Practical Printed-Circuit Boards

A simple direct-mask method of producing single-quantity printed-circuit boards

By Wayne Richardson

Home fabrication of printed-circuit boards can be a frustrating proposition. Those of us who have made our own pc boards are already familiar with the little things that make it so. Leading causes are the resist ink pen that works on everything but the copper on a pc blank, dry-transfer patterns that float off the blank in the etching bath, and messy photoresists that are costly and complicated to work with. Presented here is a reliable procedure for making pc boards inexpensively, though it does take a lot of patience.

Being limited to single-quantity boards does not negate the utility of the procedure we are about describe. After all, it is only the rare project for which you want two identical pc boards. On the plus side, the material needed for the resist pattern is commonly available at any housewares supply or hardware store at relatively low cost.

By The Numbers

There are five basic steps involved in the procedure described here. No special training or experience is needed to fabricate working printed-circuit boards using this procedure. You can use it to fabricate very simple single-sided boards, more complex boards and even some fairly complex double-sided boards if you work carefully and follow the steps detailed exactly.

It is assumed that before you begin laying out your pc board you know exactly what the copper-trace pattern is to look like in 100-percent scale. If you are starting with a pc etching-and-drilling guide in a magazine or book, full-size artwork is already available. However, if you are fabricating a pc board for a circuit of your own design, you must prepare on paper a full-size pc guide from which to work.

Whichever type of guide you are going to work from, it is a good idea to work directly from an exact-size photocopy of it. This way, you will not ruin the original, to which you can always return if you make an error during the procedure.

• *Step 1.* Begin fabricating your pc board by cutting to the size needed a piece of copper-clad pc blank. Smooth the cut edges of the blank and then scrub the copper cladding with scouring powder and water until the copper is bright and shiny. Thoroughly rinse off the scouring powder and air dry the cleaned blank. From now on, handle the blank only by its edges.

Now trim the photocopy of your actual-size artwork to the final size of the board and rubber cement this to the copper-clad side of the now dry pc blank. Use only enough rubber cement to prevent the artwork from moving as you handle the board.

Once the cement has dried, drill an appropriately sized hole for each

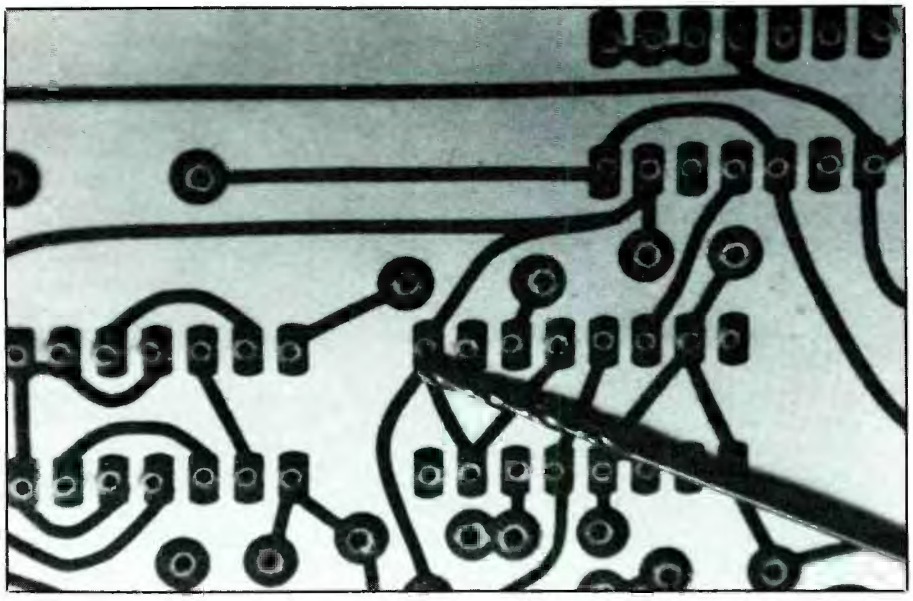

Fig. 1. After rubber cementing photocopy of original actual-size artwork to copper-clad side of pc blank, drill all component lead and pin holes and mounting holes for board.

component lead or pin and mounting hole in the pc guide. Use of a drill press stand or a hobby type drill will make this part of the procedure easier to perform. Work carefully, especially when drilling holes through the centers of IC pads. Use a sharp bit and allow the drill to do the work. The procedure up to this point is photographically illustrated in Fig. 1.

When you are finished drilling all component lead and pin holes and the mounting holes for the board, backlight the pc blank and check for any holes you might have missed. If you did miss one or more holes, drill them now.

