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Crystal Test Oscillators

These oscillators can test a wide range of fundamental and overtone crystal frequencies, and can measure the crystal activity.

Many experimenters have accumulated an assortment of oscillator crystals, and some will be unmarked or marked with a channel number or the output frequency of a transmitter rather than the crystal frequency. A test oscillator for determining the condition of a crystal and its actual frequency is therefore a worthwhile addition to the amateur radio workshop. My own collection of more than 2,000 crystals allows me to almost always find one very close to the desired frequency.

The UCO

The ideal universal crystal oscillator (UCO) should oscillate with any quartz crystal of any frequency and should give sufficient output to drive a frequency counter. It should also give an indication of the crystal's inclination to oscillate — what in the old days was called “activity” of a crystal.

An exhaustive search for such an ideal UCO has evolved into the circuit shown in Figure 1. It will oscillate with any crystal from below 25 kHz to above the 25 MHz upper frequency limit of fundamental-mode crystals. In essence, the circuit is an FET Pierce oscillator with switchable capacitance between drain and ground. Strength of oscillation (activity), which corresponds to rectified drain voltage, is indicated on the meter. The 1N34 diode across the meter prevents over-deflection and gives a somewhat logarithmic response. Output for a frequency counter is also taken from the FET drain. Oscillation frequency will be close to the parallel resonant combination of the crystal in combination with a shunt capacitance of about 50 pF. This frequency is typically less than 200 parts per million above the series resonant frequency.

The UCO will oscillate with overtone

crystals, but the frequency will be the crystal's fundamental, not the overtone. Although the overtone frequency does not bear an exact numerical relationship to the fundamental, it will always be very close, within 0.1%, to an odd integer (3, 5, 7, ...) multiple of the crystal's fundamental.

When investigating unknown crystals, all positions of switch S1 should be checked. This is because of different crystal modes. I have a 100 kHz crystal that oscillates at 100 kHz in the LF position of S1, as it should, but in the MF position it oscillates at 500 kHz, and in the HF position at 3.639 MHz! Of course, the MF position is the fifth overtone. However the HF position is not an overtone but some completely different mode of vibration.

The UCO, along with a frequency counter, can also be used as an inductance meter where an unknown inductance replaces the crystal. Inductance will be inversely proportional to the square of the frequency. Table 1 gives the frequencies for different inductance values that were measured with my UCO. The Table also gives the calculated capacitance that would resonate with those inductance values at the measured frequency. I was astonished at how consistent the capacitance was over an inductance range of more than ten million to one.

Because of the consistency in capacitance, it is possible to derive simple formulas for

approximate inductance vs. frequency. In the VLF and LF ranges,

$$L = \frac{500}{F^2}$$

where L is in H and F is in kHz.

For the MF and HF ranges,

$$L = \frac{900}{F^2}$$

where L is in μH and F is in MHz.

Of course, these will be ballpark values. If you want precision you should use an impedance bridge operating at 1000 Hz. Since the UCO works at a much higher frequency, inductance will be affected by distributed capacitance of the coil. Remember that apparent inductance tends toward infinity at the self-resonant frequency of the inductor. Even at half the self-resonant frequency the apparent inductance is one-third larger than the low frequency value. If you are not interested in inductance, the 0.01 μF blocking capacitor on the drain of Q1 can be omitted. If you are interested only in crystals above 1 MHz, the range switch S1 can be omitted.

The UOO

Above about 20 MHz crystals are always overtone types. A Universal Overtone

Table 1
Frequencies for different inductance values measured by the UCO.

Range	Inductance	Frequency	Capacitance
VLF	2.85 H	14.1 kHz	44.7 pF
LF	116 mH	63 kHz	55 pF
MF	8.6 mH	317 kHz	29.5 pF
HF	10 μH	10.1 MHz	24.8 pF
HF	0.25 μH	60 MHz	28.1 pF

Oscillator (UOO) must be tunable to select the correct overtone. The circuit shown in Figure 2 does this well. It will tune in any overtone between 18 and 160 MHz. Overtones other than the intended one are often just as usable. By using unintended overtones you can double or triple the number of frequencies available from your crystal collection.

