Build A TRANSISTOR

Experiments show that the average experimenter can construct a crystal amplifier from parts of 1N34's

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End plug at right holds the two catwhiskers.

SINCE the sensational announcement of the crystal triode, or transistor, several months ago, radio experimenters have been waiting impatiently for manufactured versions of this device. We have communicated with several manufacturers known or expected to be planning transistor production, but have obtained no commitments as to a date on which crystal triodes might be expected to appear on the market. In the meantime, a few brave souls have made simple experimental transistors for the prime purpose of doing a little advance playing with the gadget; most builders, however, have complained of electrical instability and lack of mechanical ruggedness.

The author has constructed several transistors employing various mechanical arrangements. Although the electrical behavior of some of the models was interesting and quite satisfactory, all suffered more or less from mechanical delicacy. In each case, the germanium wafer and the two S-shaped, pointed, tungsten whiskers required were obtained by disassembling two 1N34 crystal diodes. One whisker is obtained from each diode, and one germanium wafer is left over for experimentation. The 1N34 undoubtedly has been the source of parts for all home-made transistors built up to this time.

Without going into the theory of transistor operation in this article, we show the basic arrangement of a crystal triode as an amplifier in Fig. 1. An oscillator circuit also can be made by introducing feedback between the output and input portions of the triode circuit. From this drawing, it may be seen that the transistor is simply a two-whiskered crystal unit. The *emitter* whisker is biased with a low positive voltage and is comparable to the control grid of a triode tube. The *collector* whisker receives a much larger negative voltage from a B-battery and is comparable to the plate of a tube. The germanium wafer, commonly referred to as the *crystal,* is comparable to the cathode of a tube. In order to obtain transistor action (that is, to have the emitter voltage control the collector current in much the same fashion as the grid voltage of a tube controls the plate current), the two whiskers must touch the germanium surface firmly at points ex-

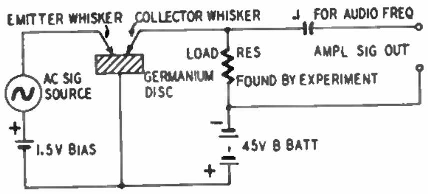

Fig. 1—This is a basic transistor amplifier.

tremely close to each other (.002-inch separation is the figure that has been published widely). The job of mounting the two whiskers as close together as this, so that their tips do not touch each other but still press down upon the germanium surface, is the formidable mechanical obstacle which most experimenters have found.

Recently, Ralph Jacobson, WØYEE, produced a mechanically rugged transistor for the author's experiments, using 1N34 parts. It is the novel, easily duplicated construction of this unit which is described here.

Construction

Fig. 2 is an exploded view, showing how the various parts of a 1N34 have been utilized in construction of the crystal triode.

The 1N34 consists of two threaded brass end plugs which are screwed into opposite ends of a small ceramic tube. The tungsten whisker is soldered to one of these plugs and rests upon the surface of the germanium wafer. The wafer is soldered to the end of a brass pin passed through a central hole in the other end plug and held by a setscrew. These parts are all shown, ready to go together, in Fig. 2. After adjustment at the factory, the ceramic tube is filled with wax. This wax has been injected through a hole in the side of the ceramic tube; this hole served previously for an access point through which the whisker could be moved about to various spots on the germanium surface during electrical adjustment.

After obtaining two 1N34's, the first step in the construction of the triode is carefully to pick out the sealing material which plugs the hole in the ceramic tube of each unit. This may be done with a needle, being cautious not to dig any deeper into the unit than the thickness of the ceramic wall. The next

Five simple tools used in making transistors.

step is slowly to melt out the wax by heating the entire unit. Hold it high over a low flame. Make no attempt to rush this operation. The wax will run out through the side hole. After the wax has been expelled, the tinned ferrules which hold the pigtails may be peeled off the end of each unit with the aid of diagonal cutters. This will expose the two brass end plugs which then may be unscrewed.

After removing the end plugs, unsolder the whiskers from their plugs and bathe them in carbon tetrachloride. The next step requires painstaking care: saw one of the whisker plugs vertically in half, using the thinnest obtainable jeweler's saw blade, to obtain the two separated halves shown as parts A and C in Fig. 2. Solder one whisker to each half. The tungsten wire is a little tricky to solder and may require acid soldering flux. If the latter is used, wash the finished job thoroughly in strong soapy water, give several rinsings in clear water, then dry the parts and bathe them in carbon tetrachloride. Next, using Duco cement, fasten the two halves of the split end together with an insulating separator (part B in Fig. 2) made from Lucite or Plexiglas 1/64 inch thick. Be careful to keep the threads of the split plug aligned. Then, with a needle, toothpick, or slender tweezers, bend the tips of the whiskers together until they have the smallest separation without actually touching each other. It will help to use both a magnifying glass and continuity meter in this operation.

Screw the two-whiskered plug back into one end of the ceramic tube, and the germanium-holding plug F into the other end. Using a magnifying glass (or the naked eye if yours is that good), look through the tube hole to see whether the whiskers are both in contact with the germanium surface and also whether threading in the germanium plug has twisted them. If the whiskers are twisted or are touching each other, separate them with a needle or toothpick inserted through the hole. If they are spread too far apart, push them closer together with the needle. If the whisker tips are not in contact with the germanium surface, loosen the setscrew in the germanium end plug and cautiously push the end of the germanium pin inward by means of a pin inserted into the center hole of the plug, until contact is made. Then retighten the setscrew.

