Electronic TUBES

G-E HAM NEWS

TUBE DEPARTMENT
GENERAL ELECTRIC
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MAY–JUNE, 1956 VOL. 11, No. 3

TRANSISTORIZED VFOS

IDEAS

CIRCUITS

CONSTRUCTION

Slug-tuned BC VFO

Capacitor-tuned BC VFO

3.5-megacycle VFO

Last issue, we described a power type variable frequency oscillator. Now let's go to the other extreme and examine the aspects of flea-powered oscillators using popular transistors.

—*Lighthouse Larry*

CONTENTS

Transistors have found rather limited use in many fixed amateur stations to date, but two local radio amateurs, W2BMU and W2ZHI, have done some interesting work in developing transistorized variable frequency oscillators for transmitter frequency control. Broadcast band and 3.5-megacycle oscillators are described in this frank discussion of the advantages and limitations of presently available transistors in these circuits. We'll skip over basic transistor principles because they were covered in the February-March, 1956 issue of TECHNI-TALK, companion publication to G-E HAM NEWS. Pick up a copy at your local G-E Tube Distributor. If his supply is gone, mail me a postal card asking for a complimentary copy.

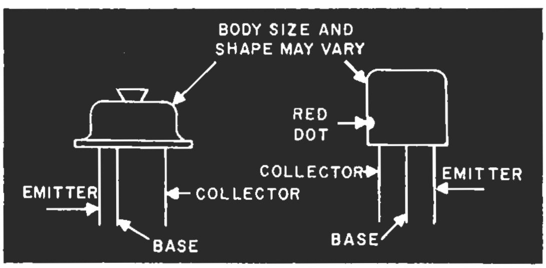
—*Lighthouse Larry*

TRANSISTORIZED VFOS

DESIGN AND APPLICATION

The low cost transistor types, such as the G-E 2N107, lend themselves to experimentation with oscillators operating in the broadcast frequency range. Inexpensive components are readily available and the frequency stability is excellent when good mechanical rigidity is employed in the construction. Frequency drift is practically nil after a minute or two of operation because of the absence of any discernible heat in the transistors, when used within the ratings and away from heat sources. Dial calibration and frequency drift checks are simply a matter of zero-beating broadcast station signals.

A few flashlight batteries in series or compact cells designed especially for transistors are stable power sources. In fact, a two-stage oscillator-amplifier circuit has such a low current drain that several hundred hours is obtained from the batteries even when the transistors run continuously, according to battery manufacturers. Obviously, the supply voltage regulation is excellent and hum-modulation of the VFO output because of AC tube heaters or inadequately filtered rectifier-type supplies is not a problem. Outlines and connections for most popular transistors are pictured below.



The main present-day transistor limitations are low power output and restricted frequency coverage in the low cost types, such as the G-E 2N107. Greater frequency stability and RF output is obtained from a transistor oscillator operating below 1 megacycle. This decrease in output at higher frequencies is apparent even with transistors having alpha cutoff frequencies of several megacycles. Thus, a transistor tends to act as its own low-pass filter. Rather than multiply the broadcast band output up to popular amateur frequencies, thus multiplying any drift by the same factor, a low-level mixer stage can be used. This necessitates feeding a crystal oscillator in the 4.5 to 5.0-megacycle range and a transistor VFO in the 0.5 to 1.0-megacycle range into the mixer. Either the 3.5 to 4.0-megacycle difference or 5.0 to 5.5-megacycle sum frequencies may be obtained in the mixer output. The latter is a VFO range which several commercially-built single sideband exciters require.

Some harmonics of the mixer input frequencies tend to cancel in the output of a push-pull low-level balanced mixer circuit recommended for this purpose. Further harmonic attenuation in the broadcast range transistor oscillator is achieved through precautions described under "CIRCUIT DETAILS." These factors all combine to produce a mixer output signal relatively free from measurable spurious modulation or "birdies" resulting from oscillator harmonics crossing the mixer output frequency.

A vacuum tube oscillator for this frequency range would have a higher harmonic content in the output, and would require an elaborate low-pass filter between it and the mixer stage. Design of suitable mixer circuits is a complete subject in itself and will be covered in a later G-E HAM NEWS article.

