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MICROELECTRONICS: Digital and Analog Circuits and Systems

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function $|\beta|$ is greater than unity at some particular frequency. In Prob. 17-26 we show an oscillator circuit consisting of a source follower and the RC circuit of Fig. 17-25 appropriately connected.

Variable-Frequency Operation

The phase-shift oscillator is particularly suited to the range of frequencies from several hertz to several hundred kilohertz, and so includes the range of audio frequencies. The frequency of oscillation may be varied by changing any of the impedance elements in the phase-shifting network. For variations of frequency over a large range, the three capacitors are usually varied simultaneously. Such a variation keeps the input impedance to the phase-shifting network constant (Prob. 17-23) and also keeps constant the magnitude of β and $A\beta$. Hence the amplitude of oscillation will not be affected as the frequency is adjusted. The phase-shift oscillator is operated in class A in order to keep distortion to a minimum.

Two active phase shifters may be used in place of the passive feedback network of Fig. 17-25c to obtain a sinusoidal oscillator with quadrature outputs, sine, and cosine waveforms (Prob. 17-30).

17-11 A GENERAL FORM OF OSCILLATOR CONFIGURATION

Many oscillator circuits fall into the general form shown in Fig. 17-26a. In the analysis that follows we assume an active device with extremely high input resistance such as a FET, or an operational amplifier. Figure 17-26b shows the

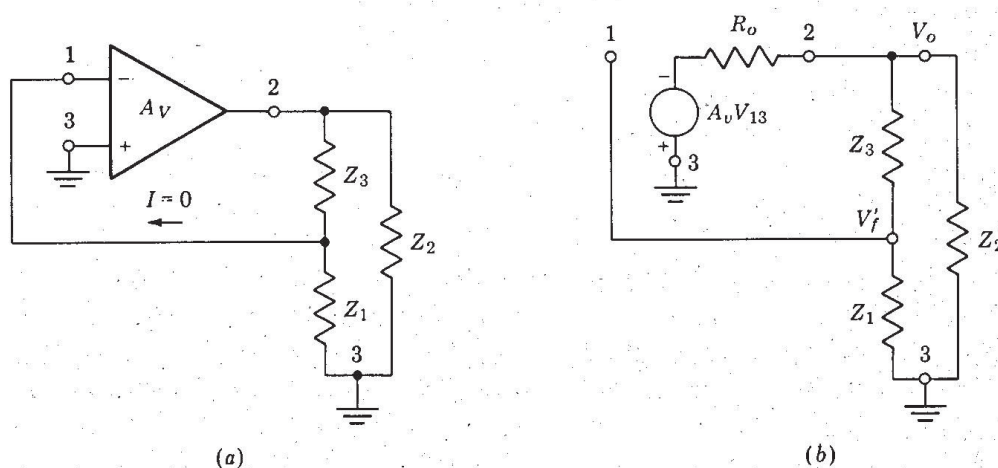


Figure 17-26 (a) The basic configuration for many resonant-circuit oscillators. (b) The linear equivalent circuit using an operational amplifier, having very high input resistance and an open-circuit voltage gain $-A_v$.

linear equivalent circuit of Fig. 17-26a, using an amplifier with an open-circuit negative gain $-A_o$ and output resistance R_o . Clearly the topology of Fig. 17-26 is that of voltage-series feedback.

The Loop Gain

The value of $-A\beta$ will be obtained by considering the circuit of Fig. 17-26a to be a feedback amplifier with output taken from terminals 2 and 3 and with input terminals 1 and 3. The load impedance Z_L consists of Z_2 in parallel with the series combination of Z_1 and Z_3 . The gain without feedback is $A = -A_o Z_L / (Z_L + R_o)$. The feedback factor is $\beta = -V_f' / V_o = -Z_1 / (Z_1 + Z_3)$. The loop gain is found to be

$$-A\beta = \frac{-A_o Z_1 Z_2}{R_o(Z_1 + Z_2 + Z_3) + Z_2(Z_1 + Z_3)} \quad (17-29)$$

Reactive Elements Z_1 , Z_2 , and Z_3

If the impedances are pure reactances (either inductive or capacitive), then $Z_1 = jX_1$, $Z_2 = jX_2$, and $Z_3 = jX_3$. For an inductor, $X = \omega L$, and for a capacitor, $X = -1/\omega C$. Then

$$-A\beta = \frac{+A_o X_1 X_2}{jR_o(X_1 + X_2 + X_3) - X_2(X_1 + X_3)} \quad (17-30)$$

For the loop gain to be real (zero phase shift),

$$X_1 + X_2 + X_3 = 0 \quad (17-31)$$

and

$$-A\beta = \frac{A_o X_1 X_2}{-X_2(X_1 + X_3)} = \frac{-A_o X_1}{X_1 + X_3} \quad (17-32)$$

From Eq. (17-31) we see that the circuit will oscillate at the resonant frequency of the series combination of X_1 , X_2 , and X_3 .

