

Tutorial: A Method for Prototyping Mixed-Signal Circuits

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Introduction

I always say that prototyping of mixed-signal circuits is tricky, **especially if one wants the circuits to work, ha, ha**. This is good to do using one of the white plastic “solderless plug-boards,” cheesy offshore “fly-wires” or blob-soldering heavy stranded wire. No, it is not. One can do that in a pinch, but do not expect good performance from your circuit.

The main issue is signal integrity – usually aided by a ground plane and thoughtful power supply and current return paths. Then we have the issue of where to connect analog and digital grounds around an ADC or DAC (hint – only at one place... but deciding that place isn’t always easy). Then (ouch) all of those tiny surface-mount parts (most of which can be soldered with a steady hand and microscope, but not BGA. I’m assuming that the reader wanting to use surface-mount parts (e.g., IC’s) can find appropriate adapters, so the prototyping here is all through-hole (“DIP”) style.

The assumption here is that the reader is not a senior engineer at a big company, and just hands a schematic to a layout person who orders several variants of a nice PCB for them. Nope. This is for someone who is hands-on, and wants to build a “works-alike” (but sure as heck doesn’t look alike!) prototype and **then** send it off for layout if necessary.

So, the prototyping has to be doable by hand and without exotic equipment.

There are just a couple of central messages in this tutorial:

- 1) Use fine, solid-core wire to connect between components (passives, sockets, a microcontroller, etc.) – I recommend 30-gauge “wire-wrap” wire and a matching stripper tool (I’ll note here that a friend did once date a stripper, but that’s a different tutorial).
- 2) Choose a quality ground-planed board with the ground-plane on the bottom of the board, and covered with a solder mask. Grind off the solder mask locally to expose clean copper and solder the pin(s) you want to ground directly to it (not by running a wire).

If you remember these two things, the hassles of mixed-signal prototyping will be greatly reduced.

How I Do It

Here I am using a prototype board that our own team designed at VoidLoop – so ground plane and solder mask is on the bottom. The ideas will work with any protoboards with a groundplane like that, but I really don't recommend groundplanes without solder mask (Figure 1) – unwanted solder bridges are too easy to form, and are difficult to find and fix. Figure 2 shows some of the protoboards I actually use, with solder mask on the bottom, some with Teensy 4.X pinouts, some with BNC and SMA connectors, some with just a “sea of holes.” You can easily have your own boards made or find several commercial options.

In my (several) years of experience, the best method I've come to is to grind off the solder mask down to clean copper, and solder “ground” connections right there. No wires. This works wonderfully, and one can get analog and mixed-signal performance that is very close to, or equivalent to, that of a good final PCB layout. One simply makes a solder bridge between the exposed copper of the ground-plane and the desired component pin. Done – solid ground.

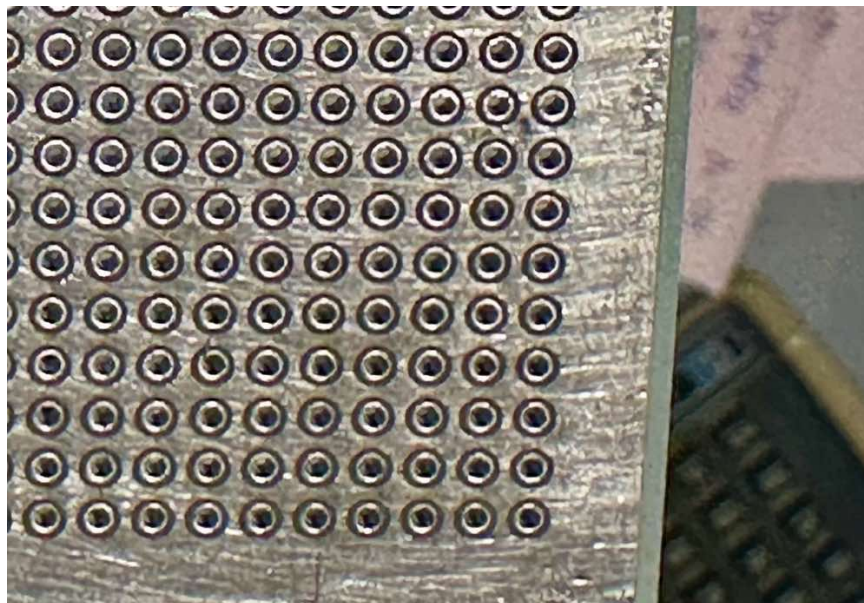


Figure 1: Example commercial prototyping boards with exposed (bare-metal) ground planes – super easy to short with solder bridges (this stuff was meant for wire-wrap, which is 1970's prototyping). Don't do it.

