

14.9 Tuned Collector Oscillator

Fig. 14.9 shows the circuit of tuned collector oscillator. It contains tuned circuit L_1 - C_1 in the collector and hence the name. The frequency of oscillations depends upon the values of L_1 and C_1 and is given by :

$$f = \frac{1}{2\pi\sqrt{L_1 C_1}} \quad \dots(i)$$

The feedback coil L_2 in the base circuit is magnetically coupled to the tank circuit coil L_1 . In practice, L_1 and L_2 form the primary and secondary of the transformer respectively. The biasing is provided by potential divider arrangement. The capacitor C connected in the base circuit provides low reactance path to the oscillations.

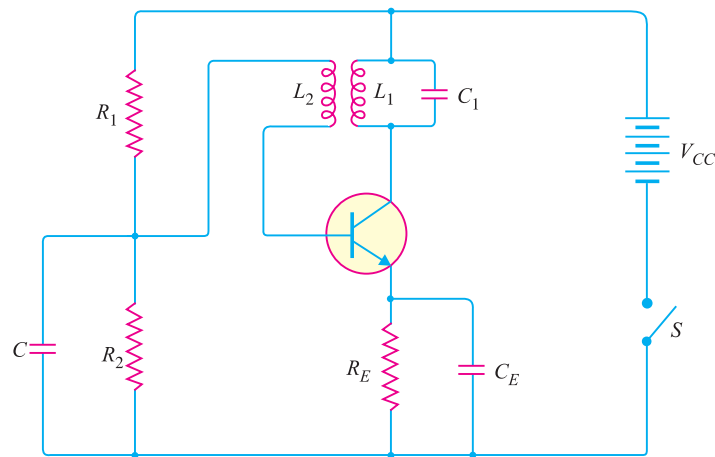


Fig. 14.9

Circuit operation. When switch S is closed, collector current starts increasing and charges the capacitor C_1 . When this capacitor is fully charged, it discharges through coil L_1 , setting up oscillations of frequency determined by exp. (i). These oscillations induce some voltage in coil L_2 by mutual induction. The frequency of voltage in coil L_2 is the same as that of tank circuit but its magnitude depends upon the number of turns of L_2 and coupling between L_1 and L_2 . The voltage across L_2 is applied between base and emitter and appears in the amplified form in the collector circuit, thus overcoming the losses occurring in the tank circuit. The number of turns of L_2 and coupling between L_1 and L_2 are so adjusted that oscillations across L_2 are amplified to a level just sufficient to supply losses to the tank circuit.

It may be noted that the phase of feedback is correct *i.e.* energy supplied to the tank circuit is in phase with the generated oscillations. A phase shift of 180° is created between the voltages of L_1 and L_2 due to transformer *action. A further phase shift of 180° takes place between base-emitter and collector circuit due to transistor properties. As a result, the energy feedback to the tank circuit is in phase with the generated oscillations.

Example 14.1. The tuned collector oscillator circuit used in the local oscillator of a radio

* All transformers introduce a phase shift of 180° between primary and secondary.

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receiver makes use of an LC tuned circuit with $L_1 = 58.6 \mu\text{H}$ and $C_1 = 300 \text{ pF}$. Calculate the frequency of oscillations.

Solution.

$$L_1 = 58.6 \mu\text{H} = 58.6 \times 10^{-6} \text{ H}$$

$$C_1 = 300 \text{ pF} = 300 \times 10^{-12} \text{ F}$$

$$\begin{aligned} \text{Frequency of oscillations, } f &= \frac{1}{2\pi \sqrt{L_1 C_1}} \\ &= \frac{1}{2\pi \sqrt{58.6 \times 10^{-6} \times 300 \times 10^{-12}}} \text{ Hz} \\ &= 1199 \times 10^3 \text{ Hz} = \mathbf{1199 \text{ kHz}} \end{aligned}$$

Example 14.2. Find the capacitance of the capacitor required to build an LC oscillator that uses an inductance of $L_1 = 1 \text{ mH}$ to produce a sine wave of frequency 1 GHz ($1 \text{ GHz} = 1 \times 10^{12} \text{ Hz}$).

Solution.

Frequency of oscillations is given by ;

$$f = \frac{1}{2\pi \sqrt{L_1 C_1}}$$

or

$$\begin{aligned} C_1 &= \frac{1}{L_1 (2\pi f)^2} = \frac{1}{(1 \times 10^{-3}) (2\pi \times 1 \times 10^{12})^2} \\ &= 2.53 \times 10^{-23} \text{ F} = \mathbf{2.53 \times 10^{-11} \text{ pF}} \end{aligned}$$

The LC circuit is often called *tuned circuit* or *tank circuit*.

