Experiments with SMT Breadboarding

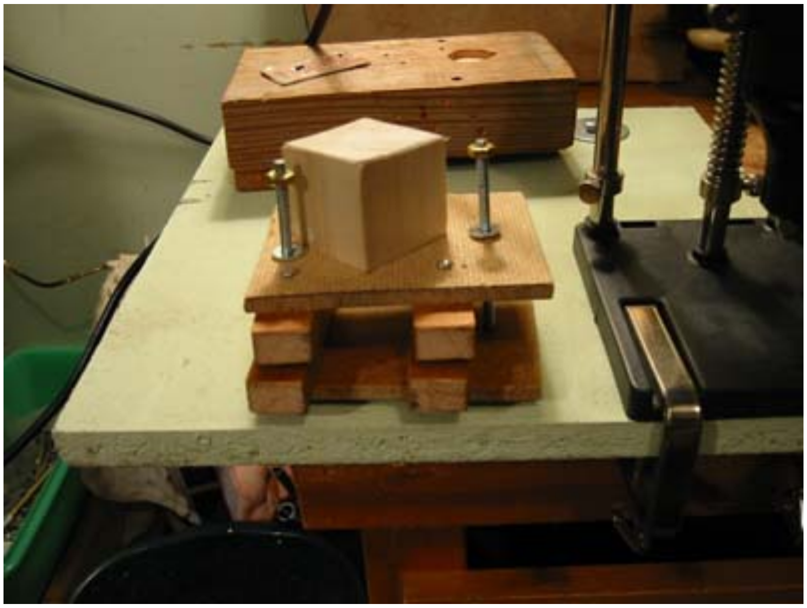
For the past several years I have dabbled with SMT construction here at home. It was standard procedure at work, but we always made boards for the packaged parts we built. SMT circuit performance tends to be better, especially at VHF and above. There are now many parts that are available ONLY in SMT format, especially some high-end RF integrated circuits. SMT construction is easy enough when one already has a printed circuit board. However, breadboarding is more difficult than it was with leaded parts. I did a couple of simple projects (a receiver in Chapter 1 of Experimental Methods in RF Design, ARRL, 2003) with a home built etched board. Board layout was done on a one-time basis with a Sharpie Pen on clean, double sided board stock. It was then etched, washed, drilled, and built. This worked, but the appearance was sloppy at best. Resolution was poor and it took a lot of time to prepare and etch the board. What was really needed is a method as simple and quick as the "ugly" breadboarding schemes used with leaded parts. (Hayward & Hayward, "The Ugly Weekender," QST, August, 1981.)

I've done experiments aimed at using a Dremel tool to cut patterns in PC board. While possible, it requires a very steady hand. I've recently built a "milling machine" of sorts as a way to improve the process. This is based upon a drill stand that I purchased several years ago for drilling holes in PC board. The stand normally holds the Dremel in a vertical position, allowing vertical motion for drilling. I've used carbide tip ultra high speed bits, which are delicate, but do a wonderful job. The first photo shows the empty drill stand and Dremel tool.

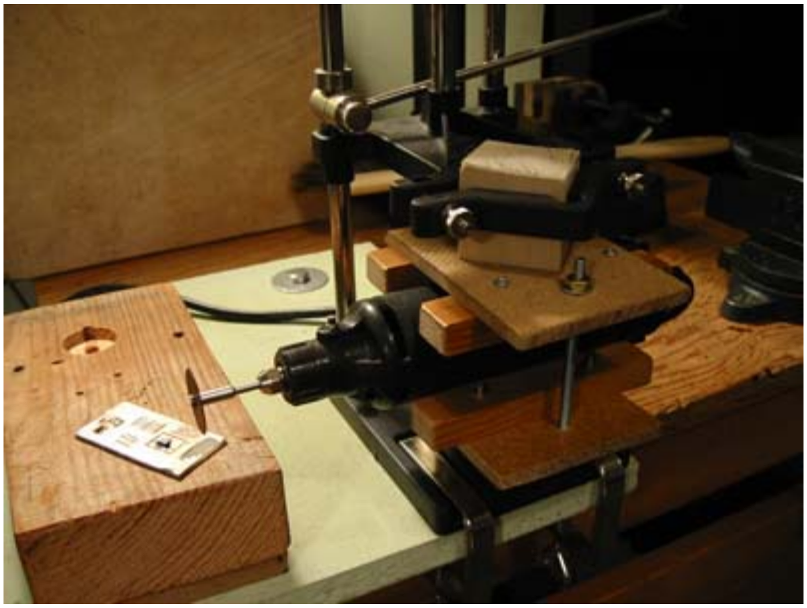
The stand is C-clamped to a board that can then be bolted to a work table.

