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# A Remote-Oscillator High-Frequency VFO

## This simple-to-build oscillator-buffer design is just the thing for weekend QRP projects.

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If you need a stable, simple variable-frequency oscillator (VFO), a remote oscillator (Figure 1) is a good way to get it. Especially on the higher-frequency bands, locating a VFO outside of the receiver, transmitter or transceiver it controls can enhance frequency stability by keeping the oscillator away from heat sources and the electromagnetic fields around other circuitry. This article presents a simple diode-tuned remote oscillator that you can build for any band from 30 through 10 meters.

### The Remote Oscillator Circuit

The remote oscillator schematic (Figure 2) is almost as simple as the most basic 80-meter VFO. It uses a time-honored Colpitts JFET circuit[1] and a logic-gate IC buffer. The control unit (Figure 3) contains a second logic-gate IC buffer and a voltage regulator. The main difference between this circuit and a standard inboard VFO is that the remote oscillator is built into a separate, outboard, RF-tight box. This lets you locate the VFO a few inches to a foot or two away from the equipment it drives.

A voltage-variable-capacitance diode, D2 in Figure 2 (a *tuning diode*, sometimes referred to by trade names like Varicap, Epicap, or Varactor), tunes the remote oscillator. Unlike a rectifier or switching diode, a tuning diode is reverse biased—current doesn't flow through it—in normal use; it acts only as a variable capacitor and not as a semiconductor. The higher the dc voltage across a tuning diode, the lower its junction capacitance. In our remote oscillator, a 10-turn potentiometer (R4, **TUNING**) located in the control unit (Figure 3) adjusts D2's capacitance by supplying a voltage that varies with R4's shaft rotation. An external frequency counter (or the station receiver) serves as frequency calibration.

Diode tuning lets us address several VFO issues easily. First of all, using a tuning diode means we don't have to find an air-dielectric variable capacitor (often expensive) to do our tuning. Secondly, a tuning diode's capacitance can easily be adjusted remotely: just two wires (control voltage and ground), carrying only dc, are necessary. Thirdly, we can easily "kick" a diode-tuned oscillator far off frequency just by lifting its control potentiometer's ground connection. (We may need to do this to avoid receive-period interference if we want to use the remote oscillator as a CW-transmitter VFO that stays on during receiving periods for maximum stability.) Opening the tuning pot's ground lead sends a high tuning voltage to the diode, reducing its capacitance nearly to minimum and driving the VFO's frequency to the top end of its range.

### Construction Topics

For 15-meter operation, the oscillator coil can be either a Toko TK2722 inductor with its powdered-iron slug removed, or 5 turns of #20 enameled wire close-wound on a 3/8-inch plastic rod. To make a neat homemade coil, drill two 1/16-inch holes into the plastic rod and force two brass escutcheon nails into the holes to anchor the wire. Coat L1 and L2 with epoxy, Duco or plastic cement for mechanical stability.

The MV1662 tuning diode is now obsolete.[2] If you can't find one (or the two MV2100-series diodes listed in the Figure 2 caption as parallel substitutes), you can use the built-in diode in an IRF510 MOSFET instead. The MOSFET's drain lead (common to its mounting tab) connects to the internal diode's cathode; connect this lead to the junction of C7 and R2. The MOSFET's source lead connects to the diode anode; connect it (and the MOSFET's gate lead) to ground.

An RF-tight box is one of the most important parts of the remote oscillator. The two-piece sheet-metal project boxes often used for home brew projects may not be RF-tight unless you add extra fasteners to improve closure. (A die-cast aluminum box would be fine, though expensive.) A small box made out of six pieces of PC-board material will be better, cheaper and perhaps more pleasing to the eye. (To make a really tight PC-board box, seam-solder the mating inside edges of its top and four sides. After you debug the oscillator, solder the outside edges of its bottom to the rest of the box.) A 1/8-inch hole can be drilled into the bottom for adjustment of **TRIM** capacitor C1. Shielding of the control unit is not critical.

The remote oscillator can be constructed using ground-plane construction (also known as ugly construction) or on a single-sided etched board. (A circuit board is not currently available for this project.) Double-sided etched boards—that is, circuit boards with copper traces on both sides, or a copper ground plane on one side and circuit traces on the other—are not recommended for low-drift oscillators. The parasitic capacitances formed by both sides' copper are relatively temperature-unstable and may cause temperature-dependent drift.

