SHREE H. N. SHUKLA GROUP OF COLLEGES

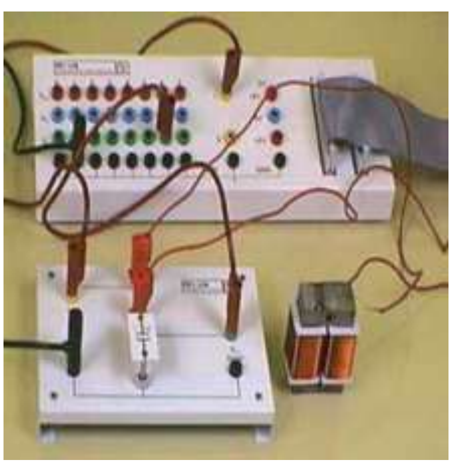
S.Y.B.Sc. SEM – IV

Subject: Physics

Paper- 401

Unit -5

OSCILLATOR



- Introduction
- Sinusoidal oscillator
- Types of oscillator
- Hartely oscillator
- Colpitt's oscillator
- RC phase oscillator
- Wein bridge oscillator

INTRODUCTION:

SINUSOIDAL OSCILLATOR :

- ***"An electronic device that generates sinusoidal oscillations of desired frequency is known as a *sinusoidal oscillator. "***
- Although we speak of an oscillator as "generating" a frequency, it should be noted that it does not create energy, but merely acts as an energy converter. It receives d.c. energy and changes it into a.c. energy of desired frequency. The frequency of oscillations depends upon the constants of the device.
- Firstly, an alternator is a mechanical device having rotating parts whereas an oscillator is a non-rotating electronic device. Secondly, an alternator converts mechanical energy into a.c. energy while an oscillator converts d.c. energy into a.c. energy. Thirdly, an alternator cannot produce high frequency oscillations whereas an oscillator can produce oscillations ranging from a few Hz to several MHz.

Advantages:

(i) An oscillator is a non-rotating device. Consequently, there is little wear and tear and hence longer life.

(ii) Due to the absence of moving parts, the operation of an oscillator is quite silent.

(iii) An oscillator can produce waves from small (20 Hz) to extremely high frequencies (> 10 MHz).

(iv) The frequency of oscillations can be easily changed when desired.

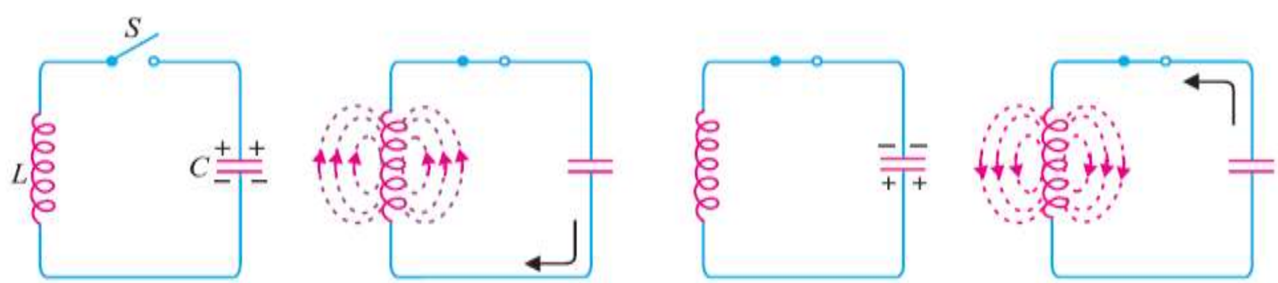
(v) It has good frequency stability *i.e.* frequency once set remains constant for a considerable period of time.

(vi) It has very high efficiency.

OSCILLATORY CIRCUIT :

- ***" A circuit which produces electrical oscillations of any desired frequency is known as an oscillatory circuit or tank circuit."***

- A simple oscillatory circuit consists of a capacitor (C) and inductance coil (L) in parallel as shown in Fig. This electrical system can produce electrical oscillations of frequency determined by the values of L and C. To understand how this comes about, suppose the capacitor is charged from a d.c. source with a polarity as shown in Fig. (i).



