Some Thoughts on Breadboarding

W7ZOI, Jan 2, 2000, update June 10, 2000, Feb 23, 2002.

Reinstated on 23July03, modified 25March04, 16July06, 5March07.**

Reinstated again on 18 Sept 05, including SMT comments.

Breadboard, as applied to electronics, is a term left from a time when early radio experimenters built their equipment on slabs of wood, often procured from the kitchen. The term remains as an industry wide description of a preliminary experimental circuit.

Roger (KA7EXM) and I published a paper titled "The Ugly Weekender" that featured one of the breadboarding schemes we used. (QST, August, 1981.) The transmitter in that article merely illustrated the method. Ugly construction, although certainly not unique, works well and continues as my method of choice. The method consist of the following:

A ground plane fabricated from scraps of copper clad circuit board material,

Grounded components soldered directly to the ground foil with short leads,

Some non grounded parts soldered to and supported by the grounded components,

Other non grounded components supported with suitable "tie down points" consisting of high value resistors.

Once finished and working, the board can be mounted in a suitable box (hidden from view if desired) where it becomes a permanent application of the idea.

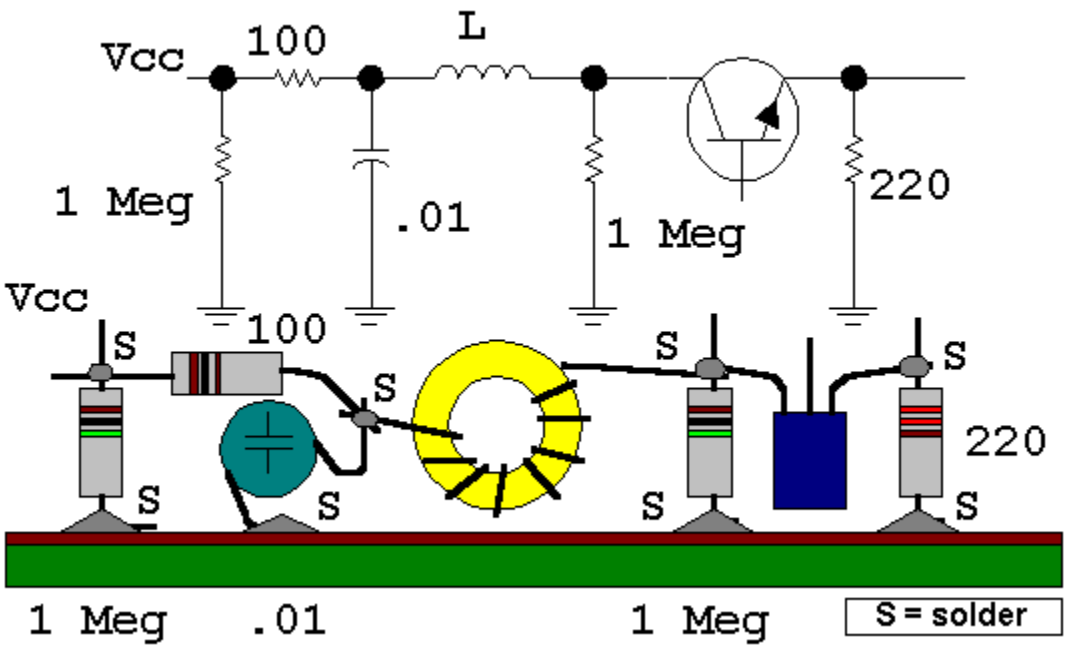


Fig. 1. A partial circuit illustrating the "ugly" construction.

Casual circuit analysis allows the builder to pick the standoff resistor values. Usually, 1 Meg-Ohm resistors work well anywhere within RF circuits. The typical 1/4 watt resistor (any value) has a stray lead-to-lead parallel capacitance of about 0.2 pF and a series inductance of 3 to 5 nH. High R means that the inductance is of no consequence. I sometimes use R values as low as 10K.

It is often surprising just how few standoff resistors are needed. The original 'Weekender transmitter used just 5 or 6.

