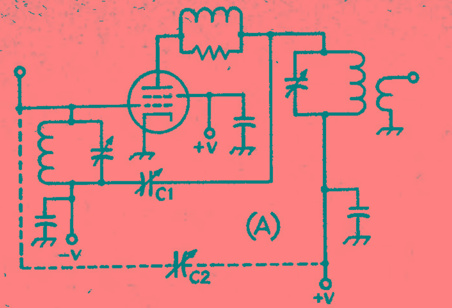


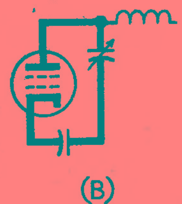


Fig. 6-30 — (A) A neutralizing scheme may use either C1 or C2 to cancel the effect of grid-to-plate cepacitance in the tube (B) Vhf parasitic circuit shown with heavy lines.

A check on external coupling between input and output circuits can be made with a sensitive indicating device, such as the wavemeter shown in the Measurements chapter. The amplifying device is removed. With the driver stage running and tuned to resonance, the indicator should be coupled to the output tank coil and the output tank capacitor tuned for any indication of rf feedthrough. Experiment with shielding and rearrangement of parts will show whether the isolation can be improved. For additional information on transistor circuits see Chapter 4.

Screen-Grid Tube Neutralizing Circuits

The plate-grid capacitance of screen-grid tubes is reduced to a fraction of a picofarad by the interposed grounded screen. Nevertheless, the power sensitivity of these tubes is so great that only a very small amount of feedback is necessary to start oscillation. To assure a stable amplifier, it is usually necessary to load the grid circuit, or to use a neutralizing circuit.

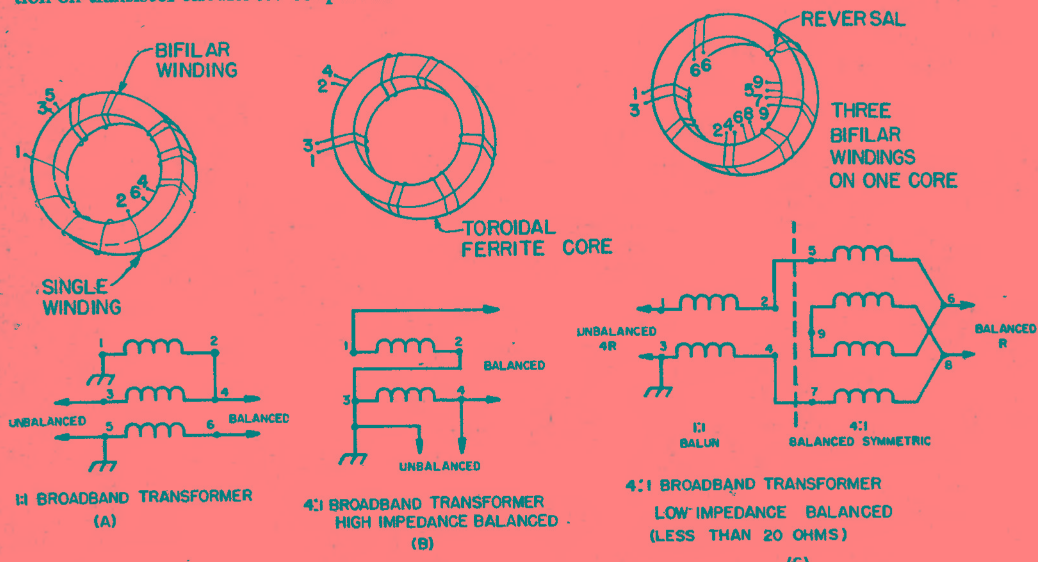
The capacitive neutralizing system for screen-grid tubes is shown in Fig. 6-30A. C1 is the neutralizing capacitor. The capacitance should be chosen so that at some adjustment of C1,

$$\frac{C1}{C3} = \frac{\text{Tube grid-plate capacitance (or } C_{GP})}{\text{Tube input capacitance (or } C_{IN})}$$

The grid-cathode capacitance must include all strays directly across the tube capacitance, including the capacitance of the tuning-capacitor stator to ground. This may amount to 5 to 20 pF. In the case of capacitance coupling, the output capacitance of the driver tube must be added to the grid-cathode capacitance of the amplifier in arriving at the value of C1.

Neutralizing a Screen-Grid Amplifier Stage

There are two general procedures available for indicating neutralization in a screen-grid amplifier stage. If the screen-grid tube is operated with or without grid current, a sensitive output indicator



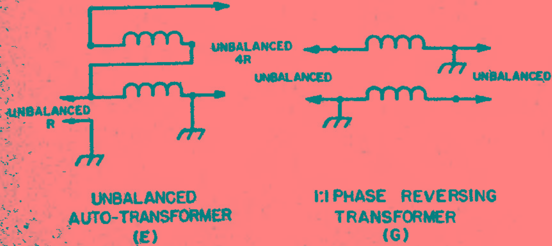


Table 6-II – Basic broadband balun transformers. Bifilar windings are six to ten turns, depending on the ferrite-core permeability. A suiteble ferrite material is *Q*1 with a permeability of 125. Very smell size cores (1/4-to 3/4-inch OD) mey be used for receiving and low-power applications. For full-power applications a 2-1/2-inch OD *Q*1 core with 1/2-inch cross section wound with No. 14 Formex copper wire, seven turns per winding, is recommended.

can be used. If the screen-grid tube is operated with grid current, the grid-current reading can be used as an indication of neutralization. When the output indicator is used, both screen and plate voltages must be removed from the tubes, but the dc circuits from the plate and screen to cathode must be completed. If the grid-current reading is used, the plate voltage may remain on but the screen voltage must be zero, with the dc circuit completed between screen and cathode.

The immediate objective of the neutralizing process is reducing to a minimum the rf driver voltage fed from the input of the amplifier to its output circuit through the grid-plate capacitance of the tube. This is done by adjusting carefully, bit by bit, the neutralizing capacitor or link coils until an rf indicator in the output circuit reads minimum, or the reaction of the unloaded plate-circuit tuning on the grid-current value is minimized.

The wavementer shown in the Measurements chapter makes a sensitive neutralizing indicator. The wavemeter coil should be coupled to the output tank coil at the low-potential or "ground" point. Care should be taken to make sure that the coupling is loose enough at all times to prevent buring out the meter or the rectifier. The plate tank capacitor should be readjusted for maximum reading after each change in neutralizing.

When the grid-current meter is used as a neutralizing indicator, the screen should be grounded for rf and dc, as mentioned above. There will be a change in grid current as the unloaded plate tank circuit is tuned through resonance. The neutralizing capacitor (or inductor) should be adjusted until this deflection is brought to a minimum. As a final adjustment, screen voltage should be returned and the neutralizing adjustment continued to the point where minimum plate current, maximum grid current and maximum screen current occur simultaneously. An increase in grid current when the plate tank circuit is tuned slightiy on the high-frequency side of resonance indicates that the neutralizing capacitance is too small. If the increase is on the low-frequency side, the neutralizing capacitance is too large. When neutralization is complete, there should be a slight decrease in grid current on either side of resonance.

Grid Loading

The use of a neutralizing circuit may often be avoided by loading the grid circuit if the driving stage has some power capability to spare. Loading by tapping the grid down on the grid tank coil (or the plate tank coil of the driver in the case of capacitive coupling), or by a resistor from grid to cathode is effective in stabilizing an amplifier.

VHF Parasitic Oscillation

Parasitic oscillation in the vhf range will take place in almost every rf power amplifier. To test for vhf parasitic oscillation, the grid tank coil (or driver tank coil in the case of capacitive coupling) should be short-circuited with a clip lead. This is to prevent any possible t.g.t.p. oscillation at the operating frequency which might lead to confusion in identifying the parasitic. Any fixed bias should be replaced with a grid leak of 10,000 to 20,000 ohms. All load on the output of the amplifier should be disconnected. Plate and screen voltages should be reduced to the point where the rated dissipation is not exceeded. If a Variac is not available, voltage may be reduced by a 117-volt lamp in series with the primary of the plate transformer.

With power applied only to the amplifier under test, a search should be made by adjusting the input capacitor to several settings, including minimum and maximum, and turning the plate capacitor through its range for each of the grid-capacitor settings. Any grid current, or any dip or flicker in plate current at any point, indicates oscillation. This can be confirmed by an indicating absorption wavemeter tuned to the frequency of the parasitic and held close to the plate lead of the tube.

The heavy lines of Fig. 6-30B show the usual parasitic tank circuit, which resonates, in most cases, between 100 and 200 MHz. For each type of tetrode, there is a region, usually below the parasitic frequency, in which the tube will be self-neutralized. By adding the right amount of inductance to the parasitic circuit, its resonant frequency can be brought down to the frequency at which the tube is self-neutralized. However, the resonant frequency should not be brought down so low that it falls close to TV Channel 6 (88 MHz). From the consideration of TVI, the circuit may be loaded down to a frequency not lower than 100 MHz. If the self-neutralizing frequency is below 100 MHz, the circuit should be loaded down to somewhere between 100 and 120 MHz with inductance. Then the parasitic can be suppressed by loading with resistance. A coil of 4 or 5 turns, 1/4 inch in diameter, is a good starting size. With the tank capacitor turned to maximum capacitance, the circuit should be checked with a GDO to make sure the resonance is above 100 MHz. Then, with the shortest possible leads, a noninductive 100-ohm 1-watt resistor should be connected across the entire coil. The amplifier should be tuned up to its highest-frequency band and operated at low voltage. The tap should be moved a little at a time to find the minimum number of turns required to suppress the parasitic. Then voltage should be increased until the resistor begins to feel warm after several minutes of operation, and the power input noted. This input should be compared with the normal input and the *power* rating of the resistor increased by this proportion; i.e., if the power is half normal, the wattage rating should be doubled. This increase is best made by connecting 1-watt *carbon* resistors in parallel to give a resultant of about 100 ohms. Or, one of the Globar surge-protection resistors may be used. As power input is increased, the parasitic may start up again, so power should be applied only momentarily until it is made certain that the parasitic is still suppressed. If the parasitic starts up again when voltage is raised, the tap must be moved to include more turns. So long as the parasitic is suppressed, the resistors will heat up only from the operating-frequency current. In grounded-grid

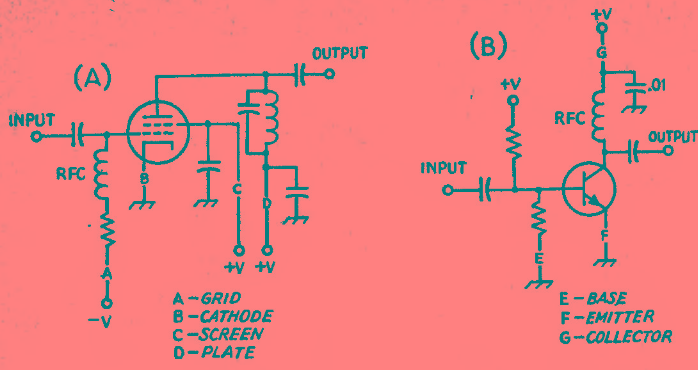


Fig. 6-31 — Metering circuits for (A) tubes and (B) transistors. To measure current, connect a meter at the point shown *in series with the lead.* For voltage measurements, connect the meter from the point indicated *to the common or ground connection.*

circuits it is useful to locate the parasitic suppressor in the cathode lead, as the rf power level is less than at the plate terminal.

Since the resistor can be placed across only that portion of the parasitic circuit represented by L_p, the latter should form as large a portion of the circuit as possible. Therefore, the tank and bypass capacitors should have the lowest possible inductance and the leads shown in heavy lines should be as short as possible and of the heaviest pratical conductor. This will permit L_p to be of maximum size without tuning the circuit below the 100-MHz limit.

Another arrangement that has been used successfully in transistor and low-level tube stages is to place one or more ferrite beads over the input or output leads, as close as possible to the amplifying device. The beads have sufficient low-*Q* inductance at vhf to discourage any tendency toward parasitic oscillation.

Low-Frequency Parasitic Oscillation

The screening of most transmitting screen-grid tubes is sufficient to prevent low-frequency parasitic oscillation caused by resonant circuits set up by rf chokes in grid and plate circuits. When rf chokes are used in both grid and plate circuits of a triode amplifier, the split-stator tank capacitors combine with the rf chokes to form a low-frequency parasitic circuit, unless the amplifier circuit is arranged to prevent it. Often, a resistor is substituted for the grid rf choke, which will produce the desired result. This resistance should be at least 100 ohms. If any grid-leak resistance is used for biasing, it should be substituted for the 100-ohm resistor.

Transistor LF Parasitics

Using transistors with shunt feed often means low-frequency parasitic trouble. A word about this problem is in order as it usually doesn't occur in vacuum-tube circuits and is often a rough problem for the newcomer to solid state. These parasitics manifest themselves as a wide spectrum of white noise (hash) around and below the operating frequency. They can often be heard on a broadcast receiver several feet away from a transmitter under test. The desired signal may sound clean, so it is necessary to check far below the operating frequency. Two transistor characteristics combine to cause this trouble. First, transistors have higher gain at lower frequencies than they do at hf. Second, interelement capacitances vary over a wide range of changes in voltage, the result being varactor action that causes spurious outputs. The best way to avoid the problem is to use a minimum of inductance in the collector circuit. Large chokes are unsatisfactory. Series feed is a good answer as no choke is needed. Bypass capacitors should be the minimum value required. Decoupling on power leads between stages should have at least two capacitors, one effective at the operating frequency and a second large capacitor that is good at low frequencies.

METERING

Fig. 6-31 shows how a voltmeter and milliammeter should be connected to read various voltages and currents. Voltmeters are seldom installed permanently, since their principal use is in preliminary checking. Also, milliammeters are not normally installed permanently in all of the positions shown. Those most often used are the ones reading grid current and plate current, or grid current and cathode current, or collector current.

Milliammeters come in various current ranges. Current values to be expected can be taken from the tube tables and the meter ranges selected accordingly. To take care of normal overloads and pointer swing, a meter having a current range of about twice the normal current to be expected should be selected.

Grid-current meters connected as shown in Fig. 6-31 and meters connected in the cathode circuit need no special precautions in mounting on the transmitter panel so far as safety is concerned. However, milliammeters having metal zero-adjusting screws on the face of the meter should be recessed behind the panel so that accidental contact with the adjusting screw is not possible, if the meter is connected in any of the other positions shown in Fig. 6-31. The meter can be mounted on a small subpanel attached to the front panel with long screws and spacers. The meter opening should be covered with glass or celluloid. Illuminated meters make reading easier. Reference should also be made to the TVI chapter of this *Handbook* in regard to wiring and shielding of meters to suppress TVI.

COMPONENT RATINGS

Output Tank Capacitor Voltage

In selecting a tank capacitor with a spacing between plates sufficient to prevent voltage breakdown, the peak rf voltage across a tank circuit under load, but without modulation, may be taken conservatively as equal to the dc plate or collector voltage. If the dc supply voltage also appears across the tank capacitor, this must be added to the peak rf voltage, making the total peak voltage twice the dc supply voltage. If the amplifier is to be plate-modulated, this last value must be doubled to make it four times the dc plate voltage, because both dc and rf voltages double with 100-percent amplitude modulation. At the higher voltages, it is desirable to choose a tank circuit in which the dc and modulation voltages do not appear across the tank capacitor, to permit the use of a smaller capacitor with less plate spacing.

Capacitor manufacturers usually rate their products in terms of the peak voltage between plates. Typical plate spacings are shown in the following table, 6-III.

Output tank capacitors should be mounted as close to the tube as temperature considerations will permit, to make possible the shortest capacitive path from plate to cathode. Especially at the higher frequencies where minimum circuit capacitance becomes important, the capacitor should be mounted with its stator plates well spaced from the chassis or other shielding. In circuits where the rotor must be insulated from ground, the capacitor should be mounted on ceramic insulators of size commensurate with the plate voltage involved and – most important of all, from the viewpoint of safety to the operator – a well-insulated coupling should be used between the capacitor shaft and the dial. *The section of the shaft attached to the dial should be well grounded.* This can be done conveniently through the use of panel shaft-bearing units.

Table 6-III

Typical Tank-Capacitor Plate Spacings

Spacing (In.)	*Peak Voltage*	*Spacing (In.)*	*Peak Voltage*	*Spacing (In.)*	*Peak Voltage*
0.015	1000	0.07	3000	0.175	7000
0.02	1200	0.08	3500	0.25	9000
0.03	1500	0.125	4500	0.35	11000
0.05	2000	0.15	6000	0.5	13000

Tank Coils

Tank coils should be mounted at least their diameter away from shielding to prevent a marked loss in Q. Except perhaps at 28 MHz it is not important that the coil be mounted quite close to the tank capacitor. Leads up to 6 or 8 inches are permissible. It is more important to keep the tank capacitor as well as other components out of the immediate field of the coil. For this reason, it is preferable to mount the coil so that its axis is parallel to the capacitor shaft, either alongside the capacitor or above it.

Wire Sizes for Transmitting Coils for Tube Transmitters

Power Input (Watts)	*Band (MHz)*	*Wire Size*
1000	28–21	6
	14–7	8
	3.5–1.8	10
500	28–21	8
	14–7	12
	3.5–1.8	14
150	28–21	12
	14–7	14
	3.5–1.8	18
75	28–21	14
	14–7	18
	3.5–1.8	22
25 or less*	28–21	18
	14–7	24
	3.5–1.8	28

* Wire size limited principally by consideration of Q.

There are many factors that must be taken into consideration in determining the size of wire that should be used in winding a tank coil. The considerations of form factor and wire size that will produce a coil of minimum loss are often of less importance in practice than the coil size that will fit into available space or that will handle the required power without excessive heating. This is particularly true in the case of screen-grid tubes where the relatively small driving power required can be easily obtained even if the losses in the driver are quite high. It may be considered preferable to take the power loss if the physical size of the exciter can be kept down by making the coils small.

Transistor output circuits operate at relatively low impedances because the current is quite high. Coils should be made of heavy wire or strap, with connections made for the lowest possible resistance. At vhf stripline techniques are often employed, as the small inductance values required for a lumped inductance become difficult to fabricate.

RF Chokes

The characteristics of any rf choke will vary with frequency, from characteristics resembling those of a parallel-resonant circuit, of high impedance, to those of a series-resonant circuit, where the impedance is lowest. In between these extremes, the choke will show varying amounts of inductive or capacitive reactance.

In series-feed circuits, these characteristics are of relatively small importance because the rf voltage across the choke is negligible. In a parallel-feed circuit, however, the choke is shunted across the tank circuit, and is subject to the full tank rf voltage. If the choke does not present a sufficiently high impedance, enough power will be abosrbed by the choke to cause it to burn out.

To avoid this, the choke must have a sufficiently high reactance to be effective at the lowest frequency, and yet have no series resonances near the higher-frequency bands.

A 10-WATT PACKAGE FOR 160 METERS

The transmitter is housed in a homemade aluminum cabinet. The dimensions are (HWD) 3 × 10 × 7-1/2 inches. A Calrad ball-drive vernier mechanism is used to adjust the VFO. Kurz-Kasch aluminum knobs have been added. The front and rear panels have been spray painted a dark green. Green Dymo tape labels identify the controls.

It is unlikely that anyone could become the 160-meter DX mogul of his locale by operating with a 10-watt cw rig. However, the transmitter described here should provide plenty of solid contacts when band conditions are not clouded by QRN and QRM. Certainly, the transmitter is suitable for use as an exciter. One should be able to drive a 100-W (dc input) solid-state amplifier with the output from this strip. Alternatively, a pair of sweep tubes could be connected in parallel to serve as a grounded-grid "pair of shoes" to increase the station power to a more competetive figure.

