Making Printed-Circuit Boards Without Photography

How to use transfer film to copy an artwork image and transfer it to a pc blank as etchant resist

By Jan Axelson

It's hard to beat a printed-circuit board as a method of construction when you want to give a professional internal appearance to your electronic projects. Many different techniques exist for fabricating pc boards, including the photographic approach, using press-on or rub-on transfers (so-called "dry-transfer" technique), and drawing directly on a copper-clad pc blank with an etch-resist pen.

In this article, I'll describe a new way to make pc boards using a specially coated TEC-2000 plastic film. The method to be described is especially useful when you have an existing conductor pattern and wish to make just one or a few copies of a board. You can use a published artwork like that which appears in many articles in *Modern Electronics*, or you can use a pattern that is taped on transparent Mylar film, drawn by hand on paper, or created with a computer with graphics software and a printer or plotter.

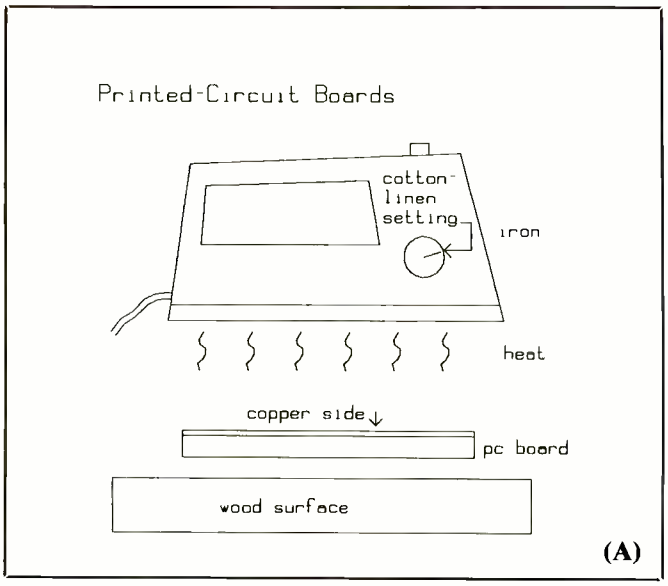
In the method described here, an ordinary photocopier first copies the pattern onto the film. A clothing iron is then used to transfer the image from the film to the printed-circuit blank by heating and pressing the two together. Thereafter, you etch and drill the board as usual. Of course, a little practice may be required in the beginning to master the transferring technique. But with some experience you can quickly and reliably create functional and professional-looking boards.

Fabricating a circuit board with this method requires three main steps: copying a pattern onto the film, transferring the pattern to the board, and etching and drilling the board. There's nothing special about the etching and drilling step; this is done exactly the same as with other methods. So in this article we'll concentrate on how to copy and transfer a pattern.

Materials & Equipment

The Bill of Materials and Equipment box details what you need to make a printed-circuit board using this heat-transfer method. The TEC-200 film comes in 8½ by 11-inch sheets. Cost is around a dollar per sheet, and the film and an instruction sheet are readily available by mail from the suppliers listed in the Supplier Address box.

According to Meadowlake Corp., which distributes TEC-200 film in the United States, the film was created in Germany by a chemist who was looking for a more convenient way of creating circuit boards. This film has a Mylar base with a coating that loosely holds an image photocopied onto it. When heated, the copied image melts and then transfers and fuses to the copper surface of a pc blank.



