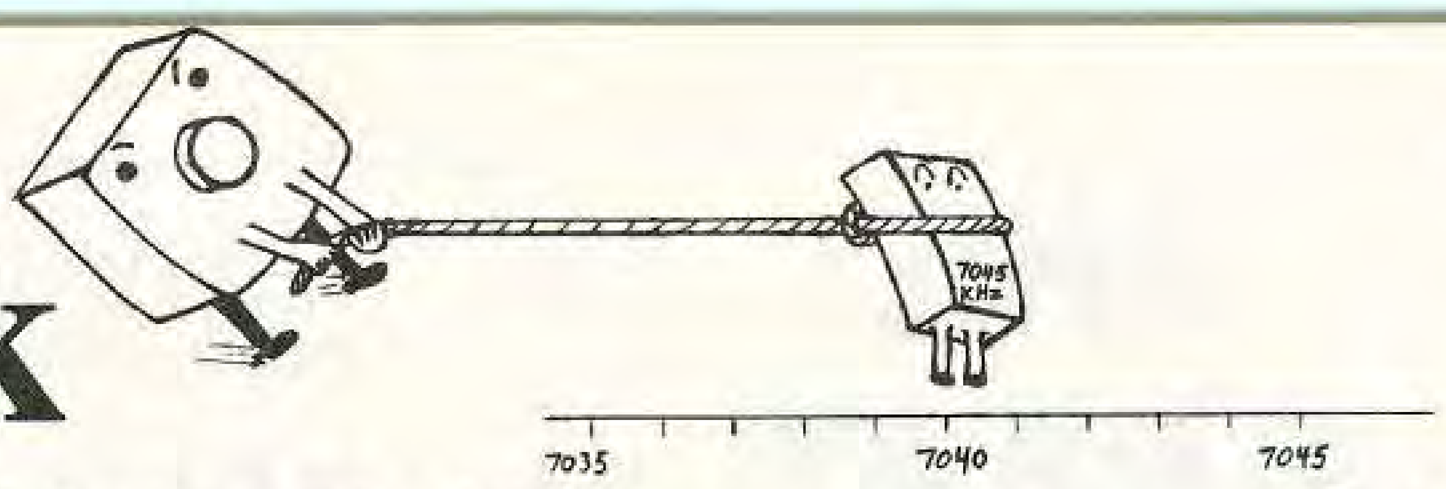
The Rock Bender QRP Transmitter



Win QSOs and influence crystals.

by Randy Henderson WI5W

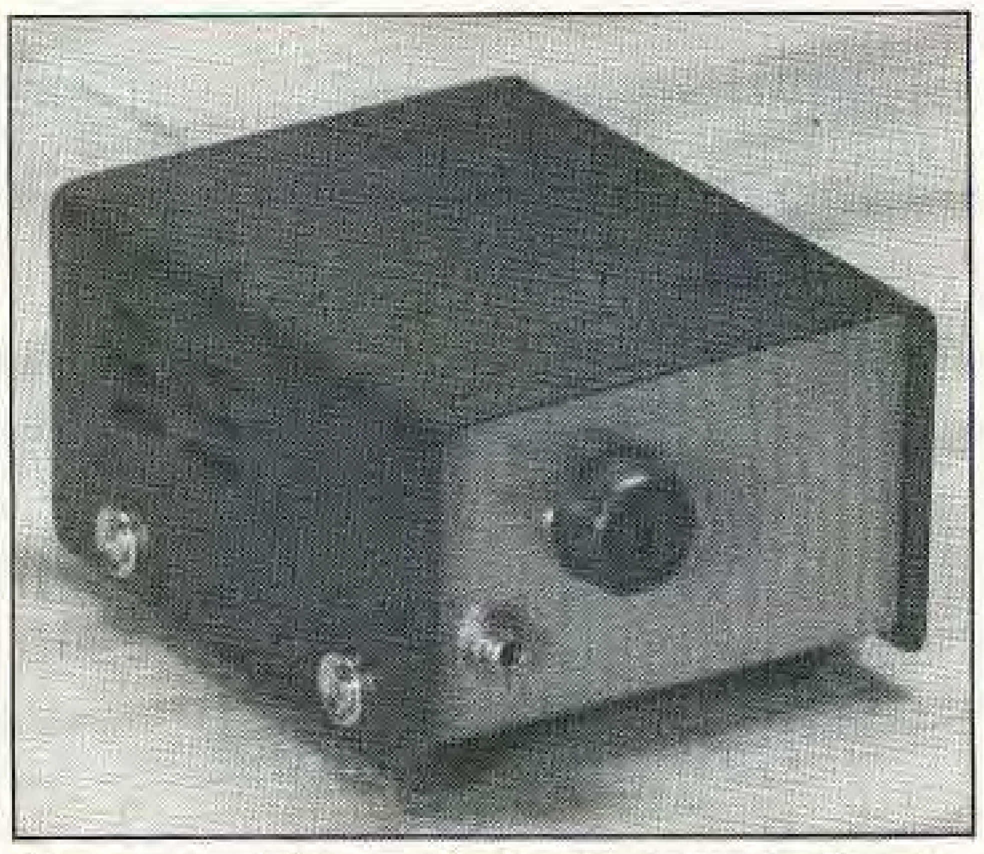


Photo A. This well-dressed Rock Bender sports a black-and-gray cabinet from Mouser Electronics (part number 40UB101). The key jack is near the lower left corner of the front panel. The tuning knob is a black rubber cabinet foot.

If you want a simple way to generate stable signals, a crystal oscillator will do nicely. The only problem is, you have one available frequency per crystal. This transmitter will "bend" the frequency of your "rock" (quartz crystal) to create a tunable oscillator.

The "Rock Bender" features two stages, an oscillator and a power amplifier. The tuning range varies with individual crystals. Various 7 MHz crystals will allow 6 to 20 kHz of tuning range. The version shown here has an output power of 3 watts into a 50 ohm load. A slight modification allows output levels of 10 watts or greater. It is extremely tolerant of mismatched loads.

Construction

The circuit board is double-sided. One side is a conventional etched pattern, shown in Figure 1. The other side is a solid copper ground plane, except where holes are drilled for component leads. All ground connections are soldered on this side. If you are making your board from the pattern, many methods can be used to form the resist paths. These include: tape, resist pen, and photo resist. See the construction chapter in recent versions of the *ARRL Handbook* to learn more about such techniques. Enamel spray paint is an easy way to cover the ground plane.

