15-meter sideband transceiver

A construction project
of solid design
with step-by-step explanations
of each circuit function

With some careful shopping, it's possible to build a 15-meter sideband transceiver for less than $100. The design presented here is for a basic rig at minimum cost, but with excellent features:

Receiver: 0.5 μV sensitivity; 1.0 μV agc threshold; 0.5-watt audio output; 2000-Hz selectivity; agc; 80 dB compressed to 4 dB; CW audio filter.
Transmitter: 10 watts PEP; fully adjustable output; CW break-in keying; 50-dB carrier and LSB suppression.

I designed this rig for 15-meters because propagation conditions on this band put low-power operators at less of a disadvantage than on the other bands. If you prefer, the rig could be built for the 20-meter band by using a different offset crystal frequency and by adjusting several tuned circuits. With an output that is fully adjustable from a pot, it makes a good exciter for a linear amplifier.

theory of operation

Some of the circuit details may appear unfamiliar or unusual, but I will provide enough of an explanation for you to understand how the circuit operates. Component substitutions may be made to hold the cost down.

Let's start by reviewing the receiver signal path, beginning at the antenna jack (see **figs. 1** and **7**). No antenna relay is used. Instead, the input signal is coupled from the antenna low-pass filter to the receiver rf amplifier through a series-resonant circuit, C1-L1. This series-resonant circuit is used both as a T-R switch during transmit and as an rf attenuator during receive.

A series L-C circuit presents a low impedance at resonance, while the center junction is at a high im-

pedance. If you put a variable resistor from this junction to ground, you create a variable attenuator. But instead of a resistor, use the collector impedance of a transistor. The transistor looks like a small capacitor (junction capacitance) in parallel with a variable resistance. The resistance value is controlled by the dc base current, as shown in **fig. 2**, as long as the signal amplitude doesn't forward-bias the transistor junctions. A typical value is less than 10 ohms with 1 mA of base current, and it increases to nearly infinity as base current reduces to zero. The effect of the junction capacitance must be compensated for, so avoid transistors with large capacitance. A diode across the transistor protects the receiver's front-end from other transmitters feeding antennas on the same tower. The circuit can also be used for filtering if desired, but it doesn't have to be. In this case, filtering was not a concern.

There is a trade-off that must be made. As the L/C ratio gets larger, you get higher Q and more attenuation range. But as the capacitor value approaches the value of the shunt capacitance from the transistor and diode, the capacitive voltage-divider effect significantly attenuates the input signal. The L1-C1 values were chosen for a good compromise, and they have low Q so that fixed components with normal tolerances can be used.

The input signal from the rf attenuator is coupled to an rf amplifier, Q2, with about 20 dB of gain. Tuned transformers are used at the input and output of this stage to prevent image and i-f feedthrough. The transistor that I used was an inexpensive general-purpose type, the 2N3904. This transistor's input impedance is about 50 ohms, so the transformer has unity impe-

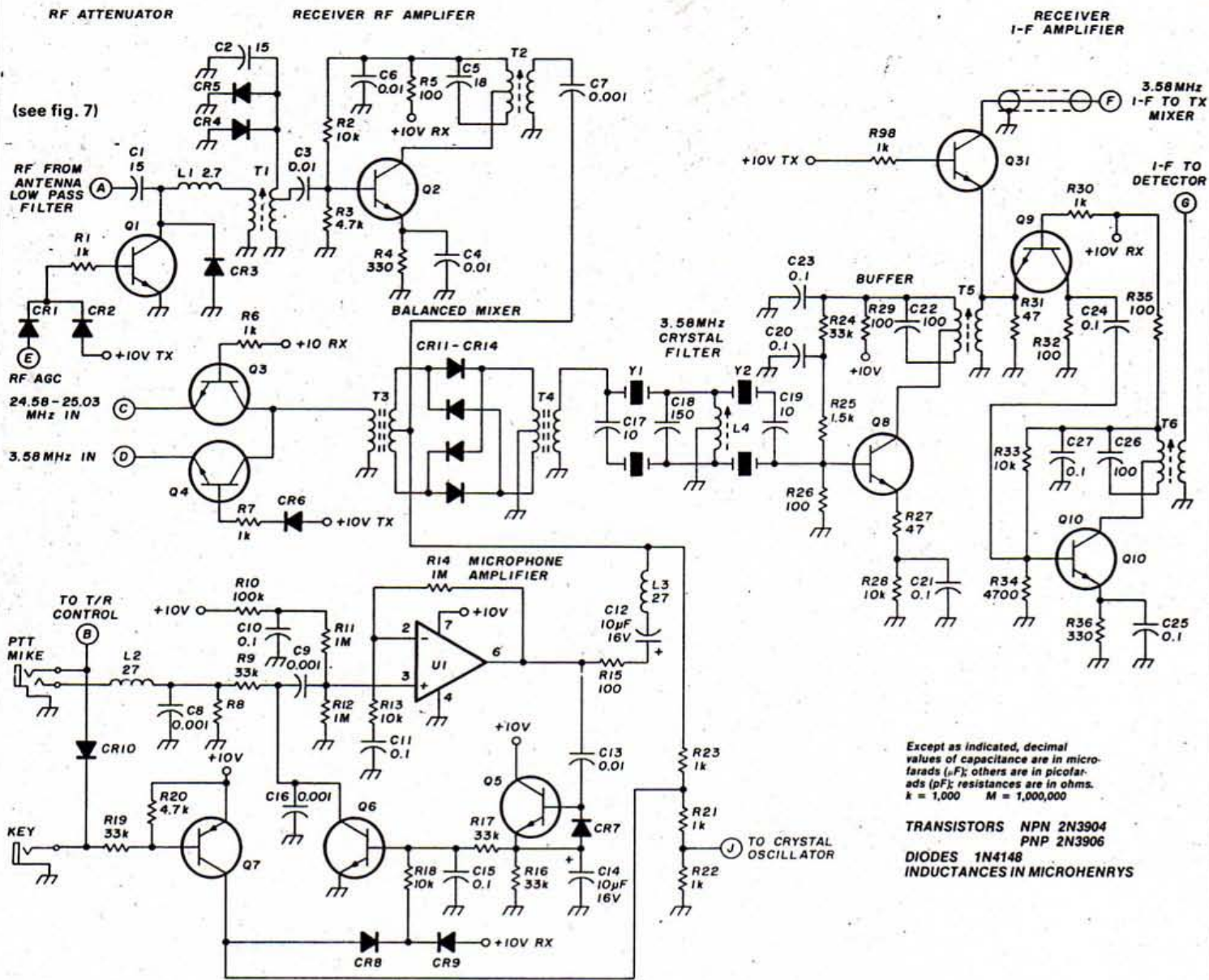By **Douglas Glenn, WA4ZXF**, 715 Fairlane Drive, Lewisburg, Tennessee 37091

fig. 1. The heart of the rig is a homebrew balanced mixer and crystal filter. Schottky diodes in the balanced mixer would be good substitutes.

dance ratio from input to base. The circuit Q is not allowed to get too high, which would hurt sensitivity at the band edges. Diodes across the high impedance winding give extra protection from high-level signals.

The output of the rf amplifier is coupled to the first mixer by a capacitor, C7. This same mixer is used as the balanced modulator during transmit. The mixer is a double-balanced, diode-ring-type, selected because it provides good performance, is inexpensive, and is easy to build. The output transformer is wound to provide the impedance needed by the crystal filter instead of the usual 50 ohms. Good carrier suppression requires matching of the diodes. But this is easy, as explained later.

The mixer input that is used for the signal from the receiver's rf amplifier is also used as the audio input

during transmit. To avoid the need for a switch of some kind at this mixer input, the high frequency signal in receive is coupled through capacitor C7, blocking the low-frequency audio during transmit. Similarly, coil L3 in series with the audio blocks the rf.