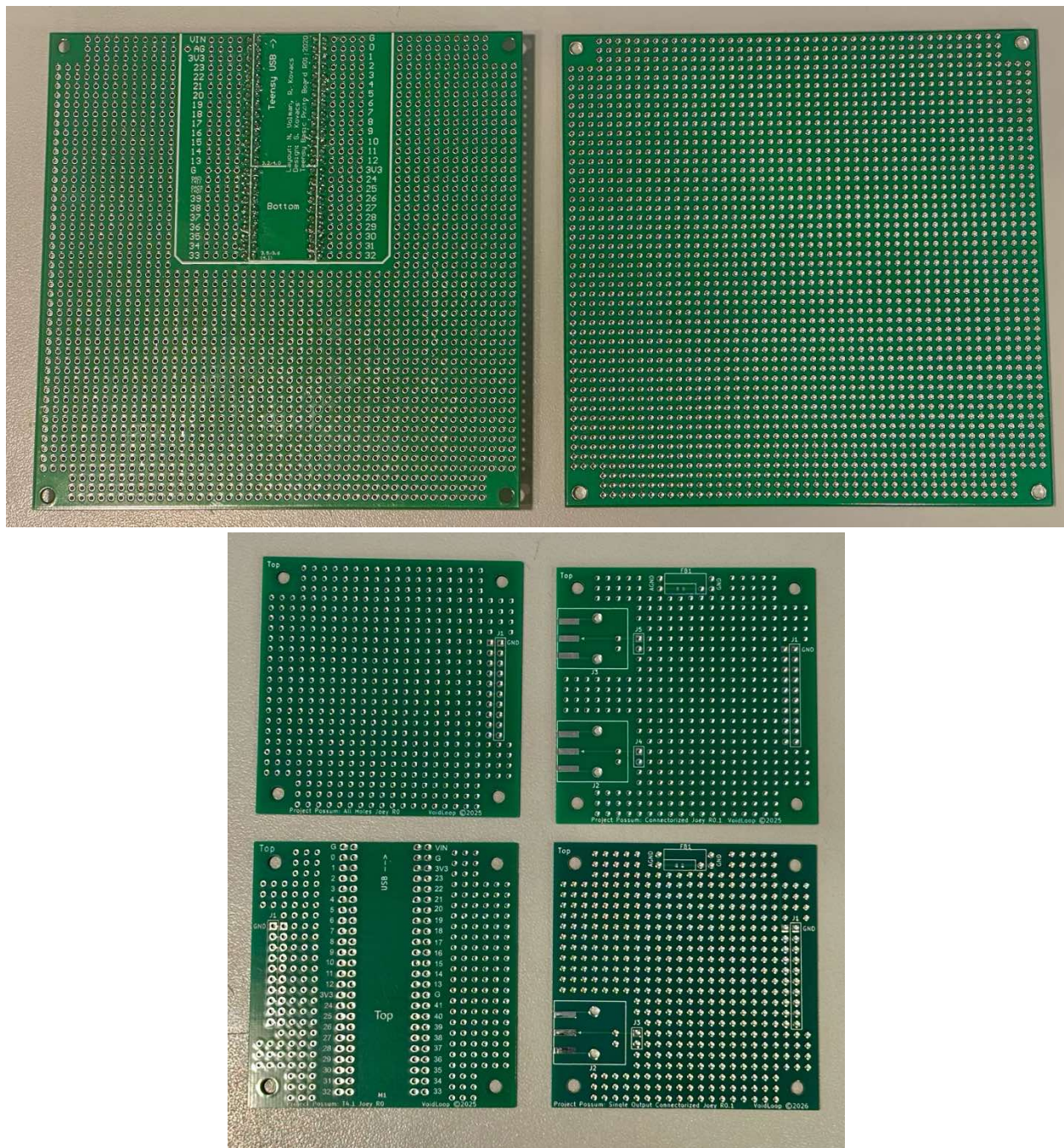


Figure 2: Examples of protoboards with solder-mask-coated ground-plane on the bottom. Grind it off only where you want to solder. The to left and bottom left boards are examples for the Teensy 4.1.

