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Title: Meet the Remarkable but Little-Known Vackar VFO!

Meet the Remarkable but Little-Known Vackar VFO!

Searching for a VFO with Rock of Gibraltar stability? End your band-edge worries with this self-contained unit. For the serious-minded cw operator, the chirp-free operation and undetectable frequency drift make this VFO a natural!

By Floyd E. Carter,* K6BSU

The dedicated cw operator must make severe demands of his station equipment. He knows that an elusive DX station amateur cannot be asked to tolerate a signal which drifts through the passband of his receiver or one which has keying chirp. For the cw man, his fist and the note of his transmitter form his "voice" to distant stations. Modern electronic keyers have made machine-like keying an inexpensive reality. Couple a keyer with a fine-quality VFO, and the DX station operator just cannot refuse to QSO.

In designing this heterodyne VFO, the goal was to produce a keyed oscillator with undetectable chirp or frequency drift. Keying of a conventional VFO invariably produces some instability because the starting and stopping of an oscillator upsets the fine balance of dc and ac conditions within the circuit, and with each key-down transition oscillation equilibrium must be reached. During this transient period, the oscillation frequency generally changes, resulting in chirp. Keying of a subsequent buffer stage following a free-running VFO generally allows a small portion of the VFO output to reach the receiver during key-up conditions if the station is set up for full-break-in cw. VFO shielding only reduces the feedthrough, but this may not be adequate for very sensitive station receivers.

Heterodyne-frequency generation eliminates all these problems because the VFO operates continuously on a non-harmonically related frequency which is converted to the operating frequency in a mixer or balanced modulator. Both the keyed crystal oscillator and the VFO operate far from the receiver frequency. Therefore, even though the VFO is not keyed, no harmonic of the oscillator will reach the receiver. Fig. 1 shows the block diagram of the heterodyne process, with frequency values applicable to this VFO.

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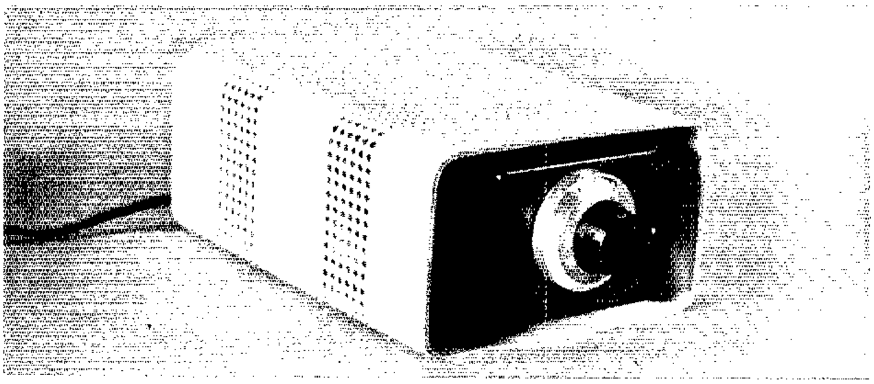


The Vackar oscillator VFO enclosed in an attractive, contemporary-styled cabinet. Below is an inside view showing rather high component density. The U3 output amplifier is on a separate board next to the transformer.

