A 7 Mcs V. F. O.

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Introduction

SCORES of articles have appeared, time and again, in the leading ham magazines, describing 'stable' and 'rock-like' V.F.O.'s. However, the very first time the writer assembled a VFO, he realised that some of the pitfalls in assembling a VFO are not often stressed sufficiently to catch the attention of the unacquainted reader.

One of these is the proper adjustment of feedback. There are cases of hams who copied standard circuits and yet came up with two signals on the air, some kilocycles apart! Some other hams are carried away by such glamorous titles as 'one-tube VFO' and 'Stability with simplicity' and put out chirpy or frequency modulated signals, suffering from transmitter pulling. The writer wishes to repeat the time-tested maxim here: *There is no shortcut for making a good V.F.O.*!

This article is the outcome of the writer's experiments in VFO construction. The writer feels it worthwhile sharing with other amateurs, the experience gained during his construction of two VFOs. The VFO described here is designed to meet the most exacting demands of amateur radio communication.

The Circuit

The writer prefers an independent VFO with its own power supply. The hot inside of a transmitter cabinet is a poor place to locate a good VFO. Moreover as the frequency of a VFO is affected even by the filament voltage, it is undesirable to combine the VFO with the transmitter, where the voltages are liable to vary during keying or modulation.

As is often reported, the circuit of a VFO is not as important as its construction. There is nothing unusual about the circuit adopted here (fig. 2). It is a simple Clapp Oscillator circuit. The VFO proper has three tubes—the oscillator, a cathode-follower-cum-doubler and the buffer amplifier. The VFO output is on 7 mcs. No bandswitching arrangements are provided, as these are best located in the transmitter.

The choice of a suitable oscillator tube is important. The tube should preferably be a sharp-cut-off pentode of high transconductance, so that the feedback can be a minimum. After assembling VFOs with and without a cathode follower, the writer found that, to ensure perfect isolation of the oscillator, it is very desirable to run the oscillator unloaded and follow it up with a cathode follower stage. When this is the case, a low level oscillator is preferable to a high level oscillator. The writer prefers an octal base metal tube to a noval or 7 pin tube, as the former obviates the need for external shielding, and will 'sit tight' in its seat. The above considerations single out the 6AC7 as one of the best tubes for a VFO. (Incidentally 6AC7 is one of the few metal tubes which are available at reasonable prices in the Indian market!)

The oscillator frequency is kept as 3.5 mcs, following standard practice. Pulling of the oscillator is very much less when the oscillator frequency is half of the operating frequency.

Another important aspect of the VFO is the choice of the L/C ratio for the oscillator tank circuit. The ARRL handbook recommends a low-C circuit for the Clapp Oscillator—using a tank coil of about 33 μH for 3.5 mcs. However, after some experimentation, the writer found that a low-C circuit has some disadvantages—the VFO becomes hypersensitive to vibration, a tap on the VFO producing a ringing modulation; and the tendency for squeeging is more pronounced, calling for critical adjustment of the feedback. Consequently a medium-C tank circuit has been adopted, with a tank coil of 16 μH.

The Oscillator tank coil needs special attention. The coil must preferably be space-wound with at least 20 gauge bare copper wire. The coil may be air-wound on longitudinal perspex strips or tightly wound over a grooved or plain ceramic former. Its length must be not less than its diameter (at least 1") and not more than twice its diameter. The coil should be rigidly mounted, preferably on ceramic pillars. The inductance of the coil may be checked by the formula:

$$L \text{ in } \mu H = \frac{0.2\, a^2 n^2}{3a + 9b}$$ where *a* is the diameter of the coil and *b* the length of winding in inches, and *n* is the number of turns.

One interesting point in the circuit is the provision for easy adjustment of feedback. The tank circuit is coupled to the oscillator grid by means of a good-quality 70 pf air-trimmer.

This trimmer is so adjusted that stable oscillation is just maintained over the entire band. Under these conditions, the tank circuit is coupled very loosely to the oscillator tube, contributing to excellent frequency stability.

The total warm-up drift of the VFO has been considerably reduced by wiring a NTC tubular ceramic capacitor between the cathode and the ground right at the tube socket. Its value has to be determined experimentally. The writer is using a 330 pf capacitor.

The oscillator stage is coupled to the next stage by choke coupling, which is superior to tuned plate coupling, from the view point of reduced oscillator pulling. The coupling capacitor is again a 70 pf air trimmer, in series with a 1000 pf silver-mica capacitor to block D.C. The air trimmer is adjusted to a value of about 10 pf so that the oscillator runs practically unloaded.

