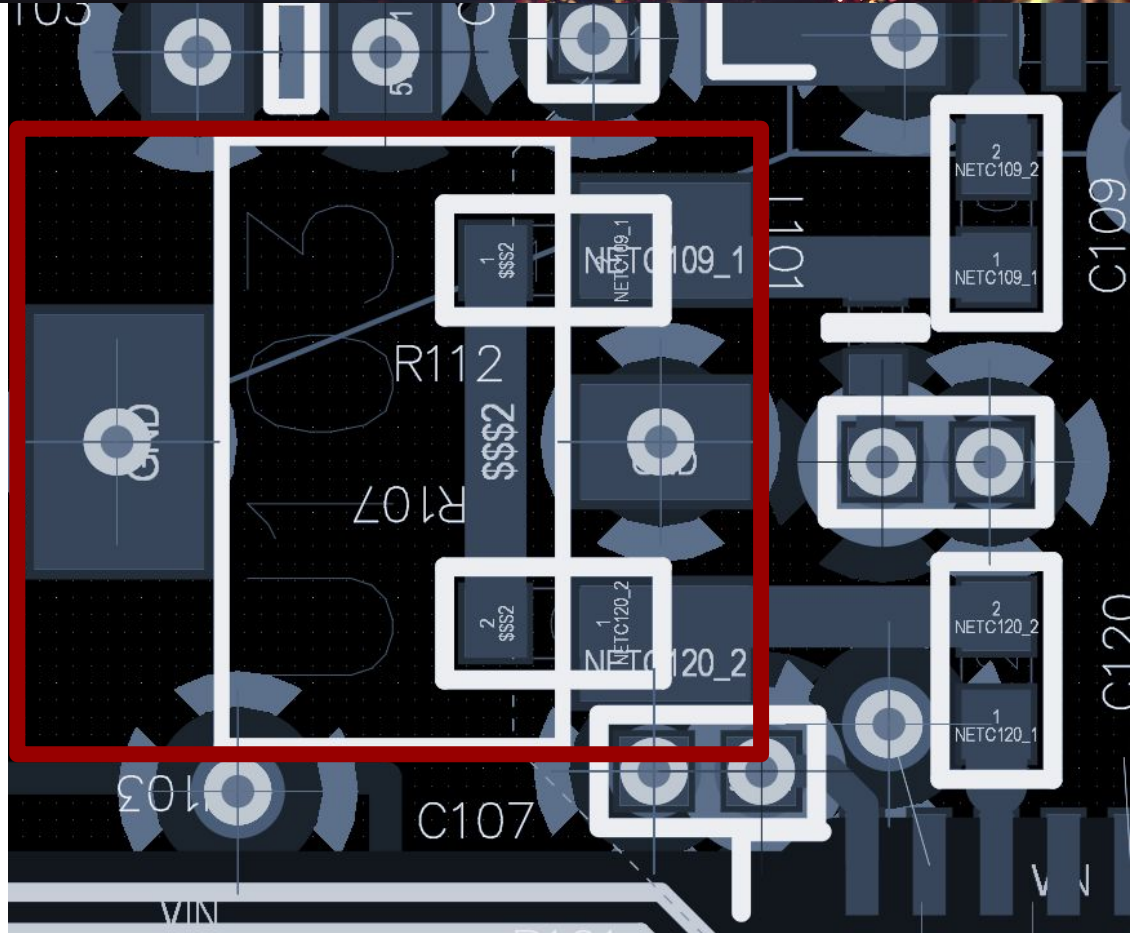
Footprint in footprint



Give yourself options

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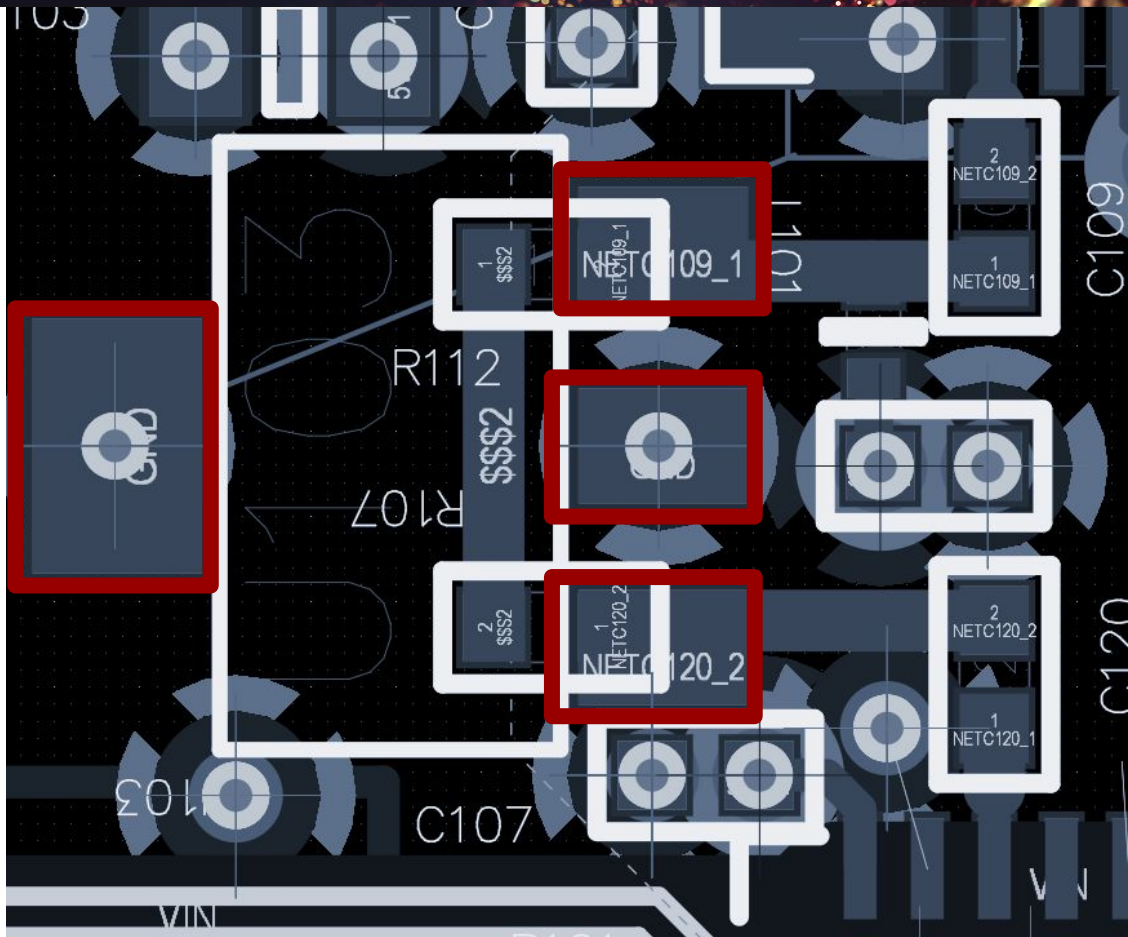
Footprint in footprint