The VFO

For obscure reasons the well-proven series-tuned Clapp VFO of the vacuum-tube days has been obtrusive by its absence in solid-state circuits. Most transistorized oscillator circuits require lots of shunt capacitance to reduce drift. This is a requirement brought about as the result of relatively high amounts of junction capacitance and low circuit impedances in solid-state devices (not common to vacuum tubes). Large amounts of shunt *C* tend to mask changes in junction capacitance, and this aids stability. By employing a series-tuned Clapp oscillator one uses a fairly high value of inductance as compared to that of a parallel-tuned Colpitts or similar oscillator. High *C* and high *L* both contribute to improved stability. An MPF102 JFET was selected for Q1 (Fig. 1) because of its characteristic high input impedance. This desirable trait minimizes loading of the VFO tuned circuit, helping to preserve the *Q*. CR1 is a high-speed switching diode which is used as a clamp on positive-going rf peaks.

A frequency spread of exactly 100 kHz is provided by C1, a 35-pF air variable. C2 and C3 in combination share the rf current which does not flow through C1. C3 is an NPO capacitor, and was required to assure minimum drift. C4 and C5 are polystyrene capacitors. Mallory type SX units are used on this design. There is no teason why a polystyrene capacitor could not have been used at C2. One of the proper value was not on hand, so a silver-mica type was unokited. The same os true of C18.

Q2 operates as a source-follower buffer. Its purpose is to help isolate the oscillator from changes in load impedance as seen at the output of amplifier Q3. It can be noted that the pi-section collector tank of Q3 is designed for a low output impedance. This calls for 4600 pF of output capacitance (C17 and C19). A 50-ohm output impedance was chosen to minimize loading effects on the VFO brought about by operation of Q4, Fig. 2. Q4 operates as a low-level Class A stage, and has an input impedance of approximately 500 ohms. The mismatch is intentional in an effort to prevent load variations from being seen by the VFO. Output from Q3 across 50 ohms is 1.75 volts rms. Were it not for amplifier Q3 there would be insufficient output from Q2 (across 50 ohms) to excite Q4 adequately. Changes in the internal capacitance of Q4 have a minor effect on the VFO.

Interior view of the transmitter. The VFO is situated at the upper center. At the upper left is the break-in delay module. On the right of the VFO is the side-tone module. The transmitter strip occupies the rear of the chassis (lower portion of photograph). Heat sinks for the PA transistors are made from Reynolds angle aluminum. Fiber washers insulate the heat sinks from ground. An aluminum cover encloses the VFO box during operation. Circuit-board patterns for the VFO and transmitter strip, and layout data, are available from ARRL for $1.50 and a large self addressed stamped envelope.

Use of a pi-network tank helps reduce harmonic currents in the output from Q3; still another part of the design rationale.

VFO drift was checked at a constant room temperature of 75 degrees *F*. From cold start to full stabilization (1-1/2 minutes) a change of only 15 Hz was observed. No evidence of pulling was detected when the transmitter was keyed. Mechanical stability was excellent, even when the VFO case was tapped sharply with a screwdriver handle.

The Transmitter

Low-cost transistors are specified in Fig. 2. The 2N5320 transistors used at Q5, Q6 and Q7 were tried experimentally and proved to be excellent performers at 1.8 MHz. They are rated at 10 W dissipation, have an *f*T (min.) of 50 MHz, and can handle 75 V_{ceo}. Full efficiency should be possible at 160 meters with *f*T ratings above 20 MHz (10 times the operating frequency recommended), so the 2N5320 fits the application nicely. Heat sinks are required on each transistor.

Class C operation is established by virtue of near zero-bias conditions in the driver and PA sections. R17 and R19 are used in the base-emitter junctions during key-up periods, thereby maintaining a resting collector current of zero when excitation is not present at the input of Q5. The resistance value must be kept small (and chosen carefully) in order not to exceed the rated collector-to-emitter breakdown-voltage rating. Reduction in resting collector current aids in eliminating VFO leakthrough (backwave) during transmit periods. During signal periods the base-return resistances improve the efficiency of the driver and PA stages by allowing Q5, Q6 and Q7 to more closely approach true Class C operation.

A drive control, R15, was included to permit varying the power levels of the Q5 and Q6/Q7 stages to determine what effect, if any, the stray rf energy within the cabinet might have on the VFO. No change in VFO characteristics was detected as the power output from the PA was varied from 0.5 to 8.5 watts. A 50-ohm load was used to terminate the transmitter output port during the tests.

Zener diodes VR1 and VR2 are used to clamp positive rf peaks should they reach beyond the normal 25 volts (twice the supply voltage). The diodes conduct at 36 volts. This prevents damage to Q6 and Q7 if the operator mistakenly permits an open- or short-circuit condition to occur at the output of the transmitter. Self-oscillation of the PA could take place if no load was present, causing high rf peak voltage, and that could quickly destroy the transistors. The Zener diodes protect Q6 and Q7 from such an eventuality.

A half-wave harmonic filter is connected between L9 and the output terminal of the transmitter. It assures a clean waveform from the transmitter. The energy at L9 is not a pure sine wave, so the low-pass filter is desirable. Maximum rf output from this circuit is

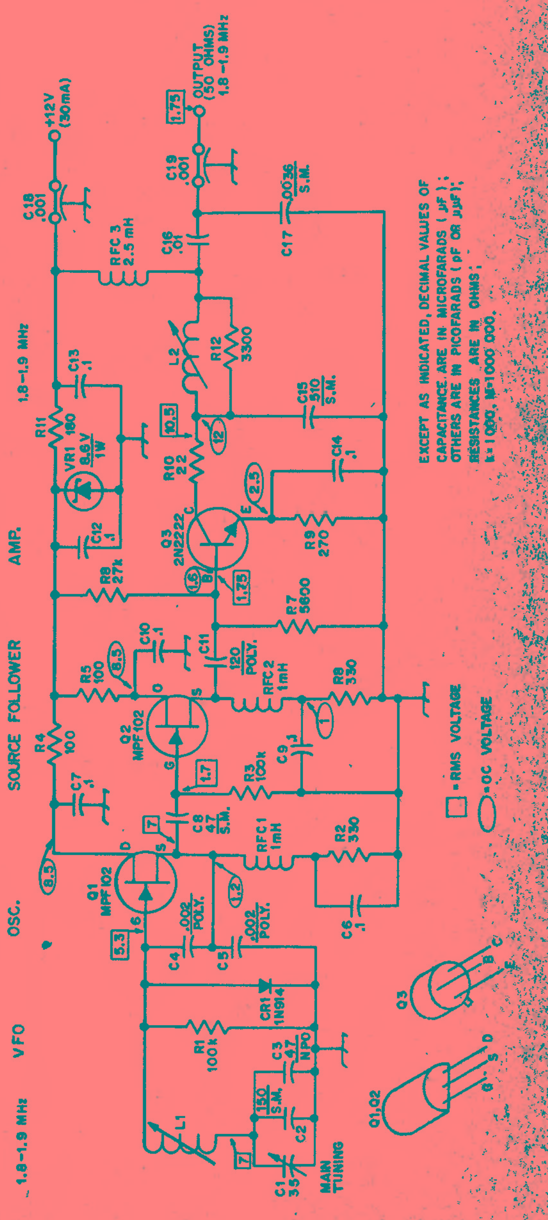


Fig. 1 — Schematic diagram of the 160-meter VFO. Capacitors of fixed value are disk ceramic unless otherwise indicated. Resistors are 1/2-watt composition. Numbered components not appearing in parts list are numbered for pc-board layout purposes. Rms voltages measured with a VTVM and diode probe.

C1 — 35-pF air variable (Millen 28035MK8B or equivalent.)
C18, C19 — .001 µF feed through capacitor.
CR1 — Small-signal high-speed silicon diode, 1N914 or equivalent.
L1 — Slug-tuned high-*Q* inductor, 25 to 58 µH (Miller 43A47C8I, *Q*u = 180 at 2.5 MHz).
L2 — Slug-tuned, pc-board-mount inductor, 10 to 18.7 µH (Miller 23A155RPC or equivalent).
Q1, Q2 — Motorola JFET.
RFC1, RFC2 — Miniature 1-mH rf choke (Millen J301-1000 or equiv.).
RFC3 — Miniature 2.5-mH rf choke (Millen J302-2500 or equiv.).
VR1 — 8.6-V, 1-W Zener diode.

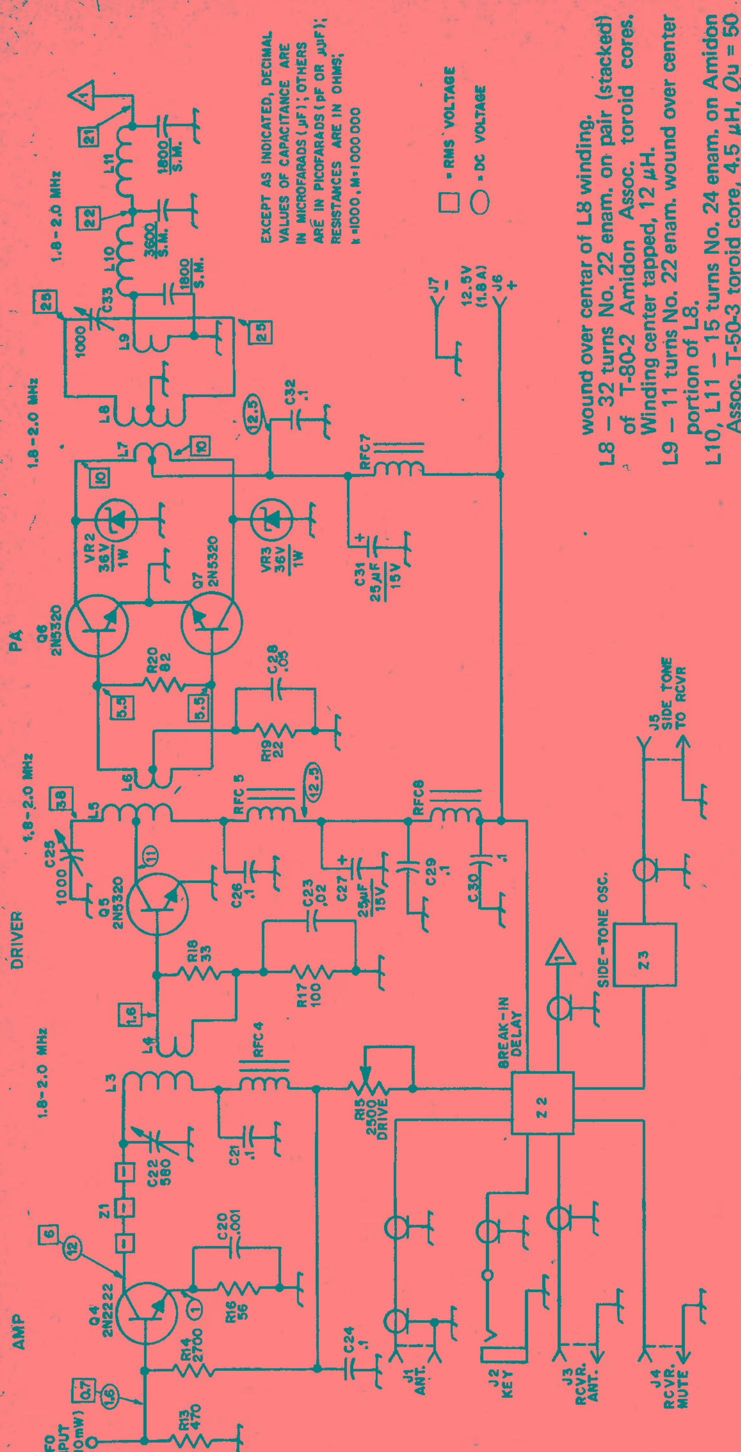


Fig. 2 — Schematic diagram of the 160-meter transmitter power strip. Fixed-value capacitors are disk ceramic unless specified otherwise. Polarized capacitors are electrolytic. Fixed-value resistors are 1/2-W composition. Numbered components not appearing in parts list are numbered for pc-board layout purposes only.

C22 — Mica compression trimmer, 580 pF (Miller 160C or equiv.).
C25, C33 — Mica compression trimmer, 1000 pF (Miller 160A or equiv.).
J1-J7, incl. — Chassis-mount connectors of builder's choice.
L3 — 25 turns No. 24 enam. on Amidon Assoc. T-68-3 toroid core, 14 µH, Qu = 75 at 2.5 MHz.
L4 — 5 turns No. 24 enam. over C21 end of L3.
L5 — 40 turns No. 24 enam. on Amidon Assoc. T-80-2 toroid core. Tap 15 turns above C26 end, 12 µH, Qu = 150 at 2.5 MHz.
L6 — 10 turns No. 24 enam. center tapped, wound over center of L8 winding.
L7 — 8 turns No. 22 enam., center tapped, wound over center of L8 winding.
L8 — 32 turns No. 22 enam. on pair (stacked) of T-80-2 Amidon Assoc. toroid cores. Winding center tapped, 12 µH.
L9 — 11 turns No. 22 enam. wound over center portion of L8.
L10, L11 — 15 turns No. 24 enam. on Amidon Assoc. T-50-3 toroid core, 4.5 µH, Qu = 50 at 7.9 MHz.
R15 — 250-ohm, linear-taper, 2-watt control.
RFC4-RFC7, incl. — 6 turns No. 24 enam. wound through pair (side by side) of Amidon Assoc. jumbo ferrite beads, 70 µH.
VR2, VR3 — 36-V, 1-W Zener diode.
Z1 — Three miniature Amidon Assoc. ferrite beads on 1/2-inch length of wire. Mount near collector of Q4.
Z2 — T-R break-in delay module. Described in 1975 *Handbook*, p. 169, Fig. 3.
Z3 — Side-tone oscillator module. Described in 1975 *Handbook*, p. 168, Fig. 2.

8.5 W, using 13.5 volts dc to power the strip. Output at 12.5 V is approximately 7 W. Key-down time should not exceed 30 seconds during any two-minute period. The circuit is designed for a cw duty cycle only. The circuit was described originally in November, *QST* 1974.

A TWO-BAND SOLID STATE TRANSMITTER

The VFO is an adaptation of the one described in *QST* for November, 1974, page 22. It can be seen that this circuit is not for beginners to tackle, and for that reason we are not providing a blow-by-blow circuit description. There are no templates or additional data available for this project. Advanced builders should have no difficulty getting a "handle" on this equipment, and can design a suitable pc board for the circuit. The design outlook for the VFO was treated thoroughly in the earlier issue of *QST*. The main difference in the versions is the operating frequency and the offset circuit at CR1. Since it is desirable to keep a VFO running all of the time to minimize warm-up drift, the operating frequency needs to be offset during receive. That prevents the VFO from interfering with the received signal. In standby 12 volts dc is applied through K1C to saturate CR1. When it is saturated C2 is placed in parallel with tuning capacitor C1, thereby dropping the operating frequency several kHz below the transmit frequency. A larger capacitor can be used if the operator wishes to "kick" the signal out of the band completely. This 7-MHz VFO stabilizes in 30 seconds. Drift was measured as 25 Hz from a cold start. Stability in models duplicated will vary in accordance with the capacitors used in the frequency-determining section of the Q1 tank. No two capacitors of a given type or brand will act the same way in a VFO.

The transmitter power strip, Q4 through Q6, uses a 2N2222 as a buffer/doubler. Shield compartments isolate the stages to enhance stability. On the side wall of each compartment is a miniature slide switch for changing bands. The switches are ganged by means of a flat strip of pc-board stock. Small rectangular holes are cut in the strip to accommodate each switch handle. A quarter-inch diameter metal shaft is soldered to one end of the strip and is brought out through the front panel for push-pull band-change action. This was done to assure short lead lengths in the switching lines. Q5, the driver, is an RCA TO-5 device to which a crown-type heat sink is added. The PA, an RCA 40977, is mounted on a large heat sink fashioned from a piece of 1/16-inch-thick aluminum stock. The sink is formed into a U-shaped piece, 2-1/2 × 1-3/4 inches in size. The lips of the U are 1 inch high.

To make network design easier, the 8-ohm collector impedance of Q6 is stepped up to 32 ohms by means of T1 (1:4 transformer). A half-wave filter is used as a PA tank. The constants given are for matching 32 ohms to 50 ohms in the first section of each filter, with a loaded *Q* of 1. The last half of each filter is set to match 50 ohms to 50 ohms, also for a *Q* of 1. The low *Q* assures good bandwidth and minimum difficulty with PA instability, yet it provides good rejection of harmonic energy. No tuning controls are required.

A 7-MHz parallel-tuned trap is used at the output of the 20-meter half-wave filter. This was necessary in order to suppress a small amount of 7-MHz energy which passed through the PA and filter section (half-wave filters are low-pass filters). A pure sine wave appears at the transmitter output when full power is being fed into a 50-ohm load. No harmonic current could be seen when examining the waveform by means of a high-quality 50-MHz scope.

The circuit for generating a sidetone, Q10, was garnered from the Ten Tec Argonaut. It is simple and provides an output frequency of approximately 700 hertz.

Although it is not shown in the schematic diagram, an SWR bridge is installed between the arm of S1D and K1B.[1] It is helpful to have that as part of the package, thereby eliminating the need to carry a separate instrument and one more coax cable.

A drive control, R2, was included to permit using the transmitter as a low-power exciter with Class AB solid-state amplifiers. The so-called QRPP operator (5 watts or less) can set the power output level by means of R2.

Someone may wonder why there are two output coupling capacitors between L3 and the base of Q5. The technique serves to equalize the output from the transmitter, thereby avoiding the necessity of an equalizing network of more conventional design. By tapping the 180-pF capacitor down on L3, the drive to Q5 is lessened considerably during 40-meter operation.

This circuit performs smoothly and provides a quality cw note. There are no clicks or chirps. Output on 40 meters was measured as 7.2 watts. The 20-meter power output is 6.7 watts.

