Oscillator Circuits

Part two in a series of three.

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As you may recall, last time we discussed the feedback and crystal control of an oscillator. This month, we'll look at some typical self-excited and crystal-controlled oscillator circuits.

Remember, a crystal operating in the resonant mode will exhibit a low impedance across its terminals and a zero degree phase shift, while an anti-resonant crystal will exhibit a high impedance across its terminals and a 180° phase shift. In this article, circuits #3, #6, #7, #10, and #12 have a resonance requirement for the crystal. The crystals in #1, #2, #5, and #9 are anti-resonant.

The design of a circuit will take advantage of the specific impedance and phase characteristic provided by the crystal. In the case of the self-excited oscillator, the coil and capacitor in the resonant circuit are connected to meet the oscillator design requirements in a manner similar to the crystal.

Circuit 1: A Pierce design using an anti-resonant crystal in the feedback path between the collector and base of a transistor. Excitation, or crystal drive, is adjusted by the value of the 390 pF base bypass capacitor. This value is kept as small as possible, but large enough to achieve reliable oscillator starting. The frequency operating range for this circuit is about 100 kHz to 18 MHz.

Circuit 2: Another Pierce design uses an FET and operates as described in Circuit 1 above. The excitation capacitor is variable and is used to control the excitation level and to "pull" the frequency of the oscillator for netting purposes.

Circuit 3: This common-base Colpitts design requires the base impedance to be low for oscillation to be sustained. A resonant crystal exhibiting a low impedance from base to ground will enable oscillation to occur only at the frequency of the crystal's overtone. Frequency netting may be accomplished by varying the value of either the 3.9 pF or 47 pF capacitors. The 3.9 pF capacitor provides the feedback and the 47 pF controls the excitation level. The operating frequency range is crystal-overtone dependent (3rd, 5th, and 7th) covering 12 MHz to 200 MHz.

Circuit 4: In this self-excited common-emitter Colpitts oscillator, the coil and capacitor control the operating frequency. The ratio of the capacitor values connected between base, emitter and ground establish the feedback and oscillator stability. The frequency band is typically between 3 MHz and 30 MHz. Temperature stability of the circuit is fair and is dependent upon the mechanical stability of the resonant circuit components.

Circuit 5: This circuit is a crystal-controlled version of Circuit 4. It uses an anti-resonant crystal; the frequency stability is as good as the crystal. The 39 pF capacitor value may be varied for frequency netting and the excitation level is controlled by the value of the 68 pF capacitor. The operating frequency range for this circuit is about 100 kHz to 18 MHz.

Circuit 6: This is the common-base Colpitts oscillator; the feedback is obtained from the collector and coupled back to the emitter through the resonant crystal. Oscillation occurs when the impedance of the series crystal is slightly lower than the tuned circuit. The crystal drive is determined by the ratio of the 470 pF to the 130 pF capacitors. Note the 6.8 μH inductor across the crystal: Its purpose is to provide a DC path for the isolated top terminal of the crystal. The operating frequency range is crystal-overtone dependent (3rd, 5th, and 7th) covering 12 MHz to 200 MHz.

Circuit 7: A Hartley circuit is as popular as a Colpitts for implementing an oscillator. The basic difference between the designs is in the method for obtaining feedback—Hartley uses a tapped inductor while Colpitts uses a capacitor divider. Circuits 6 and 7 are nearly identical, including the frequency range, with the exception of the feedback method.

Circuit 8: This is a classic common-collector Hartley oscillator, used in broadcast radios since the late 1930s.