Many amateurs who have built the SSB, Jr. (See G-E HAM NEWS, Vol. 5, No. 6, for details) have wished for the more flexible frequency control provided for in commercial SSB gear. W2BMU has placed his SSB, Jr. on a fixed frequency of 4.54 megacycles, well within the tuning range of the original coils. SSB output is taken from the diode modulator stage, instead of the 6AG7 linear amplifier, and fed into the low-level mixer stage. A transistor VFO tuning from 0.54 to 0.74 megacycles also drives the mixer and SSB output in the 3.8 to 4.0-megacycle band is obtained in the mixer plate circuit. The exact frequencies used are not critical —the 4.54-megacycle crystal happened to be available.

CIRCUIT DETAILS

A choice of several frequency determining circuits, all designed for the 0.54 to 0.74-megacycle tuning range, are illustrated on page 3. Slug tuned coils in each circuit give considerable latitude in exact frequency coverage, but best coil "Q" is obtained with the slugs well inside the winding. In Figures 1 and 2a, this 200-kilocycle tuning range is covered in two segments by switching additional capacity across the series-tuned Colpitts tank circuit. If an insulated-rotor variable capacitor is available, the circuit of Fig. 2a is suggested. Fig. 2b shows the components required if you wish to use the vari-loopstick coil slug for tuning. The 250-mmf silvered mica capacitor across C_2 may be changed to cover other tuning ranges.

A Miller No. 2020 transistor oscillator coil is used for L_1 in the Hartley circuit, Fig. 2c. The 2N107 emitter and collector elements are tapped down on this tank coil to obtain a proper impedance match. Variable capacitors C_1 and C_2 are for tuning and zero-setting, respectively, in circuits showing them. Each circuit has been tested, so available components will dictate the circuit chosen.

These oscillator circuits operate the transistor base at RF ground. The low impedance output required to match the amplifier base is taken from the emitter, approximately comparable to a tube cathode follower circuit driving a grounded-cathode amplifier. Voltage dividers provide negative bias for the base element in both stages, although a separate battery could be employed for that purpose. The divider reduces the bias in the same proportion that the collector battery voltage drops with age.

The output voltage from all circuits is inversely proportional to the operating frequency, ranging from 1.5 to 1.0 volts RMS with a 6-volt battery. The output

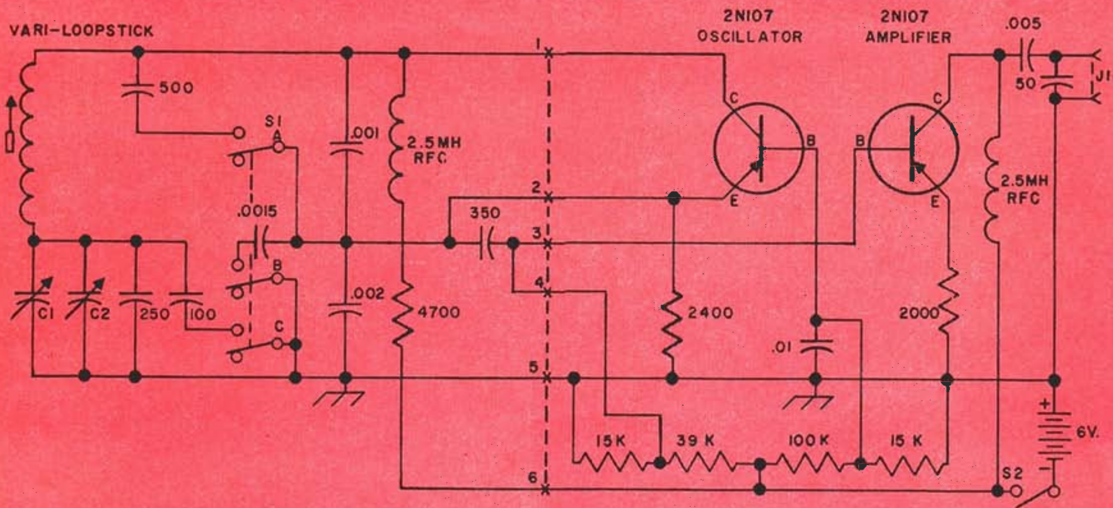


Fig. 1. Schematic diagram of the capacitor-tuned broadcast band VFO. Variable capacitor C_1 is 250-mmf and C_2 is 10-mmf maximum. RF chokes are Miller No. 953, 2.5 mh. Tap switch S_1 is 3-pole, double-throw, single section. All fixed capacitors to left of dotted line are silvered mica. Other capacitors are disc ceramic. All resistors are ½ watt, ±10%.

