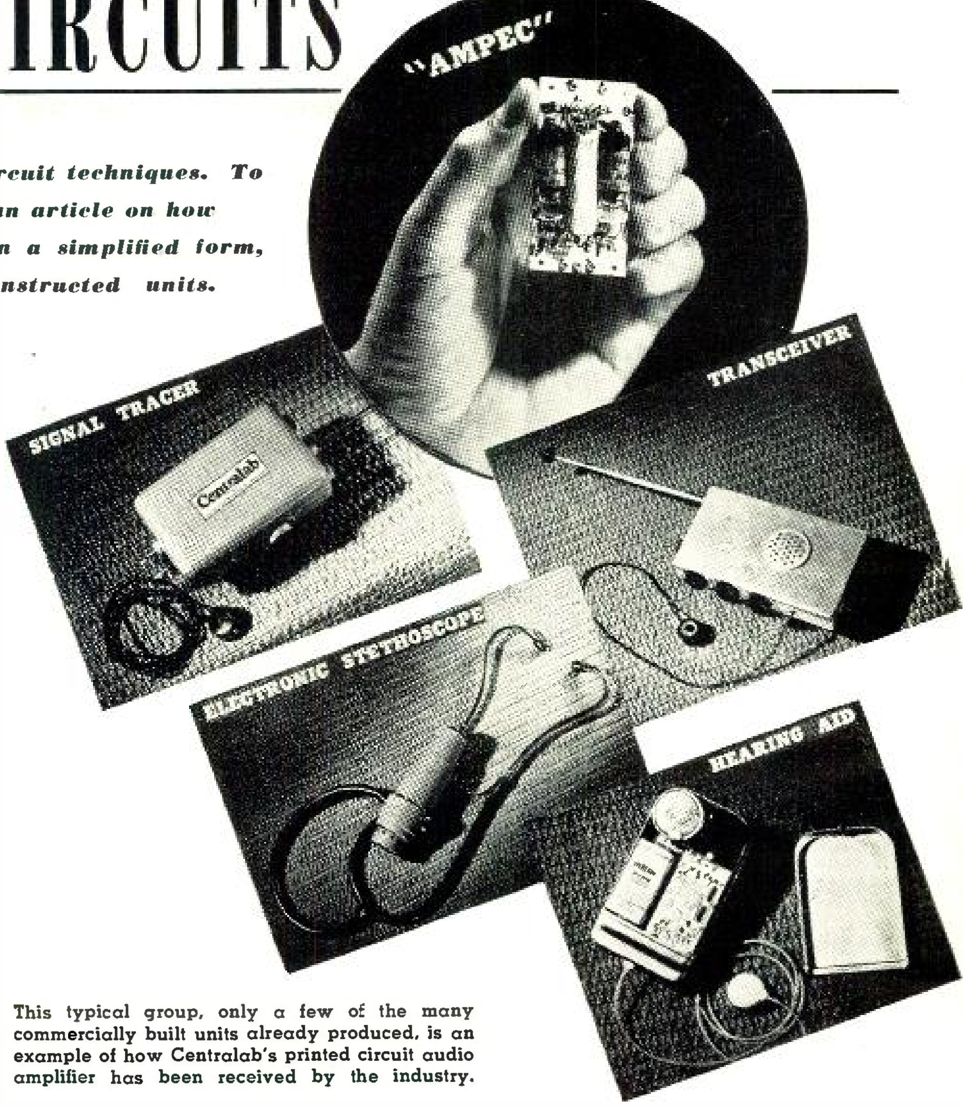
PRINTED CIRCUITS



Part I. A review of printed circuit techniques. To be concluded next month with an article on how the experimenter can apply, in a simplified form, printed circuits to home constructed units.

By

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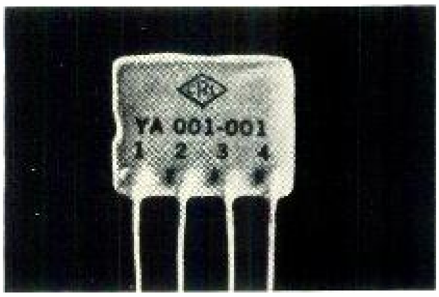
This typical group, only a few of the many commercially built units already produced, is an example of how Centralab's printed circuit audio amplifier has been received by the industry.

