# ETCH YOUR OWN PC BOARDS

*Don't let the fear of making PC boards stop your project cold. Let us show you the easy way to make even complicated boards.*

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**Part 3** WE HAVE ALREADY shown you how to design a PC board layout and how to make a photo mask. Now we are ready to make the foil mask—the first step in transferring the pattern onto the PC board.

### Making the foil mask

One of the things you'll need to make the foil mask—the film that's used to produce the PC board—is a contact frame. You have two options here. You can either spend a lot of money and get one in a camera shop or you can buy a cheap picture frame—the kind into which you slide a photograph; once the photograph is in place, it's held tight against the glass.

Working under the safelight, cut a piece of black paper to fit the inside of the frame and put a fresh sheet of film on top of it, emulsion-side-up. Put the positive you've just made on top of it, emulsion-side-down. Sandwich the whole thing together in the frame and use the light from the slide projector to make the exposure. If you are using a picture frame, be sure that the film is pressed tightly against the positive and that the positive is pressed tightly against the glass; if needed you can use cardboard inserts to accomplish that. Keep everything as dust free as possible.

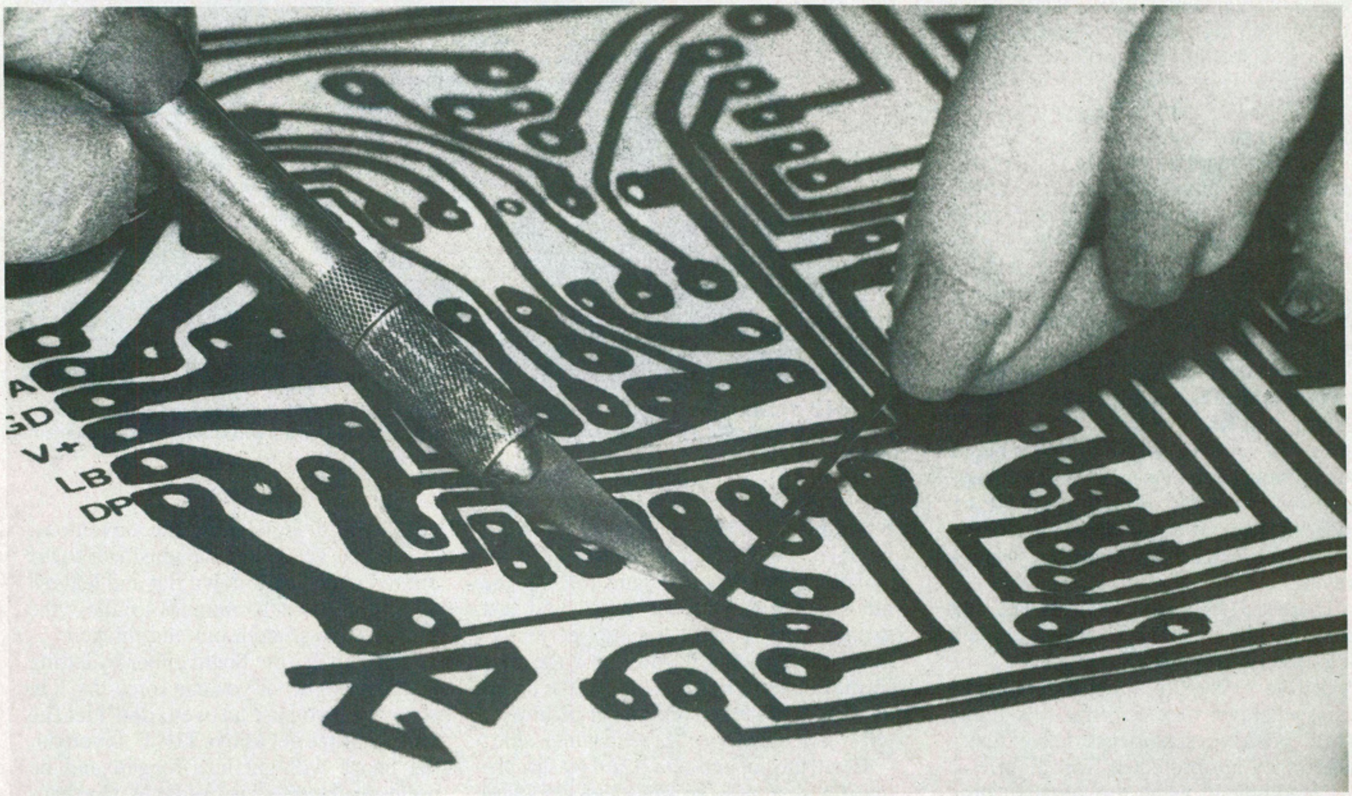
The length of the exposure should be the same as the one you used in the last step, (see Part 2 in January's **Radio-Electronics**) as long as you keep the distance to the slide projector the same. After you develop that piece of film you will have a full-size negative of your foil pattern. The only thing you need to do with it is to check the clear areas and scrape them clean.