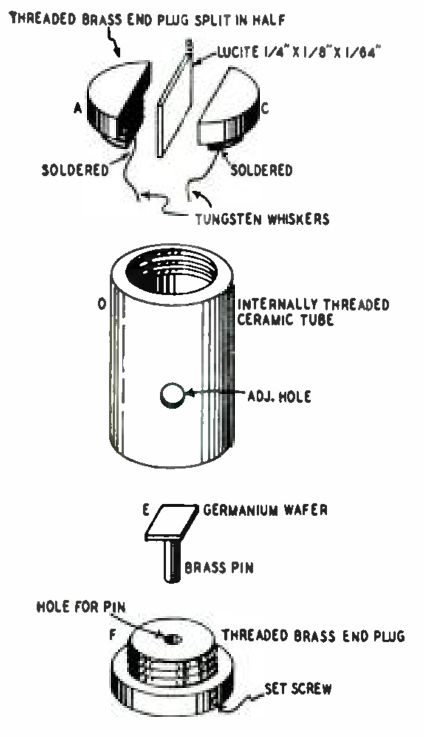

Fig. 2—Exploded view shows transistor parts.

The final step is to solder a wire pigtail lead to each half of the split whisker plug (A and C in Fig. 2) and also to the germanium plug F. The soldering operation must be completed quickly in order not to melt the solder holding the whiskers or damage the germanium wafer.

Throughout the construction, take care not to handle the germanium wafer or the whiskers with the fingers any more than is absolutely necessary. If there has been excessive handling, both the whiskers and the germanium wafer should be bathed in carbon tetrachloride or lacquer thinner.

Fig. 3 shows how the completed transistor assembly appears in cross section. Letter symbols are the same as those in Fig. 2. The photographs also show constructional details.

Adjustment

After the unit has been assembled, set up the test circuit shown in Fig. 4, and test the crystal triode according to the following procedure. Either half of the split end plug may be chosen as emitter or collector.

1. With switch S2 open, close switch S1. The emitter current, read with milliammeter M1, should not exceed 20 ma and undoubtedly will be in that neighborhood at the outset.

(The 20-ma emitter current is very much greater than the figures commonly published. These range from a fraction of a milliampere to 1 or 2 ma. Transistors made by different experimenters vary widely for reasons still unknown. The performance of transistors made by readers therefore may be entirely different from that of the one described here; the difference should be no cause for discouragement or alarm but should, instead, prove to be a strong incentive for experimentation.—*Editor*)

2. Open S1 and close S2. The collector current, read with milliammeter M2, should not exceed 0.5 ma.

3. If emitter or collector current is in excess of the values given, reverse the emitter and collector terminals and repeat steps 1 and 2. If the currents still are excessive, unscrew the germanium end plug, loosen the setscrew, and rotate the germanium pin to expose new surface points to the whiskers. Reinsert the end plug, respace the whiskers if necessary, and repeat the tests.

4. When approximately correct emitter and collector currents are obtained, label the emitter and collector terminals by marking the whisker end of the ceramic tube.

Check the transconductance of the triode in this manner:

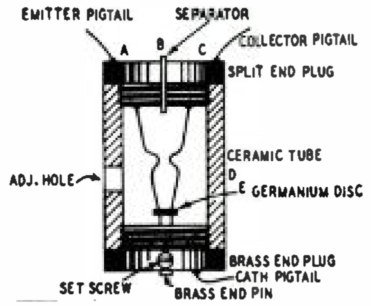

Fig. 3—Cross-section of finished transistor.

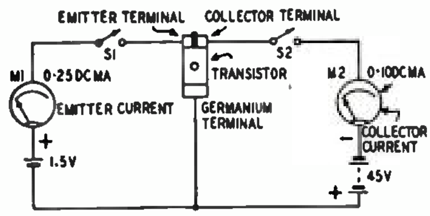

Fig. 4—Test circuit reveals characteristics.

1. Close switch S2 and record the reading of milliammeter M2 as I1.

2. Leaving S2 closed, close S1, noting the new reading of milliammeter M2. Record this second M2 deflection as I2.

3. The transconductance in micromhos is

$$\frac{1{,}000\,(I_2 - I_1)}{1.5}$$

The builder should aim for the highest transconductance he can obtain with a given germanium wafer. Magazine articles have reported transconductances as high as 15,000 micromhos. The author has found that transconductances of 1,000 to 3,000 (comparable to such tubes as the 6J5, 6SQ7, 6T7, etc.) may be obtained readily with little or no adjustment on a transistor of the type described in this article. Rotating the germanium wafer to expose better spots to the two whiskers has yielded transconductances a little higher than 5,000, but the author has not exceeded that figure.

After all adjustments are completed, the side hole in the ceramic tube should be closed with a small piece of Scotch tape. We do not recommend filling the interior of the unit with any of the waxes ordinarily available to the home experimenter.

Some question is apt to arise as to capacitance between the two halves of the split whisker plug. The author checked this and found it to be 2.45 $\mu\mu f$ in his unit at a test frequency of 1 mc. This is comparable to the grid-plate capacitance in a corresponding triode tube, smaller, in fact, than in such triodes as 6J5, 6SL7, 6SN7, etc. It should cause no trouble.