Give yourself options

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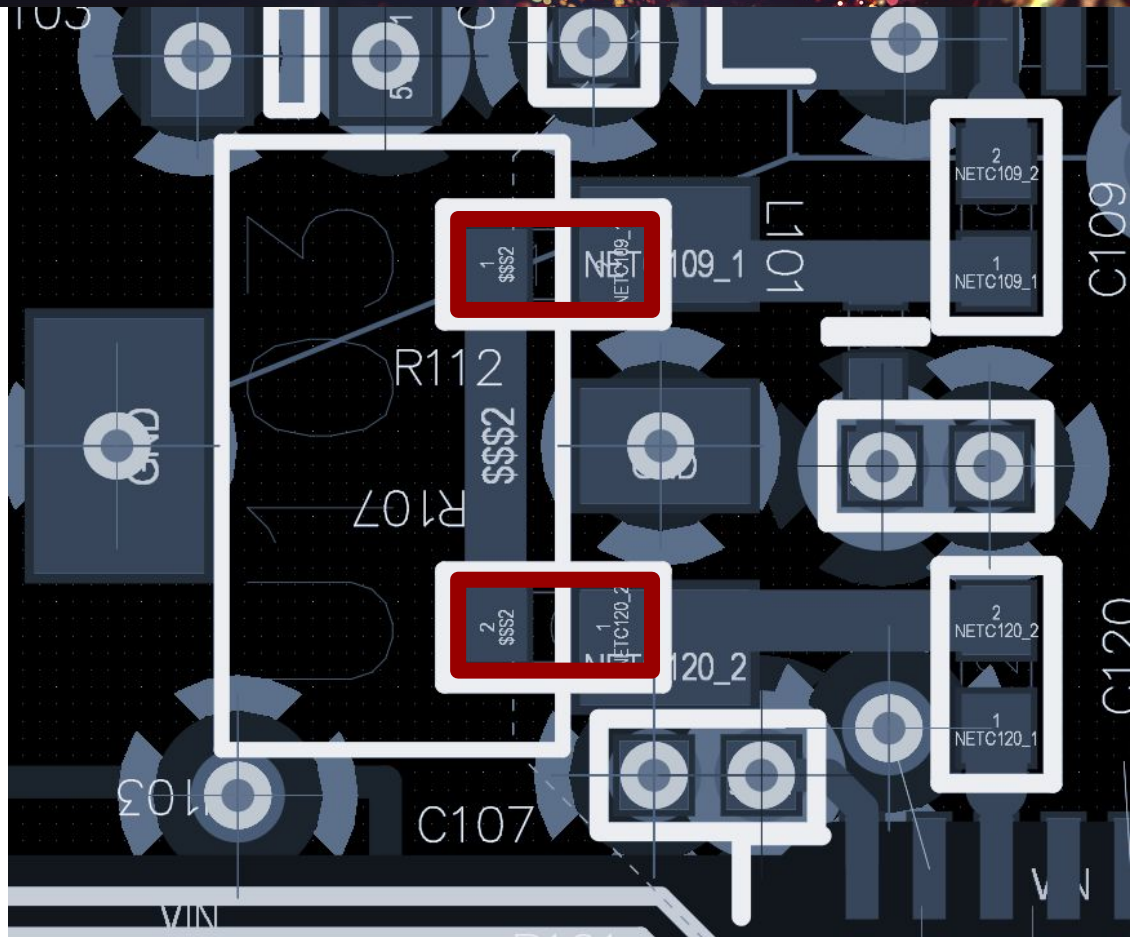
Footprint in footprint



Give yourself options

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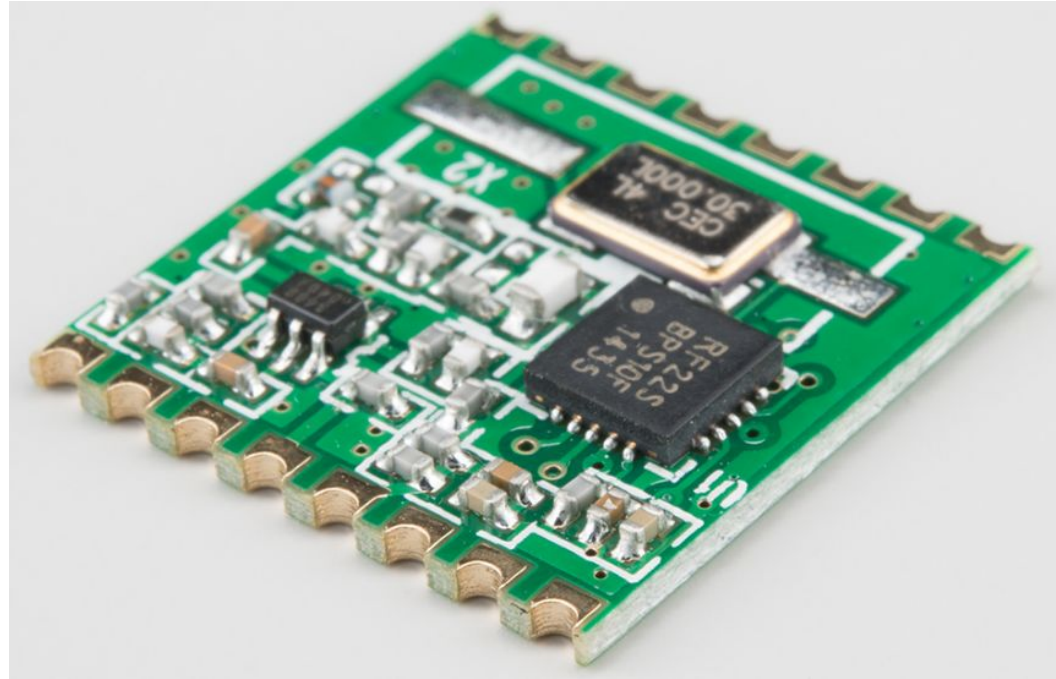
Footprint in footprint



Give yourself options

Castellated modules

- Add and remove entire subcircuits
- Easier to redesign a risky section instead of the whole board
- Allows easy isolation for test before integration

