The Franklin VFO

A nifty chill-chasing project for the serious home-brewer.

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The Franklin oscillator circuit makes a terrific frequency control for ham transceivers, transmitters and receivers. It is inherently stable because only the tuning tank circuit controls the oscillating frequency. Band-switching is very simple because the L/C circuit is in parallel, with one end grounded.

The Franklin oscillator is unique in that the capacitors and resistors in the oscillator circuit are not frequency-determining components. The values of the internal NPO capacitors remain the same without regard to the frequency being generated—it's a truly universal VFO circuit.

Although this oscillator requires using two JFET transistors, the actual oscillator contains only four NPO capacitors and four resistors, which remain the same regardless of frequency. There are no critical parts, no tapped coils, and no capacitive voltage dividers to provide feedback.

The tuning capacitor and its parallel inductance, plus any necessary padder and trimmer capacitors, must be of the highest quality because they are the only frequency-determining components. They also contribute to the inherent stability. The main tuning capacitor should have a ceramic frame, be double-bearing, and have plated, soldered-in brass plates. As it is relatively large, its thermal inertia adds greatly to the frequency stability.

Any variable capacitors used as trimmers or padders should preferably be air-dielectric type, although ceramic NPO trimmers are almost as good. Of course, fixed padding capacitors must be NPO ceramic-disc types of the largest diameter you can find. Because the capacitors are heated by the RF current flowing through them, the total amount of padding should be divided among several smaller-value capacitors, and the large-diameter ones can provide additional area and keep RF heating-induced instability minimal. This is not the place to use tiny monolithic COG type capacitors!

The coil used is equally important. The best would be a solidly-mounted air-wound coil such as the B&W Miniductor® series, but you may be unable to find them (hamfests and swap meets are a possible source). Almost as good is a coil wound on a hollow ceramic form of a diameter which allows close to a 1:1 ratio (diameter to length) for the needed inductance. This will provide the highest "Q." There must be no slug in the coil form.

Most of us hard-core home-brewers will end up winding our coils on iron powder toroid cores. The Amidon® Mix-7 is a good choice. The T68-7 has an AL of 50, and Mix-7 has a temperature coefficient of 30 ppm/°C, the most stable mix available today. The T50-7 has an AL of 43 if a smaller core is desired. However, the larger T68-7 core has a greater thermal inertia, and aids long-term stability.

The JFETs you choose should be of high quality, though they don't need to be expensive. Although MPF102s will generally oscillate in this circuit, they are not recommended. Among the recommended JFETs are 2N4416, 2N5486, U310, J308, J309 and J310. Other JFETs with a transconductance of 4000 or more will also be suitable *if* they have a maximum frequency rating of 300 MHz or higher. The two JFETs (Q1 and Q2) in the actual oscillator must be the same type number but they don't have to be perfectly matched.

As in any VFO, the oscillator must be isolated from the load. Normally, this requires another JFET as a source follower, followed by a bipolar NPN Class A amplifier.

Here's what it looks like

The schematic diagram of the Franklin VFO is shown in **Fig. 1**. The components and values specified provide a stable range of 5.0 to 5.5 MHz, perhaps the most widely used VFO frequency. Changing the oscillator to cover other frequency ranges is discussed later in this article.

Operation of the oscillator, Q1 and Q2, and associated components is unusual—I don't know of any other VFO circuit like it. The four resistors, R1 through R4, establish operating conditions and the oscillator and source follower are powered with a regulated +9 V supplied by U1. The tank circuit (C11 and L1, and the parallel connected trimmer and padder capacitors, C12 through C16) is very lightly coupled to the oscillator at the junction of C1 and C2, which are very small capacitors. This essentially isolates the frequency-determining components from the oscillator and prevents loading the tank circuit, maintaining circuit "Q." C1 and C2, in conjunction with C3, cross-connect Q1 and Q2 similarly to connections used in an astable multivibrator. Thus, the Franklin oscillator is foolproof—it *has* to oscillate!

When power is applied, the slightly different transistor characteristics cause a tiny difference in current flow through the drain resistors, and this starts oscillation, which is maintained by the cross-connections of C1, C2, and C3, with frequency being controlled solely by the components connected between the junction of C1 and C2, and ground.

RF from the drain of Q2 is fed through C4 to the gate of source follower Q3. Output from Q3 is taken across RFC1 and fed through C7 to the base of Q4, an NPN bipolar Class A amplifier, which amplifies the RF and provides it through C10 to the following circuit being driven by the VFO—normally a transceiver, transmitter or receiver.

