• Technical Topics —

A High-Stability Oscillator Circuit

A RECENT paper by J. K. Clapp[1] of the General Radio Company discusses a type of oscillator circuit that, from our preliminary experience with it, has stability of such a superior order that we wouldn't be surprised to see it become the standard amateur VFO circuit. It has "super-high-C" characteristics but, paradoxically, gives best stability when the tuning capacitance is made as *low* as possible.

The basic principle is loose coupling between the oscillator tube and a high-Q tuned circuit, a method of stabilizing suggested some years ago by G. F. Lampkin.[2] The Lampkin arrangement used inductive coupling (or a coupling tap on the tuned-circuit coil) between the tuned circuit and the tube, a system which, as Clapp points out, is prone to set up parasitic oscillations. The Clapp oscillator, a Colpitts circuit, avoids difficulties of this sort.

The circuit in its simplest practical form is shown in Fig. 1. The complete tuned circuit consists of L_1, C_1, C_2 and C_3 in series. The voltage drops across C_2 and C_3 provide the feed-back necessary to maintain oscillation; the ratio of the capacitances of these two condensers determines the amount of feed-back just as in the normal Colpitts circuit. The secret of the high stability of the Clapp oscillator lies in the fact that condensers C_2 and C_3 are made very much larger than C_1. This does two things: it makes the coupling between the tube and the tuned circuit very loose, so that the circuit Q can be kept high; and the large capacitances at C_2 and C_3 "swamp" the grid-to-cathode and plate-to-cathode capacitances of the tube to such an extent that the effects of any *changes* in these capacitances, from whatever cause, become almost negligible. The principal causes of such changes are variations in the plate voltage applied to the oscillator tube, and thermal changes caused by heating. The combination of a high-Q tuned circuit and swamping of tube effects results in an oscillator whose frequency is almost independent of plate voltage and tube thermal effects.

Fig. 2 is the voltage-*vs.*-frequency characteristic of an oscillator built in the *QST* laboratory, using the circuit of Fig. 1. The component values given were the first ones tried; no attempt has been made as yet to determine the optimum constants because of lack of time. As an arbitrary, but reasonable, guess, the shunting condensers, C_2 and C_3, were made 0.001 μfd. each. C_1 was a 150-μμfd. variable, and L_1 a small transmitting coil taken from the junk box, its principal qualification being that it looked about right to tune somewhere in the 3.5-Mc. range. By actual measurement it tuned to 3550 kc. (the frequency at which the data for Fig. 2 were taken) with a capacitance of 88 μμfd. C_4, C_5 and R_1 are the usual blocking condensers and grid leak. The circuit is of the grounded-plate type, but could easily be rearranged to operate with the cathode grounded, if that arrangement is preferred; it is only necessary to insulate the tuning condenser from ground, leave the −B grounded, ground the cathode, and shift the choke to the +B lead. The output then can be taken from between cathode and plate as before, except that the plate connection then becomes the "hot" output lead. It will also be necessary to ground the cathode through another by-pass condenser if cathode keying is to be used.

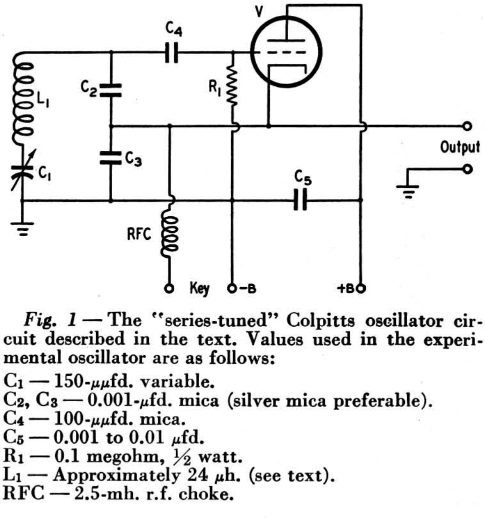

Fig. 1 — The "series-tuned" Colpitts oscillator circuit described in the text. Values used in the experimental oscillator are as follows:

C_1 — 150-μμfd. variable.
C_2, C_3 — 0.001-μfd. mica (silver mica preferable).
C_4 — 100-μμfd. mica.
C_5 — 0.001 to 0.01 μfd.
R_1 — 0.1 megohm, ½ watt.
L_1 — Approximately 24 μh. (see text).
RFC — 2.5-mh. r.f. choke.

C_2 and C_3 in series have a total capacitance of 500 μμfd., which is about what we normally use in a high-C circuit at the same frequency. However, the high-C effect is greatly stepped up by the loose coupling to the tank. It is doubtful if a conventional high-C circuit of equivalent C could be made to oscillate, because of the difficulty of constructing a coil with reasonable Q when the inductance is very low. However, it is not difficult

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[1] J. K. Clapp, "An Inductance-Capacity Oscillator of Unusual Frequency Stability," *Proc. I.R.E.*, March, 1948.