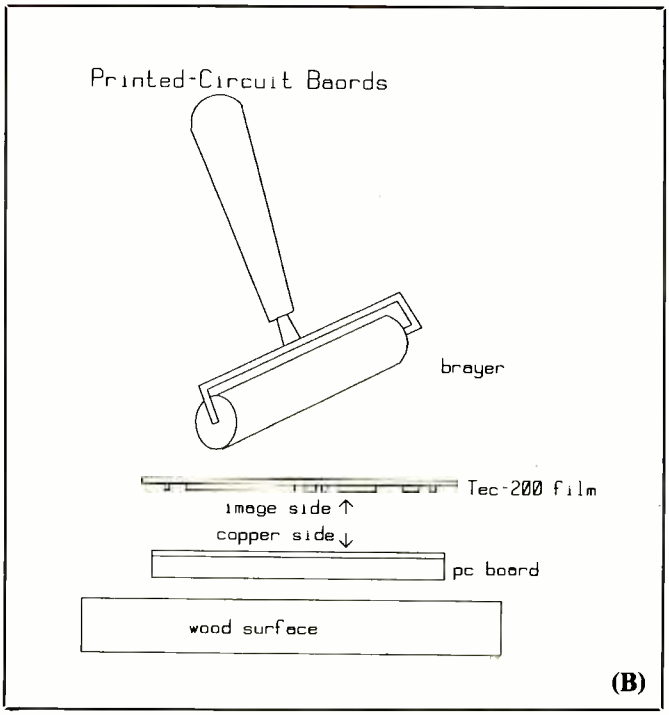


Fig. 1. In brayer method of transferring conductor pattern to pc blank, clothes iron preheats copper cladding of blank (A); then transfer film is quickly placed on heated blank and brayer is drawn across it (B) to effect image transfer.

The resulting transferred image forms a varnish-like, acid-proof coating that serves directly as the etch resist. When the board is placed in an etchant bath, the coating deposited on the pc blank during the transfer process prevents the etchant from dissolving the copper beneath it. Only exposed copper is dissolved. The result is a board with the conductor pattern etched in copper on it.

To copy a pattern onto the TEC-200 film, you can use any "plain-paper" copier that uses a heat-fusing toner (the dry ink that forms the image) to form the copy on the paper. This type of copier includes most traditional electrostatic photocopiers. Most copy shops will copy a pattern onto the film for a minimal charge.

An alternate method is to draw the desired conductor pattern using a computer and graphics software, then print it directly onto the TEC-200 film with a laser printer. We'll concentrate here on the photocopier method, since it's more widely available. If you have the necessary hardware and software, though, you can experiment with the laser-printer method as well.

An additional recommended item is a brayer, or print roller. This is a small rubber roller that can be obtained from any photographic and art-supply outlet.

Copying the Pattern

No matter what the source of your conductor pattern, an image that has high contrast—jet black against pure white—works best in this process. You can copy several small patterns, or several copies of one pattern, onto one sheet of TEC-200 film.

From here on, it will be assumed that you have an actual-size ready-to-be-copied conductor pattern ready to copy. The following techniques are presented for making a single-sided board—one with an etched pattern on one side only. Double-sided boards are also possible with this technique if the patterns are positioned accurately on the pc blank during the transfer process.

One of the most confusing parts about creating printed-circuit boards is keeping track of the orientation of the pattern. The two sides of a board may be thought of as the "component" side (where the components are mounted) and the "solder" side, (where the pattern is etched and the leads and pins of the components are soldered into place).

For the components to line up properly with the pattern on the solder side of the board, the solder side must be a mirror image of the component-side layout. In the transfer method described here, the pattern reverses when the image is transferred from the film to the board. This means that the pattern you copy onto the film should show the component-side orientation—or the reverse of how the pattern will look when etched onto the solder side of the board.

If you have a conductor pattern that shows the solder side, all you have to do is copy it onto an extra sheet of TEC-200 or transparent My-

Bill of Materials & Equipment

- Printed-circuit-board pattern for your circuit
- TEC-200 transfer film
- Copper-clad pc blank
- Isopropyl (rubbing) alcohol
- Acetone, paint thinner, or other organic solvent
- Paper towels
- Etchant of choice
- Photocopy machine or laser printer (see text)
- Non-metallic scouring pad or mild abrasive cleanser
- Scissors or hobby knife
- Clothing iron
- Brayer or small rubber print roller
- Resist pen for touch-ups as needed

