Vol. 23 MAY - JUNE, 1958 No. 5

CORNELL-DUBILIER ELECTRIC CORP.
Hamilton Boulevard, South Plainfield, N. J.

POSTMASTER: If undeliverable for any reason, notify stating reason, on Form 3547 postage for which is guaranteed.

Sec. 34.66 P.L.&R.
U. S. POSTAGE
PAID
So. Plainfield, N. J.
Permit No. 1

FRANK EAMES
5 RICHARDSON AVE.
ATTLEBORO, MASS.

SERVICING TRANSISTOR RADIOS

Tranistorized radio receivers now are well established in the field. Several set manufacturers offer portable or personal receivers. By this time, some of the early models have received up to three years of use. Several home-type midget receivers are commercially available ready-made or as kits for private assembly. In addition, fully-transistorized auto radios are in use, as are also hybrid types (tubes in the low-level stages and power transistors in the audio output stage). At least one transistorized short-wave converter is on the market.

The consumer public is catching on to the advantages of transistorized operation: Instant service, small size and light weight, absence of heat, no power-line connections, long life with inexpensive batteries, freedom from hum and microphonics, and mechanical ruggedness. In transistorized auto radios, there are the additional advantages of direct operation from the car battery without vibrators, lower current drain than with tube-type sets, and longer periods of trouble-free operation.

The service technician may expect soon to be called upon to repair or adjust these sets. It is timely, therefore, to take note at this writing of the differences between tube and transistor sets and to outline the methods of servicing these new receivers.

Small Size Factor

One of the very first points to note is the size factor. The transistor is a subminiature component, and new types are being made progressively smaller. An impressive line of subminiature and sub-subminiature components have been developed to go along with transistors. These units include fixed capacitors, variable capacitors, transformers, coils, resistors, potentiometers, loudspeakers, crystal diodes, batteries, switches, and loop antennas. Designers have been quick to exploit the tininess of these components and to produce the first really practical miniature receivers. Getting in and around the circuitry and mechanism of these small sets requires tools less bulky than some of the smallest ones ordinarily used in working on conventional tube sets.

The technician will find that he can work better with the following pieces of equipment which may be foreign to his present tool box: Tweezers, forceps, fine-pointed soldering pencil, needle-nose pliers, midget diagonal cutters, scriber, set of jeweler's screwdrivers, set of needle-point files, and miniature insulated alignment tools. A jeweler's loupe also is recommended.

Since the small transistorized sets employ printed circuitry, any skill the technician may have acquired in working with printed circuit boards will be to his advantage.

Troubleshooting

Functionally, troubleshooting in a transistorized receiver does not differ from that in a tube set. However, the transistor and its circuits have some peculiarities which will modify test procedures to some extent.

To begin with, the transistor is a resistive device. Its input is a resistance, and so is its output and also the internal path between output and input. A tube has input and output resistance components too but they disappear when the power is shut off. In a tube circuit, many continuity tests can be made if the operating voltages first are switched off. Not so in a transistor circuit — the resistance path remains and, in addition, is unilateral. In some transistor circuits, it is impossible to make a