During receive, the local oscillator input to the mixer is from the high frequency VFO, but in transmit this same input is from a lower-frequency crystal oscillator. Two transistors (Q3 and Q4) provide the mixer input switching function. A relay could be used but it would probably cost more, take up more board space, and draw more power-supply current. This analog switch doesn't provide the high isolation of a relay, so you may notice a birdie 30 kHz above the top edge of the band (6 × 3.58 MHz) in receive. To minimize this, a diode is placed in series with the base of Q4, increasing the turn-on threshold.
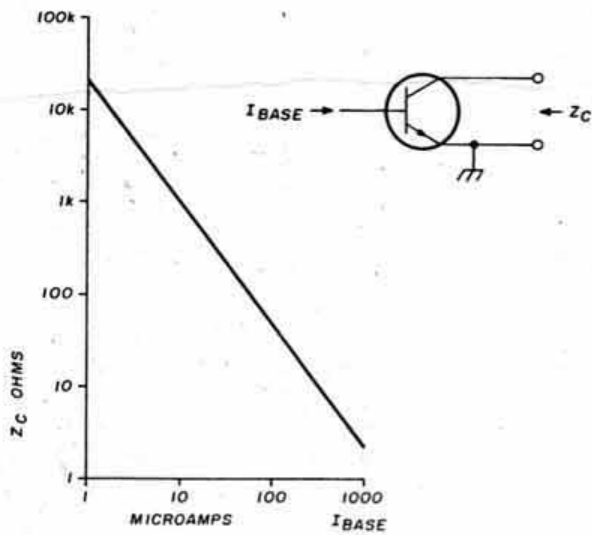
fig. 2. Resistive part of small-signal collector impedance versus dc base current. At high frequencies, the collector junction capacitance will appear in parallel with the resistance.
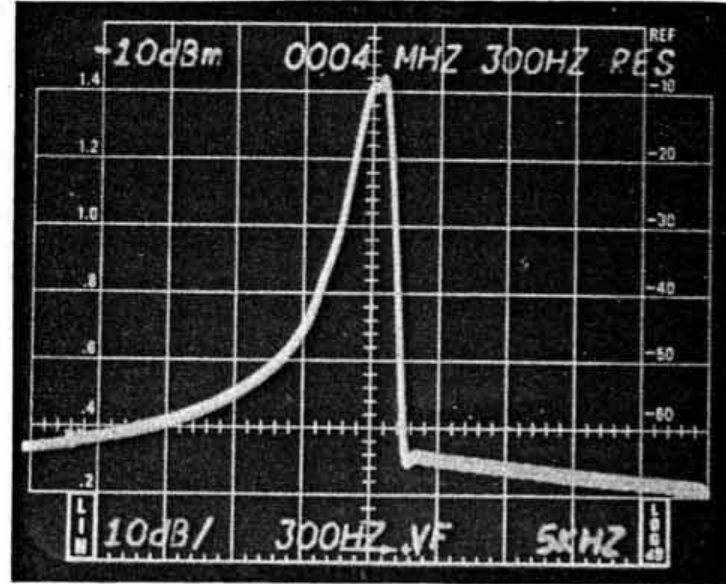

fig. 3. Crystal filter response with 1000 ohm source and load. Insertion loss is 5 dB.

crystal filter

An inexpensive crystal filter requires inexpensive crystals. At present, the most readily available and inexpensive crystals are TV color-burst crystals at 3.58 MHz, which are used here. The circuit is a standard four-crystal lattice. This requires two sets of two crystals with a small frequency difference. Since color-burst crystals all come at the same frequency, small capacitors are inserted in series with the crystals on opposite corners of the lattice to provide the needed frequency difference. The value of the capacitors establishes the filter's bandwidth. I used capacitor values of 10 pF, which results in about a 2-kHz bandwidth. Smaller capacitor values will give wider bandwidth. You should not try to make it too
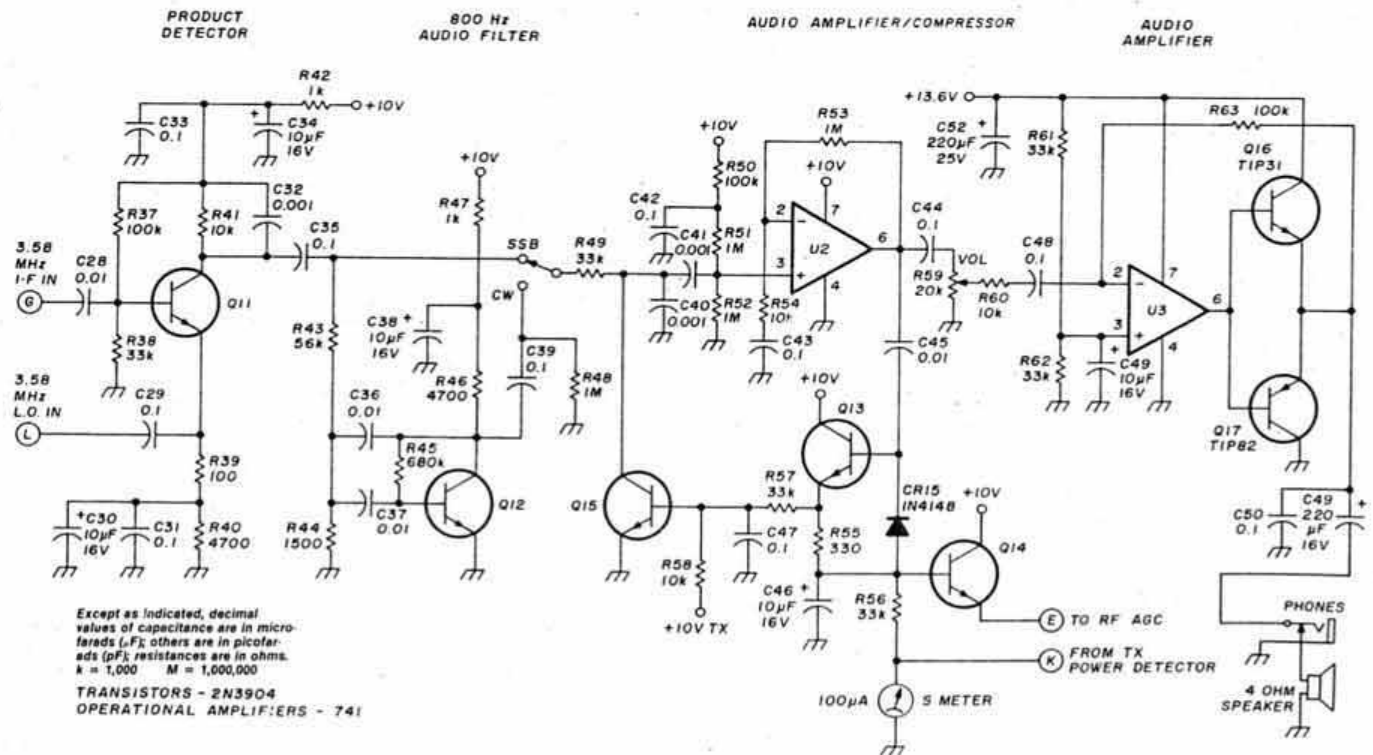

fig. 4. The audio circuit provides a lot of the receiver's gain. The input to the detector at the compression threshold is about −55 dBm.

much wider or you will have trouble adjusting the 3.58-MHz oscillator later. I used the small, round, axial-leaded, titanium-dioxide capacitors found in many TVs and fm tuners, but only because I had some handy; other ceramic or mica 5-percent-tolerance types will work. **Fig. 3** shows the shape of the filter. The shape obviously dictates use for the lower sideband. Since the upper sideband is commonly used on 15-meters, high side injection must be used in a mixer to invert the sidebands.

The filter's output is terminated by a buffer amplifier, Q8. The 1000-ohm filter load is supplied by the base bias resistors in parallel with the transistor's input impedance. Part of the amplifier's emitter resistance is un-bypassed to keep the transistor's impedance high. This sacrifices some gain, but allows for accurate control of the filter's termination impedance by the fixed resistors.

The output of the buffer amplifier is coupled to an i-f amplifier, Q10, in receive, or to the second conversion mixer in transmit. Transistors Q9 and Q31 are again used as analog switches. In receive, the i-f signal is amplified and sent to the receiver's detector. The receiver i-f amplifier is turned off during transmit to prevent the possibility that the oscillator signal might bypass the crystal filter.

receiver audio circuits

The receiver's detector (see **fig. 4**) is a single transistor, Q11, configured as a mixer for product detection. Signals feed the base while the local oscillator is injected at the emitter. The collector load of the detector is bypassed for rf, leaving only the recovered audio.

The audio is coupled to an active unity gain bandpass filter, Q12, centered at 800 Hz. Since neither high gain nor high Q is needed, I couldn't justify using an op-amp when a single transistor would do. The formulas that you would use with an op-amp don't work with the low-input impedance of the transistor. The filter Q and center frequency will be less than predicted. As shown, the filter is centered at 800 Hz with a 300-Hz bandwidth. There's no need for precision components in the filter because the filter's performance can be easily adjusted using the two voltage divider resistors at the input (R43 and R44). The small resistor to ground, R44, will vary the center frequency (less resistance for higher frequency) and the large resistor in series with the input, R43, is then changed to set the gain again to unity. A SPDT switch bypasses the audio filter for phone reception.

The wide or narrow audio from the bandwidth switch is coupled to the receiver's audio amplifier/compressor. This circuit is configured as a current-controlled attenuator followed by a 40-dB gain amplifier. I used 741-type op-amps because they are inexpensive and readily available. The op-amp is not being used near its maximum gain or slew rate, so you can get by with a 10-volt supply. The attenuator is ahead of, not inside, the feedback loop and consequently loop gain remains high at all input levels. This arrangement provides tight control of the audio level. You'll never have to dive for the gain control or claw at your headphones when a strong signal comes on frequency.