The drill stand I use is imported from Germany and is part of a set of equipment known as Hobby Drill 2000, part number 0510. It is sold by Donau Elektronik GMBH. A search on the web will produce data. The drill stand was purchased locally in an electronics distributors shop. The box was labeled as a Hobby Drill from Sterling, manufactured in West Germany for Wahl Clipper Corporation of Sterling, Ill. 61081. The box also was labeled "Drill Press for Mini/Maxi Drill Part No. 6643." Dremel also manufacturers drill stands for their product although I prefer the German product.

SMT breadboarding needs slots cut in the copper surface of a circuit board. This requires precise vertical positioning, allowing the copper to be cut with minimal penetration into the fiberglass. Our scheme required that the rotary Dremel instrument be horizontally positioned, but with the capability for vertical motion. The drill press stand provides the needed vertical motion, so the first requirement was a suitable mounting adapter. Our solution is shown below.


Two approximately square pieces of masonite or plywood (about 1/4 inch thick by 3x3 inches) serve as a base for wood strips that clamp the Dremel tool cylinder. One of the masonite squares is screwed to a piece of wood 2x2 (1.5x1.5 inch, finished) that clamps in the drill stand. The two pieces of masonite are clamped together with two 3 inch machine screws to hold the Dremel too in place.


A close-up view of the clamp holding the Dremel tool. The Dremel cylinder is positioned by one corner of each of the four wood strips. The strips used 1/2 x 3/4 inch molding material cut to a 4 inch length.

 Another view shows the set up in operation.

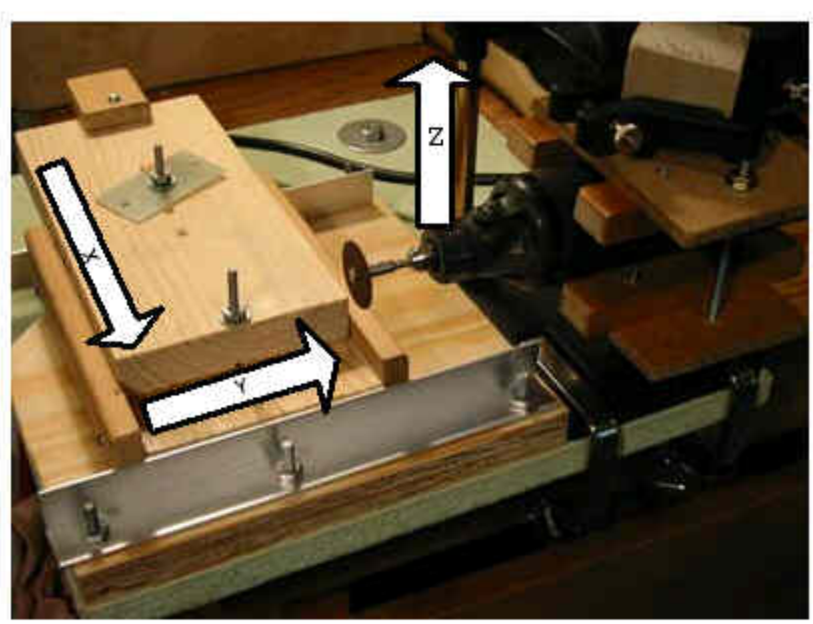
First Results

Our first cuts on a scrap of circuit board worked, but were less than satisfying. Two cutting tools proved useful. One was a very thin blade with a diameter of about 0.85 inch. This would produce very thin cuts, but was hard to control. The better tool was the Dremel Cut-Off Wheel No. 409. This is a disc of abrasive material with a diameter of about 0.9 inch. The material is 0.025 inch thick and produces a cut of about this width in the copper surface. We were able to make a pattern that would accommodate an 8 pin SOIC (Small Outline Integrated Circuit) that uses a pin to pin spacing of 0.05 inch or 50 mils. It will take practice to do a good job. An SOIC-14 or SOIC-16 will present greater challenge.

Adding X-Y Motion

The first lines were not very smooth, a problem when making a cutout for an SOIC. A method is needed to generate cuts that are straight and uniform. Fixing the board to a table with X-Y motion capabilities should produce the desired result. This variation was implemented from wood scraps, as shown below.

