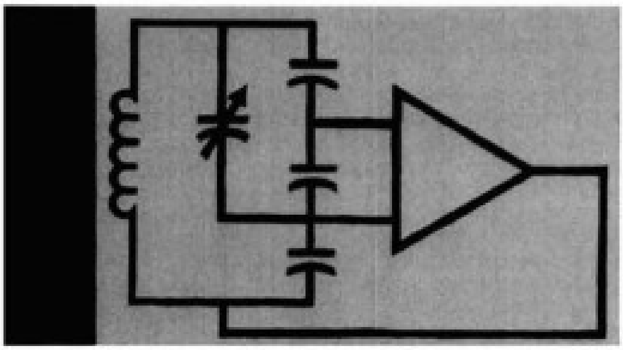

stable transistor vfo's

A discussion of the Vackar and Seiler oscillator circuits

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There has been a lot of interest in the Vackar oscillator lately because of a recent article[1] describing its many merits. Although there hasn't been too much information on this circuit in the American magazines, a wealth of information has been published in the **RSGB Bulletin.** In addition, there have been a number of amateur articles which have used a somewhat similar circuit—the Seiler oscillator.

Actually, both the Vackar and Seiler circuits are closely related to the Colpitts oscillator. The Vackar, named after its inventor, Jiri Vackar, a Czechoslovakian, was originally described in 1949.[2] The Seiler circuit, although almost forgotten, was described in **QST**[3] in 1941. Both of these circuits were designed to minimize loading on the tuned circuit, thereby increasing stability.

Most VFO's in use today use the series-tuned Colpitts or Clapp circuit; interestingly enough, Clapp based his design on the work of Vackar.[5] You can see from **fig. 1** that the Colpitts, Clapp, Vackar and Seiler circuits are very closely related. The Colpitts circuit, of course, is the father of them all. Seiler added a third capacitor in the divider to lessen the load on the tuned circuit. Vackar did much the same thing, but put a variable capacitor across a portion of the tank circuit to increase the tuning range. Clapp went on to simplify the basic Vackar circuit.

Since the Colpitts and Clapp circuits have been covered quite well in the amateur literature,[17-24] the discussion here will be limited to the Seiler and Vackar circuits.

the Seiler oscillator

Until Seiler's article in 1941, most VFO's used the Hartley or high-C Colpitts circuit. The Seiler design permitted the amateur to

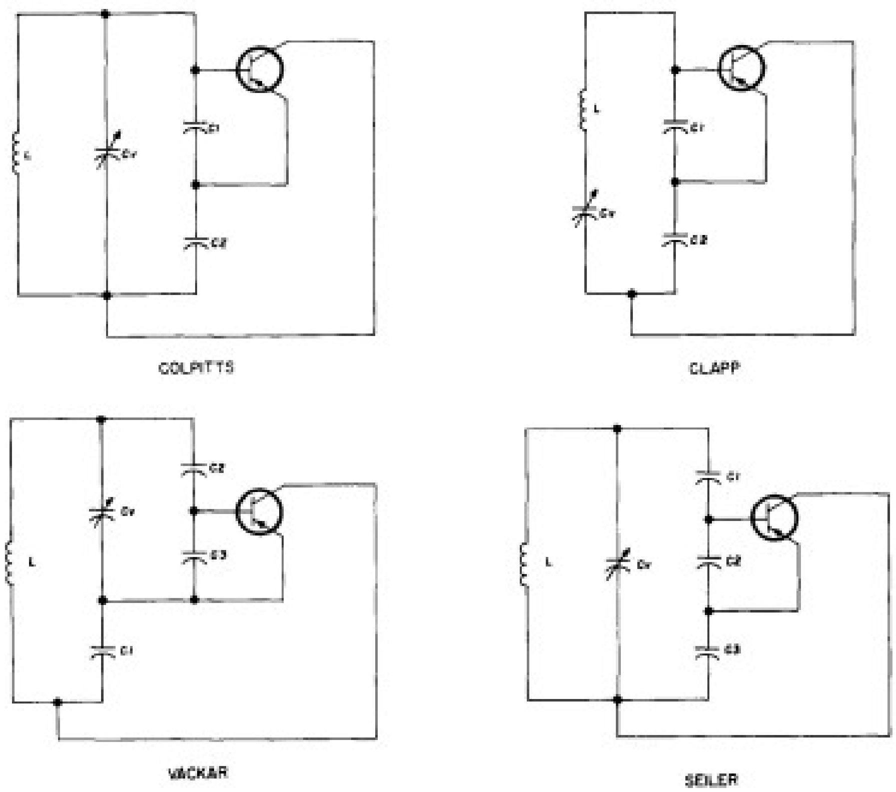


fig. 1. Circuit configurations of the Colpitts, Clapp, Seiler and Vackar oscillators. The Clapp, Seiler and Vackar circuits are derivations of the basic Colpitts circuit.

use a relatively low-C circuit that provided high stability and a tuning range of 1.8:1. A 6F6 was used in the original article, without voltage regulation, and by 1941 standards, the stability was very good.

