Series-LC-tank VCO breaks tuning-range records

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This Design Idea applies a novel topology to an oscillator. It uses a series-connected LC (inductive-capacitive) tank circuit to give the circuit a higher tuning range than circuits that use a parallel-LC connection. The architecture of the oscillator permits wide frequency swings, well beyond the capabilities of the best hyperabrupt varactor. Engineers deem a VCO (voltage-controlled oscillator) capable of covering one octave as state of the art. This topology allows a 4-to-1 ratio in output frequency. The LC tank alone sets this frequency so that the parasitic capacitances of other components do not limit the output frequency. Unlike standard oscillators, this circuit works well at its frequency extremes.

At first glance, the central structure of the oscillator resembles two transistors that form a latching SCR (silicon-controlled-rectifier) structure (**Figure 1**). The structure is similar to that of a thyristor, but you add degeneration resistors that keep the circuit in a linear mode of operation. The resistors make the gain of this "SCR" smaller than one, and it is dc-stable. The series-tuned tank circuit increases the gain beyond one at the resonant frequency, causing the circuit to oscillate. No auxiliary components are necessary for oscillation, and the node between the inductor and the capacitor is free of other connections, meaning that only the varactor you use as the capacitor determines the tuning range. The frequency varies as the square root of the tuning elements. To change the frequency by a factor of two, you need a fourfold variation of the tuning capacitance.

Unlike a parallel-LC tank, the resonant current passes through the active element and is, therefore, limited. This limit in turn means that the ac voltage appearing across the tuning components is small—typically, less than 100 mV. The small signal reduces the effects of circuit nonlinearity and the impact of the self-biasing effects of the signal on the varactor. You can use control voltages as small as 0.3V across the varactor. If you use a 1-μH inductor, the circuit still oscillates with capacitor values of 4.7 pF to 4.7 μF—a ratio of 106-to-1.

For the detailed design, move the LC tank to the emitter of PNP transistor Q_2 (**Figure 2**). The lower speed of the PNP creates greater phase difference and encourages oscillation. Connect L_2 and C_2 at a common power point on the power rail, emphasizing

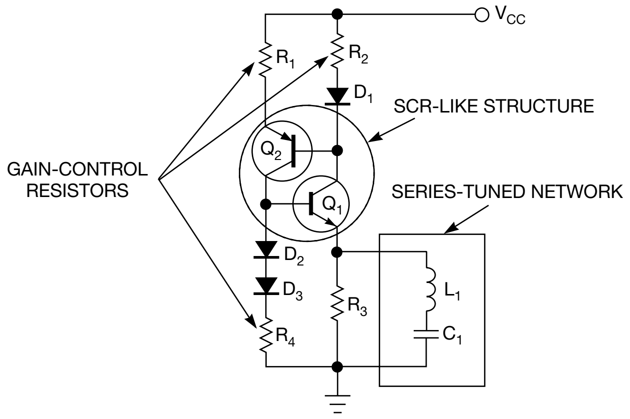

Figure 1 The heart of the oscillator are two transistors and a series-LC tank. The gain-control resistors add degeneration so that the transistors operate in their linear range instead of latching, as an SCR would.