Make all connections between the remote oscillator and control unit, and between the control unit and the equipment driven by the VFO, with shielded cable and phono plugs (or similar shielded connectors). Don't use ready-made phone-plug equipped cables intended for audio use. Their shielding is inadequate for radio use.

The VFO shown in the photographs was built as part of a 15-W 15-meter transmitter. The control unit also contains an IRF510 MOSFET final amplifier keyed by a TIP115 Darlington PNP bipolar junction transistor. The gate of the IRF510 final connects directly to the second 74HC240 buffer (U2 in Figure 3). The schematic of the final, keying stage and buffer connection is essentially identical

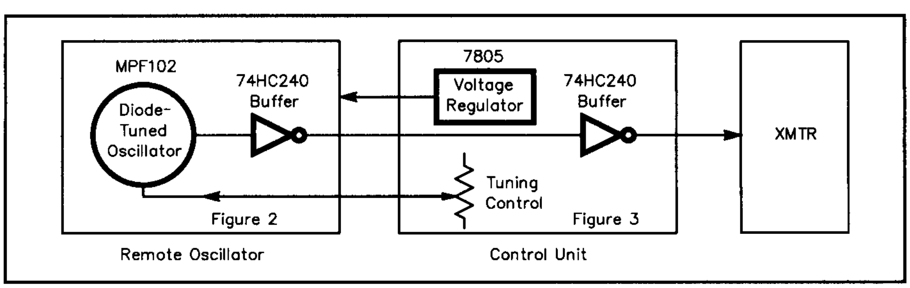


Figure 1—Block diagram of the remote oscillator system. Although a transmitter hookup is shown, you can also use the remote oscillator in receiving and transceiving applications.

[1]Notes appear on page 40.

