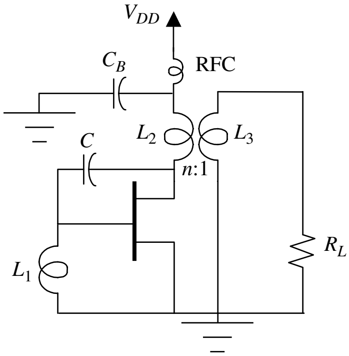

Figure 12.7 Hartley oscillator for Example 12.2.

Capacitor C_3 and total inductance $L_1 + L_2$ are determined such that (12.1.17) is satisfied at the desired frequency of oscillations. C_3 and L_2 satisfy (12.1.16) as well when the oscillator circuit operates. A Colpitts oscillator will require capacitors C_1 and C_2 in place of inductors and an inductor L_3 that replaces the capacitor C_3.

Example 12.2 The Hartley circuit shown in Figure 12.7 is oscillating at 150 MHz. If the transconductance g_m of the FET is 4.5 mS, the load resistance R_L is 50 Ω, and there is no coupling between L_1 and L_2 whereas L_2 and L_3 are tightly coupled, find the values of the circuit components.

SOLUTION RFC is used in this circuit to block, and the capacitor C_B to bypass, the RF signal. Thus, the unknown values are only L_1, L_2, L_3, and C. The load resistance R_L contributes to G_o via the coupling of L_2 and L_3 (see Example 8.17). If $L_1 = L_2 = 1\,\text{nH}$, then from (12.1.19), $G_o = g_m$. Therefore,

$$n = \sqrt{\frac{1}{G_o R_L}} = \sqrt{\frac{1}{4.5 \times 10^{-3} \times 50}} = 2.1082$$

For a tightly coupled case, (5.3.10) gives

$$L_3 = \frac{L_2}{n^2} = \frac{1}{2.1082^2}\,\text{nH} = 0.225\,\text{nH}$$

The capacitor C is found from (12.1.20) as follows:

$$C = \frac{1}{(L_1 + L_2)\omega^2} = \frac{1}{2 \times 10^{-9} \times (2\pi \times 150 \times 10^6)^2}\,\text{F} = 562.9\,\text{pF}$$

Example 12.3 The Colpitts oscillator shown in Figure 12.8 is oscillating at 200 MHz. The transconductance g_m of the FET is 4.5 mS, $R_D = 50\,\Omega$, $R_G =$

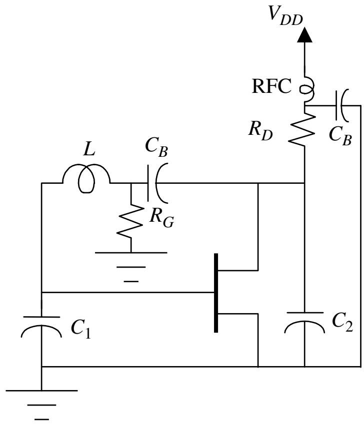

Figure 12.8 Colpitts oscillator for Example 12.3.

200 kΩ, and the two coupling capacitors C_B are large, to provide almost a short circuit for the signal. Find the values of the remaining components.

SOLUTION Capacitors C_B are large in value such that an RF signal is passed through almost unchanged. The resistor R_G provides a dc path to the gate. Resistors R_G and R_D appear in parallel at the output. Therefore,

$$R_o = \frac{1}{G_o} \approx \frac{R_G R_D}{R_G + R_D} = \frac{200 \times 10^3 \times 50}{200 \times 10^3 + 50} = 49.9875\,\Omega$$

From (12.1.19),

$$\frac{C_1}{C_2} = \frac{g_m}{G_o} = 4.5 \times 10^{-3} \times 49.9875 \to C_1 = 0.225C_2$$

and from (12.1.21),

$$\frac{C_1 + C_2}{C_1 C_2} = \frac{1}{C_2} + \frac{1}{C_1} = L\omega^2$$

Assuming that $L = 1$ nH, C_2 is found from the two equations above as follows:

$$C_2 = \frac{49}{9 \times 10^{-9} \times (2\pi \times 200 \times 10^6)^2} \text{F} = 3.4477\,\text{nF}$$

Therefore, $C_1 = 77.7$ pF. A BJT-based Colpitts oscillator is shown in Figure 12.9. Resistors R_{B1}, R_{B2}, and R_E are determined from the usual procedure of biasing a transistor. Reactance of the capacitor C_{B1} must be negligible compared with parallel resistances R_{B1} and R_{B2}. Similarly, the reactance of C_{B2} must be negligible compared with that of the inductor L_3. The purpose of capacitor C_{B2} is

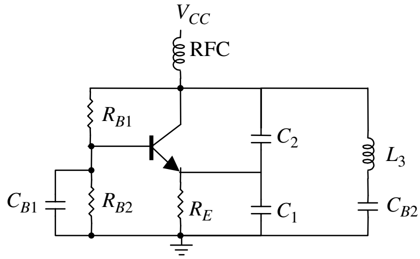

Figure 12.9 Biased BJT Colpitts oscillator circuit.

to protect the dc supply from short-circuiting via L_3 and RFC. Since capacitors C_{B1} and C_{B2} have negligible reactance, the ac equivalent of this circuit is the same as that shown in Figure 12.5(*b*). C_1, C_2, and L_3 are determined from the resonance condition (12.1.21). Also, (12.1.16) holds at the resonance.