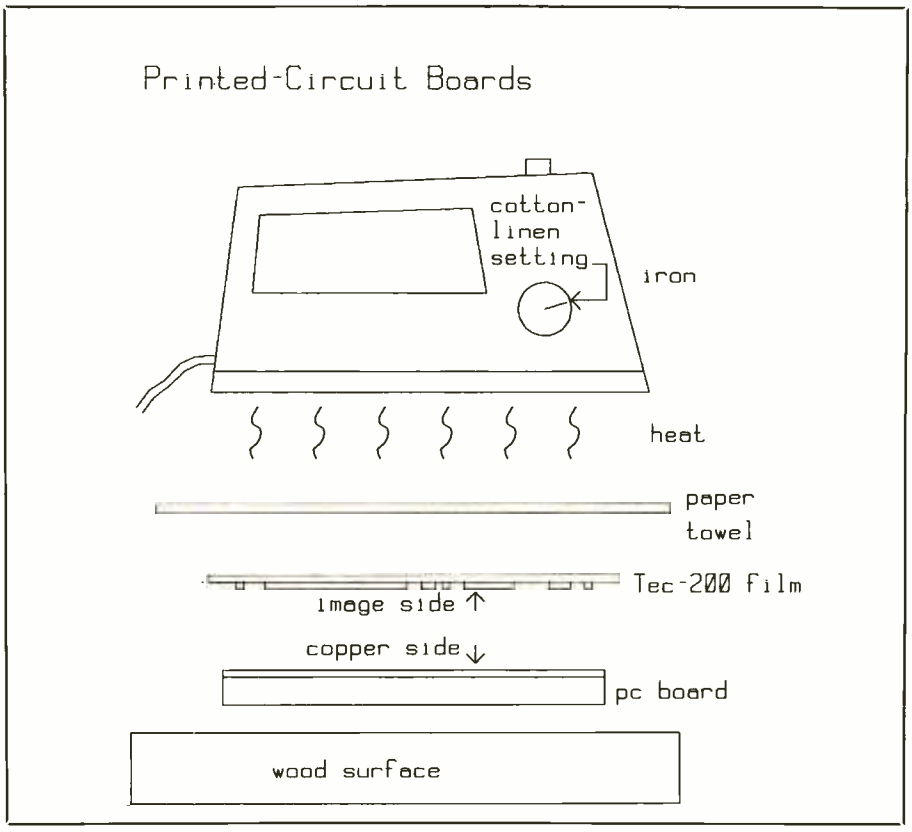


Fig. 2. In direct method of pattern transfer, iron simultaneously heats transfer film and pc blank, causing pattern to transfer from film to blank.

lar and flip the sheet over and you'll have the correct image to copy. Because they are solder-side views, the conductor patterns published in *Modern Electronics* must be reversed in this way.

Preliminary to copying any pattern, always check it over carefully. Look for hairline discontinuities in the trace lines and for traces or pads that are touching but should be separate. Correct any defects *before* you proceed to the copying stage.

When you have a pattern ready to copy, take it and the TEC-200 film to a photocopy shop. If you have an extra sheet or two of the film, it doesn't hurt to make extra copies. If you find you don't need the extra copies, you can wipe the copied patterns off and use the film again.

Bear in mind that most—if not all—photocopiers have distortion built into them. Some copiers have minimal distortion and will work fine for even fairly detailed conductor pattern copying. Others have excessive distortion that may be useless, especially if they do not provide reasonable spacing for DIP integrated circuits. If a copier you try has excessive distortion, try another and another until you've reduced the distortion to a negligible amount. Even moderate distortion will be unacceptable for larger-size conductor patterns.

Keep the film clean by handling it only by its edges and storing it in a manila folder for protection. At the copy shop, first make a trial copy of your pattern on paper. If your image is on transparent film, lay a sheet of white paper over the back of it when you copy to prevent any dirt or other images on the cover of the copier from copying onto the film along with the conductor pattern. If necessary, experiment with different darkness settings on the copier until you have a solid black image against a white background.

