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FIVE-BAND VFO

Direct Output on 80, 40, 20, 15 and 10 Meters

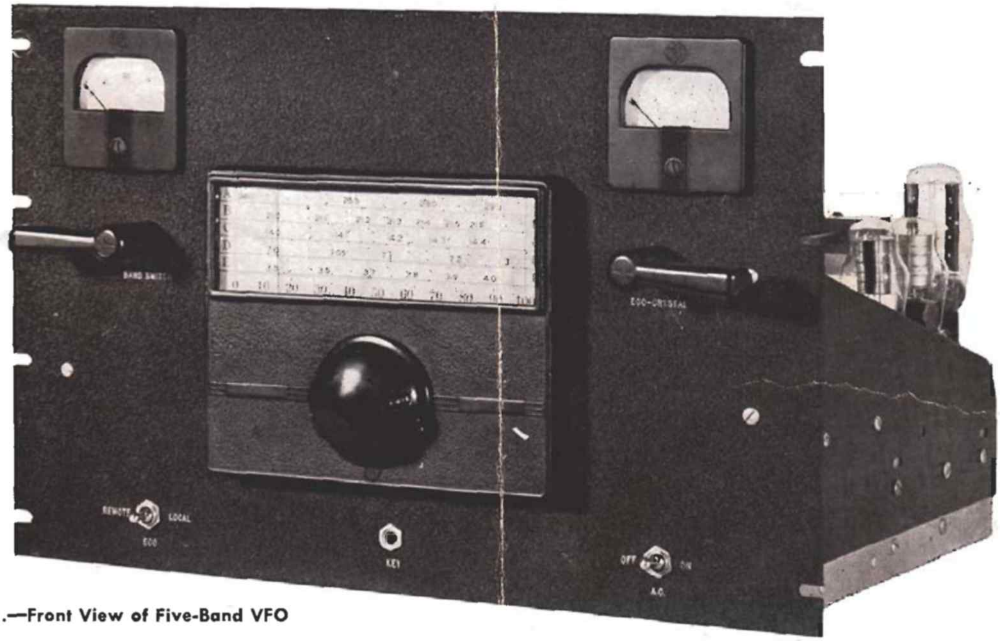


Fig. 1.—Front View of Five-Band VFO

The September-October G.E. Ham News discussed VFO design in general. It pointed out that a VFO may be simple or very complex, depending upon the desires of the builder. In its simplest form it may consist of one tube, capable of operation on one band only. In its most complex form, it will have ganged variable condensers, ganged switches, several tubes and be capable of operation on many bands.

The transmitter pictured in Fig. 1 follows the general design data given in the last G.E. Ham News and is of the complex variety. Every feature possible which would provide flexibility and usability has been incorporated. All tuning is accomplished by a single tuning control, which in turn drives six variable condensers. Bandswitching is similarly handled by a single control. This includes the switching of separate output circuits, so that separate antennas may be used, or separate finals may be driven. Provision has been made for crystal control, either for spot frequency checking or for net operation.

The Five-Band VFO is therefore five complete low power transmitters in one unit. It may also be used as a driver unit, in which case it is able to drive high-power finals directly. The output is between 25 and 35 watts on the major low frequency bands—80, 40, 20, 15 and 10 meters. (The 11 meter band may be covered by extending the 10 meter band.)

Inasmuch as the Five-Band VFO was designed to cover five amateur bands, and hence is a rather complex unit, it may be fancier than certain groups of amateurs will desire. For example, traffic-handlers might want a similar unit for 80 and 40 meter c-w alone. Dx men (c-w) may require the 80, 40 and 20 meter bands. Phone men might want 75, 20 and 10 meters. Whatever particular requirements you may have, you will find that this unit can be simplified to meet them.

OSCILLATOR CIRCUIT

The complete schematic for the Five-Band VFO is shown on pages 4 and 5. The oscillator circuit, using a GL-837, is identical to that shown and discussed in the last G.E. Ham News. It is now more complex because of the added switching circuits. Switch S-1A selects the proper coil for the grid, switch S-1C does the same for the cathode, while switch S-1B adds the proper series condenser

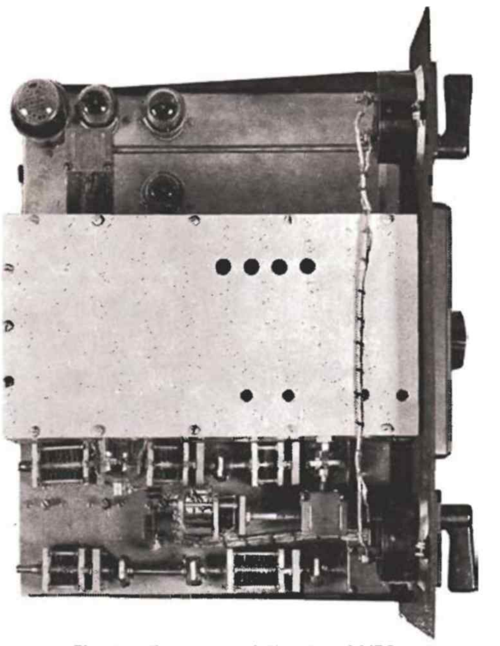


Fig. 2.—Top View of Five-Band VFO

to give the desired bandspread. It is not necessary to switch the cold ends of the grid coils, as they are all at ground potential. Coils L_1, L_2 operate on the 160 meter band, L_3, L_4, on 80, L_5, L_6 on 40 and coils L_7, L_8 on the 20 meter band. These are the only frequency bands generated by the ECO, although output is obtained on five bands by tripling from seven megacycles to the 15 meter band, in addition to doubling to the 20 meter band from the same seven megacycle oscillator output.