For solder-mask removal, I prefer the cordless Dremel™ Model 1100 tool (Figure 3 – not sponsored by Dremel!), but there are many, many tools out there and I do not think this one is still available. You also need to buy “diamond” (quotes because the offshore versions on Amazon are “diamond” as much as I’m “well-dressed,” but in any case work) burrs that are typically used in nail salons (hence the disco colors) as shown in Figure 4. An alternative – although not as good in tight spaces on the board – is to use a disposable scalpel, which are inexpensive and relatively easy to find. In Figures 5 and 6, the two methods are shown, respectively.



Figure 3: Example grinding tool, in this case a Dremel™ Model 1100 cordless unit.



Figure 4: “Diamond” burrs from Amazon. You really only need one, a shallow, rounded “cone” or the sphere. But if you get the set, you could have a side gig giving manicures.

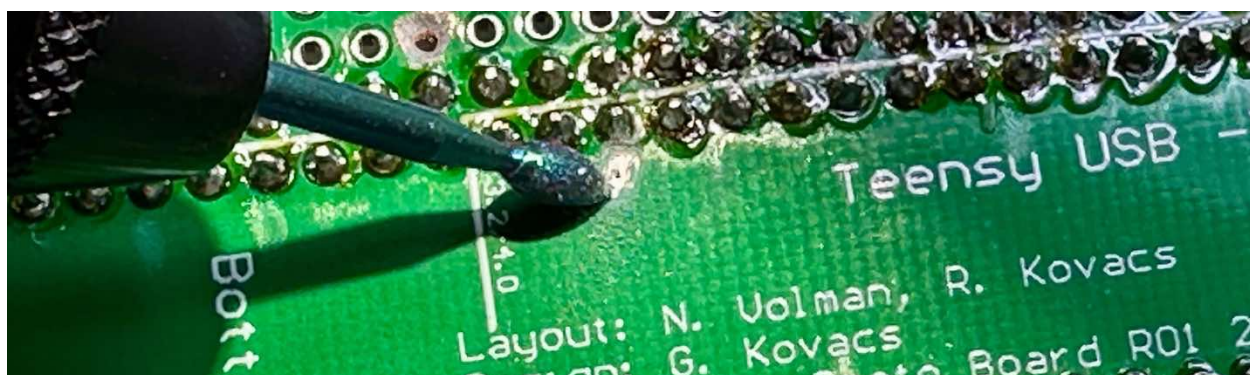


Figure 5: Example of grinding away solder mask near a pin to be grounded.