The attenuator is a voltage divider that consists of a fixed resistor, R49, and the variable impedance of Q15, which has the characteristic shown in **fig. 2.** This controls the signal level at the op-amp input. A transistor peak detector, Q13, at the amplifier's output provides drive to the attenuator in the form of base current to Q15. The compression threshold occurs when the peak-to-peak output of the amplifier exceeds the base-emitter diode drop of Q13. This corresponds to 210 mV rms for a silicon transistor, or 2 mV at the compressor input. The circuit features a fast-attack, slow-decay characteristic compatible with speech signals. The circuit also limits sharp noise pulses. A small resistor, R55, is placed between the emitter of the peak detector transistor and the large storage capacitor, C46. Short noise pulses are coupled directly to the attenuator, but only slightly affect the charge on the storage capacitor. A smaller capacitor, C47, is placed across the base-input of the attenuator transistor; it serves only to eliminate the audible pop that would occur when the input signal crosses the compression threshold. Once in compression, the voltage across this capacitor is fixed at the potential of a base-emitter diode drop and will not limit the response to the noise pulses or the fast attack characteristic. During transmit, the receiver's audio gain is killed by forcing the attenuator transistor to saturate. This doesn't charge the storage capacitor, so the receiver is at full gain and ready to go as soon as the transmit bias is removed.

The voltage on the storage capacitor is fed to the receiver's front-end attenuator as rf agc. An emitter follower, Q14, is used to reduce the loading on the storage capacitor and a diode is placed in series with the emitter follower output to protect it from reverse bias damage during transmit. The result is that the rf agc voltage is reduced by two diode drops. This provides delay in the activation of the rf attenuator so that the input is not attenuated until the signal is well above the noise.

The voltage on the storage capacitor is also used to operate the receiver's S-meter. The S-meter current helps to control the decay time of the receiver agc and it ensures that the capacitor discharges completely when there is no signal received. If you don't use a meter, replace it with a short; don't omit the discharge resistor. I used a surplus meter that I
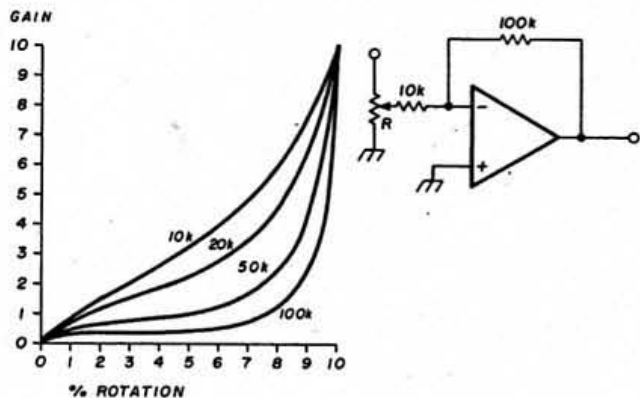
fig. 5. Gain versus pot rotation. You can simulate a logarithmic response by selecting the pot's resistance.

increase the damping of your meter if you want. You'll have to experiment to find the right value.

The audio output amplifier uses an op-amp followed by a high current buffer. The buffer transistors are not biased into the linear range, but they are included inside the feedback loop. The slight amount of crossover distortion won't be noticed under normal conditions, and it's a small price to pay for circuit simplicity and the saving in quiescent bias current. A capacitor was found to be necessary across the output to bypass rf pickup that had the effect of making the audio amplifier squeal during transmit, especially when I was using an external speaker.

The output amplifier is operated directly from the external 13.6-volt supply. Power supply hum is not a problem because of the op-amp's good power supply rejection ratio and a heavily bypassed reference (noninverting) input. Operating from a higher supply voltage also increases the maximum output power available. In addition, stability of the audio circuits is improved because the supply voltage for this high level circuit is isolated from the supply for the low-level circuits.

One interesting effect of this circuit is that a linear volume control gives a non-linear response to the cir-

picked up at a hamfest for half a dollar. I painted over the face and drew a new scale. The meter doesn't read until the received signal is above the agc threshold at 1 microvolt. This corresponds to an S-level of about 3.5, so the first mark on the meter is S-4. You can add capacitance across the meter's terminals to
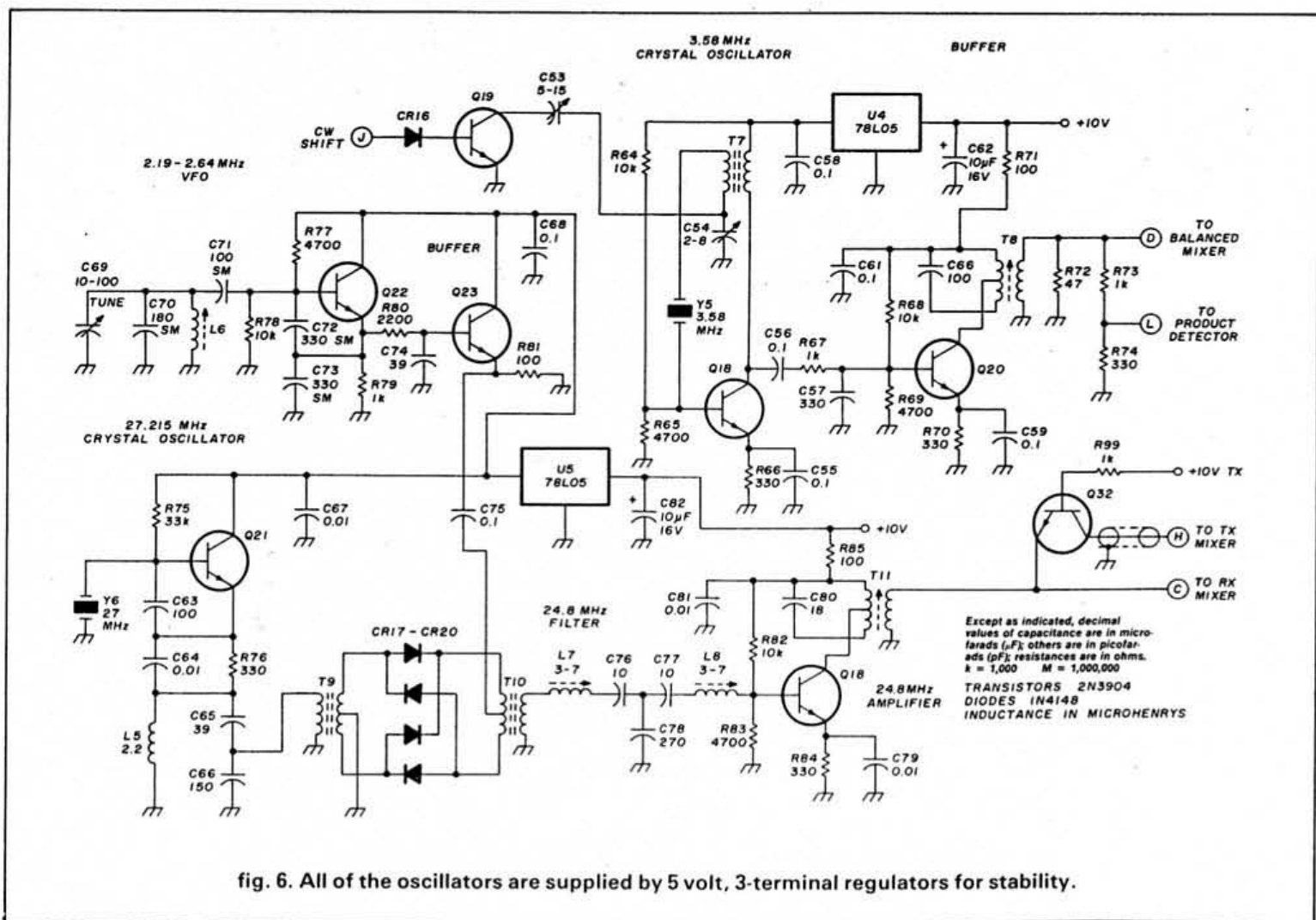