The plate circuit of the GL-837 oscillator makes use of four broadly resonant tank circuits. Coils L_{10}, L_{11}, L_{12} and L_{13} each cover an entire amateur band without tuning of any sort—160, 80, 40 and 20 meters respectively. These tank coils are selected by switches S-1E and S-1F. Once they have been made to operate properly no further adjustment need be made. (See September-October Ham News.)

BUFFER CIRCUIT

The buffer and output stage uses a GL-807 and is similar to the buffer unit discussed last month. Switch S-2A in the grid circuit permits the use of crystal control, selecting one of two crystals so that the GL-807 becomes the crystal oscillator. This feature is mainly useful on the lower frequency bands—80 and 40 meters—because higher frequency crystals may not oscillate in this circuit. When switch S-2A is set to allow crystal operation, the other sections of the same switch turn off the GL-837 plate voltage (S-2D), remove GL-837 screen voltage (S-2C) and also changes the dial illumination from white to red (S-2B). This latter stunt warns the user that the frequency dial is no longer in use and that the transmitter is on crystal control.

The buffer stage employs both grid bias and cathode bias. The cathode bias resistor, R_{11}, is a part of the power supply bleeder. Screen voltage is obtained from a voltage divider made up of R_5 and R_6. Resistor R_4 is a 50 ohm resistor which was added as a convenience in measuring screen current. When it is shorted out by a milliammeter screen current may be read directly, making it unnecessary to open up the screen circuit.

The GL-807 tank circuit is actually five separate tank circuits. Each consists of a coil, an output link, a tuning condenser tapped into the coil, and a frequency setting condenser. These separate tanks are selected by switch S-1G. The other switch section is used to short the unused plate tanks to ground. This refinement may not be necessary, especially if less than five output tank circuits are used. Switch section S-1H is made by removing the usual middle movable section and taking off the metal contact material. This is replaced by a circular piece of brass or copper, which has a small segment removed. This open point should be arranged so that it opens the circuit to ground for the coil in use. The photograph in Fig. 4 shows this altered switch.

The five tuning condensers in the GL-807 plate circuit (C_{27}, C_{29}, C_{32}, C_{34} and C_{36}) are ganged to the main tuning condenser in the oscillator grid circuit (C_{17}). Two sets of ganged switches are also used. All sections of switch S-1 are ganged, and all sections of switch S-2 are ganged.

METERING

Two meters have been included in the circuit. Meter M_1 acts as the band indicator, in conjunction with resistors R_{12} through R_{16}. Six volts a-c is placed across these resistors, and switch S-1D causes the 0–5 volt a-c meter to read various voltages, depending on the setting of the band switch. A blank meter scale is marked to correspond to the band in use.

Meter M_2 reads GL-807 plate current. GL-837 screen current is read across the 50 ohm resistor R_7, and GL-837 plate current is read across resistor R_8. A jack is provided in the GL-807 grid circuit so that current readings may be taken at this point.

POWER SUPPLY

The power supply is a full-wave rectifier circuit. Switch S-3 is the on-off switch, controlling the a-c voltage entering on plug P_2 while switch S-4 acts as the Local-Remote switch. When this switch is in the up position plate voltage is off, as relay RY1 is not energized, and hence the transformer center-tap is open. Any a-c voltage applied to plug P_1 will energize this relay, and turn on plate voltage. A remote operating switch may thus be employed. If this is not done, switch S-4 still acts as a plate voltage on-off switch.

Voltage regulator tubes V_1, V_2 and V_3 supply plate and screen voltage to the GL-837 oscillator tube. The sum of the voltages across the three voltage regulator tubes is the plate voltage, while the voltage across V_3 is the screen voltage. This system of obtaining voltage makes it relatively easy to adjust the voltages on the oscillator tube. The VFO will work with any combination of tubes, although some experimentation is desirable in order to achieve maximum frequency stability. Recommended tubes are: V_1, OD3/VR-150; V_2, OD3/VR-150 and V_3, OB3/VR-105. These values give a total plate voltage of 405 volts and a screen voltage of 105 volts. If sufficient output can be obtained with less voltage on the screen, frequency drift will be lessened by using an OA3/VR-75 at V_1.

CONSTRUCTION

The actual layout of component parts depends upon their size and their quantity. The particular layout employed in the Five-Band VFO need not be followed, especially if fewer bands are to be covered. It would be wise to follow several general principles. All radio-frequency components are mounted on a single piece of metal which in turn is held by four shock mounts to the 17 by 13 by 4 inch chassis. This is shown in Fig. 4, where one of the shock mounts is visible. This base plate is $\frac{3}{16}$ inch thick, 12 inches wide and 13 inches deep.