Hold the negative over a strong light to make sure that the black areas are completely opaque and that there aren't any pinholes in them. (Pinholes are tiny clear areas that are caused by dust getting trapped between the two pieces of film when the exposure is made.) Although there are special dyes available to correct pinholes, I've found that the white correction-fluid used to fix typing errors works well for small ones (see Fig. 14). Use a very fine brush and dab on a tiny drop of the fluid to cover the holes. Once you're satisfied that the holes have been covered and the traces (the clear areas) are clean, the negative is finished. If your board is single-sided you can start preparing the circuit-board blank, but if you're making a double-sided board, you still have a bit more work to do with the film.

Put the original 35mm film of the second side of the board into the slide projector. Tape the positive (black-on-white) film of the first side of the board to the wall and project the image of the second side on to it. You'd think that if you adjusted the size the way you did for the first side the two would be the same. Well, it never works. Slight differences in measurement can wreak absolute havoc with the registration of the two negatives. The only way to be absolutely sure that the masks for the two sides of the board will be in perfect registration is to measure one against the other.

Adjust the projected image to match the film you've pinned to the wall. There are two things to check: size and alignment. You can use the IC pads to check for both purposes. Adjust the projected image so the IC-pad spacing is the same as that on the film you've taped to the wall. Once you've done that, make sure that both images are in register at the top and bottom.

If you've made registration marks on the artwork use those; otherwise use the IC pads and the feedthrough points as references for alignment. You may find that you have to tilt the projector and distort the image to make everything line up properly. Pay careful attention to that part of the process because, if the two




images aren't in register, you're going to have a lot of problems drilling holes once the board is etched. Obviously there's some leeway in all this—even when it comes to drilling the holes. As a general rule, however, if the size or alignment is off by more than about 1/32 inch you're going to have real problems.

Errors have a nasty habit of adding to each other rather than cancelling out, and that's the reason you have to measure one side of the board against the other instead of using a grid for both of them. After the exposure has been made and the film developed, tape the two positives together to make sure the registration is correct. Try to line up the holes at both edges. If they're off you're going to have to do the second side of the board again. The chances are, however, that if you've been careful all along the registration will be correct.

Once you're satisfied that everything is lined up properly, make the actual negative (white-on-black) exposure mask for the second side of the board, check it one more time, and put all of the negatives safely away.

### Board and processing materials

There are different types of copper-clad PC-board material available. The differences have to do with the weight of the copper and the material the board is

