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ON THE USE OF PRINTED CIRCUIT CONDUCTORS IN THE LABORATORY

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By Richard J. Watts

ABSTRACT

An investigation was made on the use of Printed Circuit Conductors from the point of view of the "Fast" electronic circuits used in the laboratory. Prototype instruments were built and compared with the equivalent conventional instruments.

INTRODUCTION

It is not the purpose of this paper to go into the economics of laboratory operation, however, some digression is necessary in order to explain the motivation for the present investigation.

In many laboratories a situation exists in which there is a need to produce specialized electronic instrumentation in quantities which, although not negligible, do not warrant the time and effort of mass production. This quantity will fall between two and thirty units. It often happens that these specialized instruments are only needed for a particular experiment, or it may happen that these instruments are destroyed in the course of the experimentation.

In either case a grievous burden is placed upon the laboratory in time, material, personnel and financial resources. The high cost of such specialized electronic equipment therefore makes fruitful the investigation of any method which will reduce this burden.

It was with these considerations in mind that the present investigation was undertaken.

PRINTED CIRCUITS

It has been pointed out by Sargrove (1) that the present day electronic instrument is essentially a "hand-tooled" instrument not well adapted to Automatic Production. Other authors (2) have shown that there are techniques which offer promise of cheaper and more reliable instrumentation. The most promising technique in this respect is printed circuits.

Consequently, the interest in Printed Circuit Techniques has been widespread both in the electronics industry and the Armed Forces. This interest, however, has not been reflected in the specialized production of the laboratory. It can be conceded that Printed Circuit Techniques are applicable only to mass produced instruments and that comparatively little can be gained by its application to specialized instrumentation.

It is the purpose of this paper to investigate the validity of this assumption.

POSTULATED REQUIREMENTS

Although the adequacy of Printed Circuits has thus been recognized by the industry, to the author's knowledge there has not been as yet any application to "Fast" electronic circuits, that is, circuits with response to pulses with durations of the order of one microsecond. The principal application has been to the miniaturization of low-power electronic circuits. It would appear that little thought has been given to the use of printed circuits without miniaturization,

*Work done under the auspices of the AEC.

although from the published data of Brunetti and Curtis (2) it would seem that miniaturization is only a correlary of the process. These authors report that a silver conductor fired on steatite, 0.843″ long and 0.041″ wide with a thickness of about 0.001″, fused at a current of 8 amperes. It would thus seem that the current carrying capacity is more than adequate for all but the most powerful of electronic circuitry.

If this technique is to be of use to the laboratory, however, it is necessary that the method of application be extremely simple. For it seems reasonable to assume that in the laboratory the method with the greatest facility and flexibility will be preferred. From the point of view of dissemination of information, a method which can be shared by the greatest number of people is to be preferred. From the point of view of a definite life to an instrument, the method need be no better than is required to produce the stipulated reliability consistent with lifetime.

METHOD OF APPLYING THE PRINTED WIRING

With these ideas in mind, it was decided that a simple stencil technique might be one of the best avenues of approach. A stencil technique combined with paint spraying appeared to be the cheapest and most flexible method. The metallizing-milling (1) technique although much better technically, required a greater investment in machinery and seemed more adapted to mass production. The silk-screen process (2) although more flexible than the metallizing-milling technique, still required a greater investment than the spray-stencil technique. "Auto-Sembly" which is an etched copper clad phenolite process at the present time seemed definitely more expensive in materials.

The method as finally decided upon consisted of a distinct number of steps. The first step consists of laying out the wiring pattern on heavy drawing paper (K. & E.333) as shown in Figure 1. Since both sides of a ⅛″ bakelite panel may be used, the wiring is reduced to a problem in two dimensions. Dotted lines are used to indicate the wiring on the other side of the bakelite plate. The second step consists in transferring this master copy to two other pieces of drawing paper by means of carbon paper and retracing. One side only is retraced on each paper.

The third step consists in cutting out the stencils so formed with a Stencil Knife (Paasche Swivel Knife).

A fourth step consists of making a third carbon copy which consists of the points at which the sprayed wires terminate.

The fifth step consists of coating the back of the drilling pattern (third copy) and the bakelite plate with a coat of rubber cement and allowing to dry. When dry, the pattern and bakelite are pressed together and it will be found they will adhere in intimate contact. The plate can then be punched or drilled with accurate register.

The holes which terminate the wires are drilled to size for Turret Lugs.