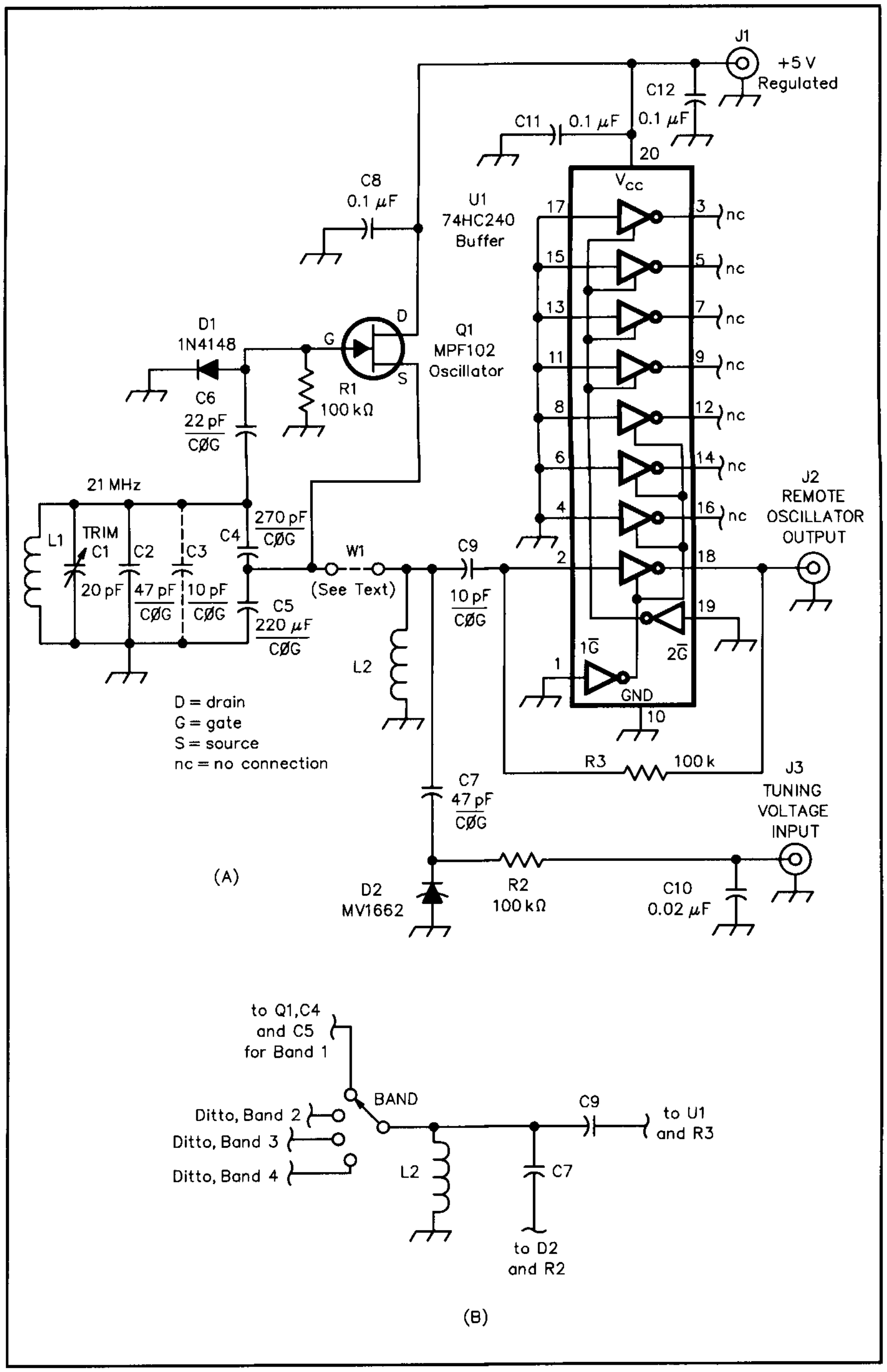


Figure 2—The remote oscillator (A) consists of a diode-tuned MPF102 JFET Colpitts oscillator and a high-speed CMOS 74HC240 octal inverting buffer. Capacitors marked C0G (equivalent to the older term *NP0*) are zero-temperature-coefficient ceramics; others are general-purpose ceramics. The circuit's two resistors are 1/4-W carbon-film or composition parts. Several oscillators can be bandswitched, as shown at B.

C1—Low-drift mica, ceramic or air-dielectric trimmer

C3—Optional; see text

D2—The Motorola MV1662 "20-V" tuning diode (capacitance: 250 pF at 4 V bias) used for D2 by the author is now obsolete, but is available from at least one source as outlined in the main text's Note 2. One MV2111 "30-V" diode (capacitance 47 pF at 4 V bias) paralleled with two MV2115 "30-V" diodes (100 pF at 4 V bias) can be substituted, or the built-in diode in an IRF510 power MOSFET may be used as described in the text

L1—For 15 meters: Toko TK2722 unshielded inductor (available from Digi-Key Electronics, 701 Brooks Ave S, Box 677, Thief River Falls, MN 56701-0677, tel 800-344-4538 and 218-681-6674, fax 218-681-3380) with its powdered-iron slug removed, or 5 turns of No. 20 enameled wire close-wound on a 3/8-inch plastic rod. Table 1 summarizes band-specific values for this and other bands from 30 through 10 meters

L2—RF choke consisting of 40 turns of #30 enameled wire close-wound on a 1/4-inch-diameter plastic rod

**Table 1**
**Band-Specific Oscillator Component Values**

| *Band (m)* | *L1 (turns*)* | *Approximate Tuning Range† (kHz)* |
|---|---|---|
| 10 | 3 | 110 |
| 12 | 4 | 100 |
| 15 | 5 | 80 |
| 17 | 6 | 65 |
| 20 | 7 | 50 |
| 30 | 10 | 40 |

*Close-wound #20 enameled wire on a 3/8-inch plastic rod; see text.
†With an MV1662 diode used at D1, and C7 (Figure 2) equal to 47 pF. See text, Note 2 and the Figure 2 parts list.

to a transmitter described in an earlier article.[3]

## Testing and Adjustment

Once you've got the remote oscillator correctly wired and oscillating, all you need to do before going on the air is adjust C1 so your VFO starts tuning at the right spot in the band. If the VFO can't tune low enough with C1 adjusted to maximum, add capacitance (C3, the optional capacitor in Figure 2) across the VFO coil as necessary.

Check the VFO's frequency drift. During the first minute after power is applied, the frequency may shift 1 kHz. During the next 5 or 10 minutes, another 100 Hz of drift may occur. Assuming a reasonably constant room temperature, drift should be less than 100 Hz in the hour following a 10-minute warm-up.

Wait one hour after making a temperature change—for instance, after soldering a connection in the remote oscillator box or moving the assembly to a different room— before testing it for drift. If drift is excessive, make sure that C2, C3, C4 and C5 are *really* zero temperature coefficient (NP0 or C0G) parts. If you find any that weren't specifically sold as NP0 or C0G capacitors, replace them with C0G parts.