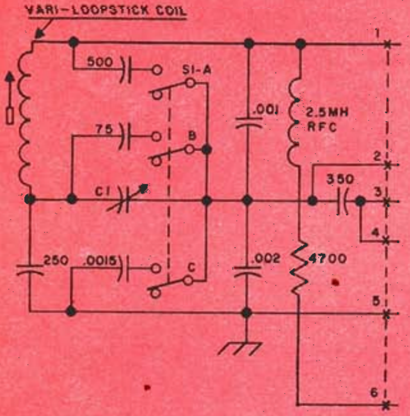


Fig. 2a

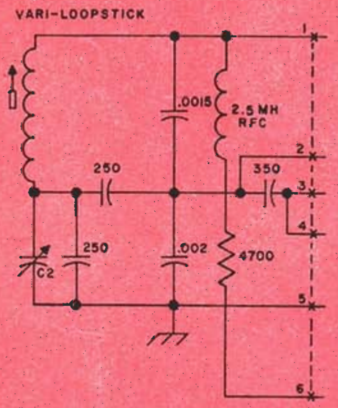


Fig. 2b

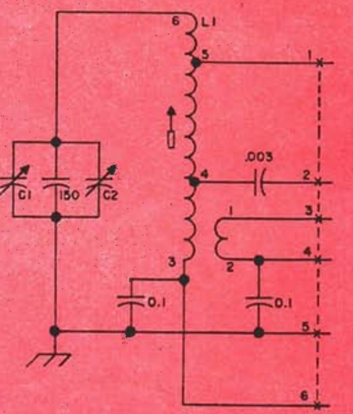


Fig. 2c

Variable capacitors same as Fig. 1. In Fig. 2c, L_1 is a Miller No. 2020 broadcast band transistor oscillator coil and the 0.1-mfd by-pass capacitors are 200-volt paper. Any of these frequency determining circuits may be substituted for that in Fig. 1 by connecting points numbered 1 through 6 to corresponding connections on Fig. 1.

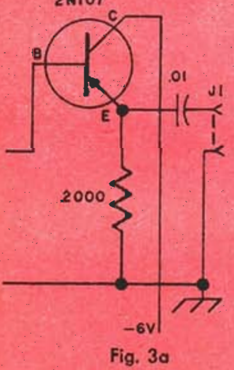


Fig. 3a

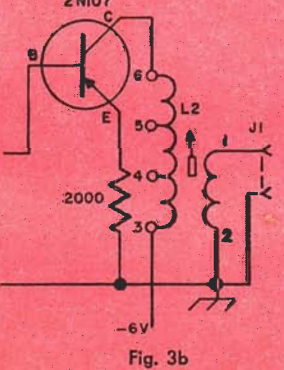


Fig. 3b

Optional output circuits for the amplifier stage in Fig. 1. Coil L_2 is the same as L_1 in Fig. 2c.

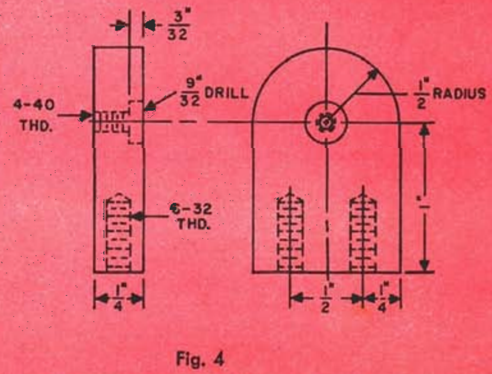


Fig. 4

Mounting block for the loopstick coils.