A VERY loud *Bang* announced to the electronic world early in 1945 that printed circuits had moved from the experimental to the practical stage, for it was at that time that the National Bureau of Standards, working closely with the *Centralab-Division* of the *Globe Union Company,* began mass production on the tiny radio proximity fuse for mortar shells: a fuse incorporating a complex electronic circuit "printed" on a thin steatite plate 1¾" long by 1¼" wide!

Since that time, the printed circuit has thrust its tentacles into every portion of the electronic field, and it has miraculously shrunk everything it touched. Hearing aid amplifiers, complete with batteries, that are smaller than a cigarette package; personal radios that can be cradled in the palm of the hand; radio and television subassemblies occupying only one-tenth the space needed for conventional assemblies and requiring one-half as many soldered connections for installation: these are but a few of the achievements of this new process, and the surface has barely been scratched. Every day sees new applications of this method by which space is saved, weight is reduced, assembly is simplified, and cost is cut.

Every electronic worker is certain to come in contact with printed circuits in increasing number, and it is the purpose of this article to prepare him for that contact by making him familiar with the various methods and techniques by which these circuits are produced commercially and then showing him how he can develop and experiment with his own printed circuits.

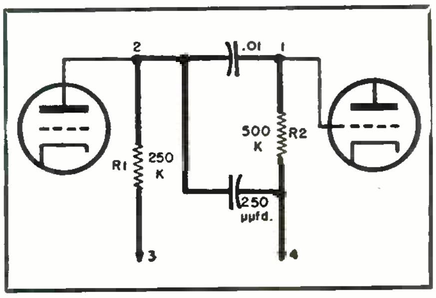
Fig. 1. The "Couplate" unit. It contains a complete interstage coupling circuit.



First, it should be clearly understood that the term "printed circuit" covers any reproduction of an electrical circuit upon an insulating surface by any process. Essentially it changes a bulky three-dimensional array of electrical parts and conductors into a compact and very nearly two-dimensional arrangement. An example best shows how this is done:

Suppose we want to build the complete interstage coupling circuit shown in Fig. 2. First, let us redraw our diagram on a tiny plate of steatite approximately 1"x¾". Then let us carefully trace out the heavy lines with a small brush which we have dipped into a "paint" made by mixing fine particles of silver together with a liquid binder to hold the particles together and a solvent used to make the mixture thin enough to brush.

Fig. 2. Diagram of "Couplate." Finished unit measures 1-1/16 x 13/16 x 3/16 in.



Next, suppose we have several different solutions of finely powdered graphite or lamp-black, a resin binder, and a solvent. We can experiment with these until we find just the right combination of mixture, thickness, and length of line needed to produce resistances equal to R_1 and R_2; and then we carefully paint in these resistance lines at the proper points between the silver conducting lines already drawn. Then we place our little plate in an oven and raise the temperature to the point where our lines of paint will be "fired" directly to the ceramic base, adhering to it with a tensile strength of 3000 pounds to the square inch. Finally we solder tiny ceramic condensers of the proper values across the gaps representing the condensers, and then we attach flexible leads to our silver paint at points 1, 2, 3, and 4. The result is a "printed circuit" that will perform exactly the same as one using conventional components, but our printed sub-assembly will be no bigger than a postage stamp and require only four soldered connections to be made by the radio assembly-line operator. A commercial version of just such a printed circuit is shown in Fig. 1.

Such a manual process, while pointing up the difference between printed and conventional circuits, obviously could not be adapted to mass production. Various stencilling methods are the answer to producing more uniform circuits at higher speed, and the silk-screen process is one of the most successful.

In this system, a fine-meshed silk screen is tightly stretched on a wooden frame and covered with a photosensitive material that becomes insoluble when exposed to strong ultraviolet light. A photographic-positive mask of the exact shape of the required conducting circuit is placed on top of the screen, which is then exposed to the rays from an ultraviolet lamp. Finally, the portions of the film protected by the mask are washed away in cold water, leaving a stencil of the conductor design to be printed. All four of these steps are clearly illustrated in Fig. 3.

