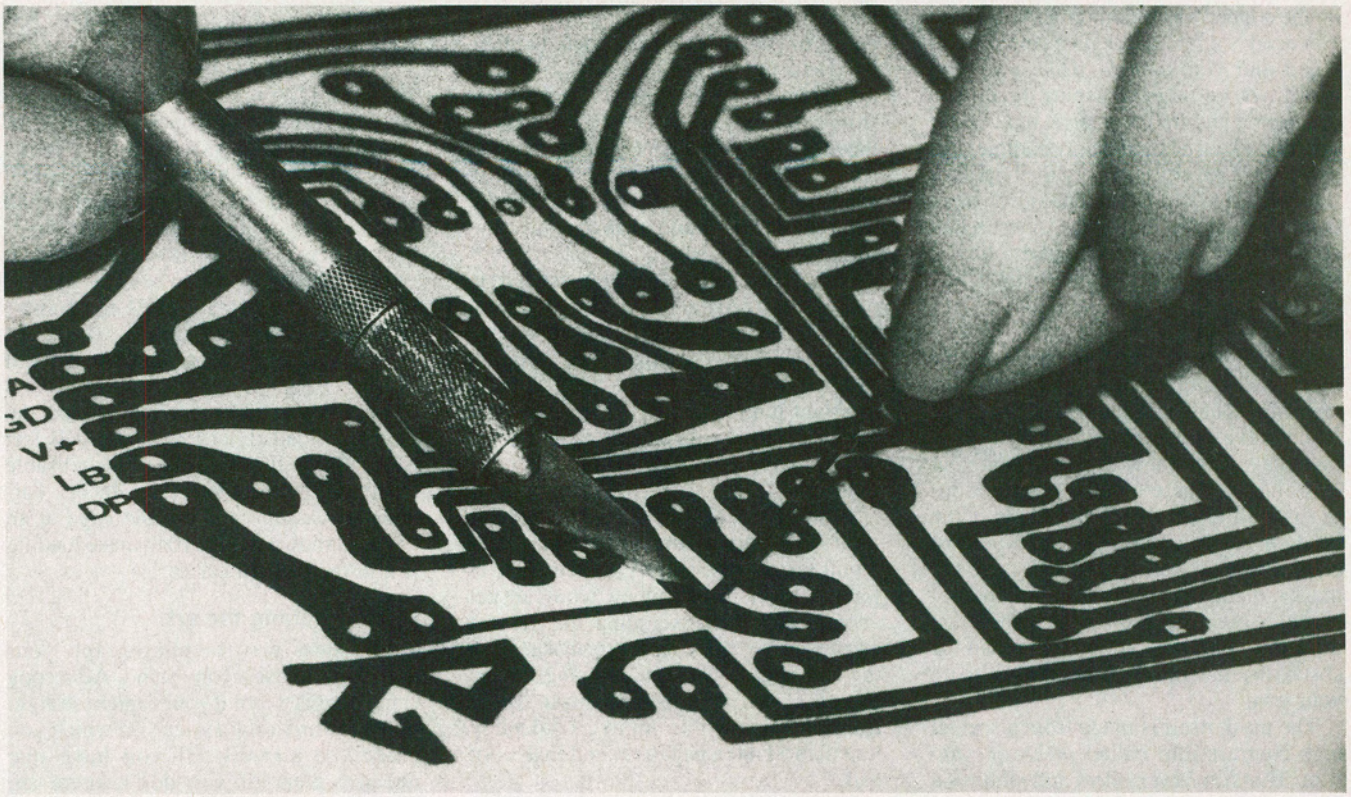

ETCH YOUR OWN PC BOARDS

Now that you've drawn your layout, what's the best way to transfer it to the board? Do it the easy way—photographically!

ROBERT GROSSBLATT

Part 2 LAST TIME, WE SHOWED you a step-by-step method for developing a PC-board layout from your working prototype circuit. The first thing we'll do this month is finish that layout.

At the risk of sounding monotonous, recheck all the connections against your schematic once again—and it's not a bad idea to check the schematic against the breadboard, either.

This is the last chance you'll have to make any changes in the pattern easily. Get out the straightedge and calipers again and make sure that the pads at the top and bottom of the boards are in register. Count squares from the middle center line and use the straightedge to verify everything. Finding a pad that's off by a sixteenth of an inch when you're drilling holes can really ruin your day.