TYPES OF OSCILLATOR :

- The following are the transistor oscillators commonly used at various places in electronic circuits :

  (i) Colpitt's oscillator

  (ii) Hartley oscillator

  (iii) Phase shift oscillator

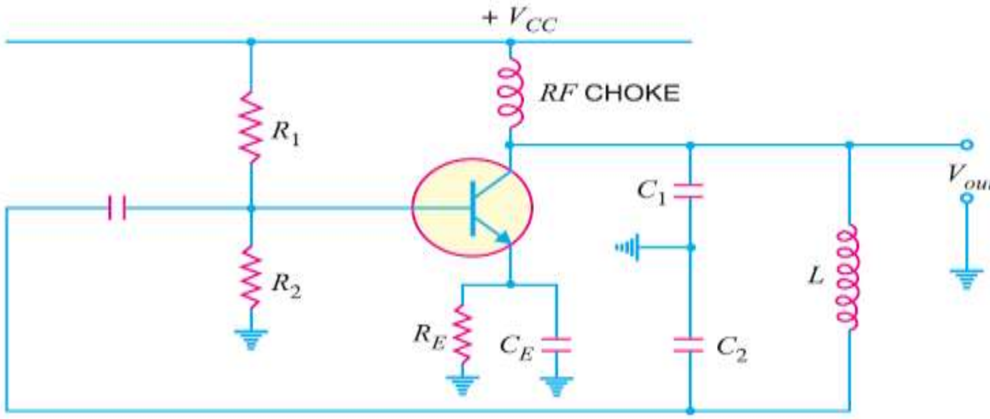
  (iv) Wien Bridge oscillator

COLPITT'S OSCILLATOR :

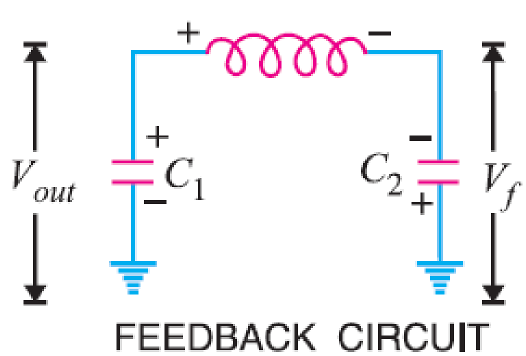
- Fig. shows a Colpitt's oscillator. It uses two capacitors and placed across a common inductor L and the centre of the two capacitors is tapped.
- The tank circuit is made up of $C1$, $C2$ and L. The frequency of oscillations is determined by the values of $C1$, $C2$ and L and is given by ;

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

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



- **CIRCUIT OPERATION :**



- When the circuit is turned on, the capacitors $C1$ and $C2$ are charged. The capacitors discharge through L, setting up oscillations of frequency determined by exp.** (i).
- The output voltage of the amplifier appears across $C1$ and feedback voltage is developed across $C2$. The voltage across it is 180° out of phase with the voltage developed across $C1$ ($Vout$) as shown in Fig. It is easy to see that voltage fedback (voltage across $C2$) 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 $C1 - C2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillation.
- **FEEDBACK FRACTION :**

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

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

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

- **Determine the (i) operating frequency and (ii) feedback fraction for Colpitt's oscillator.**

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

Operating frequency, $f = \dfrac{1}{2\pi\sqrt{LC_T}}$

$$= \frac{1}{2\pi\sqrt{15 \times 10^{-6} \times 909 \times 10^{-12}}}\ \text{Hz}$$