The sixth step consists in applying the stencils to the two sides of the drilled bakelite in the same manner. A small piece of latex tubing is then used to pick up the rubber cement from the bakelite panel where it shows through the stencil. It will be found that the rubber coating will adhere to the tubing and rip cleanly away from the bakelite base. By this means the stencil adheres closely to the bakelite and there is no possibility of the sprayed paint running under the stencil.

The silver paint (3) is best applied with an artist's airbrush (4). Vigorous shaking of the paint mixture is necessary before applying. Methods are suggested in the literature (2). The author used a Cenco-Meinzer sieve shaker which worked quite well. Since the paint is rather thick the best results were obtained by using as an air supply a Carbon Dioxide Cylinder with the regulator set at 40 lbs. pressure. The Carbon Dioxide has the advantage that no moisture is introduced through the air lines. By this means the paint dries quickly, however the completed circuit was placed in an oven for an hour at 200°F. in order to complete the process.

The seventh step consists in swaging in the turret lugs and socket pins. The turret lugs

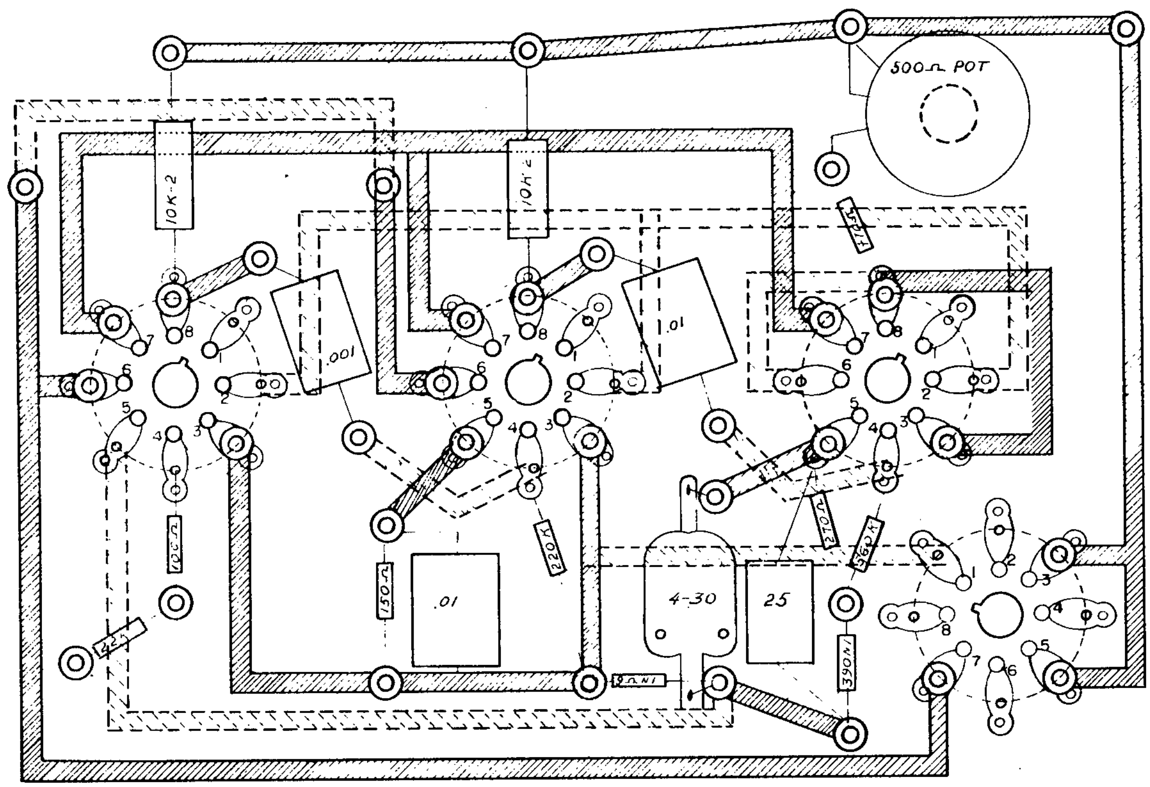

Figure 1

are swaged tightly through the holes, the shoulder of the lug thus making a press contact with the wiring. In the event that the lug is also a feedthrough from one side of the plate to the other a washer is put over the lug before it is swaged. The lugs thus provide a secure foundation for the resistors and capacitors. The circuit lines are then painted with a dielectric varnish (5). By this means the circuit was both insulated and protected from abrasion.