Trimmer capacitors can be another source of drift. Some trimmers sold as "NP0" parts have temperature-coefficient tolerances several hundred parts per million wide! Air-dielectric variables are best, although mica trimmers have worked fine for me.

Finally, don't use powdered-iron or ferrite cores in L1 or L2 if you can avoid it. Even the most stable powdered-iron core can cause drift in a high-frequency VFO. Also, be sure to keep L1 at least 1/2 inch away from other components and shield-box walls. Because it's solenoidal and not toroidal, it has a large external magnetic field that makes wide spacing important.

## Output and Buffering Issues

At its tied-together pins 3, 5, 7, 9, 14 and 16, U2's output is a square wave with a peak value that's essentially equal to $V_{CC}$ (pin 20)—that is, 5 V. C17 (Figure 3, between U2 and **VFO OUTPUT** jack J7) blocks the dc component of this signal, resulting in a square wave that still has a peak-to-peak value of 5 V, but which is centered at 0 V—in other

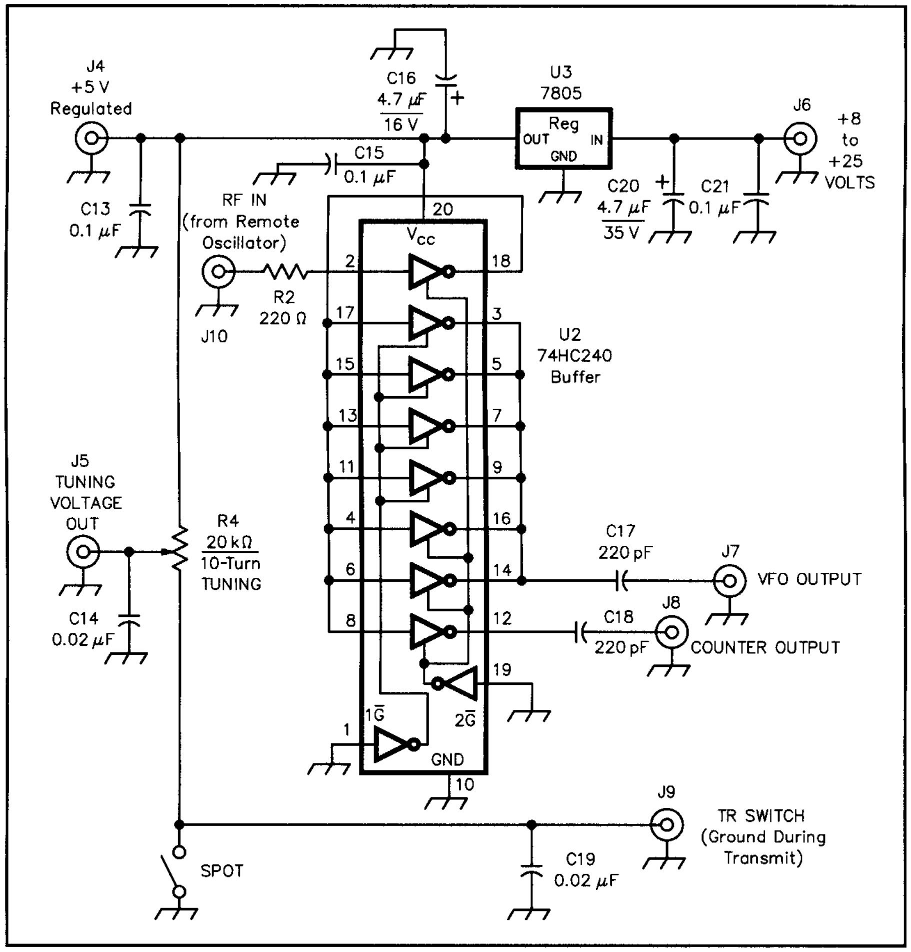


Figure 3—The remote oscillator control unit houses a 10-turn **TUNING** potentiometer (R4), another 74HC240 buffer stage, and 5-V regulator for enhanced stability. The two 4.7-µF capacitors are tantalum electrolytics; others are general-purpose ceramics. The 220-Ω part (R2) is a ¼-W carbon-film or composition unit.

words, a peak value of 2.5 V.