One of the big advantages of the Seiler circuit is the large capacitors which are placed across the active device—in this case a transistor. These large capacitors tend to swamp out any reactive changes in the transistor and limit the harmonic output, thereby increasing frequency stability. Since capacitors C2 and C3 are usually much larger than C1 or the variable capacitor (Cv) in the Seiler oscillator, the frequency of oscillation may be simplified to:

$$f_{osc} = \frac{1}{2\pi \sqrt{L(C1 + Cv)}}$$

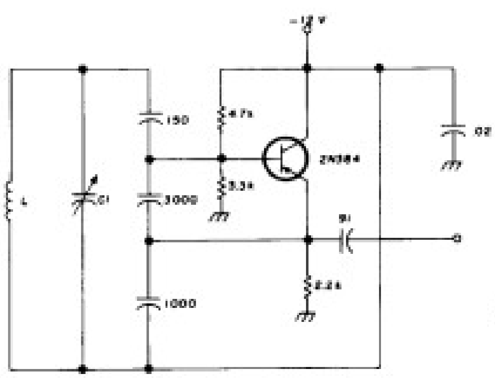
Several vacuum-tube versions of the Seiler oscillator have appeared in the amateur-radio magazines, but in most cases the designers weren't aware that their circuit was an extension of W8PK's original design. In at least one case, the author called his circuit a, "groundplate Colpitts type."[6]

To my knowledge, the first transistorized version of the Seiler oscillator was W3JHR's "synthetic rock" which was published in **CQ** in 1963.[7] This circuit was extremely popular and subsequently appeared in amateur magazines in England, Germany and South America. W3JHR used an old ARC-5 transmitter as the basis for his VFO; he cut the unit down and used the original variable capacitor and tuning coil to cover the frequency range from 4.9 to 6.1 MHz. Although only the oscillator stage is shown in **fig. 2**, he included a 2N384 emitter-follower buffer for isolation from the next stage.

K9ALD described another transistorized Seiler oscillator for ssb in 1964[8] and claimed exceptionally stable results. His oscillator, designed to cover the range from 4.95 to 5.6 MHz, is shown in **fig. 3.** Because of the relatively low-capacitance characteristics of the 2N2219, the feedback capacitors from base to emitter and from emitter to ground are smaller than those which are usually used in the Seiler oscillator. However, drift was negligible—about 25 Hz after warmup, and that was measured with a digital counter!

Don't let that 200-pF capacitor in series with the variable capacitor confuse you. It

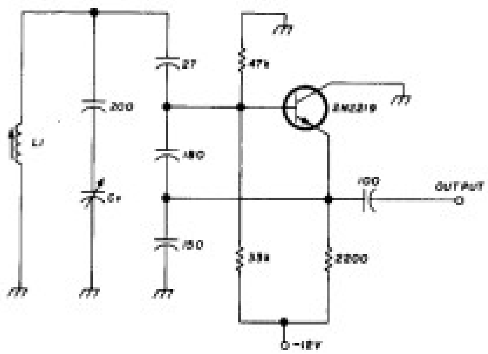
fig. 2. W3JHR's "synthetic rock" —a Seiler oscillator—tunes from 4.9 to 6.1 MHz with tank components from an old ARC-5 transmitter.



was used to set up the bandspread range of the variable capacitor.

Another transistorized Seiler oscillator was described by G3BIK,[9] although he mistakenly identified it as a Vackar. This oscillator used a 2N706 and covered the range from 1.8 to 2 MHz (**fig. 4**). G3BIK reported exceptional stability with this circuit—a change in voltage from 12 to 6 volts results in a 100-Hz change in frequency. He did experience some difficulty with temperature drift, but cured it by using a high-Q coil and silver-mica capacitors and by putting the complete circuit in an enclosed metal box. This doesn't reflect on the Seiler oscillator though—it's good construction practice with **any** VFO!

