Colpitts Oscillator

In the Colpitts oscillator shown in Figure 1, Z_1 and Z_2 are capacitors and Z_3 is an inductor. The resistors R_1, R_2 and R_E provide the necessary dc bias to the transistor. C_E is a bypass capacitor. C_{C1} and C_{C2} are coupling capacitors. The feedback network consisting of capacitors C_1 and C_2 and an inductor L determines the frequency of the oscillator.

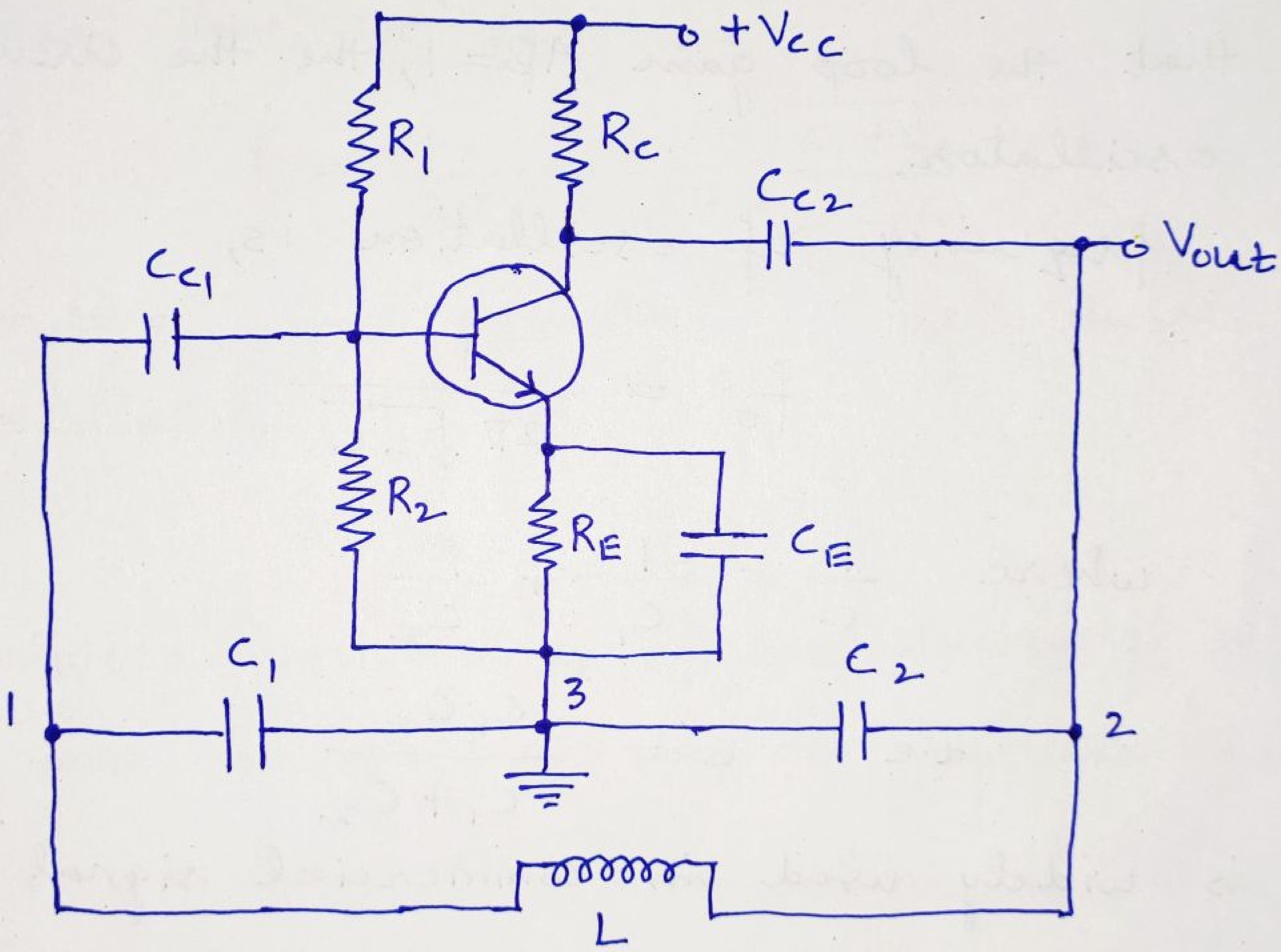

Figure 1. Colpitts Oscillator.

When the supply voltage +Vcc is switched ON, a transient current is produced in the tank circuit and consequently, damped oscillations are setup in the circuit. The oscillatory current in the tank circuit produces ac voltage across C_1 and C_2. As terminal 3 is earthed, it will be at zero potential. If terminal 1 is at a positive potential with respect to 3 at any instant, terminal 2 will be at a negative potential with respect to 3 at the same instant. Thus, the phase difference between the terminals 1 and 2 is always 180°. In the CE mode, the transistor provides the phase difference of 180° between the input and output. Therefore, the total phase shift is 360°. Thus, at the frequency determined for the tank circuit, the necessary condition for sustained oscillations is satisfied. If the feedback is adjusted so that the loop gain $A\beta = 1$, the the circuit acts as an oscillator.

The frequency of oscillation is,

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

where $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

i.e $C = \frac{C_1 C_2}{C_1 + C_2}$

It is widely used in commercial signal generators for frequencies between 1 MHz and 500 MHz. It is also used as a local oscillator in superheterodyne radio receiver.