At a $V_{CC}$ of 5 V, the combined output impedance of the six paralleled buffers driving C17 is about 9 Ω. Their combined output current capability is such that a 50-Ω load connected to J7 dissipates about 70 mW—about 18.5 dBm—of RF.

The buffering action of 74CH240s U1 and U2 is good enough that a MOSFET power amplifier driven directly from U2's outputs (that is, with its gate connected directly to tied-together pins 3, 5, 7, 9, 14 and 16) causes no audible frequency shift at 10 meters when keyed on and off. (By the way, it might appear that connecting all of U1's unused buffer sections in series with the single section used might improve the system's buffering to some degree. But the 74HC240's geometry is so compact that inter-section coupling works against any possible improvement from that approach. If you want better buffering, you'll need to use more 74CH240s!)

The square-wave nature of U2's output might seem to require some pretty heavy-duty harmonic filtering before you could use this signal to drive a receiver mixer or transmitter, but this isn't so. If you're feeding any of the balanced solid-state mixers commonly used today—a doubly balanced diode mixer, an NE602 or a pair of JFETs—square-wave drive is actually what you want. If you're feeding a transmitter, square-wave drive should be no problem because a square wave consists largely of a fundamental (the output frequency you expect) and odd (3, 5, 7...) harmonics. The output filtering that helps a transmitter keep second-harmonic energy down to a legal level should be more than sufficient to take care of any output energy attributable to odd-order harmonics in its driving signal.

### Using the Oscillator on Other Bands

The VFO can be adapted to other frequencies by changing the values of L1 and C7 (Figure 2) as shown in Table 1. C7 sets the tuning range. The ranges shown in Table 1 will double if C7 is changed to 68 pF and halve if C7 is made 33 pF. Keep the tuning range to less than 100 kHz unless you add diode temperature compensation[4] to the tuning-diode circuit.

If you want to build a multiband VFO, don't attempt to do it by just switching in various coils for L1. Losses in the switch contacts will make the oscillator electrically and mechanically unstable, especially on 10 meters. A better way is to make a multiband version is to duplicate C1 through C6, C8, R1, Q1 and D1 for each band you want, substituting different values for L1 as appropriate. (Two or more oscillator sections can be built into just one remote oscillator box because only one section is active at a time.) Then, remove jumper W1 in each oscillator and wire each oscillator's W1 point to a single-pole multiposition switch as shown in Figure 2B.

### Application Suggestions

Adding a VFO to a crystal-controlled solid-state transmitter is usually straightforward. Remove the crystal, and then connect a short piece of well-shielded miniature coax between the crystal socket and the control unit's **VFO OUTPUT** jack (J7). Connect the coax's center conductor to the ungrounded socket pin if one of the pins is grounded; if both pins are ungrounded, experiment to determine which socket pin to connect to for adequate drive.

If homebrew transceiver operation appeals to you, you can use the control unit's **COUNTER OUTPUT** (J8) to provide local oscillator drive for a direct-conversion receiver. Replace the spotting switch with a 1-kΩ control for receiver incremental tuning (RIT).

I recommend this remote-oscillator circuit for experimenters. I've built a 10/15-meter remote oscillator, another 17/20/30-meter version, and the 15-meter version described in this article. All three have performed flawlessly for several years.

### Notes

[1]Doug DeMaw, W1FB, *QRP Notebook*, first edition (Newington: ARRL, 1986), pp 27-28.

[2]A few weeks before press time, I called Marlin P. Jones and Associates, PO Box 12685, Lake Park, FL 33403-0685, tel 408-848-8236, fax 800-4 FAX YES or 407-844-8764. They said they had about 1000 MV1662s in stock, which are available in matched sets of three (part no. 0087-DI) for $1/set. (They also have low-cost [$3.50] surplus 10-turn, 20-kΩ pots suitable for this project's **TUNING** control.) Marlin P. Jones has a $15 minimum order, but a set or two of MV1662s, a 20-kΩ pot, a pound of solder and a few more trinkets will probably push your order over $15 anyway!

[3]Lew Smith, N7KSB, "An Easy-to-Build 15-Watt Transmitter," *Hambrew*, Spring 1994, p 9.

[4]Doug DeMaw, W1FB, "Tuning Diode Applications and a VVC-Tuned 40-m VFO," *QST*, Sep 1987, pp 25-29.

# Strays

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