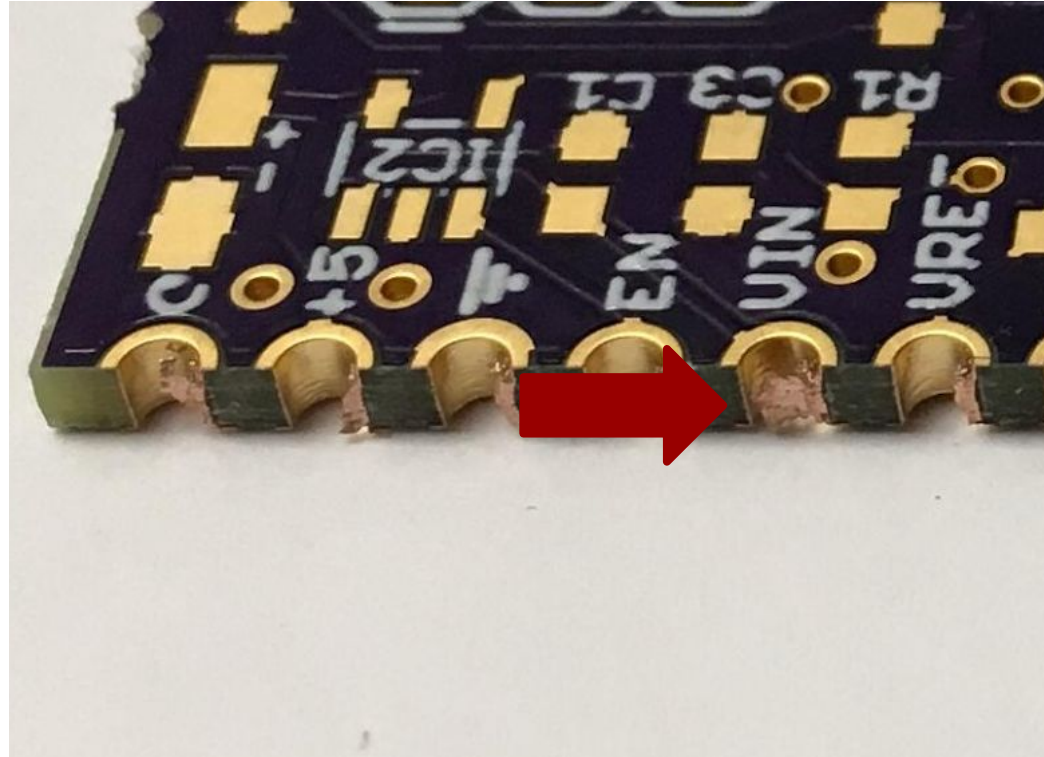


Give yourself options

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Castellated modules

Make sure to tell your fabricator
you want the board to be
castellated

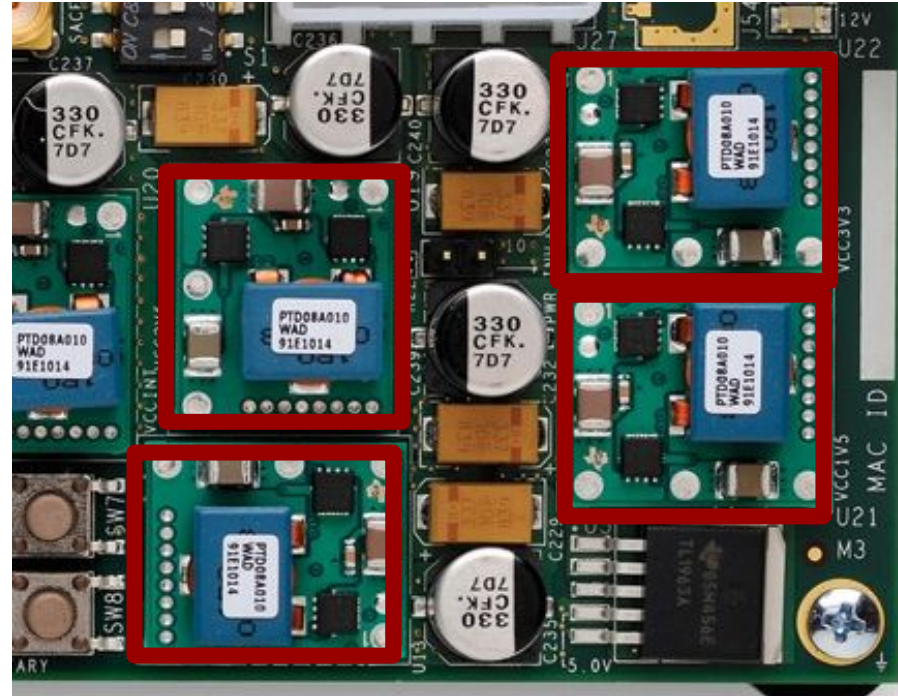


Give yourself options

Castellated modules

They also allow you to use pre-made components, like power supplies.

If you want to make multiple versions of a product, but they have different power requirements, you can swap out modules.



Give yourself options



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Castellated modules

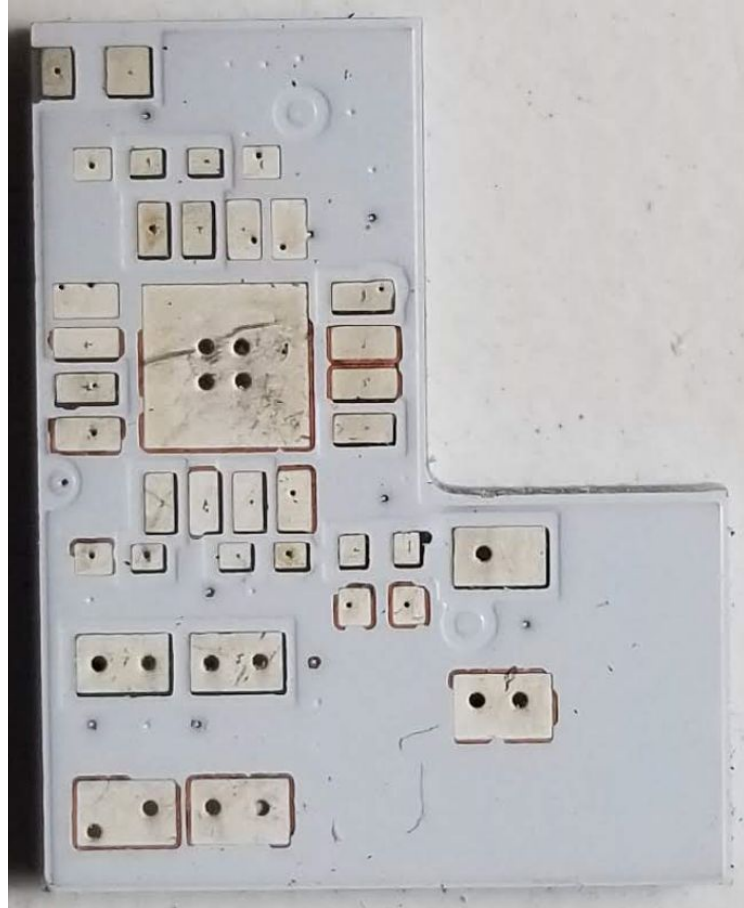
Downsides:

- Takes up way more space
- If you have lots of pins, you need a larger module
- Not great for RF
- Not great for high power
- Not great for high speed

Give yourself options

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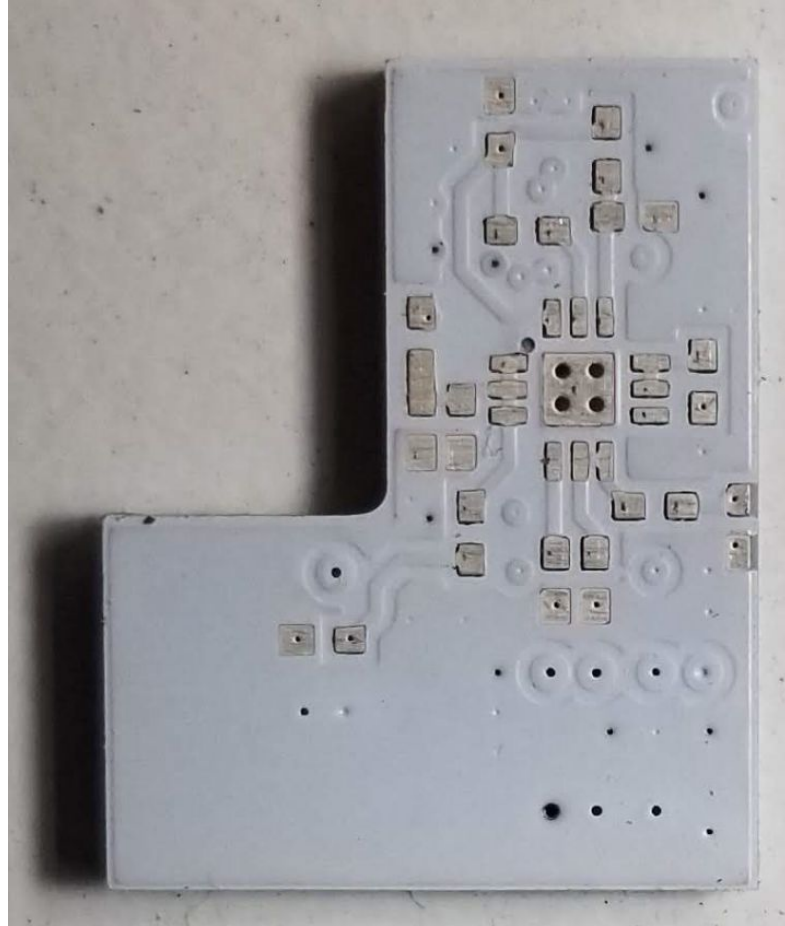
Adapter/riser board