Bear in mind that the pattern must show the component-side view. If necessary, copy your pattern onto TEC-200 or transparent Mylar film and flip the copy over for the correct orientation. It's also a good idea for the pattern to include some way of identifying the view. One way to do this is to write "image side" just outside one edge of the pattern to be copied. Then after copying, you'll know that the side of the film with the readable label is the side that has the toner on it from the copier.

If your conductor pattern is enlarged or reduced, you must reduce or enlarge it accordingly to obtain an actual-size pattern. If you do enlarge or reduce the image, be sure to check for correct dimensions on your copy.

When you have your pattern in the correct orientation and you're satisfied with the photocopies of it on paper, it's time to copy onto the TEC-200 film. (*Caution:* When copying onto TEC-200 film, proper operating temperature of the copier is mandatory. The photocopying process uses

heat to melt the toner that forms the image on the copy. Although TEC-200 film is highly heat-resistant to the heat ordinarily developed in photocopiers, it will begin to soften at around 325 degrees Fahrenheit.

If the copier temperature is set too high, the film and the copier may be damaged. Typical recommended operating temperatures for copiers are between 275 and 300 degrees Fahrenheit. Temperatures in this range should yield good results with the TEC-200 film. If you're not sure about the temperature setting on the copier you're using, ask for help at the copy shop.

You can copy onto either side of the TEC-200 film. Remember to handle the film only by its edges. Copy shop personnel can help you feed the film into the copier. When you have your copy or copies on the film, examine them for contrast and overall quality. Slight transparencies or pinholes in the image are not critical, since the melting toner will fill these in as it heats and transfers to the copper surface of the pc blank. Always handle the film with care because the coating will flake off it easily. An example of a photocopied conductor pattern on TEC-200 film is shown in Fig. 3.

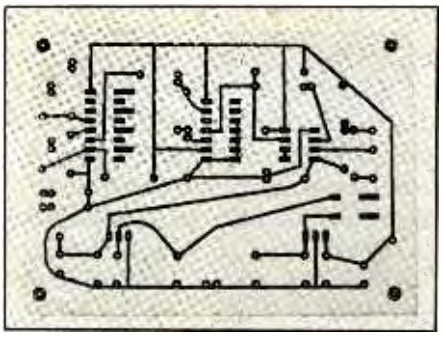


Fig. 3. A sheet of TEC-200 film onto which image of desired pattern has been photocopied for transfer to copper cladding on a pc blank.

Transferring the Pattern

The pattern is now ready to be transferred onto a copper-clad pc blank. If necessary, cut the pc blank to size.

A scrupulously clean pc blank is essential to successful transference of the toner to it and reliable etching. Thoroughly scrub the copper cladding on the blank with a mild abrasive cleanser or non-metallic scouring pad such as Scotch-Brite. When the surface is clean and shiny and has a burnished copper appearance, give it a final, thorough cleaning with a clean rag or paper towel dipped in isopropyl alcohol.

Do not touch the copper surface of the pc blank once it has been cleaned. Handle it only by its edges. While the blank dries, gather your clothes iron, film onto which the conductor pattern has been copied, and a brayer (if you're using the last item).

Prepare a work surface for ironing the pattern. I found the transfer process easiest to perform with the pc blank board resting on something firm, such as a wooden plank, rather than on the padded surface of an ironing board. Whatever surface you choose, though, make sure it can bear up under the heat of the iron.

Set the iron to the cotton-linen setting and give it a few minutes to come up to the needed temperature (265 to 295 degrees Fahrenheit). Carefully cut your conductor pattern from the film, leaving a border of half an inch or less all around the image. Once again, remember to handle the film carefully: don't touch the image, and set the film down with its image side (the component orientation) up. When the cleaned board is thoroughly dry, you're ready to transfer the pattern to it.