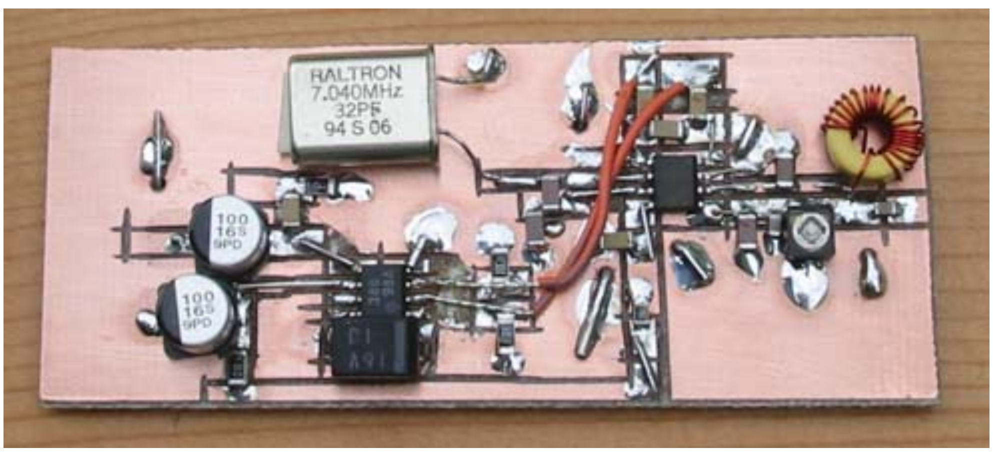

The X motion (front to back) is implement with two pieces of 1 x 4 board (3.5 inch wide, finished.) One piece was cut as a base while a second became the moving table. Molding strips were screwed to the sides of the base to allow the table to move. Some edge sanding of the table allows smooth motion. The 1x4 was cut with a miter box, vital to smooth X motion. The 1x4 base moves in the Y direction (left to right) on a scrap of 3/4 inch plywood. Y motion was restricted by aluminum angle from the junk box. No dimensions are critical and were determined by the wood and metal junk boxes.



This view of the XY table shows the table moved in X from the above figure. Two 6-32 bolts are mounted in the table to allow PC board to be held firmly. The bolts are counter sunk in the bottom to prevent interference with the X-motion. Extra mounting holes are drilled, allowing for a variety of board sizes. We found that just one mounting hole is adequate for most applications. An intermediate sized PC scrap (shown in the photo) is used as the top piece that holds the board in place. A small scrap of board should be placed under the upper piece opposite to the board being cut, keeping the hold down piece flat and parallel to the moving table.

Second Results

We did some random cuts as the first experiment, producing clean and long lines. The moving wheel was pushed into place with the Z-motion of the drill stand and the table was then moved in the X direction. One experiment began with a clean piece of PC Board with an SOIC-8 IC held against it. Pencil marks were made around the leads, serving as guides, allowing us to generate a pattern for the IC. The first one looked good, so another was made a short distance away, also producing a usable result. We then realized that we had the beginnings of a simple direct conversion receiver. Additional cuts were made around the SOIC patterns for the handful of parts needed to complete the design. We did the cuts and built the receiver in an hour or so, with the result shown below. The board size was trimmed after the cuts were made, but before parts were added. Holes were drilled in numerous places to tie top and bottom side ground planes together.

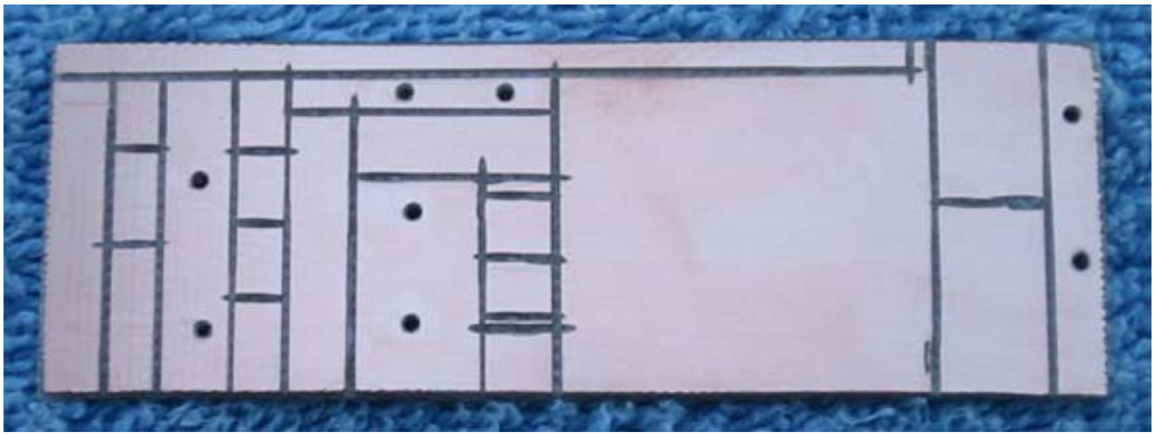


The receiver uses an NE-612 and LM386. (See WA3RNC, QST, Feb, 88) It was designed to accommodate components available in our SMT junk box. This board is not as small as it could be at 1.3 x 3 inches. However, smallest possible size is not always a goal in a breadboard. Two leaded parts (a crystal and a toroid) were required. The toroid is held by the leads while the crystal is held in place with double sided foam tape.