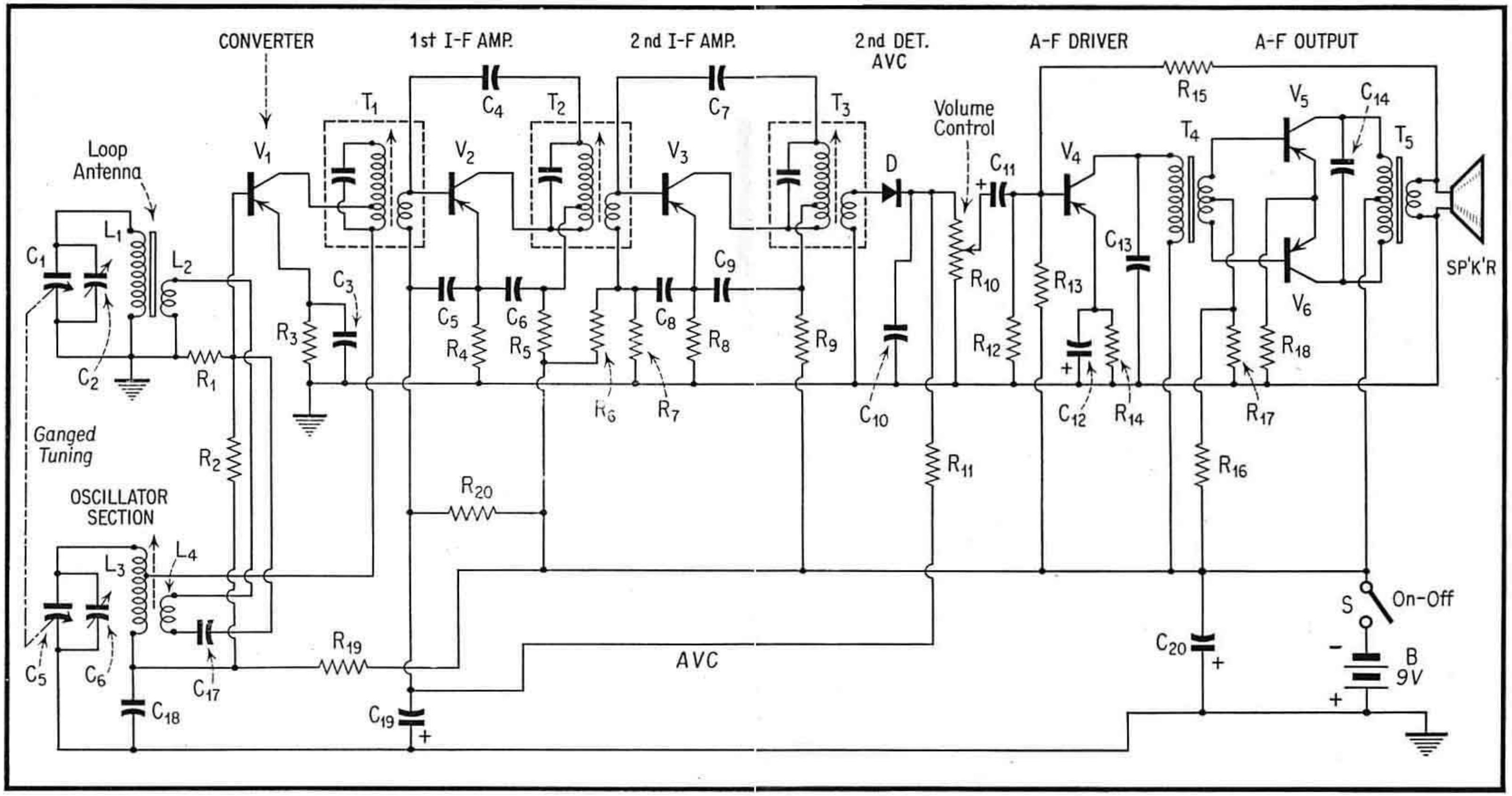

Fig. 1. Typical Transistorized Superheterodyne Receiver.

continuity test without removing the transistors completely. In some instances, the transistor might even be damaged by current from the ohmeter.

Figure 1 shows a transistorized superheterodyne circuit of the type used in many receivers. The stage functions are the same as in a tube receiver. Transistor V_1 is the combined oscillator and mixer, V_2 the 1st i-f amplifier, V_3 the 2nd i-f amplifier, diode D the 2nd detector and avc rectifier, V_4 the a-f driver, and V_5-V_6 the pushpull Class-B a-f output amplifier. Signal pickup is provided by a high-Q ferriterod antenna of which L_1 is the antenna winding and L_2 a smaller, inductively-coupled secondary to match the low input impedance (of the order of 1000 ohms) of the converter transistor, V_1. Inductor L_3 is the oscillator coil which has an r-f output winding, L_4.

The transistors are connected in the common-emitter configuration; that is, base-input and emitter-grounded. This is roughly equivalent to the well-known grounded-cathode tube. The base electrode of the transistor is equivalent, in this application, to the grid of the tube, the emitter to the cathode, and the collector to the plate.

The i-f and a-f transformers have a stepdown ratio for matching the collector impedance of one stage to the lower base impedance of the following stage. This is an important point to remember when tracing a signal voltage through the transistorized receiver, since a voltage stepdown normally will be observed between the output of one stage and the input of the next. Thus, circuit points which the technician customarily has recognized as high-impedance in tube circuits (such as the grid input) are low-impedance in the equivalent transistor circuit. This is reasonable when it is considered that the transistor is a current-operated device and its basic function is to provide power amplification (although it secondarily provides voltage amplification), while the vacuum tube is a voltage-operated device. The oscillator coil also has a stepdown ratio between L_3 and L_4.