The greatest virtue of this method is **low inductance grounding**, the characteristic that makes it work so well. Any construction scheme that preserves this grounding integrity will work as well. Picking a method is a choice that the builder has, a place where he or she can develop the methods that work best.

Integrated circuits can be placed on an ugly board with leads up, "dead bug" style. There is little need to glue the chips down, for components and wires will eventually hold them in place. Grounded IC leads are bent and soldered directly to the foil. Some folks prefer to maintain ICs with the IC label facing upward, allowing later inspection. They then bend all the leads out in a "spread eagle" format.

I have never had a problem with ugly equipment being less than robust. Many such rigs have been hauled through the mountains of the Pacific NW in packs without incident. An outstanding example, the work of a friend, is the W7EL Optimized QRP Transceiver (Roy Lewallen, QST, Aug 1980), a rig that has traveled around the world in suitcases and packs. (I don't think Roy used any standoff resistors in that box.)

Several other construction schemes offer similar grounding fidelity, including those where small pads of circuit board material are glued or soldered to the ground foil. These pads then have components soldered to them. I've found this to be useful when a slightly massive component such as a floating (non grounded) trimmer capacitor is used. The specific glue type has little impact on circuit performance. Variations of this method have been called "Manhattan Construction," and can be mixed with other breadboarding schemes.* (see footnote at the end of this section.)

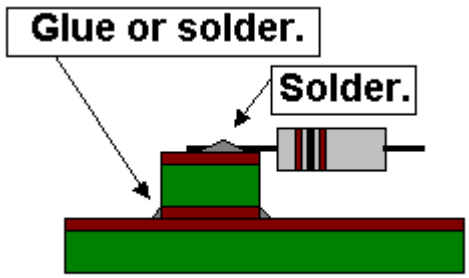


Fig. 2. An example of "Manhattan" breadboarding.

There is a virtue to NOT having things quite as permanent as realized with glued pads. With traditional ugly construction, parts can be moved about to make room for another stage. In the extreme, an entire circuit can be lifted and moved, a stage at a time, to another board.

The primary virtue I seek in a bread-boarding scheme is construction speed and flexibility. I'm usually after information; the resulting rig is just an enjoyable afterthought. Any scheme that allows me to quickly build and evaluate circuits supports that goal.

Some folks would argue that a circuit should be rebuilt after a breadboarding phase, replacing the ugly prototype with a more permanent, production-like version. This presents two additional challenges. First, it takes time, hours that would otherwise produce additional information. It's an individual's call on

what is an important way to spend that time. Second, the production variant (including etched boards) rarely works better, if indeed as well as the original ugly one. Most of my own amateur radio gear consists of ugly boards hidden in boxes that are functional, but only on rare occasion, borderline attractive.

Many folks have objected to the word "ugly." Roger and I picked it to emphasizes that a rig with an unsightly appearance can still be very functional, offering outstanding performance. The radiated signals are not ugly. The use of an etched board with clean lines, laced wiring harnesses, and other artifacts of craftsmanship in no way guarantees superior performance! In fairness to my friends who pride themselves in the way their creations look, I need to admit that craftsmanship need not preclude performance. But it should not be confused with proper circuit implementation, which usually emphasizes clean (low inductance) grounding and low coupling between critical circuit parts.

Some experimenters prefer to build equipment that looks like an ECB, even when the board is not etched in a circuit-specific pattern. One method ("checker-board") uses double sided circuit board with one side functioning as a ground foil. The other side consists of a matrix of small islands of copper. These regions are created either by etching or manually with a hack saw. Patterns of squares on 0.1 inch centers accommodate traditional ICs. Holes are drilled in the islands where components must reside. A large drill bit then removes ground foil around the hole without enlarging it. No holes are required where a ground connection is needed. Components usually reside on the ground side of the board.

