Unit- 4

Sinusoidal Oscillator

Electronics Oscillator

⇒ Positive feedback

$$A_f = \frac{A}{1 - A\beta}$$

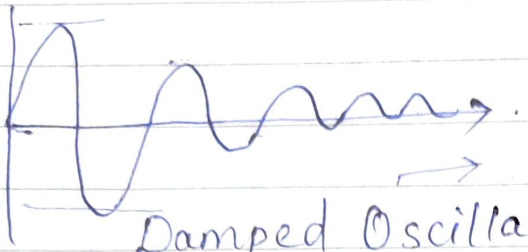
Negative feedback

$$A_f = \frac{A}{1 + A\beta}$$

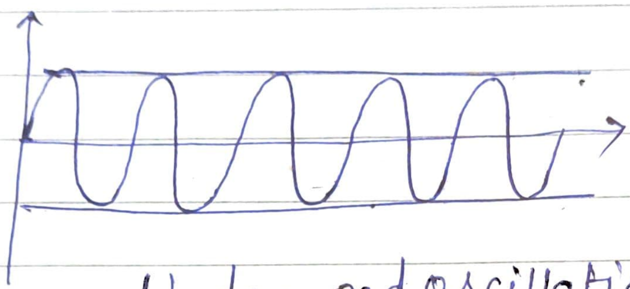
An electronic device that generates sinusoidal oscillations of desired frequency is known as sinusoidal oscillator.