The tube is not affected severely by temperature changes, while the transistor is. Also, tubes may be interchanged with others of the same type without drastically upsetting the operation of most circuits, while this is not universally true with transistors. Fortunately, shift of the d-c operating point with temperature and as the result of transistor replacement may be minimized by stabilizing the operating point with stiff voltage dividers. Thus, the d-c base voltage and the d-c operating points are stabilized in the circuit in Figure 1 by voltage dividers R_1-R_2, R_6-R_7, R_{12}-R_{13}, and R_{16}-R_{17}, and by emitter resistors R_3, R_4, R_8, R_{14}, and R_{18}. These latter resistors are equivalent roughly to the cathode resistor in a tube circuit. The presence between base and ground of one resistor of the voltage divider clearly would make impossible the checking of the transistor input resistance. For example, voltage-divider resistor R_{12} shunts the input of transistor V_4.

Another important point of difference, imperative to remember in troubleshooting, is the polarity of the d-c operating voltage when PNP transistors are used as in Figure 1. That is, the output (collector) voltage is negative with respect to ground, while the technician has habitually seen the output (plate) of tube circuits as positive. The polarity of electrolytic capacitors in the circuit therefore appears to be backward. (See C_{11}, C_{12}, C_{19}, and C_{20} in Figure 1.) When NPN transistors are employed, the polarity of d-c voltages and capacitors is reversed and becomes the same as in tube circuits.

The i-f amplifier stages are neutralized, by means of fixed capacitors C_4 and C_7, to prevent self-oscillation. This feature is not found in tube circuits for the reason that screen-grid tubes are employed. The transistors, being triodes, have no such screening electrode and are subject to oscillation in high-gain circuits of this type.

The volume control potentiometer, R_{10}, must be dc-isolated from the base of transistor V_4, otherwise it will change the d-c bias of this transistor as the potentiometer resistance is varied to change the volume. Capacitor C_{11} provides this isolation; but, since this capacitance must be high to pass low audio frequencies into the low-impedance V_4 input circuit, C_{11} is an electrolytic.

The foregoing are the important respects in which the transistor circuit differs from a tube-type superhet. In other particulars, the two circuits are reasonably similar. The differences require certain modifications of approach in troubleshooting procedures, as detailed in the following discussion.

Basic Test Procedure. Good transistors have long life, are mechanically rugged, and usually are not the cause of trouble in well-designed receivers. A bad transistor, such as one in which collector current drifts upward, can cause trouble. Since transistors operate at low d-c voltages, the resistors associated with them seldom burn out. Most of the time when a set has acted up, the trouble will be found in a worn or disconnected battery, broken connections, an open circuit in one of the a-f or i-f transformers or volume control (these tiny components being wound with very fine wire which has small current-carrying capacity), or in damaged subminiature electrolytic capacitors which have been operated too close to their maximum d-c working voltage and have had to withstand peak signal voltages as well.

As in checking tube sets, a quick visual inspection first should be made to spot obvious troubles such as a disconnected battery, loose or mechanically-damaged components, and broken printed circuitry. These defects should be corrected immediately and sometimes are the only trouble present. Next, the battery voltage should be measured under full load. Since there might be a short circuit in the receiver, it is best to remove the battery and make the voltage test with a load resistor connected in parallel. Select the resistance such that the current drain is 30 to 50 ma and replace the battery if its voltage has dropped below 65% of rated value.

When checking a tube set, the next step customarily would be to test all the tubes, replacing any defective ones. There are two reasons for not following this procedure in transistor circuits. The first is that transistors are most often not defective. The second is that the transistor must be removed from the circuit for testing and may be damaged by the heat of the soldering iron. Hence, it is better not to unsolder their pigtails unless all evidence from other electrical tests points toward transistor trouble. If the battery is good, a test signal should be injected at various circuit points, starting with the speaker and working back to the antenna, to determine which portion of the circuit is inoperative. When the first faulty stage is located, d-c voltage tests then may be made to isolate the possible cause of the trouble. In all testing of the receiver, leave the speaker connected to the circuit or, if a quiet test must be made, substitute an equivalent load resistor.

