A Sensitive Bandspread SWL Receiver

Aaah, the nostalgiac smell of dust burning off tubes!

by Eric R. Johnson XE2/KB6EPO

Back in the 1920s and during the Great Depression era, the home-brew regenerative shortwave receiver was all the rage. Radio was coming of age and everyone wanted to listen in. Money was tight and although most commercially made radios were of the regenerative type, they were still too expensive for the average consumer. Yet the low parts count of the regenerative receiver made construction a snap and kept costs down, keeping this type of receiver popular with the home-brewer right up to the 1960s. And the regen's sensitivity was hard to match by all but the best superheterodyne receivers of the time. These attributes still hold true today!

This little radio can "hear" everything on the SWL bands that my Yeasu FT-747 can! An 8-foot piece of wire strung out along the test bench or behind the desk is more than enough to pick up all the major broadcasters. Of course, the more antenna the merrier—but the point is that excellent reception is possible with an indoor antenna right at your listening position. The three-stage circuit is typical of a "deluxe" setup of the era. The physical size is less than half of what someone in those days might have constructed using the same schematic, thanks to the substitution of "modern" miniature tubes and components.

I have departed from our theme era in the design of the power supply in order to make the receiver completely portable. In the old days they used bulky, non-rechargeable "A" and "B" batteries to provide filament and plate voltages. The super deluxe setup sported a line-operated transformer and vacuum rectifier "B battery eliminator," the use of which often required the owner to replace all the existing "DC filament" tubes in the radio with "modern AC filament" tubes. Portabili-