Slowly and carefully to avoid tearing it, strip the artwork from the pc blank. If you are successful in peeling away the artwork in one piece, you can keep it for use at another time or later reference. Now examine the copper cladding to see if any rubber cement has been left behind. Remove any you find by rubbing it away with a fingertip.

If you are fabricating a double-sided pc board, turn over the drilled pc blank and use very fine sandpaper to smooth the rough copper edges only around each drilled hole (see Fig. 2). Next, test position the actual-size artwork for the other side of the board against your work thus far. It is helpful at this point to backlight the board to aid in positioning the artwork. Your second-side artwork should exactly mesh with the hole pattern already drilled in the blank. Set the artwork aside.

• *Step 2.* Now cut a piece of clear Contact™ or other self-adhering plastic sheet of the kind used to cover shelves to dimensions large enough to completely cover the copper cladding on the board. (You need two such sheets of clear plastic if you are fabricating a double-sided board.) Remove the paper backing from the plastic sheet.

Working carefully, roll the plastic sheeting, adhesive side down, onto the copper cladding. Firmly burnish the plastic sheeting onto the copper cladding to avoid wrinkles and eliminate trapped air bubbles. Work from the center outward in all directions. When you are finished, trim the plastic to the exact dimensions of the pc blank, using a safety or hobby knife. If the board is to be double sided, repeat the procedure for the second side.

Lightly sand with very fine emery cloth the entire exposed surface(s) of the plastic to give it a "tooth" on which to draw. Do not push down

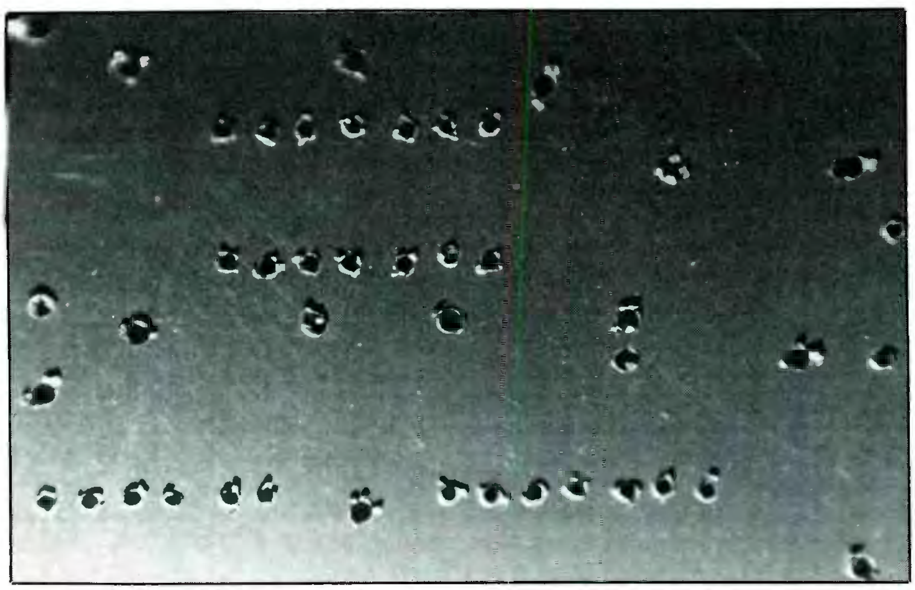

Fig. 2. Sharp copper edges will appear on the exit side of holes drilled through double-sided pc blank. These must be smoothed with very fine emery cloth.

hard or cut through the plastic with the sandpaper!

• *Step 3.* It is now time to draw the conductor pattern onto the plastic exactly as it appears in the original artwork. Place your artwork beside the pc blank in the same orientation as the holes you drilled in the latter.

Now use a soft lead pencil with a rounded—not sharp—point to draw each pad outline and conductor run on the dulled plastic sheeting exactly as it is shown in the original artwork. Work carefully, and draw each complete conductor run from beginning to end before proceeding to the next. This way, you are less likely to miss a conductor run. If you make any errors during this phase of the procedure, simply erase your mistake and correct it immediately.

If desired, you can adjust the width of the board perimeter (usually a surrounding ground trace) to make it possible to remove a minimum amount of copper during the etching operation—provided this does not interfere with circuit performance. By reducing the amount of copper to be removed to a minimum, you can extend the life of your etchant.