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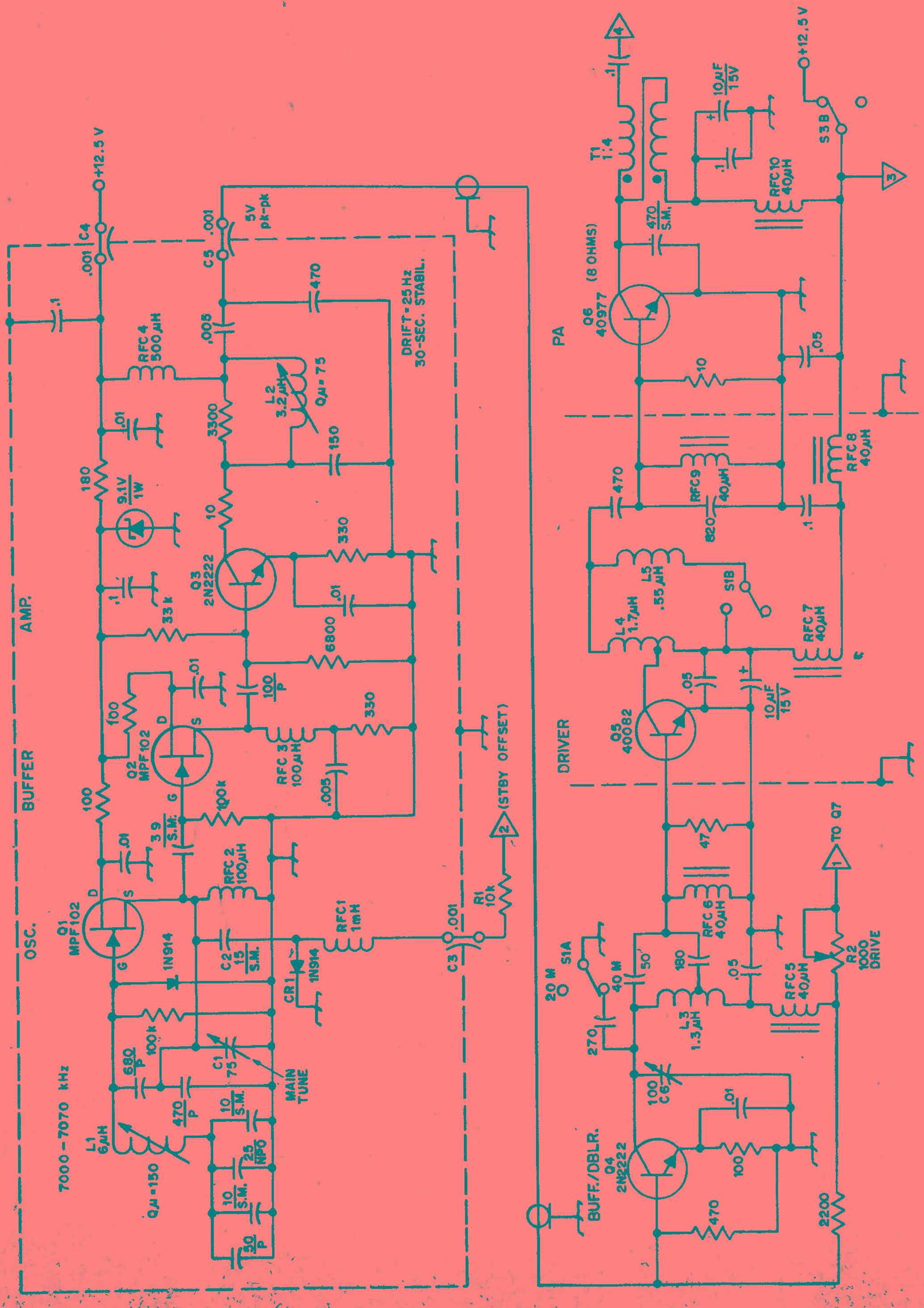
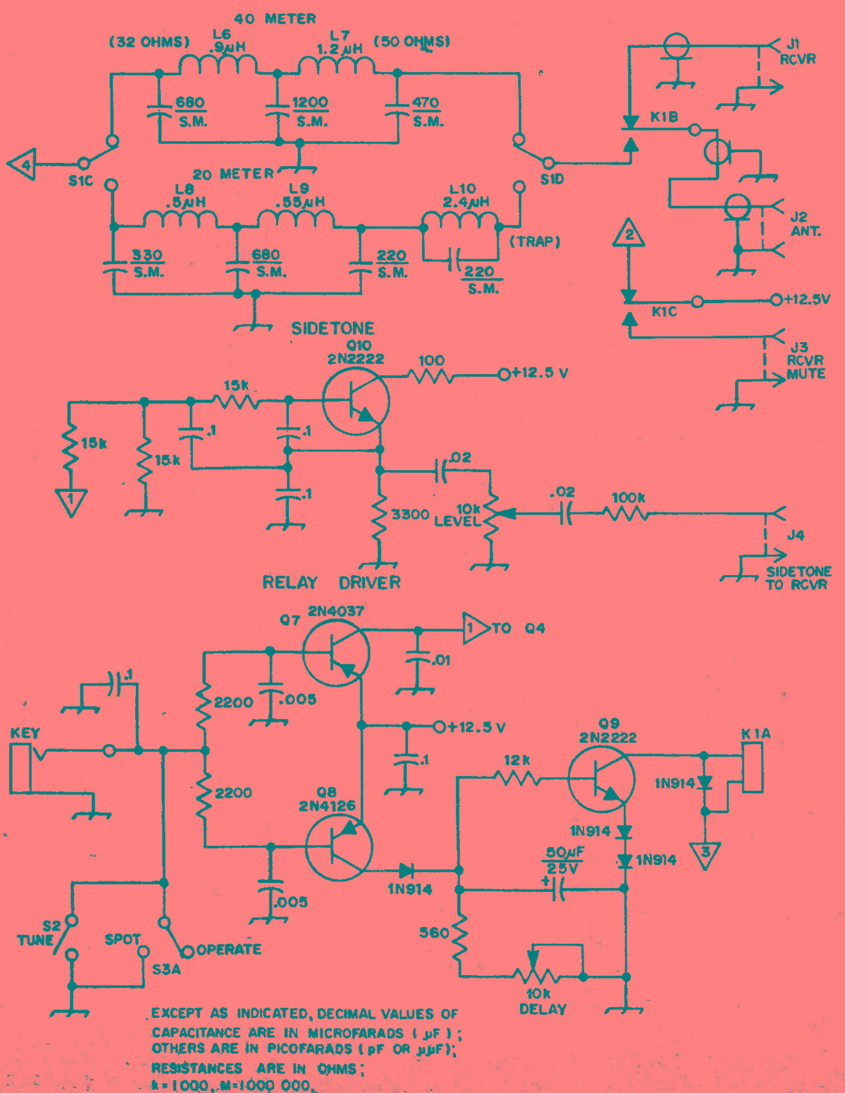
[1] The bridge circuit and pc-board layout are identical to those shown in *QST* for June, 1973, p. 13.

Fig. 1 — Schematic diagram of the QRP transmitter. Fixed-value capacitors are disk ceramic unless otherwise indicated. Capacitors with polarity marked are electrolytic. Fixed-value resistors are 1/2-W composition unless noted differently. S.M. means silver mica. P means polystyrene. Triangles containing numbers indicate circuit connactions which are joined directly. Numbered components not listed in caption are so identified for text reference only.

C1 — Small 78-pF air variable. (Miller No. 2109 dual-gang miniature with only 78-pF section connacted was used here.)
C3-C5, incl. — .001-µF feedthrough type.
C6 — 100-pF mica compression trimmer.
CR1 — Silicon switching diode, 1N914 or equivalent.



J1-J4, incl. — Panel-mount coaxial jacks of builder's choice.
K1 — Two-pole, double-throw, 12-volt, low-current relay. (24-V P&B KHP17D12 used here, with spring tension reduced for fast pull-in at 12 V.)
L1 — Slug-tuned coil with *Q*u of 80 or more, 6 µH nominal. (Miller 42A686CBI used here.)
L2 — Pc-board-mount slug-tuned coil, 3.2 µH nominal. (Miller 23A476RPC used here.) J. W. Miller Co., P.O. Box 5825, Compton, CA 90224.
L3 — 17 turns No. 26 enam. wire to occupy total area of Amidon T-50-6 toroid core (1.3 µH).
L4 — 7 turns No. 26 enam. wire to occupy total area of T-50-2 toroid core (0.57 µH).
L5 — 17 turns No. 26 enam. wire to occupy total area of T-50-2 toroid core (1.7 µH), tapped at 6 turns from collector end.
L6 — 11 turns No. 20 enam. wire to occupy total area of T-68-2 toroid core (0.9 µH).
L7 — 13 turns No. 20 enam. wire to occupy total area of T-68-2 toroid core (1.2 µH).
L8 — 8 turns No. 20 enam. wire to occupy total area of T-68-6 toroid core (0.5 µH).
L9 — 10 turns No. 20 enam. wire to occupy total area of T-68-6 toroid core (0.55 µH).
L10 — 25 turns No. 26 enam. wire to occupy total area of T-50-6 toroid core (2.4 µH).
Q1, Q2, Q8 — Motorola transistor.
Q5, Q6, Q7 — RCA transistor.
Q3, Q4, Q9, Q10 — Surplus 2N2222 or equivalent.
R2 — 1000-ohm linear-taper control.
RFC1-RFC4, incl. — Miniature rf choke (Millen J301 series or equivalent).
RFC5-RFC10, incl. — 40-µH low-*Q* rf choke. Five turns No. 26 enam. wire on Amidon jumbo ferrite bead.
S1 — Subminiature slide switch. S1A and S1B each spdt. S1C and S1D, single dpdt unit. (Radio Shack switches. See text.)
S2 — Spst miniature toggle switch (Radio Shack).
S3 — Dpdt miniature toggle switch (Radio Shack).
T1 — Broadband 1:4 toroidal transformer. Ten bifilar-wound turns No. 24 enam. wire, 8 twists per inch, to occupy entire area of two Amidon FT-61-301 ferrite toroid cores (stacked one atop the other). Amidon Associates, 12033 Otsego St., N. Hollywood, CA 91607.



A 75-TO 120-WATT CW TRANSMITTER

The transmitter shown in Fig. 1 is designed to satisfy the cw requirements of either a Novice or higher-class licensee. The PA stage will operate at 75-watts dc input for the Novice. The rig provides station control and other operating features. Holders of General Class or higher licenses can run up to 120-watts dc input. A SPOT position is provided on the FUNCTION switch which permits identifying the operating frequency in a band. The transmitter has been designed for ease of assembly, with the beginner in mind.

The circuit diagram of the transmitter (Fig. 2) shows the oscillator tube, V1, to be a 6GK6. This pentode works "straight through" on some bands while multiplying in its plate circuit on others. An 80-meter crystal will develop either 80- or 40-meter energy in the subsequent stage (6146B) grid circuit, depending on the setting of S2 and C1. Similarly, a 40-meter crystal will permit the oscillator to drive the final tube on 40, 20, 15 and 10 meters. The final amplifier is always operated straight through for maximum power output. Since the amount of excitation will vary with the degree of frequency multiplication, a screen-voltage-adjustment control, R1, is included.

To insure stability, the 6146B amplifier is neutralized. This is done by feeding back a small amount of the output voltage, (out of phase) to the 6146B grid through C2. The adjustment of this circuit is described later. Provision is included to measure the grid and cathode current of the amplifier stage. With the 6146B it is important to insure that the grid current is kept below 3 mA at all times; *high grid currents will ruin the tube in short order.* The meter, which has a basic 0-1-mA movement, uses appropriate multiplier and shunt resistors to give a 0-10-mA scale for reading grid current, and 0-250 mA for monitoring plate current.

The plate tank for the final amplifier uses the pi-section configuration for simple band switching. This network is tuned by C3, and C4 provides adjustment of the antenna coupling. The pi-network also assures excellent suppression of harmonics when properly terminated, typically 35 to 45 dB. All connection points to the transmitter are filtered to "bottle up" harmonic energy, which, if radiated, could cause television interference.

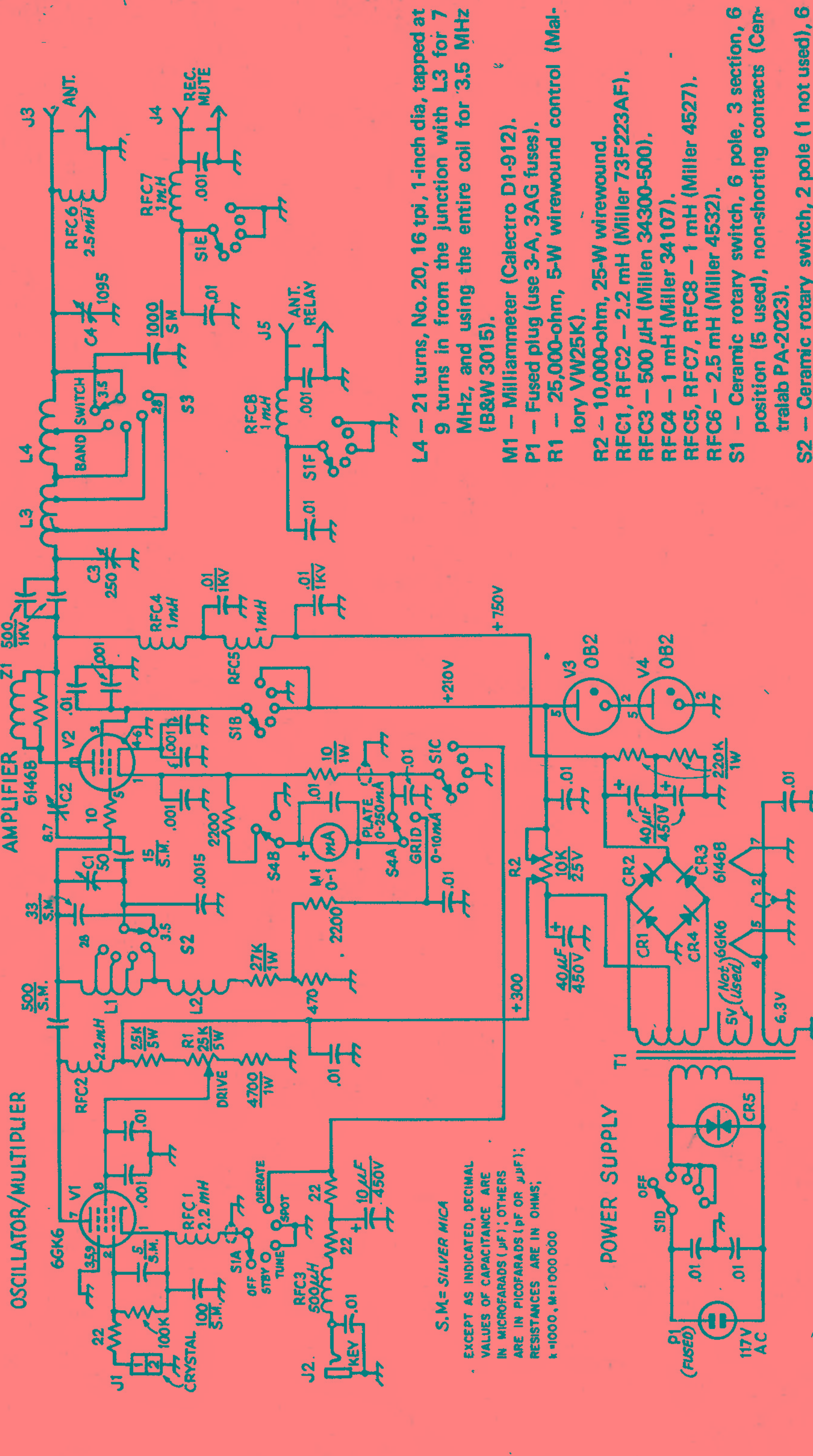
Silicon rectifiers are used in the "economy" power supply. A center-tapped transformer with a bridge rectifier provides all of the operating voltages for the transmitter. Depending upon the line voltage, the high-voltage supply will deliver about 750 volts, key up, dropping to about 700 volts under load. If the line voltage is above 120, these figures will be increased by about 50 volts. The screen supply to the 6146B is regulated by two OB2 VR tubes.

The FUNCTION switch turns the transmitter on and selects the spot, tune or operate modes. Leads from this switch are brought out to the rear deck of the transmitter to mute the station receiver and key the antenna relay. Thus, S1 provides one-switch transmit-receive operation. In the OPERATE position, the oscillator and amplifier are keyed simultaneously by grounding the common cathode circuit. A *RC* network across the cathode line is included to shape the keying, thus preventing key clicks.

Construction

An 11 X 7 X 2-inch aluminum chassis (Bud AC-407) is used as the base for the transmitter. A homemade aluminum U shield encloses the final amplifier. The chassis is fitted with an 11 X 7-inch front panel which is cut from sheet aluminum. The panel is held to the chassis by the switches and panel bushings common to both units. Correct placement of the various parts can be determined by viewing the photographs. Only an experienced builder should try to relocate the major components. The rf compartment has 3/4-inch mounting lips bent along the back side and the ends to give a finished size of 5 X 8 3/4 inches. This rear housing is held to the chassis and front panel with 6-32 hardware, and a perforated metal cover is fastened to it with No. 6 sheet-metal screws.

Fig. 1 — This 120-watt cw transmitter can be operated at 75-watts dc input for Novice-band use. The slide switch puts the meter in the grid or cathode circuit of the 6146B amplifier. Directly to the right of the slide switch is the FUNCTION switch and crystal socket. Continuing at this level, farther to the right is the GRID TUNING, grid BAND SWITCH, and the DRIVE level control. The controls to the upper right are the final BAND SWITCH, FINAL TUNING, and FINAL LOADING.



C1 — Air variable (Hammarlund APC-50B).
C2 — Air variable (Johnson 160-104).
C3 — Air variable (Hammarlund MC250M).
C4 — Three-section broadcast variable, 365 pF per section, all sections connected in parallel (Miller 2113).
CR1-CR4, incl. — 1000-PRV, 1-A silicon.
CR5 — Transient suppressor (GE 6RS20SP4B4).
J1 — Crystal socket.
J2 — SO-239-style connector, panel mount.
J3, J4 — Phono connector, panel mount.
L1 — 37 turns, No. 20, 16 tpi, 3/4-inch dia, tapped at 4 turns from the tube end for 28 MHz, 6 turns for 21 MHz, 12 turns for 14 MHz, and using the entire coil for 7 MHz (B&W 3011).
L2 — 28 turns, No. 20, 32 tpi, 3/4-inch dia (B&W 3012).
L3 — 12 turns, No. 18, 8 tpi, 1-inch dia, tapped at 3 turns from the tube end for 28 MHz, 6 turns for 21 MHz, and using the entire coil for 14 MHz (B&W 3014).
L4 — 21 turns, No. 20, 16 tpi, 1-inch dia, tapped at 9 turns in from the junction with L3 for 7 MHz, and using the entire coil for 3.5 MHz (B&W 3015).
M1 — Milliammeter (Calectro D1-912).
P1 — Fused plug (use 3-A, 3AG fuses).
R1 — 25,000-ohm, 5-W wirewound control (Mallory VW25K).
R2 — 10,000-ohm, 25-W wirewound.
RFC1, RFC2 — 2.2 mH (Miller 73F223AF).
RFC3 — 500 µH (Millen 34300-500).
RFC4 — 1 mH (Miller 34107).
RFC5, RFC7, RFC8 — 1 mH (Miller 4527).
RFC6 — 2.5 mH (Miller 4532).
S1 — Ceramic rotary switch, 6 pole, 3 section, 6 position (5 used), non-shorting contacts (Centralab PA-2023).
S2 — Ceramic rotary switch, 2 pole (1 not used), 6 position (1 not used) section, non-shorting contacts (Centralab PA-2003).
S3 — Ceramic rotary switch 1 pole, 6 position (1 not used), non-shorting contacts (Centralab 2501).
S4 — Dpdt slide switch.
T1 — Power transformer, 117-volt primary, secondary 540 volts ct at 260 mA, and 6.3 volts at 8.8 A (Stancor P-8356).
Z1 — 7 turns of No. 16 wire on a 100-ohm, 1-W composition resistor.

Fig. 2 — Circuit diagram of the 6146B transmitter. Capacitors with polarity marked ara electrolytic, others are disk ceramic. Resistors are 1/2-watt composition.

Fig. 3 – Top view with the perforated metal cover removed. The small capacitor beside the 6146B provides the neutralizing adjustment. L3 and L4 are mounted one above the other. The smaller tube inside the rf compartment is the 6GK6 oscillator.

The lead to RFC4 is routed through an insulated bushing. A small bracket supports a piece of Lucite which insulates C2, the neutralizing capacitor, from ground. Another bracket supports C1 and S2. C1 is above ground for rf and dc, so an insulated coupling (Millen 39016) is to be used on its shaft. Tie strips are used to support the small capacitors, resistors, and rectifier diodes.

The 5-volt winding of T1 is not used. Therefore, these leads should be cut and taped to avoid accidental contact with the chassis. The filter capacitors and bleeder resistors are mounted on tie strips. Care should be used in making all high-voltage connections to prevent accidental shorts from occurring. Also, don't omit the "spike prevention" Thyrector diode, CR5, as this unit protects the supply from transient voltage surges.

Fig. 4 – Looking inside the bottom of the transmitter, L1 and L2 are located at the center, next to the grid-tuning capacitor. All of the output jacks ere spaced along the rear wall of the chassis. The bottom cover has been removed in this photograph. It should be kept in place during operation.