14.10 Colpitt's Oscillator

Fig. 14.10 shows a Colpitt's oscillator. It uses two capacitors and placed across a common inductor L and the centre of the two capacitors is tapped. The tank circuit is made up of C_1 , C_2 and L . The frequency of oscillations is determined by the values of C_1 , C_2 and L and is given by ;

$$f = \frac{1}{2\pi \sqrt{LC_T}} \quad \dots(i)$$

where

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

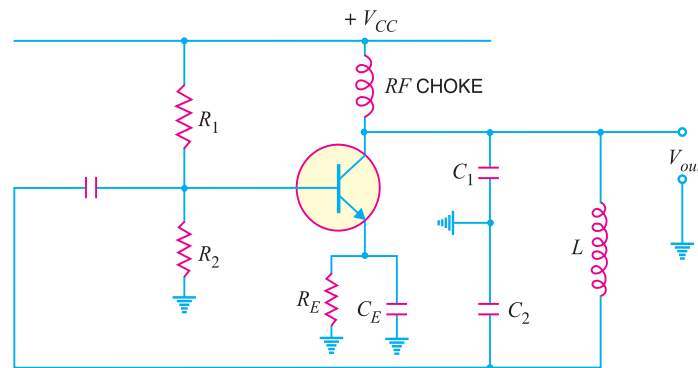


Fig. 14.10

*Note that $C_1 - C_2 - L$ is also the feedback circuit that produces a phase shift of 180° .

Circuit operation. When the circuit is turned on, the capacitors C_1 and C_2 are charged. The capacitors discharge through L , setting up oscillations of frequency determined by exp.** (i). The output voltage of the amplifier appears across C_1 and feedback voltage is developed across C_2 . The voltage across it is 180° out of phase with the voltage developed across C_1 (V_{out}) as shown in Fig. 14.11. It is easy to see that voltage feedback (voltage across C_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the transistor and a further phase shift of 180° is produced by $C_1 - C_2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillation.

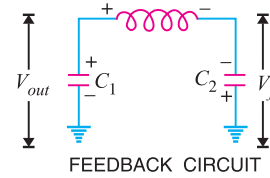


Fig. 14.11

Feedback fraction m_v . The amount of feedback voltage in Colpitt's oscillator depends upon feedback fraction m_v of the circuit. For this circuit,

$$\text{Feedback fraction, } m_v = \frac{V_f}{V_{out}} = \frac{X_{c2}}{X_{c1}} = \frac{C_1}{C_2}^{***}$$

$$\text{or } m_v = \frac{C_1}{C_2}$$

Example 14.3. Determine the (i) operating frequency and (ii) feedback fraction for Colpitt's oscillator shown in Fig. 14.12.

Solution.

(i) Operating Frequency. The operating frequency of the circuit is always equal to the resonant frequency of the feedback network. As noted previously, the capacitors C_1 and C_2 are in series.

$$\begin{aligned} \therefore C_T &= \frac{C_1 C_2}{C_1 + C_2} = \frac{0.001 \times 0.01}{0.001 + 0.01} = 9.09 \times 10^{-4} \mu\text{F} \\ &= 909 \times 10^{-12} \text{ F} \end{aligned}$$

$$L = 15 \mu\text{H} = 15 \times 10^{-6} \text{ H}$$

$$\begin{aligned} \therefore \text{Operating frequency, } f &= \frac{1}{2\pi \sqrt{LC_T}} \\ &= \frac{1}{2\pi \sqrt{15 \times 10^{-6} \times 909 \times 10^{-12}}} \text{ Hz} \\ &= 1361 \times 10^3 \text{ Hz} = \mathbf{1361 \text{ kHz}} \end{aligned}$$

(ii) Feedback fraction

$$m_v = \frac{C_1}{C_2} = \frac{0.001}{0.01} = \mathbf{0.1}$$

* The RF choke decouples any ac signal on the power lines from affecting the output signal.

** Referring to Fig. 14.11, it is clear that C_1 and C_2 are in series. Therefore, total capacitance C_T is given by;

$$C_T = \frac{C_1 C_2}{C_1 + C_2}$$

*** Referring to Fig. 14.11, the circulating current for the two capacitors is the same. Further, capacitive reactance is inversely proportional to capacitance.

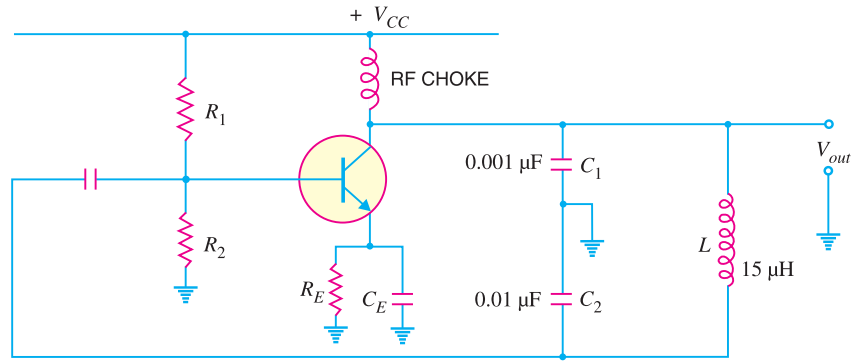


Fig. 14.12

Example 14.4. A 1 mH inductor is available. Choose the capacitor values in a Colpitts oscillator so that $f = 1$ MHz and $m_v = 0.25$.