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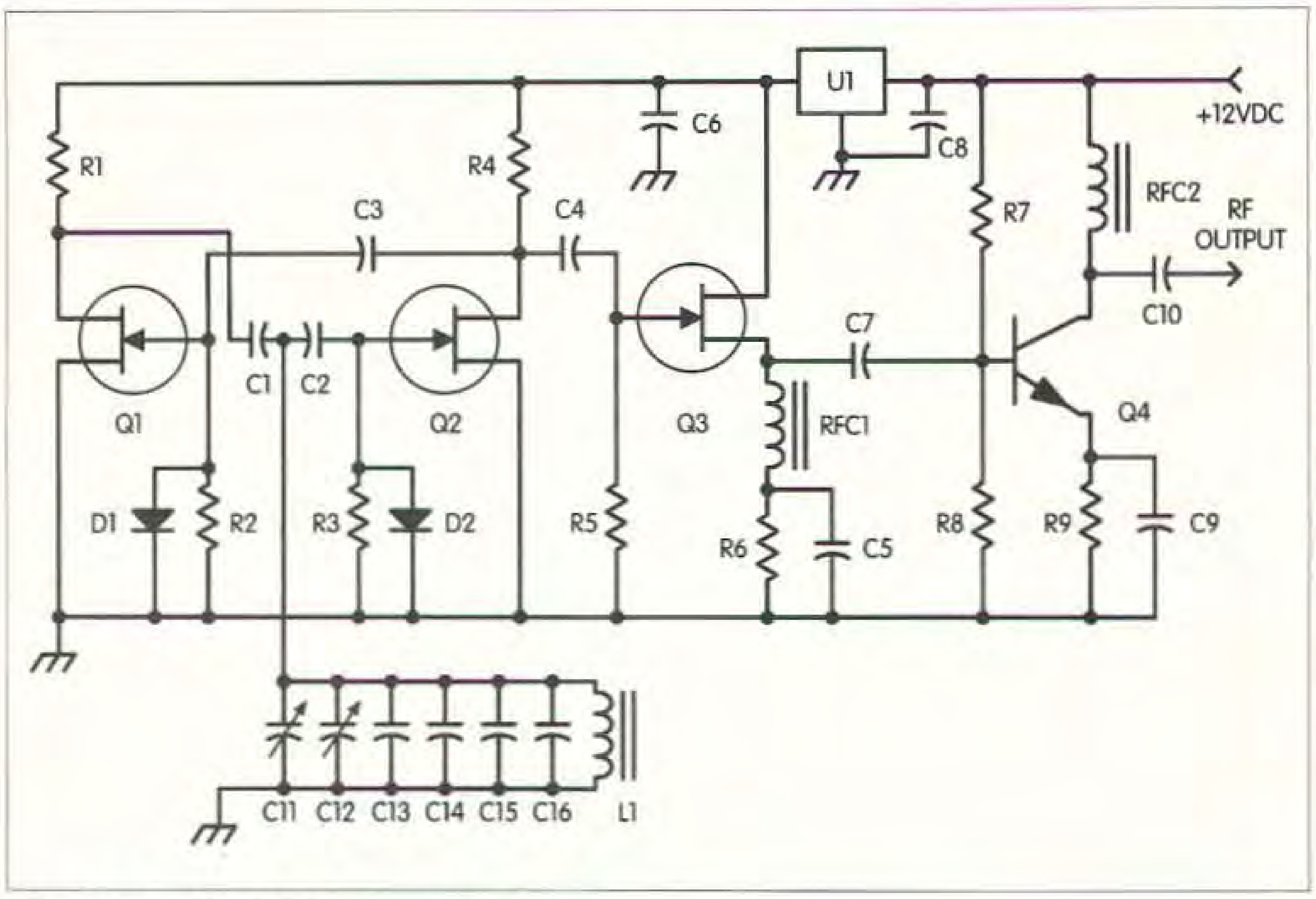

Fig. 1. Franklin VFO schematic diagram.

The Franklin VFO

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Here's how to build it

Mechanical stability is of the utmost importance for all components. The VFO should be constructed in a shielded enclosure, either aluminum or one made from double-sided printed circuit board material with soldered seams. The main tuning capacitor should be mounted through the front of the enclosure. An access hole must be drilled for tuning access to trimmer C12 so it can be adjusted from outside the enclosure. However, if an air-dielectric capacitor is installed at C12, it will mount through the top or side of the enclosure as well.

Although a single-sided glass epoxy printed circuit board could be etched and drilled for the VFO circuit, going "dead bug" style with point-to-point construction is often better, with short leads, and the transistors and L1 epoxied in place. All ground connections are made directly to the ground plane. Because tiny monolithic COG capacitors are specified for C1 through C4, little space is needed. Besides, the circuit will be completely hidden inside the enclosure and no one will see the "ugly" construction.

