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Making your own PC Boards

This month we debunk some of the myths about making PC boards and show you some shortcuts to success.

HERE AT **RADIO-ELECTRONICS** WE GET hundreds if not thousands of questions a year on a variety of electronics topics. One of the most common questions, especially from beginning hobbyists, is about PC boards.

That's really not surprising. If you've never done it before, making a PC board can seem like an enormous job. That's why many builders will only undertake a project where a pre-etched PC board is available.

But if you do that you're missing out on a good deal of the fun of building! What's more, etching a PC board is really simple, once you've learned how and have mastered the techniques that are required.

In this article we are going to debunk some of the myths about etching boards. We'll show you that you don't need a darkroom or a camera to use the photographic method. We'll explain the difference between the positive and negative etching systems, and how you can use either regardless of whether you start off with positive or negative art. We'll show you how to make simple PC boards by just drawing right on the copper blank. We'll show you how to make a PC board without etching at all. And we'll name suppliers of PC-board supplies for the hobbyist.

We'll even show you how to use our very own PC Service!

Making PC boards

The final goal of making a PC board is creating a pattern in copper on a phenolic, glass-epoxy, or similar board. The various methods differ only in the technique used to get the pattern onto the board.

There are three basic steps in making a PC board. They are:

- Create the original artwork.
- Transfer the artwork to the PC board
- Etch the board.

For the purposes of this article, we have assumed that you already have a PC pattern (if you need help in creating a pattern from a schematic, see "Etch your own PC Boards, Part 1" in the December 1982 issue of **Radio-Electronics**). Your next problem, then, is to transfer the artwork to the PC board.

The most popular way to do that is the *photographic method*. It's named that because it uses photographic techniques to transfer the pattern to the copper. That is, a photographic print is made on a photosensitized copper-clad board. The material used

FIG. 1—PRESENSITIZED PC BOARDS conveniently take a step out of the board-making process.

FIG. 2—PHOTORESISTS are available in positive aerosols and negative aerosols and liquids. A negative liquid in a pump bottle from Datak is shown here.

to render the board photosensitive reacts in such a way when exposed to light that part of the copper is removed when placed in an etchant bath, and part is unaffected.

However, the photographic method does not require an elaborate darkroom, a camera, or any extensive photographic skills. Only a working area away from direct light, some trays, an inexpensive *contact frame* (or even just a piece of glass), a strong light source, a few chemicals, and access to running water. You also need the artwork in a form where it can be transferred to the board; that is called a *photomask*. We'll show you how to make a photomask shortly.

Copper blanks come in two varieties: presensitized and unsensitized. Both types have their advantages and disadvantages. Presensitized blanks (see Fig. 1) are easier to use since they take a step out of the PC-board making process. The photosensitizing material, called *photoresist*, has already been applied to the board for you. However, presensitized boards come in only a limited number of sizes and are relatively expensive.

If you use unsensitized blanks, you must coat them with photoresist (see Fig. 2) prior to transferring the pattern. Applying photoresist to unsensitized blanks is cheaper and gives more flexibility than using presensitized blanks; but the process is tricky to master for beginners and takes time. Apply too much sensitizer and it will run, apply too little and it will disappear during the developing process. And after the sensitizer is applied, the board must be dried either overnight or carefully in an oven.

Positive or negative

Photoresists come in two varieties—positive and negative. The type of photoresist you use determines whether you are using the *positive* photographic method or the *negative* one.

Photoresist is a plastic resin whose properties change when exposed to light. A negative photoresist toughens when exposed to light; when the exposed board is placed in etchant the copper under the now toughened photoresist is protected while the rest etches away. Therefore, *to create a positive image in copper, the negative method requires that you use a negative image of the foil-pattern artwork.* That's because we want light to reach the copper only at the traces and the pads, and nowhere else.

A positive photoresist breaks down when exposed to light; when placed in the etchant, the copper under the unexposed areas is protected, while the copper under the exposed areas is etched away. Therefore, *to create a positive image in the copper, the positive method requires that you use a positive image of the artwork.* We want to keep light away from the pads and traces.