fig. 6. All of the oscillators are supplied by 5 volt, 3-terminal regulators for stability.
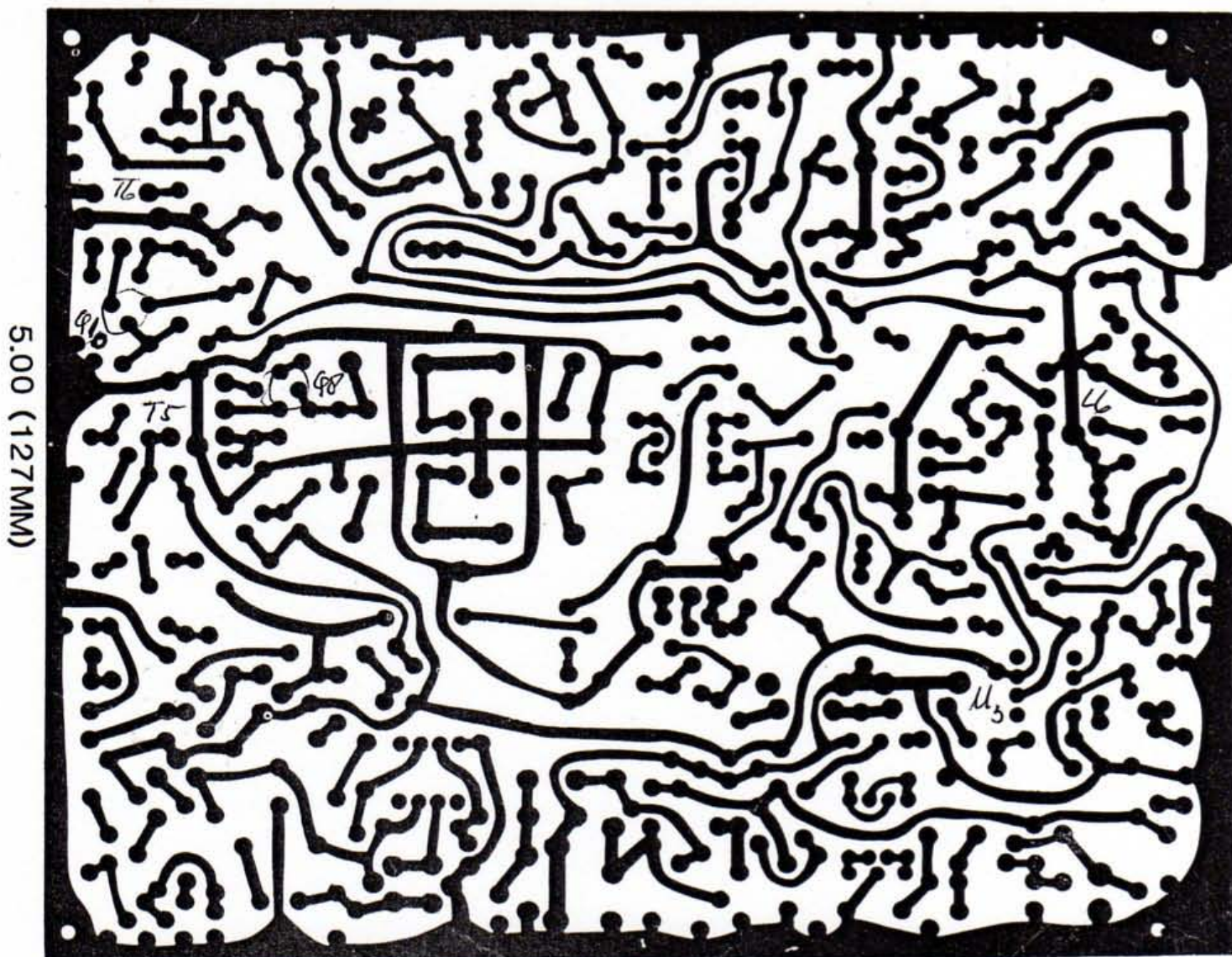
cuit. The shape is not the true logarithmic curve of audio controls, but the overall effect is similar. Part of the pot's resistance adds to the resistance in series with the op-amp input and so changes the circuit's gain slope as the pot is rotated (see **fig. 5**). The effect is more pronounced for pots with larger resistance values. If you use a pot that is significantly more than 20 kilohms, you may want to proportionately increase the input and feedback resistors.

transmitter circuits

Transmitter circuit review begins at the microphone input. (see **fig. 1**) The microphone amplifier uses a compressor amplifier (U1, Q5, Q6, etc.) nearly identical to that used in the receiver. By using a compressor that maintains a constant audio level, the other circuits can be optimized for this level. The only circuit difference (from the receiver's compressor) is one missing resistor. The resistor is omitted since the microphone amplifier doesn't have to contend with receiver impulse noise.

The amplifier input is terminated for a dynamic microphone. This is because the inexpensive, readily available microphones for citizen band sets are usually of this type. A filter consisting of a coil and capacitor keeps rf pickup out of the radio. A higher input impedance, for another type of microphone, would require some redesign of the input.

The output of the microphone amplifier is coupled to the balanced mixer. The carrier signal is suppressed at least 30 dB by the balanced mixer. The signal then passes through the crystal filter, which removes the upper sideband and suppresses the carrier another 20 dB. When keyed for CW, the mixer balance is upset intentionally and the carrier comes up to full level. A transistor switch, Q7, supplies current to the dc-coupled input of the mixer to unbalance the mixer. At the same time, this switch sends current to the current-controlled attenuator of the microphone amplifier. This kills the gain of the microphone amplifier and prevents audio from being superimposed on the CW signal.
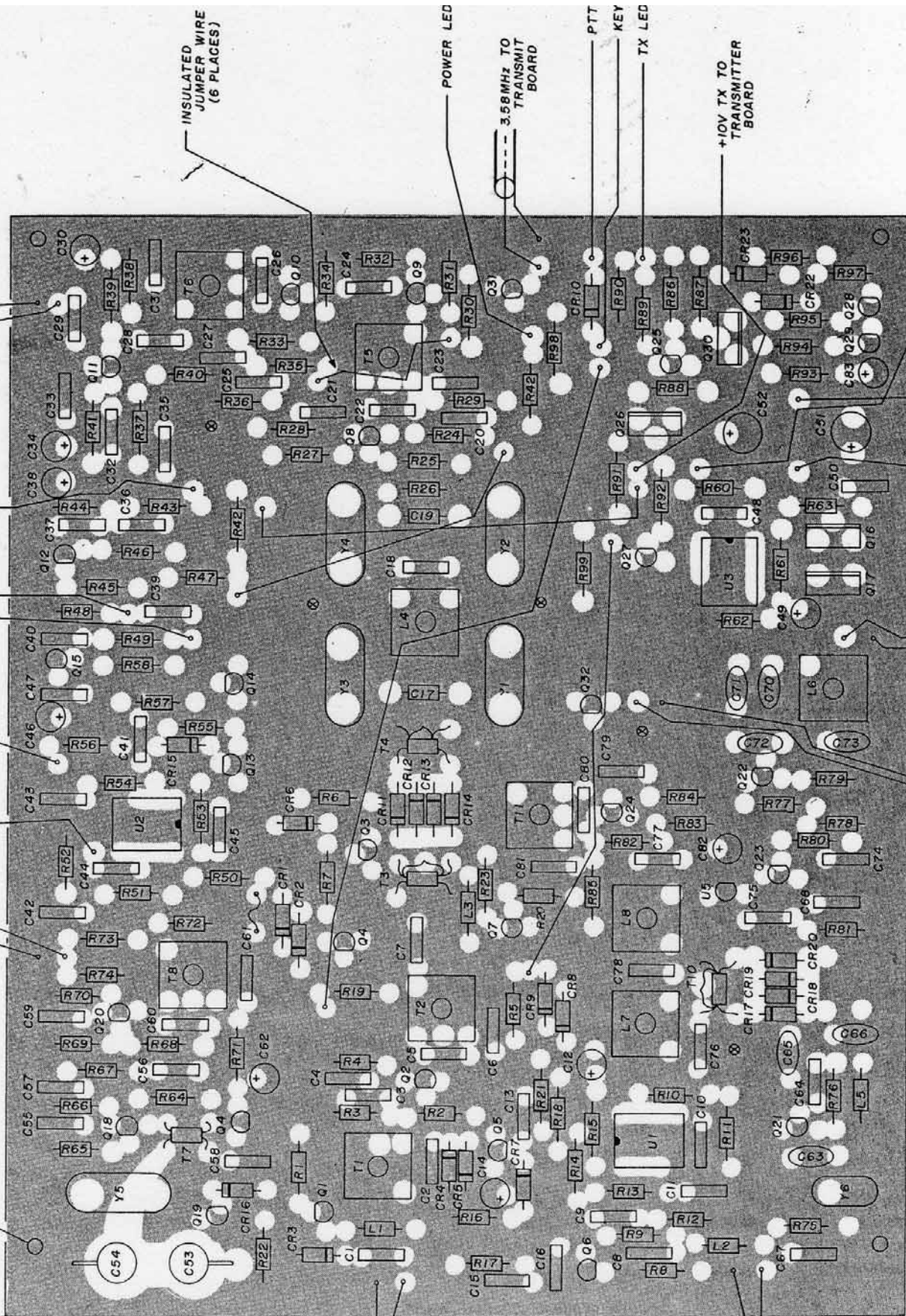

6.25 (159MM)

Main circuit board PC layout.