If you're sure—really sure—that everything is correct you can go on to the window dressing. It's always a good idea to label things. If you have edge connections on the board, you'll usually find it helpful later on if you number them. The same is true for pin 1 of each IC. You can do all that, and include any descriptions you want on the board, using transfer type as shown in Fig. 6. It's nice to indicate different sections of the board, which way polarized components should be inserted, IC numbers, and so on. After all, the whole purpose in making printed-circuit boards is to make life easier and more reliable. Use transfer type that is at least ⅛-inch wide; any smaller and you run the risk of having it thin out and disappear somewhere along the line.

Your drawing should be finished now. The pattern should be completely blacked in and you should be able to see the components drawn in blue on the component side of the board. Check everything over a final time and then mark off as long a segment as possible on the center line. Label the length in black as shown in Fig. 7. The longer the segment you can mark, the more accurate your measurement is going to be when you shrink it down to half size. Once that is done you're ready to begin making the etching mask.

Transferring the pattern

There have been lots of methods devised to get a foil pattern transferred from paper to circuit board. They have been as simple as drawing directly on the copper or as involved as cutting out patterns in copper or tape. All those methods were developed because there's a myth that the photographic process is too difficult to be done at home—some claim that the equipment is too expensive; others that the materials are too exotic. In any event, when I made the decision to make prototype boards at home I read all that propaganda and, (perhaps like you?) believed it all. I tried every method I could find. I cut, drew, pasted, taped, and scraped—and unless the pattern was an exceptionally simple one, the results were usually disappointing. Then I decided to do it the hard way—photographically.

I was amazed—the results were perfect, the process was easy, and the amount of detail that could be reproduced on the copper was astounding. Now, if all you need is a few traces on a single-sided board and you want to make only one board, you're better off taping directly on the copper and letting it go at that. But if you're making a board of any complexity, if you want several copies of the board, or if the board has to be double-sided, there is no method simpler, safer, or more secure than the one everyone else told you to avoid—the photographic method.

Photo masks

Preparing a photographic mask is like most other things in life—if you have the right tools and use them correctly you won't have any problems. Don't automatically dismiss the idea of making your own masks. There's nothing mysterious or difficult about the process, and it can be done easily with a bare minimum of equipment. Of course you can have the masks made by a professional photographic house, but the cost of having that done once or twice will be more than the cost of the materials you have to buy to do your own.

The mask itself is made from a special high-contrast film called *ortho* or *litho* film. That film is very slow and requires a lot of exposure, but it produces the kind of negatives that are ideal for printed-circuit work. When the film is developed, the image is either completely opaque, or completely clear; there are no in-between shades of gray. There is no secret to using it properly and it's very tolerant as far as exposure and processing are concerned.

To keep things simple, we will proceed under the assumption that you have a basic knowledge of darkroom techniques and terminology. If you do not, it would be a good idea to get hold of a basic book on the subject, either from your public library or from a photography store, and look through it.

What you'll need

Although ortho (litho) film is manufactured by several different companies, it is most readily available from Kodak. Their brand name for the film is *Kodalith* and it comes in a variety of shapes and sizes, ranging from 35mm roll film to sheets of film that measure more than 20- by 24-inches (see Fig. 8). That film is available from most well-stocked camera stores; if they don't ordinarily carry it they usually will special order it for you. If you can't get it locally, the film is also available from many mail-order firms; their ads can be found in almost any photography magazine.

Very little equipment is needed to make your own masks—a 35mm camera, some reusable 35mm cassettes, and a slide projector. The unexposed *Kodalith* must be handled under a safelight, but a red light-bulb will also work well. Any hardware store can supply you with a 15-watt red bulb, and even a 25-watt one will do.

If you do decide to order by mail, be aware that there is often a minimum-order requirement—typically $35.00 or so. But for that amount of money, you can get enough supplies (excluding the camera and projector, of course) to make more than 50 negatives, even allowing for the mistakes you're bound to make while learning. That works out to considerably less than $1.00 a negative, and that's not bad.

You're going to have to find someplace in your home that can be made reasonably light tight. That doesn't mean that it has to be hermetically sealed—a closet, etc. will do fine. Make sure there's some way of running electricity into it for the safelight. You'll also need enough space to lay out the three chemical trays. Mind you, if you do all your work at night, the whole business can be done in the bathroom—even if it has a window (which you should cover up to play it safe).

