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For tunable oscillators, it's the 'Pitts

I recently discussed in *MT* a group of circuits for crystal controlled oscillators. Some of the readers have asked me to prepare a similar text about tunable oscillators or VFOs. Let us now consider an overview of the most common of the tunable oscillators -- the Colpitts circuit.

Although there is a host of possible oscillator circuits we may adopt, the Colpitts appears to be the most popular one. Furthermore, it is an easy circuit to build and get operational with minimum fuss.

Four Common Configurations

Please refer to Fig 1. You can see recommended hookups for bipolar, JFET (junction field-effect transistor) and dual-gate MOSFET (metal oxide field-effect transistor) transistor VFOs (variable frequency oscillator).

The circuits are essentially the same except that different active devices (those that require an operating voltage) are used. Also, we find parallel-tuned VFOs (A, B and D) and a series-tuned version (C). We'll discuss those differences now.

L1 in each example is shown as a slug-tuned coil. The tuning slug allows us to vary the VFO operating frequency for dial-calibration purposes. The main tuning control is a variable capacitor, C1.

You may use air-wound, toroidal or other nonadjustable coils also. However, a fixed value coil requires the addition of a stable trimmer capacitor in parallel with C1 for calibrating the VFO readout dial and trimming the operating frequency for the required range.

Perhaps the most frequency-stable coil you can use is one that is air wound with rigid wire, such as B & W Miniductor coil stock. This assumes that the coil is mounted securely to minimize the effects of vibration. A coil that is wound on a ceramic form then glued is also good. Coils that are wound on toroid cores are the least frequency-stable, owing to changes in core permeability during temperature variations.

In each of the Fig 1 circuits we need to use temperature-stable capacitors at C2 through C7. This practice helps minimize VFO drift that is caused by RF heating (current) within the capacitors. Stable capacitors also reduce frequency drift that is brought about by changes in ambient (environmental) temperature.

Generally speaking, NPO ceramic capacitors are the best to use. They look like any other disc-ceramic capacitor, but are manufactured to maintain their capacitance value when the temperature rises above or falls below a specified value. Most NPO capacitors have a black spot painted on them to indicate they are NPO types.

Polystyrene capacitors are suitable also, at least as a second choice over NPOs. These units are very stable and they are less costly than NPO capacitors, even though they are physically larger.

Since RF current flows through the capacitors in a VFO circuit, internal heating does occur. The drift from this phenomenon can be reduced if you use two or more capacitors in parallel to obtain the desired value.

This practice distributes the heat over a larger internal area, which in turns retards drift caused by heating. An example of this measure is seen in Fig 1 where C2 and C3 are in parallel. This can be done also at C4, C5, C6 and C7.

C5 and C6 are the oscillator feedback capacitors. They operate as a capacitive divider to allow some of the Q1 output energy to be fed back to the input of the oscillator (positive feedback). It is this feedback that causes the VFO to oscillate.

Normally, C5 and C6 are the same value, although some circuits have a C5 value that is less than that of C6. The smaller the C5 value the lower the feedback amount. We should never use more feedback than is necessary to permit reliable oscillation. Too much feedback can worsen oscillator stability.

C7 in each Fig 1 example should have as small a value as practicable, consistent with supplying enough RF output energy to excite the following stage or stages in the VFO chain. The lighter the C7 coupling the better the VFO stability when load or operating changes occur after the VFO.

A diode, D1, is shown at B, C and D of Fig 1. This is a small-signal diode of the 1N914 silicon variety. It stabilizes the Q1 bias and minimizes changes in the Q1 junction capacitance. This diode greatly improves the VFO stability without impairing the performance.

The operating voltage for the VFOs in Fig 1 should be regulated. Normally, a 6.8- or 9.1-V, 400-mW Zener diode is used (see fig 2) when a + 12-V or greater supply is available. Changes in VFO dc voltage also disturb the frequency stability.

Fig 1C illustrates a series-tuned Colpitts VFO. This scheme is helpful when the L1 inductance value (at higher frequencies) is very small. Substantially more inductance is required for series-tuned circuits, compared to parallel-tuned ones.