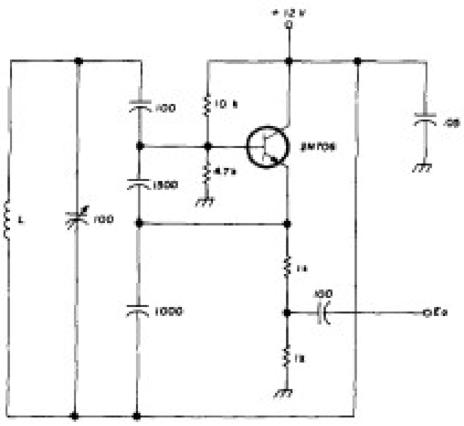
fig. 3. This Seiler oscillator, designed by K9ALD, tunes from 4.95 to 5.6 MHz. Total drift is reported to be 25 Hz. L1 is 2-1/2 turns number 16 on a 1-1/4" ceramic form. Variable capacitor C_v is a 100-pF variable in parallel with an 82-pF silver mica.



Since all the amateurs who have built transistorized Seiler VFO's have claimed such extraordinary results, I thought that an FET would make a good thing better. I was right; the results with the circuit shown in **fig. 5** were nothing short of remarkable! When the circuit was breadboarded on a piece of Vector board, drift was unmeasurable, even with a fresh spring breeze blowing through the window. When the supply voltage was varied from 22 to 9 volts, total drift was less than 1 kHz. This could be cured quite easily by putting a zener diode in the circuit.

The total current drain of this circuit is a little over 4 mA, so a couple of 9-volt transistor-radio batteries would power it for many months of operation. The output is constant within 2 dB over the complete tuning range, 3.49 to 4.01 MHz, so it makes an ideal rf driving source. When it's keyed, there is no chirp or drift; it sounds like it's crystal controlled. It far surpasses any VFO circuit I've ever built, transistor or vacuum tube.

fig. 4. G3BIK's Seiler oscillator covers the frequency range from 1.8 to 2.0 MHz. L1 is 65 turns of number 30 on a 5/8" diameter form.



Seiler design

The design of the Seiler circuit closely parallels the design procedure used for the basic Colpitts oscillator.[10] First of all, choose a transistor that has an f_T several times greater than the frequency you're interested in. Then design a bias network which will put the transistor in the linear operating range. Choose a value of tank tuning capacitance (C_T) from the following formula:

$$C_T = Q/6.28fZ$$

Where C_T is the sum of C_v and C1 (**fig. 1**); f is the center of the desired frequency range; **Z** is the impedance of the tank circuit at resonance; and **Q** is the tuned-circuit Q.

For maximum power transfer from the transistor, the tuned-circuit impedance should equal the transistor output impedance and may be approximated from:

$$Z = V_{CE}/I_C$$

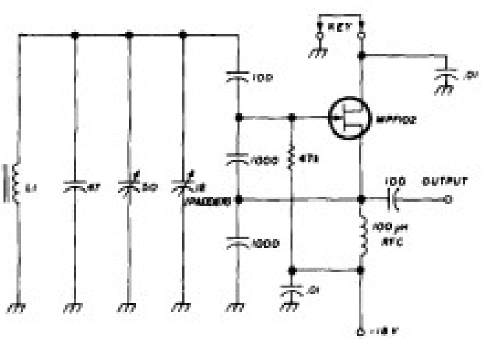
Where V_{CE} is the voltage between the collector and emitter of the transistor and I_C is the collector current.

Choose a value of **Q** as high as possible, because oscillator stability is very closely related to tank-circuit Q. For all practical purposes, the Q of the tank will be determined by the inductance you select, so use the best coil you can. If you have lots of room, air-wound coils are very good; if you're interested in miniaturization, try a ferrite toroid. In any event, when you're calculating for tuned-circuit capacitance, use a value of Q that is attainable in practice.

After you've calculated the total equivalent tank-circuit capacitance that you need, you can choose the coil to resonate in the center of the desired tuning range.

The values of the two large capacitors in the capacitor divider network, C2 and C3 (**fig. 1**), are not critical. However, they should be

fig. 5. Stable Seiler oscillator using an FET. The tuning range of this circuit is 3.49 to 4.01 MHz. L1 consists of 44 turns number 30 on a 1/2" ferrite core (Amidon T-50-2*).



* Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607 (formerly Ami-Tron Associates). T-50-2 ferrite cores are 45c each; minimum order, $1.00. Add 25c for packing and shipping.

quite a bit larger than C1 or the variable capacitor. Typical values range from 150 pF up to several thousand picofarads, depending on the frequency of interest and the gain of the transistor. The rule of thumb to follow here is to use the largest capacitors that will still result in oscillation. If a high-gain transistor is used, these two capacitors are usually equal. If a relatively low-gain device is used, it may be necessary to set the ratio of C3 to C2 less than the current gain of the transistor.

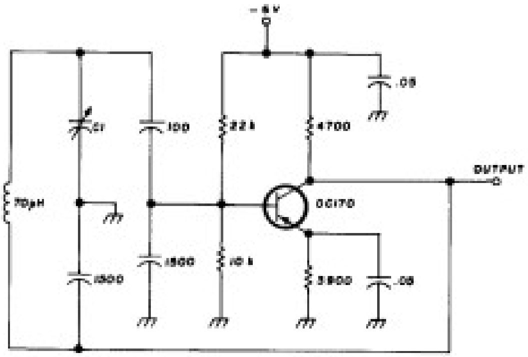


fig. 6. Transistorized Vackar oscillator designed by L. Williams, a British SWL. C1 is a 30-pF trimmer in parallel with a 75-pF air variable.

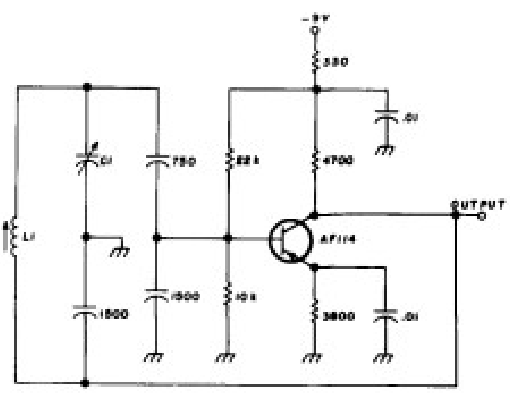
The variable capacitor, C_v, usually consists of a variable in parallel with a padder. The padder can be adjusted so that the variable will cover the desired frequency range. Capacitor C1 determines the amount of drive to the transistor and is relatively small. The best approach here is to start off with about 100 pF at C1 and reduce it until the oscillator ceases to function. Add about 50% to this value as a safety factor for the final value of C1.

This design method will put you in the right ball park with a working oscillator. All that is left is to set the tuning range of the variable capacitor. This is best accomplished on the bench. First, put in a variable that you think will do the job and measure the frequency with your grid dipper. If the circuit covers the frequency range you want, but the tuning range is too broad, reduce the size of the variable and put in some padding capacitors. If the range is about right, but the center frequency is off, change the size of the inductor. With a few minutes work on the bench, you'll have a stable VFO that tunes just where you want it to.

the Vackar oscillator

The Vackar circuit was another solution to the same problem—to reduce the load on the tuned circuit. In the Vackar, the transistor is again connected across a relatively low impedance and is very loosely coupled to the tuned circuit. This oscillator will tune over a frequency range of at least 2.5:1; the output can be made absolutely constant, and, according to Jordan,[1] it has the greatest inherent stability of any known oscillator configuration except for a design with independent

fig. 7. Vackar oscillator design by G5BB for use on 21 MHz. L1 is 19 turns number 22 on a 1/4" form. C1 is a 35-pF air variable in parallel with a 30-pF trimmer.



external load feedback. Those are pretty strong words!

Although the Vackar circuit was originally described in 1949, and publicized, at least in this country, by Clapp in 1954,[4] it has remained virtually unused. W9IK described a vacuum-tube Vackar oscillator built by W9TO[11], and a design appeared in **Radio and TV News**,[12] but that was over ten years ago.

The Vackar oscillator was resurrected when the first transistorized version was published in the **RSGB Bulletin** in July, 1966.[13] This circuit, shown in **fig. 6,** tunes over the frequency range of 2 to 2.5 MHz. The designer reported the prototype "will stay zero beat with a crystal frequency standard for hours."

This article aroused considerable interest in the Vackar oscillator. G3RAE reported[14] that he modified the circuit shown in **fig. 6** for use as a 465-kHz BFO. He increased the inductance to 460 microhenries and changed the tuning capacitor to 100-pF in parallel with a 270-pF fixed capacitor. All other values were the same as shown in **fig. 6.**

Shortly thereafter, G5BB described another transistorized Vackar, this one designed for 21 MHz[15] (**fig.** 7). He experienced some difficulties with temperature drift, but felt they could be cured by putting the circuit in a diecast box. I suspect that replacing the slug-tuned coil with an air-wound inductor would also help.