For example, I have a fifth overtone crystal at a fundamental frequency of 14.09 MHz that will oscillate at 42.3 MHz on its third overtone, 70.5 MHz on its fifth (the marked frequency), 98.7 MHz on its seventh, 126.9 MHz on its ninth, and 155.1 MHz on its eleventh overtone. I get six frequencies from one crystal! I even have one crystal that can produce a nineteenth overtone.

The UOO of Figure 2 tunes from 18 to 160 MHz in 3 overlapping ranges, 18 to 67 MHz, 31 to 97 MHz, and 75 to 160 MHz. It shares the 100 μ A activity meter and power supply with the UCO circuit. A center tapped RF transformer T1 is used to neutralize the crystal capacitance, sometimes called the "holder" capacitance. The 5 pF neutralizing capacitor could be made variable but the

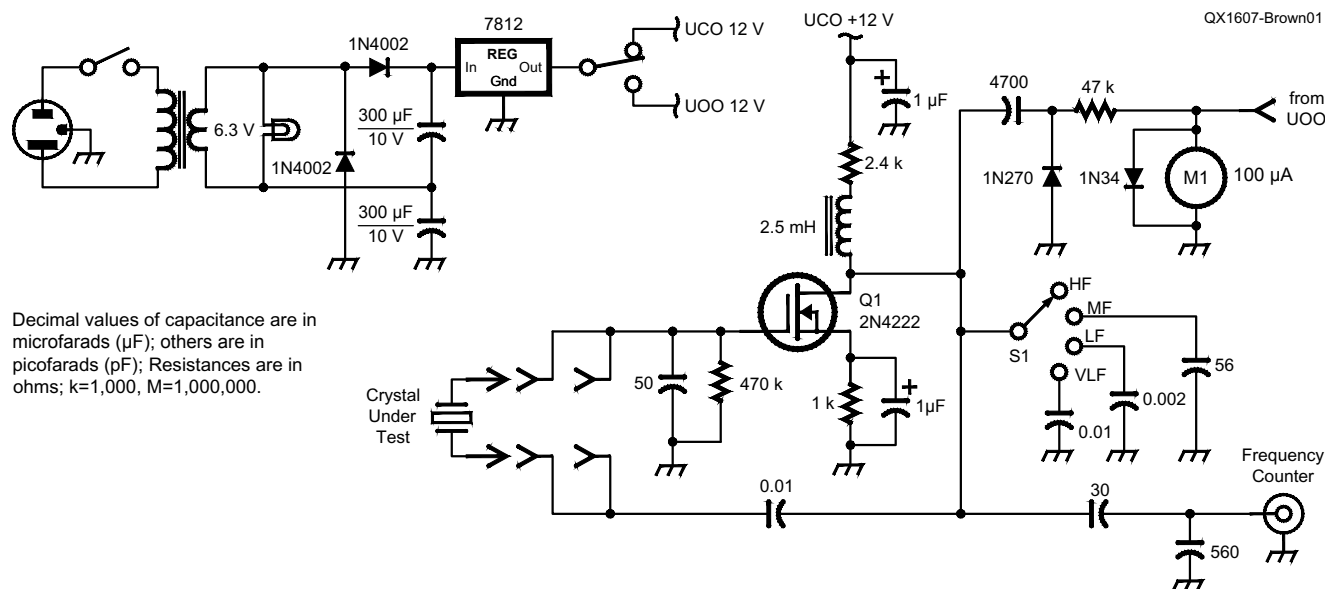


Figure 1 — The UCO, and its 12V dc power supply, covers four frequency ranges selected by switch S1.