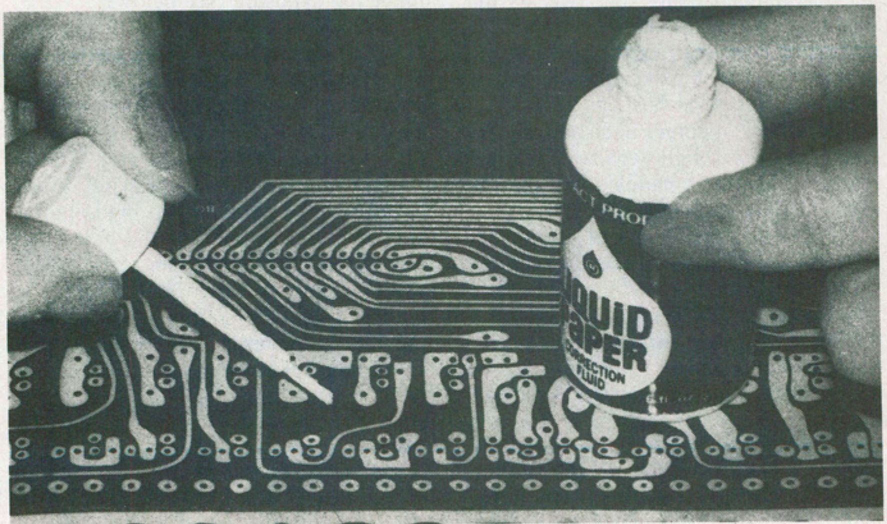


**FIG. 14—TYPEWRITER CORRECTION FLUID can be used to get rid of pinholes in the finished negative.**

**SUPPLIES**

**Layout**
20 × 24 inch sheets of 1/10-inch grid graph paper (non-repro blue)
Non-repro blue pencils
Fine-line black felt-tip pens
Double-size PC-drafting aids (IC pads, doughnuts, etc.)
Ruler and caliper
Black layout-tape of different thicknesses
Transfer-type lettering

**Mask**
35mm camera
250-watt floodlights (2)
35mm slide projector
35mm glass slide mounts
Contact frame
Ortho (litho) film (35mm and large enough for the actual-size mask)
Ortho (litho) developer, stop bath, and fixer
Red gel and safelight

**Board**
PC-board blanks
Spray-sensitizer and developer
Glass trays
250-watt sunlamp or 40-watt fluorescent lamp
Etchant

made from. The weight of the copper refers to the thickness of metal on the board and is expressed in ounces. The best all-around choice is one-ounce board. The copper is not so thick that it causes problems when you etch it, but is still thick enough to allow traces as thin as 1/32 inch. Not only that, but a 1/16-inch-thick trace of one-ounce copper can safely handle up to five amps; thicker traces can handle proportionately more.

The best board material is glass-epoxy laminate; anything else is not as good, and some types of board, such as phenolic board, are really junk. There's a difference in price, of course, but the quantities you're likely to be using are so small that the actual difference in cost is not going to be significant.

Once you've picked out your board, the next step is to sensitize it; the chemicals for that are available from a wide variety of sources. While it's possible to buy presensitized board, it's much cheaper to do it yourself. (Besides, if anything goes wrong and you have to redo the board, you'll have to resensitize it anyway.)

There are two types of sensitizers, and each has its own type of developer. Sensitizers are either "negative" or "positive." Negative sensitizers leave resist wherever they are struck by light, while positive sensitizers leave resist where they are protected from light.

I recommend using the negative process for several reasons. First, the additional mask-making step allows you to make corrections more easily to both foil and etched areas. You can make corrections on the white-on-black film with both an *X-ACTO* knife and dye or correction fluid, and corrections on the black-on-white one with the knife.

Second, if, for some reason, the mask does not make perfect contact with the sensitized board when you expose it (see below), light may "leak" under the edges of the opaque areas of the film and cause copper that you need to be etched away. If you were using the positive process, you might lose some of your thin traces. With the negative process, however, you would be more likely just to increase slightly the amount of copper that would not be etched; you might have to remove a little copper from traces that ran close together, but removing copper from a PC board is a lot easier than trying to put it back.