If we use a very small coil inductance we can experience instability caused by PC board flexing from heat changes and vibration. This is because the circuit-board foils become a working part of L1 (unwanted).

This also lowers the coil Q (quality factor), when our objective should always be to have a high-Q coil and capacitors in an oscillator circuit. High Q ensures good oscillator per-

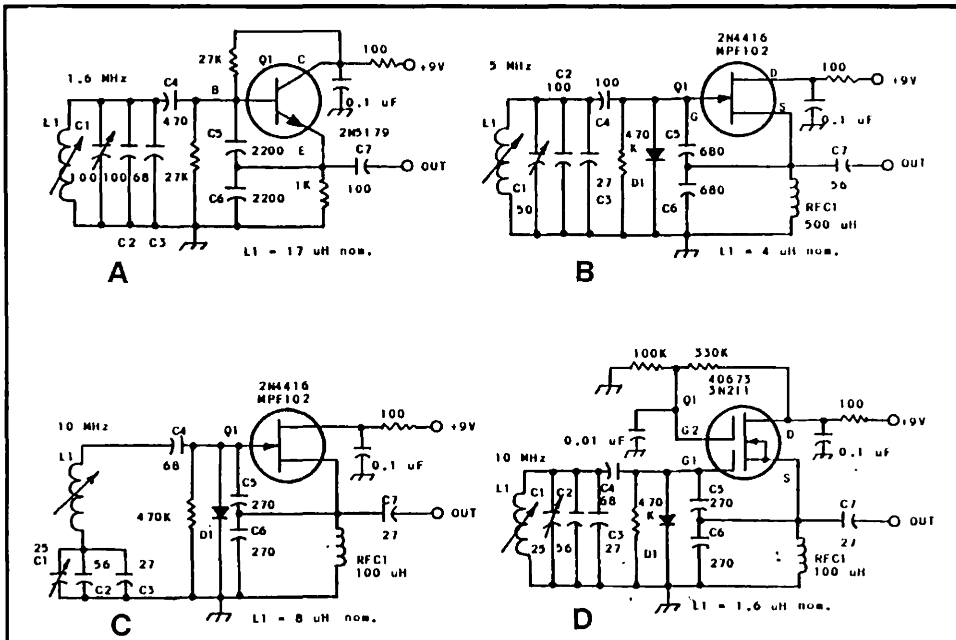

Fig 1 - Schematic diagrams of four versions of the Colpitts oscillator. Circuits A, B and D are parallel tuned. Circuit C is series tuned. Compare C to D to learn how the L1 inductance changes when using a series-tuned circuit. All other component values remain the same, as does the operating frequency (see text).

The above examples show how to use a bipolar, JFET or dual-gate MOSFET transistor in a VFO. The assigned values are suitable for developing your own circuit. Note how the critical parts values change with the operating frequency.

formance and minimum noise in the VFO output. Series tuning can, however, be used successfully at any operating frequency, irrespective of the coil inductance.

Other Stability Considerations

It is always wise to enclose a VFO in a shield compartment or box. This keeps stray RF energy from entering the VFO and affecting its performance. It also helps to prevent RF energy from other parts of the equipment from entering the VFO circuitry.

The VFO tuning capacitor (C1 of Fig 1) needs to be mechanically solid for best stability. Ideally, it should have a bearing at each end of the rotor, and it should turn easily (not lumpy). Units with plated brass plates are generally more stable than are capacitors with aluminum plates. The brass plates are less prone to expansion than the aluminum ones.

There are two kinds of VFO drift. One is known as "short-term"drift and the other is called "long-term drift." Short-term drift takes place as the transistor junction, VFO capacitors and the coil reach initial operating temperature. This usually occurs during the first five minutes or less of operation.

Long-term drift is caused by gradual increases in component heating and temperature changes within the VFO box. Long-term drift should cease within 30 minutes for a well-designed VFO. Some VFOs never stop drifting, especially if the VFO capacitors are of poor quality. Silver-mica capacitors are prone to long term drift problems as are ordinary disc ceramic capacitors.