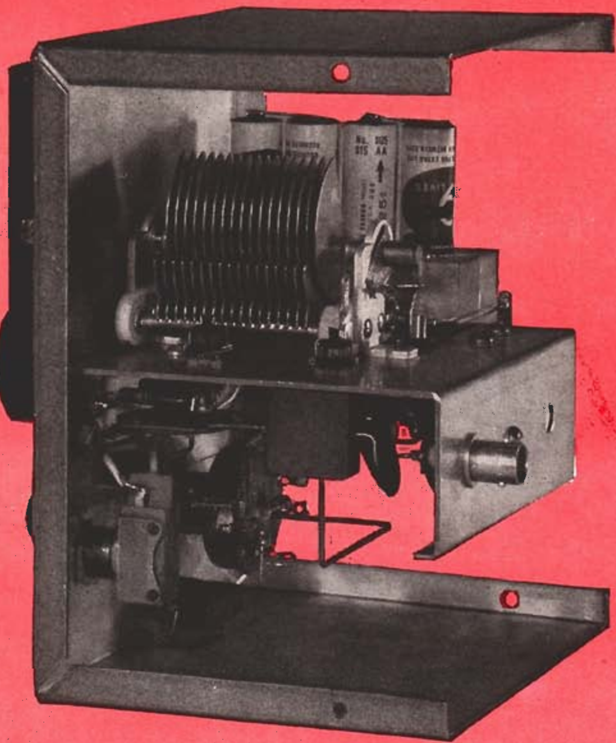
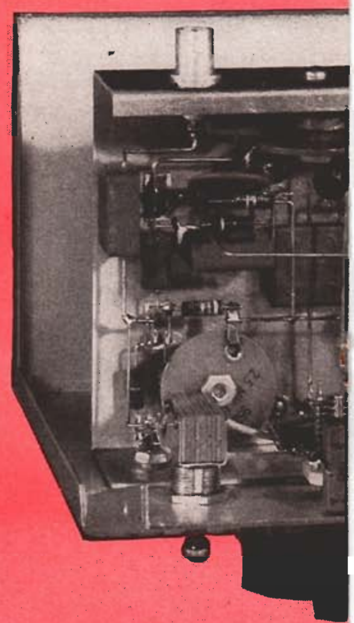


Fig. 5



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Views of capacitor-tuned oscillator showing coil positioned for adjustment through hole at rear of chassis. Batteri plastic blocks, one of which is fastened to chassis. A strip of insulating tape on chassis below batteries prevents sh

voltage rises in proportion to increases in this voltage, but stability will be improved if the oscillator transistor is not operated at maximum ratings. The amplifier collector output impedance is high enough to operate directly into the grid of a low-level mixer tube. If a coaxial connecting cable is used, the length should be less than 18 inches. Degeneration introduced by not RF by-passing the resistor from emitter to ground in the amplifier stage, and placing a 50-mmf capacitor across the output terminals, reduces the harmonic output previously mentioned.

A tuned output circuit with link coupling for longer runs of coaxial cable, shown in Fig. 3b, substitutes a second Miller No. 2020 coil in place of the 2.5-mh RF choke in the amplifier collector circuit. A third such coil will form an impedance step-up transformer at the other end of the coaxial cable. The amplifier output also may be taken across the 2000-ohm emitter resistor and fed directly into a coaxial cable through a coupling capacitor, as shown in Fig. 3a. The approximate output voltage using this connection is 0.2 volts RMS.

MECHANICAL DETAILS

Size of these transistor oscillators is mainly dictated by the dimensioning of the dial mechanism and tuning medium employed. Bud CU-2107 aluminum Miniboxes, 4 x 5 x 6 inches, easily house all components and the batteries. Bud CB-1627 3¾ x 4⅛ x 1½-inch deep miniature aluminum chassis can be used in all models. The oscillator coils should be rigidly mounted with the winding end at least 1 inch away from any metal. The metal end caps were removed from these coils and a mounting block made from ¼-inch thick sheet plastic insulation, drilled as shown in Fig. 4, is substituted. The tuning slug runs through the threaded portion of the hole into which the coil form is cemented. All wiring of chassis components, pictured in Figs. 5 and 6, was completed before the chassis was assembled 3 inches down from the top of the box. The Millen No. 10039 dial will support the shaft extension from an insulated coupling required when the insulated-rotor circuit of Fig. 2a is constructed.

The slug-tuned oscillator unit, pictured in Fig. 7, requires extra depth for the coil and slug-drive assembly. A ¼-inch thick brass mounting plate, also drilled according to Fig. 4, and a similar ½-inch thick sheet plastic bracket without threads hold the vari-loopstick coil. Heart of the assembly is a slip-joint coupling made from three 4-40 brass ¼-inch hex nuts soldered to the end of the loopstick slug screw after the brass mounting plate is assembled. Any excess solder is removed with a file so that the nuts will slide smoothly into the ¼-inch hex inside a 1¼-inch length of fiber alignment wrench tubing (Walsco No. 2503). The tubing is then bolted, with the ¼-inch overlap shown in Fig. 8, to the ¼-inch diameter shaft of a Groth Type TC-2 turn-counting dial mounted on the end of the box. The dial shaft is shortened to 1⅜ inches over-all. Reasonable care in the assembly of this coupling should be exercised to insure a smooth running, backlash-free drive for the tuning slug.

This model has the miniature chassis fastened to the side of the cabinet, permitting wiring to be done after the chassis and all small parts have been assembled. A similar battery mounting, fashioned from a 3 x ¾ x ½-inch thick block of plastic, may be used in each unit. Suitable flashlight battery holders, or a miniature 6-volt battery specially designed for powering transistors, may be installed instead.