This finished stencil is held securely against the base plate to be printed; and the circuits can be printed on practically any insulating material, or even on conducting material that has been coated with a non-conducting film, such as lacquer, and a quantity of silver paint is placed at one end of the screen. A neoprene bar, or "squeegee," is moved across the top surface, forcing the paint ahead of it and down through the open mesh of the design, as is shown in Fig. 4. When the screen is removed, the surface of the plate is found to be printed with an exact, sharp-edged, uniformly-thick design of the required conductor circuit. A second stencil can be used to print the resistors in their proper places. The paint is fired to the base exactly as was done before. This process is shown in Fig. 6. In Fig. 7 are displayed base plates at various stages of completion.

Brushing and stencilling with a silk

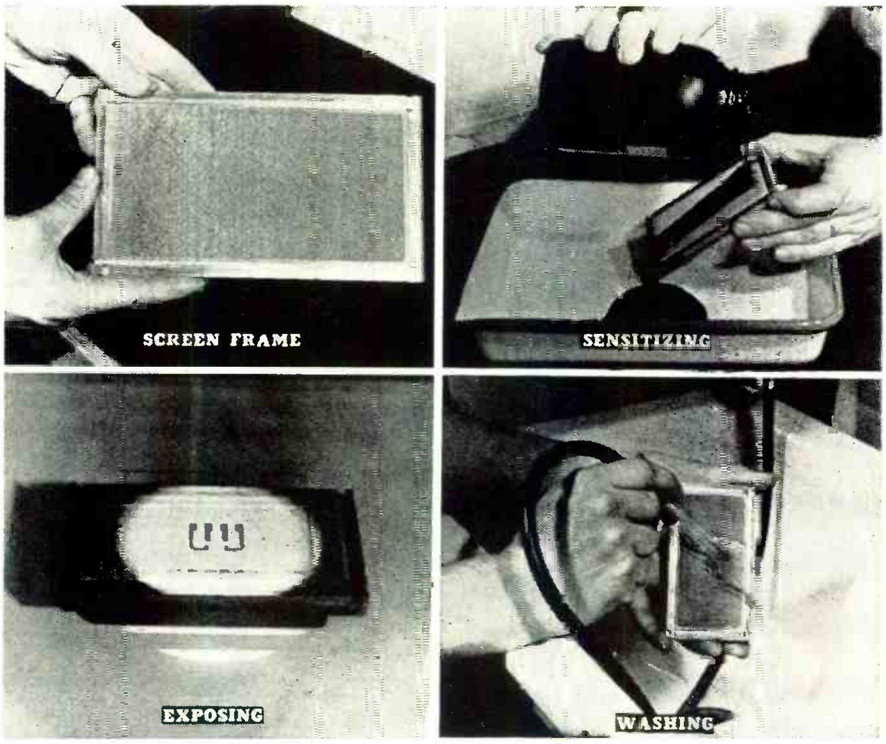
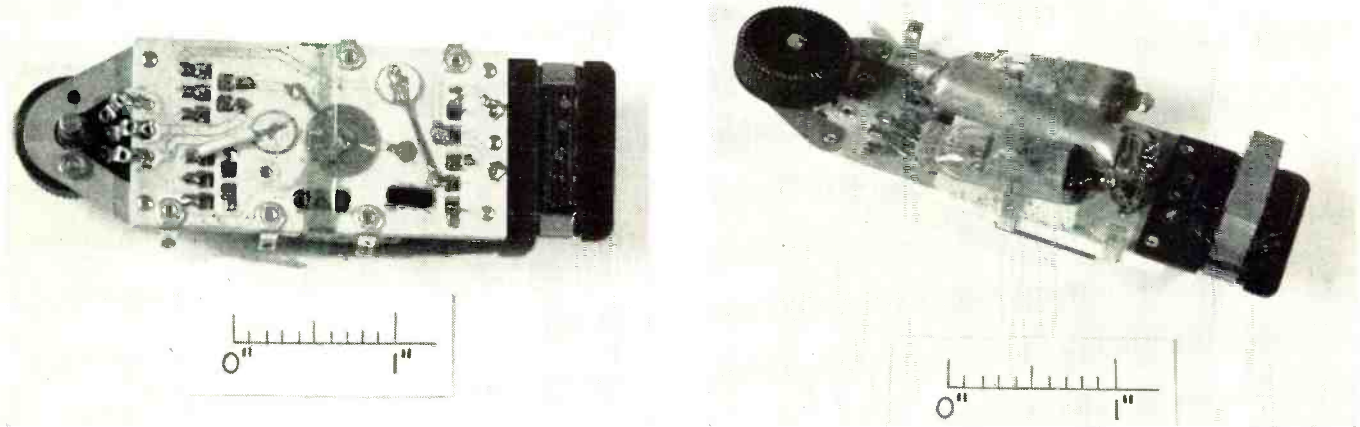


Fig. 3. These individual operations show the method used in preparing a silk screen.