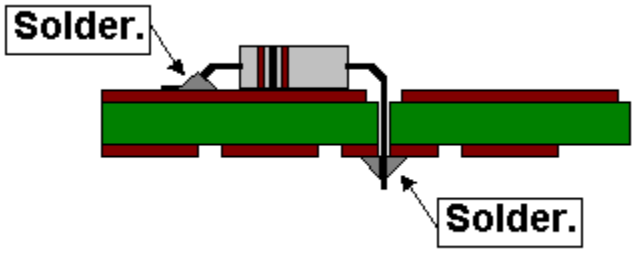


Fig. 3. A "quasi-circuit board" scheme for breadboarding. The installed resistor here is soldered to ground and to a pad that connects to the rest of the circuitry.

The double sided checker-board is also useful for breadboarding with surface mounted components. All parts then reside on the pattern side with holes drilled to reach ground. Small leaded components can also be surface mounted.

The checkerboard scheme, "Manhattan" variants, and even double-sided

printed boards have fairly high capacitance from pads to ground. These are often poor quality capacitors with low Q (under 100 for epoxy fiberglass board material) and are subject to water absorption. They are often poor in oscillator applications. A single sided format is preferred for critical sections of a VFO circuit.

Clearly, the builder has many choices. It's worthwhile to sit back and review goals, deciding what it is that YOU are trying to accomplish. This will reveal the best method for you to use. Above all else, we urge you to experiment, to go beyond the normal boundaries, for this is where the real excitement and learning is to be found!

Footnote: * For a more detailed look at ugly-construction applications, take a look at the work presented by Todd, VE7BPO, at http://www.qrp.pops.net/ while additional information on breadboarding with special emphasis on the "Manhattan" method is available at http://www.qsl.net/k7qo/manhat.html . From what we can tell, the term refers to "Manhattan" routing, which is a lead routing method used for the layout of integrated circuits where all leads are on lines parallel to the edges of the chip. This is in line with most photographs we have seen of gear built using Manhattan methods by hams. **A recent non-ham article also brings up Manhattan Layouts in connection with evolving trends in the layouts of ICs. See John Baliga, "Chips Go Vertical," IEEE Spectrum, March, 2004, pp43-47.**

More info, along with some comment:

Here's an example of "Ugly." It is in many ways a poor example, for only one extra resistor is used as a mechanical "standoff," or support. On the other hand, this illustrates that few supports are really needed. This circuit, my own version of the original "Ugly Weekender," was found deep in my junk box, but still functional over a generation later. (Roger has the one that was in QST.) In the example shown, the support point is a 50 Ohm node in the circuit. The 510 K-Ohm resistor used for support has no impact on the performance. Even the DC current of 24 micro amps is of no consequence.

Ugly construction is really not much different than the methods we used with vacuum tubes back in our youth. At that time we used an aluminum or steel chassis with insulated terminals of one form or another bolted to chassis holes. Ground lugs were also bolted to holes. Ugly construction uses a solderable copper ground foil, so we can solder directly to ground when needed. We could even solder insulated terminal strips to the copper foil, if the strips were available in a junk box. (Can't find them in Digikey!)

There is one characteristic common to the really old methods of bygone boat anchor days and those of the recent past: In both cases, it is either necessary or at least advised that the builder consult the schematic diagram as a guide to his or her Breadboarding actions. There is no printed circuit board with a silk screened picture to be followed. Thought is required to replace blind soldering.

I have nothing against printed boards or even kits for construction of equipment by the radio amateur. They all have their place and I use them in my own efforts. On the other hand, I may offer debate to those folks who will only build things when a circuit board is available. They are missing a possible outlet for creative output, a place where a new idea could evolve from an easily realized, simple experiment. They loose the joy of gathering skills that could be very useful in other pursuits.