All components mount on the ground plane side (see Photo B). Only grounded leads are soldered to the ground plane. All other leads pass through the ground plane to the etched side of the board. They must not make contact with the ground plane. To prevent accidental contact, countersink the ground plane at the holes indicated as ungrounded in Figure 2. Use a substantially larger bit for countersinking than the component lead hole (1/4" to 1/2"). Light pressure on the drill will clear away copper from the periphery of the holes (see Photo C).

Place the components as shown in Figure 2. Q2, the IRF511 output transistor, should be mounted close to the board with short leads, as well as C8. I leave conductive foam, aluminum foil, or wire, on the leads of Q2 until all of the board components are soldered in place. Shorting the leads together protects against damage from static electric charges and soldering iron leakage. Don't forget to remove the short before applying power. All other components should have reasonably short leads. Q2, L4 and the crystal socket will need larger holes and countersunk areas.

The variable capacitor C2 does not solder directly to the board. Use a short, stiff wire jumper to connect the stator plates (see Photo D). Most defunct AM broadcast receivers have small polyethylene film variable capacitors suitable for C2. To my knowledge, all use metric-sized screws. Many have internally threaded shaft ends. I find that some rubber cabinet feet make suitable knobs when the original is not available. Use care when mounting variable capacitors. Do not run the screws in far enough to damage the plates. Use washers, spacers or shorter screws. If necessary, shorten the screw and repair the threaded end.

Photo B. Rock Bender au naturel. The board is mounted on a clear piece of Plexiglas™. The PL-259 antenna connector is wired to the board via RG-158 miniature coax. A key jack is at lower left.

L4 is made of 22-18 AWG solid copper wire. Enamel insulation is preferable, but not essential. Wind four turns over a 3/4-inch-long PVC pipe section. The size of pipe used for the coil form is known as "1/2-inch." This is a convention used by the plumbing industry and is not the actual outside diameter. The outside diameter is approximately 0.84 inches. The length of the winding is about 1/2 inch. Do not secure or cement the turns in place at this stage of construction.

The mounting holes for the circuit board are not shown in the layout. Place mounting holes as you wish, but do not allow supports to short or ground conductors on the etched side of the board.

Although Figure 3 doesn't show a fuse, some type of

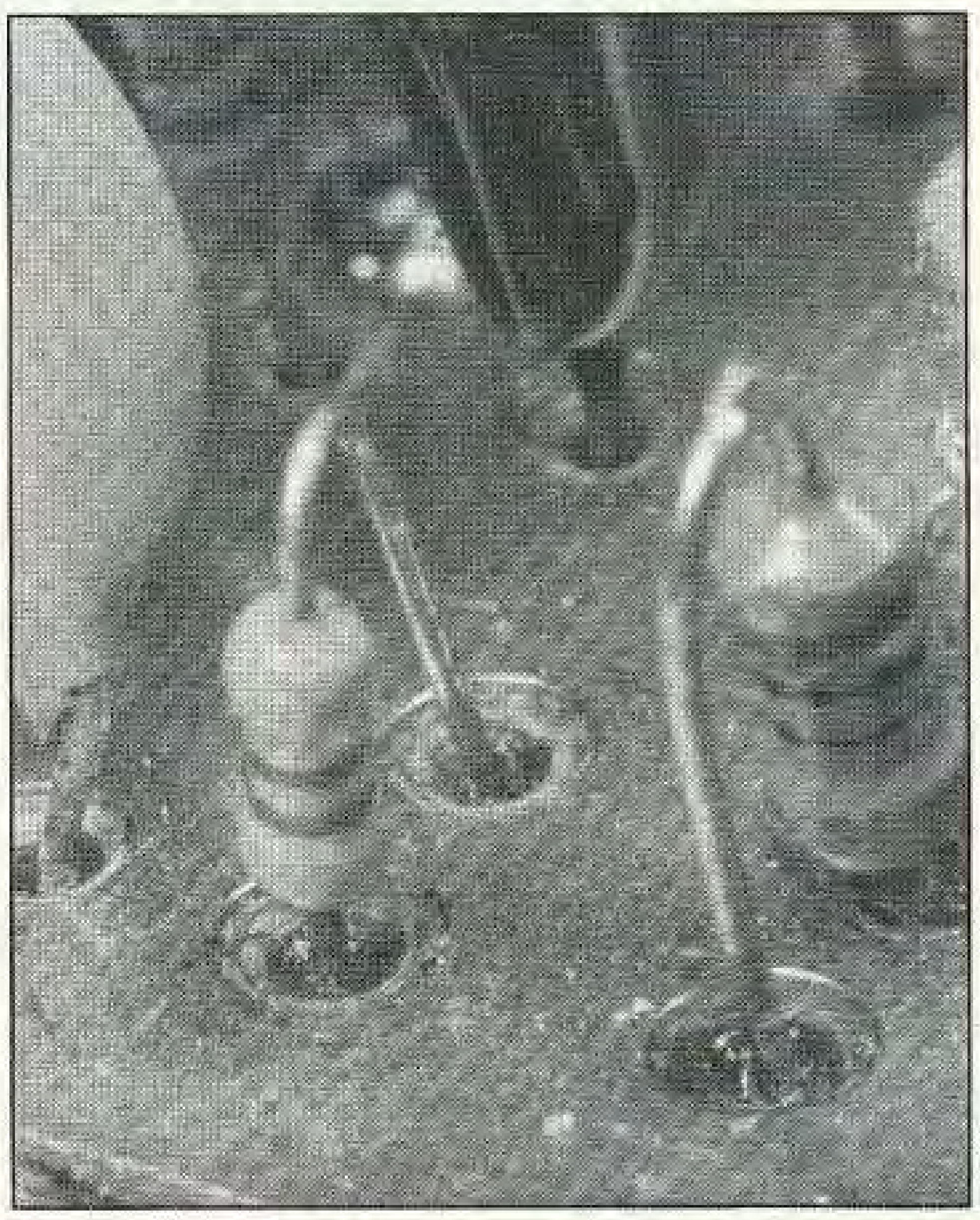


Photo C. Countersunk holes on the ground plane provide safe passage for component leads without disturbing printed circuit paths on the other side.

current limiting device should be used to protect the transmitter. If your power source does not include a fuse, circuit breaker, or active current limiter, wire one into the positive supply line. A 3/4 or 1-A rating is suitable for the 3 watt output level.