Types of Sinusoidal Oscillations

1. Damped Oscillations
2. Undamped oscillations.

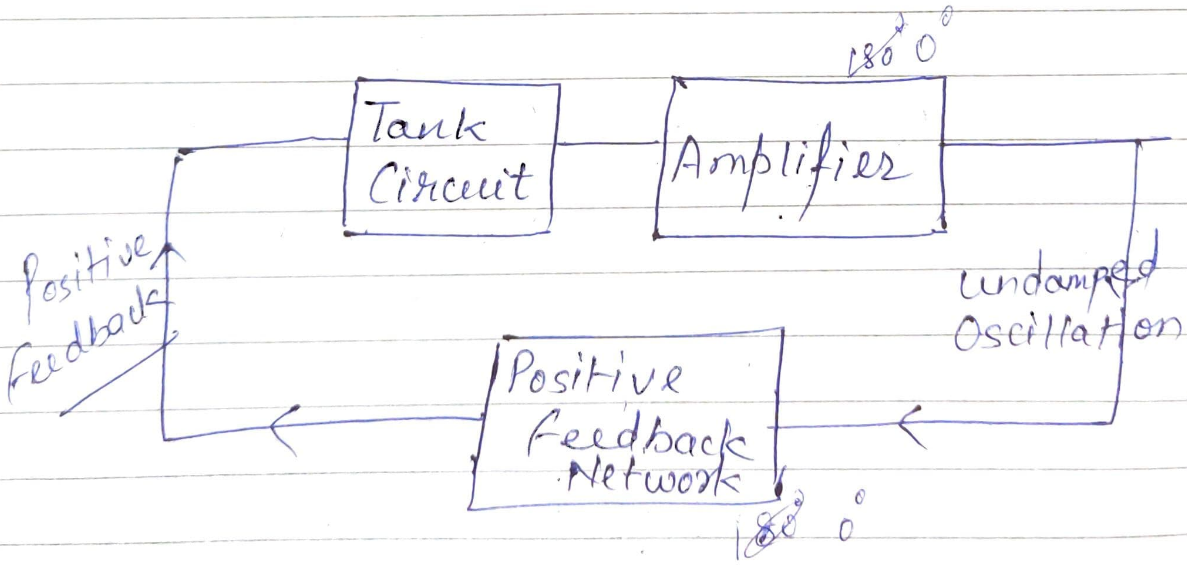


Damped Oscillations



Undamped oscillations

Positive feedback Ampr Oscillator



Imp Barkhausen's Criteria

$$A_f = \frac{A}{1 - A\beta}.$$

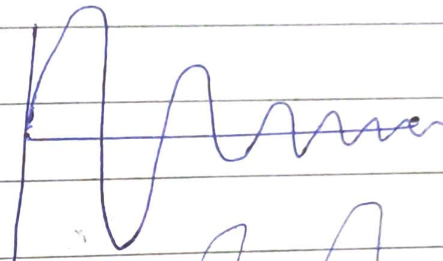
① $A\beta = 1$

$$A_f = \frac{A}{1-1} = \frac{A}{0} = \infty$$

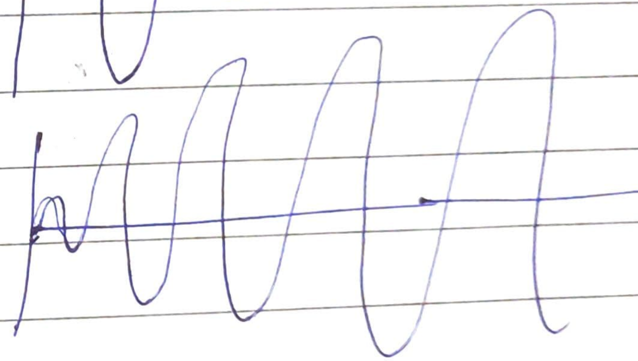
when the gain is infinity.

② Signal should be in phase. ~~the~~ i.e, 0°.

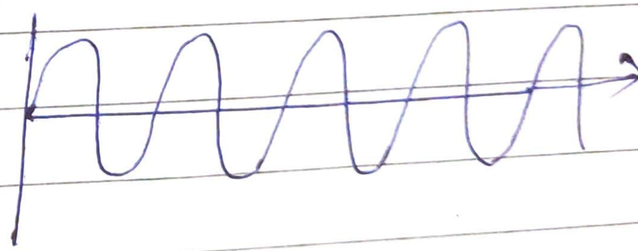
If $A\beta < 1$



If $A\beta > 1$



If $A\beta = 1$



4.8 ESSENTIALS OF AN OSCILLATOR

Figure 4.4 shows the block diagram of an oscillator.

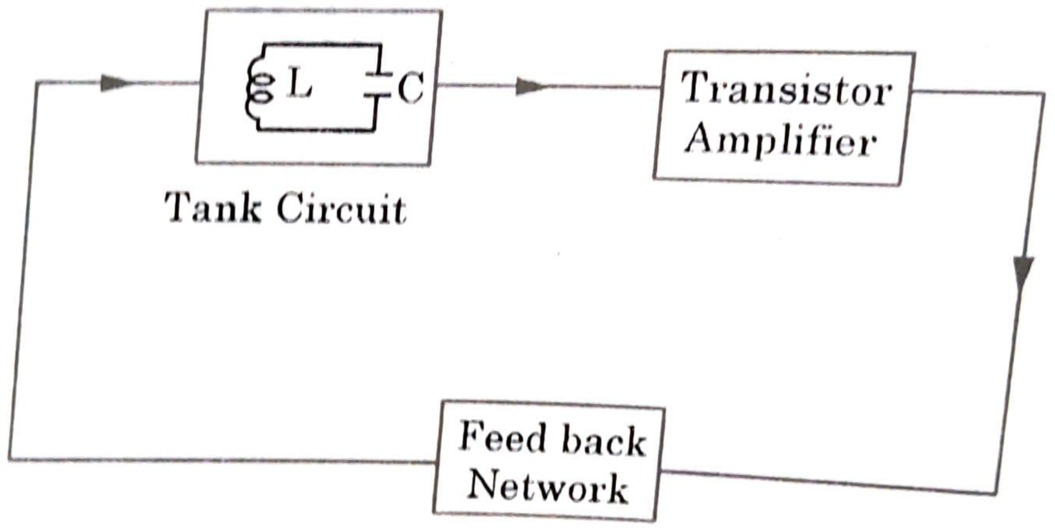


Fig. 4.4 : Block diagram of oscillator

Its essential components are

(*i*) **Tank circuit :** A circuit which can produce electrical oscillations of desired frequency is called oscillatory circuit. It is also called a TANK CIRCUIT OR TUNED CIRCUIT.

Basically it has a capacitor C and an inductance L connected in parallel. The frequency of oscillations depend upon values of C and L.

Consider a charged capacitor C in parallel with an inductor L as shown in Fig. 4.5(*a*). When switch S is closed, the capacitor will discharge through the inductor L. Electrostatic energy of the capacitor will be converted into electromagnetic energy in the inductor.

Inductor has property to oppose any change of current through it. The current through inductor increases slowly. When capacitor is fully discharged, magnetic field energy around the inductor is maximum as shown in Fig. 4.5(*b*).

When capacitor gets fully discharged, the magnetic field around the inductor begins to collapse. E.M.F. in the inductor maintains flow of current in the circuit. This makes the capacitor to charge in opposite direction as shown in fig. 4.5(*c*). As change increases, the current flowing through the circuit decreases. The electromagnetic energy of the inductor gets converted in to electrostatic charge on the capacitor. Then capacitor gets fully charged in the opposite direction.

