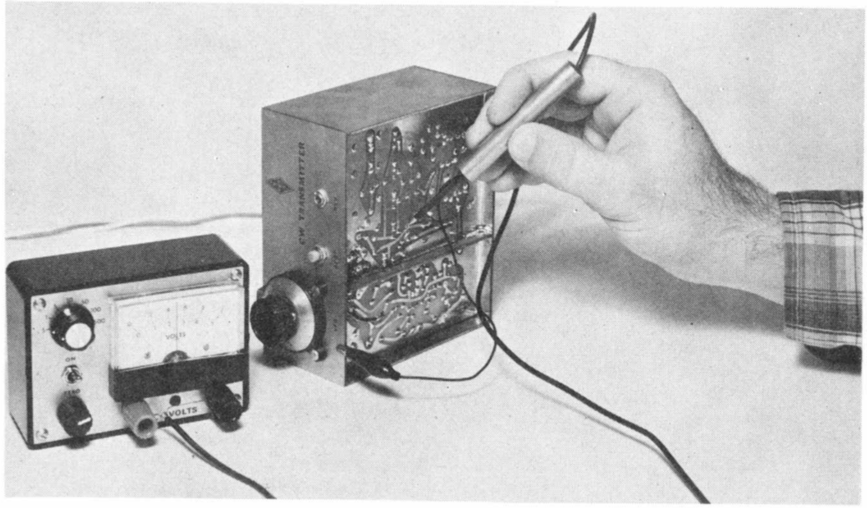
BEGINNER'S BENCH

Some Basics for Equipment Servicing



Part 3: Using the proper techniques can speed equipment servicing. The methods are easy, and you can build the test gear!

By George Collins,* KC1V

In Parts 1 and 2 of this series, we presented the basic troubleshooting methods of dc voltage and resistance measurement, and semiconductor testing. These are very effective techniques for determining which component in a particular circuit has failed. If the symptoms of the problem provide us with enough information to locate the trouble area, a check of a few dc voltages may be all that is needed to pinpoint the problem. Unfortunately, we will often face situations in which the symptoms alone are not sufficient to locate the trouble area. This month we will look at some additional methods the amateur can use to make service work less difficult and not so time consuming.

Signal Tracing

Fig. 1 is the block diagram of a typical amateur receiver. If the receiver "dies," what do we do? First, see if the symptoms indicate where the problem is located: when the receiver is turned on, we hear the normal hiss from the speaker, but do not hear any signals as we tune across the band (the antenna is connected!) Applying a strong signal to the antenna input also results in nothing but hiss. So far, all we have learned is that it is likely that the audio stages and power supply are functioning. Noting that there is no S-meter indication when we tune across the frequency of the input signal, we can conclude that the signal is not reaching the agc or detector circuits. We have been able, tentatively, to eliminate four or five stages, leaving us with nine more possibilities!

At this time we could begin measuring the dc potentials at various points in each stage. While this approach should eventually lead us to the defective stage, it could be a time-consuming process. If we can reduce the number of possible stages to one or two, we should have the receiver back in working order much more rapidly. One way we can do this is by *tracing* a signal through the receiver. The general technique is to apply a signal to the input of the unit, and then check for the presence of the signal at the input and output of each stage. When we find a stage with input but no output, chances are we have found the problem area.

Equipment

Before we can begin signal tracing, we must have a signal source of appropriate strength and frequency. A tunable signal generator with adjustable output is ideal, but simple, low-cost substitutes will serve as well. A crystal oscillator, which we will look at later, makes a good signal source for this type of work.

A second requirement is that we have some means of detecting the signal. A high-frequency oscilloscope is an excellent instrument for this application and many others. The drawback is that a good oscilloscope is expensive. An alternative to the oscilloscope is a VTVM or FET voltmeter equipped with an rf probe. The FET voltmeter and probe shown in Part 2[1] (or any similar unit) will be more than adequate for basic signal tracing. With the necessary test equipment at hand, we can begin to track down the cause of the receiver problem.