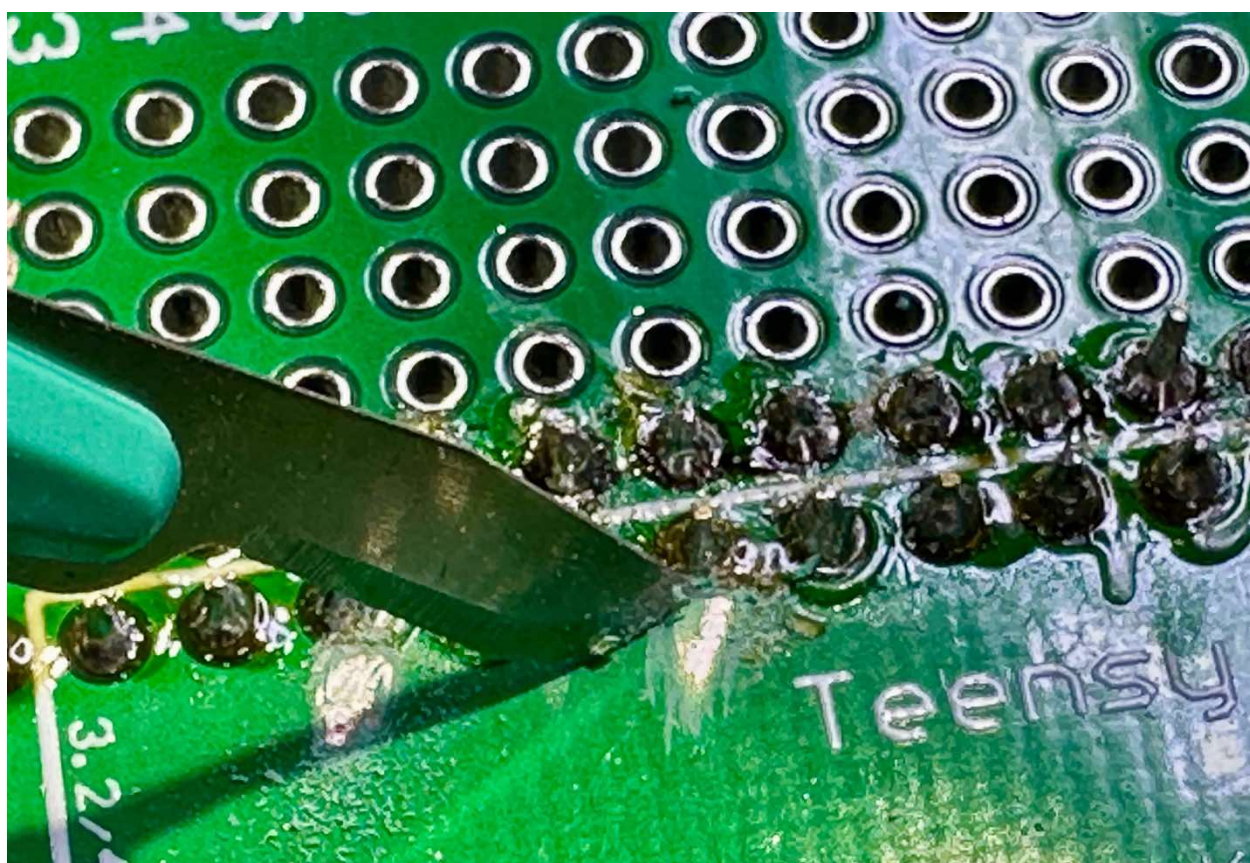


Figure 6: Alternative method of removing solder mask with a disposable scalpel (much more difficult in crowded areas of the board).

For signal connections, use the wire-wrap stripper (Figure 7) to strip away about ¼” of the 30-gauge wire and use tweezers to wrap it around the desired component pin (Figure 8), then solder (Figure 9). Figure 9 also shows a finished solder-bridge ground connection.

It is easy to get quick at this once you get the hang of it. If desired, multiple colors of wire-wrap wire can be used for signals and power. Note, of course, that **this is solid-core wire**, so it cannot be flexed too many times before the metal core (usually at the solder joint) fatigues and breaks. However, this approach is neat and tidy and works like a champ unless one continually moves wires around on the prototype. If that’s necessary due to debugging and rework, it is prudent to continuity check the connections against the schematic with a digital multimeter (best if it has the “beeper” continuity mode!).



Figure 7: A spool of 30-gauge “wire-wrap” wire and “wire-wrap” stripper. There are many brands and often the strippers turn up on EBay. As of September 2026, both the wire-wrap wire and the strippers are available on Amazon.