Fig. 4. Silk-screen printing. Paint is forced through the open mesh of the screen. After the screen is removed, the surface of the base plate is found to be printed with an exact, sharp-edged, uniformly-thick design of the required conductor circuit. A second stencil can then be used to print the resistors in their proper location.

Fig. 5. Front and rear views of one of the many hearing-aid amplifiers that are printed on ceramic plates.



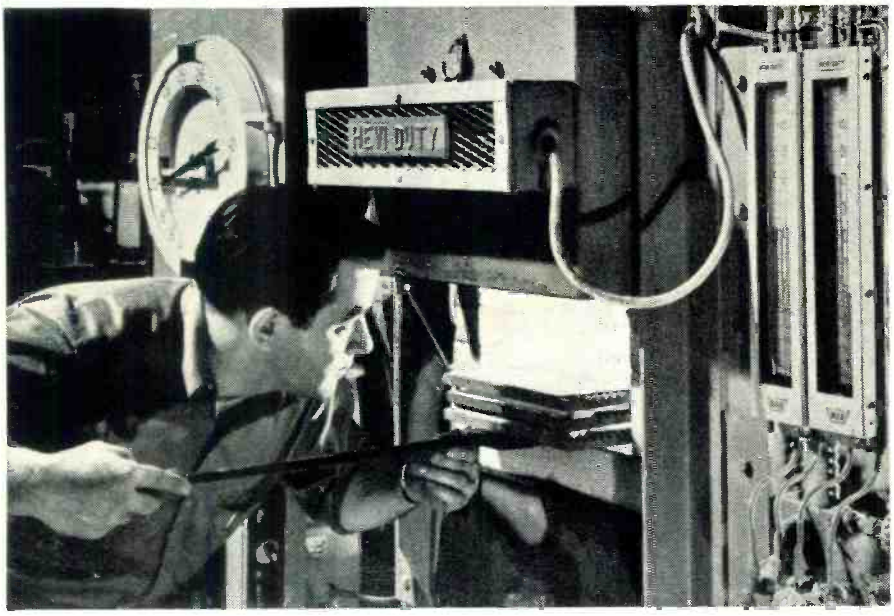


Fig. 6. A high temperature oven is used for firing a group of printed circuits.