Adjustment

After the transmitter has been wired, check it a second time for possible wiring errors. Next, the two voltage-regulator tubes should be plugged in their sockets. With S1 at off, plug the line cord into a 117-volt outlet. When S1 is moved to STANDBY, the VR tubes should glow. The high voltage at RFC4 should measure about 750 volts. The oscillator voltage, checked at pin 7 of the 6GK6, should be close to 300 volts. If it is not, move the tap on R2 accordingly. *Make all measurements with care as these voltages are dangerous.* Then turn S1 to off and make certain the voltage drops to zero at RFC4, and at the 6GK6 socket. Normally, it will take at least a minute for the high voltage to drop to near zero (A fact which should be remembered during subsequent tests.).

Remove the line cord from the outlet – *never work on a transmitter unless the ac power is disconnected.* Install the tubes and connect the plate cap to the 6146B. Insert an 80-meter crystal in J1 and set both band switches to the 80-meter position. Set the FUNCTION switch to the tune position, and plug the power cord into the mains. After the tubes warm up, swing C1 through its range. If the oscillator stage is working, grid current will be read on M1. C1 should be used to peak the grid current. The total current drawn should be kept below 3 mA. Use the DRIVE control, R1, to set the drive level. Change S2 to the 40-meter position and confirm that the second harmonic of the crystal frequency can be tuned. With a 40-meter crystal in J1, it should be possible to obtain grid current with S2 set for 7, 14, 21 and 28 MHz. The maximum grid current obtainable on the higher-frequency bands will be somewhat less than on 80 and 40 meters (about 2.5 mA on 21 MHz, and 1.5 mA on 28 MHz). The latter value is not enough for full drive on the 10-meter band. The dc input power to the 6146B should be limited to 90 watts on 10 meters, and this operating condition will provide approximately 50 watts output. On the other bands 60 to 70 watts output will be possible. If an absorption wavemeter is available it is a good idea to check the setting of C1 for each band to insure that the tuned circuits are operating on the proper harmonic frequency. It may be possible to tune to an incorrect harmonic frequency, *which can lead to out-of-band operation.* Once the proper setting of C1 has been determined, mark the front panel so that this point can be returned to quickly when tuning up. Lacking a wavemeter, a receiver (with the antenna disconnected) can be used to check output on the various bands.

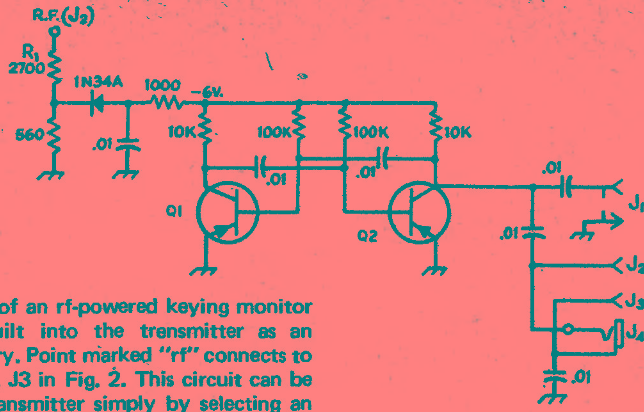


Fig. 5 – Circuit of an rf-powered keying monitor thet may be built into the trensmitter as an operating accessory. Point marked "rf" connects to the antenna jack, J3 in Fig. 2. This circuit can be used with eny transmitter simply by selecting an input resistor, R1, that gives about –6 volts et the point shown. Only the desired output jacks need to be included.

J1 – Phono jack for audio output from the receiver.

J2, J3 – Tip jacks for headphones or receiver.

J4 – Phone jack for headphone connaction.

Q1, Q2 – 2N406 or equivalent (pnp).

With S2 and S3 set for 15 meters, tune C1 for maximum grid current. Then, set the indicated value to about 2 mA with the DRIVE control. Set C4 at half scale, and slowly tune C3 while watching the grid-current meter. At the point which C3 tunes the tank through resonance, a dip in grid current will be seen, unless by chance the amplifier is already neutralized. A slow rate of tuning is required, as the indication will be quite sharp. When the dip has been found, adjust C2 until no dip can be noted, or, at least, the dip is less than 0.1 mA. All preliminary tests should be made as quickly as possible, as the transmitter is operating without a load, and extended operation can damage the final-amplifier tube.

When neutralization has been completed, and all circuits appear to be operating normally, connect a load to the transmitter. Preferably, this should be a 50-ohm dummy load, but a 100-watt light bulb will do. If an output indicator or SWR bridge is available, it should be connected between the transmitter and the load. The lamp is a fair output indicator on its own. Adjust the transmitter as outlined above for 2 mA of grid current on the desired band. With a key plugged in at J2, set C4 at full mesh, and switch S4 to read plate current. Watching the meter, close the key and adjust C3 for a plate-current dip. The dip indicates resonance. If the plate current dips below 150 mA, decrease the capacitance setting of C4, and again tune C3 for a dip. This dip-and-load procedure should be repeated until a plate current of 170 mA is reached at resonance. If the Novice 75-watt input limit is to be observed, the plate current at resonance must be held to 100 mA. This can be accomplished by using additional capacitance at C4.

If extended operation is planned at 75 watts or less input, it is advisable to reduce the screen voltage on the 6146B to insure that the rated screen dissipation rating of this tube is not exceeded. This can be done by using an OA2 in place of one OB2, jumpering the other VR-tube socket, and readjusting R2 so that the single VR tube draws about 25 mA. The OA2 will deliver 150 volts, regulated.

A HIGH-OUTPUT TRANSISTOR VFO

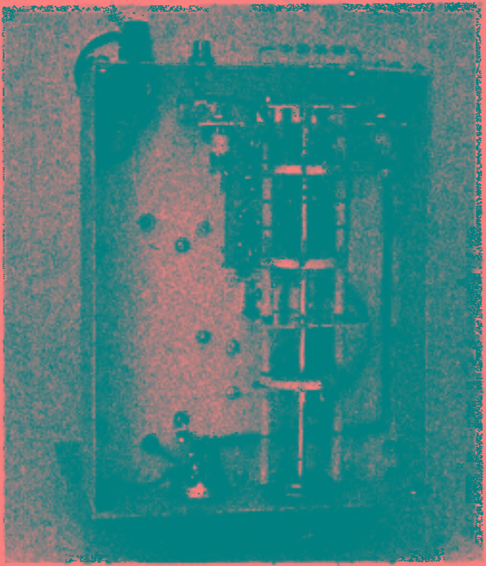
If a solid-state VFO is to be used with tube-type transmitters, it must have sufficient output to drive a crystal-oscillator stage as a doubler or tripler. Most of the Novice-class transmitters require 10-25 volts of rf to produce sufficient drive to succeeding stages. The VFO shown in Fig. 1 serves as a "crystal replacement" for the type of transmitter that uses a 6GK6, 6AG7, 12BY7 or similar tube in the oscillator. To provide sufficient output level, a two-watt amplifier is added to the basic transistor VFO. To reduce harmonic output and eliminate tuning of the amplifier stage, a fixed-value half-wave tank is used as the output circuit, followed by broadband rf step-up transformers. The VFO will develop 20 volts or more across a 5000- to 50,000-ohm load.

The basic VFO design was originally described in *QST*, June, 1970.

Circuit Data

In the circuit of Fig. 2 are two completely separate tuned circuits – one for 3.5 to 4.0 MHz, and one for 7 to 7.35 MHz. A split-stator broadcast-type variable, C3, is employed so that there is no need to switch a single tuning capacitor from one tuned circuit to the other. Also, the arrangement shown places the tuning-capacitor sections in different parts of the circuit for the two bands. The 7-MHz tuned circuit uses C3A from the junction of the feedback capacitor (C1 and C2) to ground. This gives the desired amount of

Fig. 1 — The two-band VFO. This unit operates on 3.5 to 4 and 7 to 7.3 MHz. Included is a 2-watt amplifier and broad-band rf transformers so that the VFO can drive tube-type transmitters directly.



The bottom view of the VFO shows only the two switches and the output transformers — other components are mounted on the etched circuit boards "topside."

bandspread for 40-meter operation, but, when hooking the 80-meter tuned circuit up the same way, only 200 kHz could be covered with C3B. So, for 3.5 to 3.8-MHz operation, C3B is connected from the high-impedance point on L2 to ground.

It will be noted that a rather high value of *C* is used in parallel with each of the inductors, L1 and L2. This measure was taken to enhance the frequency stability of the VFO. By using a high *CL* ratio, small changes in the junction capacitance of Q1 have a less pronounced effect on the tuned circuit than would be experienced when using smaller values of capacitance. Silver-mica capacitors are used in the interest of good stability. So that the oscillator will start readily, despite the high *C* to *L* ratio, Q1 was chosen to have high beta and f_T. However, the high gain and frequency ratings caused the stage to be unstable at vhf — approximately 150 MHz. As C3 was tuned, vhf oscillations could be seen on the output waveform. The vhf energy was tunable, and it was found that the lead from Q1's base-blocking capacitor, C6, to the arm of S1A, was long enough to act as a vhf inductance, which was being tuned by C3. The addition of a 3-ferrite-bead choke, RFC1, mounted right at the circuit-board terminal for C6, cured the problem. Ideally, RFC1 would be mounted on the base lead of Q1, with the beads up against the transistor body. However, this is not always a practical method of mounting, so one should attempt to get the beads as close to the base connection as possible, thus minimizing the possibility of a vhf inductance being set up in that part of the circuit. To further discourage parasitic oscillations a collector resistor, R2, was included. It would be connected as close to the collector terminal of Q1 as possible, for the same reasons given when discussing RFC1.

Output from Q1 is taken across R4. Direct coupling is used between the low-impedance takeoff point of Q1 and the base of emitter-follower, Q2. Resistor R1 sets the forward bias of Q2 by picking some dc voltage off the emitter of Q1. Sufficient rf passes through R5 to drive Q2.

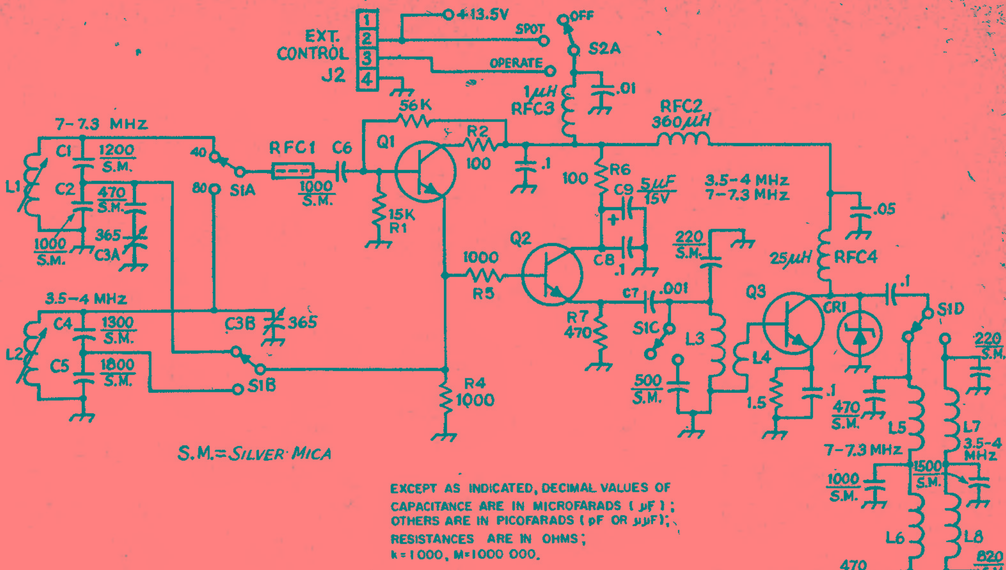
The collector of Q2 is bypassed for high and low frequencies to assure stability. A 100-ohm collector resistor, R6, decouples the stages at rf.

The drive signal for Q3 is taken from the emitter of Q2 through a small-value capacitor, C7. The larger the capacitance, the greater will be the available output voltage across a given load, but the smaller the capacitance value used, the better will be the VFO isolation from the succeeding circuit. One should use only the amount of capacitance that will provide adequate peak output voltage.

An RCA 2N2102 is used in the output amplifier. This transistor has a power rating of 5 watts, so it can be safely operated at two-watts dc input without a large heat sink. This stage operates Class C, using no fixed forward bias. A Zener diode, CR1, is used to prevent destruction of the transistor if the load is inadvertently removed. The PA tank is fixed tuned. The output is essentially flat over the 80- and 40-meter bands. The constants have been chosen for a 50-ohm output, so it is necessary to transform this impedance up to the high *Z* found at the transmitter tube grid. Separate tuned circuits, L10 and L12, are used for this purpose. The length of the connecting cable will affect the tuning of the output stage; with the values shown, a 36-inch length of RG-58/U should be used.

Construction Information

The VFO is built on a 9 X 7 X 2-inch chassis which is fitted with a 9 X 4 1/2 X 4 1/4-inch box



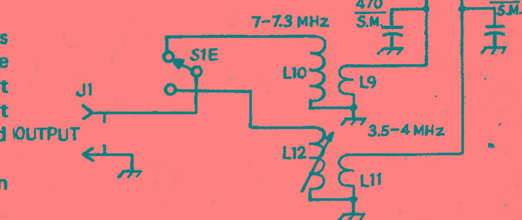


Fig. 2 — Schematic diagram of the VFO. Resistors are 1/2-watt composition; capacitors, except those marked as silver mica, are disk ceramic. Parts not listed below are marked for text reference. Layout diagrams are available for the VFO, amplifier and power-supply boards.*

C3 — Dual-section air variable, 365 pF per section (Miller 2112).
CR1 — Zener, 36 V, 1 W.
J1 — Phono connector, panel mount.
J2 — 4-terminal ceramic strip (Millen E-304).
L1 — 0.68-1.25 μH, slug tuned (Miller 42A106C8I).
L2 — 2.2-4.1 μH, slug tuned (Miller 42A336CBI).
L3 — 2 μH, 25 turns of No. 24 enam. wire on Amidon T-50-2 toroid core (Amidon Associates, 12033 Otsego Street, North Hollywood, CA 91607).
L4 — 12 turns No. 22 hook-up wire over L3.
L5, L6 — 13 turns of No. 20 enam. wire on Amidon T-68-2 core.
L7, L8 — 18 turns of No. 20 enam. wire on Amidon T-68-2 core.
L9 — 7 turns of No. 26 enam. wire over L10.
L10 — Approx. 3 μH, Miller 4405 with slug and 4 turns removed.
L11 — 7 tums No 26 enem. wire over L12.
L12 — 23 μH (Miller 4407).
Q1 — HEP-55.
Q2 — HEP-728.
Q3 — 2N2102.
RFC1 — Three Amidon ferrite beads on a 1/2-inch length of No. 22 wire. A 15-ohm resistor mey serve as a substitute.
RFC2 — Miniature choke (Miller J300-360).
RFC3 — Miniature choke (Millen 34300).
RFC4 — 2.5 μH rf choke (Millen J300-25).
S1 — Home-assembled switch made from a Centralab PA272 kit and 3 Centralab RRD sections. (See Fig. 6-5).
S2 — Ceremic rotery switch, 2 pole, 3 positjon, one section, non-shorting contacts (Mallory 3223J).

* See *QST* for December, 1970.

to house the rf assemblies. The VFO circuit board is mounted on two brackets (Fig. 3). The amplifier etched-circuit board is mounted over a hole cut in the chassis. All components for the power supply (except the transformer) are mounted on a third circuit board, which is mounted on short stand-off pillars above the chassis. The power transformer is positioned on the right-rear side of the chassis.

S1 is a homemade assembly built from Centralab switch sections and parts. The mounting bushing supports the front end of the switch, and an aluminum L bracket supports the rear. The ceramic spacers supplied with the PA272 kit are used to separate the various wafers so that they are as close as possible to the circuits that they switch. A second switch, S2, turns the power supply on, as well as activating the VFO alone for zero-beating purposes. In operation, external connections are required from the station transmitter to J2 so that the VFO will come on simultaneously with the transmitter.

Adjustment

The power supply section should be tested before it is connected to the VFO. After the unit has been checked against the schematic diagram to

Fig. 3 — Top view, with the cover removed, of the rf compartment. The VFO board is mounted on two aluminum brackets. All leads from this circuit board should be made with heavy wire to minimize mechanical instability from vibration. The amplifier board is flush-mounted on the chassis. The dual-section broadcast variable is driven by a Miller MD-4 dial. L1 and L2 ere adjusted through holes cut in the left side of the shielded compartment.

spot and correct any wiring errors, attach a voltmeter (VOM or VTVM) to the power-supply output. Plug P1 into a 117-volt outiet, and switch S2 to SPOT. The voltmeter should read approximately 13.5 volts. Then connect a 47-ohm, 2-watt resistor across the power supply output — the meter should continue to read the same voltage, even with the heavy load. If the power supply checks out correctly, remove the 47-ohm resistor and connect the supply to the VFO. With S1 set for 80-meter operation, tune a receiver across 3.5 to 4 MHz until the VFO signal is found. Then, check the 7-MHz range to see that the VFO is also operating in the 40-meter range. Connect a patch cable between the transmitter and the VFO. If a cable length other than the 36 inches is used, it may be necessary to add or subtract turns from L10 to achieve maximum drive to the transmitter. The slug in L12 should be set for maximum 80-meter drive to the following transmitter oscillator stage.

Once the entire VFO has been tested, the next step is calibration of the dial. With the plates of C3 set at about 95 percent of full mesh, adjust L1 for 7.0 MHz and L2 for 3.5 MHz. A receiver with a crystal calibrator, or a BC-221 frequency meter can be used during the dial calibration. *When using a VFO close to the band edge, always use some form of secondary frequency standard to insure in-band operation, in accordance with FCC regulations.* Once the calibration has been set, the VFO should again be connected to the transmitter, and a monitor receiver set up. In normal circumstances it is necessary to ground the antenna terminal of the receiver to prevent overload from the nearby transmitter. Even so, the signal heard from the receiver will be quite strong, so turn the rf gain control back until a moderately-strong signal is obtained. Then, key the transmitter and monitor the output signal with the receiver. The signal should be clean (free from hum, chirp and clicks). The VFO-transmitter combination should be checked on 80 through 10 meters in this manner.

It is also useful to zero beat the VFO against the crystal calibrator in the receiver. The VFO should be left on for 15 minutes or more, and the drift, as evidenced by a change in the beat note, should be less than 50 Hz on either fundamental range. Drift will be most noticeable on the 10-meter band, as any drift at 7-MHz will be multiplied by a factor of four in the transmitter. If excessive drift is found, it can usually be traced to a defective component. The process of finding such a troublesome part is time consuming; more often than not, a defective capacitor will be the cause.

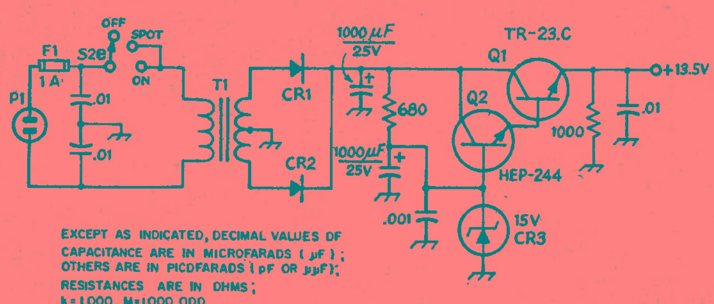


Fig. 4 — Power supply for the solid-state VFO. Capacitors with polarity marked are electrolytic, others are disk ceremic. Resistors are 1/2-wett composition.
CR1, CR2 — 100-PRV, 1-A silicon.
CR3 — Zener, 15 V, 1 W.
P1 — Fused plug (use 1-A, 3AG fuses).
Q1 — 40-watt npn power trensistor (International Rectifier TR-23C).
Q2 — Motorole HEP-24.
S2 — See Fig. 2.
T1 — Filament transformer, 24 V ct at 1 A.