The second stage is a cathode follower which is one half of the medium-μ triode ECC 82. The grid of the tube is held at a voltage of about + 26 volts, so that the tube draws enough current to raise its cathode potential to about + 30 volts. With the coupling trimmer set at about 10 pf, there is no grid loading on the oscillator.

The third stage is a class A triode doubler, which is the second half of the ECC 82. The class A triode doubler is preferable to a pentode doubler from the viewpoint of stability. The plate circuit is tuned to 7 mcs using a small $\frac{1}{2}$" diameter coil of 10 μH and a mica trimmer of 70 pf in parallel, mounted on the coil itself.

The fourth stage is the buffer amplifier, employing an EL 84. In this stage power gain is the objective, so that a decent RF voltage is developed at the low impedance RF output. The plate circuit is tuned to 7 mcs using a $\frac{5}{8}$" diameter coil of about 8 μH and an air trimmer of 100 pf in parallel, mounted on the front panel.

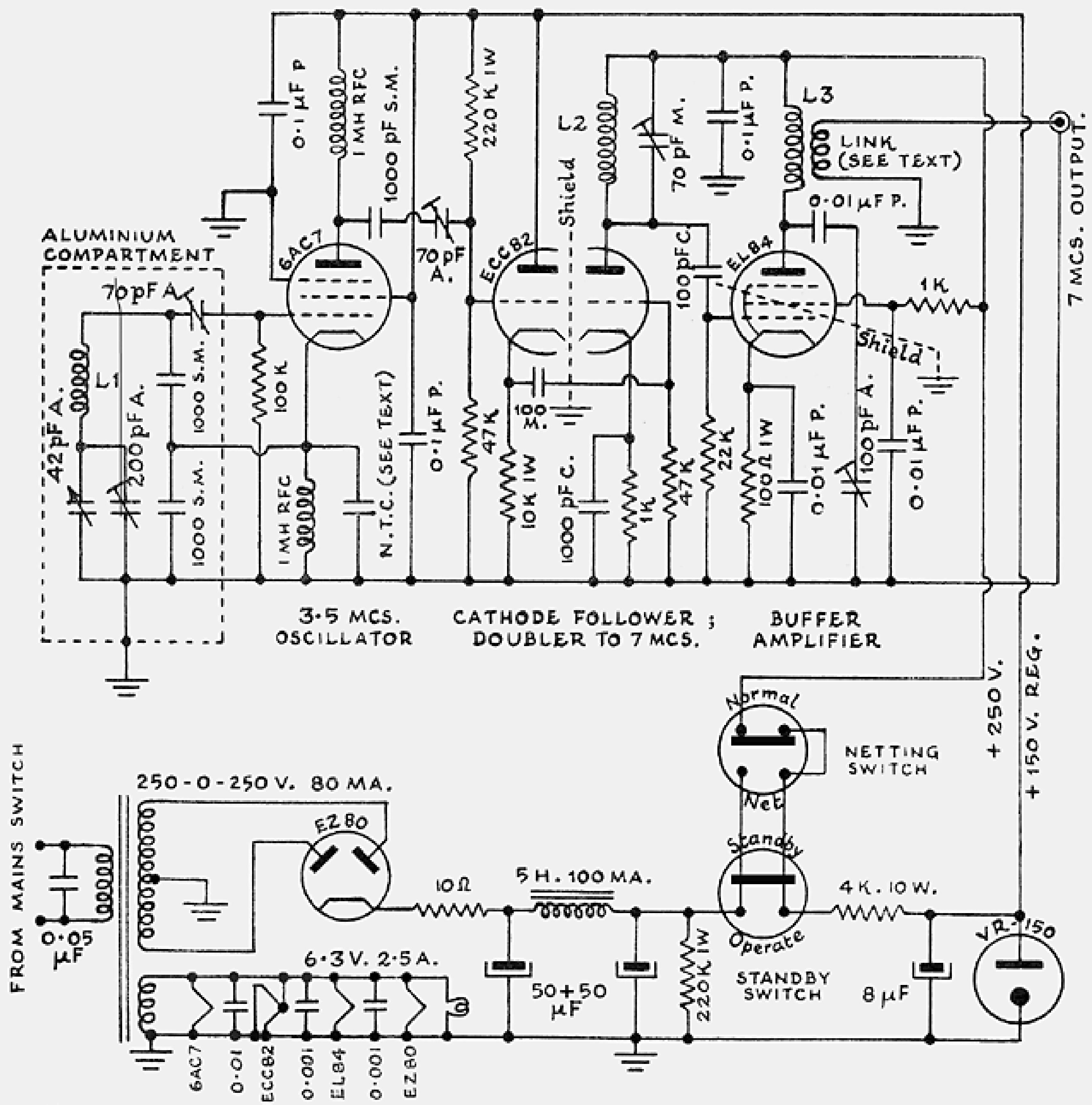
The RF output is taken by means of a resonant link winding on the plate coil, which, in the writer's opinion, is preferable to either simple capacitive coupling or transmission line coupling. Capacitive coupling results not only in an inefficient L/C ratio (due to the large shunt capacitance of the connecting cable), but also leads to greater transmitter pulling. Transmission line coupling necessitates a step-up coil right at the transmitter input terminals and can be a source of transmitter instability, in the absence of neutralisation and thorough interstage shielding.