The signal applied to the receiver input should be no greater than necessary to produce a reading on the voltmeter. Most meters will show a satisfactory reading with a 0.1-V rms signal. This is a strong signal (about 60 dB over S9), but it will not harm the receiver. Avoid input signal levels greater than 0.5 V rms, because

*Assistant Technical Editor

[1]Notes appear on page 44.

some receivers could be damaged at that level. The characteristics of the diode used in the rf probe limit the accuracy at these low (less than 0.5-V) signal levels. This need not concern us, since we are looking for relative signal levels and not specific voltages. The exact voltages will depend on the circuit impedance and the type of stage being tested.

With a 0.1-V signal applied to the receiver, we can begin tracing the signal by first checking the voltages at the preselector network input and output. These voltages may be the same, but in general the preselector output voltage will be higher than the input (the preselector may be providing an impedance step up).

Next, we move to the rf (radio frequency) amplifier output. Normally this stage will show some voltage gain (output voltage is greater than the input). If the signal is still present, we can assume that the amplifier is functioning and proceed to the next stage, the first mixer. This stage, as the name implies, mixes two input signals to produce the output signal. In this case the inputs are the signals from the rf amplifier and the heterodyne-frequency oscillator (HFO). If either is absent, the mixer will not operate correctly.

Our next step is to confirm that the rf amplifier and HFO output signals are reaching the mixer. If they are, and rf voltage is found at the mixer output, can we conclude that all is well up to the i-f (intermediate-frequency) amplifer? Probably, but one additional test should be made. In some mixer circuits the HFO signal may appear at the output. To ensure that the rf voltage we found at the mixer output is the i-f signal (and not the HFO) we should check to see if the mixer output drops when the signal generator is removed from the receiver. If the mixer stage is found to be functioning, we can proceed to test the following stages in the same manner.

As we move closer to the detector, the signal level will normally increase. The rf input to the receiver should be reduced to prevent overdriving one or more of the stages. A signal generator output level that yields a reading of about 0.5 V at the stage being tested is all that is needed.

Transmitter Circuits

The same basic method can also be applied to troubleshooting transmitter circuits. The primary difference is that we normally do not need to apply an input signal; the circuit generates the signal, and we simply follow it from one stage to the next. Because the oscillators in the transmitter will serve as our "signal sources" (a modern transmitter will have several) they are the logical places to begin signal tracing. A representative variable-frequency oscillator (VFO) and buffer amplifiers are shown in Fig. 2. The voltages shown are the rms values measured with the circuit operating normally. While the values will vary from one

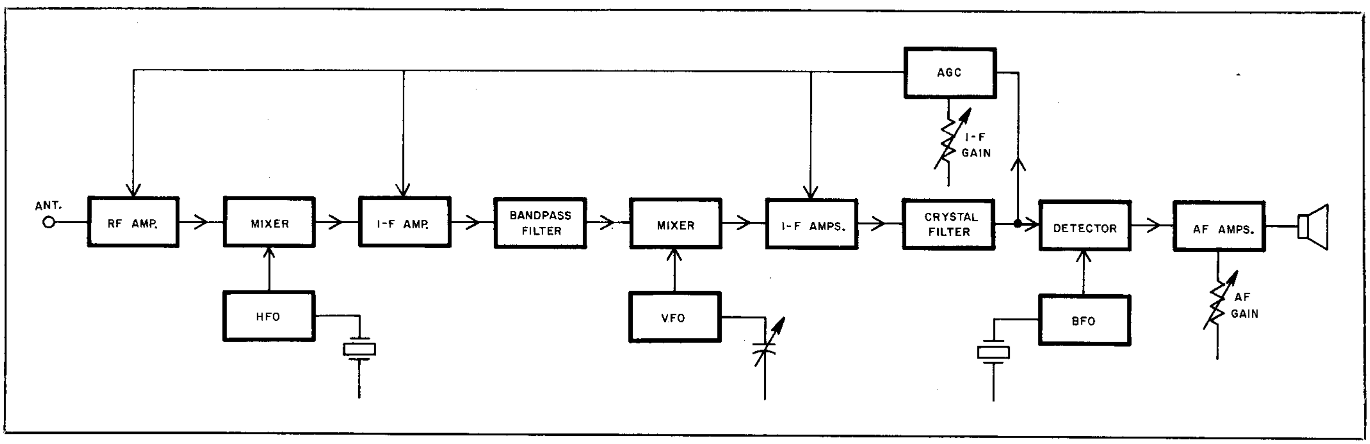


Fig. 1 — Block diagram of a typical amateur receiver.