Signal Injection. This test operation is carried on in the conventional manner. Use an r-f signal generator as the source of r-f and i-f test signals, and an audio generator for af. Many service-type r-f oscillators have a 400-cycle output which will supply the audio signal. It is important to re-

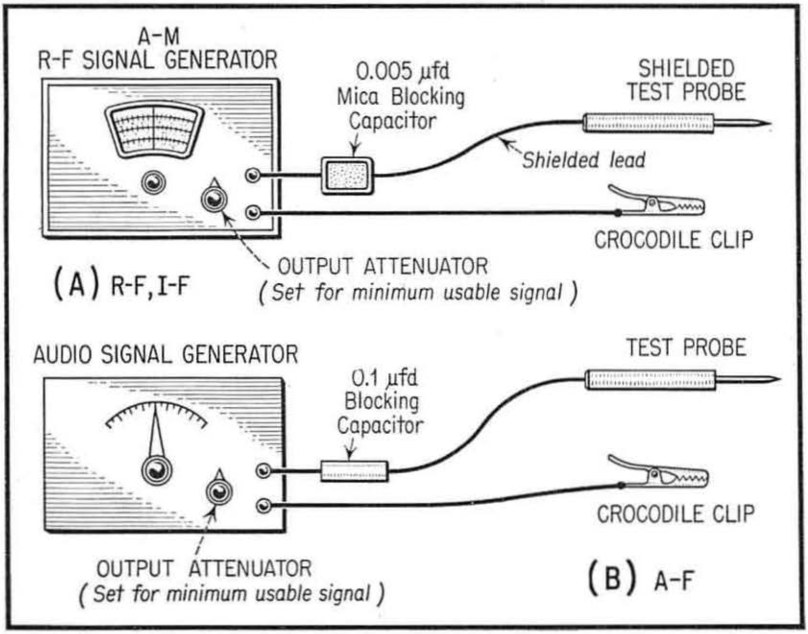

Fig. 2. Signal-Injection Instruments.

member that the injection points in a transistorized circuit have lower impedance than comparable points in an equivalent tube circuit, and the attenuators of the signal generators may need to be set higher. At all points, however, unless advised otherwise in the test instructions, use the minimum signal amplitude for a clearly audible signal. This will prevent overloading.

The output circuit of the generator must contain a blocking capacitor. If such a capacitor is not present, the output attenuator of the instrument will short-circuit the transistor circuit. Thus, if a non-blocked generator were connected between ground and the top of the secondary of i-f transformer T_2 to inject a signal into the 2nd i-f stage, the output attenuator would short-circuit the secondary and also resistor R_7. Shunting R_7 in this fashion would shift the d-c base bias and operating point of transistor V_3. Figure 2 shows how the generators should be arranged for signal injection.

In Figure 1, the a-f signal would be injected first between ground and the top of the secondary of T_5. If the signal is heard in the speaker, inject the a-f signal next between ground and the top of the primary of T_4. This will check T_4, T_5, and the Class-B output stage. If the signal is still heard, inject between ground and the top of C_{10} to check volume control R_{10}, coupling capacitor C_{11}, and the a-f driver stage. If signal still is present, inject a 455-kc (or other i-f) amplitude-modulated signal between ground and the top of the T_3 primary to check T_3 (condition and alignment) and diode D. If signal still is present, inject the a-m i-f signal between ground and the top of the primary of T_1 to check the entire i-f amplifier. If the signal still is present, an r-f test signal (amplitude - modulated) should be injected at the antenna to check operation of the converter stage. Figure 3 shows how a miniature, transistor-type loopstick antenna may be connected to an a-m r-f signal generator for inductively coupling the signal into the loopstick antenna of the receiver. Place the test loopstick close to the receiver antenna and set the at-