Tube sockets were drilled with the help of a simple jig. (Figure 2). This jig was centered by first punching the center hole of the tube socket. Ordinary tube socket pins were used. The pins were swaged by means of rivets to the wiring.

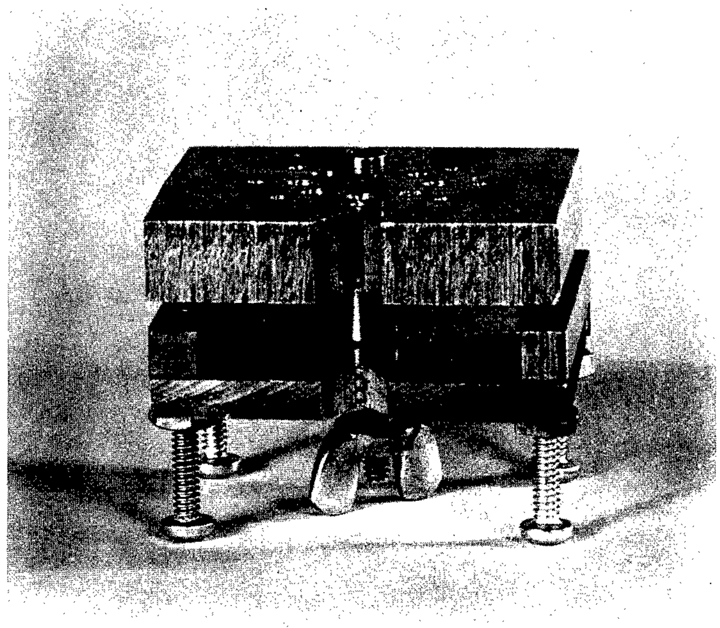

Figure 2

Figure 3 illustrates a typical circuit made by this means.

It may seem that the above described process is tedious and time consuming. However, it should be pointed out that the process has a number of compensations which led to its choice.

It may be executed by unskilled personnel. Further savings in time are possible by drawing the master pattern on a mineograph stencil, in which case a sufficient number of copies may be obtained for any purpose.

A major reason for the choice, however, is that it is an excellent solution to the criterion of the dissemination of information. It is often the experience that in "Fast" circuits no two laboratories will obtain the same result from a circuit diagram that is identical. In many cases this may be traced to the individual layouts and stray capacitances. It is suggested that by exchanging stencils the originator may be assured of an accurate reproduction of his work. A further advantage of course is the enormous collective savings in time which accrues from the fact that the layout need only be done once. Another advantage is that the layouts may be filed which permits the reproduction of a given circuit at a later date with a minimum of effort and an assurance of perfect reproducibility.

EXPERIMENTAL TESTS

Inasmuch as no data existed for this simple technique, it was necessary to investigate the behavior of this wiring to see if it was adequate for the proposed application.