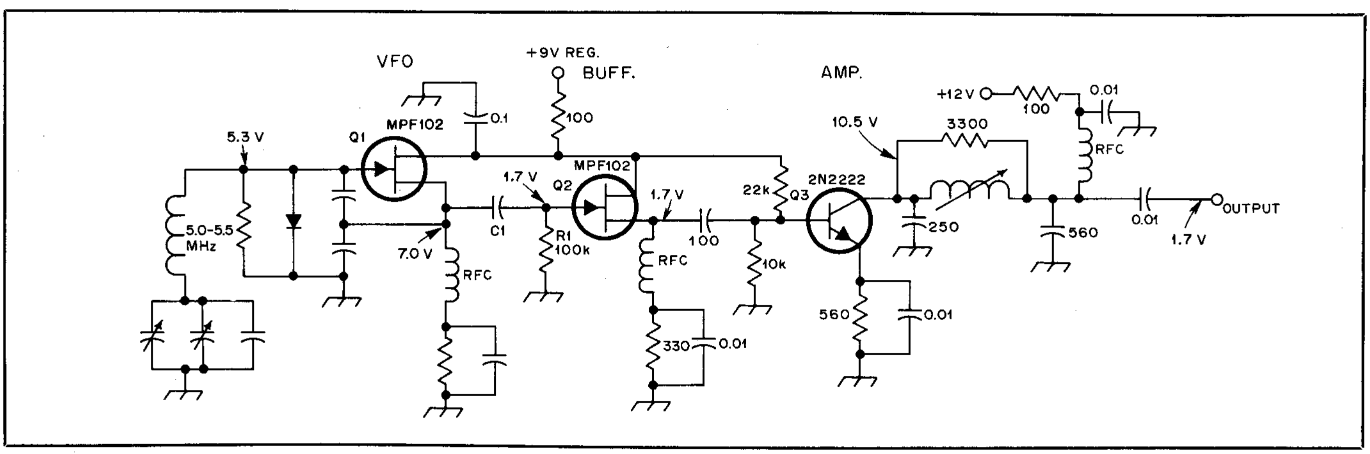


Fig. 2 — This VFO circuit is similar to that used in many transmitters and receivers. The voltages shown were measured with an rf probe and FET voltmeter.