One difficulty encountered was the result of inadequate planning. I had to use small wires to attach many of the components to the two integrated circuits. This resulted from having isolated the ICs during the initial cuts. Even the two interstage wires could be eliminated with a more careful layout. Long runs are possible as illustrated with the long Vcc line on the bottom of the board.

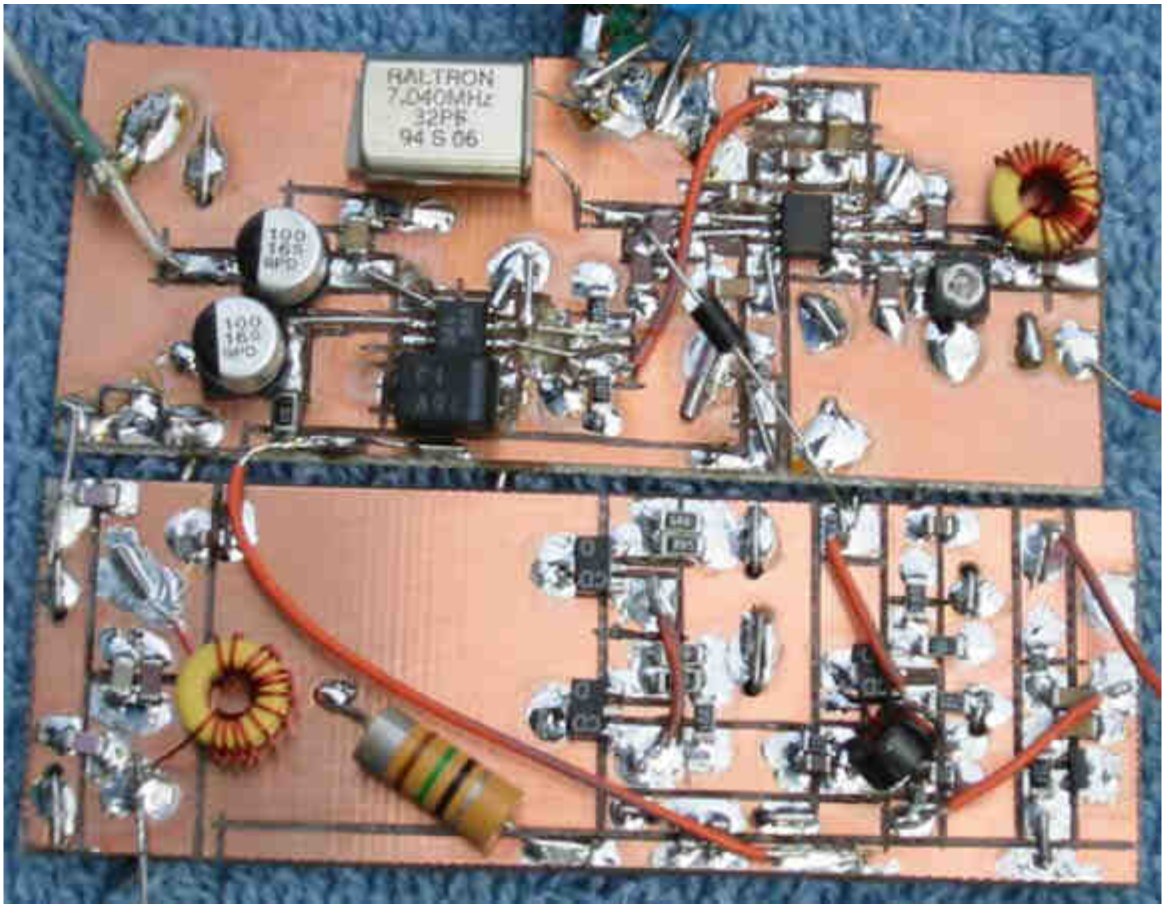
An Application:

Having built the receiver above, it seemed reasonable to add a transmitter to produce a primitive, but complete SMT station. A transmitter schematic was sketched and a layout was designed. The layout was transferred to a scrap of circuit board material in pencil and the cuts were made with the "mill." The result is shown below:



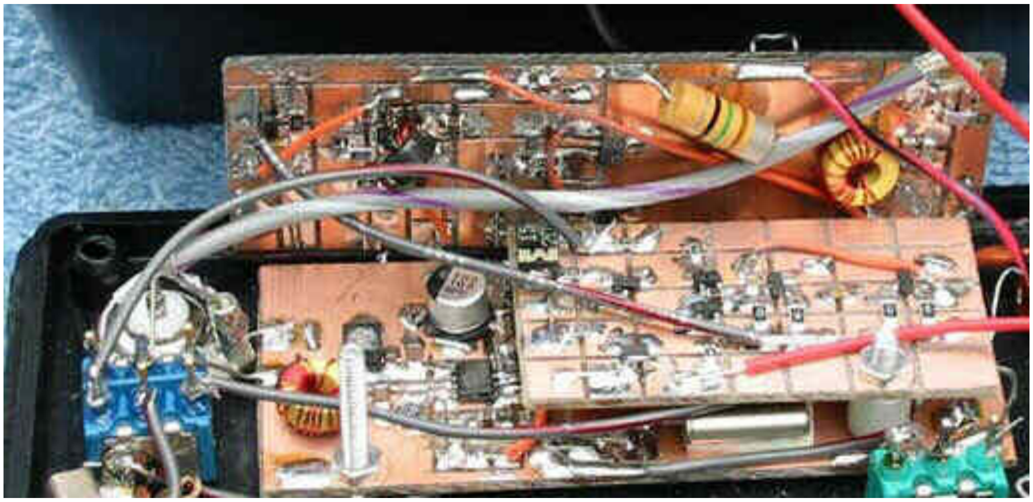
Holes were drilled and wires inserted to communicate with the ground foil on the back of the board.

The parts were put on the board and it was tested, stealing a bit of RF from the NE-602 oscillator. The next figure shows the transmitter and receiver during initial experiments.



There were several places where we cheated with leaded components. These include two T30-6 toroids (TX output elliptic low pass filter and receiver input tuned circuit), an RF choke in the transmitter, a transformer in the output of the transmitter driver, and a 100 pF capacitor between the NE-602 and the TX driver. Q measurements on available SMT inductors suggest that we may wish to stick with the toroids or similar ones on T25-6 cores. But the other components can now be replaced with SMT parts from the growing junk box.

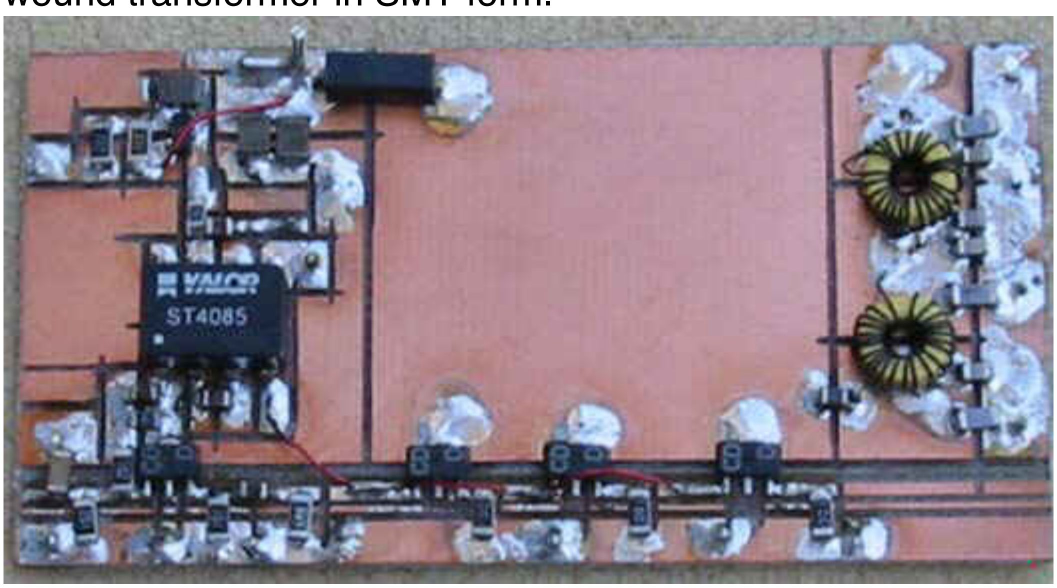
The transmitter output uses a parallel pair of SOT-89 packaged 2N3904 transistors. The large collector area on the board doubles as a heat sink. Generally SMT power dissipation, even with the smaller SOT-23 transistors, is highly dependent on the area of the collector tab. This PA runs cool with a half watt of dissipation.