The jumper shown in Figure 2 must be connected for oscillator keying. It does not connect to ground.

Connectors are needed for the antenna, the key and the power source. If you're an inexperienced builder, bring these accessories to the parts store to simplify finding the matching connector.

Circuit Description

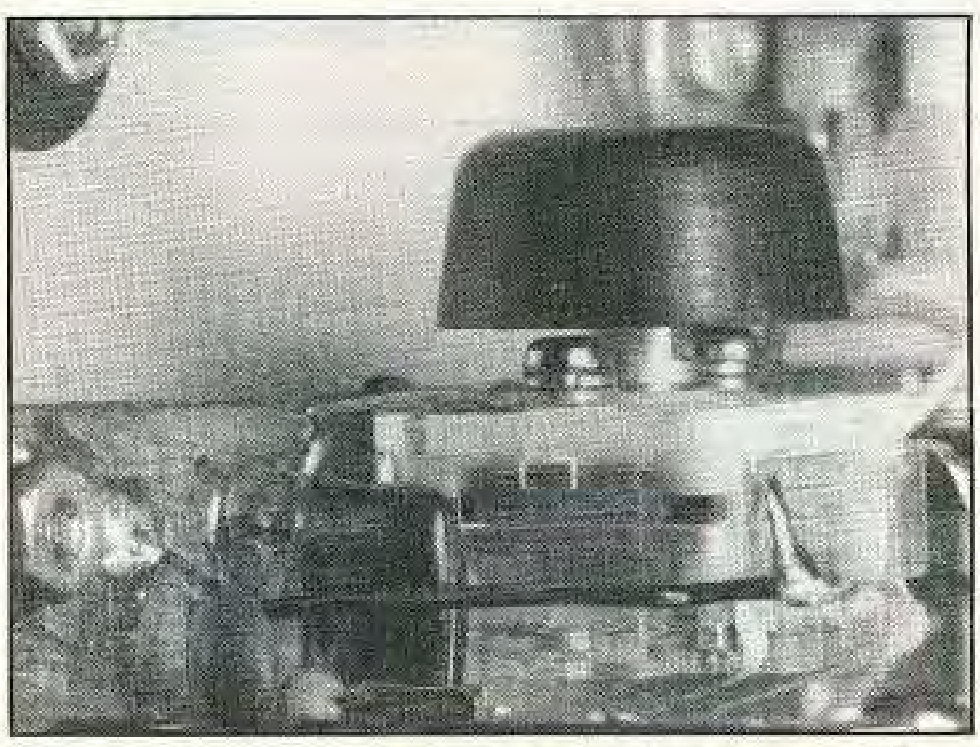


Photo D. A mounting bracket fabricated from a wire paper clip supports C2. Ground connections for C1 and C5 are visible. Hand capacity affects the frequency slightly when C2 is mounted this way.

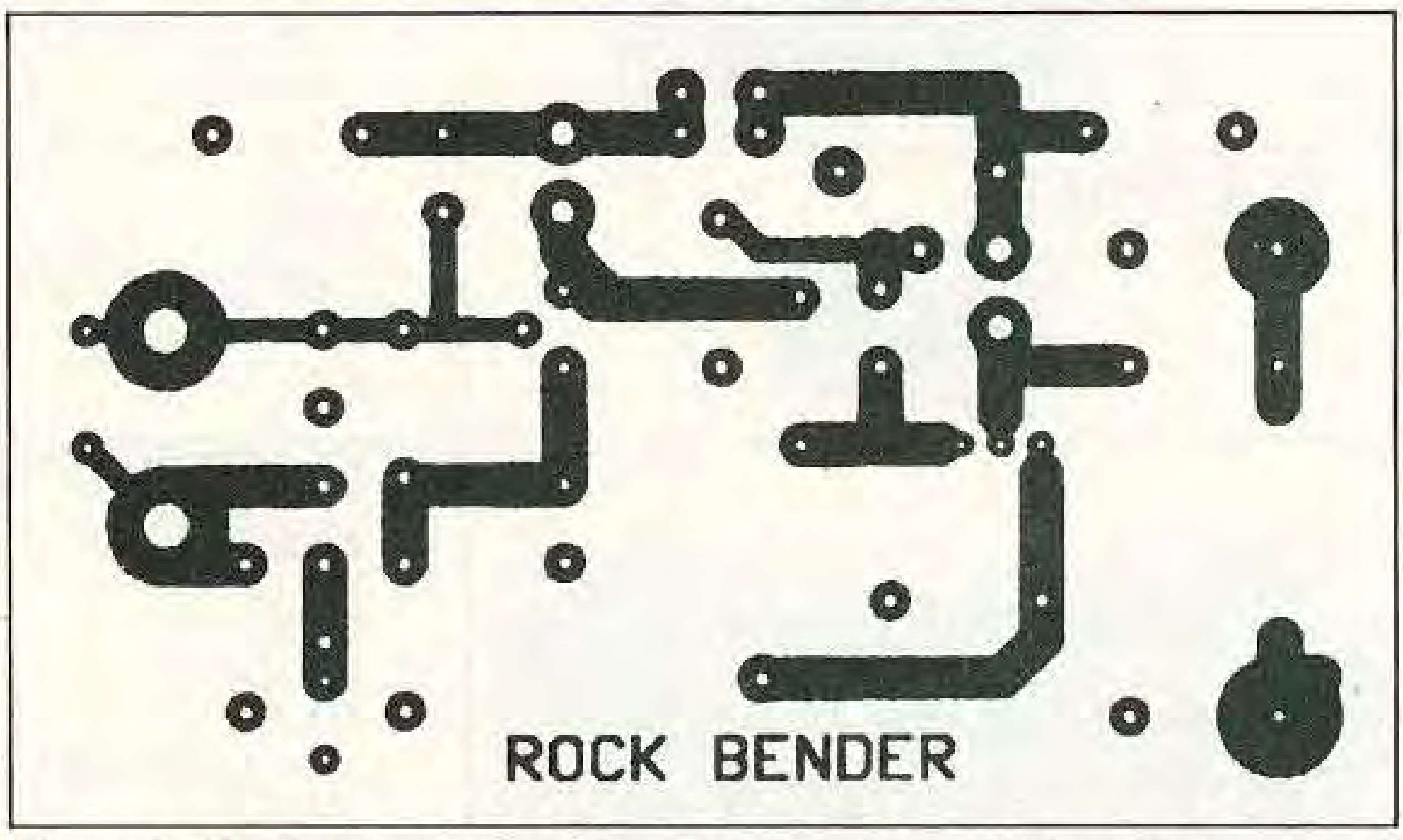


Figure 1. The isolated pads with no traces connected show the location of ground connections. These can be drilled or simply used as a visual reminder for soldering to the ground plane.