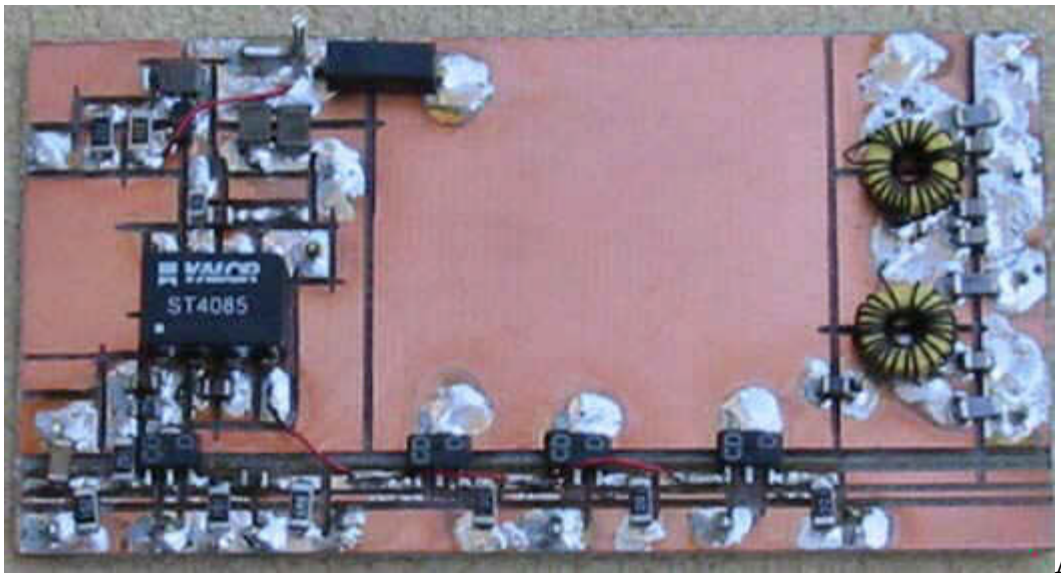
Ugly Breadboarding with Surface Mount Technology

18 Sept 05

We are now at a fuzzy, albeit definite crossroad in electronic technology. The leaded components that we have used since semiconductors, discrete and integrated, replaced the vacuum tubes of the past are disappearing. They are being replaced by the same circuit elements in very small packages that are mounted only by soldering them to a surface. This produces greater circuit density when implemented with printed PC boards. However, it offers challenge to the experimenter wishing to breadboard an idea. There are still methods that we can use--it is not necessary to give up. One avenue that allows an SMT integrated or discrete circuit to be used with some ugly leaded circuits is the "Surfboard" (TM) made by Capitol Advanced Technologies (TM). See the Digikey catalog under "PC Board Prototyping." These are just small circuit boards that can hold SMT parts.

A second avenue available to the experimenter is to purchase a custom circuit board from ExpressPCB.com. A Google search will get you to these folks where you can download a FREE schematic drafting program and a very easy-to-use circuit board layout program. Once you have your layout done, you can place an order to get the needed board. They feature a special of three boards of a specific size, constrained by a few other ground rules. The special board is big enough for quite a significant SMT function. The cost is nominal, considering the high quality and fast delivery time. These boards are plated, double sided, and through-hole plated.

You can do your own SMT breadboarding at home with a Dremel tool. (See a recent paper by Ed Kessler, AA3SJ, QST, Feb 2004, p28.) An example result is shown below.