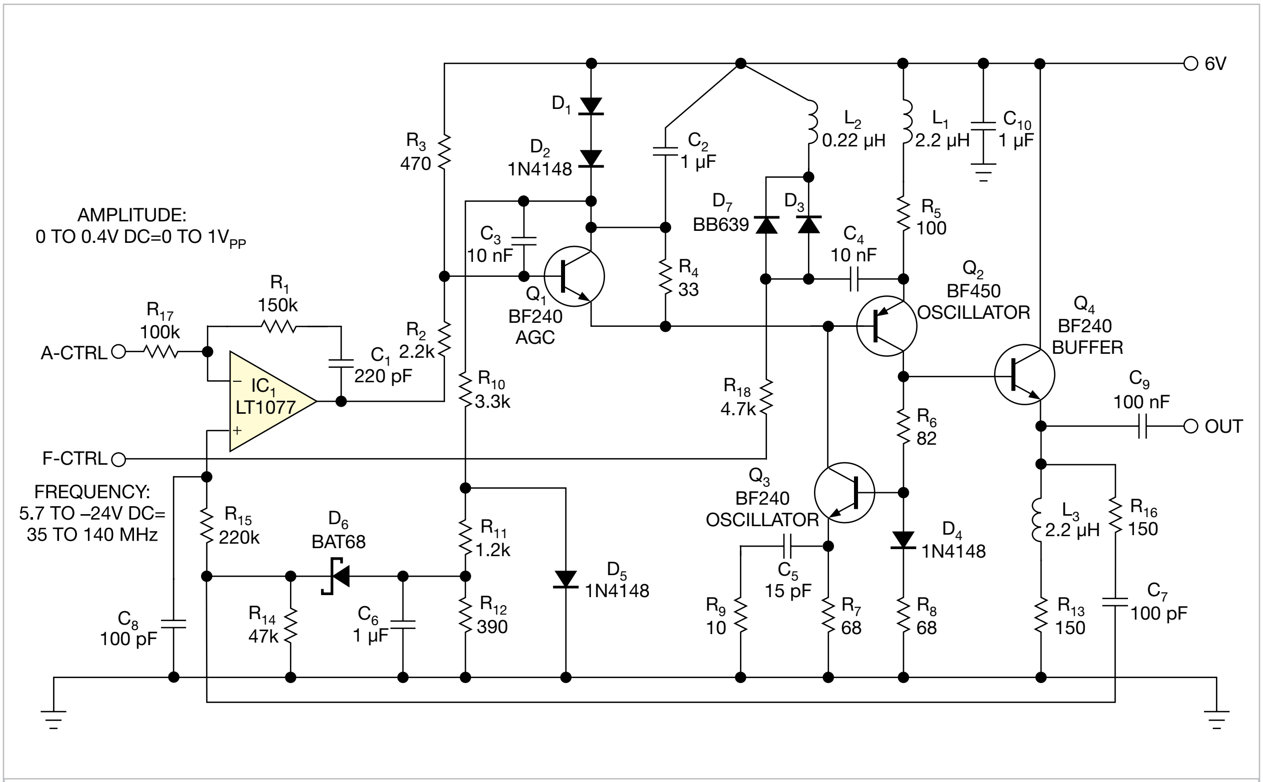

Figure 2 For the detailed design, move the LC tank to the PNP transistor. Varactors D_7 and D_3 form the capacitance, and L_2 is the inductance.

the criticality of the layout in this part of the circuit. The oscillator "senses" the tuned circuit through C_2 and C_4, and anything inside that loop adds uncontrolled parasitics to L_2. These parasitics would compromise the AGC (automatic-gain-control) action and degrade the performance and accuracy of the oscillator.

Q_1 and associated components implement the AGC. A parallel-LC oscillator tolerates clipping of the signal, but this series-LC circuit degenerates into a multivibrator if you allow the signal to grow so large that it clips. The AGC servo action has the added advantage of producing uniform output amplitude. Use D_5 to create a 0.6V dc bias. R_{11} and R_{12} form a voltage ladder that creates a dc-bias voltage close to the forward-voltage drop of Schottky diode D_6. This bias allows D_6 to work as a more perfect rectifier of the small output signal. C_8 integrates the rectified signal into a dc voltage proportional to the amplitude of the circuit's output. Apply this dc signal to IC_1, the AGC amplifier, through a filter comprising R_{15} and C_8. The op amp servo-controls the filtered dc signal against the A-CTRL input-amplitude signal you send to the circuit. This signal allows you to set output amplitude at 0 to 1V.

In this example, the output amplitude is 0.9V. The frequency range extends from 35 to 140 MHz, a 1-to-4 ratio—twice that of conventional high-performance VCOs—and requires a fourfold increase in the capacitance ratio. The overall capacitance ratio is 1-to-16, exactly that of the varactor itself. At the lowest (**Figure 3**) and highest (**Figure 4**) frequencies of the output range, the quality of the sine wave remains excellent, thanks to AGC action.EDN

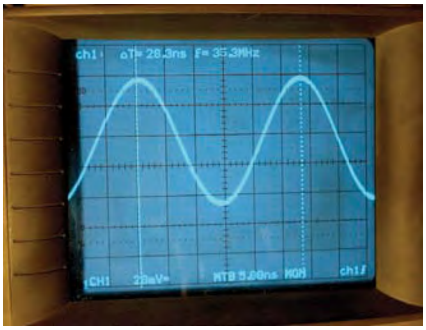

Figure 3 At 35 MHz and 0.9V output, the oscillator creates a high-quality sine wave.

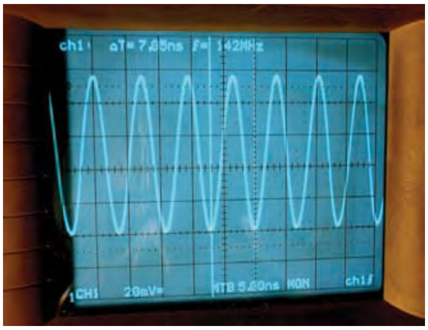

Figure 4 At 142 MHz and 0.9V, the output is still pure and stable, thanks to the AGC circuit.