On the other hand, resonant link coupling gives better isolation than capacitive coupling and at the same time ensures the maximum RF voltage transfer to the transmitter. In the method adopted here, the cable connecting the VFO to the transmitter is kept as short as possible (about 15" long). Ordinary mic. cable with *polythene* insulation is good enough. Shielded phono plugs are used at the ends of the cable and fit into phono sockets (Unfortunately coaxial connectors are so costly in India that they are beyond the reach of the average VU ham !). The cable is connected to the VFO and transmitter. The link winding is wound over the cold end of the plate coil, using 22 gauge hook-up wire. About 10 turns would be alright to start with. The number of turns is then adjusted step by step, retuning the plate each time, till the maximum RF drive is obtained in the transmitter. This adjustment calls for some patient work on the part of the assembler !

The power supply is quite conventional. Regulated voltage at 150 volts is supplied to the oscillator and cathode follower stages. The full HT of 250 volts is applied to the doubler and amplifier stages. To improve the filtering to the first two stages, a 8 μf capacitor is connected in parallel with the VR tube. This may sometimes cause relaxation oscillation of the tube, indicated by blinking of the tube. It can be readily stopped by increasing the tube current.

Separate standby and netting switches are provided. The netting switch is independent of the position of the standby switch and

7 MCS. V.F.O.



COIL DATA.

L1 : 16 μH. # AT LEAST 20 (SEE TEXT).
L2 : 10 μH. 40 T. # 26 ON ½" FORM.
L3 : 8 μH. 33 T. # 22 ON ⅝" FORM.

LEGEND.

S.M. SILVER MICA ; P. POLYSTER ;
A. AIR ; C. CERAMIC ; M. MICA.
N.T.C. : NEG. TEMP. COEFF. CERAMIC.

FIG. 2. CIRCUIT DIAGRAM.

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enables the VFO signal to be zero-beated directly with the station being received. A switch or relay in parallel with the standby switch may be used for remote control of the VFO.

Construction :

The construction of a good VFO calls for special attention to mechanical rigidity, proper ventillation and thermal shielding of the frequency-determining components from radiated heat. All components should be mounted rigidly. Improperly grounded shields or other metallic components can give rise to an annoying type of frequency instability. It is desirable to test each component for quality before wiring it.

In the VFO described here, the power supply and the VFO proper are assembled in two separate aluminium chassis, joined to a common aluminium front panel, but otherwise separated by a timber heat shield (fig. 3). The two chassis are 4″ X 7″ X 2″ and 9″ X 7″ X 2½″ in size respectively. The front panel is 14½″ X 7″. The frequency-determining components are enclosed in a 7″ X 5″ X 4″ aluminium box, with a top cover having ventilating holes and 12 screw studs. The VFO tubes are at the right side, the oscillator being at the rear, the cathode follower cum doubler at the middle, and the buffer amplifier at the front, close to the output socket. A second heat shield is interposed between the aluminium compartment and the tubes.

The entire unit is housed in a 15½″ X 8″ X 8½″ high teakwood veneer cabinet, to which the front panel is attached. The cabinet has a hinged top door, which is kept open while operating. The bottom of the cabinet is open so as to provide easy access to the wiring. A large rectangular opening on the rear side, covered with plastic grill, ensures good ventilation.

The oscillator tank coil, capacitor and reduction drive are all salvaged from a military disposal transmitter tuning unit. This sturdy tank coil is space-wound with 14 gauge copper wire on a 2″ diameter grooved ceramic form, and has a total inductance of about 20 μH ; it is tapped at 16 μH. The tank capacitor is the 42 pf neutralising capacitor of the tuning unit. The grounding of the shaft of the capacitor had to be improved a little.

Front view of V.F.O.