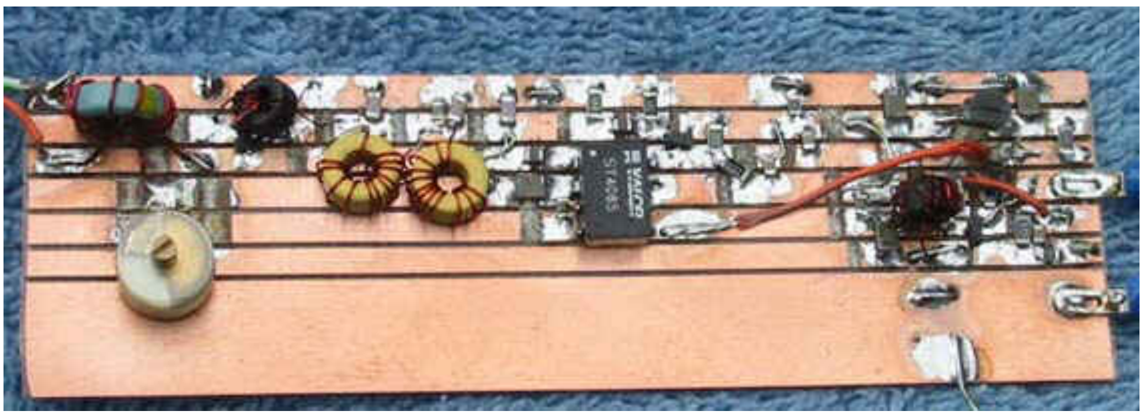
A third circuit board was added to the system. This includes some T/R control and a sidetone oscillator. The board was mounted above the receiver board. The transmitter board was mounted on stiff wires between board ground planes. It can be bent for testing, but is stiff enough to keep the board in position.

More Applications:

The next photo shows another 7 MHz board for use in a transceiver in progress. This is a power chain delivering 1 watt output at 12.0 volt with a net gain of 30 dB. The first stage is a keyed feedback amplifier using a single SOT-89 2N3904 and transformer output. Shaped keying is included on the board. The output amplifier uses three paralleled 2N3904s, again with SOT-89 sized devices. The large square area is the heat sink for the PA and runs quite cool, even during extended key-down testing. The output low pass filter uses inductors wound with #30 wire on T25-6 toroid cores. The measured Q is still well over 100. We used parallel capacitor combinations in the low pass filter. The part from Valor, discovered on EBay, is a dual bifilar wound transformer in SMT form.