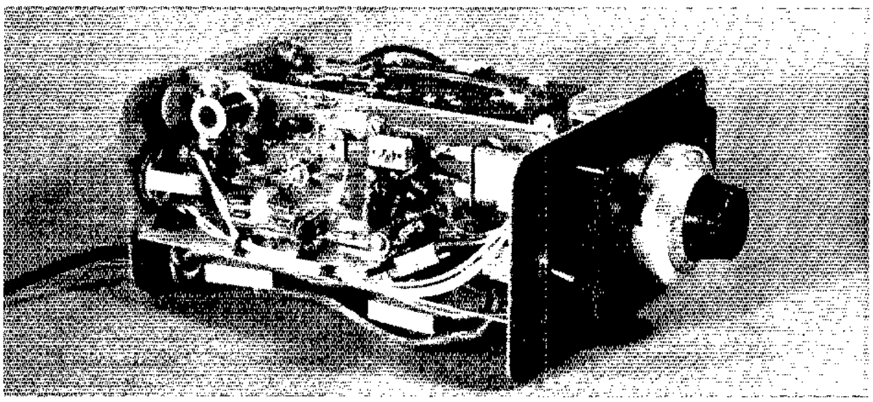
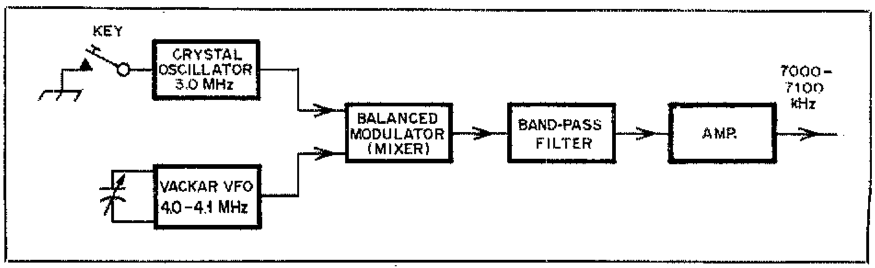


Fig. 1 — Simplified block diagram of the heterodyne VFO.