A 6-BAND TRANSMITTER FOR THE CW OPERATOR (T-9er)

Operating a transmitter and amplifier designed with cw as an afterthought can make cw very dull. Presented here is the T-9er, a hybrid circuit built with cw as the prime mode of service. Included are such features as full break-in, shaped keying, linear VFO calibration, T-R switch, built-in power supply, and a solid-state heterodyne conversion scheme. The PA stage uses a pair of 6146Bs and is capable of producing up to 240-watts input on 160 through 10 meters.

The Circuit

The VFO and buffer, Q1 and Q2 in Fig. 2, are an adaptation of a unit previously described in *QST*.[1] Q3, a second buffer, provides additional gain to assure adequate current to drive the base of the mixer, Q5. The VFO range is 5.0 to 5.2 MHz.

The heterodyne-frequency oscillator, Q4, operates at one of six crystal-controlled frequencies selected by the band switch. All of the crystals chosen oscillate at a frequency *above* the operating band. For this reason, the VFO dial tunes in the same direction on each band. CR13 is included to limit the oscillator voltage appearing at the mixer to 0.6.

Voltage from the VFO and HFO are coupled to the mixer, Q5, via C9 and C5, respectively. A tuned collector circuit operates at the *difference* frequency and provides a low-level signal to the driver stage, V1. The VFO actually tunes backwards with respect to the mixer output signal. The bottom edge of each amateur band corresponds to a VFO setting of 5.2 MHz.

A conventional grid-block system provides clickless, chirpless operation because neither oscillator is keyed. Q6 activates the mixer only when the key is depressed. The waveform transmitted is determined by R2 and C11 in the grid circuit of V1. Since the 6GK6 keys at a slightly slower rate than the mixer, any clicks generated in the earlier stages are not heard.

Voltage from the mixer is sufficient to power the driver to nearly full output on all bands. The plate circuit uses separate slug-tuned inductors for 160 through 20 meters. The 15- and 10-meter bands are covered with one coil. Neutralization of the 6GK6 is not required.

Output Circuit

A pi-network output circuit is employed with a pair of parallel-connected 6146Bs. Six 10-ohm resistors are connected between the cathodes and ground. Voltage developed across these resistors is used to indicate cathode current on the meter.

The amount of screen voltage is determined by the position of S3. When this switch is closed, the screen voltage is 150. Releasing S3 places R13 in series with the screen bus, lowering the voltage to 50. This lower voltage limits the transmitter input to approximately 60 watts. A neon lamp, DS2, has been included to indicate the position of S3. R15 and R16 form a voltage divider which allows ignition of DS2 during high screen-voltage conditions only.

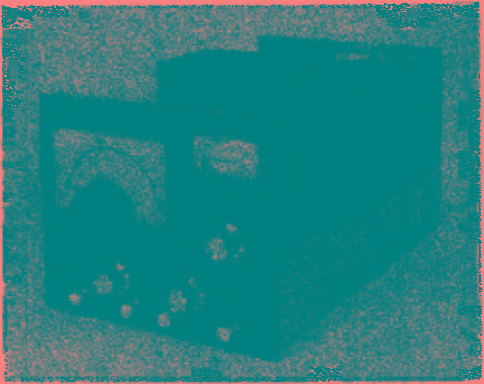


Fig. 1 — Front view of the cw transmitter. All metal work is done with sheet end cane-metal sections.

A T-R switch, V4, permits using the same antenna for transmitting and receiving. The theory and operation of this unit was described in an earlier *QST*.[2] An antenna relay is not required.

The operating conditions of the final-amplifier stage may be checked with the panel meter, M1. A 6-position switch allows monitoring of grid current, relative output, screen, plate and bias voltages, and cathode current.

The Power Supply

A silicon-diode full-wave bridge rectifier is used in the secondary of T1 to produce slightly over 1000 V dc during no-load conditions. Although this is somewhat high for 6146Bs, it has not shortened tube life. A choke-input filter is connected in the transformer center-tap lead to obtain 300 volts for powering the driver tube and the T-R switch. Sixteen volts of dc for operating the solid-state circuitry are obtained by rectifying and filtering the combined output of the two filament windings, which are connected in series. If the windings buck each other, producing no voltage, one set of leads should be reversed.

Final-amplifier screen and bias voltages are developed by T2. This part of the supply uses one half-wave rectifier for each voltage.

Construction

The transmitter is completely self-contained. It is built on a 10 X 17 X 3-inch chassis with an 8 1/2-inch-high front panel. Shielding is used between each stage and between each band-switch wafer as shown in the photograph. The final-amplifier section on top of the chassis is completely enclosed in a perforated aluminum shield. Small pieces of circuit board are soldered

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[1] DeMaw, "Building a Simple Two-Band VFO," QST, June, 1970.

[2] Myers, "Stepping Up T-R Switch Performance," QST, December, 1967.

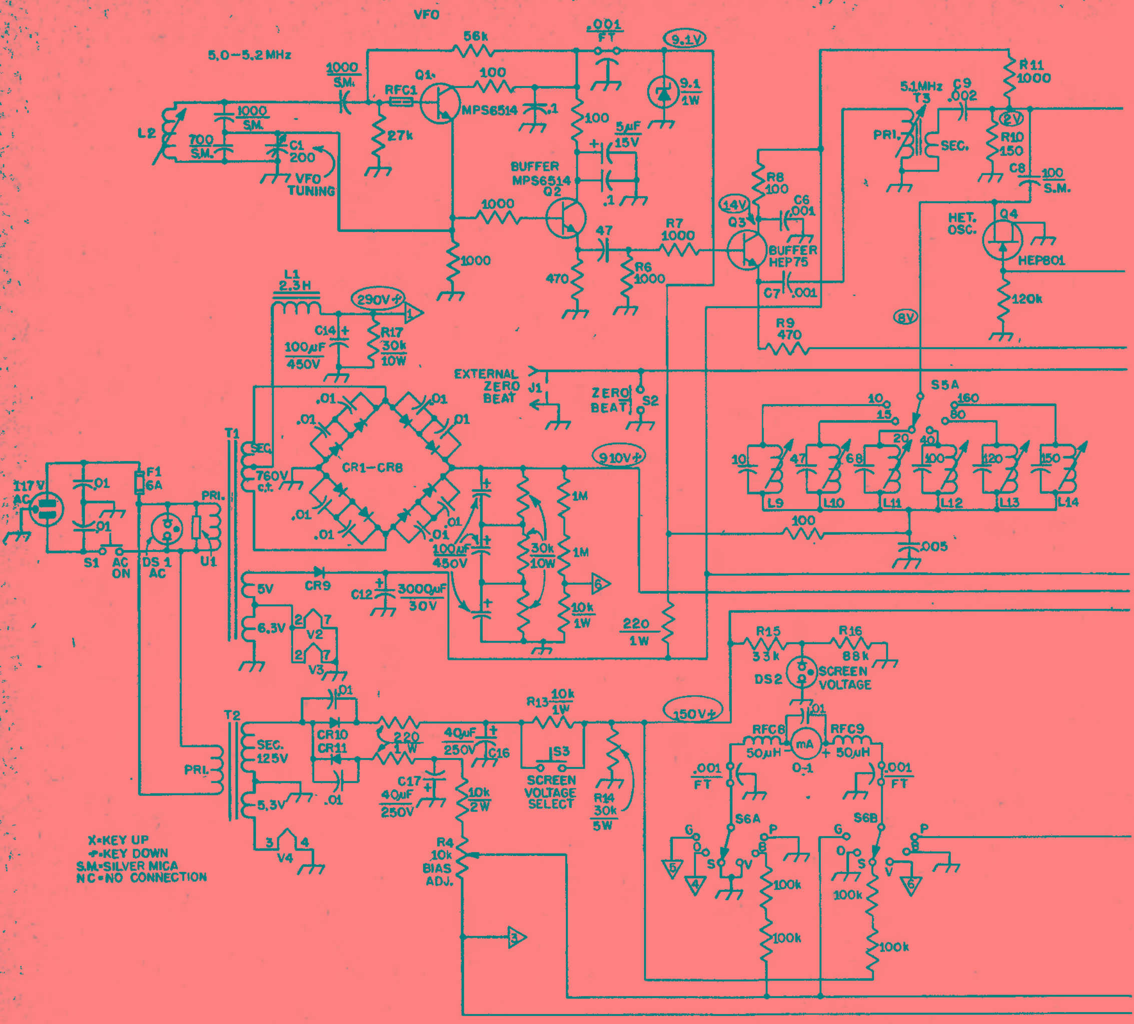


Fig. 2 — Circuit diagram for the T-9er. Component designations not listed below are for text reference.

C1 — 200-pF air variable (Hammarlund HFA-200A).

C2 — 100-pF air variable (Hammarlund MAPC-100B).

C3 — 300-pF air veriable (Hammarlund RMC-325-S).

C4 — 1200-pF air variable (J. W. Miller 2113).

CR1-CR12, incl. — 1000-PRV, 2.5-A (Mallory M2.5A or equiv.).

CR13 — Silicon small-signal switching diode (1N914 or equiv.).

DS1, DS2 — Neon indicator lamp, 117-V (Leecraft 32-211).

J1, J2 — Phono jack, single hole mount.

J3 — Coax chassis connector, type SO-239.

J4 — Open-circuit key jack.

L1 — 2.3-H filter choke (Stancor C-2304 or equiv.).

L2 — 2.2- or 4.1-μH slug-tuned inductor (J. W. Miller 42A336CBI).

L3, L16 — 1.0- to 4.1-μH slug-tuned inductor (J. W. Miller 42A156CBI). Both coils are rewound with the wire supplied: 3 turns spaced over a 3/4-inch length.

L4, L9, L10, L11, L15 — 1.0-μH slug-tuned inductor (J. W. Miller 21A106RBI).

L5 — 2.2- to 4.1-μH slug-tuned inductor (J. W. Miller 42A336BCI).

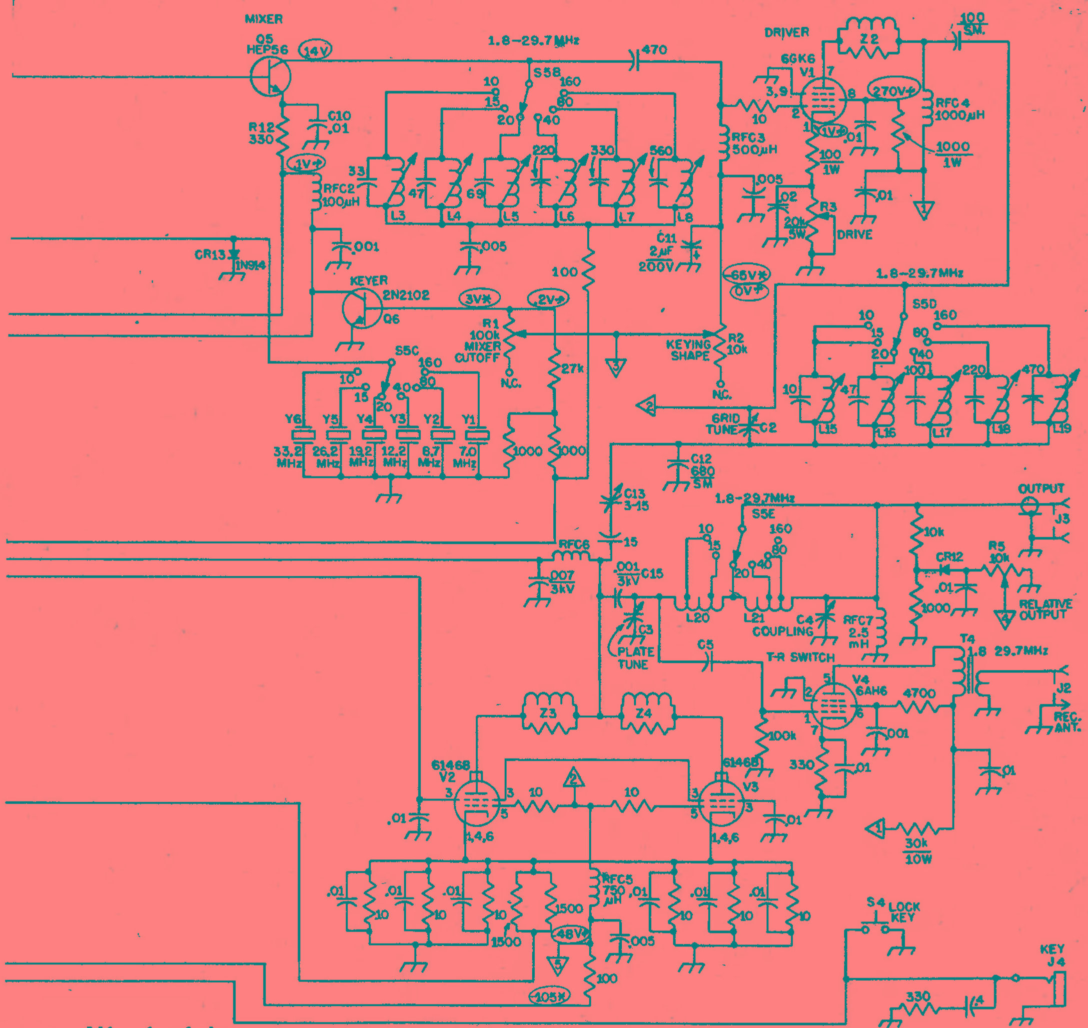
L6 — 1.6- to 2.7-μH slug-tuned inductor (J. W. Miller 21A226RBI).

L7, L8, L13, L14, L18, L19 — 6.8- to 8.5-μH slug-tuned inductor (J. W. Miller 21A686RBI).

L12, L17 — 1.5- to 1.8-μH slug-tuned inductor (Miller 21A156RBI).

L20 — 9 1/2 turns, 8 tpi, 1 1/2-inch dia tapped from tube end at 2 1/2 turns for 10 meters and at 4 3/4 turns for 15 meters (B&W 3018).

L21 — 38 turns, 10 tpi, 2-inch dia tapped from J3 end at 18 turns for 80 meters, 28 turns for 40 metars (B&W 3027).



M1 — 1-mA dc.

R1 — 100,000-ohm, linear-taper, 2-watt carbon control (Allen Bradley).

R2, R4, R5 — 10,000-ohm, linear-taper, 2-watt carbon control (Allen Bradley).

R3 — 20,000-ohm, linear-taper, 4-watt, wirawound control (Mallory M20MPK).

RFC1 — Thrae Amidon ferrite beads threaded on a 1/2-inch length of No. 22 wire. A 15-ohm 1/2-watt resistor may serve as a substitute. (Amidon Assoc., 12033 Otsego St., N. Hollywood, CA 91607).

RFC2 — 100-μH rf choke (Millen 34300-100).

RFC3 — 500-μH rf choke (Millen J300-500).

RFC4 — 1000-μH rf choke (Millen 34300-1000).

RFC5 — 750-μH rf choke (Millen 34300-752).

RFC6 — 1-mH rf choke (E. F. Johnson 102-752).

RFC7 — 2.5-H rf choke (Millen 34300-2500).

RFC8, RFC9 — 50-μH rf choke (Millen 34300-50).

S1-S4, incl. — Spst push button (Calectro E2-144).

S5 — Ceramic rotary switch, 5 poles, 6 positions, 5 sections (Centralab PA-272 index with 5 type XD wafers).

S6 — 2-pole, 6-position, single-section rotary (Centralab PA-2003).

T1 — 117-volt primary; secondary 760 volts at 220-mA, center tapped; 5-V at 3-A; 6.3-V at 5-A (Stancor P-8170 or equiv.).

T2 — 117-volt primary; secondary 125 volts at 50 mA; 6.3-V at 2-A (Stancor PA-8421 or equiv.).

T3 — Primary: B.2- to 8.9-μH slug-tuned inductor (J. W. Miller 46A826CPC). Secondary: 2 turns No. 22 enameled wire wound on the cold and of the primary.

T4 — 20 turns No. 24 enameled wire wound on a 1-inch long, 1/2-inch dia iron core from a slug-tuned coil form. The secondary is 3 turns No. 24 enameled wire wound over the cold end of the primary.

U1 — Transient voltage suppressor, 120-volt (General Electric 6RS20SP4B4).

Z1 — 3 turns No. 22 wire space-wound on a 100-ohm, 1-watt composition resistor.

Z2, Z3 — 5 turns No. 18 wire space-wound on a 100-ohm, 2- watt composition resistor.

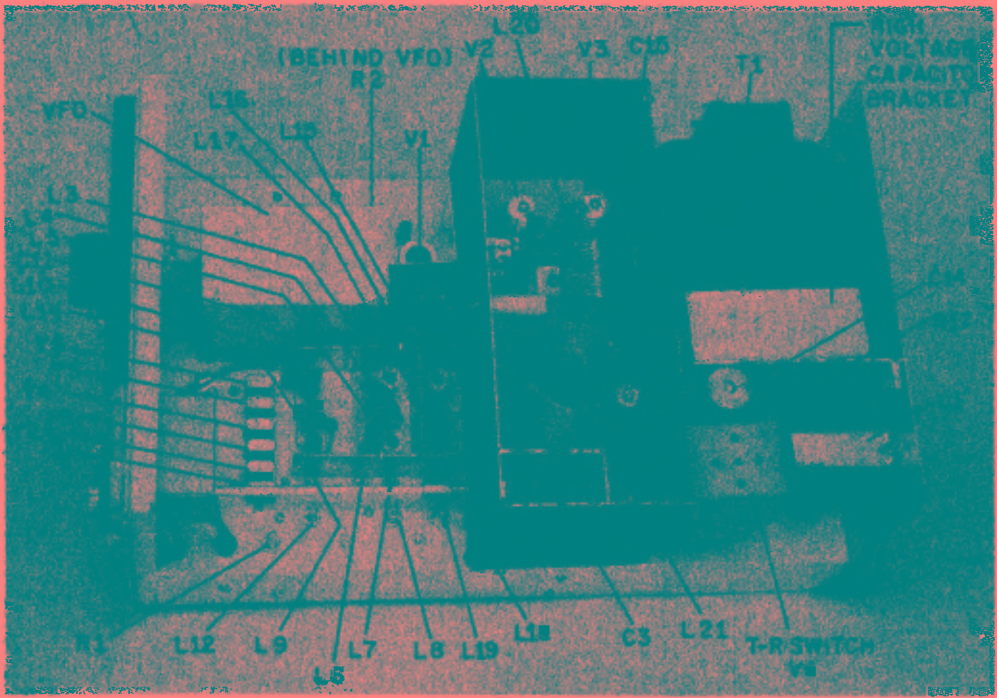


Fig. 3 — Top view of the cw transmitter.

together to form a compartment for the slug-tuned coils. The etched circuit board for the buffer, Q3, and the mixer, Q5, is mounted vertically between the slug-tuned coil compartment and the driver tube, V1. An aluminum box measuring 2 1/2 X 2 1/4 X 1 3/4 inches is used as a meter enclosure.

Most of the power-supply components are mounted on the rear quarter of the chassis. The bracket located next to the power transformer supports the three filter capacitors for the high-voltage supply. Accidental contact with the 1000-volt line is prevented by the top lip.

The T-R switch, V4, is mounted inside a Minibox attached to the rear of the amplifier shield compartment. The signal-input connection to V4 is made through the shield. Five holes in the top of the Minibox cover provide ventilation for the 6AH6.

The VFO is built on an etched circuit board and is completely enclosed in the shield cover

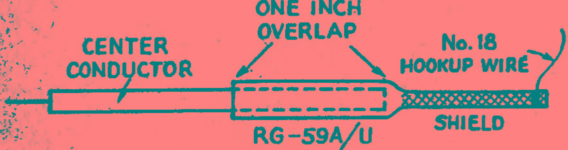


Fig. 4 — A high-voltage capacitor is constructed from a 3-inch piece of RG-59A/U. A 1-inch overlap between the braid end center conductor provides the correct amount of coupling for the T-R switch.

behind the tuning dial. In order to enhance mechanical stability, the cover is made of 3/16-inch-thick aluminum. A small hole is drilled in the side of the cover to allow for adjustment of L1.