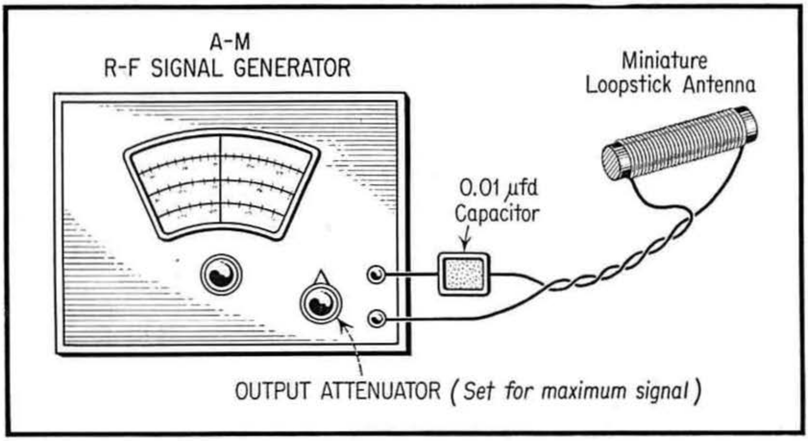

Fig. 3. Setup for Inductive Coupling of R-F Test Signal.

tenuator of the generator for maximum signal amplitude. Tune the receiver and generator to the same carrier frequency.

Loss of the signal at any of the foregoing test points may indicate either a faulty transistor or diode, a defective circuit component, incorrect d-c voltages, or misalignment of the i-f or converter stages. The i-f transformers are slug-tuned, the mixer stage is aligned by means of trimmer capacitor C_2, and the oscillator is trimmed by C_{16} and the tuning slug of oscillator coil L_3.

Signal Tracing. Some technicians prefer signal tracing to signal injection, although each of the two methods achieves the same end result. In signal tracing, use the amplitude-modulated r-f signal generator setup shown in Figure 3 to couple the test signal inductively into the receiver. Then employ a sensitive a-c vtvm to trace the signal through the various stages in the conventional manner, working from the antenna through to the loudspeaker. At all test points between the antenna and the input to diode D, an r-f probe must be provided for the vtvm unless the frequency response of this instrument extends to about 2 Mc. From the output of diode D to the loudspeaker, the r-f probe (or high frequency response) is not required. When the test signal is found at the input of the converter stage but does not pass into the i-f amplifier, the oscillator stage probably is not operating. To check the oscillator, connect the r-f vtvm between ground and the stator terminal of tuning capacitor C_{15}. An r-f voltage will be detected if the oscillator is functioning and will be fairly constant over the tuning range.

Checking D-C Voltages. When a faulty stage is located by means of either signal injection or signal tracing and (in r-f, oscillator, and i-f stages) the trouble is found not to be caused by misalignment, check the d-c voltages wih a d-c vtvm. If a voltage is absent or if it differs markedly from the set manufacturer's test data, an examination of the circuit diagram usually will give a clue as to which component might be faulty.

In each stage, the emitter-to-ground voltage of the transistor should be closely equal to the base-to-ground voltage. Collector voltages will be somewhat lower than the voltage of battery B. The collector voltage of the Class-B a-f output stage will swing between a zero-signal value close to the battery voltage, and a low, maximum-signal value. The correct values of all the d-c voltages should be ascertained from the set manufacturer's service literature. AVC voltage may be measured between ground and the cathode of capacitor C_{19}.

Since the resistors and transistors seldom are the cause of trouble, the absence of voltage often is due to an open transformer winding. Incorrect voltage usually is apt to be caused by the shunting effect of a short-circuited or extremely leaky electrolytic capacitor, such as C_{11}, C_{12}, C_{19}, or C_{20}.

Continuity and Leakage Testing. Continuity testing, in the conventional manner, is virtually impossible in the transistor circuit because of the ever-present resistance paths provided by the transistors themselves. When a transformer is suspected of open circuit, a resistor or changed value, a capacitor of high leakage, or a diode of poor front-to-back ratio, at least one lead of that component must be unsoldered from the circuit before an ohmmeter check can be made.

Even when the component is removed from the circuit a d-c continuity test of an a-f or i-f transformer is inconclusive except when an open-circuited winding is found. A conventional a-c signal test also should be made to ascertain that the transformer is operating correctly and that its windings are not short-circuited at least partially.

Current Measurement. In some instances, it may be desirable or even necessary to measure direct current levels in the circuit. In printed circuitry, it is not easy to open a line for the insertion of a milliammeter for this purpose. The only practical method in such a case is to unsolder one lead of a component in the line and to insert the meter in series.