The latest transistorized Vackar oscillator was described by G. B. Jordan in the February, 1968 issue of **The Electronic Engineer.**[1] He has done a lot of experimental work with the Vackar oscillator and found it to be an extremely stable circuit.

Jordan's circuit, shown in **fig. 8,** is particularly interesting since it was designed to tune from 26.9 to 34.7 MHz, both the CB and 10-meter bands. The output amplitude varied 1.5 dB over the frequency range, and the temperature drift was linear from +20 to +100°F. When he compensated the circuit with N750 capacitors at C1 and C3, temperature drift dropped to 10 Hz per degree F. Further compensation would reduce drift to negligible amounts.

Since I had such good luck with the FET version of the Seiler oscillator, I tried the same thing with the Vackar (**fig. 9**)—again, the results were fantastic. Stability was at least as good as the Seiler; drift was negligible, and the keyed note was crystal clear. I went on to add an FET buffer stage, a 2N706 driver and 1-watt 2N697 final. Still no chirps or drift.

Although this circuit was designed to cover the range from 3.5 to 4.0 MHz, by reducing the number of turns on L1, the same basic design could be used as a remote 5-MHz ssb VFO or 8-MHz VFO for vhf use.

Except for output amplitude stability, could detect **no** difference between the Seiler and Vackar circuits. Perhaps with a counter and a controlled temperature environment, different drift characteristics would be apparent, but in the typical amateur environment, there doesn't seem to be any detectable difference. As far as amplitude stability goes, with the Vackar circuit, the output level

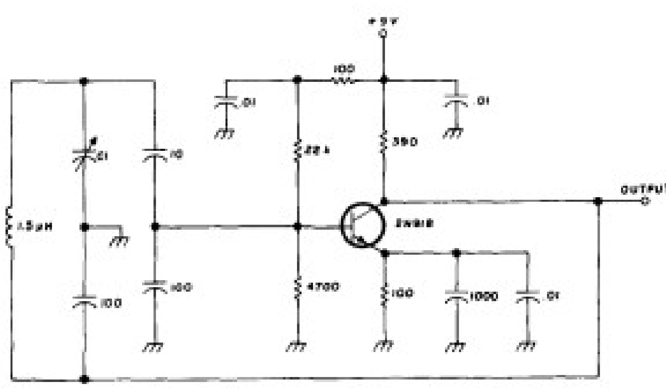


fig. 8. This Vackar oscillator designed by G. B. Jordan tunes from 26.9 to 34.7 MHz. C1 is a 12-pF air variable in parallel with a 8.2-pF silver mica.

changed less than 1 dB over the range from 3.5 to 4 MHz; the Seiler output varied slightly less than 2 dB. This is a pretty small difference.

Vackar oscillator design

As with the Seiler circuit, design of the Vackar is very closely akin to Colpitts design. Since the frequency of oscillation is determined essentially by the value of the variable capacitor and C2, these variable capacitors may be taken as the total tank-tuning capacitance. With this in mind, the tank-tuning capacitance and inductor are chosen by the same method we used for the Seiler circuit. Capacitors C2 and C3 are found from the following formula:

$$C2 = C3 = 3000/f \text{ (MHz)}$$

According to Jordan, this formula yields about optimum oscillator stability compatible with other requirements. Capacitor C1 is adjusted so that the transistor operates essentially class A and is not driven into cutoff or saturation. In the circuit in **fig. 8,** with 10 pF at C1, the peak-to-peak voltage at the junction of the variable capacitor and the inductor was 1-1/2 times the B+ supply. This is a good rule of thumb to go by when you're designing an oscillator of this type.

Most of the authors who have described transistorized Vackar and Seiler VFO's have noticed a tendency for these circuits to oscillate at audio frequencies. Since the feedback loop from the collector to the base of the transistor is through the power supply, the base-bias resistors should be decoupled from the collector resistor by a bypassed resistor as shown in **fig. 8.** Another precaution used by Jordan was to bypass the emitter for both audio and rf, although this may not be necessary.