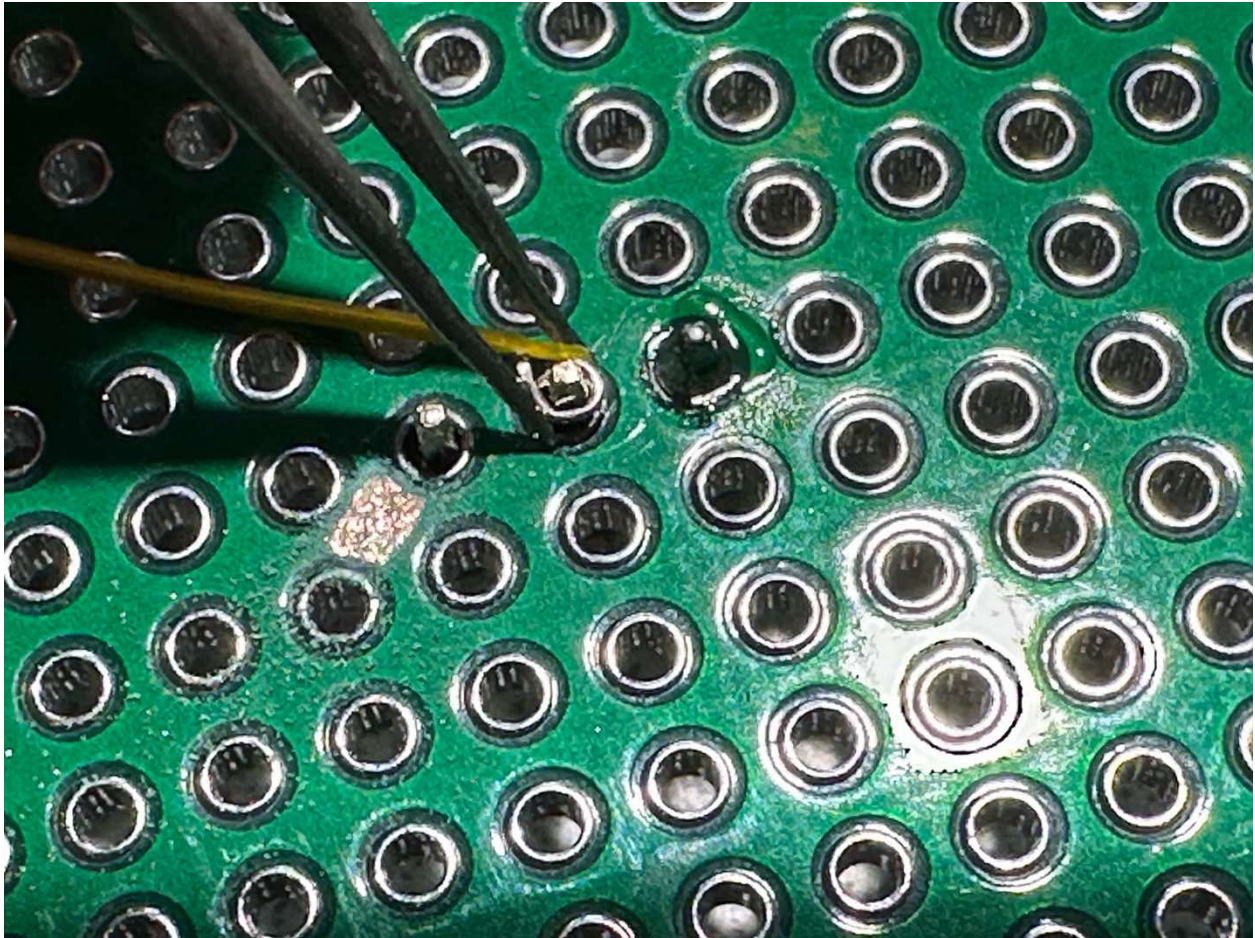


Figure 8: Method of wrapping the stripped end of a wire around a component pin. Note that the solder mask has been ground away next to the pin on the left, which will become a ground connection.