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s are clamped between two
rt circuits.

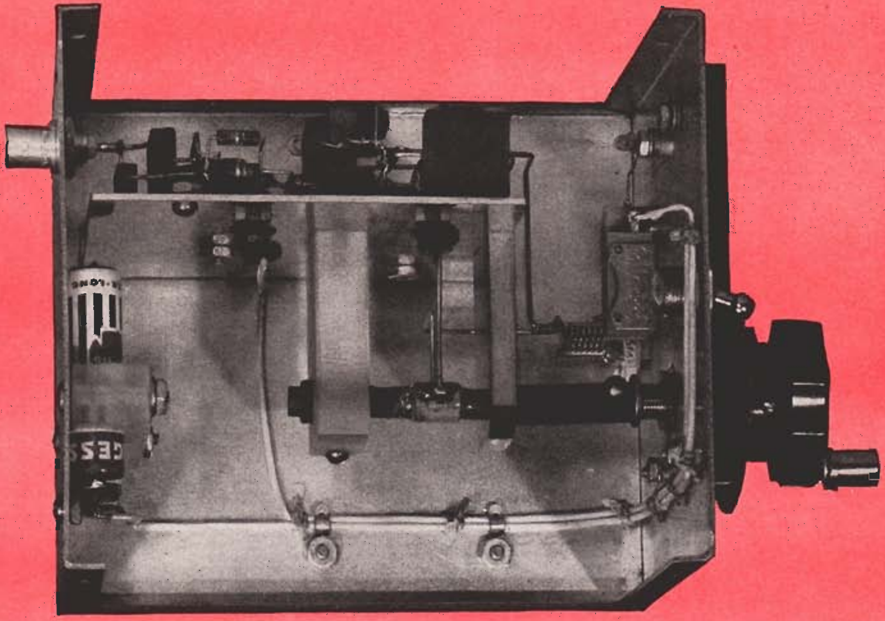

Fig. 7

Side view of the slug-tuned oscillator showing slug drive and mounting blocks supporting coil 2 inches below chassis. Nearest chassis lip was removed to show small parts placement.

3.5-MEGACYCLE VFO

A Transistorized VFO may be designed to operate directly in amateur bands by employing transistors having an alpha cutoff frequency somewhat higher than the desired operating range. Although the G-E 2N135 and 2N136 transistors operate satisfactorily at 3.5 megacycles, twice the output voltage, 0.2 volts RMS, was obtained when 2N137 transistors were used in both stages. They have a ***minimum*** alpha cutoff frequency of 7 megacycles and "loaf" at 3.5 megacycles. The low output voltage requires that a vacuum tube class A amplifier, either tuned or untuned, follow this VFO in the transmitter to which it is connected. A 6AU6 or similar miniature pentode tube will provide sufficient output voltage to drive succeeding low level buffer and multiplier stages.

This oscillator also employs a series capacitor-tuned Colpitts frequency determining circuit shown in Fig. 9, with RF component values scaled down for this band. Variable capacitor C_1 is used for setting the portion of the band to be tuned with bandspread capacitor C_2. Precise tuning is easy because the Millen 10039 panel dial covers the bandspread range in 4 knob revolutions.

The "Q" of oscillator coil L_1 should be made as high as possible. The form should be fused quartz, Pyrex glass, steatite, or similar tubing or rod with a low coefficient of expansion. A Centralab X-32 steatite pillar insulator coil form was used in this model. A winding length-to-diameter ratio of about 2:1 and space-wound coil turns also should be used, rather than depend on the enameled wire insulation, as would be the case with close-wound coils.

Construction of this oscillator, pictured in Figs. 10 and 11, is much the same as the broadcast band model in Fig. 5, except that the larger band setting capacitor, C_1, is placed below the chassis. The whole rear portion of the chassis deck behind C_2 is occupied only by the oscillator coil, spaced at least the coil diameter from surrounding metal. Two small ¼-inch thick sheet plastic brackets support both ends of the coil form. The coil wire should be heated as it is wound so that it will shrink on the form when cooled. A soldering lug was placed in a small groove filed in each plastic coil support and held with plastic cement when assembling the ¼-20 x ½-inch long machine screw which is driven into each threaded end of the coil form.

Extra self-tapping sheet metal screws may be driven into the cabinet flanges and the rear of the chassis for added rigidity. These holes should be drilled before the battery holder is fastened to that edge of the chassis.

