QUALITY CIRCUIT BOARD ETCHING AT LOW COST*

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by

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We have found that making good quality circuit boards is relatively easy and inexpensive. There are several reasons to make your own circuit boards.

- (1) Cost. The cost of making your own boards is considerably below what industry must charge you on low volume items. Only if you are making a large number of identical boards can industry outdo the individual.
- (2) Speed. From conception of an idea to final product can be a matter of hours for simple items to a matter of days for relatively complex items. This compares to a turnaround in industry of three days to four weeks.
- (3) Getting exactly what you want is often easier if you do it yourself than if you have to detail all your thoughts to someone else. That is, you have sized up the situation and know precisely where you can cut corners and where you cannot.

Quite a lot of literature exists on methods including some rather good pamphlets written by Kodak. For the novice, many of these reports are not as detailed as one would like. This report outlines quite specifically the method of circuit board production we have found quite successful.

METHODS

There are various methods one can use in the process of circuit board making. The simplest method for very simple patterns is to use a grease pen and draw on copper clad G-10 directly. One then eats or etches away the copper using a solution of ferric chloride. The copper which is not covered by grease is removed and one is left with the pattern in copper on G-10. (These pens are available from hobby shops or catalogs.)

The method we have been using largely here at Colorado is a photo etching process. Let me describe quickly the various steps. Each step will be discussed in detail further on. Here one has a photographic negative of the work he wants to put onto copper. The copper-clad G-10 is coated with a photo sensitive coating (KPR) and the negative is placed in contact with the

copper. Glass is placed on top to maintain firm contact of film and copper and this sandwich is exposed to UV light. The clear areas on the film, where the UV gets through to the copper clad, are hardened to a near plastic condition. The unexposed KPR can be washed off in a vapor degreaser or in a developing solution. The copper with no KPR can now be etched away with ferric chloride, whereas the copper under the hardened KPR remains with the pattern you want.

The photo etching process thus breaks down into a series of steps. I will discuss each step in the detail necessary to duplicate our results.

The steps are:

- (1) Art Work
- (2) Photography
- (3) Metal Preparation and KPR Spreading
- (4) Exposure
- (5) Developing the KPR Image
- (6) Etching
- (7) Tin Plating of the Circuit Boards

(1) ART WORK

Art work entails all of the preparation of what the circuit you want is physically going to look like. It can be done actual size, but is easier if the art work is done with a magnification relative to the real size of the order 2 to 1 or 4 to 1 as all slight imperfections get reduced proportionally when it is photoreduced. You can buy black tape of various widths and patterns of almost every conceivable electronic component. Bishop Graphics has a nice catalog on art work and all of their products associated with art work production.

These black tape patterns are placed on clear mylar, which can be placed on top of grids in either metric or English measurement systems in order to get whatever spacing you need for components or wires. Careful

work here results in great accuracy on the final photograph if, for example, a 4 to 1 reduction is made. We were able to make 25 pin connectors with .050 inch spacing between pins with over all length specifications of 18 parts in 100,000.

(2) PHOTOGRAPHY

Here it helps to have a local expert to call on for pointers. We found we could do quite well ourselves with pointers from our department's photographer. We used high contrast black and white kodalith film with 7 mil mylar base. Standard sizes are 4" x 5" or 8" x 10" so this sets an upper limit on your size of any one unit. Industry offers larger sizes at much larger prices, but we found for meter long boards that the symmetry involved allowed several 8 x 10 size negatives to be taped together on a sheet of plate glass to form our meter long requirements. As mentioned, our accuracy has reached 18 parts in 100,000 for in house processing.

(3) METAL PREPARATION AND KPR SPREADING

We found absolutely clean copper essential for all subsequent work. Thirty second immersion in a 10% solution of hydrochloric acid generally cleaned all but the most heavily oxidized copper. If not clean at this point, a light working with steel wool generally finished removing oxides.

Fingerprints and oil must be removed with alcohol or a vapor degreaser. When the surface is clean and dry, we spread KPR (Kodak Photosensitive Resist, available from most Kodak suppliers or on order) on the copper with a brush. After the surface is completely covered (the board is lying flat for this), we set boards on edge to dry. Thorough drying requires about one hour. The room lighting should be dim for the entire coating process until the image is developed.

This coating procedure results in very thick coats of KPR with a bead along one edge. The bead is not easily eliminated, but by making boards about 3/16 inch oversize, this portion can be unused or cut off. Note that there are many more elaborate methods of coating that eliminate this bead, but we haven't found a need to resort to these.

(4) EXPOSURE

This is not a critical point in this method as the coating is thick. We found 4-10 minutes under a normal sun lamp at a distance of 2 feet very adequate. For long pieces we used a series of sun lamps and found this arrangement adequate. Note that we always sandwiched the negative between glass and the KPR coated board as it is essential to make good contact. Otherwise, light leaks under the edges of the negative will wash out detail or even destroy it.

(5) DEVELOPING KPR IMAGE

Two methods for developing have worked for us.

- (a) Use of KPR developer which can be purchased from a supplier of photographic materials. In this method you immerse the board in a solution of developer for 2 minutes while agitating. This gives excellent detail, though only a few boards can be developed with any one solution. Then thorough washing must follow in order to remove the oil based developer.
- (b) A second method is to use a vapor degreaser with a spray nozzle which uses clean trichlorethylene. The board should be immersed in the vapor for 15 seconds of spraying and then 15 more seconds of just hanging in the vapor. This will develop a sharp clean image very quickly.

(6) ETCHING

We have had great success with ferric chloride solution. Buying it in our chemistry stores in 5 lb. bottles as solid lumps gives a very concentrated solution when mixed with about 3 quarts of water. This

solution should be heated to quite warm to the touch and placed in a plastic tray or basin to do the etching. It can be kept warm in the trays by placing a heat lamp over the solution. If agitated or rocked, etching takes place fairly quickly in around 20 minutes. Thorough washing must follow this step. Note that used up ferric chloride should not be thrown down drains as it eats any metal. Probably the best method of disposing of it is to take it to chemistry department liquid disposals.

(7) TIN PLATING

In order to clean the KPR off the copper, we found that methyl ethyl keytone works quite well. When used under a fume hood, a wet towel or rag wipes off the KPR very easily. At this point you have very clean copper. This will soon corrode, and after a week gives questionable solder connections. To prevent this, we found that a thin coating of tin gives good protection. Thus as our last step we used an immersion tinning formula. After trying several, the best formula we found was this:

1 liter of 10% solution HCl

8-16 gm Stannous Chloride SnCl_2

80-90 gm Thiocarbamide (thiourea) $\text{CS}(\text{NH}_2)_2$

By heating to from 50°C to boiling and then immersing our board for 5 minutes we got thin coats of tin on our boards which protected them from corrosion. A thorough washing is necessary after tinning.

CONCLUSIONS

One rapidly learns that cleanliness is the key to good boards. Dust on the negatives can result in broken connections in places. With reasonable care, we encountered very few troubles. The attractive thing

here is cost. For example, we were quoted prices from local board manufacturers of between \$500 and \$1500 for the first 4" x 48" circuit board. After an experimental period, we were able to do the whole process in three days for less than \$60, and were at that point set up with trays, KPR, and ferric chloride to the extent that we could make 10 more boards with the additional cost of only the G-10 copper clad.