Solution.

Feedback fraction, $m_v = \frac{C_1}{C_2}$

or $0.25 = \frac{C_1}{C_2} \quad \therefore C_2 = 4C_1$

Now $f = \frac{1}{2\pi\sqrt{LC_T}}$

or $C_T = \frac{1}{L(2\pi f)^2} = \frac{1}{(1 \times 10^{-3})(2\pi \times 1 \times 10^6)^2} = 25.3 \times 10^{-12} \text{ F}$
 $= 25.3 \text{ pF}$

or $\frac{C_1 C_2}{C_1 + C_2} = 25.3 \text{ pF} \quad \left[\because C_T = \frac{C_1 C_2}{C_1 + C_2} \right]$

or $\frac{C_2}{1 + \frac{C_2}{C_1}} = 25.3$

or $\frac{C_2}{1 + 4} = 25.3 \quad \therefore C_2 = 25.3 \times 5 = \mathbf{126.5 \text{ pF}}$

and $C_1 = C_2/4 = 126.5/4 = \mathbf{31.6 \text{ pF}}$

14.11 Hartley Oscillator

The Hartley oscillator is similar to Colpitt's oscillator with minor modifications. Instead of using tapped capacitors, two inductors L_1 and L_2 are placed across a common capacitor C and the centre of the inductors is tapped as shown in Fig. 14.13. The tank circuit is made up of L_1 , L_2 and C . The frequency of oscillations is determined by the values of L_1 , L_2 and C and is given by :

$$f = \frac{1}{2\pi\sqrt{CL_T}} \quad \dots(i)$$

where $L_T = L_1 + L_2 + 2M$

Here M = mutual inductance between L_1 and L_2

Note that $L_1 - L_2 - C$ is also the feedback network that produces a phase shift of 180° .

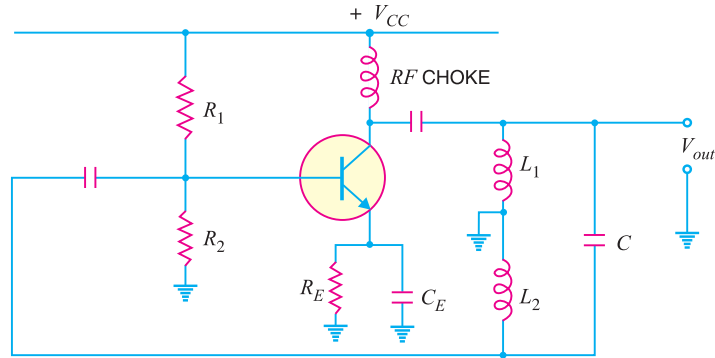


Fig. 14.13

Circuit operation. When the circuit is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils L_1 and L_2 setting up oscillations of frequency determined by *exp. (i). The output voltage of the amplifier appears across L_1 and feedback voltage across L_2 . The voltage across L_2 is 180° out of phase with the voltage developed across L_1 (V_{out}) as shown in Fig. 14.14. It is easy to see that voltage feedback (*i.e.*, voltage across L_2) to the transistor provides positive feedback. A phase shift of 180° is produced by the $L_1 - L_2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

Feedback fraction m_v . In Hartley oscillator, the feedback voltage is across L_2 and output voltage is across L_1 .

$$\therefore \text{Feedback fraction, } m_v = \frac{V_f}{V_{out}} = \frac{X_{L_2}}{X_{L_1}} = \frac{L_2}{L_1} \quad **$$

or

$$m_v = \frac{L_2}{L_1}$$

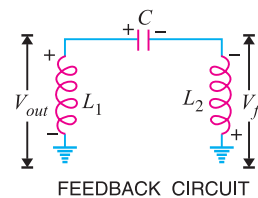


Fig. 14.14

Example 14.5. Calculate the (i) operating frequency and (ii) feedback fraction for Hartley oscillator shown in Fig. 14.15. The mutual inductance between the coils, $M = 20 \mu\text{H}$.

Solution.

$$\begin{aligned} (i) \quad L_1 &= 1000 \mu\text{H}; \quad L_2 = 100 \mu\text{H}; \quad M = 20 \mu\text{H} \\ \therefore \text{Total inductance, } L_T &= L_1 + L_2 + 2M \\ &= 1000 + 100 + 2 \times 20 = 1140 \mu\text{H} = 1140 \times 10^{-6} \text{H} \\ \text{Capacitance, } C &= 20 \text{ pF} = 20 \times 10^{-12} \text{F} \end{aligned}$$

* Referring to Fig. 14.14, it is clear that L_1 and L_2 are in series. Therefore, total inductance L_T is given by : $L_T = L_1 + L_2 + 2M$

** Referring to Fig. 14.14, the circulating current for the two inductors is the same. Further, inductive reactance is directly proportional to inductance.