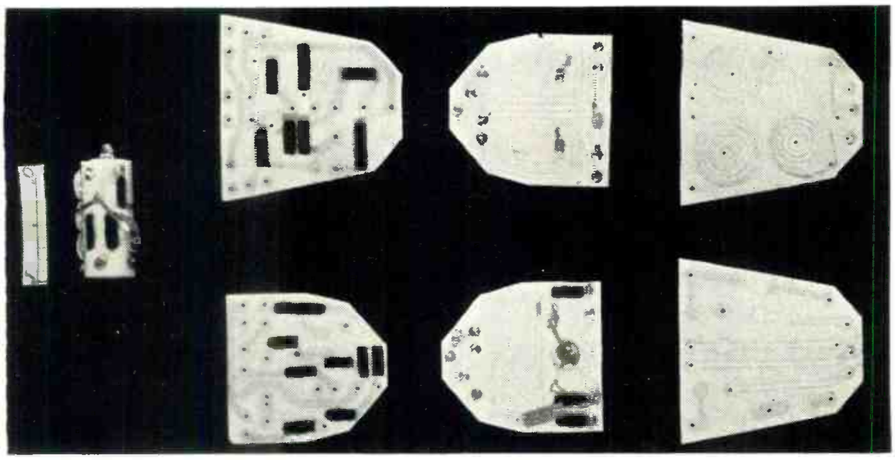
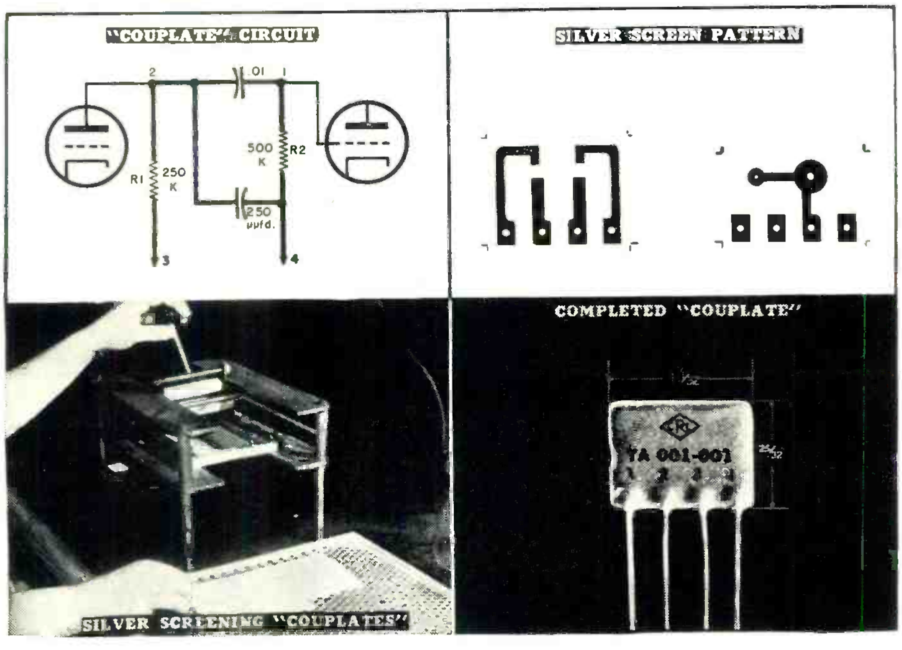


Fig. 7. Partially completed electronic circuits printed on steatite plates and cylinders by the silk-screen process. Light lines are silver conductors and inductors; dark rectangles are resistors; circular disks are ceramic condensers.

Fig. 8. Illustrating the evolution of an audio plate-to-grid coupling circuit.



screen are not the only ways in which the conducting and resistor paints are applied. For example, a decalcomania, on which the circuit is printed on a thin flexible film that can be transferred to the final surface, is useful in applying the circuits to cylindrical or irregularly-shaped objects. The film is removed by firing.

Most standard printing processes are also used. As a single example, the required design can be raised on the face of a rubber stamp, and this stamp can be pressed first on a pad of conducting ink and then on the surface to be printed. Plating of this printed design will increase its conductance if necessary. In the same way, other printing processes such as engraving, lithographing, and intaglio are also employed.

You old-timers who used to draw your own grid-leaks with a lead pencil were using a form of printed circuits that still may have possibilities. Pencils having "leads" of varying degrees of conductivity, or pens filled with conducting inks are being used experimentally. With such devices an experimental circuit could be drawn and constructed ready for testing all at one and the same operation!

Condensers can be painted, too, by employing silver disks painted on opposite sides of the base plate so that the plate material becomes the dielectric. If the plate is constructed of high-dielectric material, condensers of reasonable capacity can be obtained by this method; otherwise, miniature thin-disk ceramic condensers are often employed by soldering them with a low temperature solder directly to a silvered area on the base.

Printed inductors are also used, especially in the low-inductance values. Spiral forms are used on flat bases, although the more conventional forms can be used when the circuit is printed on the tube envelope or a cylindrical base plate as is shown in Fig. 9. The inductance of a spiral conductor can be increased by covering it with an insulating layer of lacquer and then painting another spiral right on top of it and connecting the two in series, painting another spiral on top of that, etc. The distributed capacity and the Q of the circuit required are the limiting factors to the usefulness of this method.

Placing a layer of magnetic paint, made of a colloidal suspension of powdered magnetic material, both beneath and above the spiral conductor, with insulating layers serving to protect the turns of the inductance from shorting, will also increase the inductance.

The spraying of conducting films on insulated surfaces is another method of printing circuits. The same paints can be used in paint spray guns as for the stencilled-screen process; or molten streams of metal can be sprayed through locating stencils. Guns are available in which the metal to be sprayed is fed into the gun in the form of a wire, where it is heated to the

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