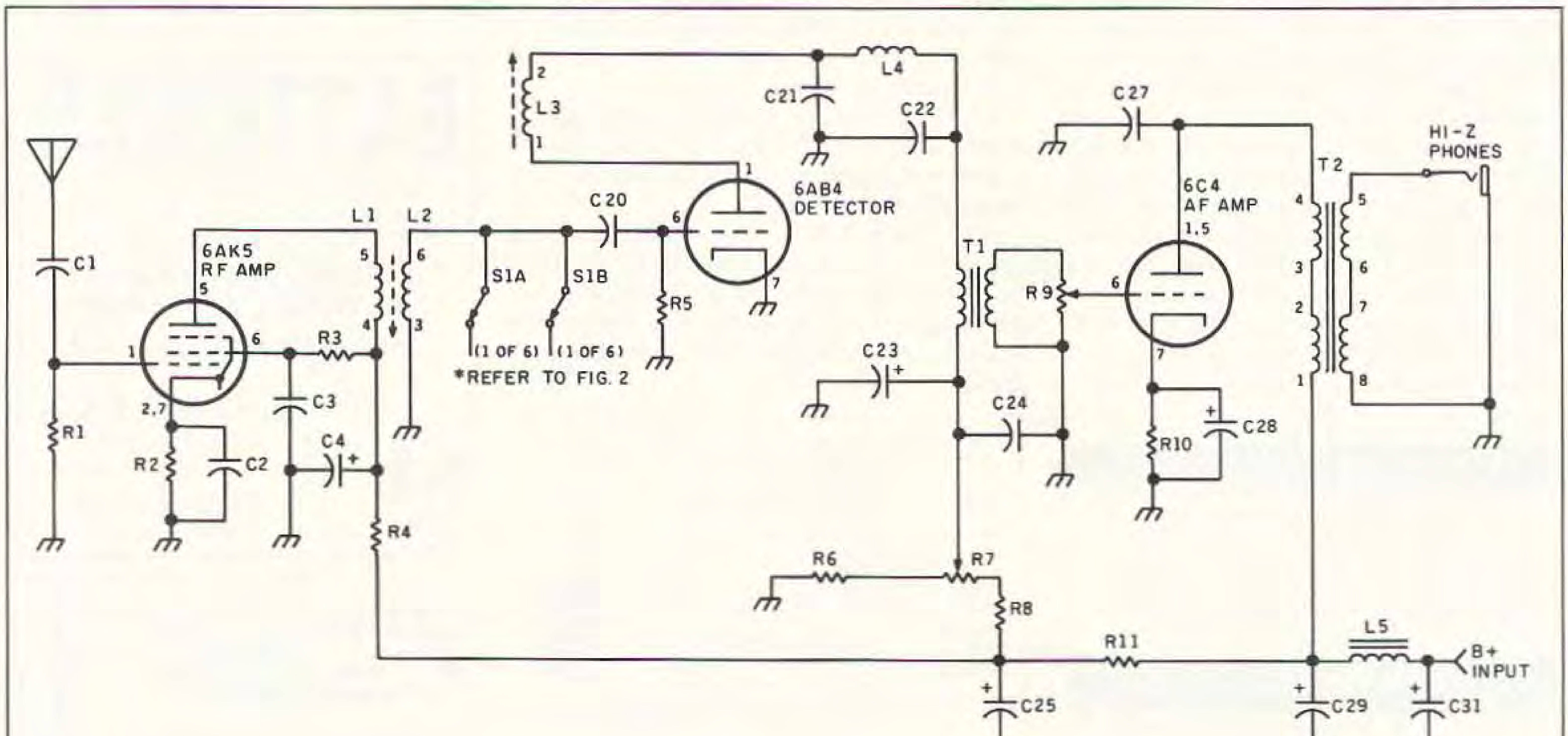

Figure 1. Receiver schematic diagram.

ty was either tedious or impossible. My power supply allows portable operation for about 10 hours from a single 6 volt, 10 amp-hour rechargeable sealed lead-acid battery (gel cell). When connected to the AC line it both operates the radio and charges the battery.

Receiver Theory of Operation

The receiver (Figure 1) consists of an untuned pentode radio frequency amplifier, a triode regenerative detector, and a power triode audio frequency amplifier. Output is into a pair of high impedance headphones, either 2k ohm magnetic types or the crystal type. Both are readily available on the surplus market. Those "extra" resistors and capacitors you see sprinkled liberally throughout the schematic are for bypassing and B+ line decoupling filters. They should not be left out of the circuit as a way to save money! These parts are what make the difference between a "sweet" stable and predictable regenerative receiver and a wild untameable howling "beast" of a receiver.