So which method should you use? It depends on which you prefer, which manufacturers' products you are using, and what form your PC artwork is in. Note, however, that positive photoresist has a limited shelf life; GC Electronics manufactures both positive photoresist and positive presensitized blanks; Vector offers positive blanks only. Negative-method supplies are available from Datak, Kepro Circuit Systems, and GC Electronics.

If you have positive artwork and negative chemicals, all is not lost. *Lithographic reversing film* can be used to convert positive artwork to negative, or vice versa. An added benefit of reversing film is it is relatively tolerant of "weak" artwork (artwork that is not perfectly opaque); that means it can be used to turn a low-contrast positive into a high contrast negative. Reversing film is available from Datak, GC Electronics, and Kepro.

Exposing the board

Once the board is sensitized it is *light-sensitive*, so it must be handled away from strong light sources to avoid exposing it prematurely. But you don't need an absolutely light-tight darkroom. In fact, some manufactures suggest that a 40-watt incandescent lamp, placed a few feet away, makes for an ideal work or *safe-light*. That may not hold true for all sensitizers, so follow the manufacturers' recommendations.

The next step is making a photographic exposure. To do that you need a strong light source. Note that different sensitizers react differently to different types of light. Some for instance, react most strongly to ultraviolet, and therefore you should use a sunlamp for best results. Follow the manufacturer's light instructions when selecting your light source.

(**Caution:** Even a short exposure to UV radiation can cause permanent eye damage. Treat sunlamps with respect and **never look directly at a lit sunlamp, or any other source of UV radiation.**)

Place the photomask on top of the sensitized copper blank and put the two under a piece of glass or into a

FIG 3—TO EXPOSE THE BOARD, place the sensitized blank and the photomask in a contact frame and place under a strong light source.

FIG. 4—AFTER EXPOSING THE BOARD, it must be placed in a tray filled with a developer like the one shown here. After developing, the board is no longer photosensitive and can be handled in normal light.

contact frame. Place the assembly under your light source and expose them, making a *contact print*. See Fig. 3.

Exposure times will vary greatly depending on the nature of the sensitizer, the photomask, and the light source. Follow manufactures suggestions, but be prepared to do some experimentation on your first attempts. Don't despair! After you've made your first few boards and have the hang of the materials you are using, you will be able to consistently produce an acceptable board on the first try without any trouble.

While the board is being exposed, prepare a developer bath. The type of tray you use may depend on the system you are following. Do not use plastic if you are using the negative system; do not use metal if you are using the positive system. Glass is fine for either. Be sure that the tray is large enough to accommodate your board and fill it to a depth of ½- to 1-inch with a PC-board developer like the one shown in Fig. 4.

When the board is exposed, turn off the light source and remove the blank. Place it copper side up in the developer bath and gently rock the tray back and forth. Follow the manufacturers instructions as to developing time; it will, as usual, vary with the materials you are using.

Once the board is developed, rinse it in cool tap water and stand it vertically to dry. Once the board is completely dry it is ready to etch.

The most common etchant is ferric chloride. It is non-toxic, effective, economical, and quick. However, its etching speed slows down as more copper is dissolved. That is not usually a problem for hobbyist applications, but it is something you should be aware of if the board you are etching is very large, or the pattern requires that an abnormal amount of copper be removed. Also, ferric chloride stains clothing and material, so avoid spattering and work in old clothing. Another etchant is sodium persulphate. Available from Kepro, that etchant is a dry crystal that must be mixed with water to be used. It is supplied with a catalyst that provides for a constant etching speed.

Another necessity is an etching tray. Be sure that the tray is large enough to accommodate your board and is made of plastic, glass, or Pyrex, *not* metal (otherwise your tray will etch away as well).

For best results, the etchant should be slightly heated and agitated during etching. Different manufacturers have different temperature recommendations, but they generally range from 90°F to 125°F. Heating can be done with an aquarium type submersible heater or by placing the etchant on a stove burner or hot plate prior to etching. (Again, use a Pyrex tray or pot for that, *not* metal.) However you heat the etchant, be sure that the ventilation in your work area is adequate.