• *Step 4.* When you are finished drawing the copper-trace pattern (see Fig. 3), compare it point for point against the original artwork—for both sides of the blank if you are making a double-sided board. If you discover any errors at this point, correct them immediately. Then, when you are satisfied that everything is okay, use a very sharply pointed hobby knife to score the plastic around every drawn trace down to the copper surface(s). Think of each trace as an elongated circle. Before you do this, however, it is a good idea to practice on a scrap plastic-clad board. Spacing between cuts, working around IC pad locations and the amount of cutting pressure are the only difficult—but easily mastered—parts of this simple pc-board-making procedure.

If needed, you can make the traces quite wide, leaving only 1/16 inch of space between them to cut down on etchant usage. This is safe to do because of the natural undercutting action of the etchant. Work only a few minutes and then rest for a few minutes. As you gain experience with this technique for fabricating pc boards, your pace will pick up considerably.

After cutting all trace shapes, you are ready to remove the unwanted portions of the plastic sheeting in the areas to be etched. To do this properly, slide the tip of your hobby knife

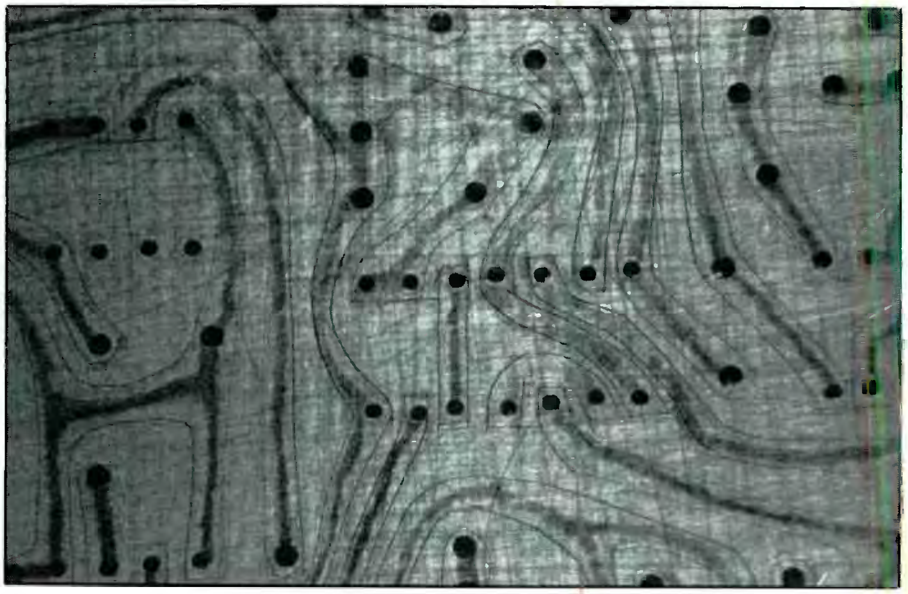

Fig. 3. Carefully following original artwork, conductor pattern is drawn on self-adhering plastic sheet with a soft lead pencil.

Fig. 4. After scoring around drawn trace pattern with sharp hobby knife and removing unwanted plastic sheeting, examination of result may show such potential problem areas like left-behind adhesive (inside large circle) and notches removed from traces (small circle).

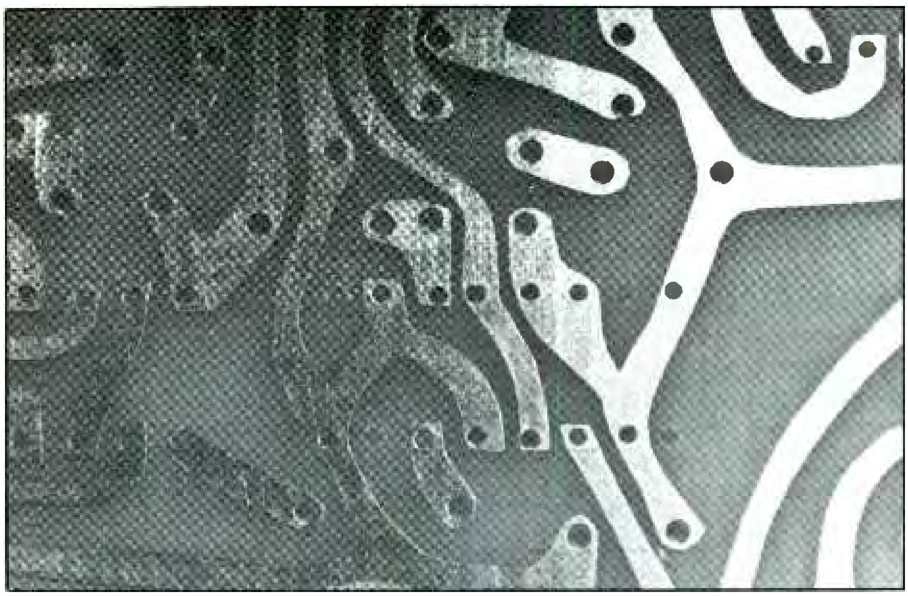

Fig. 5. After etching the pc blank and removing plastic-sheet "resist" and cleaning the blank, copper traces are sharply delineated from board substrate.

under a path to be removed and very carefully peel it away. If you encounter a point where your previous cutting failed to cut all the way through the plastic, stop and use your hobby knife to cut all the way through. Then continue peeling away the unwanted plastic sheeting until all of it has been removed. If you are working on a double-sided board, remove the unwanted plastic sheeting from the other side as well.