If you're going to work during the day, however, and you're not sure whether your work area is dark enough, or whether your safelight is safe enough, there's a simple test. Working under the safelight, take a piece of the film and lay it flat on a surface, emulsion side up. The emulsion side is lighter in color than the base side and the difference is easily seen, even under a safelight (see Fig. 9). If the film tends to curl at the edges, tape it flat with masking tape.

Put a key or a couple of coins on it and wait about five minutes. Then put the film in the developer and agitate it gently for about three minutes. After that, give it a quick dunk in the stop bath and then put it in the fixer. The film will start to clear and when you see that it has become transparent give it a quick rinse in water and take it out into the light. If you see any shadow on it from the coins, your "darkroom" isn't dark enough. Check carefully for light leaks, seal them, and try the test again.

Once your darkroom has passed the coin test, load about four-and-a-half feet of the 35mm film into one of the reusable cassettes. Leave about three inches outside the cassette and cut the edge at an angle as shown in Fig. 10 to make loading it into the camera easier.

Photographing the art

The best way to photograph your artwork is to use a copy stand. All a copy stand does is to point your camera straight down toward a flat surface on which you place the artwork. If you have one already, great; if you don't, there are several ways of going ahead without it.

You can, for example, tape the artwork to a wall and put the camera on a tripod. If you don't have a tripod, rest the camera on a table and line it up with the artwork. The important thing is to find some way to hold the camera steady during the long (at least one second) exposure time required because of the extremely slow speed (lack of sensitivity to light) of the film. If you have a shutter-release cable, use it; the steadier you keep the camera, the better.

You'll also need to make sure that the camera is pointed *directly* at the artwork; if isn't, the image on the film will be distorted and the negative will be useless. Use two 250-watt bulbs to illuminate the artwork, placing them as shown in Fig. 11. For best results, position the camera

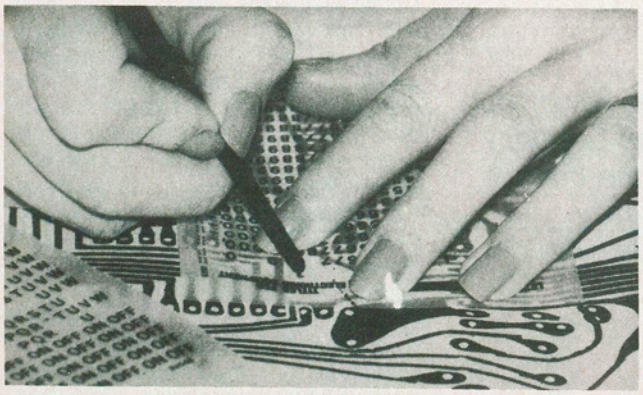

FIG. 6—IT IS OFTEN HELPFUL if you identify IC pin numbers, edge connectors, and the like for later reference. Using transfer type for that, as shown, can give your project a professional appearance.

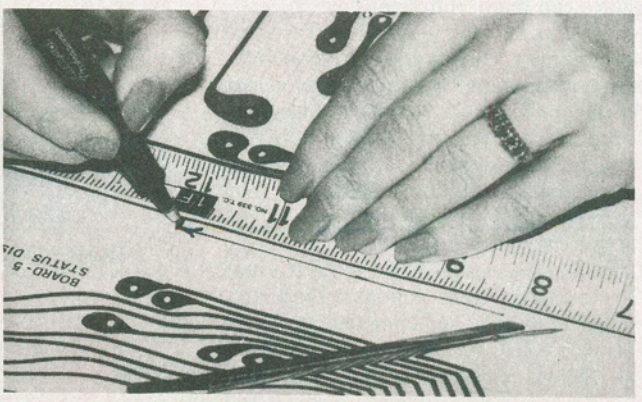

FIG. 7—MARKING OFF a segment of the center line. That segment gives you a useful reference when you make your full-sized mask from your double-sized layout.

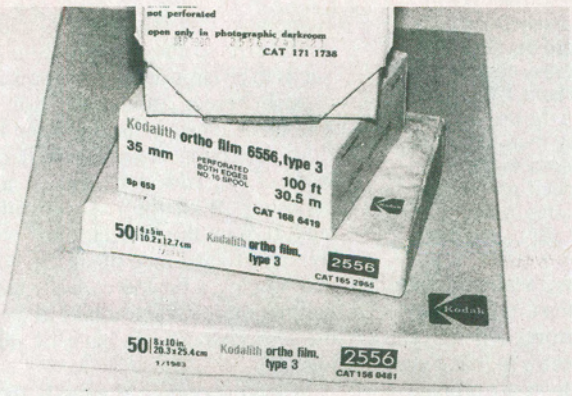

FIG. 8—ORTHO (LITHO) FILM, such as Kodak's *Kodalith*, is best for making the mask.