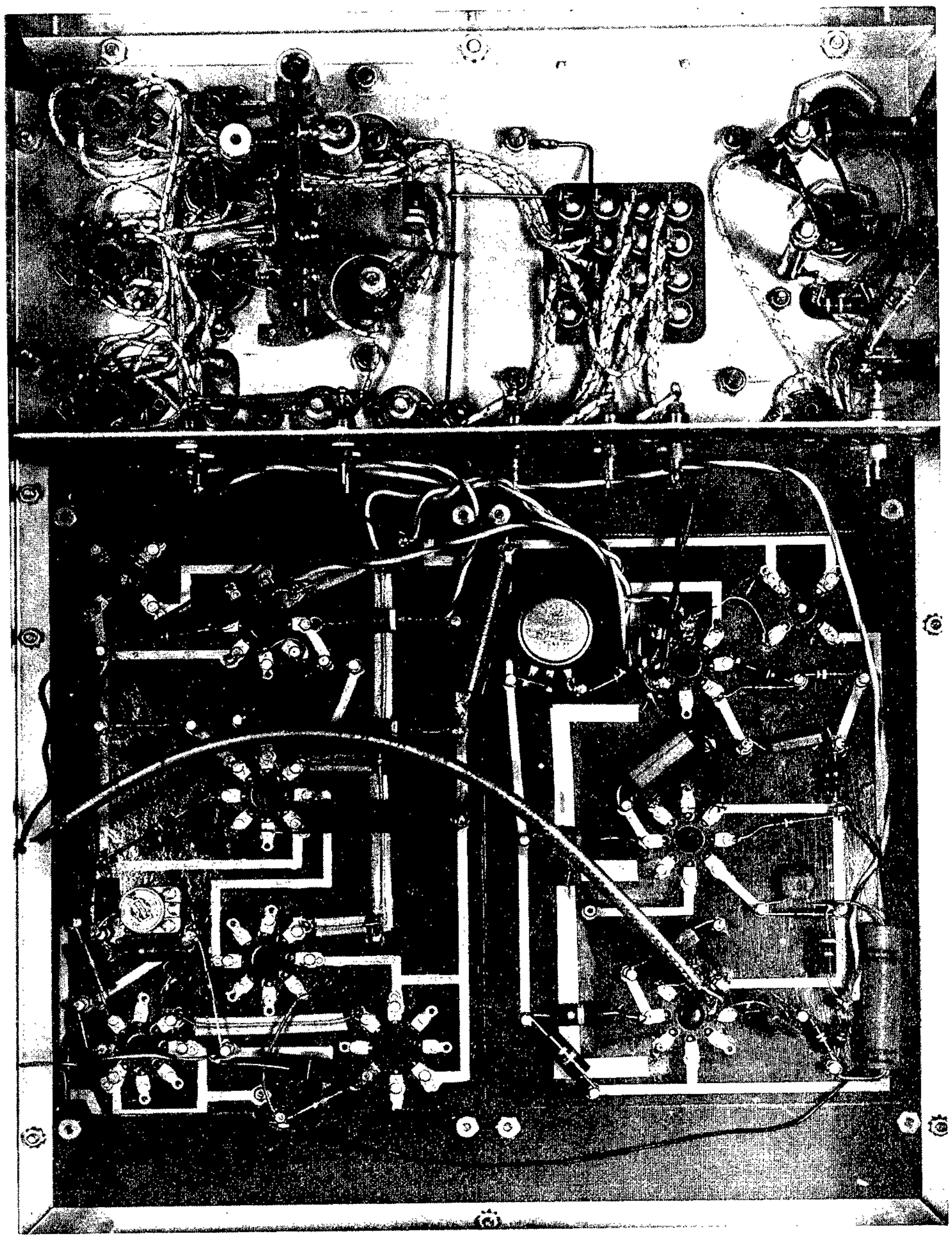

Figure 3

It was expected that since the bakelite base prohibited the use of high temperature the completed film would show an appreciable resistance per inch.

Figure 4 is a plot of the resistance of a 5-¼ inch long by 3/16 inch wide by about 0.001 inch thick sprayed conductor as a function of current. Breakdown occurred at ~5 amperes. A similar curve with ⅛ inch conductor showed a breakdown at 3 amperes, a ¼ inch wide conductor broke down at 10 amperes. In the region in which a great many electronic circuits are operated (0-200 ma) it is apparent that the conductor is reasonably stable. For the curve shown, the conductor was painted with dielectric varnish.

The erratic behavior at high currents can be accounted for by insufficient heat dissipation. The increased temperature partially fused the paint particles and carbonized the binder. The wires failed when the paint blistered from the base plate.

Various methods were tried to reduce the resistance of these wires. Higher temperatures, sandwiching, were all effective in reducing the resistance but not sufficient for its use in filament wiring. This difficulty of course could be eliminated by the use of a higher voltage filament transformer, however, in the present investigation it was thought that the method has sufficient merit for B supply and grid wiring that the filament problem could be ignored for the time being and conventional wiring used for the filaments.

EXPERIMENTAL INSTRUMENTS

In order to compare the technique with the conventional ones, it was decided to build three experimental instruments. These instruments were chosen with a view toward typical application in nuclear laboratories. The first (Figure 5) was a modified Harwell (6) preamplifier which was chosen because it offered the most promise of being least susceptible to circuit layout. The second (Figure 3) was the Model 500 Amplifier (7) a fast pulse amplifier with a rise time of 0.1 microseconds. The third instrument (Figure 6) was an oscilloscope with centering controls patterned after that of Fitch and Titterton (8) and the fast sweep of Prime and Ravenhill (9).

Figure 7 is a schematic of the modified Harwell amplifier. The trimmer condenser in the anode of the first tube is for the purpose of trimming the circuit for monatonic response to a step pulse. The circuit was tested with pulses from a Kay-Megapulser (10) through a Daven Attenuator (11) and the output observed by means of a Tektronix 511 AD Oscilloscope. Table one shows the results obtained.