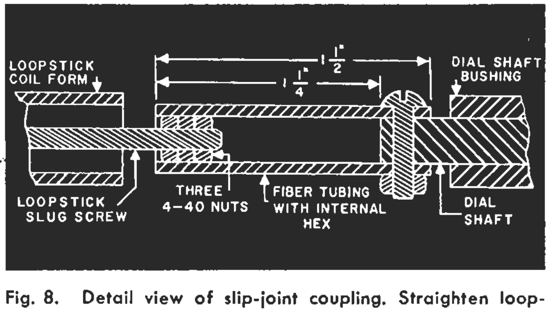

Fig. 8. Detail view of slip-joint coupling. Straighten loopstick screw to run true with slug, if necessary.

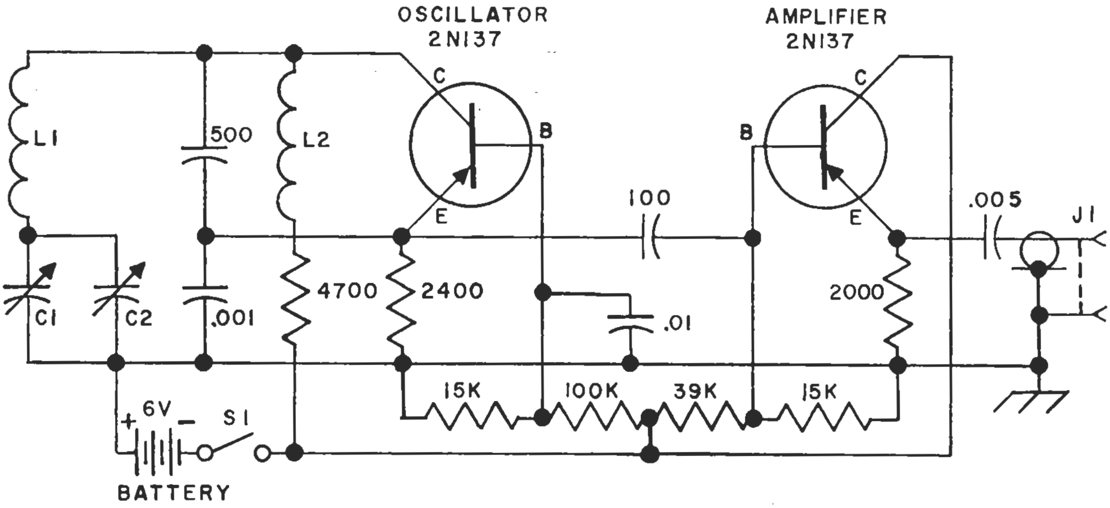

Fig. 9. Schematic diagram of the 3.5-megacycle VFO. Variable capacitor C_1 is 50-mmf and C_2 is 5 to 15-mmf maximum, depending on bandspread desired. Coil L_1 is 34 microhenries; 60 turns of No. 24 enameled wire space-wound 2¼ inches long on a 1-inch diameter x 2½-inch long steatite pillar insulator (Centralab X-32). L_2 is a 2.5-mh RF choke. All capacitors except the 0.01 and 0.005-mfd disc ceramics are silvered mica.

N-P-N type transistors, such as the G-E 2N78 and recently announced 2N167, may be operated in all broadcast range VFO circuits simply by reversing the battery polarity. The 2N167 has a 5-megacycle minimum cutoff frequency and is rated for 30 volts maximum on the collector. It also is applicable for the 3.5-megacycle oscillator, with a higher supply voltage.

Warmup frequency drift measurements were made on each of these oscillators, using a laboratory-type frequency counter reading to the nearest cycle. For comparison purposes, drift of the TRI-RANGE VFO (see G-E HAM NEWS, Vol. 11, No. 2), and a BC-696 surplus command transmitter also were checked. The test results, listed below, show the shorter time required for frequency stabilization in transistor oscillators.