Give yourself options

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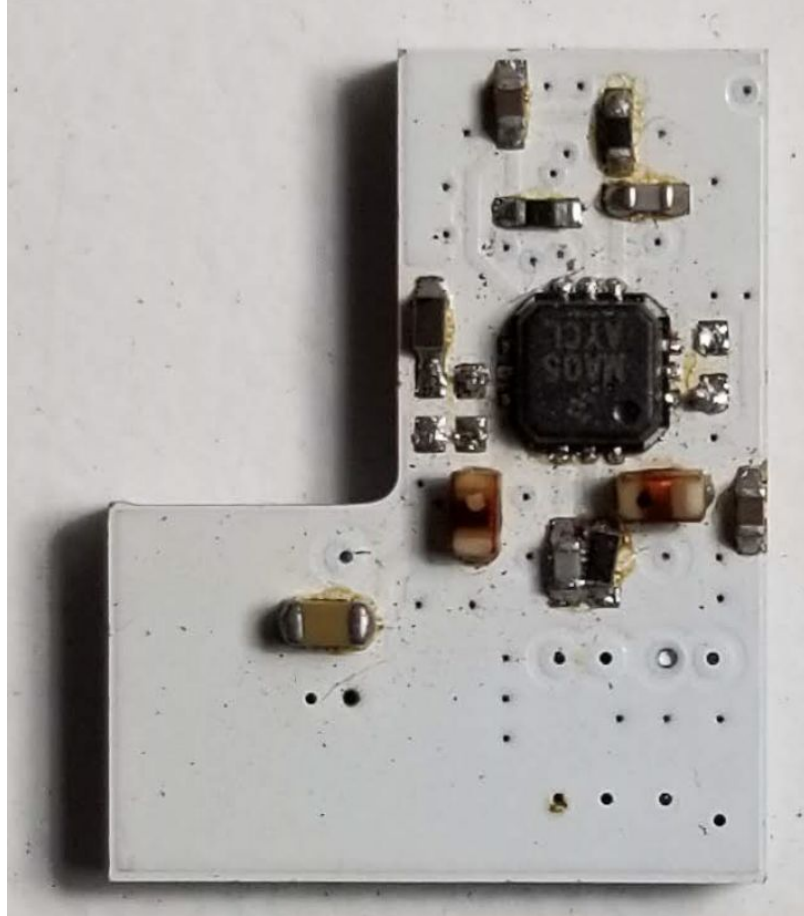
Adapter/riser board



Give yourself options

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Adapter/riser board



Give yourself options

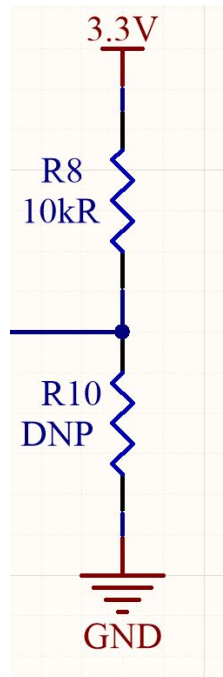
Adapter/riser board

- This can be pretty jank
- But it can also work
- The more parts that need to be covered by the adapter, the harder it is
- Don't use the datasheet recommended pad size on the bottom of the adapter board. You need to go slightly smaller.
- XRay if you can, and use flux.

Give yourself options

Pull up/down

Put in both pull up and pull down resistors, but only populate one.



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Break out spare IO and status/settings pins

Give yourself options

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PCB notes

Put a rectangle of white silkscreen in a corner and you can use it to label boards with specific changes or other notes.

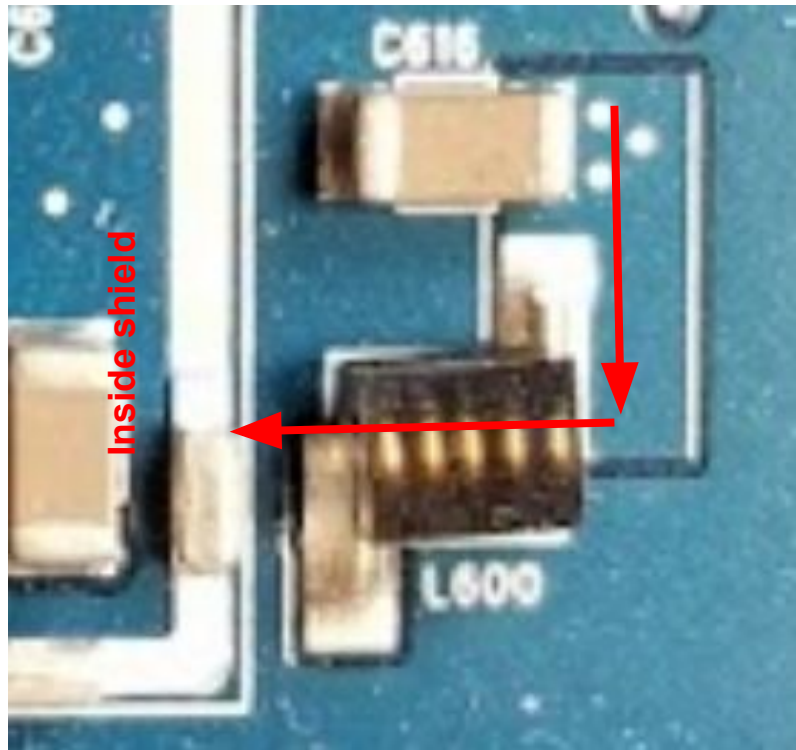


Give yourself options

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Chokes

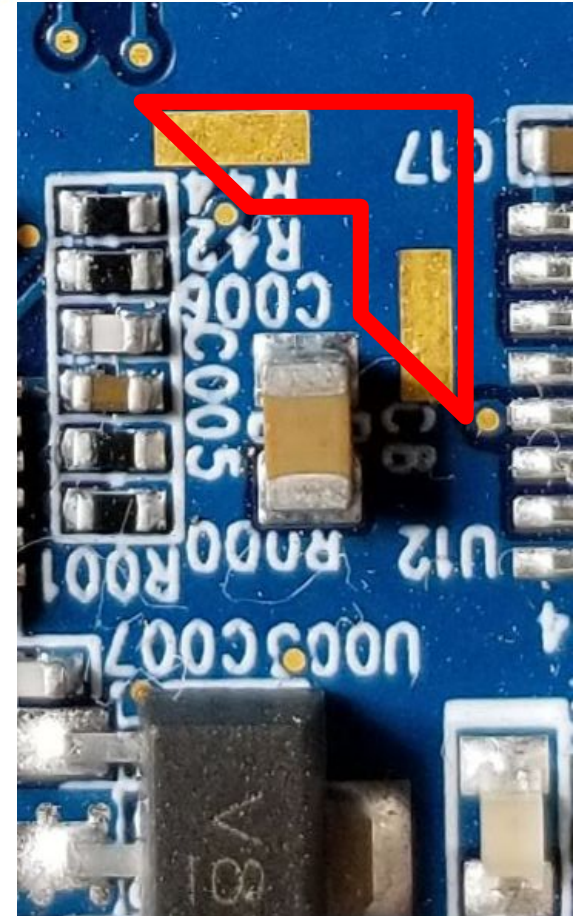
Add a series choke that you can replace with a 0R if you need to. Very helpful for EMC testing.