$$= 1361 \times 10^3\ \text{Hz} = \mathbf{1361\ kHz}$$

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

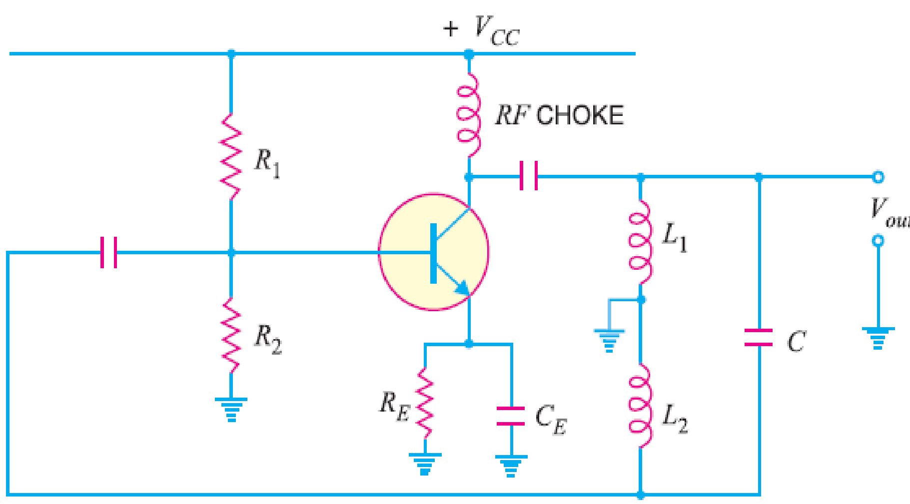
HARTELY'S OSCILLATOR :

- The Hartley oscillator is similar to Colpitt's oscillator with minor modifications. Instead of using tapped capacitors, two inductors $L1$ and $L2$ are placed across a common capacitor C and the centre of the inductors is tapped as shown in Fig. The tank circuit is made up of $L1$, $L2$ and C. The frequency of oscillations is determined by the values of $L1$, $L2$ and C and is given by :

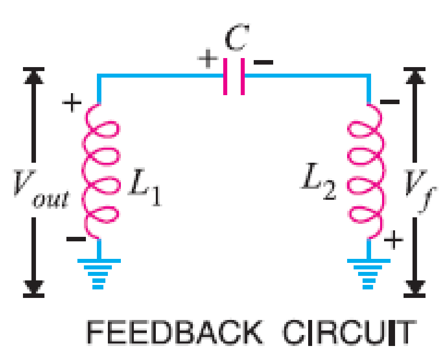
$$f = \frac{1}{2\pi\sqrt{CL_T}}$$

$$L_T = L_1 + L_2 + 2M$$

M = mutual inductance between L_1 and L_2



CIRCUIT OPERATION :



- When the circuit is turned on, the capacitor is charged. When this capacitor is fully charged, it discharges through coils $L1$ and $L2$ setting up oscillations of frequency determined by *exp. (i). The output voltage of the amplifier appears across $L1$ andfeedback voltage across $L2$.

- The voltage across $L2$ is 180° out of phase with the voltage developed across $L1$ ($Vout$) as shown in Fig. It is easy to see that voltage fedback (*i.e.*, voltage across $L2$) 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 $L1 - L2$ voltage divider. In this way, feedback is properly phased to produce continuous undamped oscillations.

- **Feedback fraction mv ;** In Hartley oscillator, the feedback voltage is across $L2$ and output voltage is across $L1$.

$$m_v = \frac{V_f}{V_{out}} = \frac{X_{L_2}}{X_{L_1}} = {}^{**}\frac{L_2}{L_1}$$

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

- **EXAMPLE :**

- Calculate the (i) operating frequency and (ii) feedback fraction for Hartley oscillator:

$$L_1 = 1000\ \mu\text{H};\quad L_2 = 100\ \mu\text{H};\quad M = 20\ \mu\text{H}$$