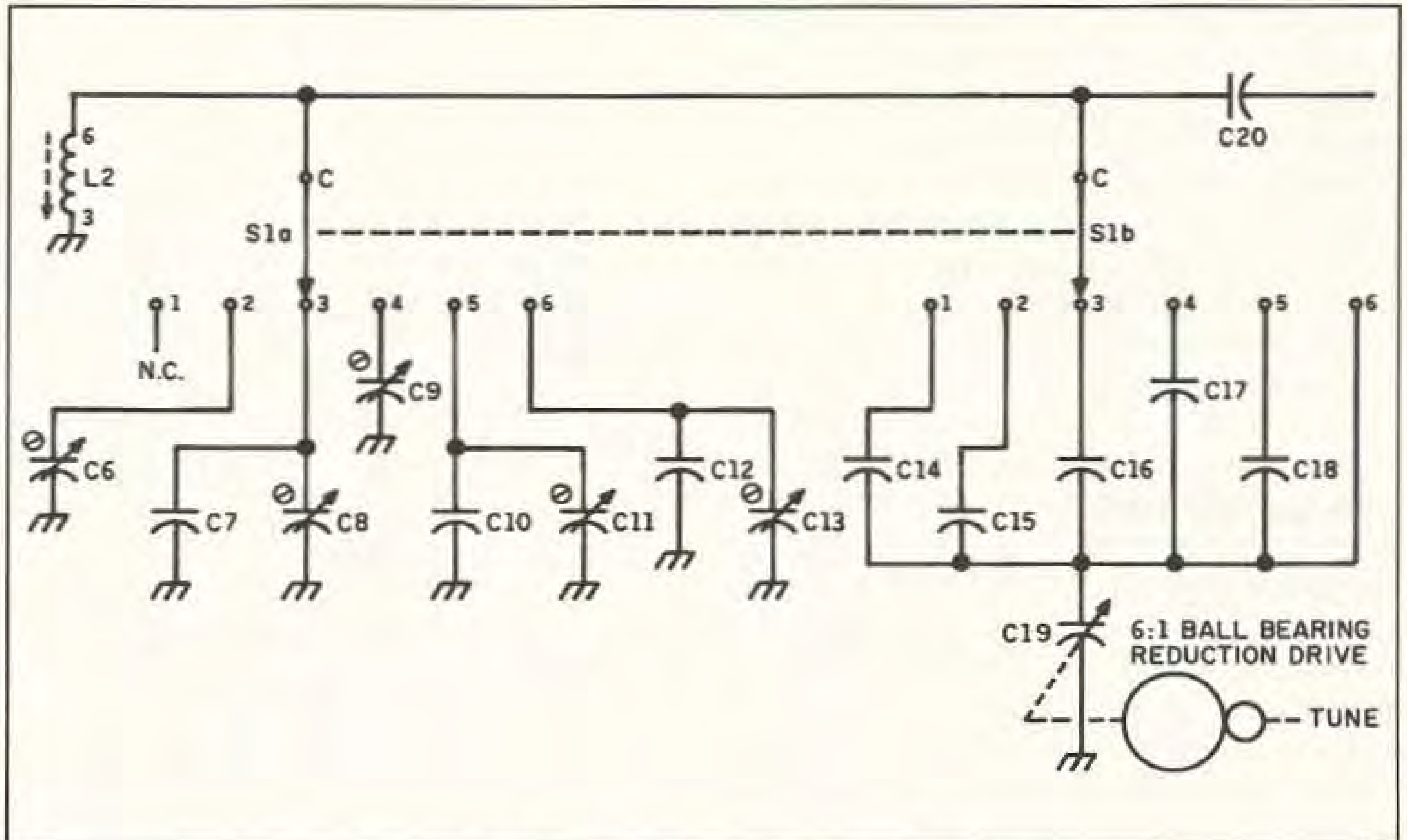

Figure 2. Tuning components schematic detail.

The RF Amplifier

The 6AK5 is a sharp-cutoff pentode designed for use in RF or IF amplifiers in high-frequency wideband applications at frequencies up to 400 MHz. Its primary purpose is to isolate the antenna from the tuned circuit in the detector's grid. This eliminates the detuning problem found in regen sets where the antenna is coupled directly to the detector. In spite of this being an untuned amplifier, and thanks to the use of the pentode, we still get about 6 dB of gain on all the bands. C1 couples the antenna to the control grid. L1 couples the amplified output to the detector.

The Regenerative Detector

The 6AB4 is a high-mu triode designed for use in cathode-drive amplifiers, frequency converters, and oscillators at frequencies up to 300 MHz. Electrically identical to one section of dual-triode type 12AT7, here it is used as a regenerative detector. L2 and the capacitors selected by S1 form the only tuned circuit in the radio. C20 couples the selected signal to the control grid and, along with R5, forms a grid-leak bias circuit. The amplified RF signal is coupled by L3, in phase, back to the tuned circuit L2/S1. This causes two effects: The signal is re-amplified, thus giving extreme sensitivity, and it introduces "negative resistance" into L2, which dramatically increases it's "Q." This allows our single tuned circuit to give our radio a selectivity on the order of 3 kHz. C21 is the return path for the RF signal. The same signal is detected by grid-leak action and the amplified audio is developed across the primary of T1. L4 and C22 filter any residual RF from the detected audio. Of course, all this must be controlled somehow or else we'd have an RF oscillator instead of a detector! R6, R7, and R8 form a voltage divider to provide variable B+ voltage to the detector. C24 filters out any noise generated by the mechanical motion of R7. In use, R7 is advanced until the tube oscillates (which can be heard in the headset), and then backed down until oscillation just stops. The circuit is now set up for best sensitivity and selectivity for AM signals.

The Tuning System

Now refer to Figure 2. L2 and the capacitors selected by S1a and S1b form the tuned circuit in our radio. Six shortwave bands are