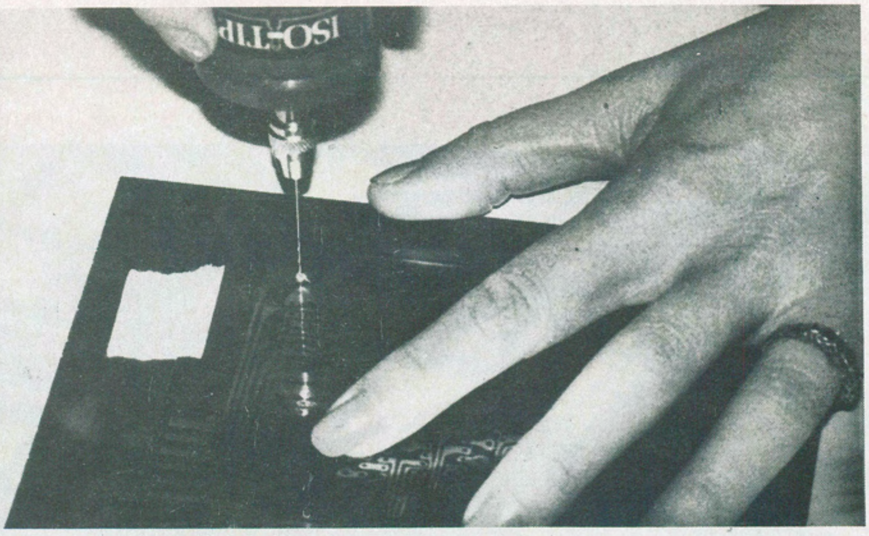


**FIG. 15—IF THE BOARD IS DOUBLE SIDED, tape one of the negatives to the board and drill out four of the feedthrough holes. Those holes will be used later to make sure that the two sides of the board are in register.**

### Making the board

Cut the copper-clad board large enough to allow at least a one-inch border around the negative. If you're making a double-sided board, tape one of your negatives to the board, emulsion-side-down; make sure that the negative is well centered. Pick four feedthroughs—one near each edge of the board—and drill holes through the negative and the board as shown in Fig. 15. Mark the corner of the board by scratching the copper so you'll be able to tell which is the top.

Turn the board over and line up the other negative with the holes you just drilled; they should line up perfectly. Drill holes in this negative for the four feedthroughs. Mark this side of the board as well, and make sure you'll be able to tell which negative goes with which side.

Clean the copper-clad board by scrubbing it with a piece of fine steel-wool and household cleanser—a soap pad is perfect. The copper probably has some oxidation on it and you want to make sure you get it all off. To test whether the board is clean enough, run water over it—if it's good and clean, the water will bead, and not spread out over the copper. (You can see the same effect on a freshly waxed car.) Dry the board with paper towels and **be sure to keep your hands off it.** The sensitizer won't adhere well to any areas of the board contaminated with skin oils.

Several companies package sensitizers, but only a few mix them with a dye. We recommend using that type as the sensitizer itself is just about colorless; the dye makes it easier to see the board during developing, which makes it easier to tell when the process is finshed.

The sensitizer comes in an aerosol can and is, of course, light sensitive. For that reason, it has to be handled like the unexposed film—under a safelight.

Be sure to spread lots of newspaper around because you can't really keep the spray from going beyond the immediate area of the board. Then, rest the board at a 45° angle and, still working under a safelight, apply the sensitizer, holding the can about 10 to 12 inches from the surface of the board. The technique here is the same used in applying spray paint. Keep the nozzle moving back and forth over the board and move from top to bottom. Don't apply too heavy a coat of sensitizer or it will run. On the other hand, too thin a coat will disappear in the developer. When you've applied the sensitizer to the entire board, lay it down flat and leave it alone for about 10 minutes to allow the sensitizer to smooth out and thicken.

You can dry the board either by letting it sit overnight, or you can force-dry it in an oven. If you use an oven, **don't let the temperature get above 110°F**. If you do, the board will get heat-fogged and be useless—the effect is similar to what happens when you expose photographic film to X-rays. Thirty minutes or so is all you need to oven-dry the board. If you're making a double-sided board you'll have to spray the other side of the board and repeat the drying procedure. If you're not sure whether the board is dry, smell it; the drying agents in the spray have a distinctive odor that will be present as long as the board is the least bit wet.