The top view, Fig. 2, shows the five condensers mounted on the base plate, and the enclosed shield box in the middle. The shield box is seven inches wide, which leaves five inches for the condensers. The space above the base plate shows the rectifier tube and the three voltage regulator tubes mounted directly on the chassis.

The underview of the chassis, Fig. 5, shows how the chassis has been cut out, to allow the GL-807 tank circuit components to be mounted on the bottom of the base plate. The use of a shock-mounted plate means that all frequency-determining elements are free from vibration and shock. This is important also if power transformers are mounted on the chassis, in order to prevent lamination vibration from affecting the signal.

Three controls—main tuning, Crystal-ECO and Bandswitching—are mounted on the base plate. This means that they must be free to move. This is taken care of by drilling oversize holes in the front panel. The main tuning dial is mounted by its mounting studs directly to the front of the shield box, with oversize holes drilled through the panel for clearance.

The 13 by 7 by 5⅜ inch shield box provides complete shielding for the oscillator grid and plate circuit and the GL-807 grid circuit. Fig. 3 gives an internal view of this shield box. The GL-837 oscillator circuit is contained in the front of the box, with the grid elements on the left, and the tube and plate elements on the right. A thin shield separates the grid and plate circuits.

The detail photograph, Fig. 6, shows the tube removed and the coil L_{10} through L_{13} which are mounted around the bandswitch. One pie of the bandswitch which is S-1E and S-1F of the circuit diagram, is in this section of the unit. On the left of the shield partition are two pies containing S-1A, S-1B, S-1C and S-1D. The grid coils and condensers are grouped around these switches.

The variable condenser in the center is C_{17} which is coupled to the dial drive through a Millen right-angle drive. A shaft from this drive also goes out through the left side of the shield box (Fig. 3) to drive two more right-angle drives, which control the five GL-807 plate tuning condensers. In Fig. 2 may also be seen the right-angle drive which handles the two bandswitching shafts. The Crystal-ECO switch, mounted in the rear of the shield box is similarly controlled by a right-angle drive (Fig. 2). Liberal use of right-angle driving mechanisms permits the placement of parts in the best electrical position, and is recommended whenever a large number of controls is to be avoided.

The GL-807 socket is mounted on a heavy aluminum piece in the rear of the shield box. A tube shield is used to prevent coupling to the grid circuit. The plate end of the GL-807 extends out the left side of the shield box (Fig. 4) and a short plate lead is made to the switch at this point. These two switch pies consist of S-1G (toward the GL-807) and the special shorting switch, S-1H, on the pie nearest the panel.

Referring again to the shield box, condensers C_3, C_6, C_9 and C_{12} are mounted on the left-hand side so that they may be adjusted by a screwdriver. Fig. 4 shows how the aluminum has been recessed to take these four condensers. Condensers C_1, C_4, C_7 and C_{10}, negative temperature coefficient variables, are soldered in position on top of the trimmer condensers (Fig. 6). These negative coefficient condensers are adjusted through holes drilled in the shield box top plate (Fig. 2). The other four large holes in this plate provide ventilation for the GL-837.

All power equipment is mounted under the four-inch deep chassis (Fig. 5). The power transformer is on the right, and the two chokes side by side in the middle. The plate voltage relay, RY1, is mounted toward the rear of the chassis and the keying relay, RY2, is mounted against the front of the chassis.

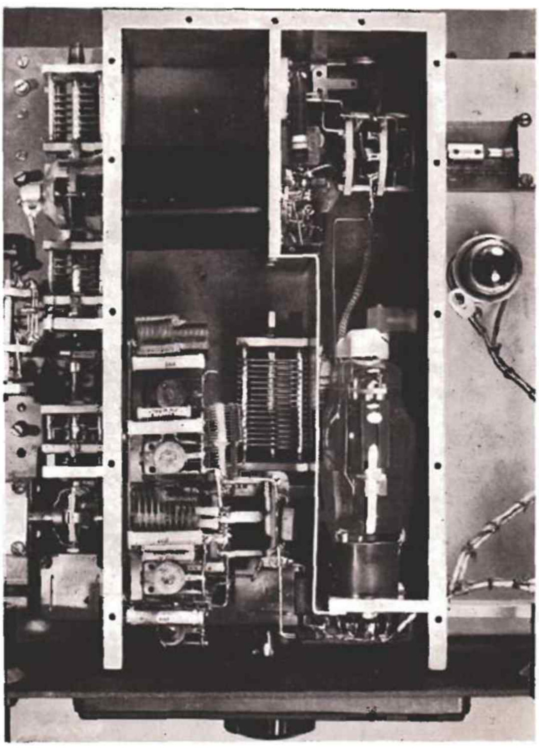


Fig. 3.—Top View Detail, Shield Box Cover Removed

On the left will be seen the five final tank coils and the five frequency setting condensers. These are mounted vertically for screwdriver adjustment from top of the chassis. The shafts, which extend above the chassis, may be seen in Fig. 4. The link lines from each GL-807 plate coil are run with 72 ohm twin lead to their individual connectors on the rear of the chassis.