After discarding the unwanted pieces of plastic, place a sheet of paper over the blank and firmly burnish through it the remaining pieces of plastic sheeting into place on the copper cladding. This second burnishing operation will reseat any plastic pieces that might have lifted from the copper surface during the removal operation.

In bright lighting, carefully examine your board to locate any errors and remains of unwanted plastic sheeting and left-behind adhesive. At the center of Fig. 4 are shown two things to keep an eye out for. One is in the large circled area, which shows some adhesive that was left behind when the plastic sheeting was removed. The other, in the small circle, shows a notch of the plastic that was erroneously removed from a conductor run.

Remove unwanted adhesive with a cotton swab dampened with ether-based engine starting fluid (work in a well-ventilated area). Alternatively, stop by an art-supply store and pick up a rubber-cement pickup block and use this to "erase" the adhesive. Repair a missing piece of plastic by removing the damaged plastic and replacing it with a strip of Scotch Magic Transparent Tape™. Do *not* substitute another brand or type of tape or you will run the risk of the tape floating off the copper in the etchant. An alternative approach to repairing a damaged piece of plastic "resist" is to paint onto the accidentally exposed area of copper clear fingernail enamel.

• *Step 5.* Burnish down your plastic-sheet resist pattern one last time through a sheet of paper. Then place the prepared blank in the etching solution of your choice. Leave the blank in the solution for a few minutes to allow the etchant to begin removing copper in the exposed areas of the blank and then remove it from the solution. Check for air bubbles trapped against the copper cladding (break them with the point of a pin) or spots where you missed seeing left-behind adhesive before (remove them as described above) while the blank is wet.

Return the blank to the etching bath, but periodically remove it to check for problems. Rectify these as you encounter them. Problem areas will be clearly visible. You can rectify these problems before permanent damage is done to the pc blank.

Once the etchant has done its work, rinse the board under cool running water to remove all etchant and stop the chemical action. Peel away and discard all plastic resist from the remaining copper traces. You will be left with sharply defined copper traces on the board substrate, as shown in Fig. 5.

Once again clean both sides of the board with scouring powder and water until the copper traces are bright and shiny. Then thoroughly rinse the board to remove all vestiges of scouring powder, especially in the drilled holes, and then air dry it or force-dry it in a warm oven.

When the pc board is completely dry, handle it only by its edges. If you wish, you can immerse the new pc board in a solution to plate all conductors with a thin layer of tin to protect them from oxidizing and make them much more solderable.

Your printed-circuit board is now ready to be populated by the components for which it was designed. It is best to wire the board as soon as possible after fabrication to prevent oxidation of the copper traces from becoming a problem during the soldering operation. Of course, if you plated the traces with tin, you can

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wait longer to populate the board, if you wish.

When working on a double-sided pc board you made yourself, keep in mind that the holes are not plated-through. Therefore, you must solder component leads and pins to the copper pads on *both* sides of the board and install bare wires in each hole that signals continuation of a conductor on the other side of the board. Also, if you are building a project that uses DIP ICs and wish to use sockets, do not use ordinary sockets that offer soldering access on only one side of the board. Instead, use Molex Soldercon® socket strips instead.

Some Caveats

The size and complexity of any printed-circuit board you attempt to fabricate using the method detailed above will depend on your persistence, dexterity and experience with this procedure. Do not try to make several of the same board, microwave inductors or computer motherboards with this technique. If you do, the attempts will be destined to fail. Such applications are jobs for the photographic technique.

As you work with the procedure described here, keep in mind that it is best to perform Steps 2, 3 and 4 at one sitting, if at all possible. The reason for this is that the adhesive on the plastic sheeting has a tendency to "grab" after a few hours, making removal much more difficult.

Making a printed-circuit board by the method described above is more dependable and no more difficult or time-consuming than other fabrication techniques. It is easy to master and requires no expensive and temperamental chemicals (other than the etchant of your choice, of course). ME