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Shielding

- Put down pads for a removable shield just in case
- Use removable can shields instead of solder down shields



High level techniques

- 3 Make it easy to go between those options

Make it easy to change

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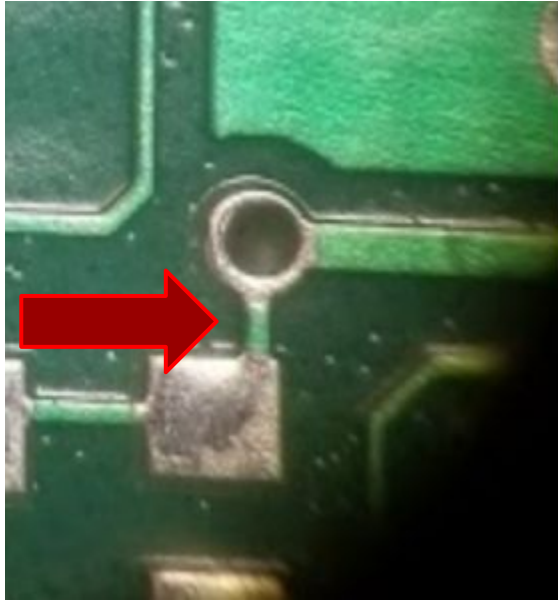
Vias in pads



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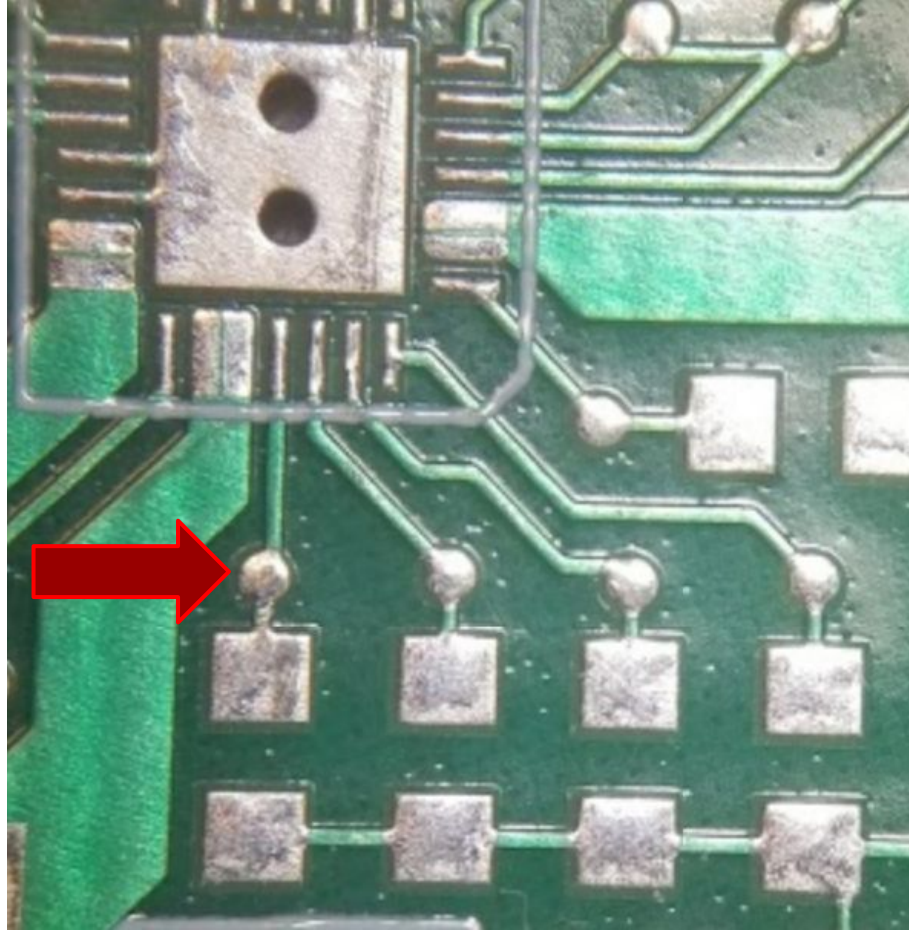
Vias in pads