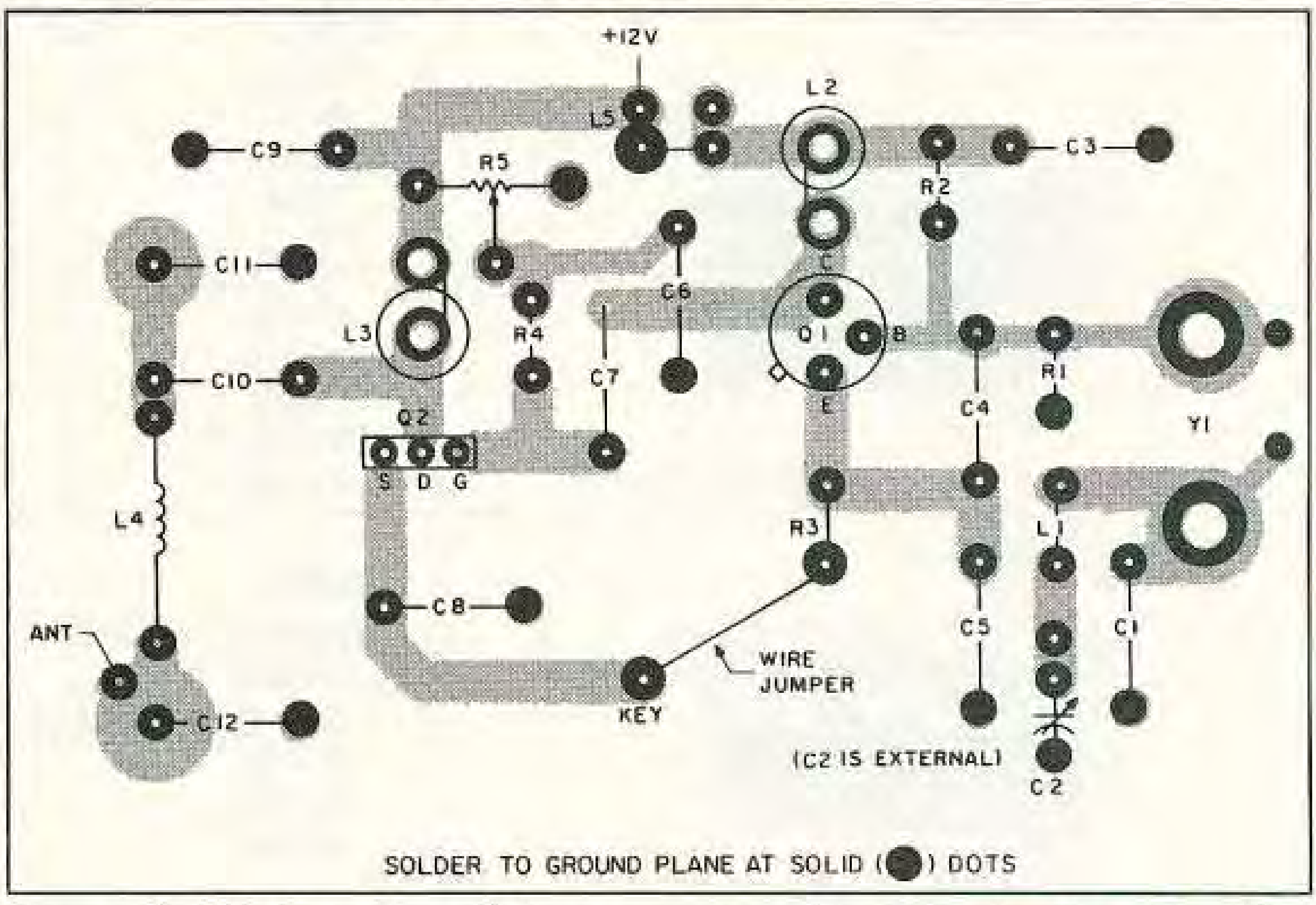


Figure 2. This is a view of the component side. It is also the side of the solid copper ground plane. The etched pattern is underneath, invisible from this side. Open circles mark component leads that pass through the ground plane to the etched side of the board. Countersink the ground plane at those locations.

Figure 3 shows Q1 in a modified Colpitts oscillator configuration driving Q2. The output of Q2 is filtered and undergoes an impedance transformation before reaching the antenna terminal. This dual function is performed by a pi network consisting of C11, C12 and L4.

Keying is accomplished by providing a ground path for the emitter of Q1 and the source of Q2. No keying transistor is used.

You may want to experiment with operating the oscillator continuously. This often provides improved keying characteristics when you're trying to stretch the tuning range. Use a small heat sink on Q1. The oscillator keys satisfactorily with moderate tuning limits. Those of you "bent" on extending the limits may find help in reducing chirp by eliminating the jumper. Install a switch between the free end of R3 and ground.

What determines the tuning range for a particular crystal? L1 has, by far, the largest effect. The optimum value for L1 depends greatly on the type of crystal used. With most FT-243 crystals, 18 to 20 µH works well. HC-6 and HC-18 types seem to need more inductance. I used a total of 38 µH with one HC-6 crystal to obtain 10 kHz of tuning range. Some builders report 20 kHz of shift using old military/government surplus crystals with very large holders.