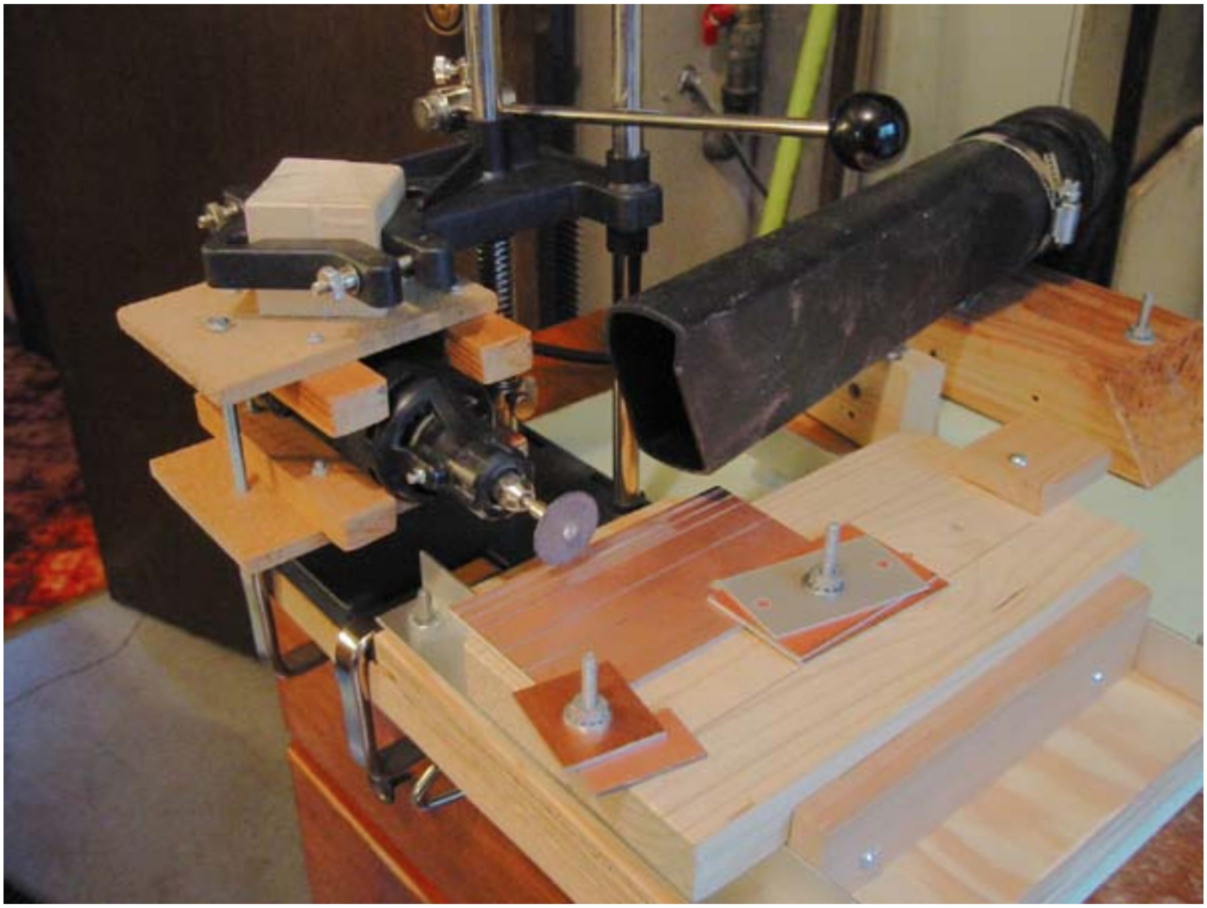


The following photo shows a general purpose scheme that seems to work well when breadboarding with discrete components. A long narrow board represents the ideal way to build a signal chain. We used the "mill" to cut six lines in the copper. These lines are then turned into isolated pads by removing small segments of copper. Cuts are made with an Exacto Knife. The region to be removed is then heated with a soldering iron, which melts the glue between the copper and the fiberglass, allowing the metal to slide away. The design shown is the beginning of a VHF LO chain. A 16.78 MHz VCXO is at the right. A leaded three terminal regulator provides a stable 5 volt supply. The VCXO drives a feedback amplifier and a low pass filter which then energizes a balanced diode frequency doubler using dual hot-carrier diodes in a single SOT-23 package. A single tuned circuit selects the 34 MHz output component. Two additional boards using a similar format generate the required 134.2 MHz with an output power of +10 dBm and good spectral purity.