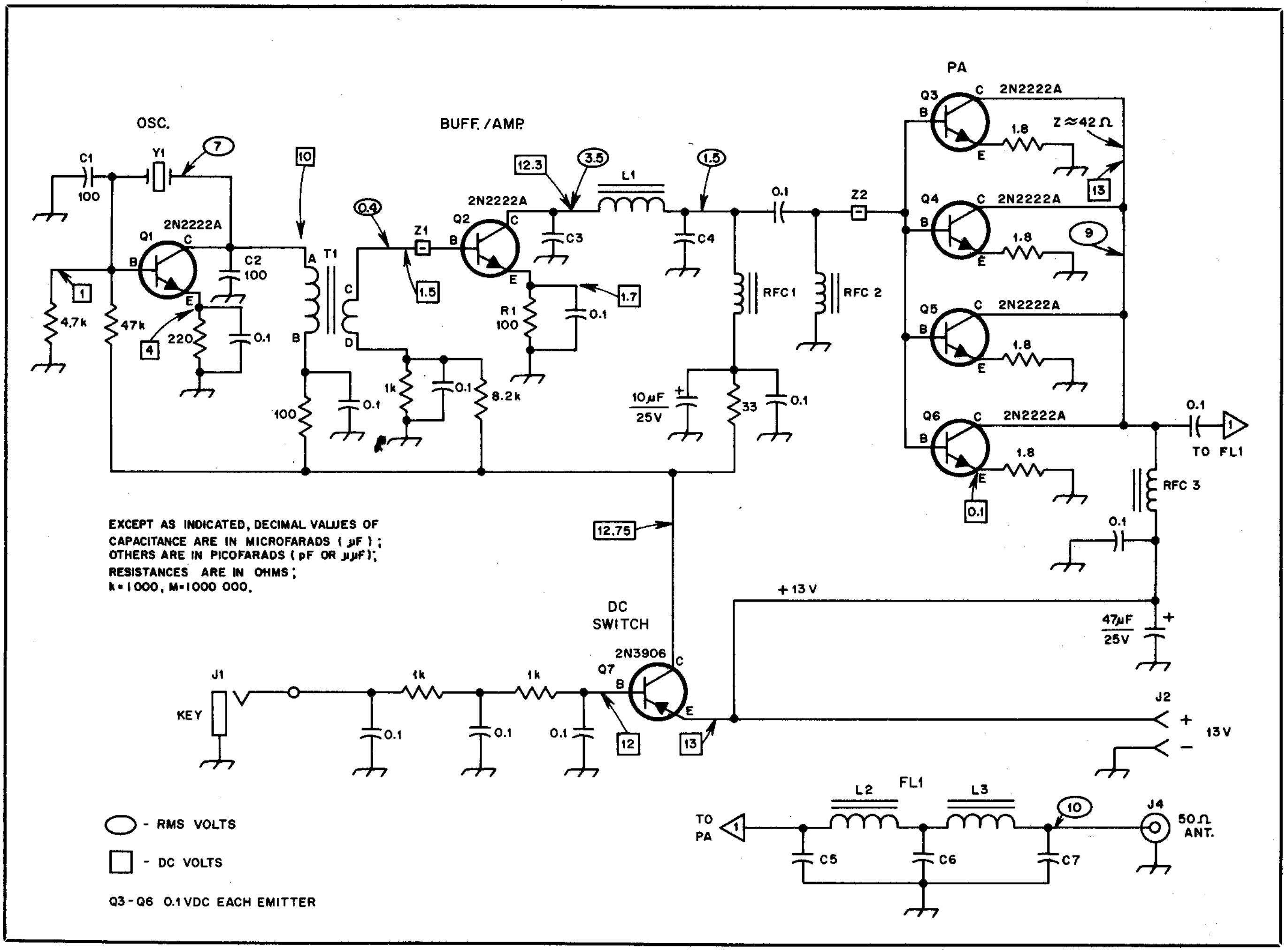


Fig. 3 — A simple low-power transmitter. The voltages were measured with an rf probe and FET voltmeter. The basic techniques used to troubleshoot a simple circuit like this can be applied to more complicated equipment.

circuit to another, the voltages shown point out some important circuit features. For example, the voltage across the tank circuit is fairly high (about one half the supply voltage), and the source voltage is also high. Capacitor C1 and the 100-kΩ resistor (R1) form a voltage divider between the source of Q1 and the gate of Q2. This results in the gate voltage being much lower than the source voltage at Q1. Buffer amplifier Q2 is operated in the source-follower configuration; thus the input and output voltages will be nearly the same. If we overlook the fact that the voltage gain of this stage *should* be only 1, we might think the stage was defective when it is actually operating correctly. The more we know about the circuits we are troubleshooting, the more likely we are to be successful in servicing our equipment.

The low-power transmitter shown in Fig. 3 provides an example of how we can apply our knowledge of circuit fundamentals to help us while signal tracing. We can