All metal used in construction work (with the exception of the chassis itself) is aluminum. It should be thick enough so that it may be drilled and tapped. Three-sixteenths thick stock is satisfactory.

Two sets of pilot lights are shown in the circuit diagram. The white lamps are furnished with the Millen No. 10035 dial, but it is necessary to add two more sockets, inside the dial for the red lamps. If these are located below the white lamp sockets, there will be ample clearance so that dial movement will not be affected.

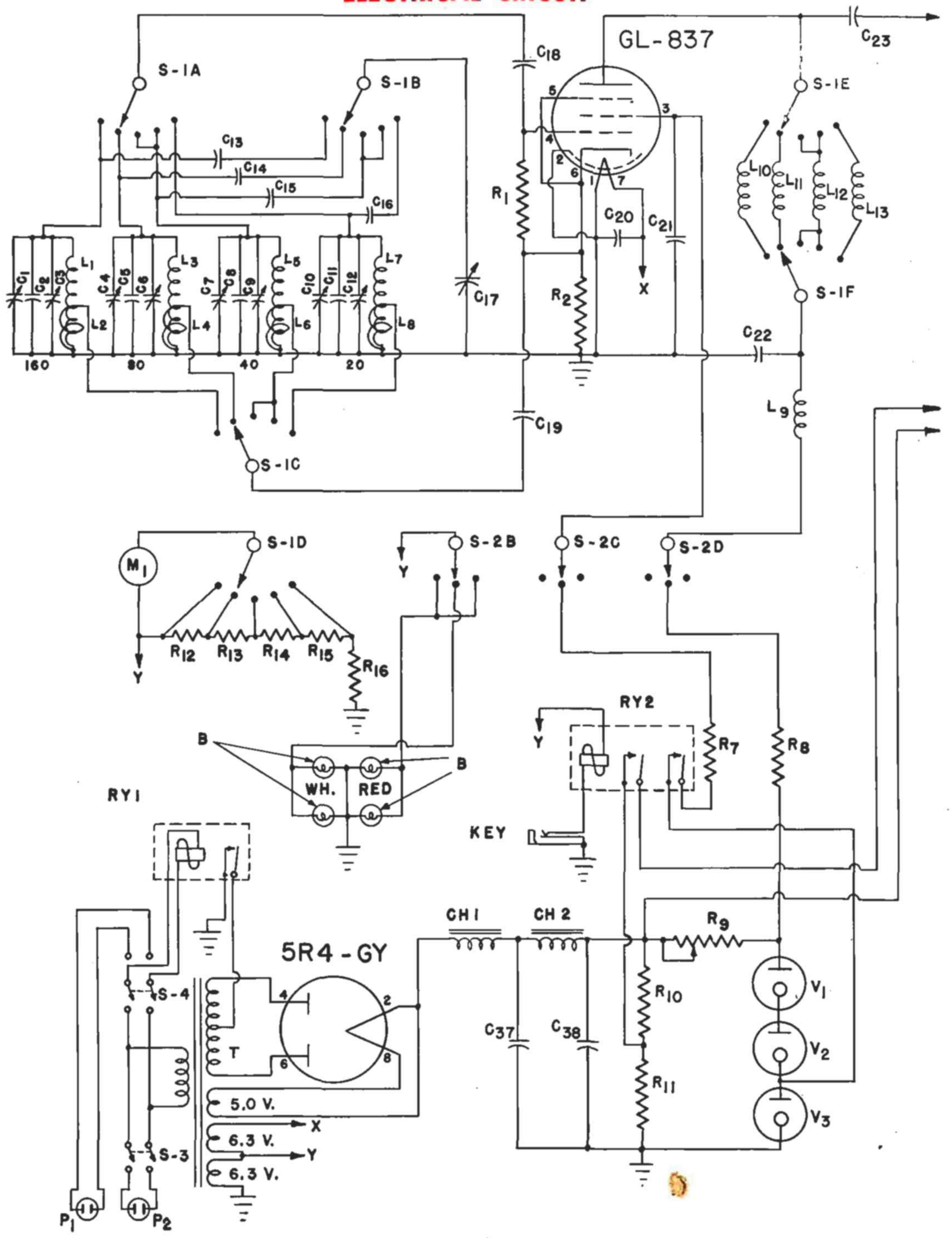
TUNE-UP ADJUSTMENTS

The biggest job in VFO construction is the work done after wiring has been completed. Bands must be set to the right frequency, band limits must be adjusted to fit on the dial, and frequency runs for drift must be made. After this, it is necessary to check the operation of the VFO while it is driving the antenna or another tube. Purity of note will suffer if succeeding stages feed any r-f energy into the VFO. The final check should be of the keying, including any key click problems which may arise.