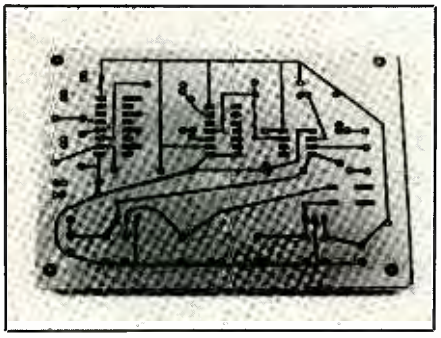


Fig. 4. When conductor pattern has been transferred from TEC-200 film to copper cladding of pc blank, latter is ready to be etched, drilled and cleaned of residual resist.

Two different methods for pattern transfer will be discussed:

• *Brayer Method.* In this method, the copper surface of the pc blank is heated. The film is then placed image-side-down on the copper surface of the hot blank and rolled on with a brayer. This method is illustrated in Fig. 1. The trickiest part of the procedure is the positioning of the pattern on the heated board. This must be done quickly and with good accuracy. Once the image touches the heated blank, it will begins to adhere; so you get just the one chance to lay the film correctly against the pc blank. The transfer procedure must be accomplished quickly, too, before the blank begins to cool.

Because it's such a critical step, it's a good idea to practice placing the film on an unheated blank before you do the actual transfer. To aid in accurately and quickly positioning the image, you can position the film and tape one end of the side of the film that is not coated to the blank. Then you can flip the film away from the blank as the latter is heating, and flip the film back over the blank to transfer the image. If you do this, be especially careful to keep the hot iron off the film.

When you're ready to heat the blank, place the preheated iron directly on its copper surface. If possible, cover the entire blank with the iron. If the blank is larger than the shoe of the iron, move the iron around to uniformly heat the entire blank. If you've taped the film to one end of the blank, be very careful to avoid touching the iron to the film as you heat the blank.

How long you must hold the iron on the blank must be determined by trial and error. In tests I've performed, I found that 30 to 60 seconds of contact with the hot iron should be sufficient to properly heat the pc blank to the desired temperature to accomplish the transfer of the image from the film to the copper surface of a small blank.

When the blank is hot enough, you're ready to transfer the pattern. This must be done quickly. Remove the iron and place the film image-side-down in its planned position on the heated copper surface. Immediately begin drawing the brayer across the film, using even, moderate pressure. Continue rolling as the blank cools. Make several passes from different angles, and be sure to roll across the entire pattern.

Do not lift the film or move the blank until the latter has cooled to room temperature. However, you can examine the blank while it is sitting undisturbed. Examine it carefully. You should be able to see where the image has left the film and is transferred to the blank. If you see sections that have remained on the film, you can briefly press the tip of the hot iron directly on the film at these locations. (Small areas can also be filled in later with a resist pen.) When you're finished, turn off the iron and leave the board to cool with the film still in place.

• *Direct-Transfer Method.* Using this method, the pattern is transferred directly with the iron, instead of with the brayer, as illustrated in Fig. 2. This method may work better for large patterns, but it requires much more careful monitoring.

Begin with a thoroughly cleaned and dried copper surface as described above. Lay the film image-side-down directly on the copper surface of the blank. Lay over this a paper towel, napkin, or thin cotton cloth. Then transfer the pattern by placing the heated iron directly on the covered board, using moderate pressure.

Check the blank frequently—every few seconds—by lifting the covering (but do *not* disturb the film) and examining the the blank to see if the pattern has successfully transferred. As was the case using in the brayer method, deciding on just how long the blank must be heated with the iron must be determined by trial and error. With this direct-transfer, method I found it very easy to heat too long and end up with a smeared and useless image; so check frequently as you heat.

When the pattern has successfully transferred, turn off the iron and leave the blank to cool without disturbing it or the film.

