Ironing Out Your Own Printed-Circuit Boards

Here's how you can make professional-looking PC boards with little trouble and minimal cost.

By John Grebenkemper, KI6WX
Tandem Computers
19333 Vallco Parkway
Cupertino, CA 95014

Many construction projects in QST and other magazines contain PC-board etching patterns as part of the article, or offer them by mail. Quite often, you can order ready-made PC boards for the project, but if they're not available and you want your project neatly arranged on a PC board, you have to find some means of making the board yourself.

Variety is the Spice of Life

Over the years since PC boards came to be, many methods of making them yourself were developed: the sharp-knife-and-hot-soldering-iron approach, the isolated-pad technique, etch-resist pens of one kind or another, rub-on transfers, adhesive and masking tapes, photographic film and photosensitive materials, to name a few. Somewhere all of these methods are still in use. For good measure, throw in the schematic-capture/PC-board artwork software packages that help design the layout.

Low-Cost Approach

One of the inexpensive ways of making PC boards is to use etch-resistant ink. Many hobbyists hand-draw the circuit on a piece of bare copper board using a pen that dispenses an etch-resistant ink. For simple circuits, this is easy to do and works fine, even though the finished product may not look very professional. Also, the would-be board maker may find it necessary (under some circumstances) to draw a mirror image of the pattern, otherwise the finished board comes out backwards. For complicated circuits, the pen-and-ink method is tedious and greatly increases the potential for mistakes.

High-Cost Approach

A more costly alternative is to use a photographic technique: Coat the board with a light-sensitive etch-resistant material, expose the board to light while covered with a transparency of the circuit-board layout, develop the board, then etch it. This method produces high-quality boards even with complicated patterns. For small-quantity production, however, it's time-consuming and a tad expensive: A single board can cost more than 50 cents per square inch!

But Wait!

If you'd like to combine relative production simplicity, low cost and produce professional-looking boards, I've got a deal for you! I'll show you how to produce boards of a quality approaching that of the photographic technique and at a cost almost as low as the pen-and-ink approach. This method makes it easy to produce any number of single-sided boards—even those with intricate patterns and fine traces.

Photocopier Etching?

The plasticized toner used in plain-paper photocopiers and laser printers is highly resistant to PC-board etching solutions. If you could pass a PC board through a plain-paper copier, you could print the etching pattern on the copper-clad board, then etch it! Unfortunately, photocopiers don't feed PC-board material as well as they do paper....

Where There's a Will, There's a Way

Ah! But, what if you first transfer the etching pattern to paper and then to the copper-clad board! How? By using a process that naturally, unknowingly (and sometimes frustratingly) occurs frequently with copied material. Have you ever placed a photocopy of something into one of the photodisplay windows in your wallet? About a month or so later, you probably discovered that some of the toner from the photocopied material had transferred to the display window. To make PC boards, you can employ a similar process to transfer the toner from a paper copy of your etching pattern to the copper-clad circuit board. You do, however, want to control the process more efficiently—and
The toner used in photocopiers starts out as fine, black particles. Through a relatively complex process involving electrical charges, these particles are transferred to a sheet of paper. The particles are melted onto the paper through a combination of heat and pressure. The melting point of the toner is relatively low, only a few hundred degrees Fahrenheit.

The method is quite simple; the title-page photo gives you an idea of the process. You place a photocopied PC pattern so that the toner is in contact with a copper-clad board. Next, you apply an ordinary household clothes iron to the other side of the paper. You apply heat and pressure until the toner melts and fuses to the copper and the paper. All you then have to do is remove the paper by dissolving it in a solution of water and bleach. What remains is a mirror image of the original copy—the correct image!

This unetched board has had most of the paper (the white, fuzzy-looking stuff) cleaned off.

You may not get a perfect transfer of the toner from the copy to the copper-clad board; some pieces of toner may flake off. If that happens, use an etch-resistant ink pen to touch up these sections. Then, etch the board with a standard ferric chloride or other etchant. The exact procedure followed is very important. Altering the steps can significantly alter the quality of the transfer. The step-by-step procedure for this method is given in the sidebar, "Thirteen Steps to Iron-On PC Boards."

**What Sort of Quality Can You Expect?**

This process can produce PC boards having trace widths of less than 0.02 inch—more than adequate for most amateur PCB applications. The method described in the sidebar gives the basic parameters and should work well for most people. If you experience problems, vary the parameters based on the following suggestions.