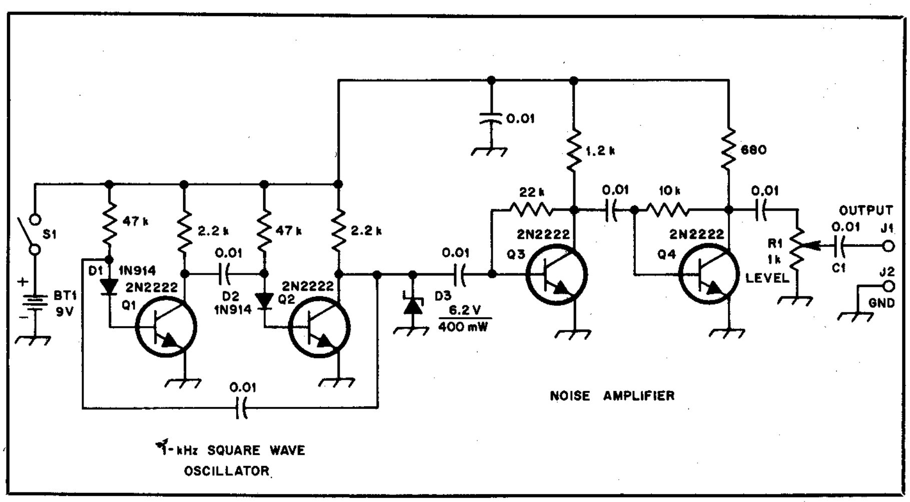
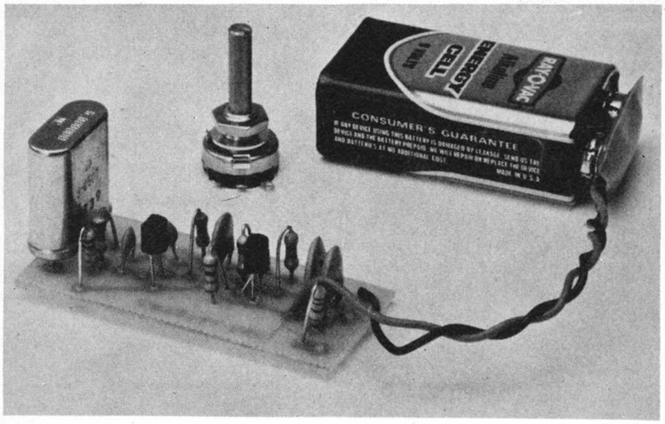
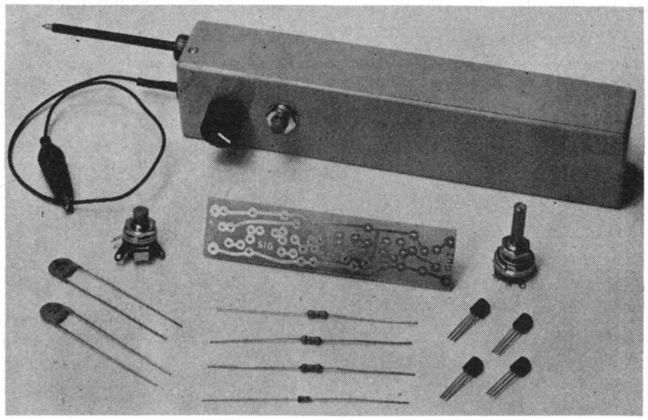


Fig. 4 — Schematic diagram of the af/rf signal injector. All resistors are 1/4 W, 5% carbon types, and all capacitors are disc ceramic.

BT1 — 9-V transistor radio battery.
D1, D2 — Silicon switching diode, 1N914 or equiv.
D3 — 6.2-V, 400-mW Zener diode.
J1, J2 — Banana jack.
Q1 - Q4 — General purpose silicon npn transistors, 2N2222 or equiv.
R1 — 1-kΩ panel-mount control.
S1 — Spst toggle switch.



Printed circuit board construction was used for this version of the crystal-controlled signal source.



The Signal Injector, housed in a homemade enclosure of circuit-board material, is a convenient, hand-held signal source.

expect the rf-voltage level at the oscillator (Q1) collector to be near that of the supply voltage; in this case we find 7 V at that point. T1 provides an impedance match between the relatively high value needed at Q1 and the lower impedance at the base of Q2. Because of this, we should expect the voltage at the base to be considerably lower than the Q1 collector voltage. Impedance matching between Q2 and the power amplifier (PA) is provided by an LC network made up of C3, C4 and L1. Again, the voltage at the low-impedance input to the PA is less than the voltage at the high-impedance side of the network.

Signal Injection

A troubleshooting technique related to signal tracing is signal injection. This method does not require a signal detector (such as the rf probe used in signal tracing) because the receiver being tested serves as the "detector" of the injected signal. Starting at the receiver output (the speaker) an audio signal is applied; if the signal is heard in the speaker, we move the injection signal to the input of the last audio amplifier stage. We continue this procedure until moving from the input of one stage to the preceding stage results in loss of audio output.