Examining & Etching

Regardless of which of the two methods you use, when the blank has cooled you're ready to check the quality of the image. To do this, begin by carefully lifting the film from the blank. Figure 3 shows a blank that has an image successfully transferred onto it. If you're lucky, your complete conductor pattern will be fused onto your blank with solid and sharply defined lines and pads. Continue to handle the blank only by its edges, since the coating can chip off the copper cladding at this stage.

Your first attempt at transferring may result in a less-than-perfect effort. Differences in such factors as iron temperature, blank size, amount of pressure, and original pattern quality may cause differences in results. However, with a little practice and experimenting, you should be able to develop a technique that works reliably for you every time.

Here are some tips on what to do if your pattern transfer was flawed:

• If just a few small areas fail to transfer, you can transfer them by repositioning the film and touching the missed sections with the tip of a heated iron. Alternatively, you can draw in missing sections onto the copper cladding with a resist pen.

• If large sections of the image fail to transfer from the film to the pc blank, or if the lines and pads in your image came out smeared or broadened on the blank, you're better off starting over. You'll need another conductor pattern photocopied onto the TEC-200 film, of course, but you can reuse the pc blank—and even the film if you properly clean all toner from it first.

• If your first try yields an incomplete image on the pc blank, next time use more heat or pressure as you perform the transference. If this is the problem, turn up the iron temperature slightly, heat the pc blank for a slightly longer time, work more quickly in positioning the film with the conductor-pattern image on it on the blank and transferring with the brayer, or use slightly more pressure on the film with the brayer or iron.

• If the lines in the image aren't solid, you can also try the above suggestions for increased heat or pressure, or use an original image with better contrast. If the lines are smeared or broadened, use less heat or pressure. In this event, lower the temperature of your iron or use less pressure on the film with the brayer or iron.

• If you encounter any difficulties and must start over, remove the pattern from the pc blank with a mild abrasive cleanser or scouring pad, or use an organic solvent, such as acetone or paint thinner, following manufacturer's precautions. Clean the blank as detailed above, finishing with a final cleaning with isopropyl alcohol, and you're ready to try again.

When the image is successfully transferred onto a pc blank, etch and drill the board as usual. Follow the directions with the etchant of your choice, or see "Making Printed-Circuit Boards the Old-Fashioned Way" by Anthony Caristi in the December 1988 *Modern Electronics*.

After etching and rinsing the board, remove the resist pattern from the remaining copper on the board (it's now a board, no longer a

Supplier Addresses

TEC-200, pc blanks, etchants
DC Electronics
P.O. Box 3203
Scottsdale, AZ 85271-3203
1-800-423-0070 (602-945-7736 in Arizona)

TEC-200
Meadowlake Corp.
P.O. Box 497
Northport, NY 11768

TEC-200, pc blanks, etchants
Small Parts Center
6818 Meese Dr.
Lansing, MI 48911
517-882-6447

"pc blank" since the only copper on it is the traces that serve as the wiring medium), using a cleanser, scouring pad or organic solvent, as described above. Figure 4 shows a pc blank onto which a desired etch-resist pattern has been successfully transferred from TEC-200 film. All that's left to do at this stage is etch the board, drill component-lead and holes, remove remaining resist from the copper conductor pattern and populate the board in the normal manner.

Examine your pc board for any broken copper traces. If you find any, you can repair the flaws with conductive ink, solder, or a small wire jumper soldered across the gap and "sweat-soldered" into place. The board is now ready for drilling, inserting components, and testing.

Whether you're new to printed-circuit-board fabrication, or you're looking for a new method of pc-board fabrication to try, you'll almost certainly discover that the transfer-film technique described here is a handy and practical alternative to the photographic and hand-drawn techniques you might have traditionally been using. In terms of neatness and freedom from the need to use chemicals alone, this technique is certainly worth a try. ME

"You don't have a hard disk drive? How do you keep track of all us kids?"