If the toner doesn’t adhere to the copper board, use a higher iron temperature, or longer contact time. Make certain that the copper surface is clean: Toner doesn’t like to stick to oily surfaces, so keep your dirty mitts off the board! (Use cotton gloves.—Ed.) If the trace width broadens excessively, use a lower iron temperature or a shorter contact time. Excessive trace broadening doesn’t seem to be a significant issue when paper is used as the transfer medium. If the toner isn’t sticking at the edges or corners of the board, concentrate on applying additional contact time to these areas.

**Thirteen Steps to Black-Belt Iron-On PC Boards**

Here’s a step-by-step procedure for making a PC board the photocopier way:

1. Most PC-board etching patterns are presented as viewed from the foil side of the board. This method requires that the etching pattern be viewed from the component side of the board. Make a mirror image of the etching pattern by copying the etching pattern onto a transparency on a plain-paper copier or a Thermofax machine. Place a blank sheet of paper behind the transparency to obtain the component-side view.

2. Copy the component view of the pattern onto a sheet of paper in a plain-paper photocopier. The copier should be set for as dark an image as possible, but not so dark that the white areas of the image start showing streaks.

3. Thoroughly clean the bare copper board. Remove all surface corrosion using steel wool. I like to make a final cleaning pass by wiping the board with acetone (use caution!). Some builders advocate placing the bare board in ferric-chloride etchant for a minute, but I’ve gotten acceptable results without using this step.

4. Set up an ironing board and iron. Set the iron’s temperature control to the COTTON or LINEN position. This heats the ironing surface to about 300 °F. Turn off the steam. Let the iron fully warm up to a stable temperature.

5. Place a blank sheet of paper on the ironing board (to protect it from toner). Place the clean copper board on the paper, copper side up. Position the plain-paper copy on top of the board, image side touching the board. Put a blank sheet of paper on top of the sheet with the etching pattern. This keeps toner on the copy from transferring to the iron. (When used for its intended purpose, an iron with toner on it does a wonderful job of making clean laundry dirty and is certain to raise the ambient noise level.)

6. Carefully place the iron against the paper. S-I-o-w-l-y slide the iron across the paper so that it’s flat against the copper board. This causes the toner to start sticking to the copper.

7. Move the iron across the paper in a circular motion with about one cycle every few seconds. Do this for two minutes. Don’t neglect the edges and corners; be especially careful about this. If the edges and corners don’t get enough heat, the toner won’t adhere to the copper when the paper is removed.

8. Let the circuit board cool for several minutes.

9. Prepare a solution of % cup of bleach in a gallon of water. Place the circuit board and adhering paper in this solution and let it sit overnight. The solution will start to dissolve the paper. Using a soft brush, gently scrub the circuit board to remove the paper. If some paper fibers stubbornly adhere to the toner, place the board back in the solution, let it sit another couple of hours, and brush again. Any paper adhering to the toner may cause the rough trace edges and possible shorts to adjoining traces.

10. Touch up any spots missing toner with an etch-resistant pen. I’ve found some “etch-resist” pens don’t work well (or not at all), whereas permanent-ink marking pens work very well. The Radio Shack etch-resist pen ink works if the etching period isn’t too long (say, in excess of 20 minutes).

11. Etch the board in ferric chloride (available at Radio Shack and other electronics stores). Carefully follow the directions on the etchant container.

12. Clean the etched board with acetone or steel wool to remove the toner. The board is now ready to drill and solder.

13. In some cases, the transfer to the board may be poor enough that it’s not worth etching the board. If this happens, remove the toner with acetone or steel wool and restart the process.—K6WXMLarge Print Edition
This process can produce PC boards having trace widths of less than 0.02 inch.

Yet Another Way

Here's another way for transferring the etching pattern to a copper-clad board. Instead of using paper as the transfer medium, use plain-paper copier transparencies such as 3M's PP2200. The transparencies can produce finer images than the paper method. One person I know who's used this method has produced line widths as fine as 0.01 inch. However, this approach is trickier to use, and the transparencies cost about 50 cents each.

The procedure is basically the same as that used for the paper method described in the sidebar, except for the following: In step 1, use a plain-paper transparency instead of paper. In step 7, reduce the heating time to about one minute, and be careful not to apply too much pressure. Excessive pressure and heat cause the traces to balloon to very wide widths. Skip step 9 entirely. Instead, hold the transparency by one edge, bent at a 180-degree angle, and s-l-o-w-l-y peel it away from the board. The toner does not like to stick to the transparency and most of it will adhere to the board.