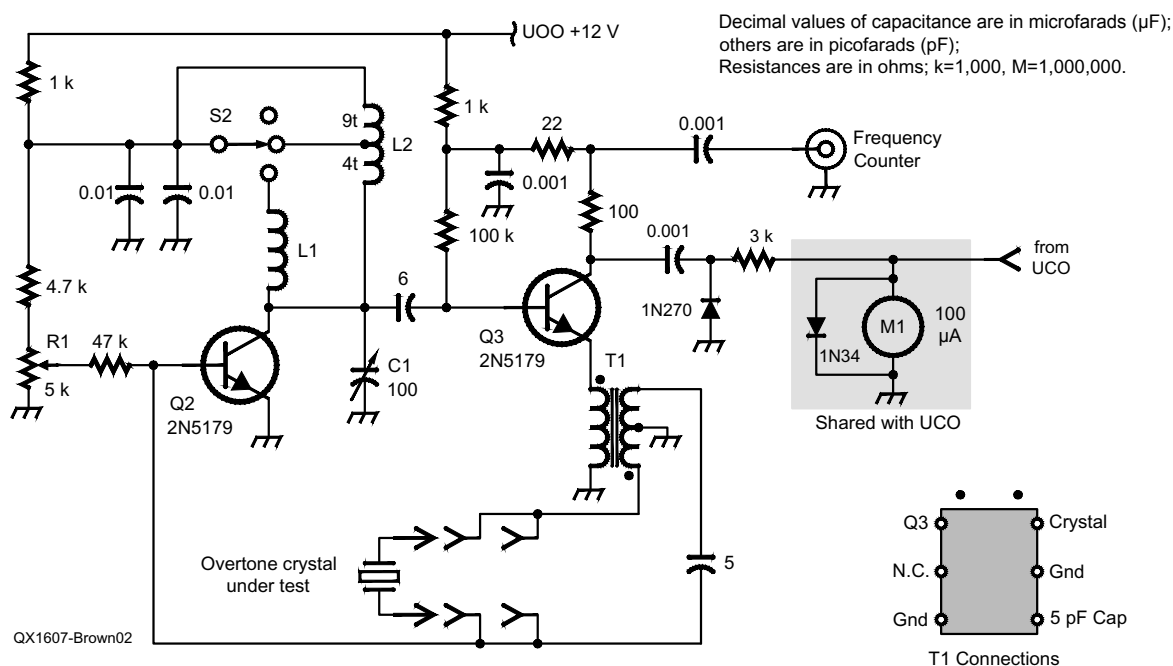


Figure 2 — The UOO shares the same meter and power supply with the UCO. RF transformer T1 is a Mini-Circuits T4-1H-X65. L1 is 1.5 inches of #22 AWG running between stator of C1 and S2. L2 is 13 turns of #18 AWG, 0.4 inch inner diameter, 0.9 inches long, tapped 4 turns from the C1 end.

fixed value shown has proven to work well. T1 has a turns ratio of 1:1 from primary to each half of the secondary. Be sure to observe the phasing.

A gain control R1 is included because if the gain is set too high the UOO will free-run with some crystals. That is, it will self-excite. You can always recognize this condition because the frequency counter will not be consistent from one count to the next. When crystal-controlled, the frequency counter will be stable, plus or minus one count.

Construction

Construction is not critical, and each builder will have a personal preference. I built both oscillators and power supply on a 7.6 by 4.2 inch aluminum panel that fits on a plastic box. The power supply, the UCO, and the UOO are each built on separate rectangles of tin cut from a tin can that is tin plated on both sides.

Q2 and Q3 are on opposite sides of the tin, which forms a shield between them. Each plate is mounted upright on the panel and I used old fashioned point-to-point wiring. It is important to keep RF leads short, especially on the UOO, which must work up to 160 MHz. RF transformer T1 is a Mini-Circuits T4-1H-X65. Figure 2 shows the connections for proper phasing.

Fred Brown, W6HPH, has held his call sign since 1949. He earned a BS in Electronics Engineering from Cal Poly and an MSEE from the University of Illinois. He has worked as an engineer and has taught electronics in college. He has authored more than 100 technical articles in amateur and professional journals.

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