At that point we have found the defective stage. When the input to the detector is reached, we must use an injection signal at the receiver i-f rather than the audio signal used earlier. The injection-signal frequency used at the input to any rf stage must be the same as the normal signal frequency. If a wide-range tunable signal generator is available it can be used for this type of testing. If such an instrument is not part of your shop equipment, a simple "signal injector" can be used in place of the tunable generator. A signal injector generates an output signal that contains a broad spectrum of frequencies. Thus it can be used for testing audio, i-f or rf stages. The advantage in using a signal injector is the low cost of the device — it should not be considered as a replacement for a high-quality signal generator. Inexpensive signal injectors can be purchased for less than $6 or constructed at home. Fig. 4 shows the circuit of a low-cost, but effective, signal injector that can be constructed in a short time.[2] Many experimenters may have the necessary parts in their junk box.

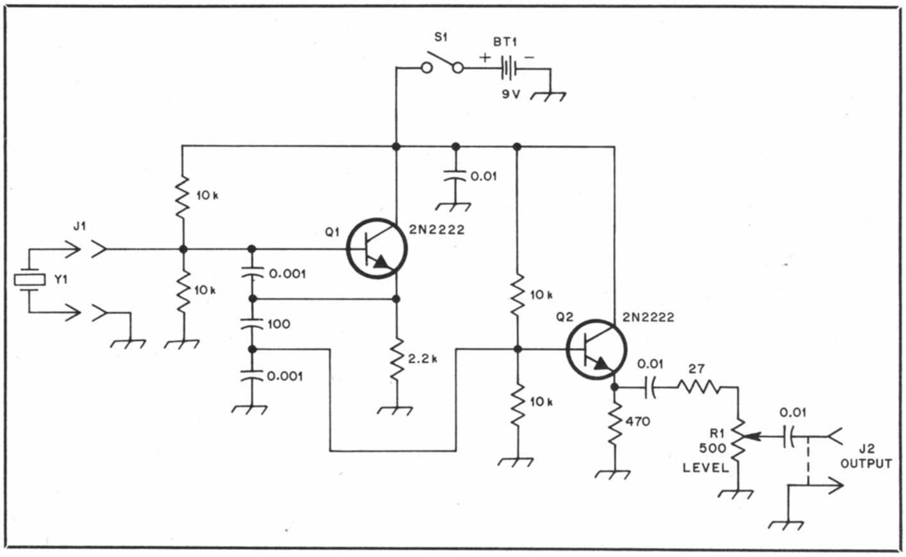


Fig. 5 — Schematic diagram of the crystal-controlled signal source. All resistors are 1/4 W, 5% carbon types, and all capacitors are disc ceramic.

BT1 — 9-V transistor radio battery.
J1 — Crystal socket to match crystal type to be used.
J2 — RCA phono jack or equiv.
Q1, Q2 — General purpose silicon npn transistor, 2N2222 or equiv.
R1 — 500-Ω panel-mount control.
S1 — Spst toggle switch.
Y1 — 1- to 15-MHz crystal.

A Crystal-Controlled Signal Source

The crystal oscillator and amplifier shown in Fig. 5 and the photograph was built as a general-purpose signal source and will serve very well for signal-tracing work. The output level is variable from 0 to more than 1 V rms into a 50-Ω load, and almost any crystal in the 1- to 15-MHz range can be used.

Q1 forms a Colpitts oscillator with the output being taken from the emitter. A capacitive voltage divider (across the 2.2-kΩ emitter resistor) reduces the voltage applied to the buffer amplifier, Q2. The buffer, an emitter follower, provides the low output impedance necessary to drive 50-Ω loads.

Construction is simplified by the use of a printed-circuit board, but any wiring method can be used. J1, the crystal socket, should be selected to match the crystals you intend to use. Multiple sockets can be wired in parallel so that any style of crystal (HC-6/U, FT-243, etc.) can be used (an HC-6/U style crystal can be soldered directly to the circuit board). The oscillator packaging is left to the discretion of the builder. A small box