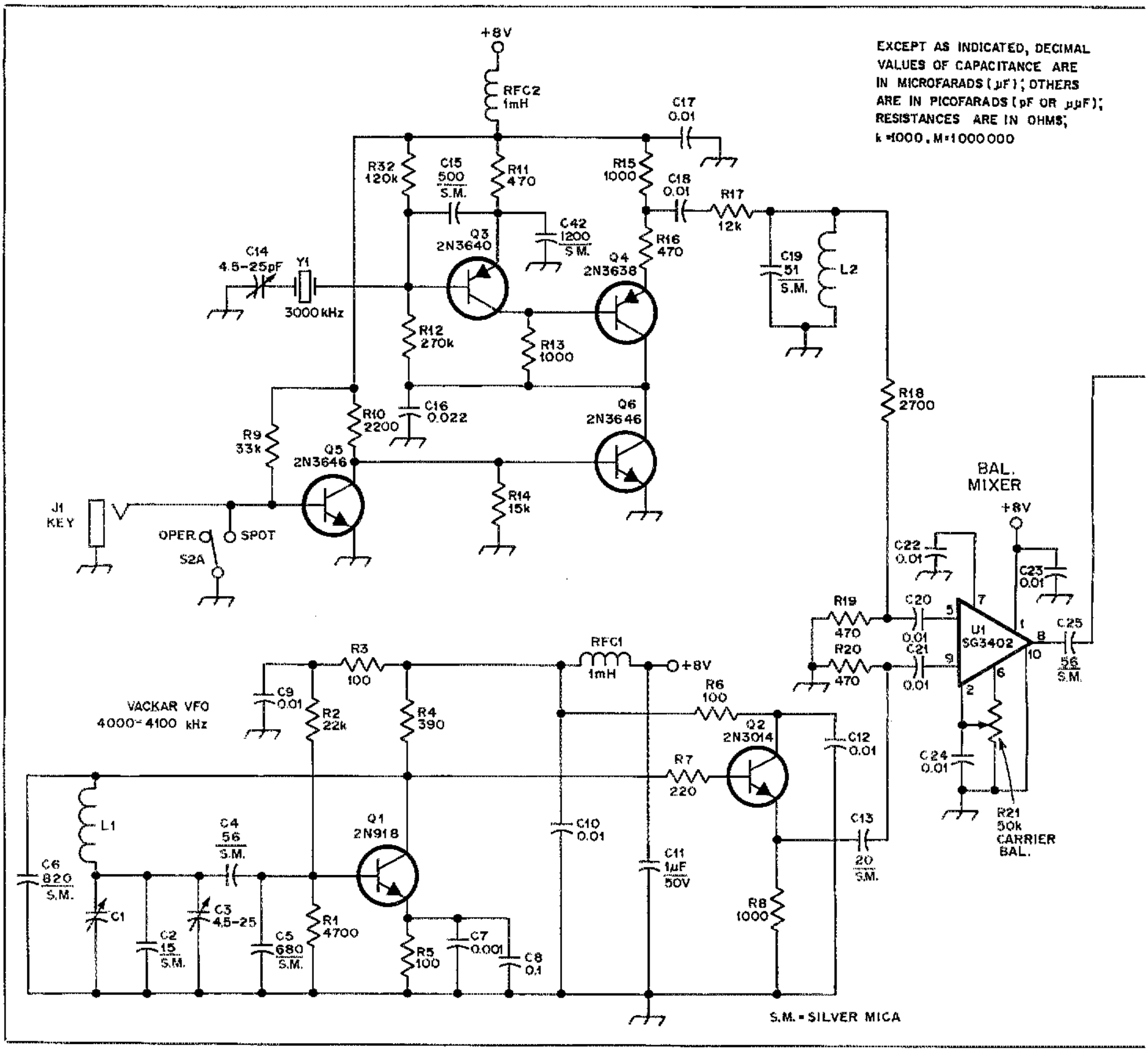


Fig. 2 — Schematic diagram of the heterodyne-oscillator VFO using the Vackar circuit. All resistors are 1/4-watt, five-percent tolerance. U1 is a proprietary product manufactured by Silicon General, Inc., 7382 Bolsa Ave., Westminster, CA 92683. The toroid core for L2, Ferroxcube no. 1041T060/4C4, is produced by the Ferroxcube Corp., Mt. Marion Rd., Saugerties, NY 12477. (For the convenience of builders who are unable to locate small toroids the author has available a limited supply.)

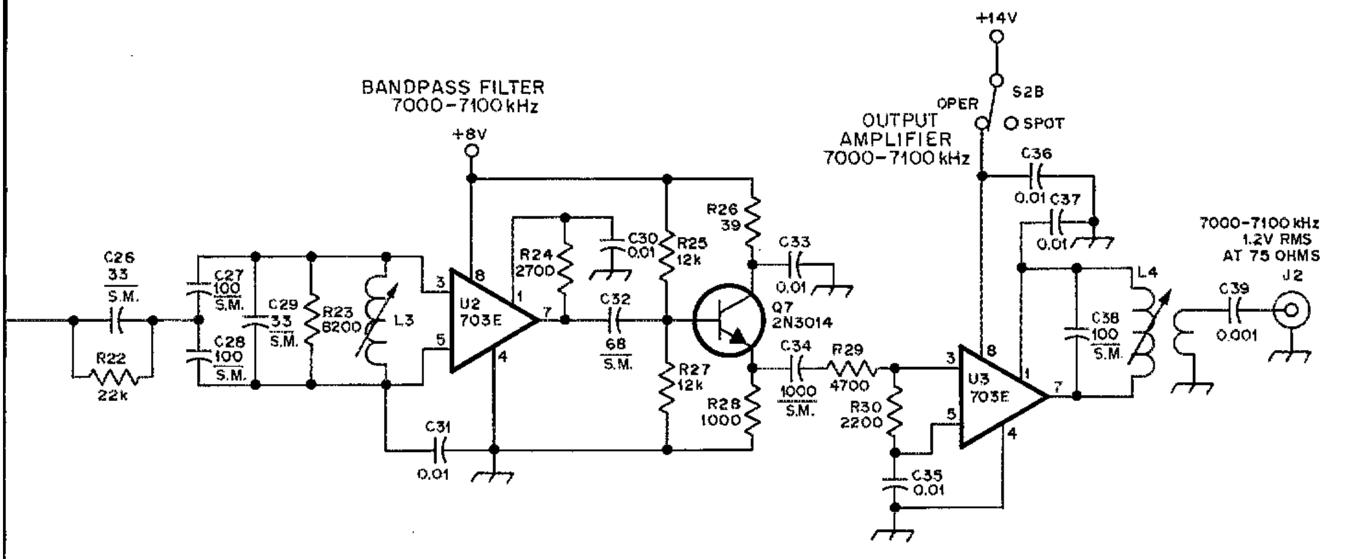
A normal mixer or unbalanced modulator output contains four prominent frequency components — the two input frequencies, their sum, and their difference. Either the sum or the difference may be used as an output by selecting the desired frequency in a band-pass filter. The balanced mixer is a more sophisticated refinement of the basic mixer circuit, because the two input frequencies are eliminated in the mixing process so that the output contains only the sum and difference frequencies. Consequently, subsequent filtering is made easier.