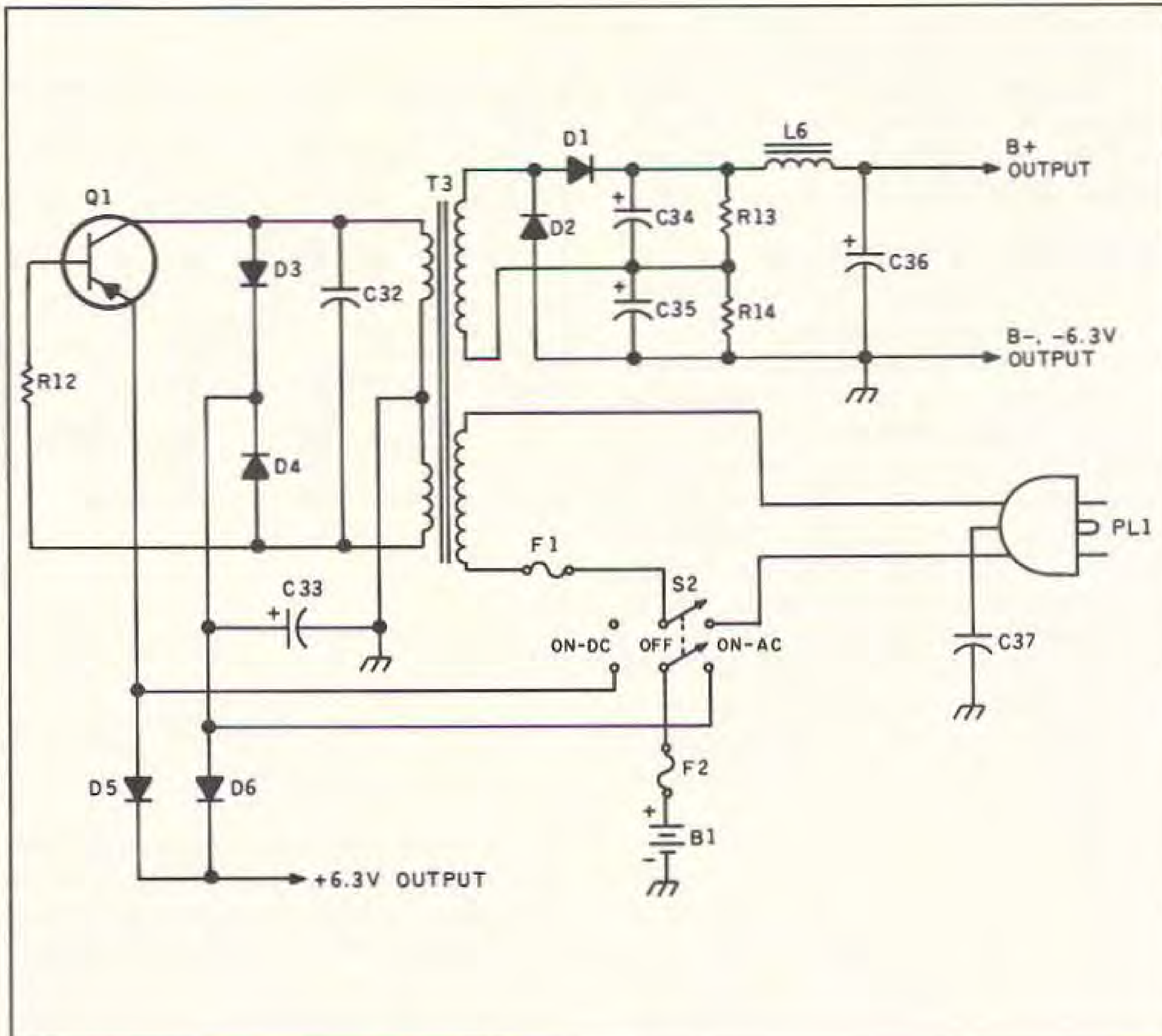

Figure 3. Power supply schematic diagram.

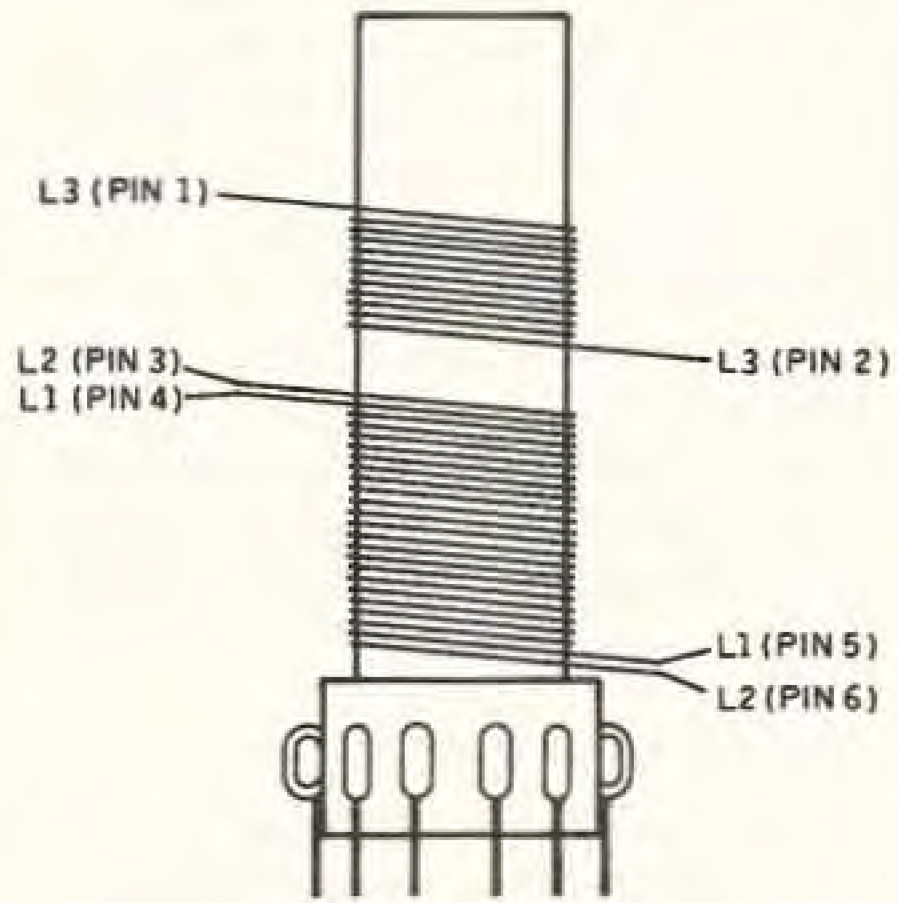

Figure 4. Coil winding diagram.