Use solid bare wire for the connections between C11 and C12, and from C11 to the junction of C1 and C2. Rotors of both capacitors should be connected to the ground plane with bare wire as well. Capacitors C13 through C16 can be connected with short leads across C11 or C12 or both.

Because C11 tunes from 5.0 to 5.5 MHz in 180 degrees of rotation, use a vernier mechanism to slow the tuning rate when using the VFO. They're often difficult to locate, and generally costly when you do find them. As this is written, Jackson Brothers' ball drives, 7:1 and 10:1, are available from Dan's Small Parts and Kits, Box 3634, Missoula MT 59806-3634, $13.50 and $15.00 respectively.

Similar vernier mechanisms may be salvaged from old Eico, Knight and Heathkit test equipment. National Radio "Velvet Vernier" mechanisms, although about two inches in diameter, can be salvaged from World War II-vintage military radio tuning units used with the BC-191 and BC-375 radio sets. These units tune very smoothly, but about the only places to find them nowadays is in old-timers' deep junk boxes.

There are also Japanese vernier dials, in two small diameters, which are available from a few mail-order dealers. These are not as smooth tuning as the Jackson Brothers' or Velvet Vernier mechanisms. Cost will probably be under $15.00.

Here's how to use it

Normally, adjusting C12 will center the frequency range of the VFO to cover the desired span. However, because of unavoidable stray capacities and component tolerances, including the winding of L1 and the core properties, it may be necessary to shift the tuning range up or down a small

Parts List

C1, C2	10, 12 or 15 pF COG or NPO. Must be same value.
C3, C4	100 pF COG monolithic
C5, C6, C8, C9	0.1 µF monolithic
C7, C10	56 pF NPO or COG
C11	50 pF air dielectric, double-bearing (see text)
C12	50 pF air dielectric or NPO ceramic trimmer
C13	30 pF NPO disc ceramic, largest diam. available
C14, C15, C16	33 pF NPO disc ceramic, largest diam. available
D1, D2	1N914, 1N4148 or equivalent
L1	T68-7, 35T #24 or #26 enamel wire
Q1, Q2, Q3	2N4416, 2N5486, U310, J308, J309 or J310 (see text; Q1, Q2 must be same type)
Q4	NPN 2N2222, 2N4400, 2N4401 or equivalent
R1, R4	1 k 5% 1/4 W
R2, R3, R5	1 meg 5% 1/4 W
R6, R9	100Ω 5% 1/4 W
R7	15 k 5% 1/4 W
R8	5.6 k 5% 1/4 W
RFC1, RFC2	390 µH (100 to 1000 µH suitable)
U1	78L09 voltage regulator

Table 1. Parts list.

amount. Adding or removing a turn or two from L1 and readjusting C12 is the easiest way to manage this. The tuning range may also be a bit short or a bit long, in which case more or less NPO padding capacity may be needed. When the frequency has been adjusted as necessary, be sure to put two coats of Q-Dope® or clear fingernail polish on the winding of L1, both to keep the winding from shifting, and to prevent moisture from changing the inductance.

Here's another way

Because the tank circuit and associated capacitors are the sole determinants of frequency, it will be easy to tailor the Franklin VFO to cover other frequency ranges, by substituting other values for the components specified. To restrict the tuning range, a fixed NPO or a variable air-dielectric capacitor can be placed in series between C11 and the junction of C1 and C2. Reducing the value of the capacitor used at C11 will also reduce the tuning span.

Here's what I think

The Franklin oscillator will happily oscillate just about anywhere you want it to. I have had a Franklin tossed together on a protoboard oscillating at over 30 MHz, but because of the long leads to the coil and tuning capacitor, I can't say how stable it would be. In my case it varied over several hundred hertz, but if it were solidly constructed and shielded properly, it probably would have proven to be much more stable. Certainly it would be far better than the Hartley, Clapp or Colpitts oscillators at these high frequencies.

I am currently working on the design of a band-switched HF signal generator based on the Franklin oscillator circuit, and if it proves to be as good as I think it will be, you may see the signal generator described in these pages in a few months.

I first stumbled across the Franklin oscillator in a forgotten publication more than 15 years ago, and have been intrigued by its possibilities ever since. I've built a number of them for experiments over the years, and have been quite impressed at their inherent stability, even though in most cases I built them from odds and ends out of the junk box. Though I've never learned the Franklin oscillator's provenance, I can't understand why such a simple, stable circuit hasn't had more exposure in the ham literature. Perhaps this article will give it a well-deserved boost. 73