

# RF design awards

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## Constant Reactance Voltage Controlled Oscillator

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*A need exists for a very wide range voltage controlled oscillator that exhibits good frequency and amplitude stability over its entire frequency span without complex band switching. Applications include wide pull phase locked loops which incorporate a single continuously tuned VCO, broadband sweep generators with good stability at the high end of the frequency range and network analyzer oscillators with extremely flat output level over frequency.*

Traditional wide-range VCOs vary only the capacitance in an oscillating tank. The reactance of this varactor and an inductor increase with frequency since the operating frequency is inversely proportional to the square root of the capacitance. Consequently, these VCOs have been limited to a tuning ratio of about 3 to 1 and the loaded Q and resulting circuit stability become degraded at the end of the frequency range. Some designs have incorporated complex switching circuits to select a more appropriate inductor as the frequency increases. Such circuits do not tune continuously from one end to the other. Varactors combined with saturable core inductors have also been used to obtain better than 3 to 1 tuning ranges, however, these circuits have been found to be hopelessly unstable, noisy and exhibit substantial hysteresis due to core magnetization.

A new approach in VCO design, a Constant Reactance VCO, (CRVCO) can be realized which exhibits the stability of a varactor-only tuned VCO while providing the wide continuous tuning range (7.5 to 1) of a varactor/ saturable core reactor VCO. By actively holding the inductor's reactance constant in a feedback system that tracks the tuning varactor, high Q and exceptionally constant output power are maintained over frequency.

The saturable core reactor consists of a ferrite toroidal inductor placed in the field of an ordinary electro-magnet. As the magnetic flux increases, the 4C4 core loses permeability without significant changes in Q. This CRVCO employs a modified Wabash reed relay (PIN: 208-31-1) with a soft iron rod replacing the switch to direct the saturating magnetic field to the VCO coil, which uses seven turns of 30 gauge wire on a Ferroxcube core (P/N: 135T050-4C4). This combination requires less than 100 mA to fully saturate the inductor.

The MC 1648 is selected as the VCO because it contains an automatic gain control which precisely sets the voltage across the tank, allowing the inductor's reactance to be determined by measuring its current. This current is metered by connecting the ground end of the coil to the synthetic ground at the collector of a grounded base stage. A voltage proportional to the emitter current appears at the collector which is amplified and detected. The low impedance collector resistor and MMIC amplifier provide very flat wide-band response.

Once detected, the inductor current results in a DC voltage which is scaled by a 50 kilo-ohm pot before it is applied to the reference pin of a TL431 shunt regulator. In this unique application the TL431 modulates the current into its cathode in an attempt to keep the reference pin at 2.5 volts DC.

As an increasing voltage is applied to the varactors, the VCO's frequency begins to rise which makes the inductor current start to drop. Since this drop in inductor current shows up as a proportionate drop in RF voltage at the detector, the voltage at the reference pin of the TL431 will attempt to increase causing the cathode to sink more current. More current through the electromagnet increases the saturation of the saturable core reactor which lowers its inductance bringing the current back up to its preset level thereby satisfying the feedback loop. The compensation network consisting of a 620 ohm resistor in series with a 0.001 CIF capacitor assures that the frequency response of the TL431 is slower than the frequency response of the electromagnet for good loop stability.

### Performance Data

With a tuning voltage of 1 volt to 24 volts, the CRVCO tunes from 20 MHz to 150 MHz - an incredible 7.5 to 1 tuning ratio! Nearly as impressive is the output flatness, a barely detectable  $\pm 0.04$  dBm from end to end.

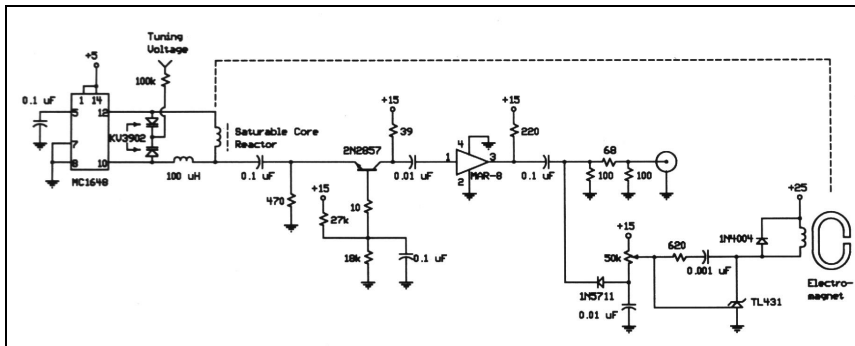


Figure 1. 20 MHz to 150 MHz CRVCO.

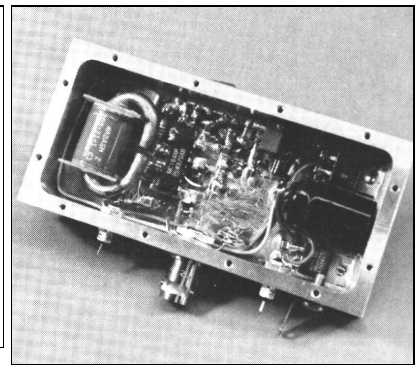


Figure 5. Photograph of CRVCO.

The combined performance of the grounded base stage and MMIC stage play a crucial role in just how well the saturable core reactor's reactance can be regulated. This transresistance amplifier is useful out to 400 MHz.

**Summary**

This CRVCO implementation need not be restricted to high ratio tuning applications. Smaller ratio designs can still benefit from its inherent stability. Other applications of the tracking saturable core reactor include high Q tracking filters or tanks with a fixed resonant frequency which alter the components' reactances. Insightful applications of this technique should lead to some very promising circuit solutions. RF