The value of L1 affects tuning in a very non-linear manner. Substituting a 15 µH inductor in place of an 18 µH inductor may reduce the available tuning range by 80 percent. If L1 is too large, the oscillator will usually malfunction in one of two ways. It may lose most or all of the tuning range. In this case, oscillation may take place at a frequency very close to the value marked on the crystal holder. Oscillation can also take place at frequencies several hundred kHz away from the marked frequency. You certainly don't want to operate the trans-

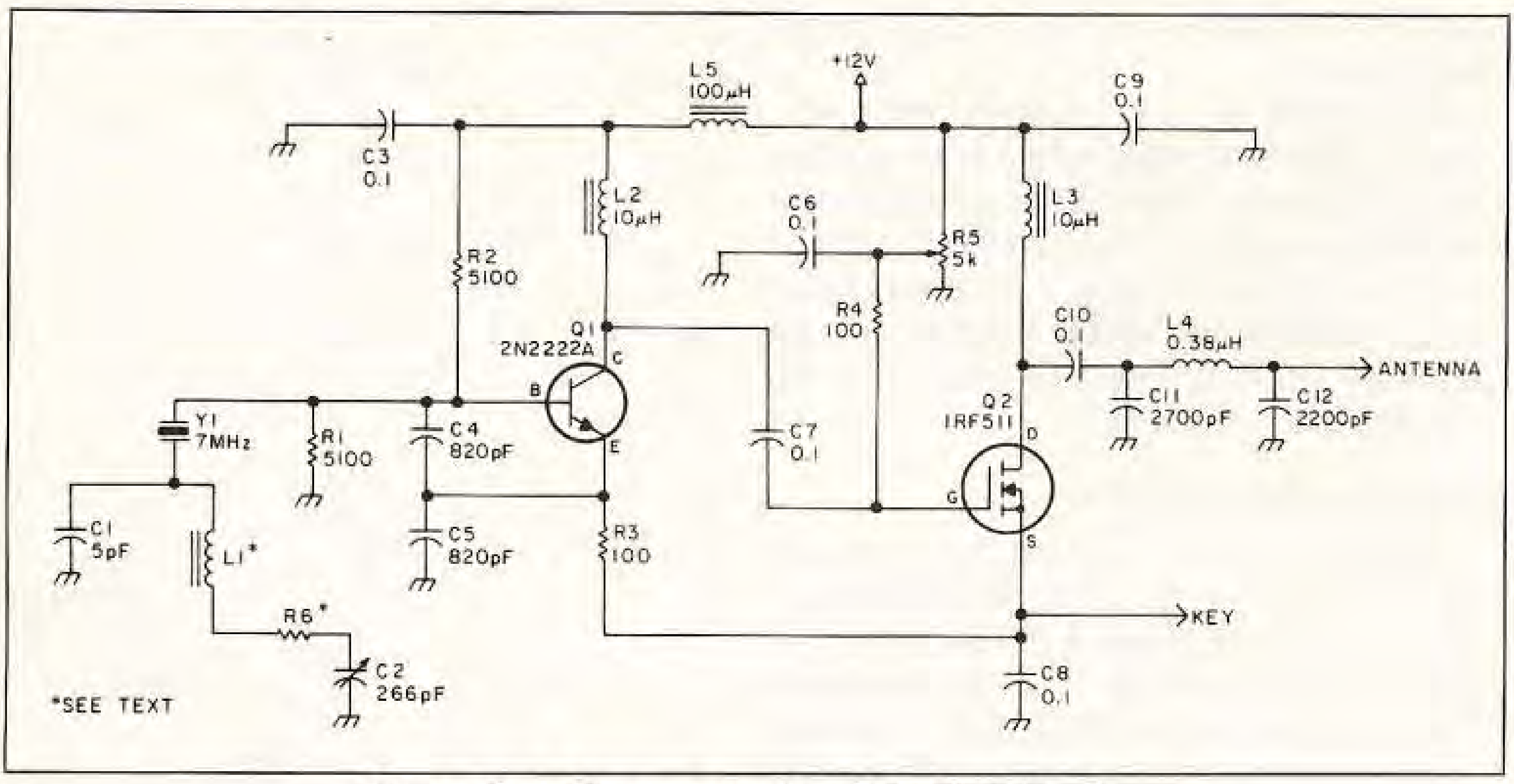


Figure 3. A 40 meter version of the Rock Bender.

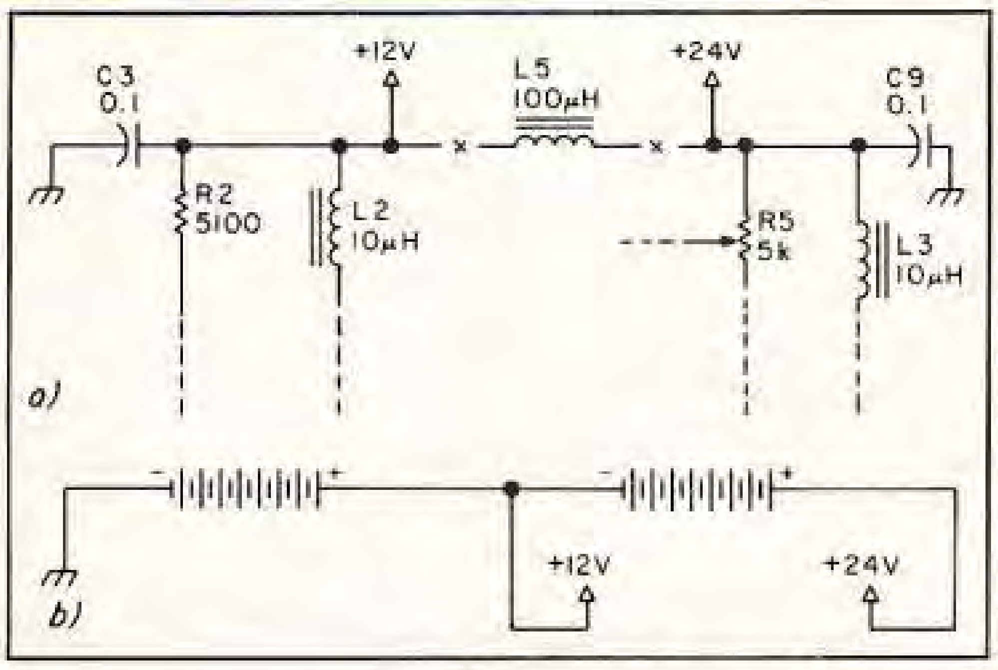


Figure 4. a) Use dissimilar power connectors for the 24 volt and 12 volt bus or one 3-pin connector keyed to plug in only one way. This will preclude accidentally swapping power sources. b) Two 12 volt batteries in series. Remember to use a fuse on both positive leads to the transmitter. About 200 mA for the 12 volt tap and 750 mA for the 24 volt lead.