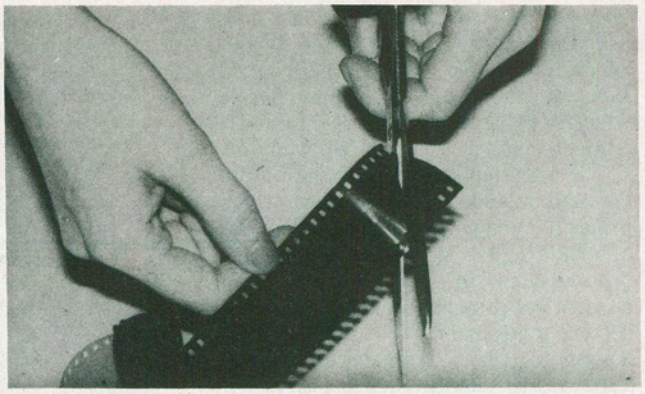

FIG. 10—CUTTING THE FILM at an angle makes loading it into your camera a lot easier.

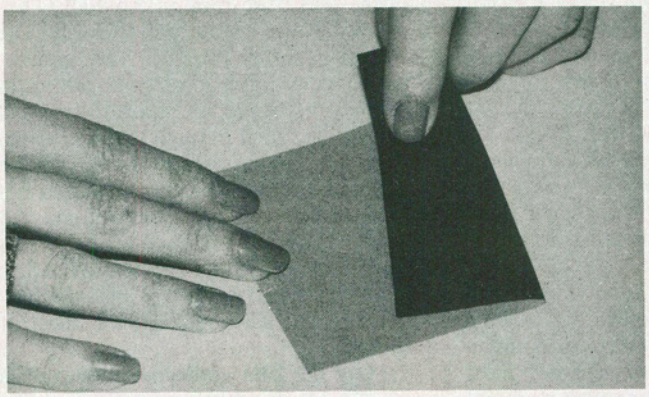

FIG. 9—THE DIFFERENCE between the film's emulsion side and base side is easy to see, even when working under a safelight.

so the artwork is as large as possible in the viewfinder.

If you're doing a double-sided board, you can photograph the art for each side separately since you'll be checking the registration of the two negatives later on in the process. Be sure to keep the camera in the same position for both shots; that will eliminate one possible registration problem.

The exposure you use will depend on a number of factors, but a good starting point is one second at *f*5.6. If your camera doesn't have a shutter speed of one second, turn off the lights, set the shutter speed to "B," and turn the lights on for one second. Remember to close the shutter after you turn the lights back off. Since you have four-and-a-half feet of film in the camera, it's a good idea to make several exposures and "bracket" them—use shutter speeds longer and shorter than one second. Making several exposures at each speed won't hurt, either; the film is cheap enough and it's good insurance.

Back to the darkroom

Many companies make film-processing chemistry. One of those chemicals, called the developer, comes in both powder and liquid form. Each has its good and bad points—for instance, the powder will keep much longer but the liquid is easier to use—the choice is up to you. Follow the mixing directions and pour enough in your developing tray to fill it to a depth of about ½ inch. If you use a 8 × 10-inch tray (which should be large enough), you will need about 16 ounces of developer. Of the remaining two trays, one is for the stop bath and the other for the fixer. Pour enough chemical into each to fill it to a depth of about ½ inch.

With the safelight on, open the back of the camera and cut off the film you've exposed, about three inches from the cassette (that will allow you to trim a new leader and use the remaining film). Place the film, emulsion side up, in the developing tray and agitate it gently; if you fit it in diagonally, you can get about 12 inches of film into an 8 × 10-inch tray. The film will probably tend to curl, so hold it under the developer or weight the edges down with paper clips. If air bubbles form on the emulsion, tap the film with your finger to remove them; if you don't, you'll wind up with undeveloped spots.

The image should start to appear within thirty seconds. Watch it carefully and when the artwork is clearly visible on the film (as a negative, of course), take the film out of the developer and put it in the stop bath.