All of the wiring between stages is done with shielded cable. Additionally, all leads to the meter-switch compartment are shielded.

A capacitor constructed from a short piece of RG-59A/U is used for C5 (Fig. 2). The shield and inner conductor overlap approximately 1 inch. If a ceramic capacitor is used at this point it should have a capacitance of roughly 3 pF, and a voltage rating of 3 kV.

Adjustments

Before power is applied to the T-9er, resistance measurements should be made at several points to assure there are no wiring errors which could cause damage to the power supply.

A general-coverage receiver is used to check the operation of the heterodyne oscillator on each crystal frequency. Then, the receiver antenna is coupled to pin 2 of V1 through a 100-pF capacitor. By setting the bandswitch at 160 meters and adjusting the VFO signal to 5.2 MHz, a signal should appear at 1.8 MHz when the spotting switch is depressed. Adjust L3 for maximum S-meter reading. Tune L4 (80 meters) through L8 (10 meters) in a similar manner. All of the tubes should be removed for these tests.

The biggest pitfall in aligning the mixer is

Fig. 5 — Chassis bottom view. The opening next to S5E is needed to make connections to L20 and L21.

tuning the output circuit to something other than the desired frequency. For instance, on 20 meters, the mixer can be tuned to the third harmonic of the VFO, producing output at 15.6 MHz! There are a few similar combinations which might be encountered.

After determining that the solid-state circuitry is functioning correctly on each band, the tubes are installed and the driver coils are adjusted. To set the final-amplifier bias, set the drive control at minimum (ccw), depress the key, and adjust R4 for a PA cathode current of 5 mA.

The entire alignment must be "touched up" under full-power output conditions. The heterodyne oscillator coils should be detuned to a point where the power output drops approximately 2 percent. This procedure assures proper oscillator injection at the mixer. When the rf alignment is completed, a receiver should be connected to J2. If any backwave is heard under key-up conditions, adjustment of R1 should eliminate it.

In a transmitter of this type, leads to the bandswitch lugs contribute stray inductance and capacitance. For this reason, the builder is advised to "tack" the mica capacitors across the inductors until it is determined that the various circuits will resonate at the proper frequencies. Only then should the capacitor leads be soldered permanently in place.

Performance

Power output from the T-9er is roughly 150 watts on 160 through 20 meters. On 15 meters the output drops to 125 watts, and on 10 meters it is slightly over 100 watts. The reduced output on the higher bands is caused by marginal drive to the 6GK6. It is not considered important enough to add another buffer stage with its associated bandswitch wafer coils.

The screen voltage (SV) switch is included to provide a low-power tune-up function. It is best not to operate (on the air) in the low-voltage position. If low power operation is desired, the drive can be reduced during normal screen-voltage conditions.

Every effort has been made to produce a TVI-free transmitter. The addition of a low-pass filter should make harmonic radiation almost immeasurable.

Keying Wave-Form Adjustment

A wide range of keying characteristics is available. R2 should be adjusted while observing the transmitted signal on an oscilloscope. Typical patterns are shown in the Code Transmission chapter. If an oscilloscope is not available, keying adjustment could be made on the air with the help of a local amateur. These tests should be made on a dead band, however, thus preventing needless QRM.

A 160-METER AMPLIFIER

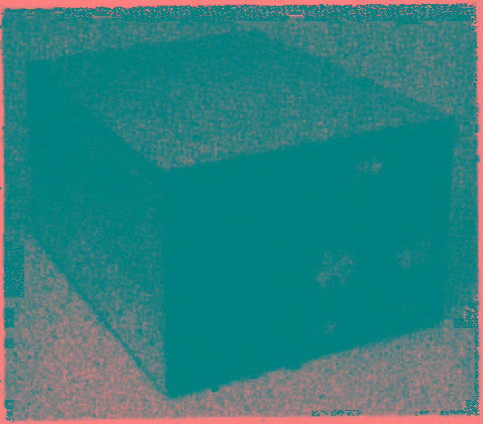


Fig. 1 — Front view of the 160-meter amplifier. Note the use of perforated aluminum stock to permit ventilation of both the rf and power supply compartments. The large front-panel knob on the right controls C3, while the edjacent knob to the left controls C2. The power switch, S1, is controlled by the smaller knob located beneath C3. Both S1 and S2, the meter switch, are mounted below the chassis, and DS1 is mounted betwean the two switches.

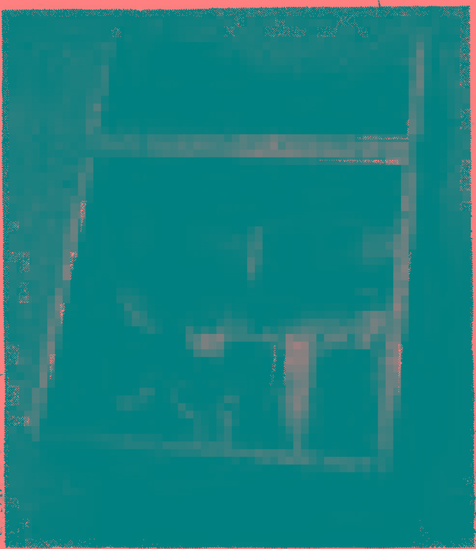
Anyone who has operated in the 160-meter band lately can attest to the fact that interest in the "top band" is on the upswing. With only a handful of manufacturers producing gear for 160, this band is somewhat of a "homebrewers' haven." Most operation takes place during the evening hours, because the high level of daytime ionospheric absorption makes communication (other than strictly local) all but impossible for low powered stations. Summertime static makes things even more difficult. At present, amateurs occupy this band on a shared basis with various radionavigation services, with maximum input power limitations imposed to prevent harmful interference from occuring. These restrictions are greatest between sundown and sunrise, when the potential for interference is at maximum. However, during the daylight hours, amateurs in 29 states are permitted to use up to 1000 watts power input, while in the other 21, the maximum is 500 watts, in selected segments of the band.[1] The amplifier described below is for use with 160-meter exciters in the 50- to 100-watt output class, for ssb and cw operation.

Circuit Data

A pair of 572B/T160L triodes are used in a cathode-driven, grounded-grid configuration (see Fig. 3). A small amount of operating bias is provided by the 3.9-volt, 10-watt Zener diode in series with the cathode return lead, and the tubes are completely cut off during nontransmitting periods by opening that lead with K1A to reduce unnecessary power consumption and heat generation. The other contacts on K1 perform all necessary antenna switching functions for transceive or separate transmitter/receiver operation. Drive power from the exciter is fed to the directly heated cathodes through a parallel combination of three .01 μF disk capacitors, and a resonant cathode tank circuit helps minimize the amount of drive required. The filament choke, RFC2, isolates the driving signal from the filament transformer. A B&W FC-15A choke was used here. A single power switch, S1, applies 117 V ac to the primaries of both the power and filament transformers simultaneously, as the 572B's require no significant warmup time. S1 also activates the cooling fan, B1, and the front-panel pilot light assembly, DS1. The self-contained high-voltage power supply uses a straightforward voltage doubler circuit. No-load voltage is approximately 3100 V dc, dropping to 2600 V dc under one kilowatt key-down conditions. R2 limits the initial surge current to the filter capacitor bank to prevent exceeding the current handling capability of the rectifier string when the supply is first turned on.

A single 0-1 mA meter is used to monitor either plate voltage or cathode current. To measure plate voltage, a multiplier consisting of five series-connected 1-megohm 1-watt resistors with one end tied to the B plus line is switched in series with the meter to provide a full-scale reading of 5000 volts. A 1000-ohm one-watt resistor between the bottom of the meter multiplier and ground prevents the full B plus voltage from appearing across the meter switch, S2, when it is in the other position. To measure cathode current, the meter is placed in

Fig. 2 — Top view of the amplifier. The rf components occupy the foreground, while the heat-generating power-supply components are visible behind the compartment shield at the rear.



[1] A chart of U.S. and Canadian 160-meter sub-allocations is available from ARRL Headquarters; send a stamped, self-addressed envelope and request form S-15A.

Fig. 3 — Circuit diagram for the 160-meter amplifier. Fixed-value capacitors are ceramic disk unless otherwise indicated. Polarized capacitors are electrolytic. All resistors are 1/2-watt compositien unless noted otherwise.

B1 — 117-volt axial fan (Rotron Whisper Fan or equiv.).
C1 — Parallel combination of one 5000, 2000, end 1000-pF silver-mice capacitors.
C2, C3 — 250-pF air variable, .075-inch spacing (E. F. Johnson 154-9 or equiv.).
C4, C5, C6 — Transmitting capacitor, 1000-pF "doorknob" (Centralab 858S or equiv.).
CR1-CR12, incl. — 1000 PRV, 2.5-A silicon (Motorola HEP 170 or equiv.).
DS1 — 117-volt ec neon pilot lamp assembly.
J1 — Phone jack.
J2, J3 — Coax chassis-mounting connector, type SO-239.
K1 — 3pdt, 10-A contacts, 110-V dc coil (Potter and 8rumfield KUP14D15 or equiv.).

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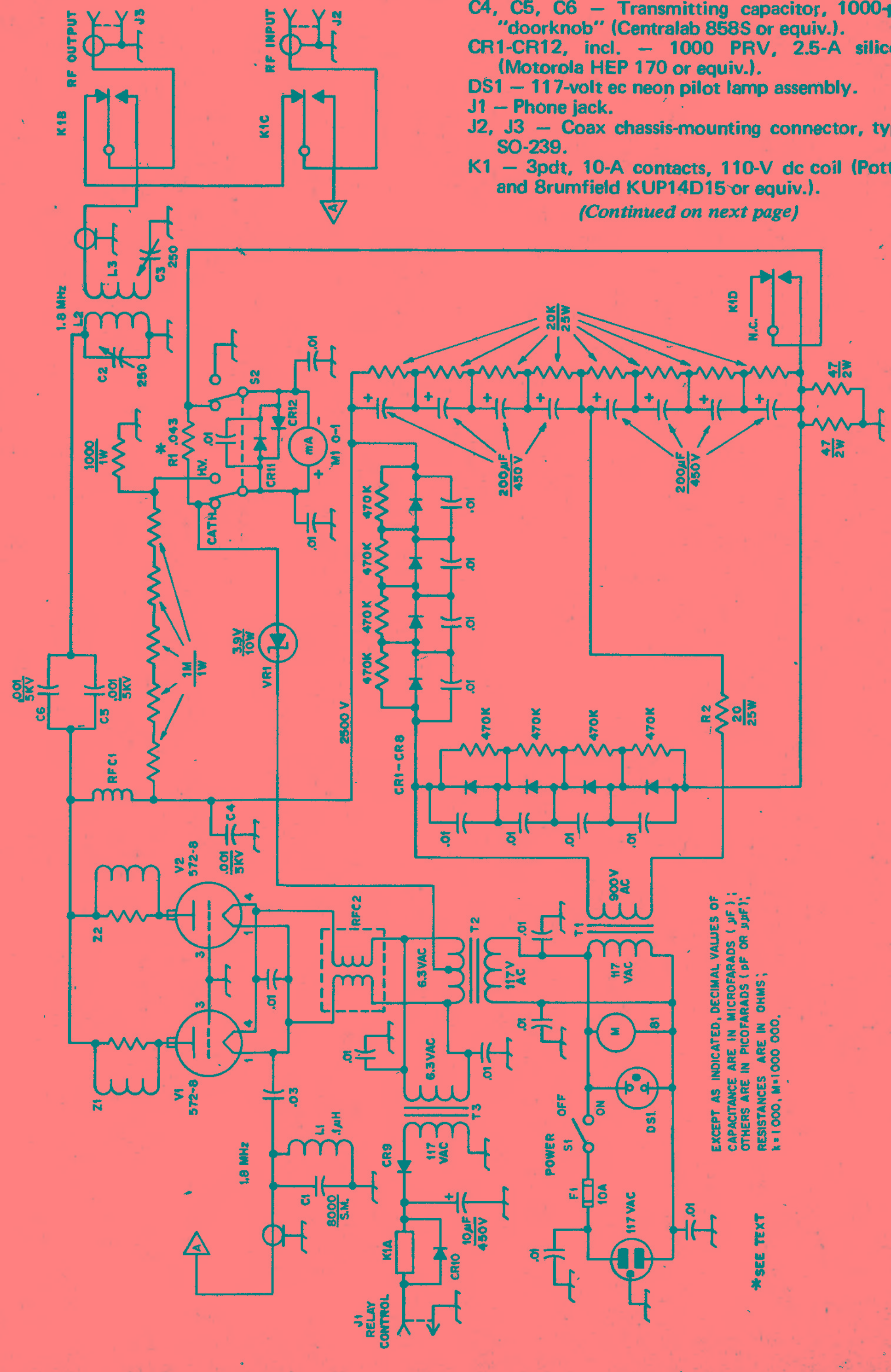


L1 – 1.0 μH
L2, L3 – See text.
M1 – 1-mA dc (Simpson model 2121 or equiv.).
RFC1 – 1.0 mH, 500 mA (E. F. Johnson 102-752 or equiv.).
S1 – Spst rotary switch.
S2 – Dpdt rotary switch.
T1 – 117-volt primary; secondary 625-0-625 volts ac (ct not used) at 450 mA (Hammond No. 720).
T2 – 117-volt primary; secondary 6.3 V ct at 10 A (Stancor P-6464 or equiv.).
T3 – 117-volt primary; secondary 6.3 V ac.
VR1 – Zener, 3.9-V, 10-watt (Motorola HEP Z3500 or equiv.).

parallel with shunt R1, which remains in series with the cathode return lead at all times. To obtain a full-scale reading of one ampere, a shunt resistance of .043 ohms was used with the Simpson model 2121 meter, as it has an internal resistance of 43 ohms (see Chapter 17).

As this amplifier is designed for monoband operation, the mechanical and electrical complexities and compromises involved in the bandswitching of an output network are not a factor here. Tuned-link coupling is used in the output circuit. The grid of each 572B is tied directly to chassis ground, using short leads, to avoid problems with instability. Parasitic suppressors Z1 and Z2 also contribute to stability. Neutralization is not necessary.

B&W Miniductor stock is used at L2 and L3. L2 is made from 43 turns of B&W 3034 (No. 14 wire, 8 tpi, 3-inch dia.) and L3 is made from 39 turns of B&W 3030 (No. 14 wire, 8 tpi, 2-1/2-inch dia.). The coils are supported on a 10-inch strip of bakelite which is mounted on three 1-1/2-inch steatite insulating cones. L2 is epoxied into place on the side of the bakelite strip nearest the tubes. L3 will be partially inserted into the cold end of L2, and is epoxied into place after initial adjustments have been made. L3 must be able to slide freely inside L2 without making electrical contact. The first 10 turns of L3 may be covered with a layer of Scotch No. 27 glass insulating tape. Leads from L3 are made with teflon-insulated flexible stranded wire to allow the coil a degree of freedom of movement during initial adjustment. Rf output from L3 is connected to K1B through a short length of RG-58/U coaxial cable.

Meter shunt R1 is made by winding 12-1/2 inches of No. 26 enam. wire around a 1-megohm 2-watt resistor. If the meter used has an internal resistance other than 43 ohms, the appropriate shunt resistance value may be wound by referring to the copper wire resistance table in Chapter 18.

Parasitic suppressors Z1 and Z2 are each made with 3-1/2 turns of No. 14 enam. wire wound around the parallel combination of three 82-ohm, 1-watt composition resistors, mounted right at each plate cap.

Operation

The power supply should be tested before rf drive is applied to the amplifier. For initial tests, it is desirable to control the power transformer primary voltage with a Powerstat, while leaving the filament transformer primary and fan connected directly to the 117 V ac line. *Remember at all times that lethal voltages exist both above and below chassis.* Do not make any internal adjustments with the power on, or even with the power off until the bleeders have fully discharged the filter capacitors (at least 40 seconds with this particular amplifier). It is good practice to clip a lead from the B-plus terminal to ground after the capacitors have discharged, whenever working inside the amplifier (remember to remove it before applying power!). The tuned-input circuit (L1-C1), should be checked with a grid-dip meter for resonance at the frequency segment of interest. K1 must be closed during transmit; this may be effected by shorting the wire from J1 to ground with a relay inside the 160-meter exciter, or with an external switch. Starting with a plate voltage of about 1500 volts, drive is applied through J2 and C2 is adjusted for maximum rf output as indicated on an external rf wattmeter or relative output indicator. C3 is then adjusted for maximum output. The plate voltage may now be advanced to its normal level. The link may be moved in or out (with power off) and C2 and C3 again adjusted until the highest efficiency is obtained. At that point the link, L3, may be epoxied in place. In the amplifier described here, the optimum position for L3 was when eight of its turns were inside L2. This may be used as a starting point for the adjustment. Normal tune-up procedure involves only the adjustment of C2 and C3 for maximum output, within the maximum legal power limits, of course. During normal operation the 572B anodes may glow with a dull red color. The tubes draw about 50 mA resting current, when K1 is closed and no drive is applied.

A CONDUCTION-COOLED TWO-KILOWATT AMPLIFIER

One of the major concerns when dealing with high power amplifiers is heat and how to reduce it. The usual method has been to use a large fan or blower, but this solution is generally noisy. By using the principles of heat transfer, a noiseless amplifier can be made with the use of an adequate heat sink and conduction-cooled tubes.

The amplifier shown in the photographs and schematically in Fig. 1 uses a pair of recently designed 8873 conduction-cooled triode tubes. The circuit configuration is grounded grid and uses no tuned-input tank components. When properly adjusted, the amplifier is capable of IMD characteristics which are better than can be achieved by a

Top view of the 80-through 10-meter conduction-cooled amplifier. The chassis is 17 × 12 × 3 inches (43.2 × 30.5 × 7.6 cm) and is totally enclosed in a shield. A separate partition was fabricated to prevent rf leakage through the meter holes in the front panel. An old National Radio Company vernier dial is used in conjunction with the plate tuning capacitor to provide ease of adjustment (especially on 10 meters). The position of the dial for each band is marked on the dial skirt with a black pen and india ink.

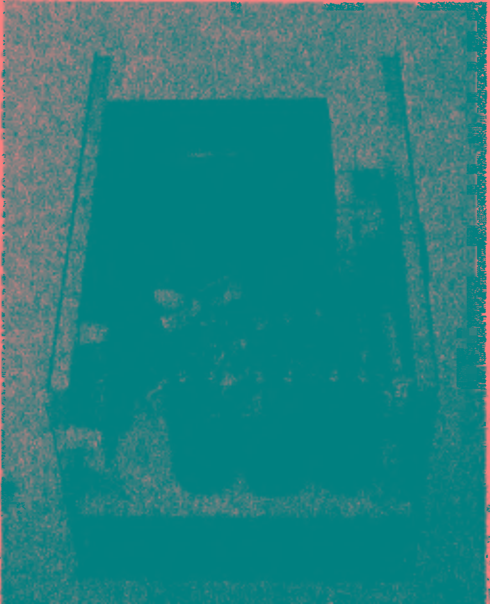
typical exciter, therefore the added complexity of band switching a tuned-input circuit was deemed unnecessary.

Construction

Building an amplifier such as this is often an exercise in adapting readily available components to a published circuit. For this reason, a blow-by-blow description of this phase of the project will not be given. An effort was made, however, to use parts which are available generally, and should the builder desire, this model could be copied verbatim.