The VFO circuit used in the heterodyne VFO was first described by Vackar[1] in 1949. This circuit formed the basis for further research by Clapp, resulting in his classic article published in 1954.[2] The Vackar circuit closely resembles the Clapp circuit except for the method of feedback. The Vackar is series tuned like the Clapp, but the tank circuit as well as the transistor are shunted by unusually low reactances which reduce the effects of the transistor reactances. Further refinements of the Vackar circuit were described in 1968 by Jordan,[3] who provides design criteria for use at any frequency.

[1]Footnotes appear on page 18.

Construction

The photographs suggest one possible layout. For ease of modification and experimentation, the prototype was built in separate modular form equipped with connectors. Only a few precautions must be kept in mind when designing a layout. First, as with any VFO, mechanical stability is essential. An aluminum extrusion was used as a base for the oscillator. The tank components were bolted to this extrusion and the remainder of the circuit is contained on a glass-epoxy-board bolted to one lip of the extrusion. Heavy solid wire is used to interconnect the tank circuit components to prevent changes in stray circuit capacitance from shock or vibration. The integrated circuits have much higher bandwidths than required, and are capable of oscillations at vhf.



C1 — Variable capacitor, approximately 2 pF (1 rotor and 1 stator).
C3, C14 — 4.5-25 pF variable capacitor, CRL no. 825-AZ.
C7, C39 — Fixed capacitor, 0.001 μF, CRL no. CE102.
C8 — Fixed capacitor, 0.1 μF, CRL no. DDA104.
C9, C10, C12, C17, C18, C20-C24, incl., C30, C31, C33, C35, C36, C37 — Fixed capacitor, 0.01 μF, CRL no. CK103.
C16 — Mylar fixed capacitor, 0.022 μF, CDE no. 1S22.
C40 — Fixed capacitor, 1000 μF 25 V dc, CDE no. HWM 1000-25. (Fig. 3)
C41 — Fixed capacitor, 500 μF, 15 V dc, CDE no. HWM 500-15. (Fig. 3)
D1 — Silicon voltage regulator diode, 8.2 V, 400 mW, Texas Instrument no. 1N756A or equiv. (Fig. 3)
J1 — 1/4-inch phone jack, Switchcraft no. 11.
J2 — Chassis rf jack, Switchcraft no. 3505F.
L1 — 19 μH, 31 turns No. 22, enameled copper wire, 7/8 inch long, 1 inch diameter. Ceramic form, National no. XR-50.
L2 — Toroid core, Ferroxcube no. 1041T060/4C4, approximately 50 turns no. 28 enameled copper wire.
L3 — Miller no. 42A000CB1-2, 26 turns no. 24 enameled copper wire.
L4 — Miller no. 40A000CB1-2, primary 26 turns no. 28 enameled copper wire, 3/8 inch long; secondary 12 turns no. 28 enameled copper wire.
Q1 — Npn silicon annular transistor, type 2N918 or equiv.
Q2, Q7 — Npn silicon annular transistor, type 2N3014 or equiv.
Q3 — Pnp silicon low-power transistor, type 2N3640 or equiv.
Q4 — Pnp silicon high-current switching transistor, type 2N3638 or equiv.
Q5, Q6 — Npn silicon low-power transistor, National Semiconductor type 2N3646 or equiv.
Q8 — Npn silicon annular transistor, type 2N697. (Fig. 3)
S1 — Spdt toggle switch, Alco no. MST-105D.
S2 — Dpdt toggle switch, Alco MST-205N.
U1 — Variable gain, wideband amplifier/multiplier, Silicon General no. SG3402.
U2, U3— Linear IC, monolithic rf i-f amplifier, Fairchild no. 703E.
U4 — Silicon miniature diode assembly, Motorola MDA 950-2 or equiv. (Fig. 3)
Y1 — Oscillator crystal, 3000 kHz. Sources listed in *QST* advertisements.