For small boards, simple hand agitation should be adequate; carefully rock the tray back and forth at regular intervals until etching is complete. But while agitating in that way greatly speeds the process, a typical board will still take 20-60 minutes to etch. If you do a lot of etching, you may want to invest in an automatic agitator. Available from Datak, GC Electronics, and others, those range from elaborate systems to simple aquarium-type air pumps terminated with a bubbler to break up the air flow. One automatic agitator is shown in Fig. 5.

SEVERAL SUPPLIERS OFFER a full line of PC products. Shown here are one company's direct-etch products, presensitized blanks, reversing film, and board-processing chemicals.

SUPPLIERS

Bishop Graphics
5388 Sterling Center Drive
Westlake Village, CA 91359

The Datak Corporation
65 71st Street
Guttenberg, NJ 07093

GC Electronics
Rockford, IL 61101

Kepro Circuit Systems
630 Axminster Drive
Fenton, MO 63026-2992

Vector Electronic Company
12460 Gladstone Ave.
P.O. Box 4336
Sylmar, CA 91342-0336

FIG. 5—TO AVOID TEDIOUS HAND agitation, you may want to use an automatic agitator like the one shown here.

Now, as to the etching itself: Use sufficient etchant to cover the board completely. Place the heated etchant in the tray (or heat the etchant in the tray with a heater) and then carefully immerse the board, pattern side up. Periodically, remove the board, rinse under tap water, and examine the progress of the etching. Once your are satisfied that all the unwanted copper is removed, rinse the board one last time and remove the resist using steel wool or a chemical solvent such as GC Electronic's *Stripping Solution*.

Finally, examine the board in good light and with a magnifier for shorted or open traces, or other defects. Shorted traces can be repaired by scraping the excess copper away with an *X-acto* or similar hobby knife.

Open or incomplete traces or pads can be fixed by touching up with conductive paints or inks, or even solder; conductive paints and inks are available from GC Electronics and others. Once you are sure you have corrected any problems your board is ready for drilling and then for mounting the components.

Making the photomask

So far things have been straightforward. That's because we've assumed that you had a photomask in hand. Unfortunately, making a photomask can be the most difficult part in PC-board making.

But, as the old proverb says, there's more than one way to skin a cat and the same is true for making a photomask. Let's next look at some of those methods.

If the design is a very simple one, you might be best off using one of the non-photographic techniques that we'll describe shortly. Otherwise, you need to transfer the design to some type of clear film or translucent medium. One way to do that is to use a camera and photograph the artwork. An excellent description of the steps involved in that appeared in "Etch Your Own PC Boards, Part 2", which was presented in the January 1983 issue of **Radio-Electronics**.

Another method is to create a duplicate artwork master using translucent Mylar film and opaque PC drafting aids. That entails first laying out the pattern on 1/10-inch grid paper. Once the artwork is drawn, a Mylar sheet is taped over it, and the pattern is copied using opaque tape, rubylyth film (for large areas of copper such as ground planes), and other drafting aids. See Fig. 6. The result is a positive photomask. Granted, the technique can be tedious and time consuming, but it is certainly a viable alternative for those not equipped with a camera or photographic skills. Suitable drafting supplies are available from Bishop Graphics, Datak, GC Electronics, Vector, and Kepro.

FIG. 6—YOUR ARTWORK can be transferred to a piece of Mylar film using drafting aids like these. The result is a positive photomask.

However, some of the products now on the market allow you even easier ways to get artwork onto film, even in cases where there is printing on the reverse side of the original. Datak offers a printed circuit kit that uses an interesting two-step *pos-neg* technique to create a photomask from a printed page. In the first step, specially processed high-contrast film is used to make a *reflex* (reflected) contact exposure. That is, the film is sandwiched between the artwork and a color filter, placed under glass or in a contact frame, and exposed to light. Enough light reflects from the printed artwork to create a low-contrast positive in the film. The low-contrast positive is not suitable for use as a photomask, but the Datak film can be processed by the user to make it act like the revering films we've already discussed. Then, the low-contrast positive can be used to make a conventional contact print on the processed film. The result is a high-contrast *negative*, which can be used to etch a board using the negative method previously described.