As described in the preceding paragraph, capacitor C_{B2} provides almost a short circuit in the desired frequency range, and the inductor L_3 is selected such that (12.1.21) is satisfied. An alternative design procedure that provides better stability of the frequency is as follows. L_3 is selected larger than needed to satisfy (12.1.21), and then C_{B2} is determined to bring it down to the desired value at resonance. This type of circuit is called a *Clapp oscillator*. A FET-based Clapp oscillator circuit is shown in Figure 12.10. It is very similar to the Colpitts design and operation except for the selection of C_{B2}, which is connected in series with the inductor. At the design frequency, the series inductor–capacitor combination provides the same inductive reactance as that of the Colpitts circuit. However, if there is a drift in frequency, the reactance of this combination changes rapidly. This can be explained further with the help of Figure 12.11.

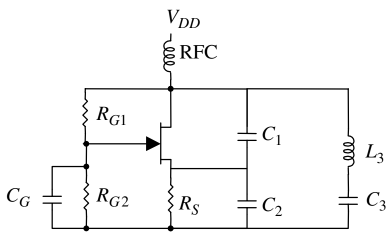

Figure 12.10 FET-based Clapp oscillator circuit.

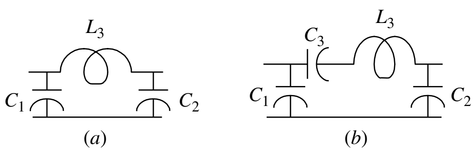

Figure 12.11 Resonant circuits for Colpitts (*a*) and Clapp (*b*) oscillators.

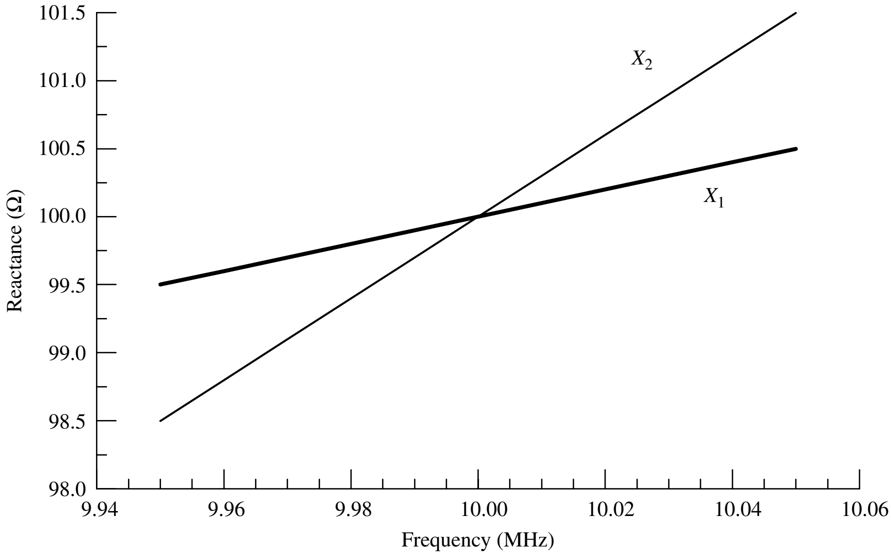

Figure 12.12 Reactance of inductive branch versus frequency for Colpitts (X_1) and Clapp (X_2) circuits.

Figure 12.11 illustrates the resonant circuits of Colpitts and Clapp oscillators. An obvious difference between the two circuits is the capacitor C_3, which is connected in series with L_3. Note that unlike C_3, the blocking capacitor C_{B2} shown in Figure 12.9 does not affect RF operation. Reactance X_1 of the series branch in the Colpitts circuit is ωL_3, whereas it is $X_2 = \omega L_3 - 1/\omega C_3$ in the case of the Clapp oscillator. If inductor L_3 in the former case is selected as 1.59 μH and the circuit is resonating at 10 MHz, the change in its reactance around resonance is as shown in Figure 12.12. The series branch of the Clapp circuit has the same inductive reactance at the resonance if $L_3 = 3.18$ μH and $C_3 = 159$ pF. However, the rate of change of reactance with frequency is now higher compared with X_1. This characteristic helps in reducing the drift in oscillation frequency.

Another Interpretation of the Oscillator Circuit

Ideal inductors and capacitors store electrical energy in the form of magnetic and electric fields, respectively. If such a capacitor with initial charge is connected across an ideal inductor, it discharges through that. Since there is no loss in this system, the inductor recharges the capacitor back and the process repeats. However, real inductors and capacitors are far from being ideal. Energy losses in the inductor and the capacitor can be represented by a resistance r_1 in this loop. Oscillations die out because of these losses. As shown in Figure 12.13, if a negative resistance $-r_1$ can be introduced in the loop, the effective resistance becomes zero. In other words, if a circuit can be devised to compensate for the