Therefore the bypass capacitors should be mounted close to the IC with short leads. The planetary ball reduction gear couples the tuning capacitor to the tuning knob. This is not an ideal setup for it is not possible to calibrate the dial because the ball drive slips at the end of travel. However, accurate calibration of a VFO is not a great advantage, inasmuch as crystal band-edge markers are required if one is going to operate within striking distance of a pink slip.

Test and Adjustment

The only tuned circuit which is not adjustable is the 3-MHz band-pass filter consisting of L2 and C19. This should be resonated with a grid-dip meter after first overwinding the toroid core and removing turns one at a time until the circuit resonates. This circuit removes harmonics from the crystal oscillator and helps to reduce spurious inputs to the balanced modulator.

With the VFO operating and keyed, the output of U1 should be monitored while adjusting R21, the carrier-balance potentiometer, for a null at both 3 MHz and 4 MHz. The null should occur simultaneously. Next, monitor the output of J2 through a length of coaxial cable terminated in the transmitter. The cable is necessary because the cable capacitance is reflected back into the circuit for L4 and C38 and forms part of the total tuning capacitance. Adjust L3 and L4 for maximum drive to the transmitter. While rapidly keying the crystal oscillator, adjust C14 for the best starting characteristics. Finally, C1 is adjusted to cover the spread of 4.0 to 4.1 MHz. Adjustment is made with C3 and by bending the plates of C1 for the desired delta C for full rotation.

If a spectrum analyzer is available, the optimum tuning may be quickly reached for maximum rejection of unwanted frequency components. The prototype circuit had all unwanted components down by at least 40 dB. With key up, the VFO feedthrough at 4 MHz was down 30 dB. This level is not detectable with the station receiver and tuned circuits in the driven transmitter will reject these components.

With S2 in the SPOT position, power is removed from the output buffer amplifier and the crystal oscillator is keyed. This