Component placement / assembly diagram of a circuit board. Labels and callouts include:

- INSULATED JUMPER WIRE (6 PLACES)
- POWER LED
- 3.58MHz TO TRANSMIT BOARD
- PTT
- KEY
- TX LED
- +10V TX TO TRANSMITTER BOARD
- VOLUME WIPER
- SPEAKER OUT
- TO VARIABLE TUNING CAPACITOR (C69)
- VFO TO TRANSMITTER BOARD
- BANDWIDTH SWITCH
- SSB
- CW
- VOLUME HI
- S METER
- HOLE FOR NO. 4 SCREW
- ⊗ SYMBOL SHOWS LOCATION OF 2-WIRES (5 PLACES)
- RECEIVER IN FROM ANTENNA LOWPASS FILTER ON TRANSMITTER BOARD
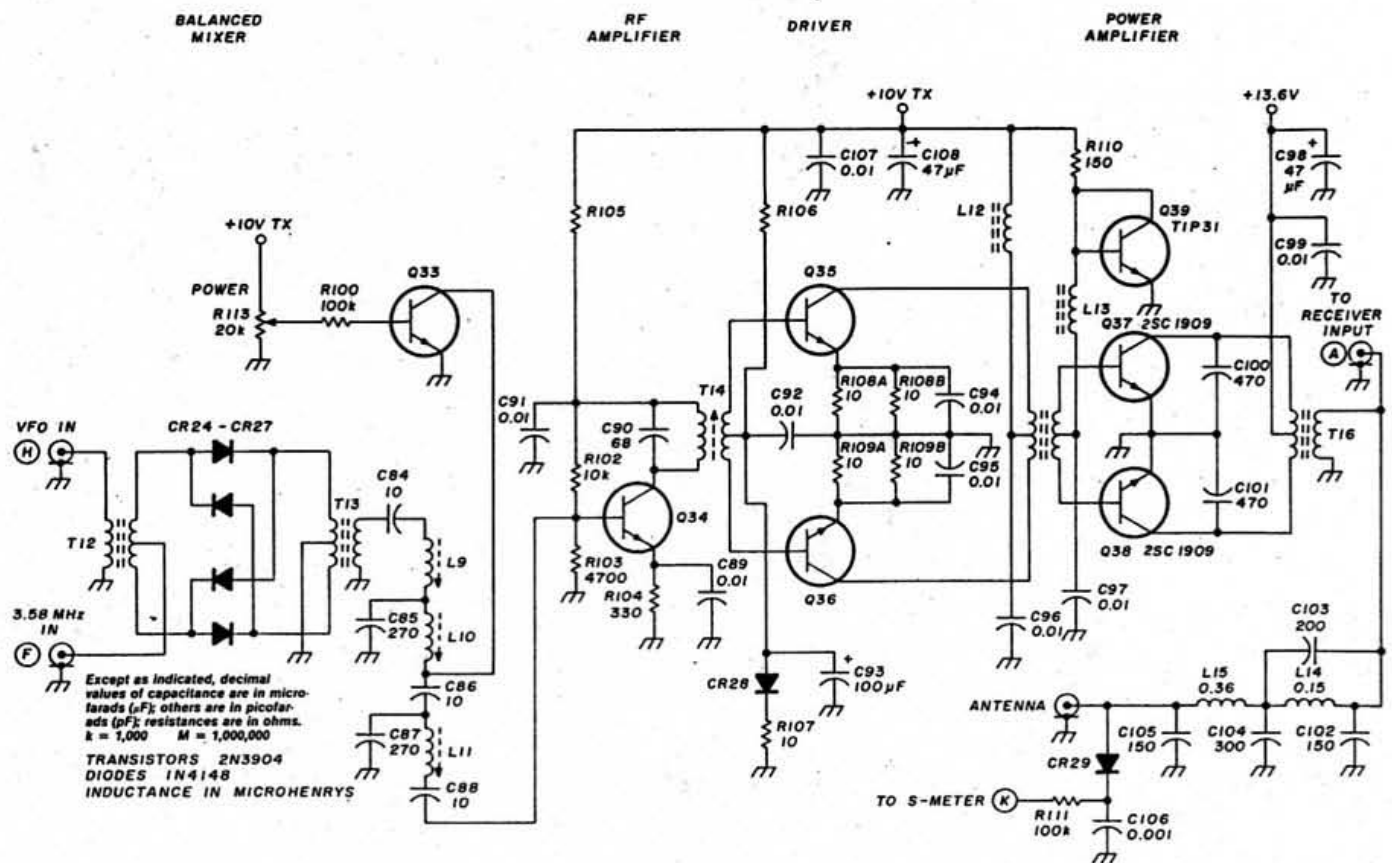- MICROPHONE IN

fig. 7. The power amplifier draws nearly 2 amperes at maximum output, but idle current is quite low; less than 20 mA.

carrier oscillator

The carrier oscillator (see **fig. 6**) also uses a 3.58-MHz color-burst crystal. The oscillator circuit configuration was selected for its very good frequency stability. The phase inversion, from collector to base of the transistor, is provided by a transformer rather than some form of resonant circuit. This helps stability by removing all frequency-sensitive components except the crystal and a small capacitor. The capacitor shifts the series resonance of the crystal-capacitor combination to the desired frequency. The transformer is constructed by winding magnet wire on a ferrite bead. The capacitor can be a fixed type that's selected for the proper frequency, or a variable if it's a stable type.

The capacitance is located in the ground leg of the series circuit so that another capacitor can be switched in parallel to shift the frequency. This is done when the rig is keyed for CW. The purpose is to shift the frequency by 800 Hz. When properly adjusted, the output in transmit will be the same frequency as a received signal centered in the CW audio filter passband. A transistor is used as the switch. A low capacitance transistor is absolutely necessary in this location.

The output of the oscillator is coupled to a buffer stage, Q29, through a low-pass R-C section. The R-C section does three things: The series resistor isolates the oscillator from the rest of the circuit, the low-pass section filters the signal providing a sine-wave output, and the signal is adjusted for optimum drive to the mixer. The value of the series resistor, R66, or shunt capacitor, C57, can be changed, if necessary, for more or less mixer drive. The best drive level would be + 7 dBm (a 0.5 V rms). However, this level is too high for the transistor analog switch. I set the drive level to approximately 0.35 V rms (+ 4 dBm) with satisfactory performance. A voltage divider across the output of the buffer sets the proper drive level for the receiver's detector, about 60 mV. This level is not critical. Any value from 40 to 220 mV will work, but you should keep it toward the low end of the range. At the higher drive levels, the receiver's detector is more susceptible to stray signals such as the ever-present 60 Hz hum.

variable frequency oscillator

The high-frequency VFO that tunes the transceiver is critical to the rig's performance. It should be stable and not change frequency when the transmitter is
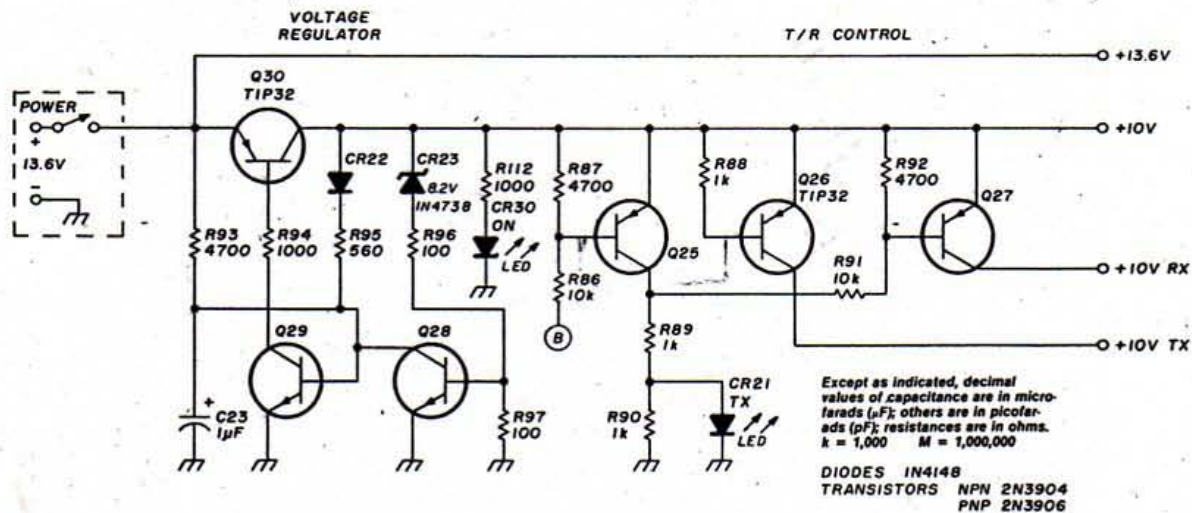
fig. 8. The voltage regulator and T/R control provide dc power to the various parts of the circuit.

keyed. The design uses a low-frequency variable oscillator which is mixed with a high-frequency crystal offset oscillator to arrive at the needed injection frequency.