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Vias in pads

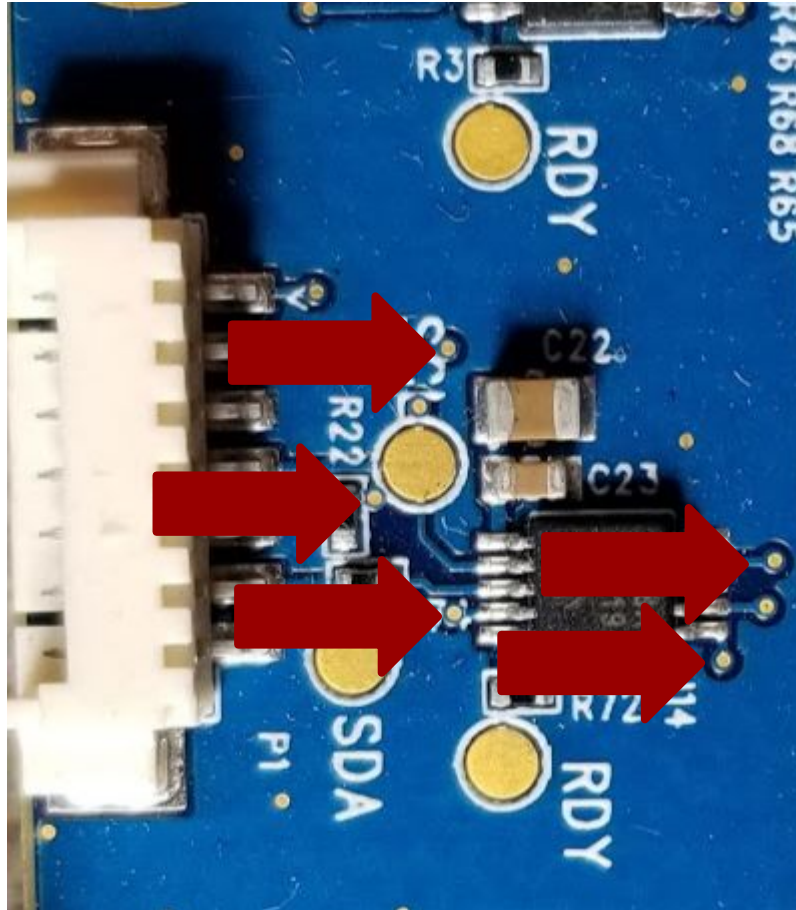


Make it easy to change

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Tenting vias

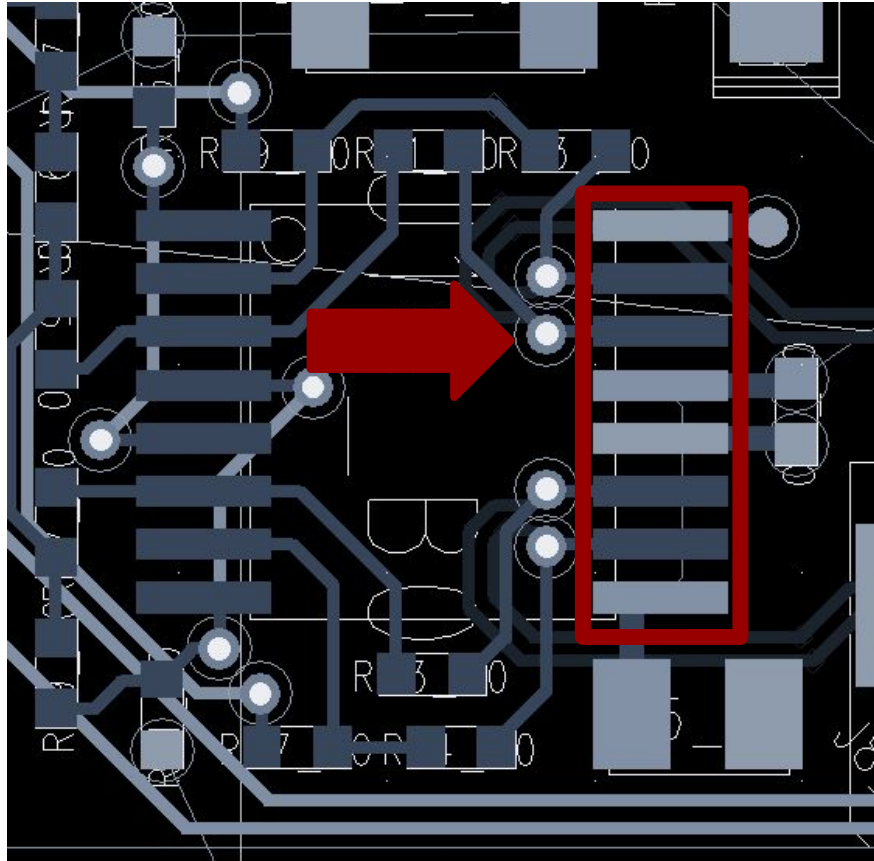
Look at all those test points!



Make it easy to change

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Tenting vias



Make it easy to change

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Test points

Put test points everywhere.

- Copper test point for small spaces
- Solderable testpoints for bigger stuff (like power)
- These big ones won't break off after hours of abuse



36-5018CT-ND



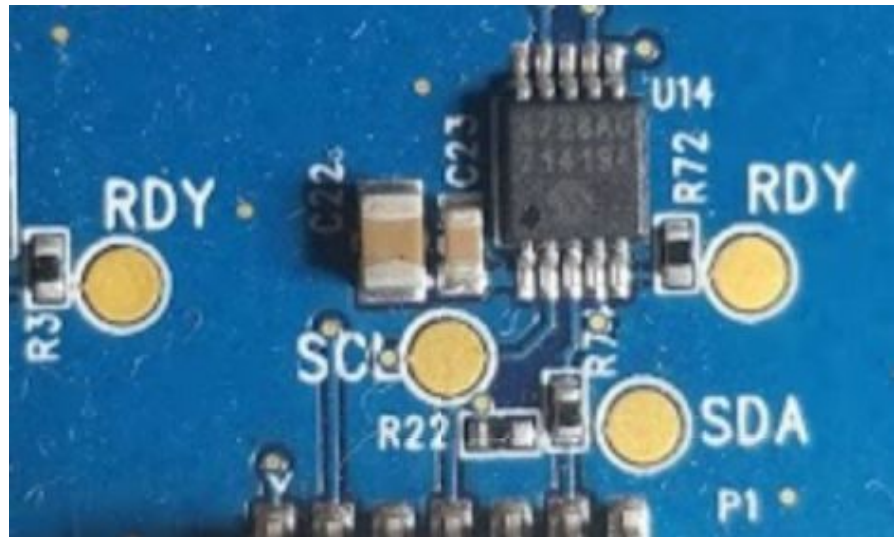
Make it easy to change

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Test points

Putting test points on communication lines helps with probing and moving/adding things to the bus.

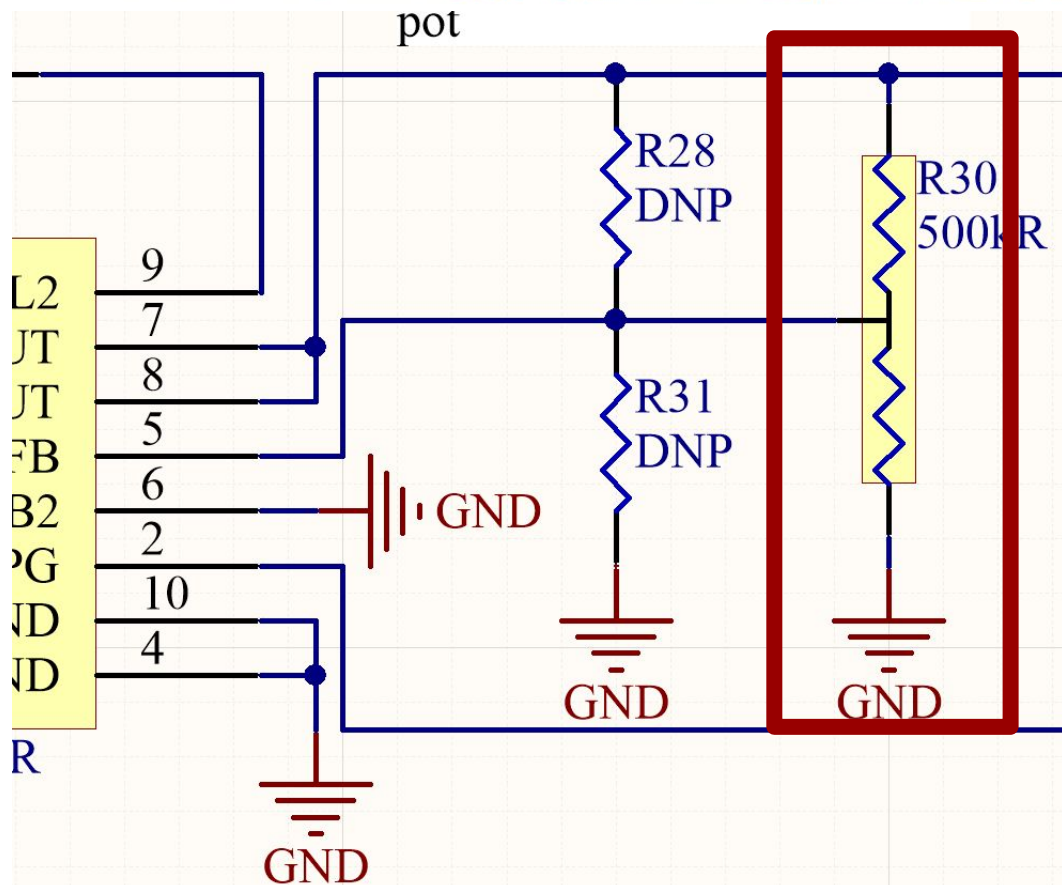
Label them in silkscreen! Make sure they're not obscured by other footprints.