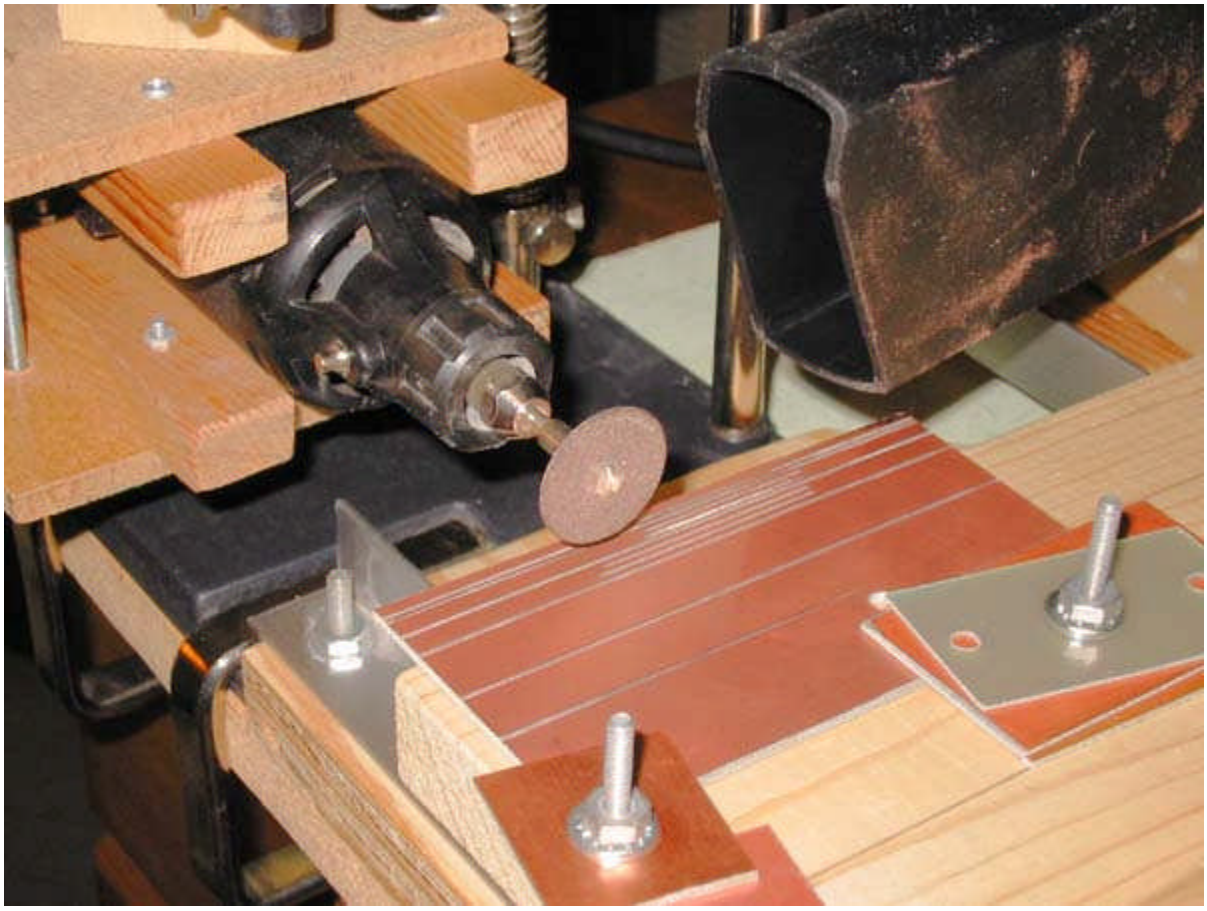
A SMT transmitter power chain with a net gain of 30 dB and an output of 1 watt. The output is from three 2N3904 transistors (SOT-89 package) in parallel. The large blank area in the board center is a heat sink for the final amplifier.

I've done this work with a drill press stand attachment for my Dremel. A fixture was built that holds the Dremel tool in a horizontal position. A crude x-y table allows the board to be moved while vertical "z" depression controls the cut depth.


The X-Y Table with the fixture to hold the Dremel tool.

The original version has been modified to cause the dust to shoot out to the back into a vacuum hose. We wear eye protection as well as magnification,

plus a face mask over our nose and mouth when using the apparatus.



The modified stand, with further detail.

There is a great deal more that can probably be done with this system. We are, at least, able to use some of the low cost SMT parts that are now readily available, parts that were often hard to obtain in leaded form.

The home breadboarding scheme shown works well with the largest of SMT formats, such as the SOIC-8 integrated circuits with 50 mil lead spacing. It is, unfortunately, not capable of the SSOP technology with 25 mil lead spacing.

The early part of this material was reinstated on our web page on July 23, 2003, the result of some interest. We added another photo as well as a bit of editorial rhetoric. All of this information, and more, is included in Experimental Methods in RF Design. ** This material was then removed from the web site in late 2004 or early 2005 when we found that we were running out of web site

room. But we are now reinstating it, for there is a demand beyond the readers of EMRFD. While I would love to have folks buy and use the book, a greater goal is to encourage folks to experiment. w7zoi, 18Sept05.

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Wes Hayward, w7zoi, 5March07.