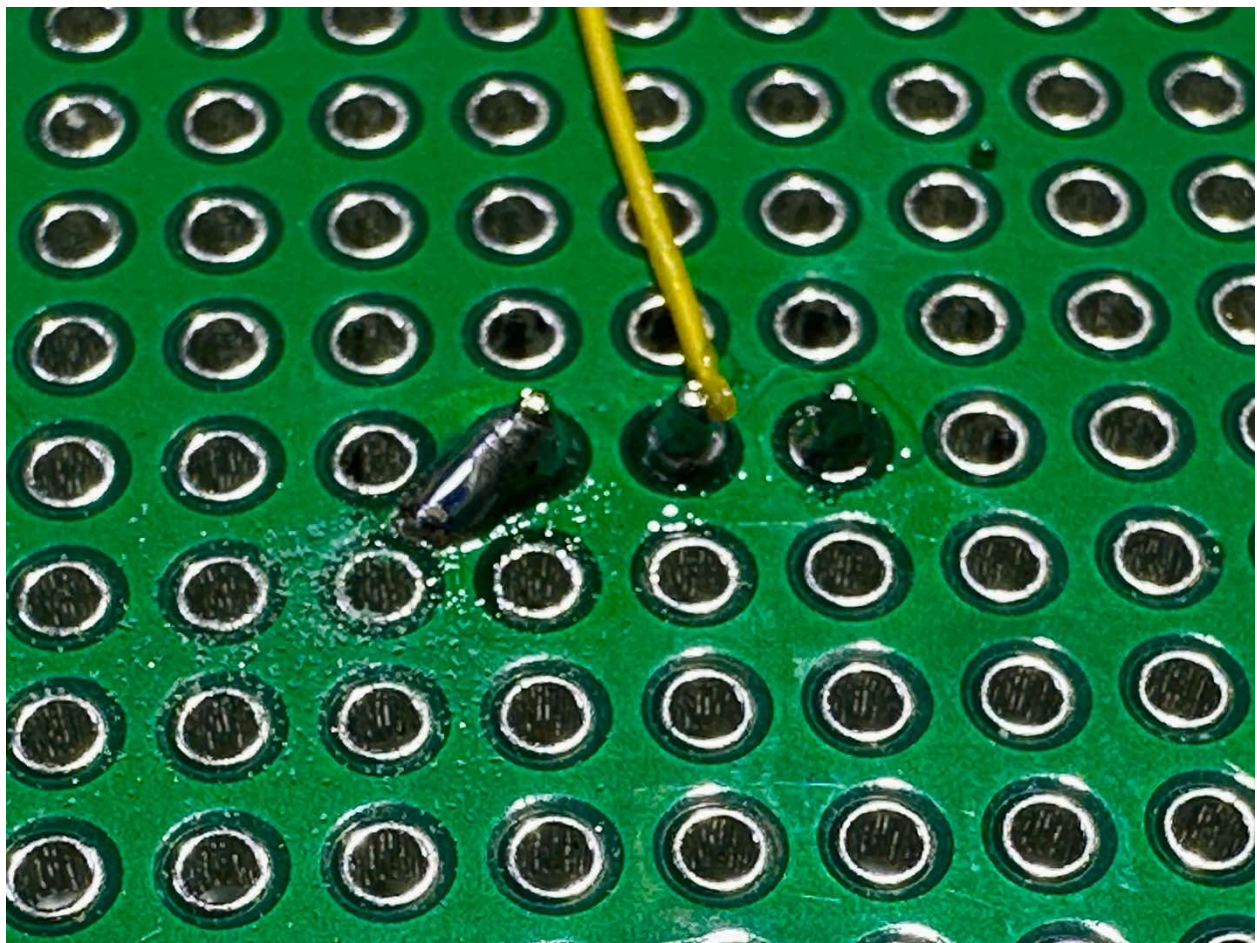


Figure 9: Pins in Figure 8 above, left one solder-bridged to the ground-plane, middle one soldered to wire-wrap wire to connect elsewhere.

Don't be discouraged if your first few efforts are a bit "messy." This approach yields good signal integrity, ground-plane benefits close to those of a final layout and – once you get the hang of it – relatively easy rework (best to have a vacuum solder removal tool, AKA "solder sucker").

Examples

Here are a couple of my own examples. I built these on the bench as prototypes of downstream educational products. Figure 10 shows a prototype of the “bending” of the amazing Burr-Brown (Texas Instruments) PCM5102A audio DAC. This is a complex chip that is typically used in consumer audio to cover the 20Hz – 20kHz range. The nasty harmonics are cleverly pushed out beyond the frequency response of the human ear (but my cats remain pissed off) and the amplifier you normally would use. The chip generates its own negative power rail so needs no output coupling capacitors and... wait for it... can thus go down to very low frequencies.

The Chinese-manufactured module common on Ebay was soldered to one of our internal protoboards, with a -5V rail generator and an output shaping filter – the end result was a dual-channel synthesizer design that can make pure (60dB SFDR) sinewaves or arbitrary waveforms out to 60 kHz (Figure 11). The design, cheap board and tutorial are coming soon, but the point here is how it was prototyped. Point-to-point soldering with 30-gauge wire and a good ground-plane.

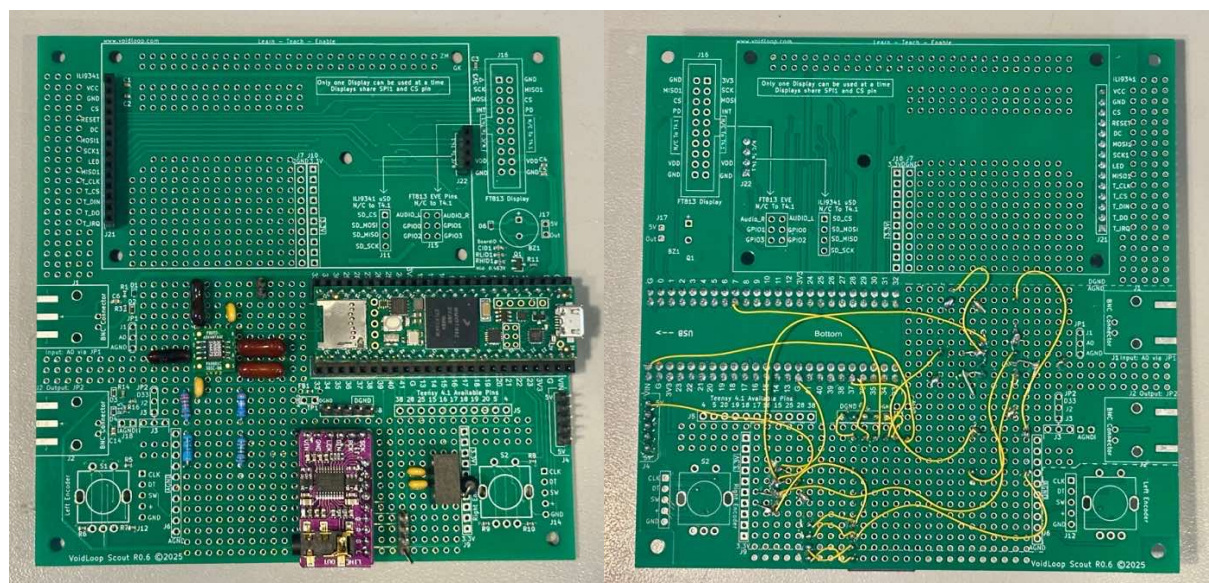


Figure 10: Pushing the PCM5102A to 60kHz. A solid ground-plane really works!