The first step in testing is to make sure that the oscillator works on all bands. Following this, the main tuning dial should be set so that C_{17} is fully meshed, the bandswitch set at 80, and condenser C_3 tuned until Coil L_1 is resonant at 1.75 megacycles (one-half of 3.5 megacycles). The tuning dial should then be run up scale until 2.0 megacycle

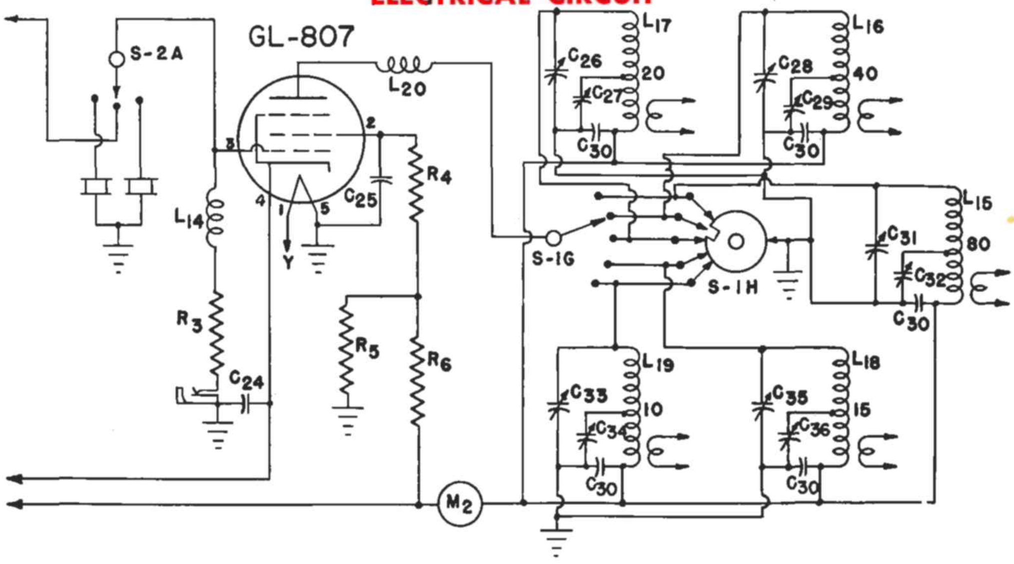
(Continued on page 6)

ELECTRICAL CIRCUIT



Band	VFO FREQUENCY TABULATION GL-837 Grid	GL-837 Plate	GL-807 Grid	GL-807 Plate
80	1.75– 2.0	1.75– 2.0	1.75– 2.0	3.5– 4.0
40	3.5 – 3.65	3.5 – 3.65	3.5 – 3.65	7.0– 7.3
20	7.0 – 7.2	7.0 – 7.2	7.0 – 7.2	14.0–14.4
15	7.0 – 7.2	7.0 – 7.2	7.0 – 7.2	21.0–21.6
10	14.0 –14.85	14.0 –14.85	14.0 –14.85	28.0–29.7

ELECTRICAL CIRCUIT



CIRCUIT CONSTANTS

B	=6.3 V. pilot lamps
C_1, C_4, C_7, C_{10}	=5–20 mmf negative temp. coefficient variable (Erie N300-TS2A)
C_2	=400 mmf ceramic (200, 200 in parallel)
C_3, C_6, C_9, C_{12}	=100 mmf air padder (Millen 26100LN)
C_5, C_8	=350 mmf ceramic (200, 100 and 50 in parallel)
C_{11}	=300 mmf ceramic (200, 100 in parallel)
C_{13}	=1000 mmf silver mica button
C_{14}, C_{15}	=100 mmf ceramic
C_{16}	=150 mmf ceramic (100, 50 in parallel)
C_{17}	=140 mmf variable (Millen 284140)
C_{18}	=150 mmf mica
C_{19}	=0.01 mf mica
C_{20}, C_{21}, C_{25}	=0.005 mf mica
C_{22}, C_{30}	=0.005 mf mica (1000 volt)
C_{23}	=100 mmf mica
C_{24}	=0.02 mf mica
C_{26}, C_{33}, C_{35}	=35 mmf double-spaced variable (Millen 20935)
C_{27}, C_{36}	=15 mmf double-spaced variable (Millen 23915)
C_{28}, C_{31}	=75 mmf double-spaced variable (Millen 28975)
C_{29}, C_{32}	=25 mmf double-spaced variable (Millen 23925)
C_{34}	=5 mmf double-spaced variable (Millen 2390[illegible])
C_{37}, C_{38}	=4 mf 600 volt Pyranol
CH_1, CH_2	=15 H. 200 ma. Choke (Stancor C-1412)
L_1-L_8	=See coil table
L_9, L_{14}	=2.5 mh., 125 ma. choke
L_{10}-L_{13}	=See coil table
L_{15}	=B & W Type 80 JEL (base removed)
L_{16}	=B & W Type 40 JEL (base removed)
L_{17}	=B & W Type 20 JEL (base removed)
L_{18}	=B & W Type 15 JEL (base removed)
L_{19}	=B & W Type 10 JEL (base removed)
L_{20}	=7 turns, No. 14 wire, close wound, 3/8 inch O.D.
M_1	=0–5 volt a-c meter (G.E. 93X467)
M_2	=0–200 ma. meter (G.E. 93X99)
P_1, P_2	=Female a-c connectors
R_1	=51,000 ohm, 1 watt
R_2	=2,500 ohm 10 watt
R_3	=51,000 ohm, 2 watt
R_4, R_7, R_8	=50 ohm, ½ watt
R_5	=0.1 megohm, 2 watt
R_6	=25,000 ohm, 10 watt
R_9	=5,000 ohm, 50 watt, semi-adjustable
R_{10}	=Three 25,000 ohm, 5 watt resistors in series
R_{11}	=400 ohm, 10 watt
R_{12}, R_{13}, R_{14}, R_{15}	=7.5 ohm, ½ watt
R_{16}	=10 ohm, ½ watt
RY1	=SPST relay, 110 v. a-c coil
RY2	=DPST relay, 6 v. a-c coil
S-1A, S-1B, S-1C, S-1D	=Two pie, double pole, six positions per pie
S-1E, S-1F	=Single pie, double pole, six positions per pie
S-1G	=Single pie, double pole, six positions per pie
S-1H	=See text
S-2A, S-2B, S-2C, S-2D	=Two pie, double pole, three positions per pie
S-3	=DPST toggle switch
S-4	=DPDT toggle switch
T	=Power transformer, 600-0-600 at 200 ma., 5 v. at 2 amp., 6.3 v. at 3 amp., 6.3 v. at 4 amp. (Stancor P-6170)
V_1, V_2, V_3	=Voltage regulator tubes (see text)