If you're making a single-sided board, all you have to do next is lay the negative emulsion-side-down on the sensitized board, put it in the contact frame, and make the exposure (see below).

A double-sided board has to be prepared differently to make sure that the two sides remain in register. Get a slab of stiff styrofoam—the white packing material used to cushion radios, etc. during shipping (you can also find it at many florists—they use it to prepare flower arrangements). Put a wire brad, point-side-up, through each of the holes that you drilled in the copper-clad board. Then lay the negative on top with the brads through its registration holes. Place the board, negative and brads on the styrofoam and take a piece of glass larger than the board and push it down over the board. The brads will be pushed into the styrofoam, and the negative will be tightly sandwiched between the glass and the copper-clad board.

The sensitizer reacts to ultraviolet light. Ordinary light-bulbs or a slide pro-

## TABLE 1—TROUBLESHOOTING GUIDE

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| **Problem** | The pattern appears on the board but is washed away by the developer. |
| **Cause** | 1. The sensitizer is sprayed on too thinly<br>2. The board wasn't completely dried<br>3. The board wasn't well cleaned before the sensitizer was sprayed on |
| **Problem** | No image appears when the board is developed. |
| **Cause** | 1. The exposure was insufficient<br>2. The board was overheated in the oven when it was dried<br>3. The developer is exhausted |
| **Problem** | The pattern is evident but the etchant has no effect on it. |
| **Cause** | 1. The etchant is exhausted<br>2. The developer is exhausted<br>3. The exposure was too long<br>4. The mask wasn't completely opaquex |
| **Problem** | The pattern is attacked by the etchant. |
| **Cause** | 1. The sensitizer was sprayed on too thinly<br>2. The exposure was inadequate |
| **Problem** | The pattern blisters and flakes away in either the developer or the wash. |
| **Cause** | 1. The board wasn't clean when it was sprayed<br>2. The board wasn't completely dried<br>3. The sensitizer was sprayed on too thickly |

jector don't put out a whole lot of energy in that part of the spectrum, but a sun lamp does. If you don't have one, you can use a fluorescent lamp, but the exposure times will be longer. I use a mercury-vapor type home sun lamp. With that, I keep the light about three feet from the board and use an exposure of about four minutes. If you use a fluorescent lamp-fixture with two 20-watt bulbs in it, try ten minutes as a starting point and keep the distance between the bulbs and the board about ten inches. You will have to experiment a bit to find the correct exposure time.

If you are making a double-sided board, you'll need to repeat the process for the other side. Working under the safelight, remove the brads, turn the board over, position the second-side negative, and re-insert the brads; the rest of the procedure is the same as that for the first side of the board.

The next step is to develop the board; that must also be done working under a safelight. Make sure the developer you get is made for the negative-type sensitizer. Don't use a plastic tray, because the solvent action of the developer will eat right through most plastics—use a glass or metal tray to avoid winding up with a ruined board and a lap full of exotic esters and ketones. Also, to make your work easier, be sure that the tray is large enough to provide a few inches of finger room all around the board.

Fill the tray with developer to a depth of ½ inch. If you are making a single-sided board, you can simply lay it on the bottom of the tray, pattern side up. With a double-sided board, however, you'll have to hold the board **by the edges** to keep it suspended above the bottom of the tray. That's because the resist gets really soft when it's in the developer and if it rubs against anything (including your fingers) its going to smear and ruin a lot of work. Gently agitate the solution and you will see the circuit appear after about thirty seconds.

You can check to see how things are proceeding by removing the board from the solution; be sure to hold the board so that any developer that remains on the board when you remove it can drain back into the tray. If the pattern appears clearly on the board, let the developer drain off and then dunk the board repeatedly in water. Don't let running water hit the board for the first twenty seconds or so because you run the risk of smearing the resist—remember that it's very soft and easy to ruin. If you've used a sensitizer with a dye, the pattern will be easy to see. If not, you'll only be able to see the pattern by holding the board so that the light from the safe light will hit it at an angle. With the resist still swollen with developer, the pattern will be easy to see. As the developer evaporates or is washed away, however, the pattern will disappear. Just remember to keep the pattern from touching anything.

