ALTIUMLIVE 2018:
Designing for Adaptation

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

Jumpers

Use a removable fuse as a jumper!
Isolate subcircuits

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.
Connectors

Example from TI Launchpad
Isolate subcircuits

Connectors

RF jumper/isolation
Give yourself options

High level techniques

2
DNP is your best friend

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

DNP Filters

Classic example: pi/T network
Give yourself options

DNP RF Connectors

U.FL connector to measure before antenna
Give yourself options

DNP RF Connectors

Another example from the TI board with a smaller connector before PCB antennas
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 ≠ E.FL ≠ W.FL ≠ 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

DNP Debug Connectors
Give yourself options

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

Footprint in footprint
Give yourself options

Footprint in footprint
Give yourself options

Footprint in footprint
Give yourself options

Footprint in footprint
Give yourself options

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
Castellated modules

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

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

Adapter/riser board
Give yourself options

Adapter/riser board
Give yourself options

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.
Give yourself options

Extra IO

Break out spare IO and status/settings pins
Give yourself options

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.
Chokes

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

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
Vias in pads

Make it easy to change
Make it easy to change

Vias in pads
Make it easy to change

Vias in pads
Make it easy to change

Tenting vias

Look at all those test points!
Make it easy to change

Tenting vias
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
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.
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

Power

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

Soldering

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

- Mark pin numbers periodically
- Make sure designator is visible when part is populated
Make it easy to change

Circuit tape

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

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

What about RF?

We already saw how to jumper RF
What about RF?

You can also buy really thin gauge coax cable (micro coax)
What about RF?

<table>
<thead>
<tr>
<th>Part Status</th>
<th>Active</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable Type</strong></td>
<td>Micro Coaxial</td>
</tr>
<tr>
<td><strong>Wire Gauge</strong></td>
<td>50 AWG</td>
</tr>
<tr>
<td>Conductor Strand</td>
<td>7 Strands / 58 AWG</td>
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<tr>
<td>Jacket (Insulation) Material</td>
<td>Perfluoroalkoxy (PFA)</td>
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<tr>
<td>Jacket (Insulation) Diameter</td>
<td>0.006” (0.16mm)</td>
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<tr>
<td>Shield Type</td>
<td>Spiral</td>
</tr>
<tr>
<td>Impedance</td>
<td>50 Ohms</td>
</tr>
</tbody>
</table>

A9450W-328-ND, $5.50 a foot
Make it easy to change

Pigtails

Semi-rigid pigtails are better than floppy ones

931-1391-ND
Make it easy to change

Pigtails

Give yourself a low inductance ground pad for your pigtails
Make it easy to change

Coplanar waveguide

- Easier to pigtail
- Possible to probe without soldering
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
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