COIL TABLE

GL-837 GRID COILS

Coil	Band	Turns	Turns per Inch	Outside Diameter	B & W Coil No.
L_1	160	47	32	¾	3012
L_2	160	22	32	1	3016
L_3	80	22	16	¾	3011
L_4	80	10	16	1	3015
L_5	40	11	8	¾	3010
L_6	40	4	8	1	3014
L_7	20	5½	4	½	3001
L_8	20	2½	4	¾	3009

GL-837 PLATE COILS

Coil	Band	Turns	Length (Inches)	Outside Diameter	Winding	Wire No.
L_{10}	160	125	1¼	½	Layer	26
L_{11}	80	70	⅞	½	Layer	26
L_{12}	40	60	1¾	½	Close	22
L_{13}	20	28	2	½	Spaced	22

(Continued from page 3)

energy is generated. If you are unable to go as high as 2.0 megacycles, the bandspread is too great, and condenser C_{13} should be decreased in value. If too little bandspread is obtained, C_{13} should be made larger.

The above procedure should be followed for each of the four bands. The next step is to plug the GL-807 in and check grid drive. As the main tuning dial (C_{17}) is moved from one end of the band to the other, the grid drive to the GL-807 should be between 2.0 and 3.5 milliamperes. If the grid drive falls off on the low end, raise the inductance of the GL-837 plate coil for that band by adding more turns, or pushing the turns closer together. Similarly, if the grid drive falls off on the high-frequency end, decrease the inductance of the GL-837 plate coil.

Next, put plate and screen voltage on the GL-807 and resonate the final tank coil, at one end of the band, by condenser C_{31} (for the 80 meter band). The plate current at resonance should be approximately 5 milliamperes. The next step is to check the tap on coil L_{15}. Assume that the final was resonated at 3.5 megacycles. Therefore, C_{17} and C_{32} are both fully meshed. Now remove the mechanical coupling on C_{32} so that it may be driven by hand. Next, set C_{17} at midscale, apply plate and screen voltage, and resonate the circuit

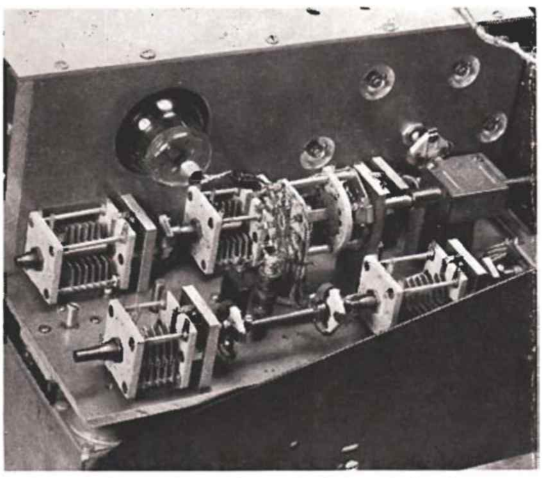


Fig. 4.—Detail View, GL-807 Tank Tuning Condensers

by tuning C_{32}. This tuning should be done with a pair of pliers on the grounded shaft on the condenser. If the tap is in the right place, C_{32} should be half-way meshed when C_{17} is half-meshed.

If C_{32} has only moved a small amount, and is more than half-meshed yet, it is acting as too large a capacitance. The tap on the coil should therefore be moved toward the plate end of the coil. Conversely, if it is found that C_{32} has moved a great deal in order to reach resonance, it is effectively too small a capacitor. This is overcome by moving the tap on the coil down toward the cold end of the coil.