Time	2 min	10 min	30 min	
Slug-tuned 0.7-MC osc.	−9	−12	−16	cycles
Capacitor-tuned 0.7-MC osc.	−7	−9	−14	cycles
Capacitor-tuned 3.5-MC osc.	+65	+82	+89	cycles
TRI-RANGE VFO at 3.5-MC.	−35	−65	−90	cycles
BC-696 VFO stage at 3.5-MC.	−20	−43	−82	cycles

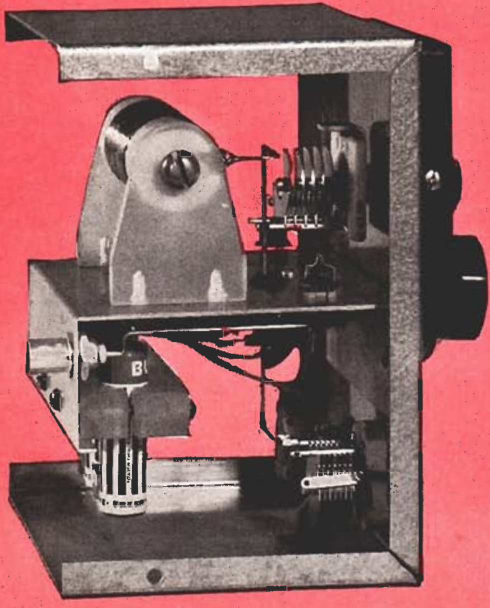

Fig. 10

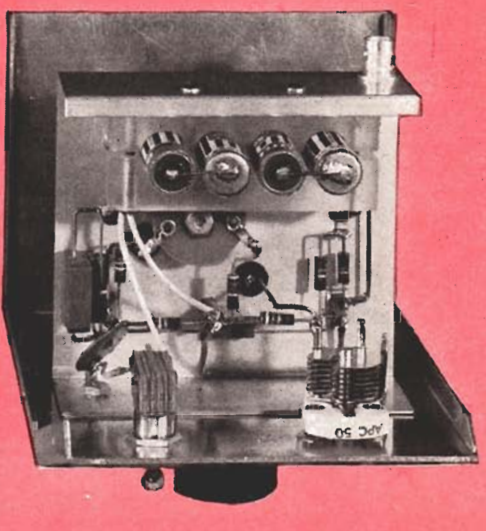

Fig. 11

Views of the 3.5-megacycle VFO showing oscillator transistor on near side. Coil brackets are fashioned from ¼-inch thick sheet plastic with coil mounting holes 1½ inches above chassis.

SWEEPING *the* SPECTRUM

In spite of the many hours I spent poring over the records of past G-E HAM NEWS DX Logs and ARRL Official Country lists, a couple gremlins in the form of mis-placed continents sneaked into the latest DX LOG, published in the January-February, 1956 issue. Under "Official Countries," DU, Philippine Islands, on page 2, should be *Oceania,* not *Asia;* and OD5, Lebanon, on page 4, is *Asia,* not *Africa.* A clarification is in order for PK, Indonesia; and Java, PK1, 2, 3; listed on page 5. These actually are the same country, but the ban on amateur communications with these prefixes is still in effect, according to latest information. A recent addition to the Official Countries list, Tromelin, FB8, also has come to my attention. This island is located about 260 miles northeast of Madagascar, in the Indian Ocean. DXCC credit will be given starting May 1, 1956, for confirmations dated on or after November 15, 1945. Many thanks to sharp-eyed Ed Hopper, W2GT, and Cedrick Justis, W3EEB, for helping me keep the listings on the beam.

* * *

While we're on the subject of DX, here's a tale for your *now-I've-heard-everything* file. I recently received a very nice note from Russ Burss, W9RKP, in which he explained the operation of his recently organized "OUTGOING DX QSL BUREAU SERVICE." For a nominal charge, you put all your QSL cards going to DX stations in one envelope and send it to him. He then collects all cards going to the established foreign QSL bureaus and sends them first-class or air mail once each week. Russ says that this provides a fast and efficient forwarding service, at less than half the cost, for all routine cards which you normally would send individually to these QSL bureaus. It is not intended for those rare countries where you usually send your QSL directly to the amateur. For further details on this non-profit DX QSL bureau-in-reverse, send him a *stamped, self-addressed* envelope.

* * *

It's happened again!! The boss says he just finishes printing an issue which describes some gadget which has been carefully designed to do a specific job and—along comes a flood of mail asking whether that gadget can be slightly changed to work—on other frequencies—with higher voltages—or different tubes. This time the TRI-RANGE VFO, just described in the March-April, 1956 issue of G-E HAM NEWS, is on the chopping block for changes.

Many radio amateurs wish to substitute a 2-gang variable capacitor, such as the Hammarlund MCD-35-SX, for the 3-gang unit specified for C_1 and cover 3.5—4.0 megacycles in two ranges. The same coils specified for L_2 and L_3, plus changing C_6 and C_7 to 50 mmf, buys you the approximate tuning ranges of 3.5—3.8 and 3.7—4.0 megacycles. Those 144-megacycle hounds who require more bandspread than the 15 dial divisions obtained with the original 4.0—4.5-megacycle range also may change C_6 or C_7 to 50 mmf and set 4.111 megacycles at 100 on the tuning dial by adjusting either C_3 or C_4. If your main tuning capacitor has midline shaped plates, 144—148 megacycles will cover about 50 dial divisions.