Currents should be measured under both zero-signal and maximum-signal conditions. A milliammeter inserted in one of the battery leads will indicate the total drain of the set, which for a circuit of the type shown in Figure 1 will be approximately 10 ma zero-signal and 36 to 40 ma maximum-signal. In a receiver having a single-ended Class-A output amplifier, this large current swing is not present. When the meter is inserted in the center-tap line of transformer T_5, the Class-B (V_5-V_6) collector current alone is indicated. This current has a zero-signal value of approximately 1 to 2 ma and a maximum-signal value of 20 to 25 ma in a receiver having a power output of 100 to 125 milliwatts. In a Class-A output amplifier, such as found in some of the headphone-type transistor receivers, the collector current is of the order of 10 to 25 ma and should be steady under both zero-signal and maximum-signal conditions.

Audio Distortion. Because of the small size of the loudspeakers in transistorized receivers, sound reproduction is these sets does not have the wider range and higher fidelity afforded by larger reproducers. Furthermore, harmonic distortion sometimes tends to run slightly higher in transistorized audio power amplifiers than in tube amplifiers having the same power output.

Precautions are taken in the circuit design to keep this distortion low. For example, in Figure 1, negative feedback is provided through resistor R_{15}. The common emitter resistor, R_{18}, is left unbypassed for further degeneration. Also, the d-c base bias provided by the voltage divider, R_{16}-R_{17}, minimizes crossover distortion which otherwise might be severe in the Class-B stage. A further advantage is obtained through the matching of transistors V_5 and V_6.

When distortion appears to be excessive, the technician should check transistors V_5 and V_6 for matching of collector current, i_{cbo}, and beta. An oscilloscopic examination of the output-voltage waveform will show up crossover distortion and point up trouble in the R_{16}-R_{17} network. The feedback resistor, R_{15}, also should be checked for resistance and for connection in the circuit. Finally, the loudspeaker should be inspected for loose parts or rubbing voice coil and replaced if defective.

Special Precautions. When high-frequency r-f transistors (such as surface-barrier types) are employed, as in transistorized short-wave converters, keep the r-f test-signal amplitude low. Do not use a power-type test oscillator. Extremely thin wires are used inside these transistors and they can be fused open by strong r-f currents.

A few transistorized receivers employ reflex circuits. Due to the peculiarities of this type of circuit, the volume never can be reduced completely to zero. This is a normal condition for such sets and does not indicate trouble. In some reflex circuits, there is a tendency, also unavoidable, toward slight oscillation at the high-frequency end of the tuning range. This gives rise to faint "birdies" on the station carriers in the upper quarter of the dial.

When making an on-the-air check of a receiver operated from its self-contained antenna, remember that most of these antennas are very directional. Unless the antenna itself is rotatable, the entire set must be turned horizontally for maximum pickup. Strong stations sometimes can be nulled out completely within a very small arc of rotation. This effect is especially pronounced when the stations are located at some distance. A set might give every indication of being dead until it is turned around a few inches.

Testing Transistors. If after performing signal and voltage tests, transistor trouble is suspected, the transistor in question must be removed from the circuit and tested. Removal requires the utmost care to protect the transistor and the printed circuit from heat damage. (Some sets have subminiature sockets to hold the transistors and thus offer no problem, but in most sets the transistors are soldered in). Use a pointed-tip soldering pencil. Hold the transistor pigtail with long-nose pliers which serve to remove the heat. Continue to hold until the pigtail has cooled. Work as rapidly as possible.

After the transistor is removed, check it in a transistor tester. If a tester is not available, use the circuits shown in Figure 4. Use 4(A) first and then 4(B). The setup shown in Figure 4(A) checks leakage current and drift: Close switch S and note the reading of milliammeter M. This deflection shows the static leakage current, i_{cbo}, which should have a value of less than 0.125 ma in a good transistor. (See transistor manufacturer's literature for rated value). This current increases with temperature. Keep the switch closed for a few minutes, observing if the current creeps or jumps. Creepers should be replaced.