The most difficult constructional problem is that of aligning the tube sockets correctly. It is imperative that the sockets be aligned so that when the tubes are mounted in place, the flat surfaces of the anodes fit smoothly and snugly against the thermal-link heat-transfer material. Any misalignment here could destroy the tubes (or tube) the first time full power is applied. The mounting holes for the tube sockets are enlarged to allow final positioning after the tubes are "socked" in place with the clamping hardware. Pressure must be applied to the anodes so that they are always snug against the thermal link. The hardware used to perform this function must be nonconducting material capable of withstanding as much as 250°C. The pressure bracket used here was fabricated from several Millen jack-bar strips (metal clips removed) mounted in back-to-back fashion. The entire assembly is held in place by means of a long piece of No. 10 threaded brass rod which passes through a small hole in the center of the heat sink. An attempt to give meaningful comments about how tight the tubes should be pressured to the copper and aluminum sink will not be given. Suffice it to say that the tubes should fit flat and snugly against the thermal hardware. The heat sink was purchased from Thermaloy and is connected to a 1/4-inch thick piece of ordinary copper plate. The total cost for the copper and the aluminum sink is somewhat more than the price of a good centrifugal blower ($30) but the savings offered by not having to purchase special tube sockets and glass chimneys overcomes the cost differential.

The power supply is built on a separate chassis because the plate transformer is bulky and cumbersome. A special transformer was designed for this amplifier by Hammond Transformer Co. Ltd., of Guelph, Ont. Canada. The transformer contains two windings, one is for the plate supply to be used in a voltage-doubler circuit and the other is for the tube filaments. The power supply produces 2200 volts under a load of 500mA, and is rated for 2000 watts. The Hammond part number is given in Fig. 1. All of the interconnections for power-supply control and the operating voltages needed by the amplifier are carried by a seven-conductor cable. This excludes the B plus, however, which is connected between the units by means of a piece of test-probe wire (5-kV rating) with Millen high-voltage connectors mounted at both ends. The seven-conductor cable is made from several pieces of two-conductor household wire (No. 10) available at most hardware stores. Since the main power switch is mounted on the front panel of the amplifier, the power supply may be placed in some remote position, out of the way from the operator (not a bad idea!). A high-voltage meter was included with the power supply so that it could be used with other amplifiers. It serves no purpose with this system. The main amplifier deck has provisions for monitoring the plate voltage.



Top view of the power supply built by WA1JZC showing the technique for mounting the filter-capacitor bank. The diodes are mounted on a printed-circuit board which is fastened to the rear of the cabinet with cone insulators and suitable hardware.

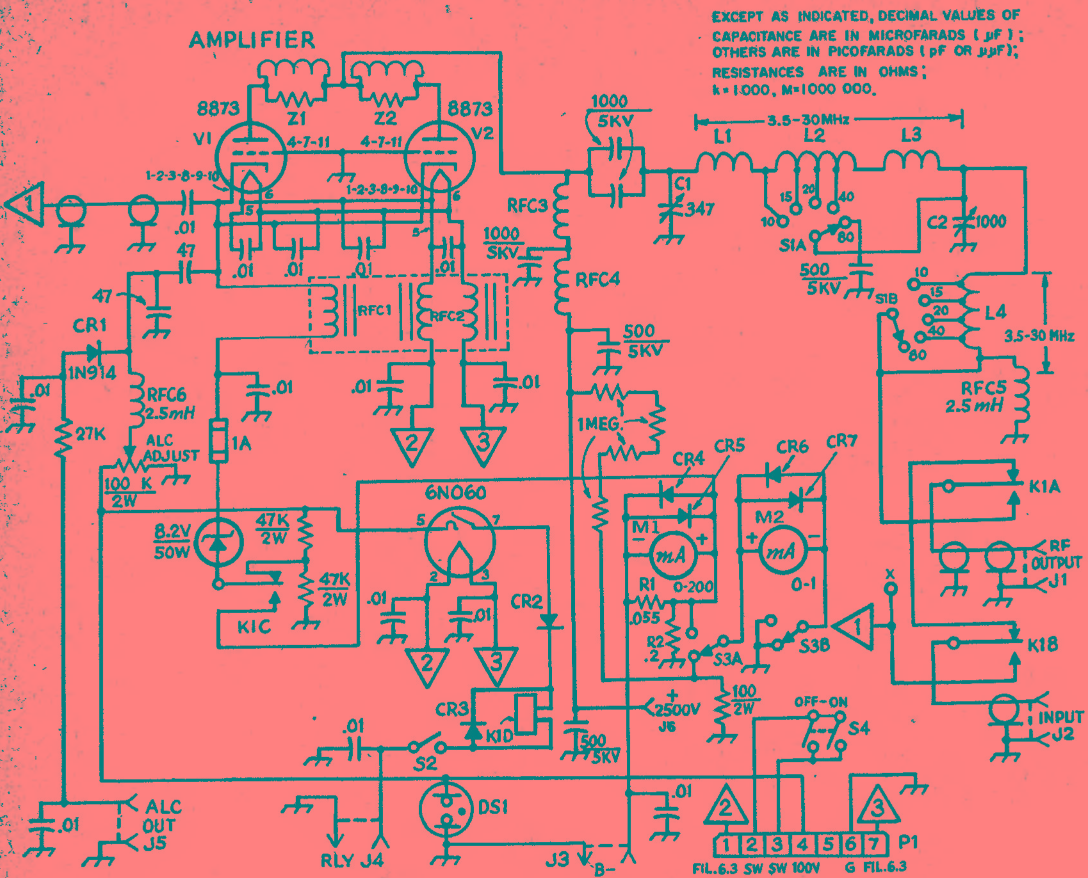


Fig. 1 — Circuit diagram for the 8873 conduction-cooled amplifier. Component designations not listed below are for text reference. RFC1 and RFC2 are wound on the same ferrite rod in the same direction; three wires ere wound together (Amidon MU-125 kit). Tube sockets for V1 and V2 are E.F. Johnson 124-0311-100. The thermal links are available from Eimac with the tubes. The heat sink is part number 2559-080-A000 from Astrodyne Inc., 353 Middlesex Ave., Wilmington, MA 01887, and costs approximately $20.

C1 — Transmitting air variable, 347 pF (E.F. Johnson 154-0010-001).
C2 — Transmitting air variable, 1000 pF (E.F. Johnson 154-30).
CR2-CR7, incl. — 1000 PRV, 2.5 A (Motorola HEP170).
J1 — SO-239 chassis mounted coaxial connector.
J3, J4, J5 — Phono jack, panel mount.
J6 — High-voltage connection (Millen 37001).
K1 — Enclosed, three-pole relay, 110-volt dc coil (Potter and Brumfield KUP14D15).
L1 — 4-3/4 turns of 1/4-inch copper tubing, 1-3/4-inch inside diameter, 2-1/4 inches long.
L2 — 12-1/2 turns, 1/4-inch coppar tubing, 2-3/4-inch inside diameter, tap at one turn from connection point with L1, 2-1/2 inches for 20 meters, 7-3/4 turns for 40 meters.
L3 — 11-1/2 turns, 2-inch diameter, 6 tpi (Barker and Williamson 3025).
L4 — 10 turns, 2-inch diameter, 6 tpi, with taps at 3 turns for 10 meters, 3-1/2 turns for 15 meters, 4-3/4 turns for 20 meters, 6-3/4 turns for 40 meters; all taps made from junction of L3 (Barker and Williamson 3025).
M1 — 200 mA full scale, 0.5-ohm internal resistance (Simpson Electric Designer Series Model 523).
M2 — 1 mA full scale, 43 ohms internal resistence (Simpson Electric, same series as M1).
R1 — Meter shunt, .05555 ohms constructed from 3.375 feet of No. 22 enam. wire wound over the body of any 2-watt resistor higher than 100 ohms in value.
R2 — Meter shunt, 0.2 ohms made from five 1-ohm, 1-watt resistors connected in parallel.
RFC1, RFC5, RFC6 — 2.5 mH (Millen 34300-2500).
RFC3 — Rf choke (Barker and Williamson Model 800 with 10 turns removed from the bottom end).
RFC4 — 22 µH (Millen 34300).
S1 — High-voltage band-selector style, double pole, six position (James Millen 51001 style).
Z1, Z2 — 2 turns 3/8-inch-wide copper strap wound over three 100-ohm, 2-watt resistors connected in parallel.

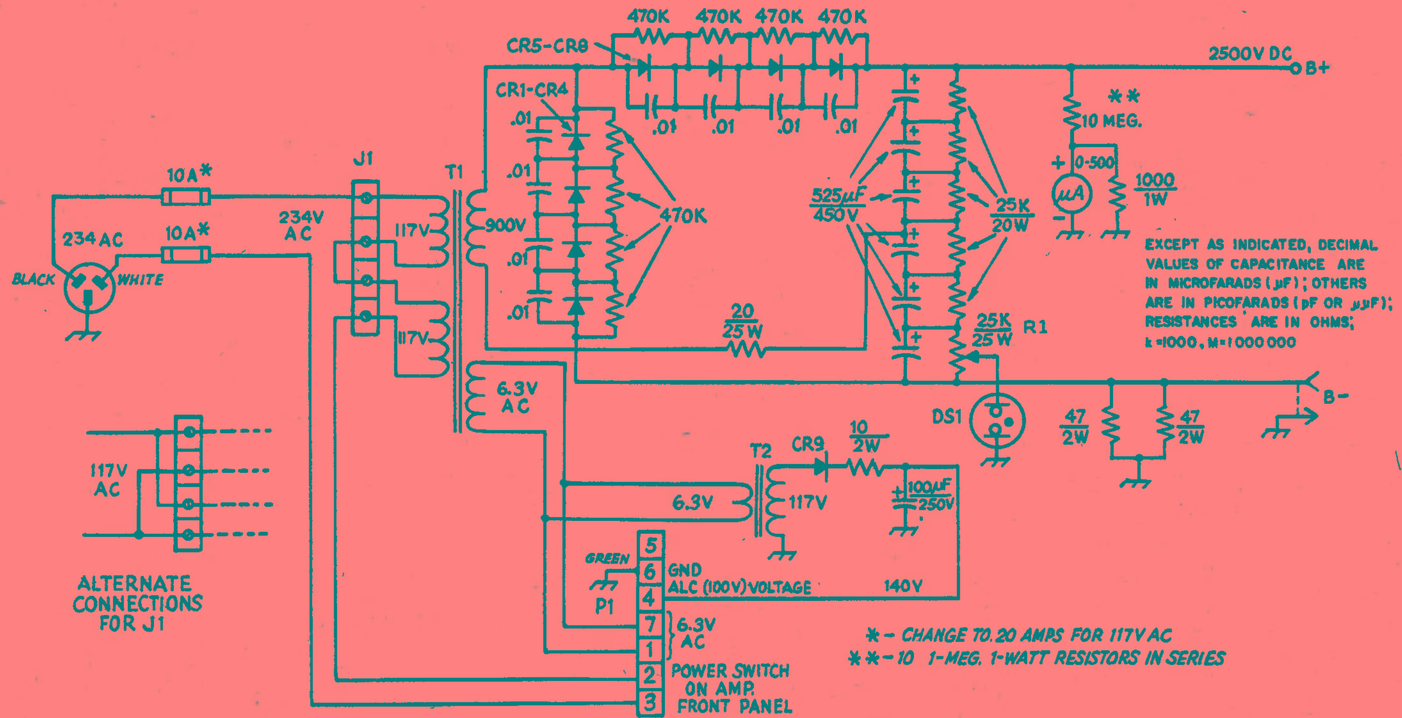


Fig. 2 — Circuit diagram for the power supply. The power transformer is available from Hammond; typa no. 101165. CR1 through CR9 are 2.5 A, 1000 PRV; see Fig. 1 for suitable part number. T2 is Stancor part number P-8190 and is rated for 6.3 volts at 1.2 amperes. DS1 is a 117-volt neon pilot lamp assembly. The tap at R1 should be set for 5000 ohms to the B minus lead. Adjustments to this tap cannot be made while voltage is applied to the power supply. *If the pilot lamp does not glow properly, remove the ac cord, allow suitable time for the high-voltage to bleed to zero, and apply a screwdriver between the B-plus line and ground before making any adjustments!*

A conventional household light switch may be used for S4. If the switch is to be mounted horizontally, be sure to use a contactor device and not a mercury type (which operates in a vertical position only). A double-pole switch was used with both poles connected in parallel. The rating is 220 V at 10 A per section.

The RF Deck

The two sections of the pi-L network are isolated from each other by placing one of them under the chassis. Although not shown in the photograph, a shield was added to prevent rf energy from entering the control section underneath the chassis. The shield divides the chassis between the tube sockets and the inductors. The loading capacitor is mounted directly beneath the plate-tuning capacitor. This scheme provides an excellent mechanical arrangement as well as a neat front-panel layout.

The 8873s require a 60-second warmup time, and accordingly, a one-minute time-delay circuit is included in the design. The amplifier IN/OUT switch is independent of the main power switch and the time delay. Once the delay circuit "times out," the amplifier may be placed in or out of the line to the antenna, whenever desired. A safety problem exists here: there is no large blower running, and there are no brightly illuminated tubes to warn the operator that the amplifier is turned on. Except for the pilot lamp on the front panel, one might be fooled into believing the amplifier is turned off! And if the pilot lamp should burn out, there is *absolutely* no way to tell if the power is turned on (with the resultant high voltage at the anodes of the 8873s). *Beware!*

Operation

Tuning a pi-L-output circuit is somewhat different than tuning a conventional pi-network because the grid current should be monitored closely. Grid current depends on two items, drive power and amplifier loading. The procedure found to be most effective is to tune for maximum power output with the loading sufficiently heavy to keep the grid current below the maximum level while adjusting the drive power for the proper amount of plate current. The plate current for cw operation should be 450 mA and approximately 900 mA under single-tone tuning conditions for ssb. This presents a problem since it is not legal to operate under single-tone tuning conditions for ssb. Sixty watts of drive power will provide full input levels. For use with high-power exciters, see *QST* for October, 1973.

A ONE-KILOWATT AMPLIFIER USING A 3-500Z

Circuit design for high-power linear amplifiers hasn't changed much in recent years. The differences between various types of grounded-grid units are usually more mechanical than electrical. The degree of circuit complexity is determined primarily by the number of features desired and whether or not the power supply and control circuits are included on the same chassis as the amplifier. Described below is a power amplifier designed to operate cw as the primary mode. A suitable exciter is described earlier in the chapter.

The Amplifier Circuit

A single 3-500Z triode tube develops 1-kW input on cw and 1-kW PEP on ssb. The output circuit is a conventional pi network which tunes the hf amateur bands from 3.5 to 30 MHz. The *L/C* ratio of the tank circuit is designed for operation at 2500 to 2800 volts. The T-R switch is coupled to the tank circuit via C1. This capacitor is constructed of RG-8A/U. A 2-inch overlap between the braid and center conductor provides the correct amount of coupling for the T-R switch (see top view photograph).

Filament voltage is applied to the 3-500Z through a bifilar-wound rf choke. Drive power is coupled to the filament circuit via C2, a combination of three .01-μF disc ceramic capacitors in parallel. A 7.5-volt Zener diode in the cathode-return lead is used to develop grid bias. K1D opens the cathode-return lead during standby, completely cutting off plate current.

S1, located on the front panel, switches on the fan motor, the pilot light, and activates the control circuits. Input jacks for high voltage, as well as filament and control voltages, are located on the rear panel.

The Multimeter

A 1-mA meter is used to measure grid current, cathode current, plate voltage, and power output. R4, mounted on the rear chassis apron, allows adjustment of the relative-output circuit sensitivity. A voltage-dropping resistor network, R3, provides a full-scale reading of 5 kV. R5 maintains a load at the meter end of R3 preventing full B+ from appearing across S2 when it is in one of the three other positions. R3 consists of five 1-

Inside view of the amplifier built by WA1JZC. The unusual plate cap is described in the text. A T-R switch is included for break-in cw operation and is mounted in a Minibox attached to the rear compartment panel.

megohm, 1-watt composition resistors connected in series thereby reducing the voltage across any one resistor to less than 600.

Grid current is measured by placing the meter in series with the grid (ground) and the cathode. The grid meter shunt, R2, provides a full-scale reading of 200 mA. R2 is equal to the internal resistance of the meter divided by 200. The resistance of M1 is 43 ohms; therefore R2 is 0.21 ohm. It is made by winding 24-1/4 inches of No. 30 wire on a 1-megohm, 2-watt composition resistor. Cathode current is measured by placing the meter in series with the cathode-return lead. Meter shunt R1 was chosen to provide a full-scale reading of 1 Ampere. It is made by winding 12-1/2 inches of No. 26 wire on a 1-megohm, 2-watt composition resistor, for a shunt resistance of .043 ohms. R2 is the primary path for the high-voltage negative lead to chassis ground. R6 provides protection in the event this meter shunt opens.

Construction

The amplifier is built on a 10 × 12 × 3-inch aluminum chassis. The high-voltage power-supply components and the 5-volt filament transformer are mounted on a separate chassis (see chapter 5). The complete amplifier occupies slightly less than 3/4 of a cubic foot, making a compact package that will fit on almost any operating desk. Location of the various components is shown in the photographs. All of the circuits carrying rf are completely shielded to reduce any instability or TVI. The amplifier exhibits no tendency to "take off" when operated without a parasitic suppressor. However, if problems with instability are encountered, a suitable suppressor made of 3 turns, No. 12, copper wire, 1-1/4-inch dia. wound over three 150-ohm, 2-watt composition resistors can be inserted between the plate cap and the top of RFC1.

The rf-output circuit is completely shielded in a compartment constructed of cane metal and sheet aluminum. Perforated material is needed to allow adequate air flow past the tube. The socket (E.F. Johnson Co. type 122-275 or equiv.) is mounted 1/2 inch above the chassis, allowing air to circulate

Bottom view of the amplifier.