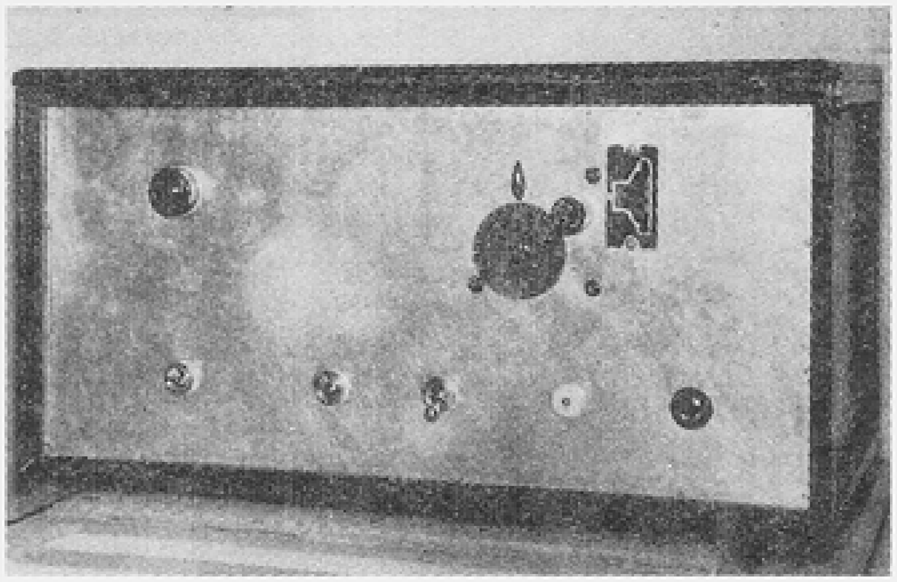

Fig. 1

The G-E. worm reduction drive has 2500 divisions corresponding to a rotation of 180° of the capacitor shaft. The zero reading is made to correspond to exactly 7 mcs. If a calibration chart is prepared by comparison with frequency standard, a resetting accuracy of $\pm$ 200 cycles can be easily achieved in this VFO.

Top view

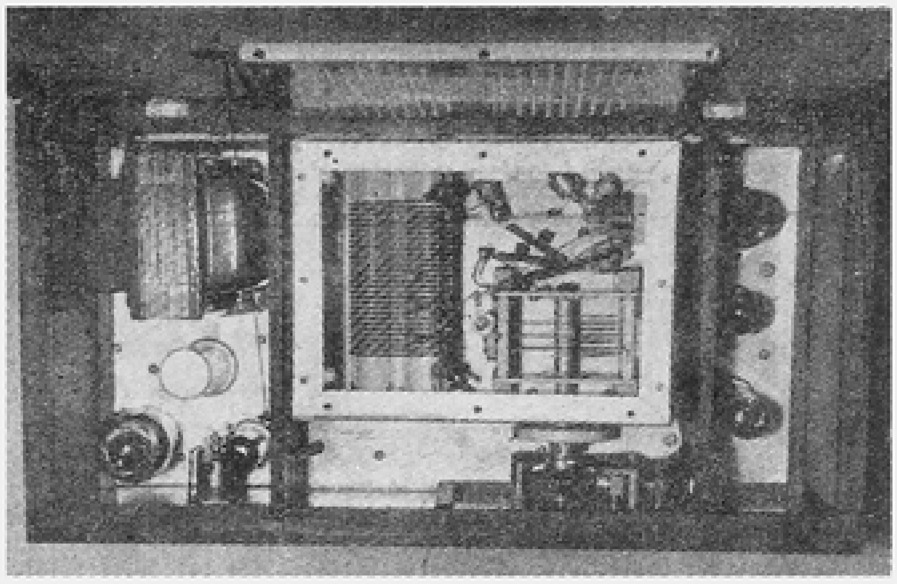

Fig. 3

The air trimmers are mostly 70 pf Philips air trimmers, which, although small, are remarkably stable. All silver-mica capacitors used in this unit have been thoroughly tested for leakage and stability (by wiring them in another VFO !). The writer was surprised to find that most of the receiving type silver-mica capacitors are not stable enough for use in a VFO ! Ceramic stand-off pillars have been used for mounting the silver-mica capacitors and air trimmers in the aluminium compartment.

The bandsetting 200 pf air-trimmer is mounted on the right side-wall of the aluminium box and may be adjusted from outside with a small screwdriver through a hole in the timber heat-shield.