Make it easy to change

Resistor dividers

If you're controlling settings using a resistor divider, use a pot instead. Makes it easier to adjust and tune rather than swap out resistors over and over.



Make it easy to change

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Power

Pick LDOs that have a high input voltage rating so you can change power sources

Voltage - Input (Max)	6V
Voltage - Output (Min/Fixed)	0.8V
Voltage - Output (Max)	5.5V

Voltage - Input (Max)	20V
Voltage - Output (Min/Fixed)	3.3V

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Footprints

If you can help it:

- Don't use QFN. External pins are easier to deal with.
- Don't pick very small parts (0201, even 0402).
- Draw footprints slightly larger or longer than in the datasheet

Make it easy to change



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Stackup

Keep all parts on the same side if possible. Way easier to reflow and rework. Big boards (large thermal mass) or parts that need to be reflowed can be done in a reflow oven.

Use leaded solder. It's easier to work with. Change to lead free during production.

Have a ground plane and power plane.

Make it easy to change

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Soldering

- Leave space for a soldering iron tip
- Think about things that can melt (like plastic connectors)



Make it easy to change



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Other materials

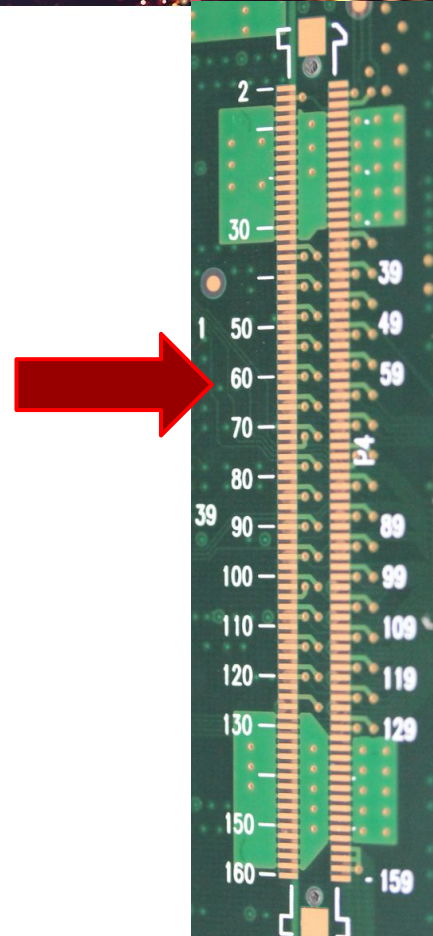
- If you need to use underfill, consider something like Loctite UF 3810. It can be removed with hot air.
- Avoid potting, RTV, or conformal coating until you're happy with the electrical performance

Make it easy to change

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Silkscreen

- Mark pin numbers periodically
- Make sure designator is visible when part is populated

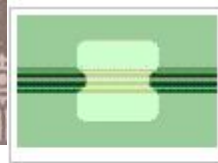
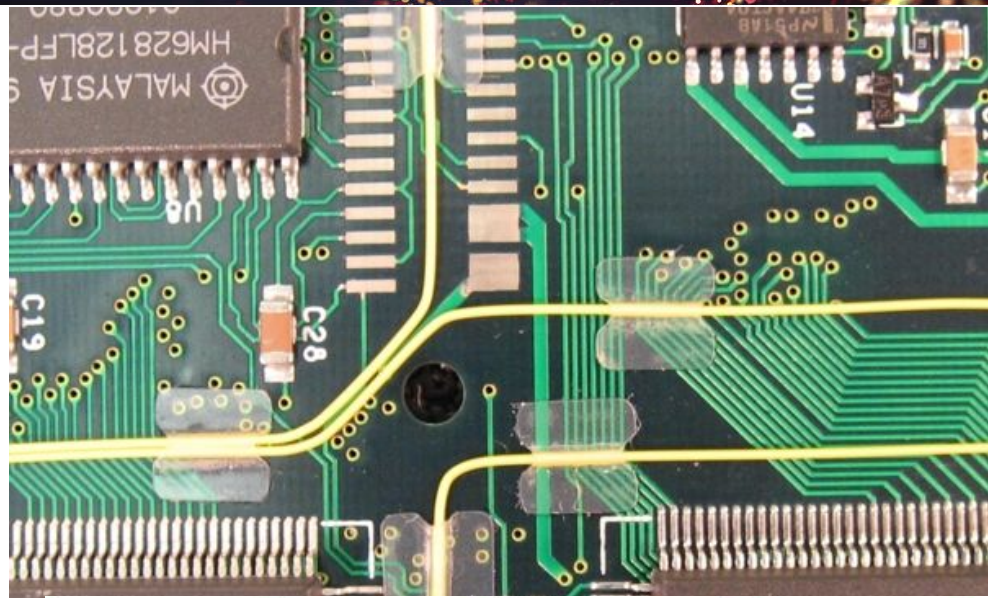


Make it easy to change

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Circuit tape

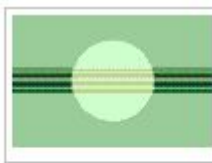
- From CircuitMedic.com
- Holds wires to PCB, cures fully in 72 hours. Leaves no residue.



310-1002

.394" (10.0 mm)

Square



310-1001

.394" (10.0 mm)

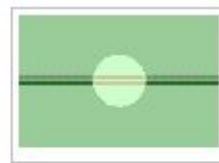
Round



310-0652

.256" (6.5 mm)

Square



310-0651

.256" (6.5 mm)

Round

Make it easy to change



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What about RF?

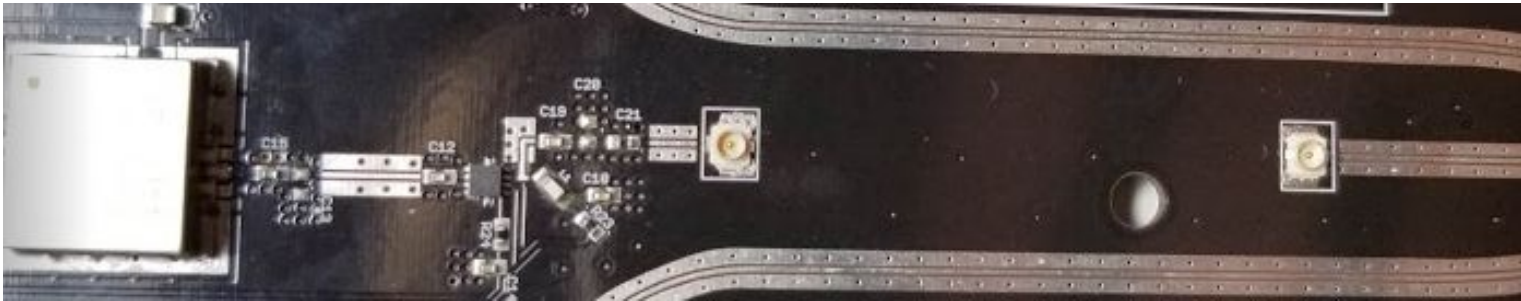
“RF is scary and fragile and I’m afraid I’ll mess it up” - almost everyone

Make it easy to change

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What about RF?