Another approach is GC Electronic's *Lift-it* kit. With that system, which is intended for use with printed magazine art, a PC-board image is literally lifted from a page and turned into a photomask. Unfortunately, the magazine page is destroyed in the process. In the system, a sheet of transfer film is applied over the artwork to be copied, sticky side down, and burnished. The sheet is then allowed to soak in warm water for 20 minutes, after which the magazine page is hand-rubbed off and the film is allowed to dry. If everything has gone well, the ink should literally have been lifted off the page onto the film. The sticky side of the film is then covered with Mylar. The result is a positive image of the magazine art.

Another major drawback of the system is that a magazine print often does not contain enough ink to provide satisfactory results. That is, the image produced is not dense enough to use conventional etching techniques. If that is the case, the *Lift-It* image can be used as an intermediate stage and reversing film used to make a high-contrast negative as previously discussed. Those films, such as GC Electronic's *Reversing Film*, can tolerate a weak image very well and still produce a perfectly opaque negative. Making a contact exposure with the film will yield a usable negative photomask, which can be used to etch a board using the negative photoresist system.

FIG. 7—PC ARTWORK CAN BE DRAWN directly on the copper blank using etch-resist pens. Lacquers and drafting aids can be used, too.

PC Service

Some publications, such as **Radio-Electronics** and the *ARRL Handbook* provide PC art on a page with no printing on the reverse side. That allows the printed page to be used as a photomask with little or no additional preparation. In **Radio-Electronics** that artwork is provided in the PC Service section; let's see how to use that art to make a PC board.

The first step is to carefully examine all traces, pads, etc. Printing is an inexact science and imperfections often creep in during the process, especially where thin, closely spaced traces are involved. Examine the art under a strong light or on a light table, and clean up any open or incomplete sections with an etch-resist pen or with PC drafting tape and aids. Shorts and bridges can be scraped away using a knife.

What you now have is a PC-board photomask that, although not as transparent as one on film, will serve nearly as well. You can make the page pass even more light by rubbing the blank side lightly with a small amount of mineral oil. Note, however, that mineral oil blocks ultraviolet light somewhat, so do not use it if your sensitizer is sensitive only to that type of light. Also be careful not to get any oil on the front (printing) side of the page; otherwise you will contaminate the board when you expose it and may get unsatisfactory results.

Once the page is dry, you are ready make the board. Place the mask *printing side down* on a sensitized board (PC-Service art is a mirror image of the actual pattern), place in a contact frame or under a piece of glass, and

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expose. Note that because of the nature of the paper, exposure time is likely to be longer than with clear film. Do some experimentation to determine the correct exposure time for your light source, chemicals, etc.

You can also use PC Service with the reversing films previously mentioned and then use the negative system to create the PC board.

Non-photographic techniques

We alluded to the fact that there are alternatives to the photographic method for simple designs. One is to place the pattern directly on the copper blank using etch-resist ink (see Fig. 7), lacquers, tapes, and patterns. The board is then etched in ferric chloride. While the technique works well for small patterns, it is tedious to use for anything larger than a one-IC or two-transistor circuit. Etch-resist inks and patterns are available from Datak, Kepro, and GC Electronics.

Finally, there is a technique that requires no etching at all. Manufactured by Bishop Graphics and called *E-Z Circuit* (see Fig. 8), it involves placing copper strips, donuts, etc. directly onto a pre-drilled, non-copper-clad prototyping board. The copper is supplied on a super-thin, epoxy-glass substrate that has a special adhesive on one side. The copper is positioned onto the prototyping board and burnished in place.

FIG. 8—A NO-ETCH SYSTEM, *E-Z Circuit* from Bishop Graphics places adhesive copper strips, pads, and patterns on a pre-drilled prototype board.

The drawback to the system is that it can't be used to mass produce boards, and that the pattern must be transferred to the board by hand. The system works well, however, especially for smaller layouts and for repairing existing boards, and it is possible to use it to do even the most complicated circuits **R-E**