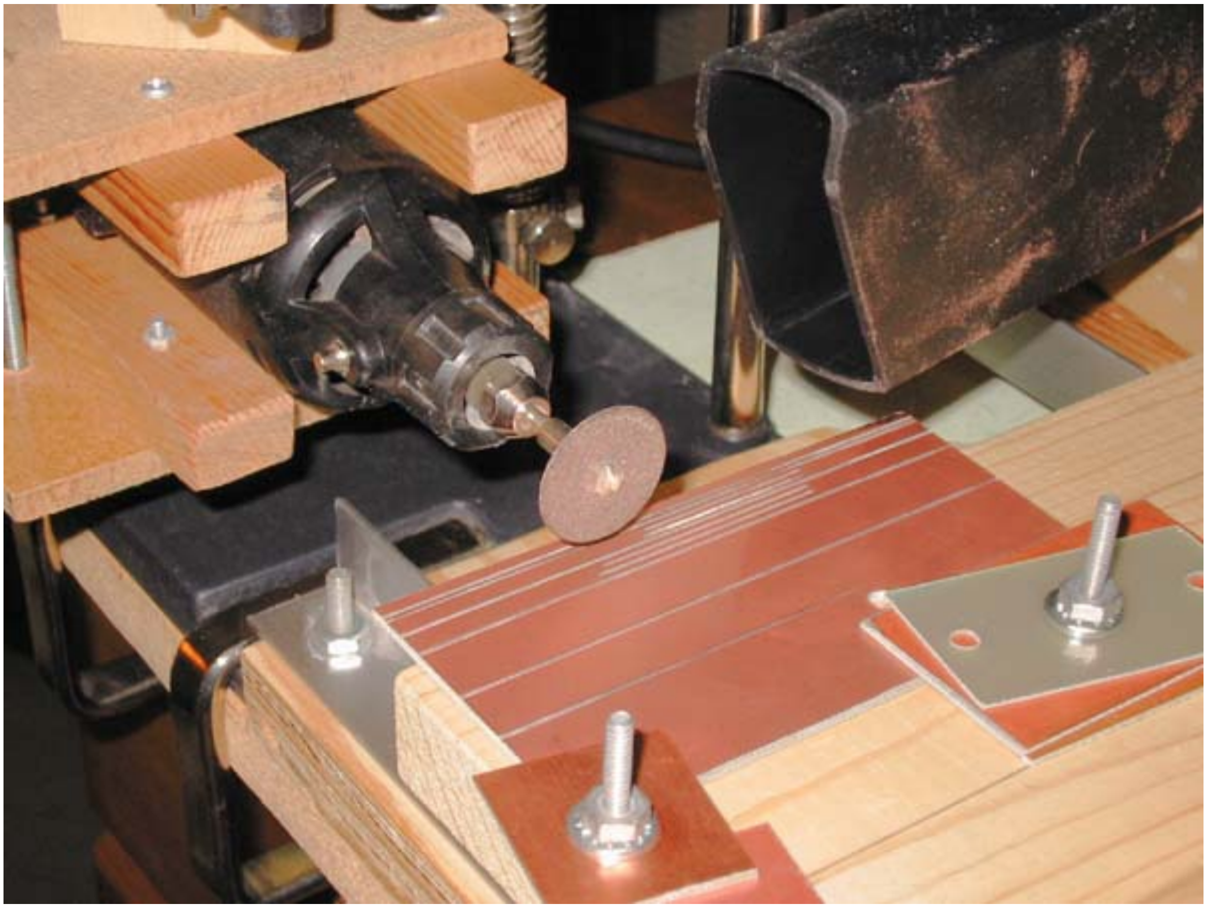


Update: March 25, 2004.

The system described has worked fairly well for some applications, especially those using discrete components and for SMT parts with the larger 50 mil lead spacing. However, there was one major failing that was severe enough that it discouraged me from using the apparatus. The way I had it set up, the material that was ground from the board by the grinding wheel was pushed out into my face. Not only did this mean that it was absolutely mandatory that I use a mask (not a problem) and live with the junk on my clothes, but the debris was spread all over my "shop" area, which also serves as a lab and ham shack. I was concerned that the grindings would end up inside vernier drives and the like. The system was rebuilt, as shown below, to get past these problems.



The original configuration has been flipped, placing the dremel tool on the left side of the work. This causes the material to shoot back, away from the operator, usually me. The second thing I did was to add a vacuum pickup. Shown in the above photo is the vacuum pickup. This is a Craftsman 916102 "Crevice Tool" for 2.5 inch tubing that fits in their line of shop vacuum cleaners. The tool is mounted on a piece of 2 x 4 wood, positioning it at approximately the right height to accommodate the grinding wheel. A couple of additional wood blocks are wedged in position to fine tune the system.



This is a close-up view of the grinding wheel in the final configuration, showing a test board with some preliminary cuts.

The recent changes should be especially useful when this setup is used for purposes other than the intend SMT "ugly" PC board generation.   For example, son Roger (KA7EXM) has recently done some experiments with PC boards built on the quick and cheap process from ExpressPCB. That option is constrained to one particular board size, which is slightly larger than he needed.   So Roger included two designs on the boards ordered.   Then he brought them over here to be cut in two. With the wheel now cutting all the way through a board, a great deal of fiberglass material was distributed around the room.   The updated system should take care of this problem.   (And yes, to anticipate a question, the ExpressPCB folks are great with a wonderful service.)

Conclusions:

This simple and ugly looking tool will become an often used addition to our home lab. It was simple to build, yet seems to do a credible job, allowing breadboards to be quickly and easily built with surface mounted parts.   So long as parts are available, a circuit idea can be built and tested within an hour.

We continue to use a face mask even after a vacuum chuck has been added to collect most of the particulate material generated by the apparatus. Eye protection and magnification are also used, creating an interesting sight. KK7B suggested that this method be named "Dust mite ugly" construction, for it is ugly, but only when viewed with a microscope.

Some readers will certainly ask about this method as compared with others. This method is not presented as the ultimate solution to the SMT construction problem. There are elegant (and expensive) computer controlled machine tools implemented just for this application. Rather, this represents a cheap and simple solution that was compatible with the equipment we already had in our ham "lab." The method seems well suited to the larger of the SMT methods with 50 mil spacing between pins (such as the SO-8) but not so appropriate for the smaller sized parts with 25 mil lead spacings. The primary limitation is the thickness of the grinding tool used.

The reader is referenced to SMT work by Ed Kessler, AA3SJ, at **http://www.qsl.net/aa3sj/HOME.html** . Go to his SMT page and then look for the S7C page and go to the end to see his version of the "milling machine." Ed gets by without a drill press stand, which is most useful. See Ed's paper in **QST, February 2004, p28, "Homebrewing--Surface Mount Style."**

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