After C_{32} has been adjusted as perfectly as possible, it may be found that perfect resonance is not obtained across the entire band. This will probably be due to the fact that C_{17} and C_{32} do not have identical capacitance vs rotation characteristics. This may be ignored in most cases, because the circuit will be broader when the GL-807 stage is loaded.

This is a good point to check parasitics. Coil L_{20} was added to the GL-807 plate lead when an oscillation was uncovered on 10 meters.

After all GL-807 tank coil taps are set, and the tuning condensers re-connected so that they are driven by the main dial, frequency drift measurements should be started. A frequency standard of some sort should be employed. Do not use a regular crystal as a standard. A 100 or 1000 Kc. crystal may be used and the VFO signal beat against the standard signal from the 1000 Kc or 100 Kc crystal. Even though your receiver drifts, this method ensures accuracy, with any frequency difference between the VFO and the standard crystal showing up as an audio note, whereas receiver drift will not cause the note to change, although the receiver should be checked every now and then to ensure that the two zero-beat signals are still somewhere in tune.

Three more tests for frequency stability should be run. The first concerns the proper number of turns on the cathode coils in the grid circuit (L_2, L_4, L_6, L_8). The second concerns plate and screen voltage ratio on the GL-837. The third test involves temperature compensation. These tests were fully explained last month (Ham News, September-October, p. 5).

When the VFO is working properly, the crystal oscillator should be checked. This involves nothing more than setting the main tuning dial on the

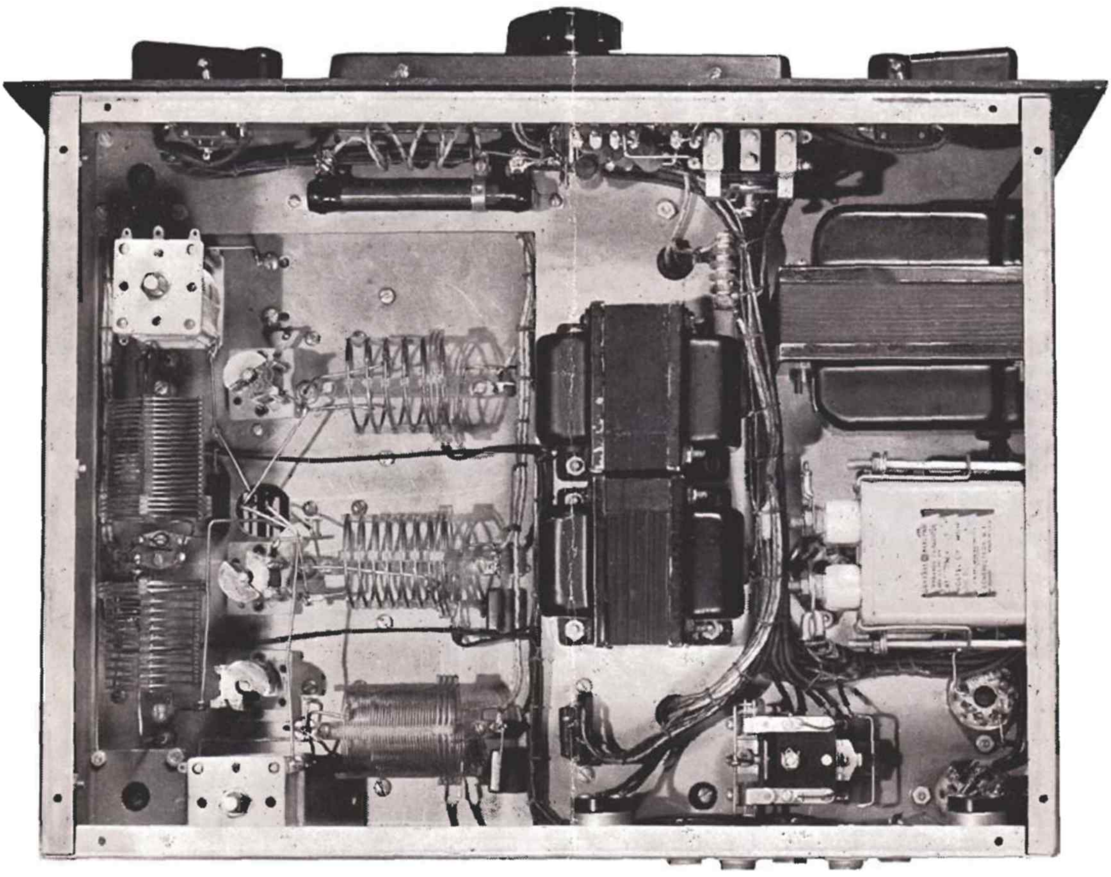


Fig. 5.—Under-chassis View of Five-Band VFO

crystal frequency, and switching the crystal ECO switch to crystal. The GL-807 should now be oscillating. It is necessary to tune the main tuning dial so that the tuning condenser in the GL-807 plate circuit is tuned to resonance. This point should be the same as that used when the VFO circuit is used.

KEYING

A keying relay is incorporated so that both the GL-837 screen and the GL-807 cathode circuits may be keyed simultaneously. By keying in this fashion, it is possible to key for either VFO or crystal operation. The keying which results is extremely clean.