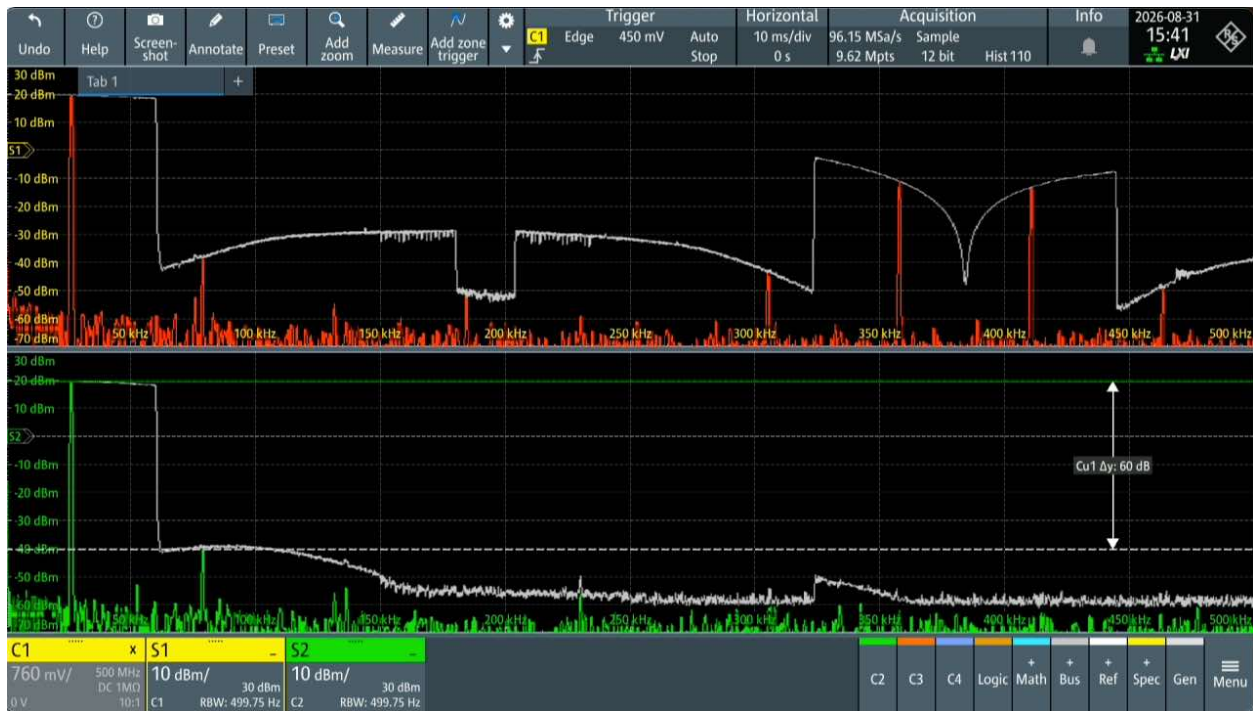


Figure 11: Results for the prototype in Figure 10... White line is the “peak-hold” envelope for the spectrum. The shaping filter keeps the output (lower traces) around – 60dBc or below, with a few dollars of parts, one beer, and a bit of math. Nice. Please do note the nasty harmonics looming (in red) without the filter. Those would not come through your audio amp, but or precision signal generation would be a problem.

Lastly, while these methods are good to 10’s of MHz as in for SPI and other lower-frequency control signals, they still have merit for boards running at higher frequencies. Figure 12 shows a lash-up of a Teensy-controlled, 3 GHz, fast, double-heterodyned spectrum analyzer built with basically the same methods for low frequencies, and coax for the higher frequencies. More on this design in a few months, but just to say that these methods are pretty solid.