That solution, as its name implies, will stop the development. The film should be

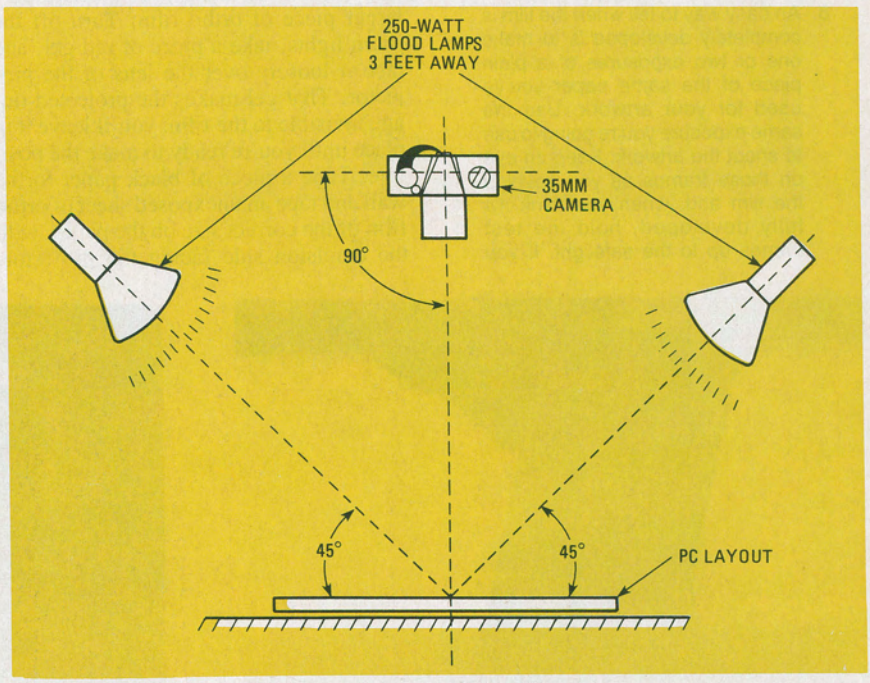

FIG. 11—IF YOU DO NOT HAVE A COPY STAND, you can photograph your layout using the setup shown here.

left in the tray for about 20 seconds and, as before, the tray should be gently agitated. Kodak makes a stop bath called *Indicator Stop Bath* that turns purple when it's exhausted. It's easy to use and is a good choice to use with the *Kodalith*.

The next step is to transfer the film to the third tray containing the fixer, which makes the image permament. After a bit of gentle agitation, you'll see the unexposed areas of the film (in between frames and around the sprocket holes) become transparent. When that happens, it's safe to go back to regular room-light. Take the film into the kitchen and wash it under running water (around room temperature) for five minutes. Hang it up to dry in a location where there's a minimum of dust; you can speed the drying up a bit by using a hair dryer **set on low**, but the film will dry all by itself in about 30 minutes.

I haven't really gone into detail about the film processing because it's virtually foolproof if you follow the directions that come with the chemicals and the film. Let me now, however, give you a few hints that can make things a lot easier:

1. You can test the developer under ordinary light. Take a piece of film and put it in the tray of developer under room light. It should turn completely opaque in less that thirty seconds (see Fig. 12). If it doesn't, your developer is exhausted and you should mix a fresh batch.
2. You can test the fixer the same way. Take a piece of film and immerse it directly in the fixer. (Don't put it in the developer first!) It should turn transparent in about a minute as the fixer removes the silver. If it doesn't, you need fresh fixer.
3. An easy way to tell when the film is completely developed is to make one or two exposures of a plain piece of the same paper you've used for your artwork. Use the same exposure you're going to use to shoot the artwork. Keep an eye on those frames as you develop the film and, when you think it's fully developed, hold the test frames up to the safelight. If you can still see the filament of the bulb, you need a bit more development. If the film is completely opaque, it's ready for the stop bath. If you have any doubts, it's better to underdevelop slightly than to go the other way. Remember, the lines you want to reproduce are very thin and any appreciable amount of overdevelopment will cause them to disappear.

Although you can use a photographic enlarger for the next steps, you probably don't own one. Therefore, I'll tell you how to use a slide projector to make your blowups. The first step is to prepare a slide. When the film is dry, pick the frame with the best exposure. The black areas should be dense, and all the lines in your artwork should be completely transparent. Cut the frame from the roll and put it in a slide mount. The best mounts to use are glass mounts; they'll hold the film absolutely flat and the heat from the projector won't cause the film to pop and buckle. There are several varieties of glass mounts, and your local camera store (or the company from which you ordered your other supplies) should have one or more of them in stock.