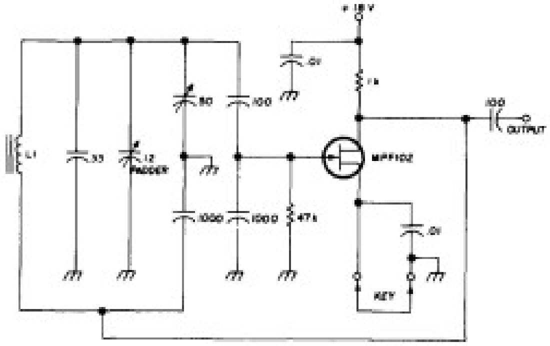


fig. 9. FET version of the Vackar oscillator is extremely stable. L1 is 48 turns number 30 on a 1/2" ferrite core (Amidon T-50-2)

summary

Both the Seiler and Vackar circuits are similar in design and, from my experiences with the FET versions, similar in stability and output. The original tube-type Vackar circuit used high-C tuning whereas Seiler designed for low-C tuning; the high-C was provided by a large trimmer across the main tuning capacitor. There **may** be some advantages to the Vackar circuit for very wide tuning ranges and some advantages to the Seiler when the low-C approach is used, but for amateur VFO's I doubt if there is any significant advantage with either circuit. With both of these circuits, stability is independent of the LC ratio, and not very dependent upon the transistor used.

All of the designers of the circuits shown here have indicated exceptional performance and stability with them. If you have done any experimenting along these lines, I would certainly like to hear about it—both of these circuits have been buried in the literature long enough. They seem ideal for transistor work, easy to design and a good choice the next time you're thinking about a new VFO.

references

1. G. B. Jordan, "The Vackar VFO, a design to try," *The Electronic Engineer*, February, 1968, p. 56.

2. J. Vackar, "L-C Oscillators and their Frequency Stability," *Tesla Tech Reports*, (Czechoslovakia), December, 1949.

3. E. O. Seiler, W8PK, "Low-C Electron-Coupled Oscillator," *QST*, November, 1941.

4. J. K. Clapp, "An Inductance-Capacity Oscillator of Universal Frequency Stability," *Proceedings of the IRE*, March, 1948, p. 356.

5. J. K. Clapp, "Frequency-Stable LC Oscillators," *Proceedings of the IRE*, August, 1954, p. 1259.

6. M. Bernstein, W2PAT, "Amplitude Limiting for the VFO," *QST*, February, 1954, p. 24. (Seiler)

7. P. H. Lee, W3JHR, "A Stable Transistorized VFO," CQ, September, 1963, p. 25.

8. R. Taylor, K9ALD, "A Stable VFO for SSB," *73*, November, 1964, p. 10.

9. E. Chicken, G3BIK, "The Transistorized Vackar Oscillator," Technical Correspondence, *RSGB Bulletin*, September, 1966, p. 600.

10. J. R. Fisk, W1DTY, "Designing Transistor Oscillators," *73*, August, 1967, p. 66.

11. H. Woods, W9IK, "Vackar VFO Circuit," *QST*, November, 1955, p. 120.

12. R. J. Ropes, "A High-Stability Oscillator," *Radio and TV News*, June, 1957, p. 142.

13. L. Williams, "Transistorized Vackar Oscillator," Technical Topics, *RSGB Bulletin*, July, 1966, p. 453.

14. "Technical Topics," *RSGB Bulletin*, September, 1966, p. 586.

15. A. H. Bruce, G5BB, "21-MHz Vackar," Technical Topics, *RSGB Bulletin*, November, 1966, p. 718.

16. G. Bird, G3KOV, "Some Thoughts on Transistor Oscillators," *RSGB Bulletin*, January, 1967, p. 42.

17. W. B. Bernard, W4ELZ, "Let's Increase VFO Stability," *QST*, October, 1957, p. 40.

18. R. Cassey, ZL2IQ, "The Clapp Oscillator—and How!," *QST*, February, 1953, p. 19.

19. D. Crowell, K6RIL, "Stable VFO for HF or VHF," 73, November, 1966, p. 46.

20. J. R. Fisk, W1DTY, "An FET VFO for 80 Meters," *73*, May, 1967, p. 56.

21. L. Howson, W2YKY, "Designing the VFO," QST, December, 1955, p. 35.

22. E. L. Klein, W4BRS, "A Toroidal VFO," *73*, April, 1967, p. 10.

23. J. Kyle, K5JKX, "VFO Circuits," *73*, October, 1967, p. 46.

24. O. J. Russell, G3BHJ, "Bandspreading the Clapp VFO," QST, October, 1954, p. 37.

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