Table I

Total Load R + Rp	Gain	Rise Time (microseconds)
250	35	0.04
500	64	0.06
1000	110	0.08

Figure 8 is a picture of the response obtained with the amplifier of Figure 3. This circuit was tested with a Model 100 pulser (12) and the output of the amplifier placed on a Tectronix oscilloscope. The picture was taken at F 2.8 at 3 sec. with a Fairchild-Polaroid Camera. Sweep speed was 0.4 μ sec/cm repetition rate 3000 cycles per second.

The oscilloscope of Figure 6 was patterned after a suggestion of Sargroves (2). The back plate contains all the centering controls plus the Post and Pre-Acceleration voltages supplies. The middle plate contains the sweep circuit only. This sweep and oscilloscope was also tested with the Kay Megapulser driven by a repetitive pulser of lower rate. Figure 9 is a picture taken with the Polaroid Camera of a 0.05 microsecond pulse. Repetition rate was 12 cycles per second. Exposure time 2 minutes, the signal was delayed by 127 feet of RG9/U cable in

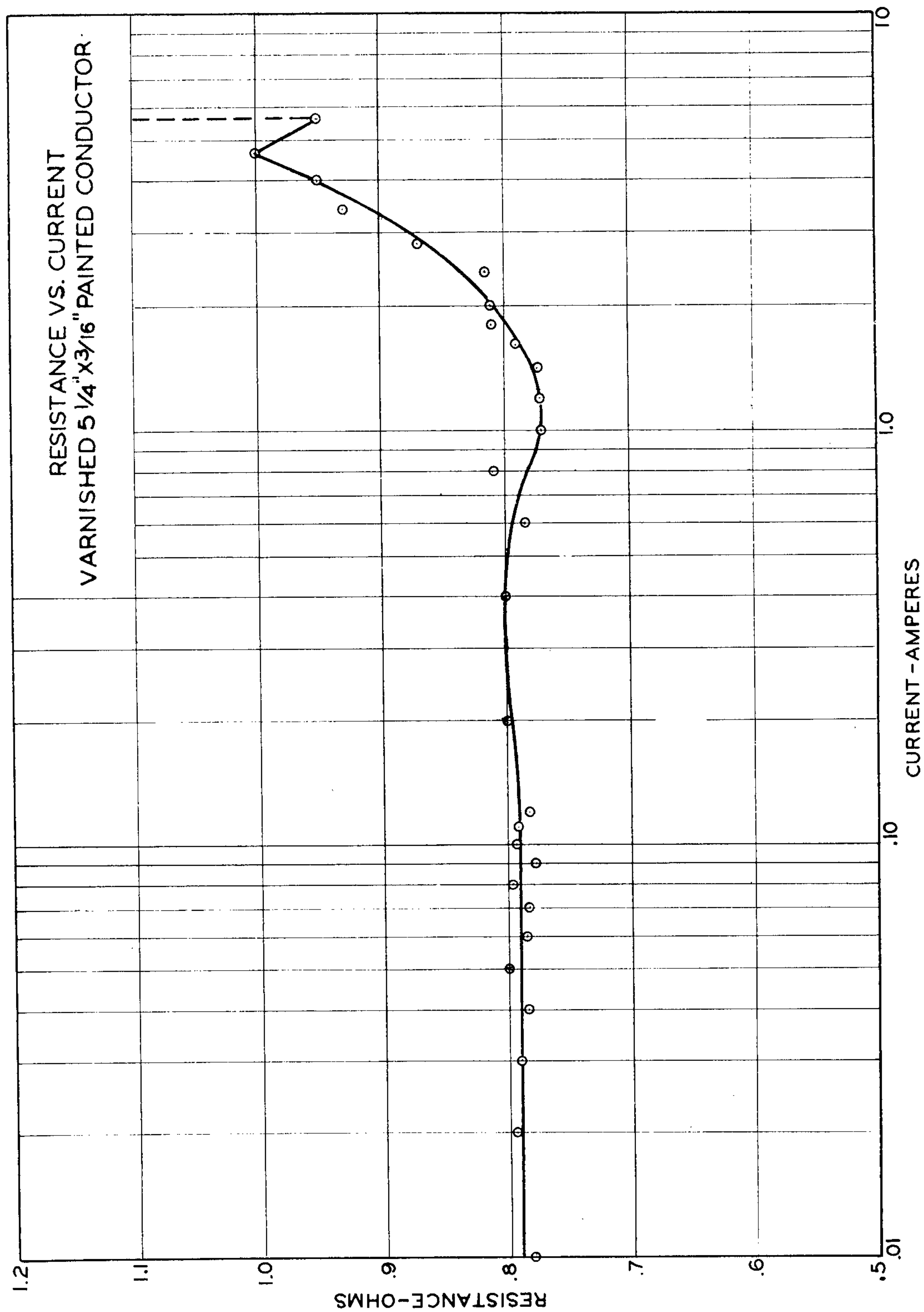
RESISTANCE VS. CURRENT
VARNISHED 5 1/4" X 3/16" PAINTED CONDUCTOR
RESISTANCE-OHMS
CURRENT-AMPERES
1.2
1.1
1.0
.9
.8
.7
.6
.5
.01
.10
1.0
10