[2] G. F. Lampkin, "An Improvement in Constant-Frequency Oscillators," *Proc. I.R.E.*, March, 1939.

to make large coils with a Q in the vicinity of 300, and there is no trouble at all in making the circuit of Fig. 1 operate with such a coil. The coil we used was an air-wound affair 1¾ inches in diameter and 1½ inches long, having 27 turns of No.18 wire. Another coil of the same inductance, but close-wound with No. 28 wire on a 1-inch diameter bakelite form, also operated well although its Q was slightly under 200.

Different values of capacitance were tried in shunt with both C_2 and C_3 to see whether anything was to be gained by changing the feed-back ratio. Apparently the 0.001 condensers were about optimum, because increasing either C_2 or C_3 raised the plate current of the oscillator and tended to increase the frequency change with varying plate voltage. Using a 6J5 oscillator tube, the plate current was approximately 6 ma. with a plate voltage of 150.

The circuit shown is quite good from the standpoint of isolation. As a check, this circuit was substituted for an ordinary ECO driving a 6SK7 tuned amplifier in a simple VFO. The frequency change when the amplifier was tuned through resonance in this particular set-up (which was not too well shielded) was approximately 50 cycles, roughly 5 or 6 times better than when the oscillator was a 6SJ7 ECO with choke coupling from its plate to the following amplifier. The amplifier output was the same in both cases, although the Clapp oscillator using the 6J5 triode was operated at 150 volts and the 6SJ7 ECO had 250 volts on its plate.

The pay-off with this oscillator was the way it keyed. We have had, as might be imagined, a considerable number of oscillators under test at one time or another in the lab. Many of them have keyed very well — even under the acid test of heterodyning with a crystal oscillator on 28 Mc. and checking for chirp with a low beat note — so long as no key-thump filter was used. But until this circuit came along we have never seen one that didn't go chirpy when keyed through a lag circuit. This one was just as good with the thump filter as without it, using cathode keying, and even the most critical ear could detect no sign of a chirp. It promises to be the long-looked-for answer to really good break-in keying.

The writer has not made more than a cursory attempt to use the circuit in ECO style. A quick trial showed rather negative results, in that an ECO arrangement with a choke-coupled plate circuit seemed to show greater frequency sensitivity to changes in the following amplifier than the cathode-output triode circuit. However, no really serious attempt was made to determine optimum constants. Further work will show whether the ECO has any advantages over the triode.

The Clapp circuit has been used in a ham-band VFO described by W1NXM and W1DDO in the program for the Boston Hamfest held last October. The authors used somewhat different circuit constants, and although no performance data were given the stability was reported to be excellent. Just as with other VFO circuits, mechanical considerations are most important; even the best electrical characteristics can be completely spoiled by "floppy" construction.

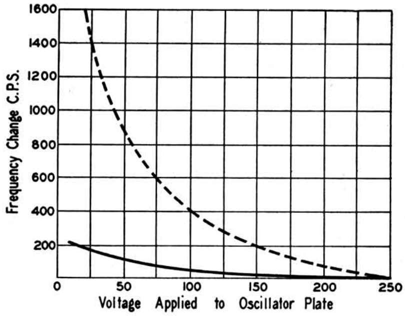

Fig. 2 — **Frequency-*vs.*-plate-voltage characteristic of the oscillator of Fig. 1, using a 6J5 tube (solid curve). The oscillations stopped at approximately 13 volts on the plate. The broken curve shows a similar run on a 6SJ7 ECO of conventional design using a tank capacitance of approximately 600 $\mu\mu$fd.**

When trying the circuit, the following points should be kept in mind:

1) The higher the L/C ratio the better the stability, up to the point where the circuit ceases to oscillate. The higher the coil Q, the higher the L/C ratio that can be used, for fixed values of C_2 and C_3.

2) The higher the values of C_2 and C_3, the better the stability for a given value of coil inductance.

3) A 1-to-1 ratio of the capacitances of C_2 and C_3 seems about right for triodes of the medium-μ class, such as the 6J5, 6C4, etc., but is not necessarily the optimum combination for other tubes.

4) Use an air-wound coil, or one wound on a ribbed ceramic form, for highest Q and lowest inductance variation with temperature. Variations in frequency caused by temperature effects are principally attributable to the coil, since the oscillator tube has so little effect on the frequency. The oscillator we tried had no temperature compensation, but nevertheless had very little drift. Listening on the 28-Mc. harmonic showed that the tube warm-up only caused a few hundred cycles frequency change from a cold start, and after a minute or so the frequency settled right down to its final value.

5) The tuning capacitance is the total of C_1, C_2 and C_3 in series. In calculating the capacitance required for tuning over a band with a given coil the effect of C_2 and C_3 must not be neglected. A fixed capacitance can be shunted across C_1 so that the latter will spread the band as desired.

— *G.G.*