We already saw how to jumper RF



Make it easy to change

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What about RF?

You can also buy really thin gauge coax cable (micro coax)

Product Attributes	
Categories	Cables, Wires Coaxial Cables (RF)
Manufacturer	Molex - Temp Flex
Series	Temp-Flex 100066
Part Status	Active
Cable Type	Coaxial
Cable Group	-
Wire Gauge	30 AWG
Conductor Strand	7 Strands / 38 AWG
Jacket (Insulation) Material	Fluorinated Ethylene-Propylene (FEP)
Jacket (Insulation) Diameter	0.071" (1.80mm)
Shield Type	Braid
Impedance	50 Ohms

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What about RF?

Part Status	Active
Cable Type	Micro Coaxial
Cable Group	-
Wire Gauge	50 AWG
Conductor Strand	7 Strands / 58 AWG
Jacket (Insulation) Material	Perfluoroalkoxy (PFA)
Jacket (Insulation) Diameter	0.006" (0.16mm)
Shield Type	Spiral
Impedance	50 Ohms

A9450W-328-ND,
\$5.50 a foot

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Pigtails

Semi-rigid pigtails are better than floppy ones

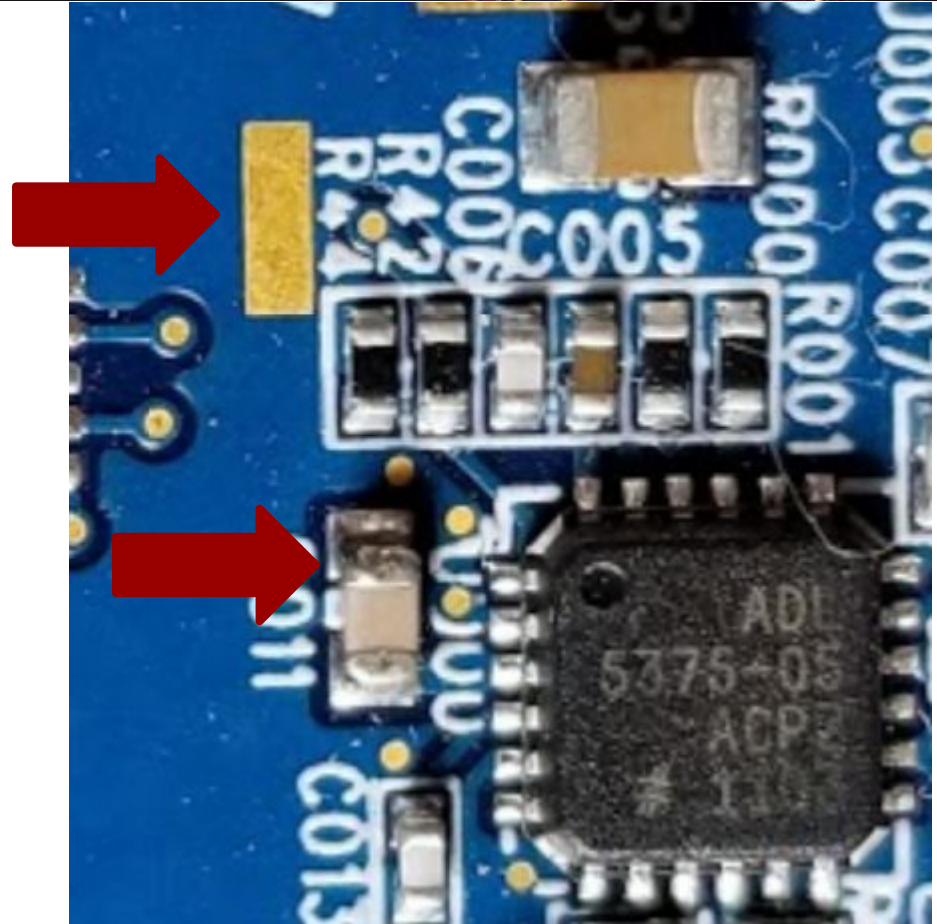


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Pigtails

Give yourself a low inductance ground pad for your pigtails

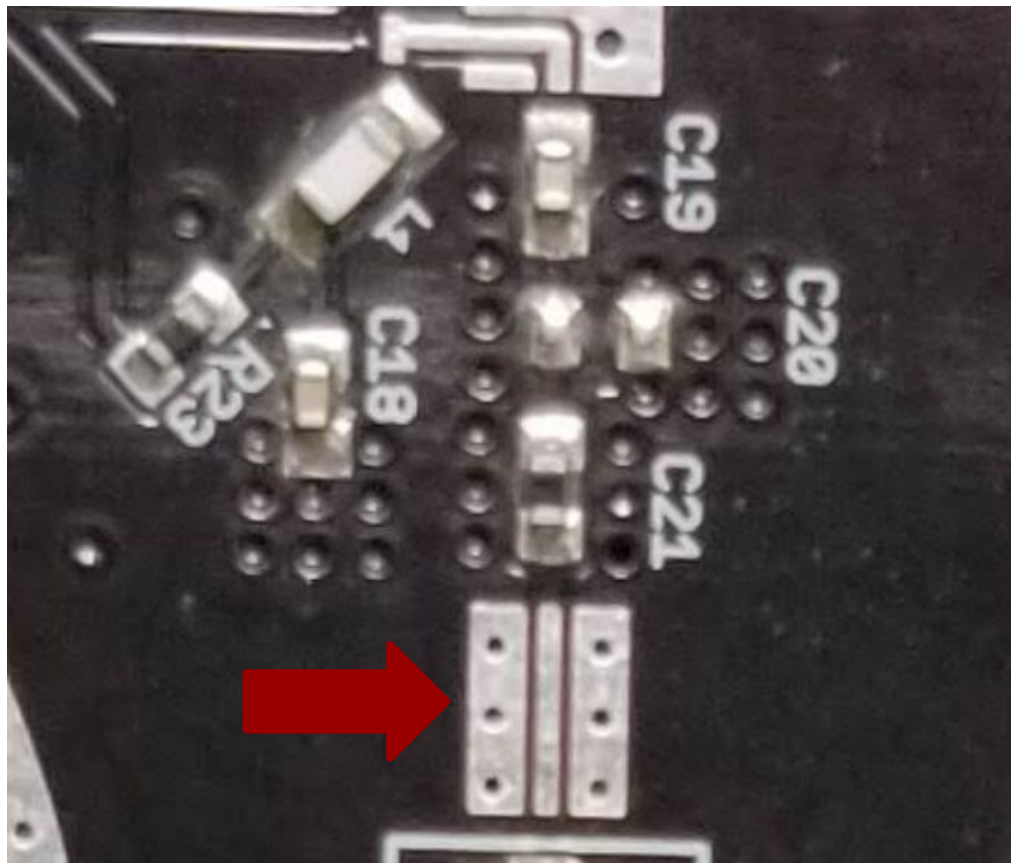


Make it easy to change

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Coplanar waveguide

- Easier to pigtail
- Possible to probe without soldering



Make it easy to change

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Antennas

If your design allows it, picking an antenna structure that is easy to modify can be helpful.



High level techniques

- 1 Isolate subcircuits
- 2 Give yourself options
- 3 Make it easy to go between those options

Thank you!

Slides: hscott.net/adaptation
@hunterscott