

How-To #9: Make a Printed Circuit Board

Background:

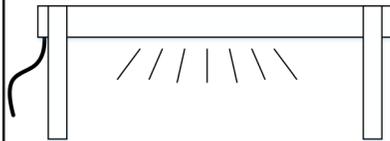
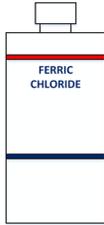
Fabricating a circuit board is a four-step process.

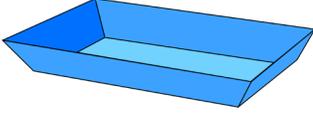
1. Expose: Use light and a mask to set the image of the desired traces on the circuit board.
2. Develop: Chemically remove the light-sensitive coating of the circuit board, except for the image of the traces.
3. Etch: Chemically remove copper from the board everywhere except in the image of the traces.
4. Drill: Use a drill press to make holes for mounting and soldering components.

Many methods exist to create a circuit board from a trace pattern. The methods shown in this How-To were developed at a large public high school, where they have been used for several years. Other methods may be faster or more precise, but the methods have proven to be reliable and reasonably safe.

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Materials:

Tool	Image	Notes
Photo exposure lamp		Light is from an appliance fluorescent bulb, very bright.
Developer		Used to develop image after exposure.  Caution: The developer contains sodium hydroxide. Dilute 10:1 (10 parts water to 1 part developer) before using.
Ferric chloride		Used to etch all exposed copper from the developed circuit board.

Tool	Image	Notes
2 Trays		Need two small plastic photographic trays, one for developing and the other for etching.
Electric tea kettle		Used to heat water for a hot water bath to speed etching.
Glass or plastic pan		Holds hot water for bathing the tray when etching the circuit board.
Flat board and matching glass		Used to hold raw circuit board and mask during exposure.
Sponge		Used to gently wipe the raw circuit board during development.
Paper towels		Used to dry board after developing and again after etching.

Procedure:

Expose

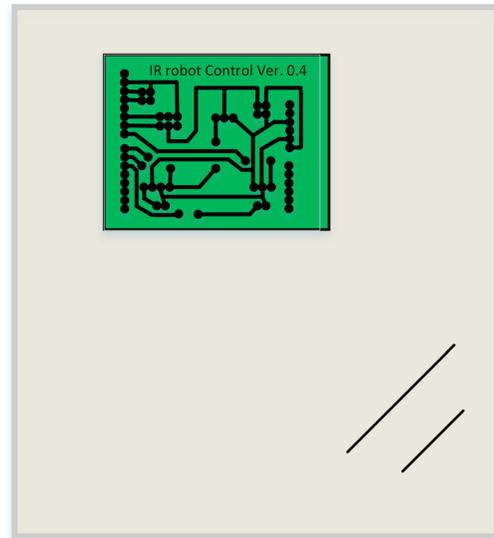
 Important	<p>Exposure is a photographic process. The copper foil on your raw circuit board is coated with a light-sensitive material. Do not peel the protective tape from the board until just before making the exposure. After the exposure, protect the board from light until after it is developed.</p>
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Make the photo exposure as follows:

1. Make an "exposure carrier" using the flat 8" by 10" board along with a matching sheet of glass. Make certain the glass is clean and dry.

2. Make a "sandwich" of the carrier as follows and as shown in Figure HT10-1:
 - a. The bottom layer is the carrier board.
 - b. The next layer up is the raw circuit board with the white tape removed, photosensitive side facing up. This is the side from which the tape was removed.
 - c. The next layer up is the mask. Make certain the mask is placed in the center of the raw board and that the text is clearly readable, left to right.
 - d. The top layer is the sheet of glass. It presses the mask close to the raw board, assuring a sharp image.

Assembled "sandwich" as seen from top. Glass, mask, and raw board must be clean and dry. Any dust or scratch will appear on the finished board.



Sandwich as seen from end.



Figure HT10-1. Assembled "sandwich" as seen from top and from end

 Important	The mask must be positioned near the center of the raw board with the words clearly readable—not mirror imaged. The glass must be clean; it must also press the mask flat against the raw board.
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3. Place the sandwich under the exposure light. Leave it undisturbed for twelve minutes.

 Caution	Do not touch the sandwich or the light during exposure. Even careful movement of the board can result in a blurred image on the raw circuit board.
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4. After exposure, disassemble the sandwich and protect the raw board from exposure to light until you are ready to develop the image.

Develop corrected image

This step uses a chemical labeled "Developer" on the bottle. The active solution is sodium hydroxide. The sodium hydroxide dissolves the coating on the raw circuit board, but only where that coating was exposed to the light. The result will be a green pattern on the board that looks exactly like the black pattern on the mask. Where the mask was clear, the board will now be bare copper.

 CAUTION	During developing, ALWAYS wear lab safety goggles and gloves!
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1. In one of the trays, mix 20 ml of developer with 200 ml of water. This is more dilute than the instructions on the bottle produce, but it also slows the development process enough to make it easily managed.
2. Submerge the exposed board in the developer in the tray. Use the sponge to gently brush the board until the trace pattern is clearly visible.
3. Remove the board the moment no trace of green is seen in the bare copper portions of the board.

 Important	An underdeveloped board will appear light green in the non-trace areas and will not etch properly. However, developing too long will result in the traces as well as the non-trace areas being erased. Developing must be stopped the moment the light areas are clear of all trace of green.
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A properly developed board has crisp, green traces and text. Copper in open areas is clear and shiny.

4. Wrap the developed board in a paper towel to prevent scratching the green pattern before etching.
5. The developer is good for several more boards. It may be kept in a tightly closed plastic bottle. Either store the developer or pour it down the drain with plenty of water.
6. Rinse and dry the developer tray and anything else that came in contact with the developer.
7. Rinse your gloves to remove all traces of the developer. Remove them and throw them away.

Etch

This step uses an aqueous solution of ferric chloride, sometimes known as iron chloride. The ferric chloride will dissolve the exposed copper on the circuit board. The copper under the green trace pattern will remain on the board.



CAUTION!

During developing, ALWAYS wear lab safety goggles and gloves!

Work in a well-ventilated space.



Caution

Ferric chloride stains almost anything, permanently!

1. Fill the electric tea kettle with water and heat it to a boil.
2. While the water is heating place the circuit board pattern side up in the second plastic tray.
3. Pour enough ferric chloride in the plastic tray to cover the circuit board by about 1/8 inch.
4. Pour the hot water from the tea kettle into the plastic tub.
5. Float the tray containing the circuit board and ferric chloride on the hot water. The idea is to raise the temperature of the ferric chloride and, thus, reduce the time required to etch the board.
6. Gently rock the tray to "slosh" the ferric chloride over the circuit board. The entire etching process should take between 10 and 15 minutes.
7. Occasionally pull the board out of the ferric chloride to assess progress. Stop when light can be seen through the circuit board everywhere except where the traces are.
8. Wash the board and your gloves thoroughly in running water.
9. Place the ferric chloride in a closable plastic bottle for later use.



CAUTION!

NEVER POUR FERRIC CHLORIDE DOWN A DRAIN! Damage to the plumbing is possible. Spent ferric chloride can be disposed of at a hazardous waste site. The solution now contains copper chloride, which is not healthy for the environment.

10. Pour the water out of the tub. Rinse it and the tray thoroughly.
11. Rinse your gloves one more time, then remove them and throw them away.

You are now ready to drill.

Drill

This How-To is not a tutorial on the use of a drill press. Do not attempt to adjust or use a drill press if you've not been shown how to do so safely.

The recommended drill size is 3/64th inch. Holes are in what are called solder pads, round circles of copper.