selected by S1 as follows:

Position 1 = 13 Meter Band, 21.200 - 22.000 MHz
Position 2 = 16 Meter Band, 17.400 - 17.980 MHz
Position 3 = 19 Meter Band, 15.000 - 15.580 MHz
Position 4 = 21 Meter Band, 13.400 - 13.900 MHz
Position 5 = 25 Meter Band, 11.600 - 12.075 MHz
Position 6 = 31 Meter Band, 9.450 - 9.900 MHz

S1a performs the function of "bandset." Capacitors C6 through C13 are either fixed silvered mica or miniature silvered ceramic trimmer capacitors. S1b selects various capacitors to be placed in series with bandspread/main tuning capacitor C19. C14 through C18 are fixed silvered mica types. C19 is a 25 pF air-dielectric variable capacitor with a standard 1/4-inch shaft. Between it and the tuning knob is a 6:1 ball bearing reduction drive to which is attached a 4-inch diameter aluminum plate that serves as the tuning dial.

In a tuned circuit with a fixed inductance, a variable capacitor will have a greater effect on tuned frequency the higher the frequency. S1b introduces ever smaller fixed capacitors in series with C19, effectively reducing its overall change in capacitance each time the bandswitch is moved to a higher band. This ensures that the entire 180 degrees of rotation on the tuning capacitor is used to tune each band, keeping the stations from being bunched up in a small area on the dial. With this system the 6:1 reduction drive is not really necessary, but I had a few laying around so I used one anyway.

The AF Amplifier

The 6C4 is a medium-mu power triode designed for use in Class C RF amplifiers. It is capable of 5.5 watts of output at frequencies in the 50 MHz range. It is used here because of its low plate and filament current requirements compared to a power pentode. This is important since we want to be able to operate the radio on battery power for long periods of time. The audio output is louder than I can stand with the volume control advanced halfway on most signals. T1 is a step-up audio transformer with a ratio of 1:2.5. R9 is the volume control. T2 matches the output impedance of the 6C4 to the headphones.

Power Supply Theory of Operation

The heart of the power supply (Figure 3) is transformer T3. And the good news is that it's nothing special! It has two 6.3 volt 2 amp secondaries, and two 115 volt primaries. A 12.6 volt transformer with two primaries would work just as well. For both AC and battery operation, we use one of the primaries to provide the B+. D1, D2, C34, and C35 form a full-wave voltage doubler. L6 and C36 smooth the rectified output.

During AC operation, one half of DPDT toggle switch S2 routes the line voltage to the other primary of T3 via F1. C37 connects the line ground to the circuit ground. The two 6.3 volt secondaries, D3, D4, and C33, form a full-wave power supply that produces 6.3 volts DC at 4 amps (under load). D6 routes this voltage to the filaments and the dial lamp, which use up 0.55 amps of the available current. The other half of S2 routes this voltage to B1 via F2, making available up to 3.45 amps to charge the battery. There is no danger of overcharging the battery because the voltage is within the acceptable range for continuous "float" charging. D5 ensures that Q1 and R12 have no effect on operation, effectively disconnecting them.

During DC operation, current from the battery is routed through F2, one half of S2, and D5 to provide power for the filaments and dial lamp. At the same time, current from the battery is used to operate the power oscillator consisting of Q1, R12, and both secondaries of T3. C32 shapes the waveform so that it is closer to being a sine wave than a square wave, thus eliminating the switching transients present in a square wave which are difficult to filter out. The 115 volt AC current generated in the unused primary of T3 is isolated from PL1 by S2, thereby eliminating a shock hazard there. Because of the way they are connected, D3, D4, C33, and D6 are effectively "not there" during DC operation.

Construction Hints

The heart of the receiver is the L1-3 coil assembly. You'll have to wind it yourself. Figure 4 shows how it's done. The coil form was found at a surplus store, and the winding that was on it had to be removed first. As previously mentioned, the output of the 6AB4 must be fed back in phase to its grid in order for it to oscillate. If the coil is wound and connected as shown, feedback will be in phase. A handy rule of thumb to keep in mind goes as follows: If L2 and L3 are wound end-to-end in the same direction, the plate connection is to the outside of the plate or "tickler" coil (L3) when the grid connection is to the outside of L2. If you lose track of the leads and the detector fails to oscillate after being wired, swapping the two leads of L3 will fix the problem. The other consideration is to make sure that when laying out your parts-mounting plan, the coil assembly is separated by at least one coil diameter from any large metal objects (such as the front panel or an audio transformer). This prevents any such object from ruining the high "Q" of the coil.