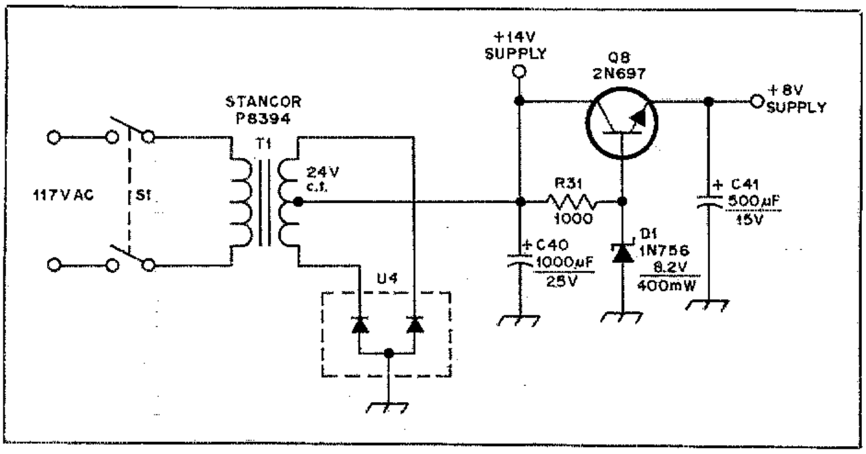
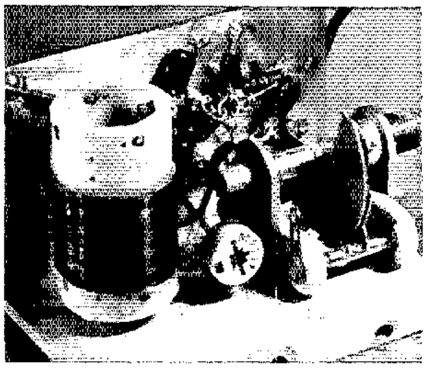
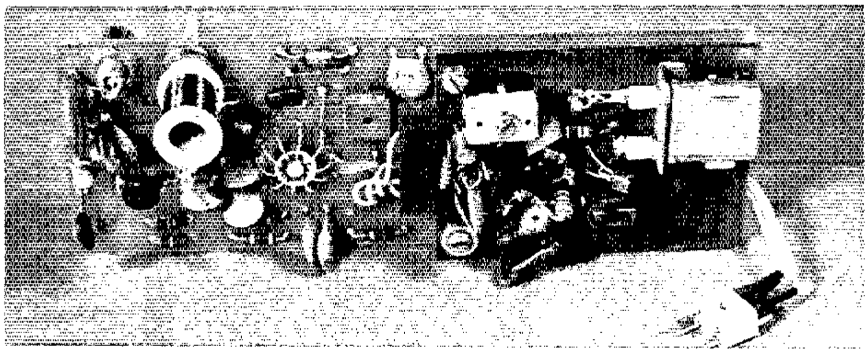


Fig. 3 — Power supply for the heterodyne VFO. Miniature diode assembly U4 is Motorola part no. MDA-950-2 or equiv.



The Vackar oscillator circuit is constructed on a heavy extrusion. Large bus wire interconnects tuned circuit components. L1 is wound on a ceramic form and coated with epoxy resin. C1 is a heavy-duty two-bearing capacitor reduced to one rotor and one stator plate.



Crystal oscillator and balanced mixer board. The oscillator is a highly modified International AO1 assembly. The small toroid coil on the oscillator board is L2. The balanced mixer (10-lead IC) is on the main board. U2 and Q6 are at far left. As is typical with developmental circuits, the board shows evidence of modifications.

generates a weak signal which can be monitored in the station receiver for frequency spotting. In the OPERATE position, control is transferred to the keyer. Any commercial keyer with an open-collector, current-sinking output will work with this VFO. If there is doubt in one's mind about this feature of a particular keyer, the schematic diagram of the keyer should be examined, or the manufacturer should be consulted. Of course, a relay output will also work with the VFO

The normal output of the heterodyne VFO is about 20 mW into a load of 75 ohms. The driven transmitter operates straight through on 40 meters for outputs of 7.0-7.1 MHz. Using the driven transmitter as a multiplier, 20-meter output from 14.0-14.2 or 10-meter output from 28.0-28.4 MHz is available. The driven transmitter must also be provided with fixed bias to prevent excessive dissipation in the final amplifier under key-up conditions. For transmitters with cathode or emitter keying, fixed bias should be added to cut off the final amplifier during key-up conditions.

The heterodyne VFO has been in use with a Viking-II transmitter with the station set up for full break-in cw operation. It is the only VFO I have ever used where operation very close to the band edges in the Extra Class portion is possible without constant nervous strain from wondering just where the transmitted frequency will end up after a long QSO.

References

[1]Vackar, "LC Oscillators and Their Frequency Stability," *Tesla Technical Reports* (Czechoslovakia) Dec., 1949.
[2]Clapp, "Frequency Stable LC Oscillators," *Proc. IRE.*, Aug., 1954, pp. 1295-1300.
[3]Jordan, "The Vackar VFO: A Design To Try," *Electronic Engineer*, Feb., 1968.

Strays

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