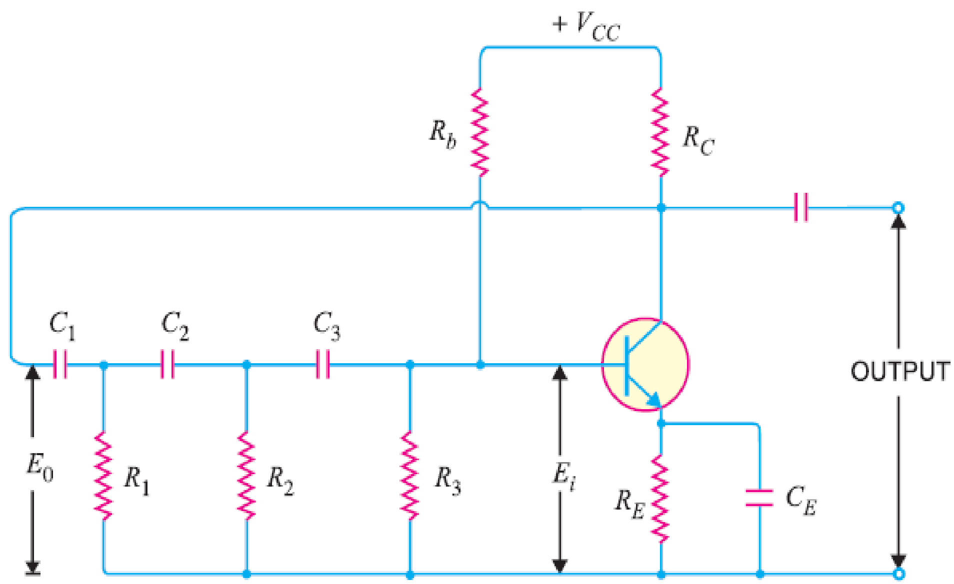
$$\text{Total inductance, } L_T = L_1 + L_2 + 2M$$

$$= 1000 + 100 + 2 \times 20 = 1140\ \mu\text{H} = 1140 \times 10^{-6}\text{H}$$

$$\text{Capacitance, } C = 20\ \text{pF} = 20 \times 10^{-12}\ \text{F}$$

PHASE SHIFT OSCILLATOR :

- Fig. shows the circuit of a phase shift oscillator. It consists of a conventional single transistor amplifier and a *RC* phase shift network.
- The phase shift network consists of three sections R_1C_1, R_2C_2 and R_3C_3.
- At some particular frequency f_0, the phase shift in each *RC* section is 60º so that the total phase-shift produced by the *RC* network is 180º.
- The frequency of oscillations is given by :



$$f_0 = \frac{1}{2\pi RC\sqrt{6}}$$

$$R_1 = R_2 = R_3 = R$$

$$C_1 = C_2 = C_3 = C$$

CIRCUIT OPERATION :

- When the circuit is switched on, it produces oscillations of frequency determined by exp. (*i*). The output *E*0 of the amplifier is fed back to *RC* feedback network.

- This network produces a phase shift of 180º and a voltage *Ei* appears at its output which is applied to the transistor amplifier.
- Obviously, the feedback fraction *m* = *Ei* /*E*0. The feedback phase is correct. A phase shift of 180º is produced by the transistor amplifier. A further phase shift of 180º is produced by the *RC* network. As a result, the phase shift around the entire loop is 360º.

Advantages:

(*i*) It does not require transformers or inductors.

(*ii*) It can be used to produce very low frequencies.

(*iii*) The circuit provides good frequency stability.

Disadvantages:

(*i*) It is difficult for the circuit to start oscillations as the feedback is generally small.

(*ii*) The circuit gives small output.

EXAMPLE :

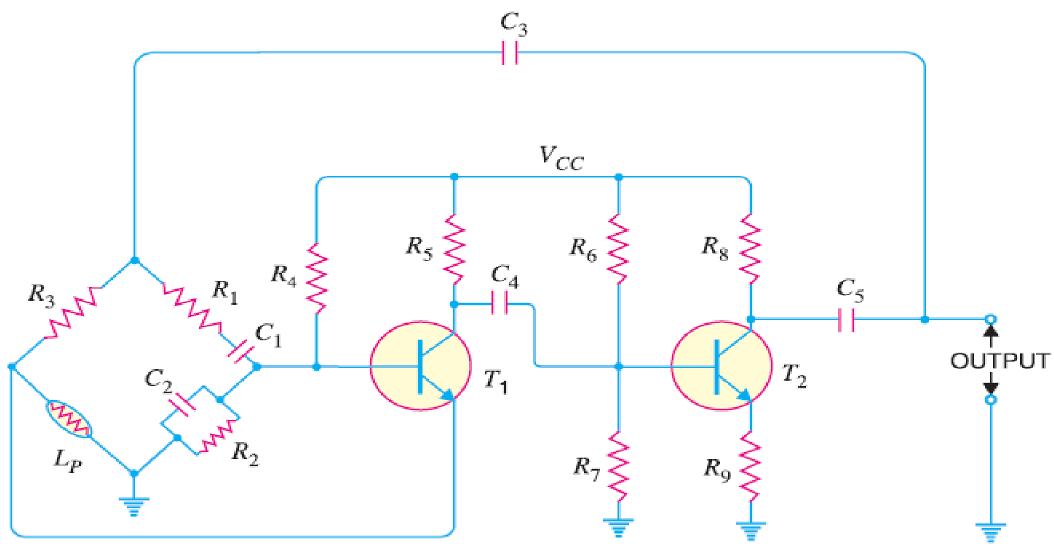
- *In the phase shift oscillator shown in Fig. 14.17, R1 = R2 = R3 = 1MΩ and C1 = C2 = C3 = 68 pF. At what frequency does the circuit oscillate ?*