No key click filter is shown, as experience indicates that key click filters are more easily designed to each individual piece of equipment.

PERFORMANCE

Frequency drift can be held to negligible proportions in the design shown. Tests run on this unit showed that the initial warm-up drift, in the first five minutes, was several kilocycles (less than the average communications receiver). After warm-up, the drift was in the order of 20 cycles per hour. This drift was not always in the same direction, so that measurements made after 100 hours of continuous operation showed a total frequency change of only 200 cycles. At this point it might be wise to point out that frequency stability is not something that occurs automatically by using a certain electrical circuit.

Most VFO designs are good enough so that adequate frequency stability may be obtained, and very few circuits are sufficiently poor that adequate stability is impossible to achieve. The important thing to realize is that, regardless of the circuit used, some experimenting must be done by the builder in order to get a stable VFO.

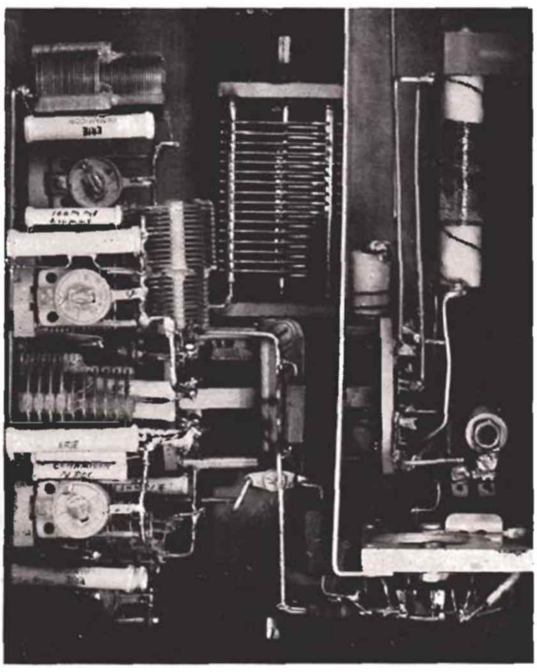


Fig. 6.—GL-837 Oscillator Circuit Detail

TECHNICAL INFORMATION

GL-807

GENERAL CHARACTERISTICS

Electrical

Cathode—Heater type

Heater voltage ¶ .... 6.3 volts
Heater current .... 0.9 ampere

Average characteristics

Grid-plate transconductance, $I_b = 72$ ma .... 6000 micromhos
Grid-screen amplification factor 8

Direct interelectrode capacitance

Grid-plate, with external shielding .... 0.2 micromicrofarad
Input .... 11 micromicrofarads
Output .... 7 micromicrofarads

Frequency for maximum ratings .... 60 megacycles

MAXIMUM RATINGS AND TYPICAL OPERATING CONDITIONS

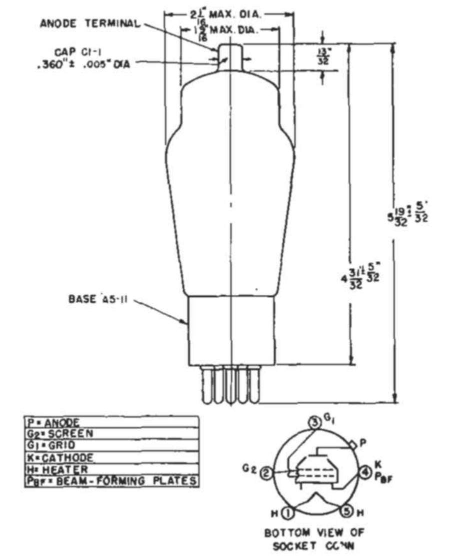
CLASS C RADIO-FREQUENCY POWER AMPLIFIER AND OSCILLATOR

Key-down conditions per tube without modulation +

	Typical Operation				Maximum Ratings		
D-c plate voltage	400	500	600	750	600	750	volts
D-c grid voltage					−200	−200	volts
From a fixed supply of	−45	−45	−45	−45			volts
From a cathode resistor of	410	410	410	410			ohms
From a grid resistor of	12800	12800	12800	12800			ohms
D-c screen grid voltage					300	300	volts
From a fixed supply of	250	250	250	250			volts
From a series resistor of	20000	42000	50000	85000			ohms
D-c plate current	100	100	100	100	100	100	milliamperes
D-c grid current, approximate	3.5	3.5	3.5	3.5	5	5	milliamperes
D-c screen grid current	7.5	6	7	7			milliamperes
Plate input					60	75	watts
Plate dissipation					25	30	watts
Screen grid input					3.5	3.5	watts
Peak r-f grid input voltage, approximate	65	65	65	65			volts
Driving power, approximate	0.2	0.2	0.2	0.2			watt
Plate power output	25	30	40	50			watts

¶ Heoter voltage fluctuations should not exceed +10 or −5 per cent from the rated value.

+Modulation, essentially negative, may be used if the positive peak of the oudio-frequency envelope does not exceed 115 per cent of the carrier conditions.



Electronics Department

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