<u>Analysis</u> : For this oscillator

$$Z_1 = \frac{1}{j\omega C_1} = -\frac{j}{\omega C_1}$$

$$Z_2 = \frac{1}{j\omega C_2} = -\frac{j}{\omega C_2}$$

$$Z_3 = j\omega L$$

Substituting these values in the general equation of oscillators,

i.e $$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0$$

$$\therefore \quad -j h_{ie}\left(\frac{1}{\omega C_1} + \frac{1}{\omega C_2} - \omega L\right) + \left(\frac{1 + h_{fe}}{\omega^2 C_1 C_2} - \frac{L}{C_1}\right) = 0$$

The frequency of oscillation $f_o = \frac{\omega_o}{2\pi}$ is found by equating the imaginary part of above equation to zero. Thus, we get

$$f_o = \frac{\omega_o}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

Substituting above equation in the general equation for oscillator,

$$h_{fe} = \frac{C_2}{C_1}$$

In Colpitts oscillator, if the loading effect of the base is ignored, then the feedback fraction becomes $\beta = \frac{C_2}{C_1}$. For oscillations to occur, the voltage gain A_v must be greater than $\frac{1}{\beta}$, i.e $A_v > \frac{C_1}{C_2}$.

Q1. In the Hartley oscillator, $L_1 = 0.4\,mH$ and $C = 0.004\,\mu F$. If the frequency of the oscillator is 120 KHz, find the value of L_2. Neglect the mutual inductance.

Solution: The frequency of Hartley oscillator is given by

$$f_o = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

There fore, $$L_2 = \frac{1}{4\pi^2 f_o^2 C} - L_1$$

$$L_2 = \frac{1}{4\pi^2 (120\times10^3)^2 \times 0.004\times10^{-6}} - 0.4\times10^{-3}$$

$$L_2 = 0.44\times10^{-3} - 0.4\times10^{-3} = 0.04\ mH.$$

Q2. In the Colpitts oscillator, $C_1 = 0.2\,\mu F$ and $C_2 = 0.02\,\mu F$. If the frequency of the oscillator is 10 KHz, find the value of the inductor. Also find the required gain for oscillation.

Solution: The frequency of the Colpitts oscillator is given by

$$f_o = \frac{1}{2\pi}\sqrt{\frac{C_1+C_2}{LC_1C_2}}$$

Therefore, $$L = \frac{C_1+C_2}{4\pi^2 f_o^2 C_1C_2}$$

$$L = \frac{0.22\times10^{-6}}{4\pi^2\times(10\times10^3)^2\times0.2\times10^{-6}\times0.02\times10^{-6}}$$

$$L = 13.932\ mH.$$

The voltage gain required to produce oscillation is,

$$A_V > \frac{C_1}{C_2} = \frac{0.2\times10^{-6}}{0.02\times10^{-6}} = 10$$

Q.3. In a Hartley oscillator, the two inductances are 20 uH and 2 mH while the frequency is to be changed from 950 KHz to 2050 KHz. Calculate the range over which the capacitor is to be varied.

Solution: Given for a Hartley Oscillator,

$$L_1 = 20\ \mu H$$

$$L_2 = 2\ mH$$

$$f_1 = 950\ KHz$$

$$f_2 = 2050\ KHz$$

Now, frequency of oscillations of the Hartley oscillator is

$$f_o = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

$$\therefore \quad C = \frac{1}{4\pi^2 (L_1+L_2) f_o^2}$$

When $f_o = 950$ KHz,

$$C = \frac{1}{4\pi^2 [20\times10^{-6} + 2\times10^{-3}](950\times10^3)^2} = 13.89\ pF$$

When $f_o = 2050$ KHz,

$$C = \frac{1}{4\pi^2 [20\times10^{-6} + 2\times10^{-3}](2050\times10^3)^2} = 2.98\ pF$$

Hence, the range of capacitance is from 2.98 pF to 13.89 pF.

Q.4. A Colpitts oscillator is designed with $C_1 = 7500$ pF and $C_2 = 100$ pF. The inductance is variable. Determine the range of inductance values, if the frequency of oscillation is to vary between 950 KHz and 2050 KHz. (6)

Solution: Given $C_1 = 7500\,pF$, $C_2 = 100\,pF$

$$\therefore \quad C = \frac{C_1 C_2}{C_1 + C_2} = 98.68 \times 10^{-12}\,F$$

Now, for Colpitts oscillator,

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

or,
$$L = \frac{1}{4\pi^2 . C . f_o^2}$$

When $f_o = 950$ KHz,

$$L = \frac{1}{4\pi^2 [98.68 \times 10^{-12}][950 \times 10^3]^2}$$

$$L = 284\,\mu H$$

When $f_o = 2050$ KHz,

$$L = \frac{1}{4\pi^2 [98.68 \times 10^{-12}][2050 \times 10^3]^2}$$

$$L = 61\,\mu H$$

Hence, the range of inductance required is from 61 μH to 284 μH.

MCQ

Q1. Which of the following network is used to give feedback to transistor in Colpitts Oscillator?

(a) inductive fixed bias
(b) capacitive fixed bias
(c) inductive voltage divider
(d) capacitive voltage divider

Q2. How many capacitors are there in the tank circuit of Colpitts oscillator?

(a) 1 (b) 2 (c) 3 (d) 0

Q3. How many inductors are there in the tank circuit of Colpitts oscillator?

(a) 1 (b) 2 (c) 3 (d) 0

Q4. Active element used in Colpitts oscillator is

(a) Cell
(b) Voltage regulator
(c) Diode
(d) Transistor

Q5. Capacitive circuit configuration in Colpitts oscillator improves

(a) Bulkiness
(b) Frequency stability
(c) Impedance
(d) Appearance