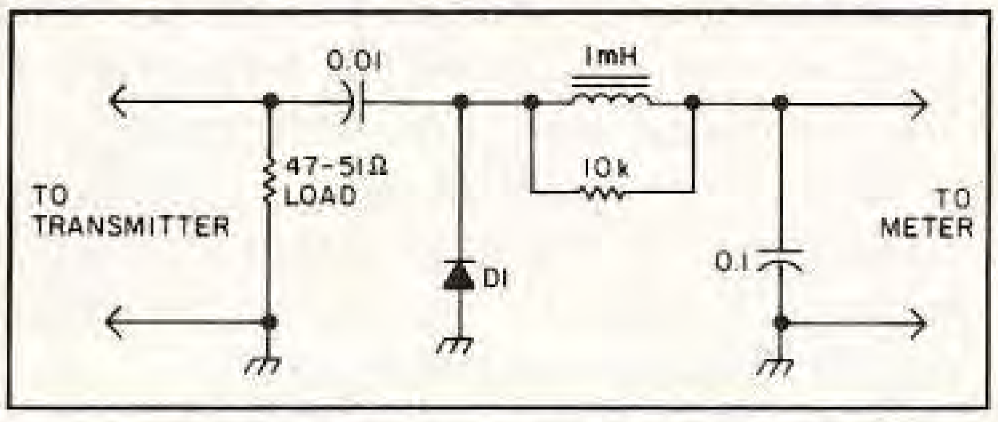


Figure 5. This circuit samples RF voltage across the load. A DC voltage appears at the meter terminals. The RMS value is approximately 0.707 x peak. If R is the load resistance and E is the voltage indicated by the DC voltmeter, then power = $(0.707E^2)/R$. D1 is an RF or high-speed switching type of diode. A 1N34A germanium or 1N914 silicon will work. If you first subtract the characteristic voltage drop from E, the calculation is more accurate. Use 0.4 volts for germanium or hot carrier diodes and 0.7 volts for silicone. The 10k ohm resistor loads the RF choke to eliminate erroneous readings caused by parallel resonance effects.

mitter out of the band.

A low-Q inductor seems to work best at L1. High-Q toroidal inductors are often unsatisfactory. Decreasing the Q and the crystal current even more by using R6 often improves keying characteristics. The largest value I've used is 47 ohms for FT-243 crystals. The lowest value is zero ohms. Small, low-Q, low current, high DC resistance, molded chokes are a good choice for L1. The best configuration for L1 is often two or three molded chokes in series. For instance, you might use two chokes of 9.1 μH each, for a total of 18.2 μH.

C2 is the tuning control for actual on-the-air operation. Using a larger value variable capacitor may provide increased tuning range in some transmitters.

Component values for the rest of the transmitter are not so dependent on crystal Y1. Potentiometer R5 sets the gate bias voltage for output transistor Q2. R4 acts as a "swamping" resistor. In other words, it loads the gate circuit of Q2 to stabilize the output stage and prevent parasitic oscillations. It also helps establish a stable load for the oscillator.

If you need a bit more output power, here's how. The output transistor, Q2, works very well with a 24 volt DC supply. At this voltage, Q2 needs a larger heat sink with a few square inches of surface area. An aluminum chassis can be used by mounting Q2 upside down (on the etched side of the board) and thermally coupling to Q2 with a mica insulating washer covered with heat-sink compound. The gate bias voltage will need to be lower (adjust R5). At 7 MHz, 10 watts of output power is available.

Wait! Don't rush to the nearest 24 volt supply. The transmitter absolutely will not tolerate a 24 volt DC supply to Q1. The drive level (RF voltage) is so high that it punctures the gate insulation, destroying Q2 instantly. L5 is a decoupling choke for the oscillator supply. By removing L5, you can operate the oscillator at 12 to 14 volts and supply 24 volts to the IRF511 amplifier (see Figure 4a).

Crystal Y1 operates in the fundamental mode in this circuit. Overtone cut crystals also operate in the fundamental mode. At present, there are sources of very inexpensive fundamental mode 7 MHz crystals. For this reason, development of the transmitter was concentrated on the 40 meter band. This transmitter also works on 14 MHz by changing a few component values. Reduce C4 and C5 by half. Change C11 and C12 to 910 pF. Change L4 to 0.24 μH. This is for a supply voltage of 13.5, 2 watts output and a network Q of 4 (including transistor output capacitance). You can achieve initial operation (and very little tuning range) by using a jumper in place of L1. With the optimum value for L1, the tuning range will be much greater than the 40 meter version. Output power is less. Operation on other bands should be possible. Certainly, 30 meters is a prime candidate.

Initial Checkout

Before applying power to the transmitter, you should make a thorough visual inspection. Check for solder bridges, poor solder connections, melted wire insulation and component leads touching other conductors. Double-check all connections to make sure they agree with the schematic diagram.

To adjust the transmitter, you will need a dummy antenna and some way to measure output power. A 47 ohm, 2 watt, carbon-composition resistor can be used in lieu of a standard dummy load for the 3 watt version. Just check it occasionally to make sure it's not getting too hot. If you don't have a wattmeter for this power level, see Figure 5.

The wiper of R5 should be rotated all the way toward the grounded leg. You can check this with an ohmmeter. Next, plug in a key. Make sure it can handle the current if it's an electronic keyer. Keying current is a hefty 500 to 600 mA at 13.5 volts.