Just as with the camera, you need to make sure that the projector is pointed directly at the wall; any angle is going to distort the image somewhat. You'll most likely have to move the projector around to get the image to the correct size. One easy way to get the size right is to use a piece of graph paper as a screen. Use paper that has a 1/10-inch grid and adjust the projector's position until the IC pads line up with the grid. Since those pads also use 1/10-inch spacing, that method will allow you to adjust the size precisely.

When you have that all taken care of you're ready to make your positive on a larger piece of ortho film. Turn off the room lights, take a piece of red gel, and tape it loosely over the lens of the projector. That gel makes the projected image invisible to the film; you'll leave it in place until you're ready to make the positive. Tape a piece of black paper to the wall and tape an unexposed sheet of ortho film of the correct size on the paper, with the emulsion side facing the projector. Remember that this image is going to be actual size so the piece of film you use needs to be large enough to allow at least a 1/2-inch border around the foil pattern. The black paper is used to keep the light from reflecting from the wall onto the back of the film and causing a double exposure. With the red gel still on the lens, turn on the projector and check the size and focus once again. If you think that's being a bit too careful, remember that the more care you take at each step, the less chance you have of making a mistake.

When everything is exactly the way it should be, turn off the projector and take the gel off the lens. Make sure you don't move the projector or change the position of the lens. The film on the wall is exposed by turning the projector on. The correct exposure time can vary greatly, but 15 seconds is a good length of time to begin with; the precise exposure time will have to be found through trial and error. After the film has been exposed, turn the projector off and develop the film as before. In this case, the foil pattern will appear as a black-on-white image. When the black lines are nice and dense, the film is adequately developed. Finish the processing, and wash and dry the sheet of film.

Lay the film emulsion-side-up on a clean piece of white paper and examine the pattern. All you want to concern yourself with here is the areas between the traces—the clear areas. Make sure there aren't any unwanted lines or spots of black. Get rid of the spots and smears by scraping them off with an *X-ACTO* knife as shown in Fig. 13. Don't worry if the traces appear too thin or if some of the black lines are broken. All you're worrying about now is the spaces between the traces. When you have that taken care of, you're ready for the next step—producing the actual foil mask.

When we continue, we'll show you exactly how that's done, as well as some inexpensive substitutes for the equipment that you'll need. We'll then finish up our discussion by showing you the easiest part of the whole procedure, etching the board itself. **R-E**

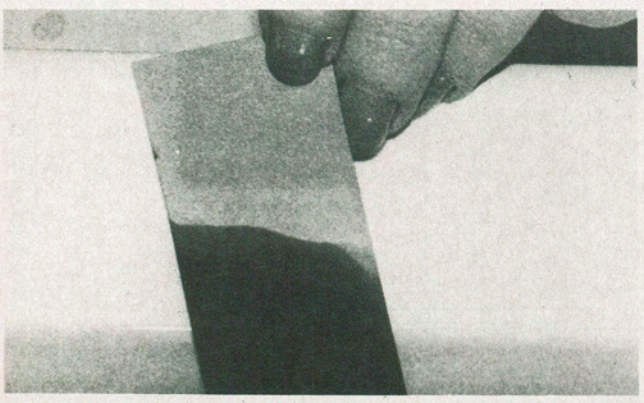

FIG. 12—TO TEST THE DEVELOPER, follow the directions in the text. If it is good, it should turn the film completely opaque.

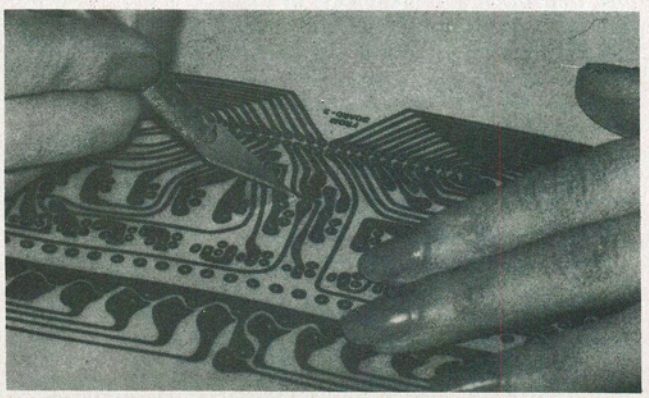

FIG. 13—WHEN THE POSITIVE mask is developed, remove any stray black lines or spots using an X-ACTO knife or similar tool.