If the transistor passes the first

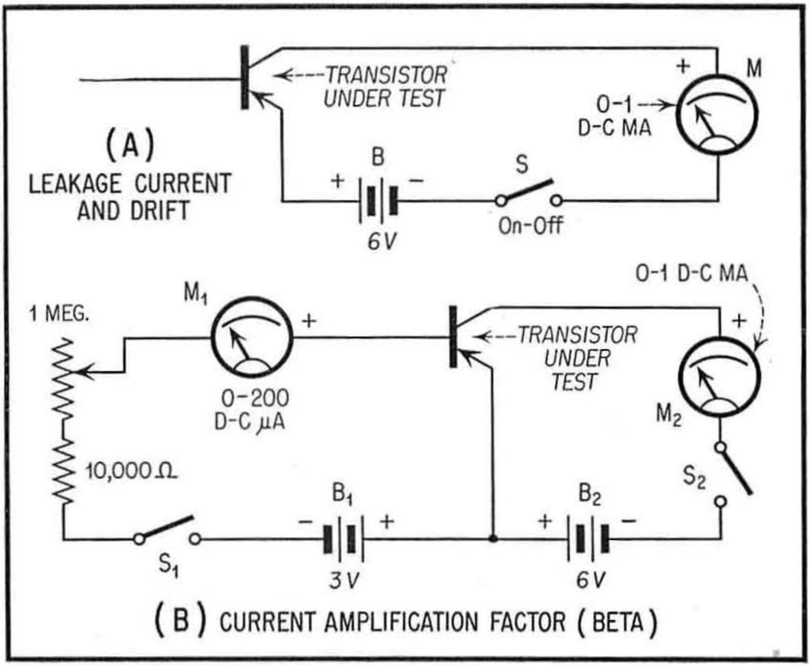

Fig. 4. Transistor Test Circuits.

test, connect it in the circuit shown in Figure 4(B). This circuit tests the current amplification factor, beta. First close switch S_2 and record the deflection of milliammeter M_2 as I_1 (in ma). Then, keeping switch S_2 closed, close switch S_1, noting that the deflection of M_2 increases. Record the new reading of M_2 as I_2 (in ma). Record the reading of microammeter M_1 as I_3 (also in ma). Calculate the value of beta from: $(I_2—I_1)/I_3$. The correct value may be obtained from the transistor manufacturer's literature. Beta is between 10 and 50 for small transistors. Replace the transistor if beta has fallen to 70% or less of rated value.

The current values will be much higher for power transistors such as are used in the audio output stage of a transistorized auto radio. Leakage current measured in the test circuit in Figure 4(A) may be of the order of 1 ma. In the test circuit of Figure 4(B), M_1 should be a 0-1 d-c milliammeter, and M_2 a 0-1 d-c ammeter. In the beta test, the collector current will increase to a value of 500 ma or higher.

Polarities in the test circuits as shown for PNP transistors. When testing NPN transistors, reverse each battery and meter.

Repairing

It was stated earlier in this article that certain small-sized tools will be advantageous in the repairing of transistorized radios. The technician will find that he can augment the suggested list with still other tools and gadgets which will make it easier for him to work with the small components and compact circuitry in the close spaces of these receivers.

A small, pointed-tip soldering pencil is superior to a soldering gun for work in printed circuits because of the former's more even heat. A 25-watt pencil is about right. Too much heat is damaging both to the printed wiring and to the transistors.

When replacing transistors, use the pigtail holding scheme described in the previous section and do the job as rapidly as possible. Always replace transistors with identical types. In the pushpull Class-B stage, the transistors may be matched for minimum distortion and should be replaced only with such a matched pair. When replacing power transistors, be careful to replace correctly all insulating washers and heat-sink parts. Power transistors must be bolted solidly to the chassis or heat sink.

In receivers employing PNP transistors, the polarities are apt to be confusing to the technician who is accustomed to tube circuits — positives and negatives seem to be interchanged. Thus, electrolytic capacitors have their cathodes grounded in tube circuits while in the transistor circuit (Figure 1) replace C_{12}, C_{19}, and C_{20} with their anodes grounded. The polarity of C_{11} also is important. To prevent malfunctioning or even burnout, be careful of the polarity of the battery, all transistors, all replaced electrolytics, and diodes.

Transformer polarities also are important. When making replacements, follow the lead color coding of the original unit or oscillation may result. If the secondary of T_5 in Figure 1, for example, is reversed, the feedback through R_{15} will be regenerative instead of degenerative, and the audio amplifier will oscillate. If one of the i-f transformers is reversed, capacitors C_4 and C_7 no longer will provide neutralization and the i-f amplifier will oscillate.

When replacing a volume control, use a potentiometer identical with the original. Some sets employ a special transistor taper which provides even control of volume over the entire rotation. If this taper is not duplicated in the replacement, the control action will be "hair-trigger" near the low end.