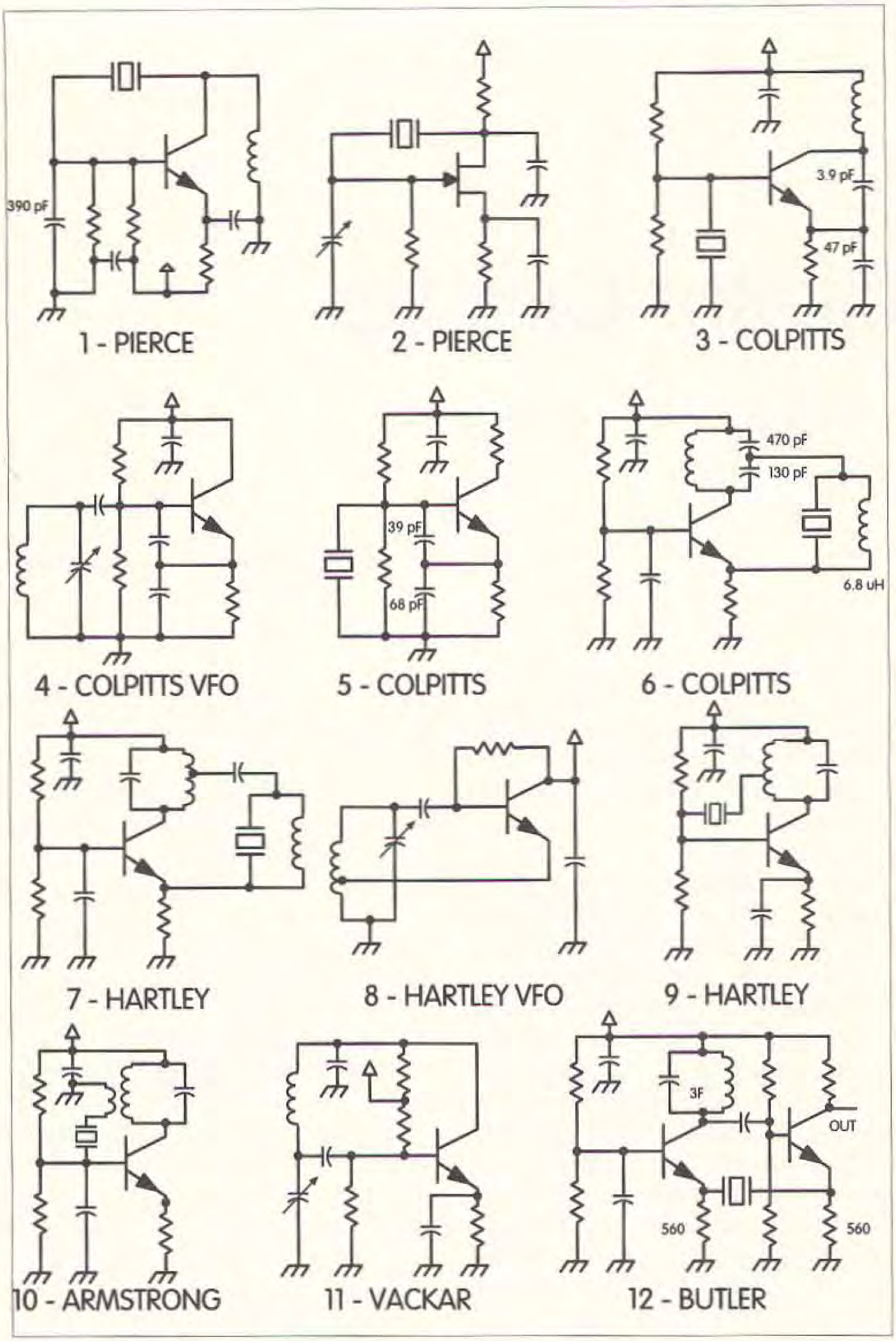

***Fig. 1.** Common—and not so common—transistorized oscillator circuits.*

The frequency stability is fair and totally dependent upon temperature and the mechanical stability of the components. It is a reliable oscillator with a wide operating frequency range from a few kilohertz to over 1 GHz.

Circuit 9: This unusual common-emitter Hartley oscillator requires the overtone crystal to operate essentially in the anti-resonant mode. However, overtone crystals are designed to operate in the shear mode which results in a resonant (series) function, yet this oscillator operates as designed by obtaining the required 180-degree phase shift across the inductance value between the collector and the crystal.

Circuit 10: Armstrong was a strong contributor to oscillator development, in addition to other radio accomplishments during the 1920s, '30s, and '40s. Characteristically, an Armstrong oscillator uses a tickler winding near the resonant circuit to obtain feedback for sustaining oscillation. In this circuit, the feedback will pass through the low impedance crystal when the operating frequency matches the resonant mode frequency of the crystal. The resonant circuit is tuned to match the overtone frequency of the crystal and can operate in the frequency range 12 MHz to 200 MHz.

Circuit 11: The Vackar oscillator is a rare design. It was developed after the advent of the transistor. This circuit takes advantage of a series-resonant circuit which has a low impedance to ground at each end and a high impedance in the middle. This high impedance point drives the base of the transistor. Note that the collector and emitter circuits are at a very low impedance to ground. Therefore, the transistor can only provide a current drive to the resonant circuit, which results in very good thermal isolation and frequency stability due to a non-dependency on transistor gain.

Circuit 12: The Butler oscillator was designed originally for use with vacuum tubes for the purpose of generating a high harmonic frequency output from a low- to medium-frequency crystal. Although the circuit shown will output the third harmonic of a resonant mode crystal (3rd, 5th, or 7th overtone), a tuned circuit originally existed in place of the 560 Ω resistor in the Butler design. The original output tuned circuit was tuned to the second harmonic of the "3F" circuit. The combination of the two tuned circuits provided a multiplier of six times the crystal frequency. The signal output amplitude was never quite as high as desired for a transmitter, but the circuit worked well when used for oscillator signal injection in a receiver, and was utilized as a stable, inexpensive local oscillator for VHF and UHF converters.

The circuits shown are only a few of the many oscillator designs developed over the years. However, those shown represent the basic design characteristics that have been the backbone of modern communications equipment. Recognizing an oscillator circuit by its designer's name enables an understanding of how the circuit functions and eases troubleshooting effort. Next time: the basics of frequency synthesizers.