High-side injection is necessary to invert the sideband, as explained above. To cover 15 meters, the injection frequency is 24.58-25.03 MHz. The least expensive and most readily available crystals, after color-burst crystals, are 27 MHz units intended for multichannel citizen band HTs. One of these is used for the offset oscillator. They are usually sold in T-R pairs for less than $5. I used a channel 21 transmit (27.215 MHz) crystal. The exact frequency is not very important since the VFO is aligned to set the final frequency. If you have a choice, use a higher channel crystal since this will improve spurious responses. The output of the crystal oscillator is coupled to the offset mixer by a capacitive voltage divider that couples the proper level to the mixer.

The low frequency variable oscillator, Q22, is a standard Seiler type that tunes 2.19-2.64 MHz to cover 15-meters. Silver mica capacitors are used in the frequency determining circuit for improved stability. The variable capacitor used is from the oscillator stage of a two-section unit salvaged from a five-tube ac-dc broadcast receiver. If you use a variable capacitor that is significantly different, you may have to size some of the fixed capacitors proportionately. This is particularly true if your variable has more capacitance, because the oscillator quits if the L/C ratio gets too low. Increasing the value of C71 usually cures this problem. A 5-volt, three-terminal regulator, U5, operated from the regulated 10-volt supply, provides a stable, doubly regulated supply that is also used by the offset crystal oscillator. Frequency stability is good. Don't use just a zener diode; use the IC regulator. The variable oscillator output is coupled to

the offset mixer through an R-C section and emitter follower, Q23, that isolates the oscillator, reduces signal harmonics, and sets the signal to the proper level for the mixer.

The mixer is a doubly balanced, diode-ring type with a two-pole, series-resonant type filter at its output. By using a balanced mixer, the oscillator feedthrough at 27 MHz is suppressed reducing the following filter requirements. The mixer design is for a nominal 50 ohms at each port, and a commercial mixer can be substituted here. The spurious responses that result from the undesired mixer outputs, as well as the transceiver image, are above the 15-meter band so that the antenna low-pass filter aids the resonant circuits of the transceiver in minimizing spurious signals. A buffer amplifier, Q24, follows the filter that provides +3 to +4 dBm drive level to the mixers.

transmitter rf circuits

The rf circuits of the transmitter (fig. 7) are activated by the microphone PTT or key. The modulated 3.58-MHz signal is applied to a balanced mixer where it mixes with the variable frequency oscillator injected signal. The balanced mixer is the same type as the one that mixes the two oscillator signals and is at the normal 50-ohm impedance level. (A commercial mixer could be used instead.) The mixer output is passed through three poles of series-resonant filtering. This is the same type of series-resonant circuit used elsewhere. A shunt transistor, Q33, is used at the second pole. The base bias of this transistor is controlled by a pot and it becomes the transmitter power control. The fixed resistor in series with the transistor's collector determines the maximum power reduction. The control can vary the transmitter output at least 30 dB (10 watts to 10 milliwatts). The

2.00 (51MM)

6.70 (170MM)

Transmitter board PC layout.

attenuator is placed after all of the mixing stages to attenuate the low level spurious signals along with the desired output.

The mixer output, after filtering, is amplified in turn by a class A stage and a push-pull driver stage running class AB, prior to the final. The final amplifier, also running class AB push-pull, uses a pair of transistors intended for the output stages of 5 watt citizen band transmitters (2SC1909 from Radio Shack). Base bias current is controlled by transistor Q39 connected as a current mirror. The bias transistor is a general purpose TO-220 type that is attached to the same heatsink as the finals for temperature compensation. The input and output transformers of the final are wound on the two-hole ferrite balun cores that are found at the VHF input of many TV sets. The ones I used were salvaged from the coupler of a TV game. The final output is passed through a low-pass filter. The filter was designed to put a notch at the mixer image frequency, which is helpful in
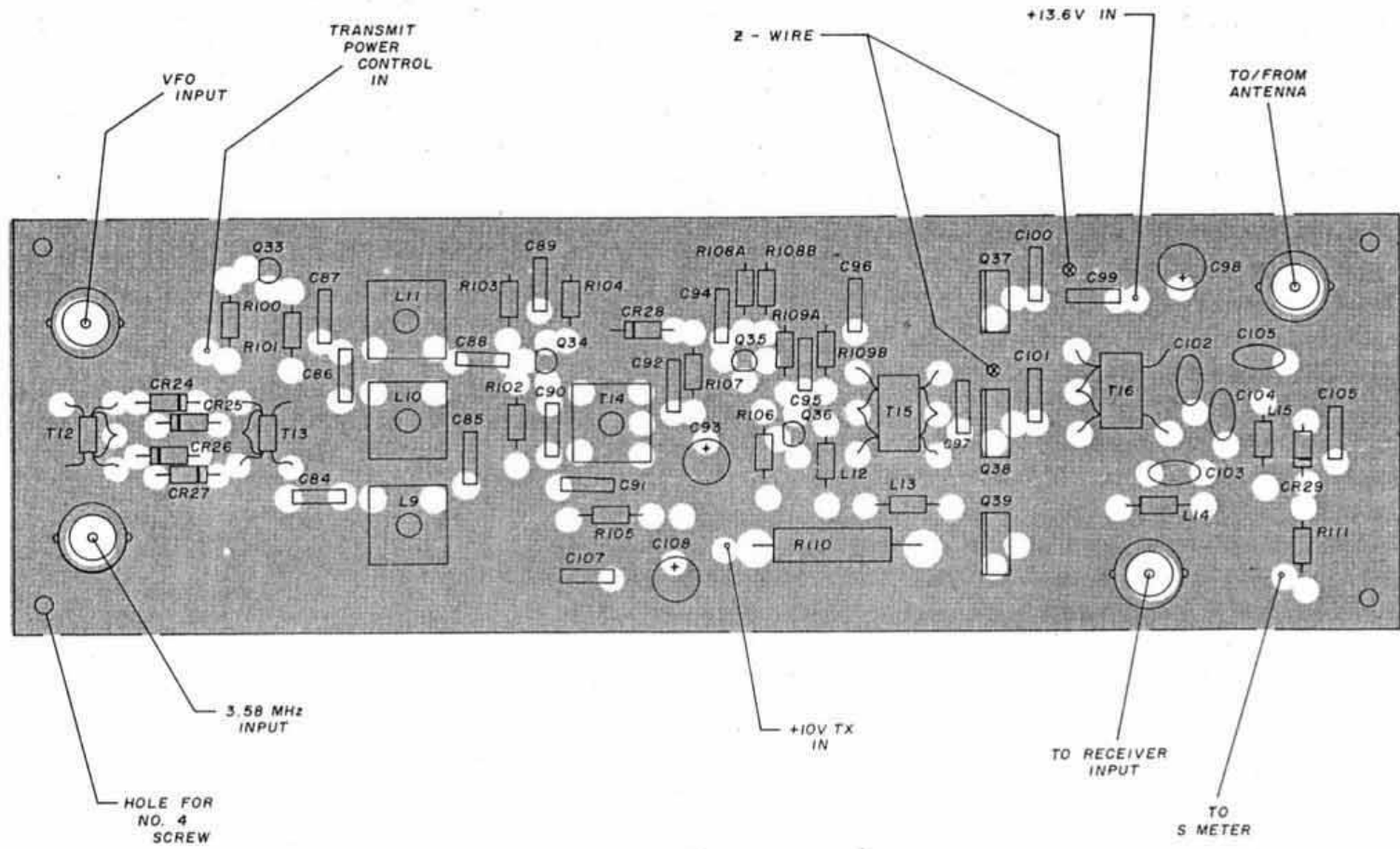
Transmitter circuit board, groundplane side with components layout superimposed.
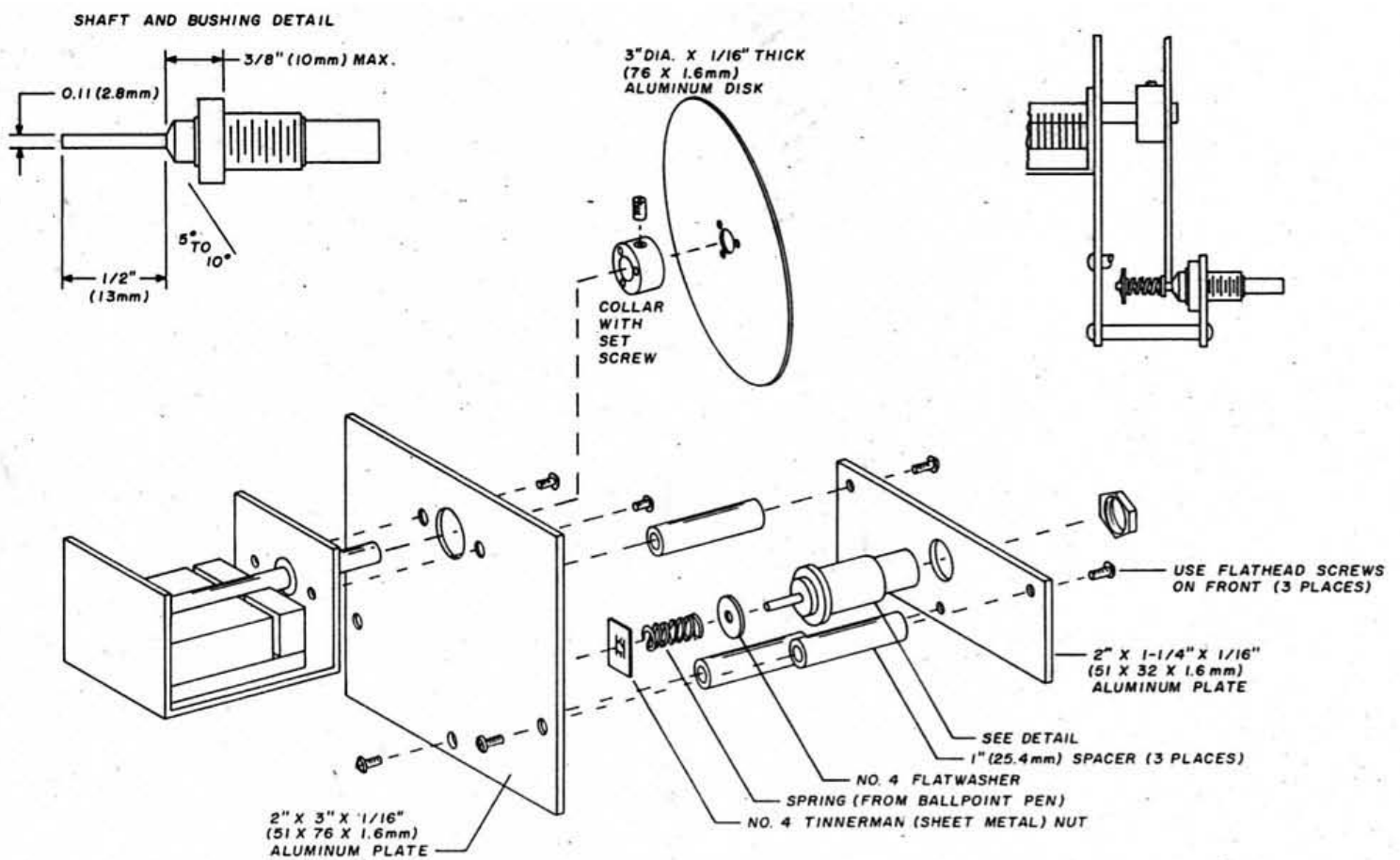
fig. 9. Exploded view of the 24:1 slow-motion drive, with the shaft and bushing detail at the upper left, and a side view of the assembly sequence at the upper right. One of the flathead screws on the front goes through the front panel to prevent rotation of the assembly around the bushing.