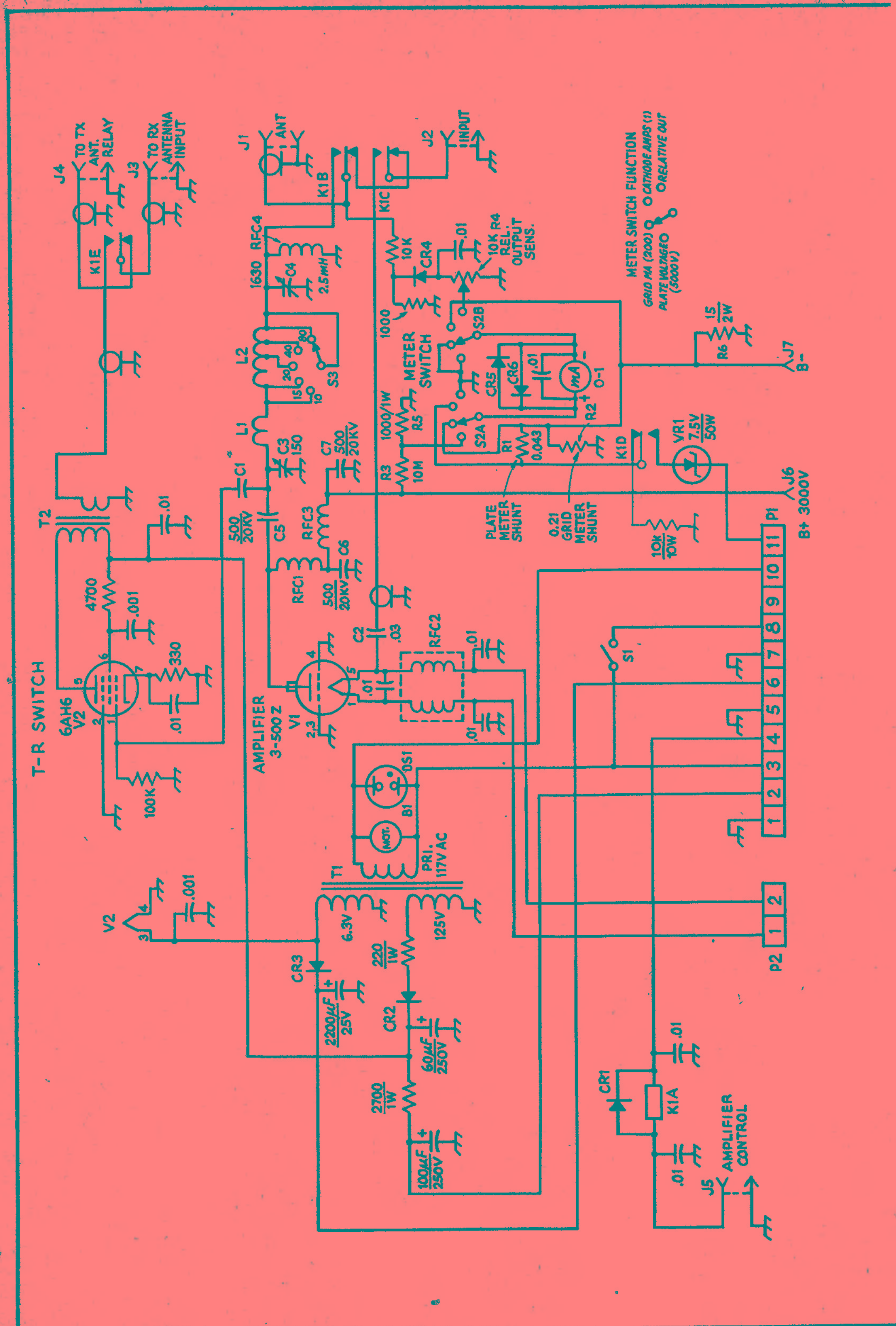

T-R SWITCH
6AH6
V2
AMPLIFIER
3-500Z
V1
J4
TO TX
ANT.
RELAY
J3
TO RX
ANTENNA
INPUT
J1
ANT
J2
INPUT
K1E
K1B
K1C
K1D
RFC4
RFC1
RFC2
RFC3
2.5mH
METER SWITCH
METER SWITCH FUNCTION
GRID MA (200)
CATHODE AMPS (1)
PLATE VOLTS/10 (5000V)
RELATIVE OUT
10K R4
REL.
OUTPUT
SENS.
PLATE
METER
SHUNT
0.21
GRID
METER
SHUNT
VR1
7.5V
50W
J7
B-
J6
B+ 3000V
P1
P2
T1
T2
PRI.
117V AC
6.3V
125V
MOT.
B1
DS1
S1
S2A
S2B
S3
CR1
CR2
CR3
CR4
CR5
CR6
K1A
J5
AMPLIFIER
CONTROL
2200µF
25V
60µF
250V
100µF
250V
2700
1W
220
1W
500
20KV
1000/1W
R5
R3
10M
R1
0.043
R2
R6
15
2W
10K
10W
4700
330
100K
1000
1630
L1
L2
C1
C2
C3
C4
C5
C6
C7
150
0-1

Fig. 1 — Circuit diagram for the amplifier. Component designations not listed are for text reference only. Polarized capacitors are electrolytic.

B1 — 117-volt fan (Rotron Whisper Fan or equiv.).
C1 — See text.
C2 — See text.
C3 — 180-pF air variable, .077-inch air gap (Millen 16250 with 4 stator plates removed).
C4 — 1630-pF maximum, receiving-type air variable.
C5, C6, C7 — Transmitting capacitor, 500-pF "doorknob" (Sprague 20DK-T5 or equiv.).
CR1-CR5, incl. — 1000 PRV, 2.5 A (Mallory M2.5A or equiv.).
DS1 — 117-volt ac neon pilot lamp assembly.
J1 — Coax chassis-mount connector, type SO-239.
J2-J5, incl. — Phone jack, single-hole mount.
J6, J7 — High-voltage chassis connector (Millen 37001).
K1 — 4-pdt, 5-A, 6-V dc coil (Potter and Brumfield GPD coil and GP-17 contact arrengement or equiv.).
L1 — 4-1/2 turns, No. 14, 1-3/4-inch dia., tapped at 1-1/2 turns, as measured from S3 end. (Coil stock: Barker and Williamson 3022).
L2 — 23 turns, No. 12, 2-1/2-inch dia., tapped at 10-3/4 turns for 40 meters, 19-1/2 turns for 20 meters, as measured from the C4 end. (Coil stock: Barkerpand Williamson 3029.)
M1 — 1-mA dc (Simpson model 2122-17430 or equiv.).
P1 — Chassis-mounted 11 pin power connector.
P2 — Chassis-mounted 2 pin power connector.
RFC1 — Trensmitting rf choke (Barker and Williamson model 800 or equiv.).
RFC2 — Bifiler-wound filament choke (Amidon 10-A choke kit).
RFC3 — 2.7 μH, 1700 mA, rf choke (Millen 34300 - 2.7 or equiv.).
S1 — Spst toggle switch (Cutler-Hammer 8381K21C or equiv.).
S2 — Double-pole, 6-position rotary (4 used), nonshorting (Mallory type 3226J or equiv.).
S3 — Rf switch, single-pole, 6-position (Millen 51001).
T1 — 117-volt primary; secondary 125 volts at 50 mA; 6.3-V at 2-A (Stancor PA-8421 or equiv.).
T2 — 20 turns, No. 24 enam. wire wound on a 1-inch long, 1/2-inch dia iron core from a slug-tuned coil form. The secondary is 3 turns, No. 24 enam. wire wound over the cold end of the primary.
VR1 — Zener, 7.5-V, 50 watt.

around the base connections and seal. The grid pins of the socket are soldered to lugs mounted on the chassis. When a standard Eimac plate cap is used with the 3-500Z, the cap extends above the edge of the cabinet. Therefore, a 1/4-inch thick aluminum plate, 1-3/4 inches square, is used in place of the Eimac unit.

The plate-tuning capacitor, C3, has too high a minimum capacitance for proper operation on 10 and 15 meters. Removing 4 of its stator plates reduces its minimum capacitance sufficiently. C4 has a shaft diameter of 3/8 inch, requiring special attention. A standard 1/4-inch coupling with one end drilled out slightly over 3/8 inch is used as an adapter. Fine-mesh screen is placed between the cabinet wall and the fan to maintain an rf-tight enclosure. The screen does not appear to reduce the air flow appreciably.

Finishing touches are added by selecting front-panel knobs, painting the amplifier cabinet with light avocado green paint, and applying appropriate decals.

Hookup and Switch Functions

The Amplifier is designed to permit true cw break-in operation when used with a separate transmitter and receiver. In most commercially made ssb/cw transmitter-receiver combinations, all transmit-receive changeover functions on both modes are handled by a VOX circuit, and relay contacts inside the transmitter perform the receiver antenna switching and muting duties. When using a combination with this amplifier, the receiver antenna terminal is connected directly to J3 on the rear chassis apron, and a cable connects J4 and the receiver antenna terminal of the transmitter. The amplifier control relay contacts of the transmitter are connected to J5, and the rf output of the transmitter is connected to input jack J2. In this configuration, the receiver is connected directly to the antenna during standby, and during transmit, the T-R switch takes over.

If the transmitter (such as the T-9er described earlier in this chapter) does not incorporate a relay-switching arrangement, then antenna changeover is handled entirely by the T-R switch. The receiver antenna is connected to J3, the transmitter rf output connects to J2, and a shorted phono plug is inserted in J5.

For use with a transceiver, the transceiver output is connected to J2, and the amplifier control relay contacts of the transceiver are connected to J5. The transceiver operates "straight through" when the amplifier is off, and K1 provides the required antenna switching functions when the amplifier is in use.

Operation

After the position of each tank-coil tap has been determined, the relative-output sensitivity control, R4, can be adjusted for 3/4 scale meter reading at full power input. The amplifier should be tuned for maximum power output into a 50-ohm nonreactive load, which should coincide approximately with the point of minimum plate current.

TWO-KILOWATT AMPLIFIER USING A SINGLE 8877 TRIODE

The 8877 is a big brother to the new 8873 series of ceramic/metal power tubes. It is a zero-biased high-mu triode having an oxide-coated cathode. The plate dissipation is 1500 watts. Heater-to-cathode capacitance is low eliminating the need for filament chokes when operated below 30 MHz. An inexpensive 7-pin socket may be used reducing the overall cost. The grid connection is near the chassis level and permits low-inductance grounding. Average IMD products for the 8877 in linear service run 38 dB below one tone of a two-tone test signal for 3rd order products, and 44.5 dB for 5th order products.

The cathode impedance of an 8877/3CX1500A7 is about 54 ohms. Direct coupling from the exciter to the cathode without the use of a cathode-tuned circuit *will* work, but performance will be degraded. The reduced-drive requirements and improved distortion products make the small effort of putting a "flywheel" in the input circuit worthwhile.

The opening in a shield surface where blower air enters the chassis may be a source of rf leakage. In this amplifier, brass-wire screen is mounted in the air stream to minimize this leakage. Tiny globs of solder at several crossover points assure positive connection on the screen. The disadvantage of this method is the eventual collection of dust, restricting air flow. It requires periodic cleaning.

INPUT CIRCUIT						OUTPUT CIRCUIT		
BAND MHz	*NO. TURNS*	*WIRE SIZE*	*INDUCTANCE RANGE IN μH*	*F* MHz*	*C1 AND C2*	*C10*	*IND.*	*C11*
3/8-inch Diameter Forms								
3.5	14	24	1.64 - 4.58	5.05	(820)	273	8.54	1473
4.0	14	24	1.64 - 4.58	5.8	(750)	239	7.47	1289
7.0	10	24	0.96 - 2.32	10.1	(430)	136	4.27	737
14.0	7	16	0.44 - .74	19.5	(220)	68	2.14	368
21.0	5	16	0.28 - 0.52	29.2	(150)	45	1.42	246
28.0	4	16	0.17 - 0.34	40	(100)	34	1.07	184

* A grid dip meter should be used to assure that the inductor resonates at the indicated frequency. These adjustments should be made with capacitors C1 and C2 out of the circuit.

Laboratory tests at Eimac indicate best performance to be at an anode potential of 2700 to 3000 volts. The efficiency runs between 60 and 65 percent.

Plate impedance figures are based on a 2 kW PEP input using 2700 volts at 740 milliamperes. The grid current for the 8877 runs about 15 percent of the plate current. At full power input, the grid current should be about 110 mA.

When plate voltage is applied, the zero-signal plate current should be about 95 mA. Drive should be applied through a directional coupler. On each band, after fully loading the amplifier to the above conditions, tune the input coil for minimum reflected power. No further adjustment is required and the directional coupler can be removed. For additional construction details, see September, 1971, *QST*.

Top view of the 8877 Amplifier built by K6DC.

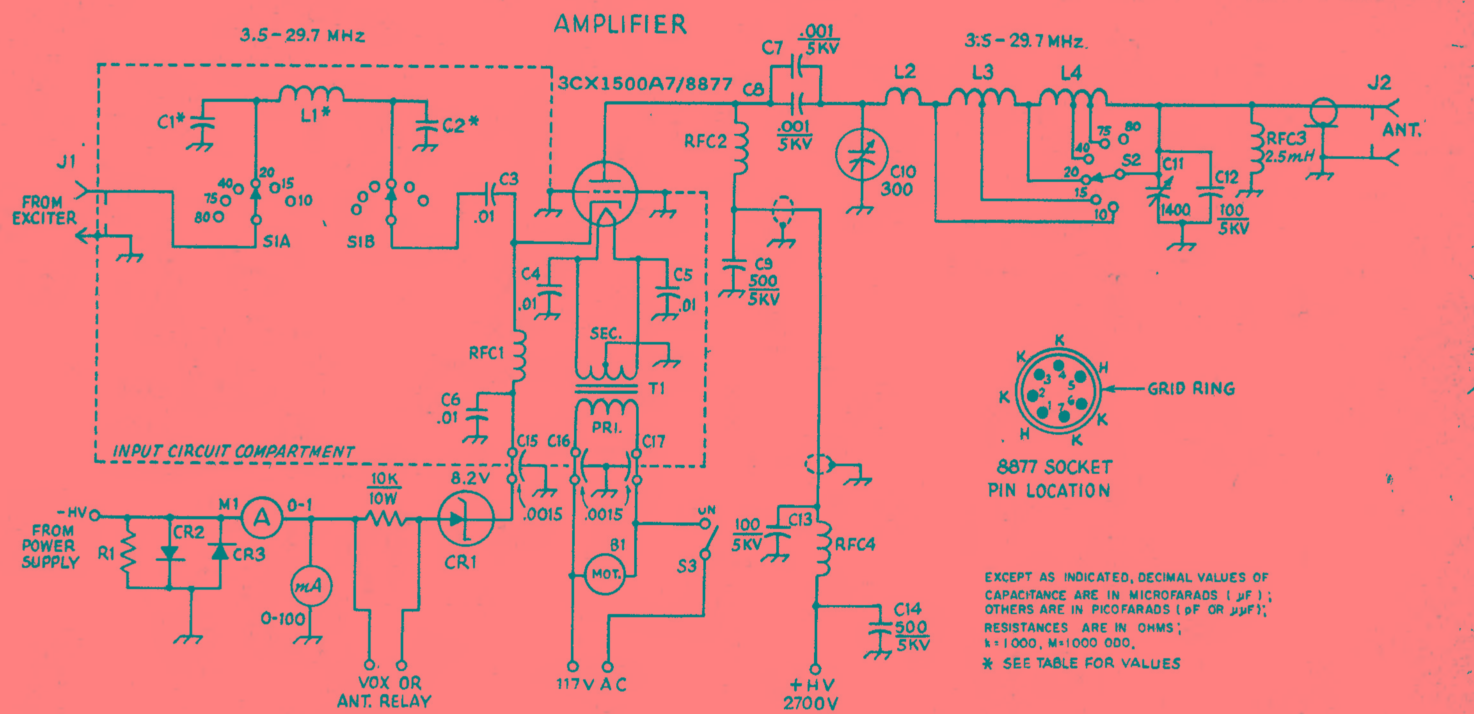


Fig. 1 — Circuit diagram of the 2-kW amplifier. Component designations not listed below are for text reference. The values for C1, C2, and L1 are given in Table 1.

B1 — Blower. (Dayton 4C012).
C3-C6, incl. — .01-μF, 600-volt disk ceramic.
C7,C8 — .001-μF, 5-kV (Centralab 858S).
C9 — 1500-pF, 5-kV (3 parallel 500-pF Centralab 858S).
C10 — Vacuum variable, 5-300 pF.
C11 — 4-section broadcast variable, 365 pF per section. All sections parallel-connected. (J.W. Miller 2104).
C12,C13 — 100-pF, 5-kV (Centralab 850S).
C14 — 500-pF, 5-kV (Centralab 850S).
C15,C16,C17 — Feedthrough, .0015-pF, 400-V.
CR1 — Zener diode, 8.2 V, 50 W (Motorola 1N3307).
J1 — BNC, chassis mount (Amphenol UG-1094/U).
J2 — SO-239 chassis connector.
L2 — 10-meter coil (see text).
L3 — 15- and 20-meter coil (see text).
L4 — 80- and 40-meter coil (see text).
M1 — 0-1 A dc meter.
M2 — 0-100 mA dc meter.
RFC1 — 15-μH, 1-A choke (Miller 4624).
RFC2 — 160 turns, No. 24 Formvar, wound on a 3/4-inch dia ceramic insulator, 4 inches long.
RFC3 — 2.5 mH, 300 mA.
RFC4 — 10 turns, No. 14 wire, 1/4-inch ID, 1-inch long.
S1 — Ceramic rotary switch, 2 pole, 6 position (Centralab PA-2045).
S2 — 1 pole, 6 position (Millen 51001).
T1 — 5-V, 10-A filament transformer.

A SOLID-STATE LINEAR AMPLIFIER

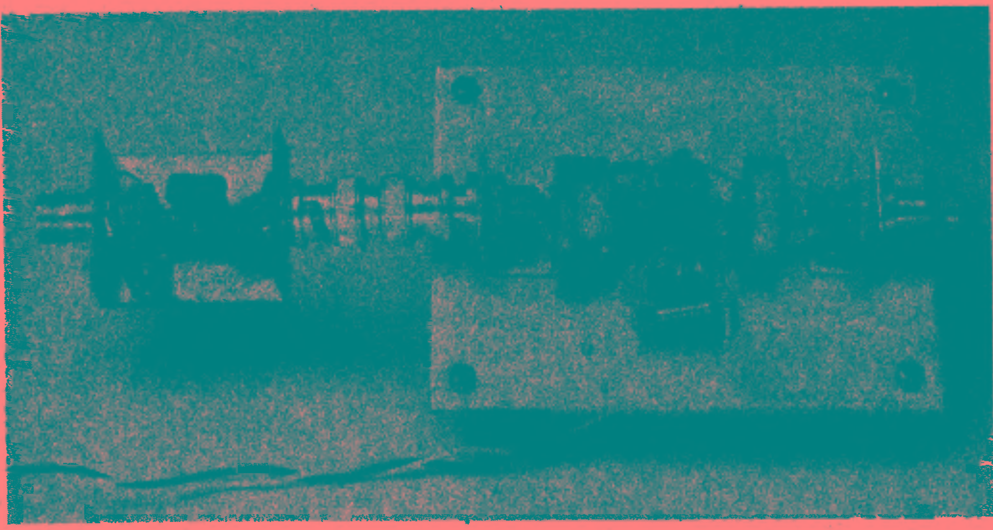
In this section a 15-watt solid-state linear amplifier for 3.5 to 30 MHz is described. A filter at the amplifier output attenuates the harmonic energy. With the proper filter in place, no tuning is necessary for complete coverage of each band. The circuit utilizes two transistors that are available surplus for $2.99 each.[1] The amplifier delivers 15-watts peak power for ssb operation, or 15 watts on cw. The collector efficiency from 3.5 to 30 MHz is no lower than 50 percent, but is approximately 57 percent on 80 meters. Intermodulation distortion products for a two-tone test signal are down 30 dB from pep at all frequencies of operation. The amplifier showed a minimum gain of 16 dB. A maximum power of 375 mW is required to drive the amplifier to 15-watts output. This excitation power is easily obtainable with a Class A driver.

A push-pull amplifier circuit is employed with suitable forward base bias to eliminate cross-over distortion (see Fig. 1). The input and output transformers are designed to match the base impedance to a 50-ohm input impedance, and the collector load impedance to the 50-ohm output impedance. Since the gain of the transistors decreases as the frequency of operation increases, a compensating network is placed at the amplifier input to attenuate the drive to the transistors as the operating frequency is lowered. The maximum SWR looking into the compensating circuit is 1.2:1, providing a constant 50-ohm load for the exciter.

[1] Poly Paks, P.O. Box 942M, Lynnfield, MA 01940.

In a push-pull circuit there is inherent cancelation of the even harmonics. Laboratory measurements for the circuit in Fig. 1 show that all harmonics are in excess of 20 dB below the fundamental signal. This figure is not acceptable for harmonic rejection, so a low-pass filter design (Fig. 6-IV) is shown that does provide sufficient attenuation of the harmonics. As long as the filter output is terminated by a 50-ohm load, the filter input looks like 50-ohms below the filter cutoff frequency. No tuning is necessary when changing frequency within any given band. A bank of four filters can be constructed to cover the 80- through 10-meter ham bands. (Only one filter is needed for both the 10- and 15-meter bands.) Band changing is accomplished simply by switching in the appropriate filter for the band of operation. If the builder is interested in only one band the remaining filters need not be constructed.

Construction of the input and output transformers is somewhat unconventional although not too difficult. The transformers are built by placing two cylinders of 3E2A ferrite material side by side and running the wires for the windings through the two holes in the cylinders as shown in Fig. 2. The wire running from A to A′ would be one turn on the primary with the wire from B to B′ being one turn on the secondary. Since the ferrite cylinders aren't available at a reasonable price, they can be constructed by stacking two toroids together for each cylinder of the output transformer and four toroids together for the input transformer. The Ferroxcube series 266 toroids are used for the



Topside view of the linear amplifier with the compensating network attached by means of BNC hardware.