If you can't find any audio transformers for T1 and T2, you can substitute resistors and capacitors without losing too much audio gain. To substitute for T1, replace the primary with a 250k ohm resistor and connect a 0.01 uF capacitor from the junction of that resistor and C22 to the top of volume control R9. To substitute for T2, replace the primary with a 47k ohm resistor and connect a 0.1 µF capacitor from the plate of the 6C4 to the headphone jack. If T2 is replaced by R/C coupling then C27 may be omitted also.

L5 and L6 are not critical. Anything from 2 henries on up should work fine. If you don't have an inductance meter, just use an ohmmeter to find one that measures between 150 and 700 ohms. The current through these is only 18 mA, so anything small in size that fits either of the above specifications will work. It can be a choke or the primary of an old tube-type audio output transformer. I used the latter for mine. They measured 4.5 henries on the inductance meter, and 150 ohms on the ohmmeter.

A regenerative detector occasionally shows a tendency to change frequency slightly as the hand is moved near the dial. This condition (body capacity) can be corrected by better shielding. I used double-sided PC board material for the front panel and receiver sub-chassis. The front panel is 10-1/2 inches wide by 6-1/2 inches high. The receiver sub-chassis is 9 inches wide by 4-1/2 inches deep, and is soldered at a right angle to the center of one side of the front panel. This results in a "T"-shaped assembly that is very strong. Once all the controls are mounted on the front panel their metal mounting bushings make contact with the copper on both sides of the panel, thereby providing double shielding. With this technique there is no body capacity and the receiver is completely stable. The tube sockets and all the other parts are mounted on the sub-chassis after appropriate sized holes are made. Wiring is done point-to-point, with the advantage that wherever a ground is required it can be soldered to the sub-chassis with minimal lead length.

You could develop your own PC artwork for the receiver sub-chassis and etch it before soldering to the front panel if you like. When making your layout for the receiver, the important thing to consider is to keep all leads and/or PC runs as short as possible between the plate of the 6AK5, L1/2/3, S1 and its associated capacitors, and the 6AB4. Any layout you can come up with that accomplishes this goal will work fine.

The power supply was also built on a piece of PC board material measuring 7-1/2 inches long by 3-1/2 inches wide. You could etch a pattern for this if you like, but it's not necessary. The power switch is a three-position "ON-OFF-ON" type, and is mounted on the front panel. Q1 is mounted on a small heat sink just slightly larger than the area of the transistor body and about 1 inch tall. The transistor runs cool to the touch even after hours of operation. R12 will probably need to be experimented with if you use a different transistor or transformer. You'll find the right value will be somewhere between 100 ohms and 1k ohm.

I built a box out of standard 1-inch appearance pine, like you would use to make shelves out of, and finished it with polyurethane varnish. The battery and power supply mount inside it towards the rear, and the receiver/front panel assembly slides in the opening on the front and is secured by several wood screws with wide decorative heads. A short cable with a plug on it connects the power supply to a socket on the receiver. The line cord and antenna jack are on the back of the wood box, and the antenna jack connects to the receiver through a short coaxial cable and RCA plug. Four rubber feet screwed into the bottom of the box finish it off, and the end product looks real "olde-tyme."

Table 1 lists all the parts, additional substitution information where allowable, and sources of parts for those who do not have any decent stores nearby.

Calibration and Operation

All calibration is done with the aid of a signal generator. It is not necessary to make a direct connection between the receiver and the signal generator. A short piece of wire connected to the output of the signal generator will radiate enough signal to be picked up by the windings of L2. Set the top (L3) slug in the coil form so that it's flush with the top of the form, then calibrate in the following order.

1. Band 1 (13 M). Set the tuning capacitor, C19, to its fully unmeshed position. Set the signal generator for 22.000 MHz. Adjust the bottom (L2) slug in the coil form until you can hear the signal best.

2. Band 2 (16 M). Leave C19 set as it is. Signal generator to 17.980 MHz. Adjust C6 for best signal.

3. Band 3 (19 M). Adjust C19 to the fully meshed position, then open it up just a tad. Signal generator to 15.000 MHz. Adjust C8 for the best signal.