both transmit and receive. A diode detector at the antenna output supplies a readout of transmitter power on the front panel S-meter.

power and control circuits

The dc power for all circuits, except the transmitter final and the receiver audio output (fig. 8), is supplied by a 10-volt regulator. The design, which was adapted from one in a Fairchild Semiconductor application note, provides good regulation even when the input voltage drops close to the regulated level. The schematic shows an 8.2-volt zener diode, but a 7.5-volt or 9.1-volt diode also works if R96 is adjusted to compensate. Don't use R97 to adjust the voltage; its purpose is to set the zener current. The circuit also has a coarse form of current limiting. This occurs when Q29 saturates and the pass transistor, Q30, gets no more base drive. The point of current limiting can be set by adjusting the value of R94.

The dc power is switched to the various sections of the transceiver by a T-R control circuit. When activated by the PTT switch or CW key, power is applied to the transmitter circuits and removed from some receiver circuits. Current is also supplied to the several transistors that act as variable impedances throughout the transceiver. Most of the receiver cir-

cuits do not have the dc power removed in transmit. This enables quick recovery of the receiver for break-in keying.

construction

All of the circuits are contained on two doubled-sided printed circuit boards. The transmitter's mixer and amplifier chain are on one board, and everything else is on the second. This separates the high-level transmitter circuits from the other low-level circuits. You'll notice from the board layouts that the top (component) side is devoted to ground plane. Jumper wires are used where necessary rather than disturb the continuity of the ground plane. If, like me, you don't have the capability of plated-through holes on circuit boards, solder a number of component leads on top and bottom to link the ground plane. I usually did this only on resistor leads and the few Z-wires where access to the top of the lead is easy. This is particularly important on the transmitter board and especially for the emitter leads of the P.A. output transistors which need a good solid ground.

The transceiver was housed in a cabinet (Radio Shack #270-270) that provides plenty of space. The main PC board is mounted on the bottom of the cabinet using metal standoffs, which grounds the circuit

to the cabinet. The transmitter board is mounted on the rear wall the same way. The layout of the transmitter board includes provisions for four PC mount phono jacks, that are used for the rf connections. This was done to simplify removal of the board, but a soldered connection is the obvious way to go if you can't find PC phono jacks. The heatsink for the transmitter's final is a 2.5 × 4 inch (60 × 100 mm) piece of 1/8-inch (3-mm) aluminum plate that is secured to and insulated from the three power transistors that stand in a line across the PC board. The heatsink is not grounded and not supported in any other way. The speaker is mounted on a bracket behind perforations in the cover since the cover has to slide on when installed. The material that forms the front panel of the cabinet is soft aluminum, but it is secured at all four corners when the cover is in place. To increase the rigidity of the front panel, I used a piece of 0.062-inch (1.6-mm) aluminum cut to fit the front panel. It is held in place by the bushings of the various panel mounted components. It is also easier

to paint and letter this flat plate and it covers four holes in the cabinet's panel intended for handles.

Because of the wide variations in tuning capacitors that might be used, mine wasn't mounted on the circuit board. Instead, it was mounted on the front panel of the cabinet and connected to the PC board with a short length of shielded wire. The details of the tuning mechanism are shown in **fig. 9**. This design evolved during my search for a simple slow-motion drive that is easy to duplicate. I salvaged the panel bushing and shaft from an open-style, rotary-wafer switch that had a standard 1/4-inch (6-mm) shaft. The detent mechanism and switch sections are removed, leaving only the bushing and shaft. The rear end of the shaft is then turned down to a diameter of 0.11 inch (2.8 mm). Notice the angled bevel where the shaft is turned down just behind the bushing. A 3-inch (76-mm) diameter disk is fashioned from 0.062-inch (1.6-mm) aluminum and secured to a collar which can be mounted on the tuning capacitor's shaft and held in place with a setscrew. Slide

COIL WINDING CHART

REF	BOTTOM VIEW	WINDING INFORMATION
T1		PRI – 16 TURNS NO. 40, TAP AT ONE TURN, 1.5 - 4.5 μH SEC – 1 TURN NO. 40
T2		PRI – 16 TURNS NO. 40, TAP AT TWO TURNS, 1.5 - 4.5 μH SEC – 2 TURNS NO. 40
T3, T9 T10, T12 T13		SEE TEXT
T4		SEE TEXT
T5, T8		PRI – 36 TURNS NO. 34, TAP AT 6 TURNS, 10 - 30 μH SEC – 3 TURNS NO. 34
T6		PRI – 36 TURNS NO. 34, TAP AT 6 TURNS, 10 - 30 μH SEC – 3 TURNS NO. 34
T7		PRI – 7 TURNS NO. 34 SEC – 1 TURN NO. 34 CORE – FERRITE BEAD AMIDON FB-43-101, FERROXCUBE K500100/3B, ETC.
T11		PRI – 16 TURNS NO. 40, TAP AT TWO TURNS, 1.5 - 4.5 μH SEC – 2 TURNS NO. 40

REF	BOTTOM VIEW	WINDING INFORMATION
T14		PRI – 8 TURNS NO. 34, 0.4 - 1.2 μH SEC – 2 TURNS, CENTER TAP
T15		PRI – 8 TURNS NO. 26, CENTER TAP SEC – 2 TURNS NO. 26, CENTER TAP FERRITE BALUN CORE
T16		PRI – 4 TURNS NO. 22, CENTER TAP SEC – 14 TURNS NO. 26 FERRITE BALUN CORE
L4		36 TURNS NO. 34, CENTER TAP, 10 - 30 μH
L6		36 TURNS NO. 34, 10 - 30 μH CUT OFF UNUSED PINS
L7, L8 L9, L10 L11		18 TURNS NO. 34, 3 - 7 μH CUT OFF UNUSED PINS
L12, L13		3 TURNS NO. 26, CORE – 2 FERRITE BEADS END TO END AMIDON FB-43-101, FERROXCUBE K500100/3B, ETC.