The last step before key-down testing is to connect a 12 to 14 volt DC power source. With C2 at midrange, key the transmitter. The grounded wiper of R5 sets the gate bias voltage to zero and the output level will be very low. It should be less than 1/2 watt, possibly less than 100 milliwatts, depending on the supply voltage. Find the transmitter signal with your receiver. If you can't find the signal, L1 may be too large. C2 should shift the frequency over a range of at least 5 or 6 kHz. If not, L1 is too small. A very few FT-243- style crystals may refuse to oscillate if their activity is on the sluggish side. At the risk of sounding like an advocate of crystal abuse, I have found that a sharp blow from a pencil or similar object brings them to life. Once so "enlightened," they work perfectly until disturbed. I suppose the spring-loaded nature of the holder may be responsible for this behavior.

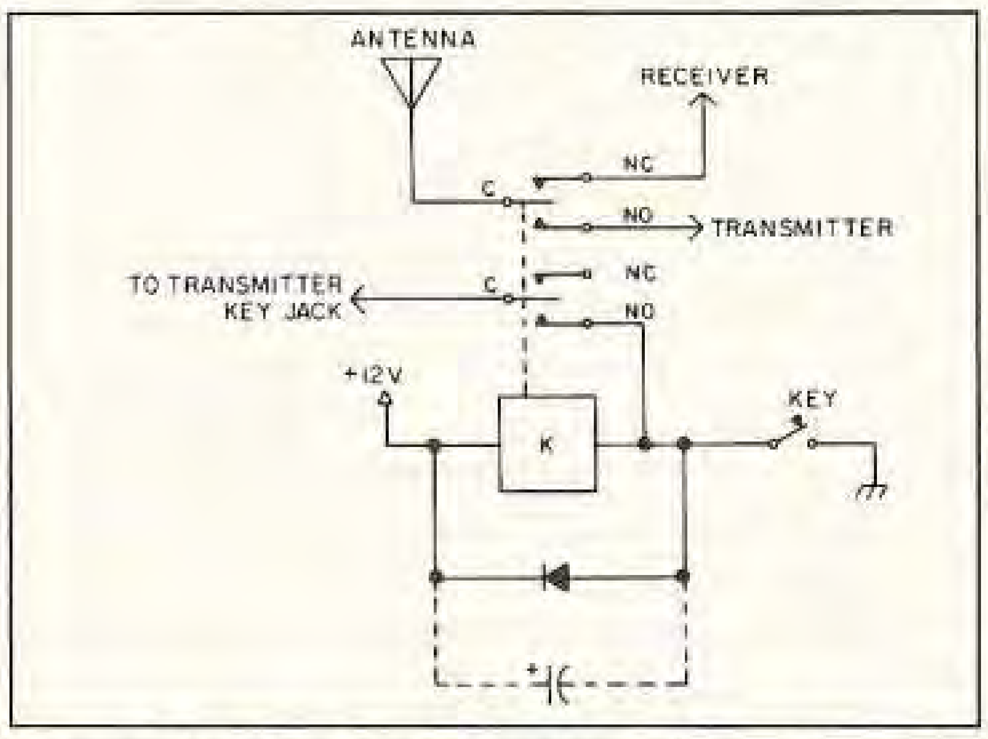


Figure 8. When you key the relay, it keys the transmitter. An optional electrolytic capacitor will provide semi break-in keying. Try 100 to 500 µF. Transmitter output occurs after relay contact is made and ceases before contact is broken. Another set of contacts or another relay can be used for gain reduction or muting at the receiver. K is a 12-volt relay to be operated from the 12-volt transmitter supply.

If everything is okay, slowly rotate R5. Stop rotation when the output level reaches about 2.5 watts. The only other adjustment needed is to tune L4. Do this by spreading or compressing the winding. The output should peak at some point. Adjust R5 for an output level of 3 watts. Re-check L4 and cement the winding in a few places.

Refinements and Options

If you have never used a separate transmitter and receiver before, you have some decisions to make. If you hook this transmitter to your antenna, how do you get incoming signals to the receiver? One way is to use a separate antenna. Most modern HF receivers (and transceivers) receive reasonably well with a few feet of wire strung up around the shack. Try to keep the receiving antenna away from the transmitter feedline and antenna. To use a single antenna with a manual TR (transmit/receive) switch, see Figure 6. A W7EL-style electronic antenna switch is shown in Figure 7. (See: R. Lewallen, "The Optimized QRP Transceiver," *QST*, August 1980, pp. 14–19.) Automatic antenna switching is performed by a relay in Figure 8.

Operation

The frequency marked on an FT-243 holder is the approximate upper tuning limit. The tuning range is downward from that point. Keep this in mind when ordering crystals. Smaller crystals (HC-6, HC-18) may tune up to 1 kHz higher than the marked frequency.

It's nice to move around the band and answer other stations when using low power instead of being "rock-bound." Once you find their signal, how do you get your transmitter there? Calibrating the dial helps, but only for approximate tuning. Unfortunately, the calibration becomes invalid if you plug in a different crystal. Simply press the key and turn the tuning knob, but not on the air. Use a dummy antenna and match the beat note by listening to your receiver. When the other station finishes calling CQ, switch to the antenna and reply.

I have attempted to make this transmitter as useful as possible, considering the limited number of parts and the circuit simplicity. I would like to thank John Carter W5LGO for providing a great deal of assistance in the circuit design, board layout, board fabrication, testing and parts procurement. Circuit board kits and bare boards are available from John at 1620 S.E. 24, Norman OK 73071. Bare boards are $7.50. Kits with a crystal are $39. Thanks also goes to intrepid Oklahoma area amateurs who served as guinea pigs by providing feedback about construction and operation.