Bottom view

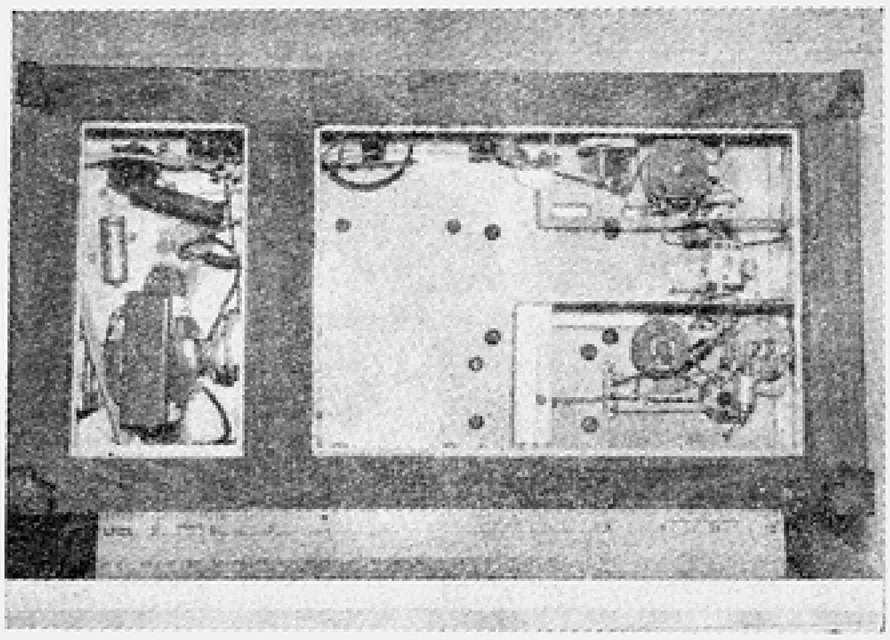

Fig. 4

Ceramic valve bases are employed. One aluminium shield encloses the oscillator and cathode follower stages below the chassis (fig. 4). It cuts through the base of the ECC 82. Another shield cuts through the base of the EL 84, isolating the input and output wiring. This shield stabilises the working of the EL 84, which would otherwise require neutralisation. The RF returns for each stage are all soldered to the tips of brass bolts fixed to the chassis, close to the respective valve bases. Long earth leads are avoided.

Wiring of the oscillator stage is done with 18 gauge tinned bare copper wire. The 'hot' grid and cathode leads from the tank circuit compartment are taken below the chassis by means of a 4-way ceramic bushing (salvaged from a burnt-out electric hot-plate !) and taken straight to the tube socket.

Testing :

The VFO has been thoroughly tested. For testing purposes a stable crystal-controlled oscillator running at 7040 kcs. has been used. The communication receiver is tuned to receive the beat note, with the BFO off. The output cable is connected to the VFO, with the other end free. Sufficient warm-up time is allowed before the tests.

Test 1: The VFO is placed on a rubber sheet over a separate table. With the VFO tuned nearly to zero-beat with the crystal oscillator, the table is tapped strongly. No vibration modulation is detectable.

Test 2 : The VFO is switched on and after 5 minutes it is zero-beated with the crystal oscillator. The subsequent long-term drift upto 1 hour is measured and found to be just 100 cycles. The frequency of the beat note is judged by comparison, with the help of an audio oscillator.

Test 3 : With the VFO tuned nearly to zero-beat with the crystal oscillator, the plug at the free end of the output cable is short-circuited. The change in frequency is just about 25 cycles. This shows that the VFO is almost free from pulling effects.

Test 4 : The HT to the VFO is switched off for 5 minutes and then again switched on. A 50 cycle beat note is heard, dying down in about two minutes' time. This slight drift may be due to several reasons, the most important of which is the expansion of tube elements when conducting. Probably the only way to get rid of this slight drift during a QSO is to run the oscillator continuously and detune VFO while receiving (VU2VK is following this method).

Test 5 : Using a voltage booster, the mains supply voltage to the VFO is varied from 200 to 230 volts. The change in frequency is about 75 cycles. This change is almost entirely due to the change in filament voltage. The writer tried introducing an unbypassed cathode resistor, as suggested in a recent article in QST, but without any worthwhile improvement. Probably the only way to get rid of this drift is to provide DC for the heater of the oscillator tube, regulated by a 6V Zener diode. The writer intends to provide regulated heater supply as soon as he gets a Zener diode.

The writer believes that all amateurs should perform these tests in order to ascertain the behaviour of their VFOs. A stable, clean signal is a pleasure to copy, and one of which any amateur can justly be proud of !

—VU2JN.

The V.F.O. (Variable Frequency Oscillator) is also known as M.O. (Master Oscillator)—Ed.