ANSWER:

$$R_1 = R_2 = R_3 = R = 1\,M\Omega = 10^6\,\Omega$$
$$C_1 = C_2 = C_3 = C = 68\,pF = 68 \times 10^{-12}\,F$$

$$f_o = \frac{1}{2\pi\, RC\sqrt{6}}$$
$$= \frac{1}{2\pi \times 10^6 \times 68 \times 10^{-12}\sqrt{6}}\ \text{Hz}$$
$$= \mathbf{954\ Hz}$$

WEIN BRIDGE OSCILLATOR :



- The Wien-bridge oscillator is the standard oscillator circuit for all frequencies in the range of 10 Hz to about 1 MHz. It is the most frequently used type of audio oscillator as the output is free from circuit fluctuations and ambient temperature.
- Fig. shows the circuit of Wien bridge oscillator. It is essentially a two-stage amplifier with *R-C* bridge circuit. The bridge circuit has the arms R_1C_1, $R3$, $R2C2$ and tungsten lamp *Lp*. Resistances $R3$ and *Lp* are used to stabilise the amplitude of the output.
- The transistor $T1$ serves as an oscillator and amplifier while the other transistor $T2$ serves as an inverter (*i.e*. to produce a phase shift of 180º). The circuit uses positive and negative feedbacks. The positive feedback is through $R1C1$, $C2R2$ to the transistor $T1$.
- The negative feedback is through the voltage divider to the input of transistor $T2$. The frequency of oscillations is determined by the series element $R1C1$ and parallel element $R2C2$ of the bridge.

$$f = \frac{1}{2\pi\sqrt{R_1 C_1 R_2 C_2}}$$

If $R_1 = R_2 = R$

and $C_1 = C_2 = C$, then,

$$f = \frac{1}{2\pi RC} \qquad ...(i)$$

- When the circuit is started, bridge circuit produces oscillations of frequency determined by exp. (*i*). The two transistors produce a total phase shift of 360º so that proper positive feedback is ensured.
- The negative feedback in the circuit ensures constant output. This is achieved by the temperature sensitive tungsten lamp *Lp*. Its resistance increases with current. Should the amplitude of output tend to increase, more current would provide more negative feedback.
- The result is that the output would return to original value. A reverse action would take place if the output tends to decrease.

Advantages:

(*i*) It gives constant output.

(*ii*) The circuit works quite easily.

(*iii*) The overall gain is high because of two transistors.

(*iv*) The frequency of oscillations can be easily changed by using a potentiometer.

Disadvantages

(*i*) The circuit requires two transistors and a large number of components.

(*ii*) It cannot generate very high frequencies.

Chapter Review Topics

1. What is an oscillator ? What is its need ? Discuss the advantages of oscillators.
2. What do you understand by damped and undamped electrical oscillations ? Illustrate your answer with examples.
3. Explain the operation of a tank circuit with neat diagrams.
4. What is the nature of oscillations produced by tank circuit ?
5. How will you get undamped oscillations from a tank circuit ?
6. Discuss the essentials of an oscillator.
7. Discuss the circuit operation of tuned collector oscillator.
8. With a neat diagram, explain the action of Hartley and Colpitt's oscillators.
9. What are the drawbacks of LC oscillators ?
10. Write short notes on the following :

    (*i*) *RC* oscillators (*ii*) Wien bridge oscillators (*iii*) Crystal oscillator