Figure 4

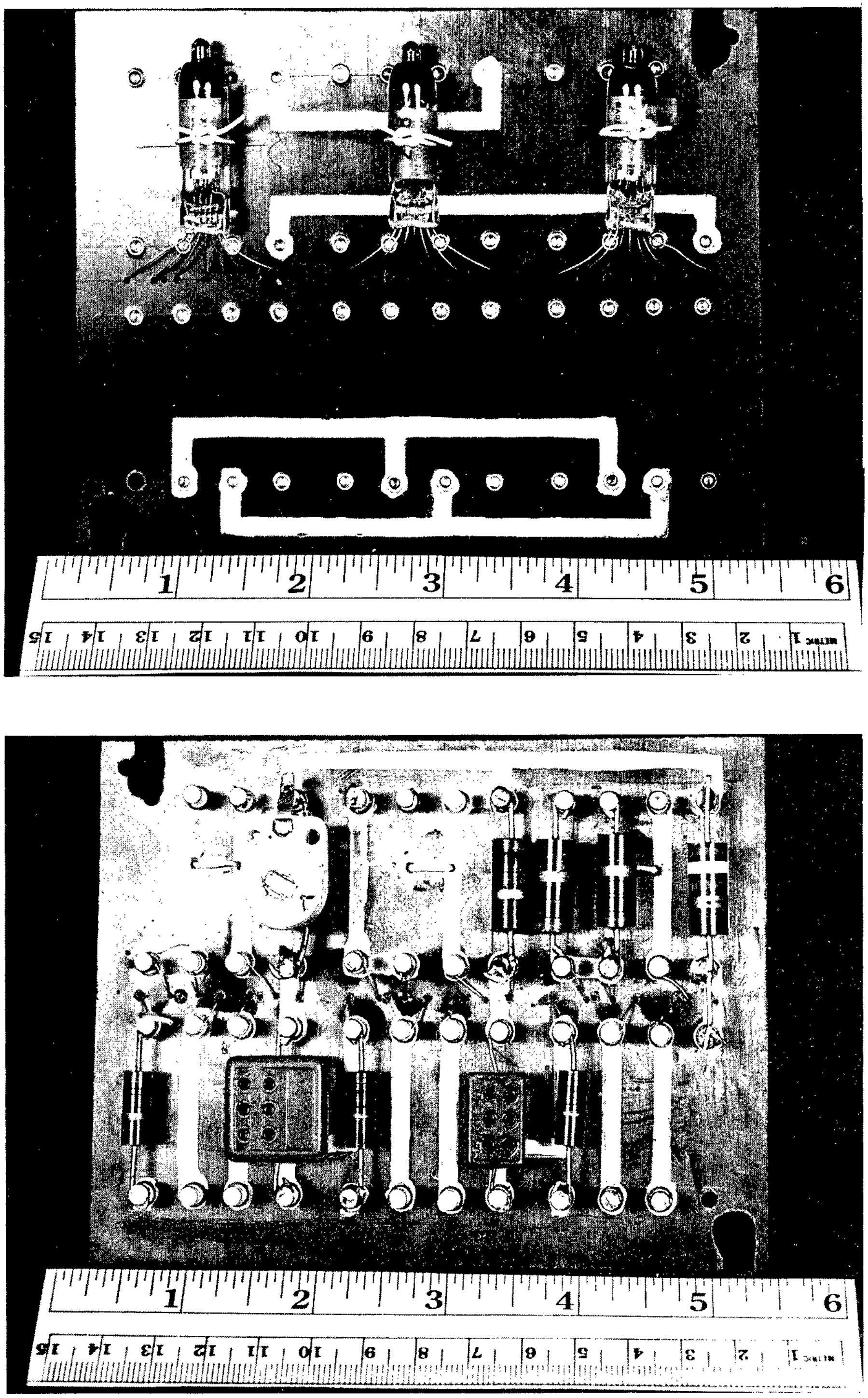

Figure 5

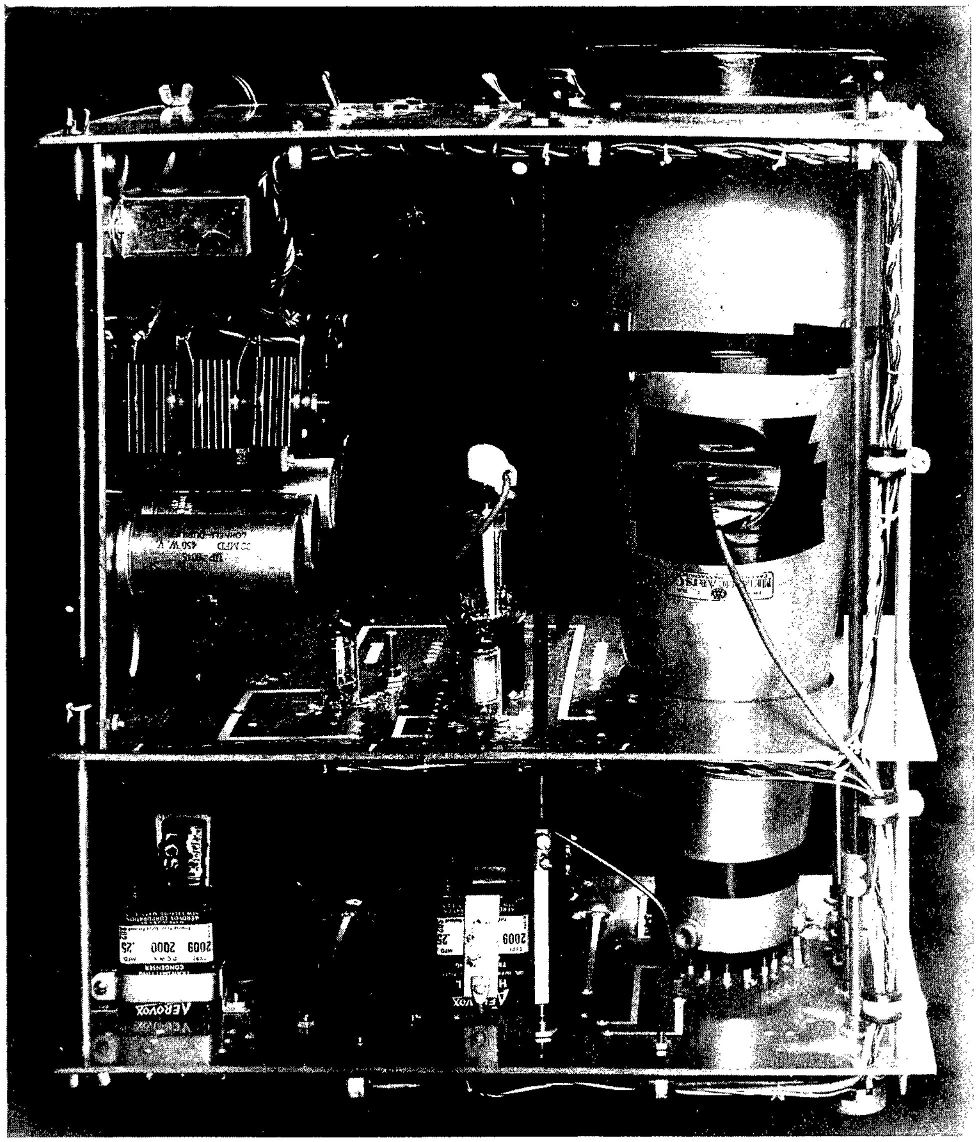

Figure 6

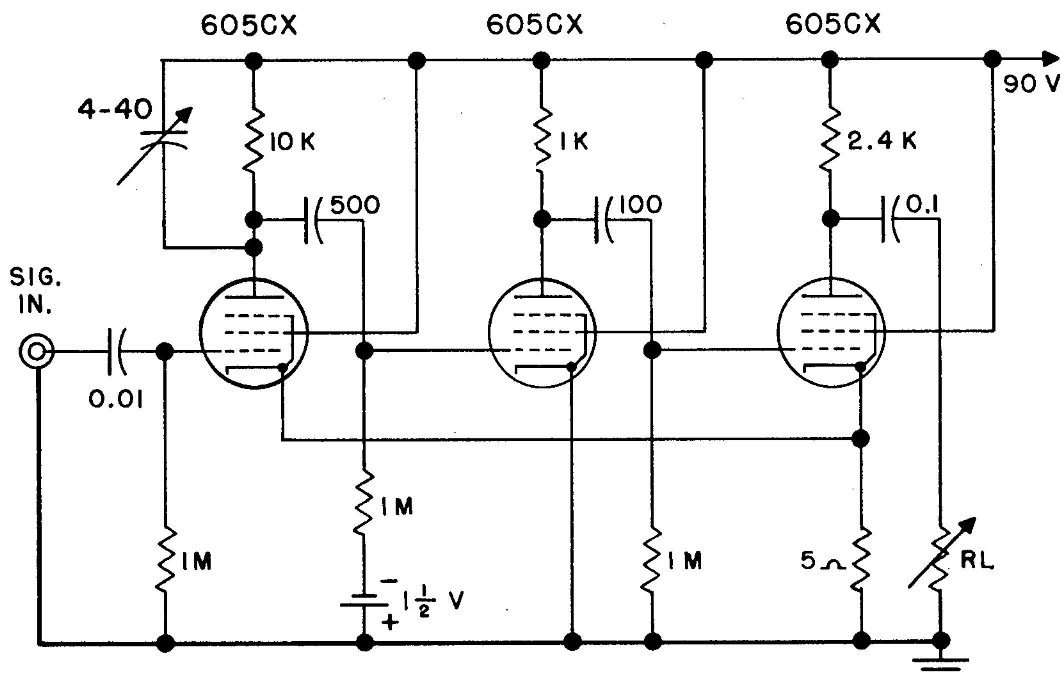
6O5CX
6O5CX
6O5CX
90 V
4-40
10 K
1 K
2.4 K
500
100
0.1
SIG.
IN.
0.01
1M
1M
1 1/2 V
1 M
5 Ω
RL

Figure 7

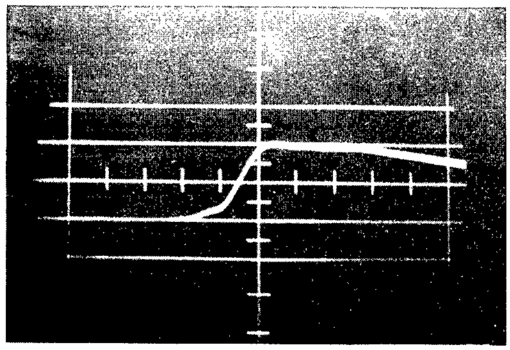

Figure 9

order to get the leading edge photographed. The low repetition rate was necessitated by the fact that the post acceleration voltage supply was used for the anode supply voltage of the Hydrogen Thyratron in the sweep circuit.

CONCLUSIONS

It is apparent from the foregoing that the method shows some promise and that printed circuits are applicable to the type of circuits used in the laboratory. No major obstacles were encountered and in all respects the printed wire circuits behaved as well as their conventional counterparts. It is concluded that printed wiring may have certain inherent advantages that will bear further study. These advantages may be enumerated as follows:

1. Reduction in cost of instruments.
2. Reduction in size and weight of instruments.
3. Improved stabilization of stray capacitances.
4. Improved ease of assembly.
5. Reduction in assembly time.
6. Ease of servicing is improved since units are more nearly identical. In this respect voltages may be printed at critical points.
7. Improved ruggedness for portable instruments.
8. Wiring mistakes cannot happen.
9. Circuits are more tamper proof since any change in wiring is easily detected.
10. Wire inventories may be reduced.
11. Better adaptation to tropicalizing.
12. Better adaptation to airborne pressurizing.

It was the experience that the sub-miniature pigtail lead tubes were better adapted to the process described. In this case no tube sockets need be drilled, the pigtails being simply passed through the bakelite plate and twisted around the appropriate lug.

ACKNOWLEDGEMENT

The author is indebted to Richard Hiebert for his assistance in testing the amplifiers and taking the pictures.

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