4. Band 4 (21 M). Return C19 to the fully unmeshed position. Signal generator to 13.900 MHz. Adjust C9 for best signal.

5. Band 5 (25 M). Leave C19 set as it is. Signal generator to 12.075 MHz. Adjust C11 for the best signal.

6. Band 6 (31 M). Adjust C19 to the fully-meshed position. Signal generator to 9.450 MHz. Adjust C13 for the best signal. Now that the band edges have been defined, you can go back and and mark whatever calibration intervals you wish for each band on your tuning dial. I painted my dial white, then used black dry transfer numbers for this.

To listen to stations, connect an antenna and select a band with S1. Set the volume control at mid-range, then adjust the regeneration control (R7) until the detector breaks into a "hiss," which indicates oscillation. Slowly reduce the regeneration control until the "hiss" just stops. You should now be able to hear stations as the tuning control is rotated. Sometimes the setting of the regeneration control needs to be changed to maintain the "sweet spot" from one end of the tuning dial to the other within the same band. If you are hearing beat notes as you tune across stations, the regeneration control is advanced slightly too far for best AM reception. This is a good way to find stations, but once you've got one tuned in to "zero beat," reduce the regeneration control a tad and you'll be in the "sweet spot" where sensitivity, selectivity, and fidelity of detected audio are all at their best.

The detector will require more voltage from the regeneration control (R7) in order to oscillate on the 31 meter band, and less voltage to oscillate on the higher bands. If it will not oscillate sufficiently on the 31 meter band, you can either turn the top (L3) slug in the coil form in until oscillation is enough, or play with the values of R6 and R8. When everything is set up right, the regenetation control will be one-quarter of its rotation from the ground end for reception on the 13 meter band, three-quarters of it's rotation from the ground end for reception on the 31 meter band, and somewhere in the middle for all the other bands. My receiver needs 16 volts from R7 to work on the 13 meter band and 60 volts to work on the 31 meter band.

To recieve signals below the 31 meter band, you will need to make your L1/2/3 coil larger (more inductance), and experiment on your own with the values of the capacitors selected by S1. You'll also want to use a larger capacitor for C19, say 50 pF, in order to get sufficient bandspread on the lower frequencies. With the coil specified in Figure 4, you cannot receive well below the 31 meter band. This is because the regenerative receiver likes to have a high "L" to "C" ratio in its tuned circuit. Adding more capacitance to make the specified coil tune below the 31 meter band ruins the high "L" to "C" ratio, resulting in a receiver that needs excessive voltage from R7 in order to oscillate and ruining the high selectivity of the circuit.

If you decide to calibrate the receiver for the ham bands instead of the broadcast bands, you'll find that CW is easy to copy. To receive CW, the regeneration control is set so that the detector is just starting to oscillate. This provides "autodyne" reception. The code signals can be tuned in and will give a beat note with each signal depending on the setting of the tuning control. As the receiver is tuned through a signal, the tone first will be heard as a very high pitch, then will go down through "zero beat" and rise up again on the other side, finally disappearing at a very high pitch. The same setting of the regeneration control used for CW reception will also allow SSB to be copied. Tuning will be very critical, but is easy to do with the help of the 6:1 ball reduction drive.

Whatever bands you calibrate your receiver for, a few moments practicing tuning-in stations will get you familiar with the way a regenerative receiver operates and soon you'll be an old pro at it. I guarantee that if you've never played with one of these sets before, the more you listen around the bands the more you'll be amazed at what a small handfull of parts in a simple circuit can do. And just maybe you'll get to feel a little of what it meant to be a "real ham" in the "old days" when "everyone built their own rigs" from whatever they could find laying around! 73