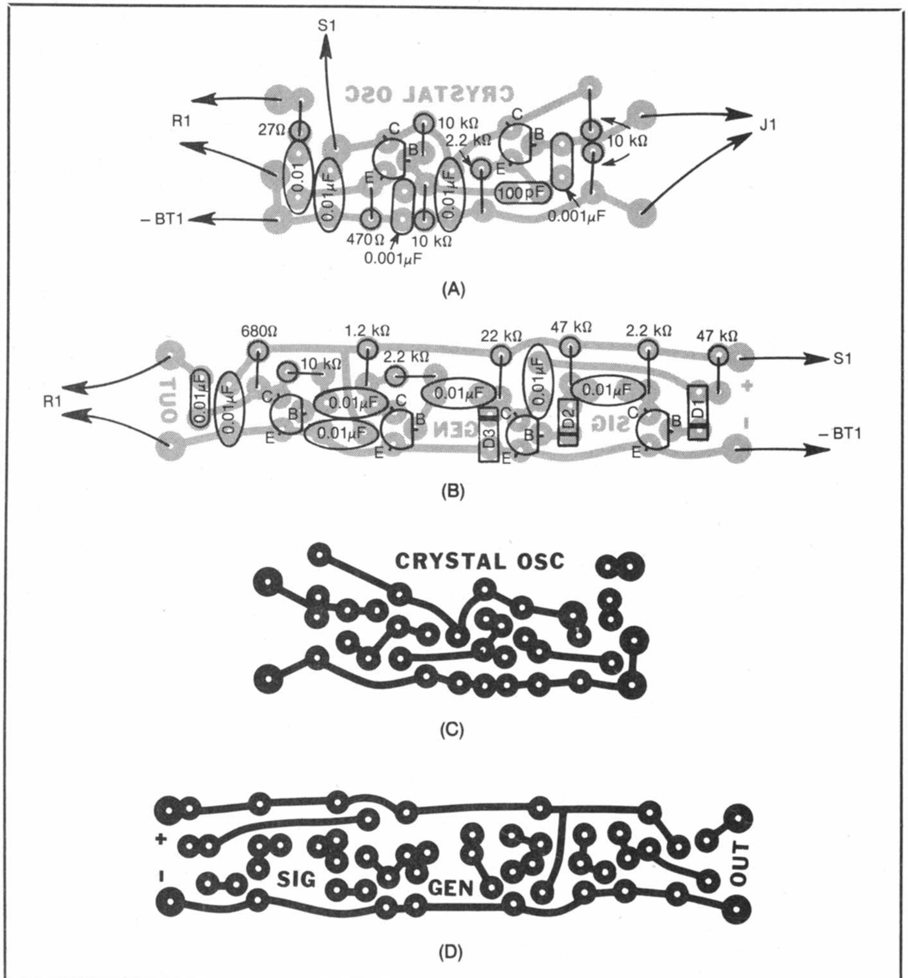


Fig. 6 — Parts placement diagram for the crystal-controlled signal source (A) and the signal injector (B). Gray areas are unetched copper, viewed from the component side of the board. Scale circuit-board etching patterns for the crystal-controlled signal source (C) and the af/rf signal injector (D).

(such as the Radio Shack no. 270-235), or an enclosure made of circuit-board material, will serve nicely.

AF/RF Signal Injector

Shown in Fig. 4 is the diagram of a simple signal injector. This device will generate detectable signals from the audio range to over 30 MHz. It consists of three basic stages: a square-wave oscillator (Q1 and Q2), a noise generator (D3) and a two-stage amplifier (Q3 and Q4). R1 is used to adjust the output level to that needed for the stage under test.

When the signal injector is applied to the antenna input of a receiver, a hissing noise should be heard. If the injector is used to test audio stages, a tone of approximately 1 kHz will produced.

The unit shown in the photograph was constructed on a printed circuit board and is housed in a homemade circuit-board box. A prototype was constructed "bread board" style on a scrap of unetched copper-clad board, and the results were the same as when the circuit board was used. The builder may select either method, and should obtain good results.

With these techniques and tools in your troubleshooting "bag of tricks" you will be able to track equipment problems easily and more rapidly. In Part 4 of this series, we will look at the use of the oscilloscope in troubleshooting and equipment servicing.

Notes

[1]G. Collins, "Some Basics for Equipment Servicing — Part 2," *QST*, Jan. 1982, pp. 38-41.

[2]Parts kits and printed circuit boards for the crystal-controlled signal source and the signal injector are available from Circuit Board Specialists, P.O. Box 969, Pueblo, CO 81002.