the disk forward in contact with the beveled part of the shaft and tighten the setscrew. This creates a friction drive with a tuning rate of about 35 kHz per revolution and no backlash. The exact tuning rate depends on the distance from the shaft's center where contact is made with the disk. The hole for mounting the bushing is a little oversized, to allow for some adjustment. Frequency markings are applied to the disk and viewed through a window cut in the front panel. You can use a commercial vernier drive, if you have one, or as a last resort, use a small trimmer capacitor in parallel with a main tuning capacitor as a bandspread control.

component selection

There is little about the circuit that is critical. You can use substitutes for many of the components with little change in performance. I made an effort to minimize the number of component values used. Where possible, resistors and capacitors were selected from decade values in 1-3.3-10 sequence. The idea was to make it easier for those who had to buy what they didn't have. Most hams will resort to the junk box first. For resistors, watch ratios and keep the dc bias conditions for active devices from varying too much. For coupling and bypass capacitors, check the reactance at the frequency of interest and keep the leads especially short in rf circuits. If you use the circuit board layout provided, all resistors, except the bias resistor for the final, are quarter watt size. I used 1/4-inch (6.3-mm) disc ceramic and radial electrolytic capacitors throughout to minimize board size.
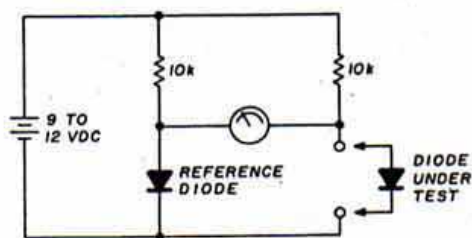

fig. 10. Use this circuit to match diodes if you don't have an accurate digital voltmeter. The reference diode is not to be one of the matched set unless you can reverse the positions of the diodes and still get a null.

You will have to wind a number of coils and transformers, the details of which are shown in the table. The variable inductances use 10-mm i-f cans that I rewound. They were originally 4.5-MHz and 10.7-MHz transformers in a selection from Poly-Paks. These higher frequency units have a plastic bobbin which makes them easy to rewind. This is not true of lower-frequency (455-kHz) transformers that use a threaded cup rather than a slug. Many of them have internal capacitors, and in some cases, I retained the internal capacitor and added enough capacitance externally to get near the value on the schematic.

Inexpensive, general-purpose transistors are used everywhere except in the final. The device that I used most was a 2N3904 (and its PNP complement, 2N3906) since it met my criteria of good performance, cost, and availability. It has the popular E-B-C lead configuration and there are a lot of substitutes that you can use without sacrificing performance,
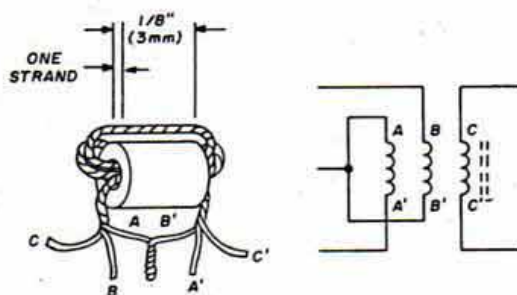

fig. 11. Typical mixer transformer. The wire should be twisted enough so you can count from 3 to 7 strands in a 1/8 inch (3 mm) length.

except possibly in the receiver front-end and transmitter driver. Remember to use transistors with low-output capacitance for Q1 and Q19. I was conservative with transistor ratings and used power-type transistors if there was a possibility of exceeding half the rating of a 2N3904.

The printed circuit layout provided accommodates the mini-dip package version of a 741 op-amp. The same layout can be used with the round metal can version if the leads are spread. Since a lot of op-amps are supplied with the same popular pinout as a 741, there are many substitutes that will work here, but make sure you use an internally compensated op-amp.

balanced mixers

The transceiver uses three double-balanced mixers. There's nothing hard about rolling your own. To get good carrier suppression, you simply have to maintain good balance. The two places where balance is important are the transformers and the diodes. Transformer balance is achieved by using transmission line techniques. Diode balance relies on matched diodes.

All of the diodes used in the transceiver, except one zener, are the same type, 1N4148 (1N914, 1N4454, etc.). You can get these diodes in quantities from mail-order houses for a nickel or less apiece.

Since you will need a total of twenty-seven for the rig, you'll have enough to find three matched sets of four. Because the highest frequency of interest is only 27 MHz, don't bother matching the reverse capacitance. Just use the same type from the same manufacturer, so the capacitance is close, and match the diodes' forward characteristic as outlined here. Measure and match the forward voltage drop across the diode with about 1 mA of bias current. A 10 K resistor in series with a stable 9 to 12 volt supply works fine. A high-impedance, accurate VTVM should be used (a digital meter is best), but don't despair if you don't have one. The bridge circuit shown in **fig. 10** works with any meter that can distinguish a change of a few microamperes.

The transformers for the transmitter and oscillator offset mixers (T9, T10, T12, T13) are the same. Using small enamel magnet wire, about AWG 34 (0.16mm), twist three strands together uniformly to make trifilar wire. Wind two turns of the trifilar wire on a ferrite bead (Ferroxcube K500100/3B, Ind. Gen. F1650-1-H, Amidon FB-43-101, etc.). Two of the strands are series connected to form the center-tap of the balanced winding (see **fig. 11**). The input transformer of the i-f mixer (T3) is constructed the same way except that two beads, stacked end-to-end, are used for the core. The output transformer of the i-f mixer (T4) is different because it matches the high impedance of the crystal filter. For this transformer, twist six strands of magnet wire together, and use two turns on a two-bead stack. Connect two strands to make the center-tapped winding, as before, then series connect the other four strands to make the high-impedance winding that connects to the crystal filter.

checkout and adjustment

Using these instructions and the theory of operation, you should have no trouble getting the rig up and running if you have had any experience with building. The first part of the circuit you want to check out is the 10-volt regulator, since this affects almost everything else. Connect the external 13.6-volt supply and monitor the input current, which should be about 100 mA for receive. The regulated output should be near 10 volts. Load the regulator's output and watch the voltage. It should change less than 10 mV for currents up to 750 mA, but go into current limiting at about 1 ampere. Adjust the value of R94 if the current limiting point is very far off.

Check the frequency response and peak gain of the CW audio bandpass filter using the adjustment points described in the theory of operation. A simple way to check out the entire audio circuit of the receiver is as follows: Set the bandwidth switch for **CW** and the **VOLUME** control at minimum, then connect a jumper from the speaker to the filter input (top of R43). When you turn up the volume, the whole loop will oscillate slightly (50-100 Hz) above the center frequency of the audio filter and the S-meter will track the volume setting.

The adjustment of the crystal filter and low-frequency crystal oscillator are interdependent. This is best done using a sweep generator. It's a slow, tedious job with an ordinary signal generator, but here's the procedure if a sweeper isn't available: Disable the AGC (lift one end of C45) and monitor the audio output, in the SSB mode, with an ac voltmeter. Start with L4 set to minimum inductance. Tune across the passband and you'll find nearly equal audio peaks at 500 and 2000 Hz with a big dip in between. Adjust the tuning of the 3.58 MHz crystal oscillator if necessary to get the frequencies near these values. Increase the inductance of L4 until the variation of audio across the passband is less than about 1 dB from 350 to 2200 Hz and there is a sharp roll-off of the audio at 300 Hz. Don't confuse the low-frequency roll-off of the audio circuits for the filter's corner. To be sure, you can tune the crystal oscillator up a little higher than normal, which will shift the audio frequencies up, so that the filter's corner frequency can be identified, then reset C54 so the corner is at 300 Hz. Set the bandwidth switch to **CW** and center the signal at the peak of the audio filter. Temporarily short the collector of Q19 to ground and adjust C53 for a zero-beat by watching the voltage at the collector of Q11 with a scope.

If you have trouble getting the 3.58-MHz oscillator adjusted properly, the problem is probably a transistor with too much junction capacitance. One possible solution is to bias the junction of Q19 by connecting a high-value resistor (10 K to 100 K) from the collector to +10 volts. You can check the operating frequency of each crystal in the circuit and use the one with the highest frequency in the oscillator.

The other adjustments consist of tuning for maximum output at the center of the band.

On-the-air reports with the rig running barefoot are favorable. A number of operators have commented on the good sounding audio quality that comes through in spite of QRP signal levels. I get questions about what kind of processor I'm using. The passband may be only 2 kHz, but only once did I get a comment about the lack of highs in the signal. My voice tends to be on the low side anyway. I've had no trouble working stations all over North and Central America from my home in Tennessee. Pile-ups on DX stations are another matter however. Of course, a linear amplifier is next on the want list.

ham radio