Short-term drift can be minimized by using the lowest VFO operating voltage practicable. The RF energy level can be built up after the VFO, so there is no need to make your VFO a mini powerhouse! The lower voltage causes less internal heating.

It is wise also to keep the value of C4 of Fig 1 as small as possible, consistent with reliable oscillation. The smaller the C4 value the less the effect of Q1 junction-capacitance changes on the VFO tuned circuit, and the higher the tuned-circuit Q.

VFO Buffering and Amplification

It is almost mandatory that we isolate the VFO from the circuit it operates with. This calls for one or two post-VFO buffers or amplifiers. Fig 2B shows a practical circuit that may be used. Q2 and Q3 not only "buffer" or isolate the VFO, but they amplify the VFO signal. RFC2 and T1 enable the two buffer/amplifiers to operate in a broadband manner (no tuning needed). Hi-Z (high impedance) and Lo-Z (low impedance) output terminals are indicated. These terminals give you the option of using your VFO with a Hi-Z or Lo-Z circuit after Q3.

Fig 2A shows how to connect a Zener diode to the VFOs in Fig 1. You may use either a 400-mW or 1-W Zener diode for D2. R1 is a dropping resistor for D2. Without it D2 would burn out and there would be no regulation. R2 is chosen to permit D2 to draw between 15 and 18 mA.

Closing Comments

I have not offered a project in this article because no two experimenters have the same needs when building a VFO. The operating frequencies depend upon the application. I have assigned values and operating frequencies to the Fig 1 circuits so that you will have ballpark values to use as a starting point for your experiments. Changes in the C1 and L1 values will be necessary for obtaining the precise tuning range you require.

Don't be afraid to experiment! You may use a general-coverage receiver for monitoring the VFO output signal as you prune the component values for the desired tuning range. Connect a frequency counter to the Lo-Z output port (Fig 2B) for checking VFO drift. Practical VFO circuits are presented in *The ARRL Handbook* and in *The W1FB QRP Notebook* (available from The ARRL, Inc.).

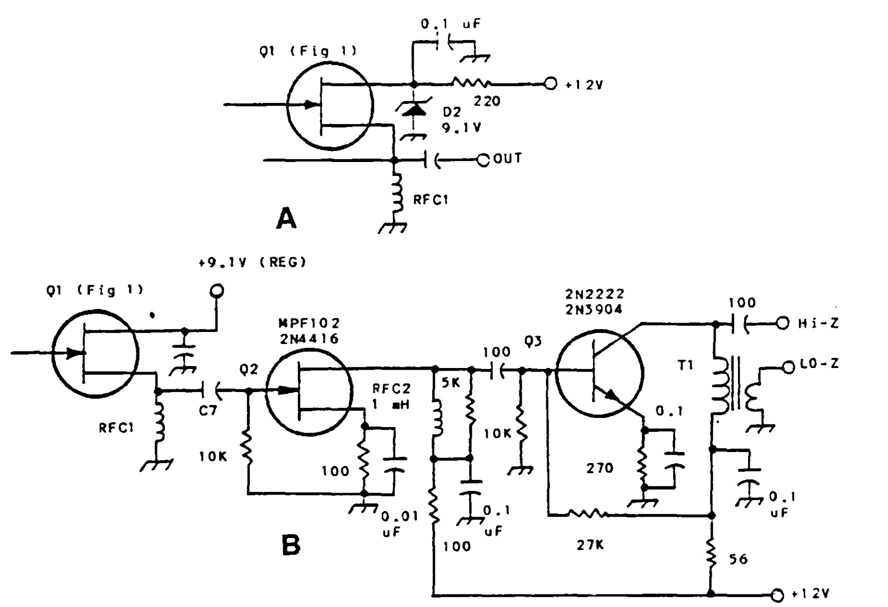

Fig 2 - The addition of a Zener diode regulator is shown at A. This may be applied to any of the circuits in Fig 1.

Circuit B shows how to add a buffer/amplifier section to isolate the VFO from its load, and to increase the RF output voltage of the VFO. High- and low-impedance output ports are provided (see text).