After you've washed the developer off, blow and shake the excess water off the board (**do not wipe it off**) and reimmerse it in the developer. Give it another 30 or 40 seconds of gentle agitation and then wash it again. The best time to tell if the board will etch well or not is when it's in the water but the resist is still full of developer. Every place that was covered by the mask will shine brilliantly because the copper won't be covered by any resist—it will look really clean and polished. If the pattern is mottled, or the resist won't clear from the areas of the board where it's not wanted, you'll have to scrub the board clean and go through the whole process again.

### Etching the board

Once the board has been developed completely, a safelight is no longer needed. Etching the board is the easiest part of the whole process. Ferric chloride is a popular etchant, but use whichever one is most convenient for you.

The first step is to heat the etchant up to 125°, since the hotter the etchant is the faster it works. Pour the warm solution into a tray (glass or plastic, as the etchant will react with almost any metal). Then, drill a hole in one corner of the board and slip a piece of heavy-duty thread through it. Tie it and use the thread to agitate the board in the etchant.

When you first immerse the board you can get a good idea of how easily it will etch because all the unprotected areas of the board will turn black as the etchant attacks the copper. If that doesn't happen, agitate the board for a few minutes and then take it out and rinse it off in running water. The pattern should be shiny and protected under the resist, but the rest of the board should be a dull copper color because of the action of the etchant. Examine the board closely and if you spot any problem areas or unwanted blobs of resist you can scrape them away with an *X-ACTO* knife. Constant agitation should etch the average board in about fifteen minutes. Take the board out and examine it periodically. If you spot breaks in the pattern you can dry the board and cover the breaks with tape. If one side of the board etches faster than the other, don't take the chance of having the faster side being undercut by the etchant. Dry the whole board and cover the areas you want to protect with spray acrylic, electrical tape, or just about anything waterproof.

When the etching process is finished, **don't scrub off the resist**. Wash the board and dry it with paper towelling. Drill the holes for the components and then use a saw to trim the board to size.

If you're making a double-sided board, drill the first few holes somewhere on the board where there is room for error so that you'll be able to see whether the alignment is exact or not. Since you made the patterns by laying one image over the other, you can be sure that the size is correct, but sometimes the negative for one side of the board can get shifted slightly and throw the alignment slightly off. You can usually correct for that by drilling the hole at an angle, rather than straight through the board. If you make your first few holes in a place on the board where things aren't so cramped, and you drill from the foil side to the component side, you'll be able to see whether such a tactic is needed. Since the negatives were made in register, if *one* hole is off to one side, *all* the holes will be off. That, however, can usually be corrected by drilling in the proper direction and you'll never probably find any correction other than that to be necessary.

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## PC BOARDS

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The reason you've left the resist on the copper is because it saves you the trouble of tinning the board to keep the copper from oxidizing. The resist protects the copper and when you solder to the board, it vaporizes. It's really similiar to the neoprene covering on wire-wrap wire. The hot solder will vaporize the resist and a good joint will be made, but the copper traces will remain untarnished and protected from moisture.

Making printed-circuit boards is like a lot of things in life—it sounds much harder than it actually is. If you try to describe everything you have to do when you drive a car, that will sound incredibly complicated, too. Persevere, and a little experience will have you doing perfectly what is essentially an easily repeatable mechanical process. The trickiest part of the whole procedure is the spraying and exposing of the copper blank. If you can get that down pat, you've got it made. If you have difficulty, take a look at Table 1; it should help you overcome most of the common problems.

Get used to the idea that you're going to make a mistake somewhere the first time you try to make your own boards. You'll probably be able to make good masks, but the procedure from there to etching is a matter of patience and experience. Notice that we do not say that it is hard—it isn't. Once you find a system that works, it will always work. And, being able to make your own boards gives your projects a professional touch, regardless of how complex they are. **R-E**