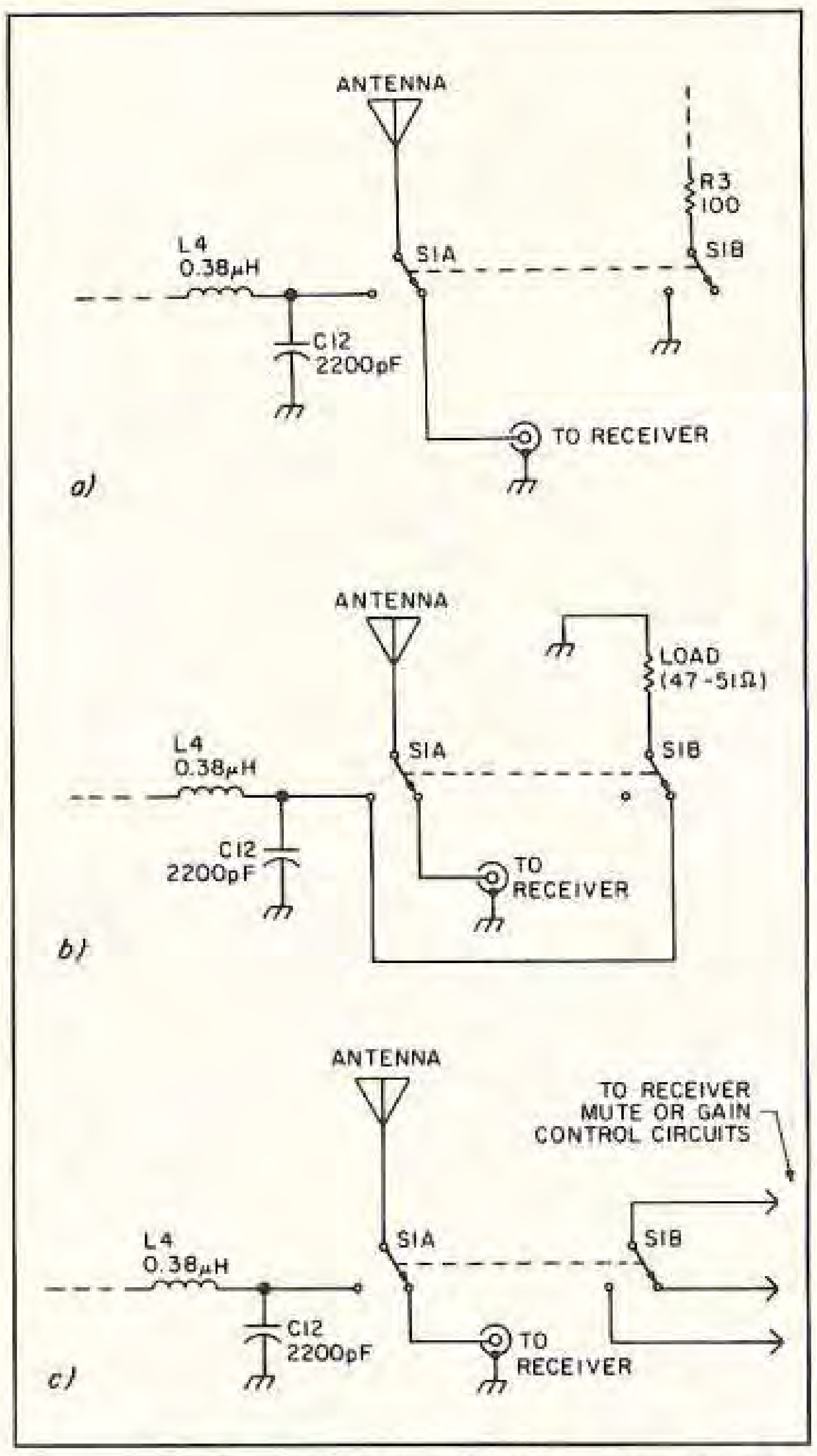


Figure 6. A miniature double-pole double-throw toggle switch can make life with a Rock Bender more pleasant. At A, antenna switching is accomplished by S1A. Amplifier keying is used. The oscillator is turned on by S1B in the transmit position. A keyed oscillator is used at B and a dummy load is automatically switched in during receive. This allows you to press the key and spot the transmitter without putting a signal on the air. C shows how S1B could also be used to reduce receiver gain. You can have a more pleasant sounding and accurate representation of the transmitted signal if receiver overload is minimized in this manner. Where and how you connect S1B will depend on the receiver being used.

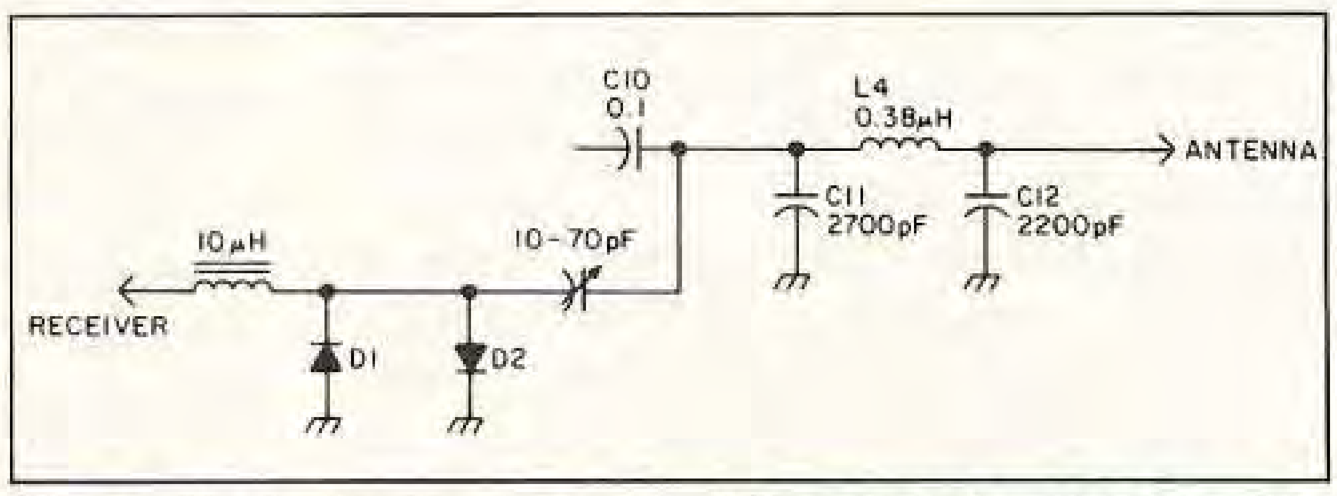


Figure 7. A simple electronic TR switch for 7 MHz. The variable capacitor is adjusted for maximum receiver sensitivity. This will be around 50 pF with a non-reactive receiver input. D1 and D2 are high-speed silicon diodes such as 1N914 types. Receiver overload is severe (not damaging). Some form of automatic or manual gain control may make the keying sound better in your station receiver.

The pride and satisfaction of telling another operator, "Rig is home-brew," has to be experienced to be believed. Building your own equipment can open up a fascinating new dimension of amateur radio. Try it out and see! 73

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