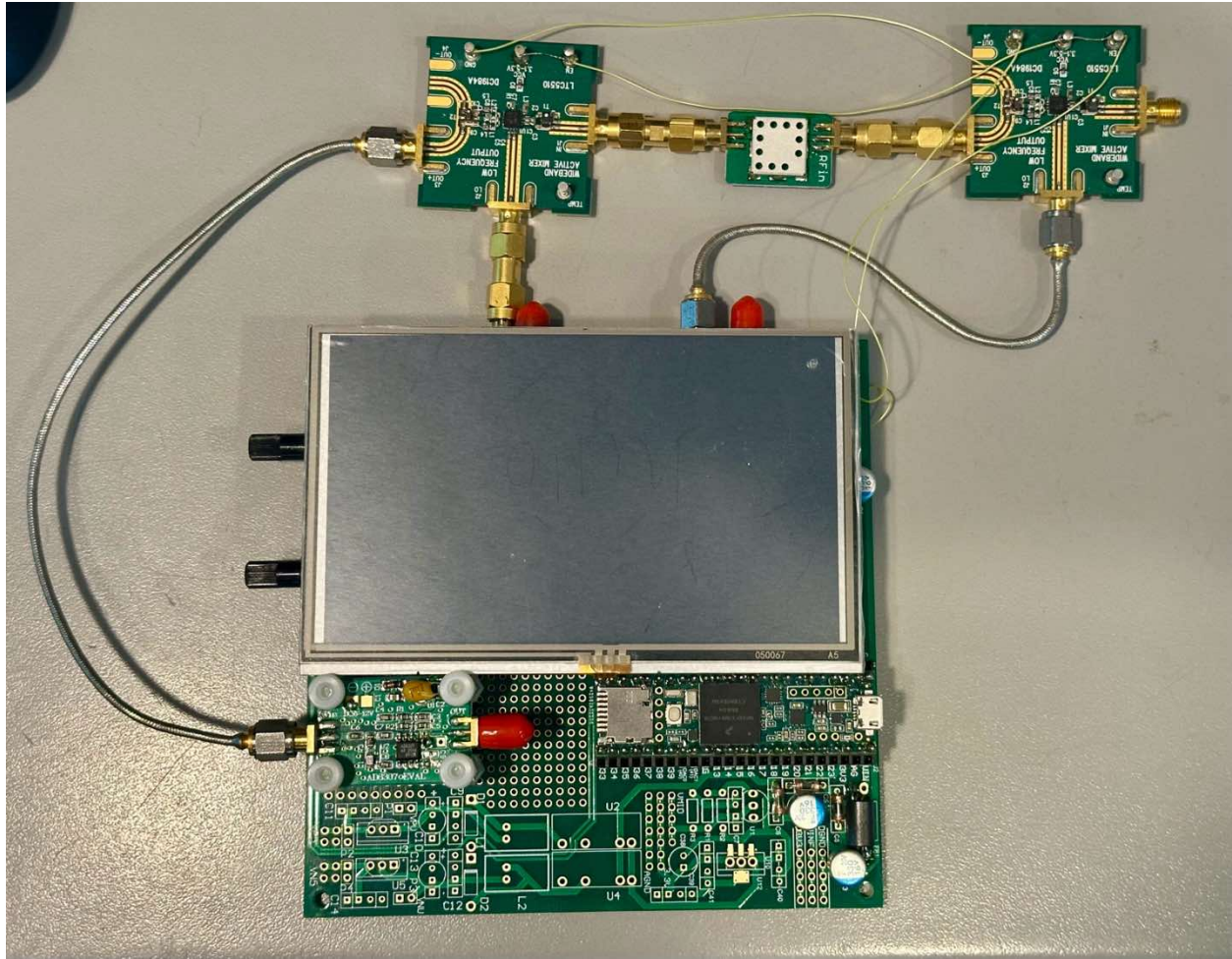


Figure 12: Working lash-up of a double-conversion, fast 3GHz spectrum analyzer with the lower-frequency signals (SPI, power, etc.) connected using the methods described here, and the high-frequency signals (ranging up to 6.4 GHz) carried via semi-rigid coax (but they can, with great care, be carried over PCB traces in a final design).

Conclusion

A good conclusion, or summary, should reiterate the points raised at the beginning. I'm a firm believer in "BLUF" (Bottom Line Up-Front) versus endless babble to finally get to a bottom-line. A decent engineer can express, succinctly, the main point of just about anything in 2 – 3 sentences. If you work with folks who cannot... run away... fast (especially if they are your boss)!

So here it is:

Use fine wire, like 30-gauge wire-wrap wire with an appropriate stripper, to connect pins.

Use a solid ground-plane on the bottom of the board, with solder mask, grind off the solder mask where you need to make a ground connection, and carefully use solder bridges to connect from the ground-plane to the desired pins.

Done.

Thanks for reading. Best of luck with your projects!

Greg