This method requires a great deal of precision to work well and is affected greatly by each person's touch and the iron temperature. If a problem develops, the following hints should provide some guidance as to what to try next.

If insufficient heat was applied, the toner may not stick to the copper-clad board. If this happens, try a higher iron temperature or a longer period of iron contact with the transparency. If the transparency wrinkles or melts, the iron is too hot or you have a transparency that is excessively sensitive to temperature. I've found that some transparencies don't work well with this method. If the trace width widens excessively, try reducing the iron temperature, the contact time or the pressure.

The most common problem—especially with larger boards—is getting an even pattern transfer. If the heat is applied unevenly, some areas may show excessive trace widening, while others don't stick to the copper. The only solution to this is to learn to move the iron around the transparency in such a way that all areas of the board are heated evenly.

The main advantage of the paper-transfer method is that it is not as sensitive to trace widening with heat; you can apply much more heat without encountering a problem.

Summary

There you have it: A method that allows you to make inexpensive PC boards with photocopiers. I generally use surplus circuit boards which I can buy for a few cents per square inch. This means that I can make a single-sided PC board for less than a dollar. Once I became practiced at using the method, I found that I could reliably produce a PC board on the first try. But it took practice. If authors start publishing PC-board patterns as viewed from the component side, we'll be able to use this method without having to go through an intermediate transparency to reverse the image.

I'd like to thank Russ Mirov and Hal Massey, WB6NMR, for initially showing me the transparency method of making circuit boards.

Notes


2. Tek-200 film, which uses a PC-board-making process similar to that described in this article, is available from several sources including Ocean State Electronics, PO Box 1458, 6 Industrial Dr, Westerly, RI 02891, tel 800-866-6626, 401-596-3080; fax 401-596-3590.

3. DynaArt Designs has a toner-transfer system that can be used to produce plastic faceplates and decal as well as PC boards. DynaArt Designs, 3555 Stillmeadow Ln, Lancaster CA 93536, tel 805-943-4746. These materials are also available from All Electronics, PO Box 567, Van Nuys, CA 91410, tel 800-826-5452, 818-904-0540, fax 818-761-2653 and DC Electronics, PO Box 3203, Scottsdale, AZ 85257, tel 602-467-7738, 602-423-0070, 602-645-7736, fax 602-994-1707.


5. PC-board etching materials are available from most electronic product mail-order distributors. Your local Radio Shack stock carries the materials, too; PC-board kit (276-1576); etch-resistant pen (276-1530); etchant, 16-oz container (276-1535).

Bibliography

W. Richardson, “Practical Printed-Circuit Boards,” Modern Electronics, Aug 1989, pp 14-17, 82.


New Products

SIMPLEX VOX PATCH

◊ The CS-900 is the first low-cost voice-activated (VOX) simplex phone patch to incorporate standard features such as a 1/2-second electronic voice delay (EVD), built-in programming keyboard with digital display, 90-memory speed dialer, last-number redial, call-progression tone detection, user-programmable CW ID and more. The CS-900 is VOX-operated and doesn’t use sampling. There are no sampling noises or interruptions; just smooth, natural audio. The built-in EVD prevents syllable and word clipping caused by slow-switching transceivers. It interfaces with most transceivers, with the only connections required to the mike and speaker jacks. Suggested list price $379. Connect Systems Inc, 2064 Eastman Ave, #113, Ventura, CA 93003; tel 805-642-7184, fax 805-642-7271.

DUAL-BAND “INVISIBLE” ANTENNA

◊ The neighbors will never know you’re a ham with the VT-27 dual-band Ventenna for 2 meters and 70 cm. This model follows the original 2-meter single-band Ventenna design, with an antenna sealed between two layers of ABS plastic in a hollow tube that slips over your rooftop plumbing vent pipe. This durable 36-inch-long antenna is virtually indestructible and undetectable by observers. It comes with an attached 2.5-foot length of Belden high-performance 8240 (RG-58) coaxial cable that connects to your equipment with an SO-239 inline connector. Retail price $74.95. Mark Forbes, KC9C, The Forbes Group, PO Box 445, Rocklin, CA 95677; tel 916-551-5156, voice or fax 916-624-7069.

Strays

RADIO-CONTROL.NET

◊ The R/C Flyers net meets on 3.933 MHz every day at 1100-1200Z (following the Southern Coffee Club Net) to discuss all aspects of R/C model aircraft. Fred Lomax, N4KYG, 204 S Claiborne St, Goldsboro, NC 27530; or David Rose, WD4DJ, 817 Hawthorne Rd, Shelby, NC 28150.