Using Eq. (17-31) in Eq. (17-32) yields

$$-A\beta = \frac{+A_o X_1}{X_2} \quad (17-33)$$

Since $-A\beta$ must be positive and at least unity in magnitude, then X_1 and X_2 must have the same sign (A_o is positive). In other words, they must be the same kind of reactance, either both inductive or both capacitive. Then, from Eq. (17-31), $X_3 = -(X_1 + X_2)$ must be inductive if X_1 and X_2 are capacitive, or vice versa.

If X_1 and X_2 are capacitors and X_3 is an inductor, the circuit is called a *Colpitts oscillator*. If X_1 and X_2 are inductors and X_3 is a capacitor, the circuit is called a *Hartley oscillator*. In this latter case, there may be mutual coupling between X_1 and X_2 (and the above equations will then not apply).

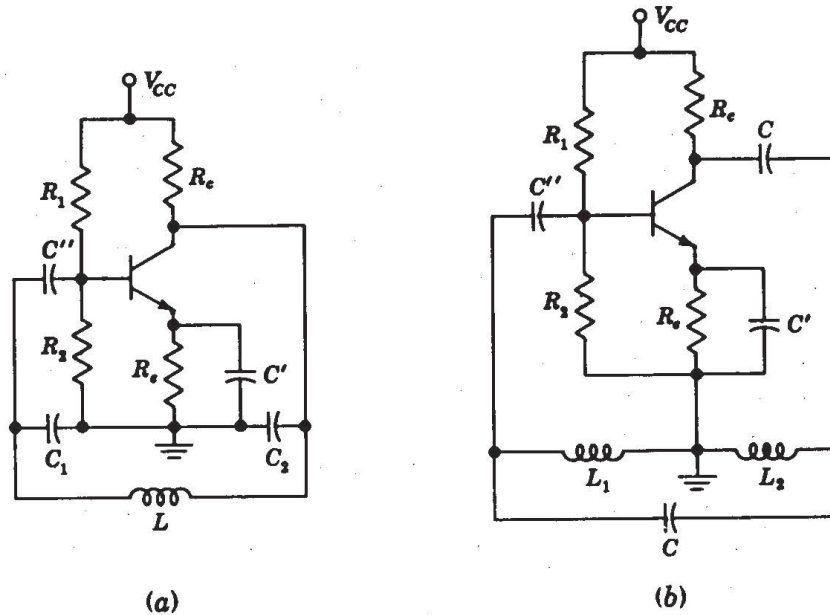


Figure 17-27 (a) A transistor Colpitts oscillator. (b) A transistor Hartley oscillator.

Transistor versions of the above types of LC oscillators are possible. As an example, a transistor Colpitts oscillator is indicated in Fig. 17-27a. Qualitatively, this circuit operates in the manner described above. However, the detailed analysis of a transistor oscillator circuit is more difficult, for two fundamental reasons. First, the low input impedance of the transistor shunts Z_1 in Fig. 17-26a, and hence complicates the expressions for the loop gain given above. Second, if the oscillation frequency is beyond the audio range, the simple low-frequency h -parameter model is no longer valid. Under these circumstances the more complicated high-frequency hybrid- π model of Fig. 13-10 must be used. A transistor Hartley oscillator is shown in Fig. 17-27b.

17-12 THE WIEN BRIDGE OSCILLATOR

An oscillator circuit in which a balanced bridge is used as the feedback network is the Wien bridge oscillator shown in Fig. 17-28a. The “bridge” is clearly indicated in Fig. 17-28b. The four arms of the bridge are Z_1 , Z_2 , R_1 , and R_2 . The input to the bridge is the output V_o of the OP AMP, and the output of the bridge between nodes 1 and 2 supplies the differential input to the OP AMP.

There are two feedback paths in Fig. 17-28a: *positive* feedback through Z_1 and Z_2 , whose components determine the frequency of oscillation, and *negative* feedback through R_1 and R_2 , whose elements affect the amplitude of oscillation. The loop gain is given by $-\beta A$ where

$$\beta = -\frac{V_f'}{V_o} = -\frac{Z_2}{Z_1 + Z_2} \quad \text{and} \quad A = 1 + \frac{R_1}{R_2}$$