If you want to build just the oscillator circuit to drive succeeding stages in your present transmitter, the 6AG7 can either be substituted for your oscillator tube or added in an unoccupied corner. In this case, a single 6 x 6 x 6-inch utility box may be substituted for the 4 x 5 x 6-inch tank circuit box and 7 x 10 x 8-inch deep instrument cabinet housing the original VFO.

* * *

If you plan to do any Field Day and portable hamming during the summer, confirming these QSO's can be a problem. An easy solution—try a stack of Log Form QSL cards and use an inexpensive rubber stamp to imprint your portable call letters and location. They will continue to be available from me at the above address, in packages of 300 cards for $1.00, postpaid.

* * *

The word has just gone out! The G-E HAM NEWS SECOND BOUND VOLUME, containing all issues printed in 1951 through 1955 (Volume 6, No. 1 to Volume 10, No. 6), is now available! My fingers took a beating typing addresses on the more than 500 postal cards I sent notifying persons who had written and reserved copies in advance.

If you've never seen or heard of the G-E HAM NEWS FIRST BOUND VOLUME, every five years we bind all issues from that preceding period into a convenient 7 x 9½-inch book having stiff black leatherette, gold-stamped covers. Also included is a handy cross-indexed listing of all information contained therein. Only a limited number of copies have been prepared, as was the case with the G-E HAM NEWS FIRST BOUND VOLUME, now extinct. The original price for that volume, two dollars per copy, postpaid, has been maintained for this new book by holding production costs to a minimum.

If you live in the continental United States, Canada, Alaska, Hawaii, and the Panama Canal Zone, send your order to: Lighthouse Larry, Tube Department, General Electric Co., Schenectady 5, New York, U.S.A. Canadian orders also may be sent to me at the Canadian General Electric Co., Electronic Tube Marketing Section, 830 Lansdowne Avenue, Toronto, Ontario, Canada. In all other countries, write me at the International General Electric Co., 570 Lexington Avenue, New York 22, N. Y., U. S. A.

—*Lighthouse Larry*

Technical Information

TRANSISTORS

The G-E type 2N107 is an inexpensive diffused junction P-N-P germanium transistor for students, experimenters, hobbyists and hams. The G-E types 2N135, 2N136 and 2N137 are alloy junction germanium transistors intended for RF and IF service in broadcast receivers. All are of hermetically sealed construction.

ABSOLUTE MAXIMUM RATINGS: (25° C)

	2N107	2N135	2N136	2N137	
Collector Voltage					
Common Base (emitter open), V_{cb}	−12	−20	−20	−10	volts
Common Emitter (R_{bc} = 100 ohms), V_{ce}	−12	−20	−20	−10	volts
Common Emitter (R_{bc} = 1 megohm), V_{ce}	−12	−12	−12	−6	volts
Collector Current, I_c	−10	−50	−50	−50	ma
Emitter Current, I_e	10	50	50	50	ma
Collector Dissipation	50	100	100	100	mw
Storage Temperature	85	85	85	85	°C

ELECTRICAL CHARACTERISTICS: Design-center Values

(Common Base, 25°C, V_{cb} = −5 v, I_e = 1 ma)

	2N107	2N135	2N136	2N137	
Voltage feedback ratio (input open circuit f = 1 mc), h 12	$3X10^{-4}$	$7X10^{-3}$	$7X10^{-3}$	$7X10^{-3}$	
Output Capacitance (f = 1 mc), C_c	40	14	14	14	mmf
Alpha Cutoff Frequency, f_{co}	1.0	4.5	6.5	10	mc
Minimum Alpha Cutoff Frequency, F_{co}	0.80	3	5	7	mc, min.
Collector Cutoff Current, I_{co}	10	5	5	5	ua
Base Current Amplification (common emitter, f = 270 CPS), β	20	20	40	60	

TYPICAL OPERATION: (Common Emitter, 25° C)

	2N107	2N135	2N136	2N137	
Collector Voltage	−5	−5	−5	−5	volts
Emitter Current	1.0	1.0	1.0	1.0	ma
Frequency	1.0	455	455	455	kc
Tuned Power Gain	38	29	31	33	db

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