See Parts List on page 38

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Parts List

Part	Description	Source (see key below)	Substitution Range
B1	6 volt, 10 Ah gel cell	2	Larger current capacity
C1	56 pF, 500V ceramic disk	1,2	33-100 pF
C2	0.02 µF, 25V ceramic disk	1,2	0.01-0.1 µF
C3,24	0.02 µF, 500V ceramic disk	1,2	0.01-0.1 µF
C4,25,31	10 µF, 400V electrolytic	1,2	10-100 µF
C5,26,30	0.15 µF, 50V ceramic disk	1,2	0.01-1 µF
C6,8	6-25 pF ceramic trimmer	2	None*
C7,14	15 pF, 500V silver mica	1,2	Ceramic NPO type*
C9,11,13	10-40 pF ceramic trimmer	2	None*
C10,16	30 pF, 500V silver mica	1,2	Ceramic NPO type*
C12	68 pF, 500V silver mica	1,2	Ceramic NPO type*
C15	20 pF, 500V silver mica	1,2	Ceramic NPO type*
C17	39 pF, 500V silver mica	1,2	Ceramic NPO type*
C18	62 pF, 500V silver mica	1,2	Ceramic NPO type*
C19	25 pF air variable	1,2,3	None*
C20	100 pF, 500V silver mica	1,2	47-220 pF
C21	270 pF, 500V silver mica	1,2	220-390 pF
C22	2500 pF, 500V silver mica	1,2	680 pF-3300 pF
C23	2.2 µF, 250V electrolytic	1,2	1-5 µF
C27	0.0015 µF, 500V ceramic disk	1,2	750 pF-0.0022 µF
C28	100 µF, 50V electrolytic	1,2	10-150 µF
C29,34,35	100 µF, 400V electrolytic	1,2,3	50-220 µF
C32	2 µF, 150V non-polarized	2,3	0.5-4 µF non-polarized
C33	1000 µF, 16V	1,2	470-5,000 µF
C37	0.1 µF, 400V	1,2	0.047-0.68 µF
D1,2	600 PIV, 1A RS#276-1104	5	Any equivalent
D3,4,5,6	50 PIV, 3A RS#276-1141	5	Any equivalent
F1	FO250V 3/8A	1,3	None
F2	FO250V 4AS	1,3	None
L1,2,3	Handwound on 1/4" form	1,2	None* (see Figure 4)
L4	4 µH RF choke	1,2,3	2.5-10 µH
L5,6	5H; 150 ohms DC choke	1,2,3	See text
PL1	3-wire line cord set	1,2	
Q1	MJ2955	5	RS#276-2043
R1	560k ohm, 1/2W	1,2	100k-1 MEG
R2	330 ohm, 1/2W	1,2	100-560 ohm
R3	22k ohm, 1/2W	1,2	18k-27k
R4	4.3k ohm, 1/2W	1,2	2.2k-5.6k
R5	3.3 megohm, 1/2W	1,2	1 MEG-4.7 MEG
R6	10k ohm, 1/2W	1,2	1k-10k
R7	50k ohm, 1/2W pot.	1,2,3	100k pot.
R8	27k ohm, 1/2W	1,2	10k-33k
R9	250k ohm, 1/2W pot.	1,2,3	100k-500k pot.
R10	2.4k ohm, 1/2W	1,2	1.8k-3.3k
R11	1k ohm, 1/2W	1,2	1k-4.7k
R12	560 ohm, 1/2W	1,2	See text
R13,14	470k ohm, 1W	1,2	220k-1 MEG, 1W
S1	2-pole, 6-Position rotary	2,3,4	
S2	DPDT "ON-OFF-ON" toggle	2,3,4	
T1	Audio transformer, UTC #TF5SX21ZZ, 1:2.5 ratio pri = 1k ohm DC, sec = 6.5k ohm DC	1,2,3	See text
T2	Audio transformer, UTC #TF4RX13YY, pri Z = 10k, 790 ohm DC sec Z = 2k, 195 ohm DC	1,2,3	See text
T3	STANCOR #P-6376 dual 115V primaries dual 6.3V, 2A secondaries	2,3	See text
V1	6AK5 sharp cut-off pentode	1,3	6AJ5,5595,5654,EF95
V2	6AB4 hi-mu triode	1,3	6664,EC92
V3	6C4 power triode	1,3	5610,6100,6135,EC90
Miscellaneous:			
(3 ea.)	7-pin miniature socket	1,2,4	
(1 ea.)	6:1 ball bearing drive	2,4	**
(1 ea.)	Bayonet lamp socket	1,2	**
(1 ea.)	#51 miniature lamp	1,2	**
(1 ea.)	HI-Z headphones military styles H-43B/U, H-23B/R, HS-16, or equiv.	1,2,3	See text

Substitution Notes Key:

none = Do not substitute or omit for safety reasons.
none* = Values may be changed to tune different bands.
Values may need to be varied slightly to tune specified bands due to differences in stray wiring capacitances between your model and the prototype.
** = May be omitted if desired.

Source Key:

1.) Antique Electronic Supply, 6221 S. Maple Ave., Tempe AZ 85283
(602) 820-5411; Fax: (602) 820-4643

2.) Gateway Electronics, Inc., 8123 Page Blvd., St. Louis MO 63130
(314) 427-6116
9222 Chesapeake Dr., San Diego CA 92123
(619) 279-6802

3.) Fair Radio Sales, P.O. Box 1106, 1106 E. Eureka St., Lima OH 45802
(419) 223-2196/227-6573; Fax: (419) 227-1313

4.) Surplus Sales of Nebraska, 1502 Jones St., Omaha NE 68102
(402) 346-4750; Fax: (402) 346-2939

5.) Radio Shack