The capacitor charged in the reverse direction makes a current to flow through the inductor, but in the reverse direction. Thus the direction of current through the circuit is reversed. The process of discharging and charging of capacitor continues thus producing oscillations in the circuit.

Ideally all the electrostatic energy stored in capacitor should be converted in to electromagnetic energy on the inductor during discharging and vice versa during charging. There should be no loss of energy during this process. If so, the oscillations so produced would be undamped and no external source of energy would be required to maintain undamped oscillations. But the resistance of the tank circuit causes some loss of energy.

The loss of energy in the circuit resistance and dielectric loss in the capacitor causes the magnitude of oscillations to reduce. Thus the oscillations so produced are damped oscillations. To produce undamped oscillations, the loss of energy in the circuit should be compensated by supplying external energy. This is done by connecting a battery in the circuit. If external source of energy is not connected the amplitude of oscillation decreases gradually and finally it reduces to zero. The damped oscillation so produced are shown in fig. 4.5(e)

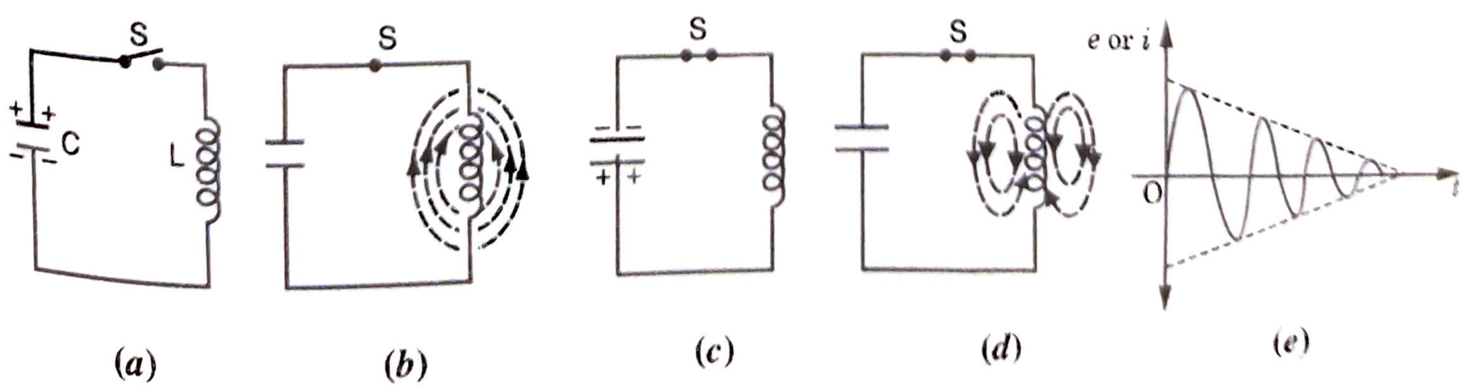


Fig. 4.5 : Generation of oscillations in a tank circuit

Frequency of oscillation: The frequency of oscillation produced in LC circuit depends the value of inductance of coil and capacitance of capacitor.

Let I be current flowing through the tank circuit

Since voltage across C = voltage across L

$$IX_C = IX_L$$

$$I.\left(\frac{1}{2\pi fc}\right) = I.(2\pi fl)$$

or
$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

If L is measured in hennery, C is measured in farads, f is in Hz. This frequency is ca resonant frequency or natural frequency of tank circuit. Thus frequency of oscillation depend circuit constants only.

(*ii*) **Amplifier:** The transistor amplifier receives dc power form the battery and change into a.c. power. The oscillations developed in the tank circuit are applied to the base of transistor amplifier as an input. The transistor amplifier, amplifies the damped oscillation and we get the undamped oscillation. This amplified output of oscillations is due to the dc po supplied by the battery.

(*iii*) **Feedback circuit:** The transistor amplifier with proper positive feedback work oscillator. The feedback circuit supplies a part of collector energy to the tank circuit in cor phase to aid the oscillation *i.e.* it provides positive feedback.

For satisfactory working of an oscillator it is essential that:

1. The amount of external energy supplied must meet the losses in tank circuit. When lo is connected, it draws energy from tank circuit. So external energy source must be a to supply this additional required energy.
2. Fedback energy must be in phase with oscillations produced in tank circuit.
3. Frequency of energy supplied must be equal to the frequency of oscillations produ in tank circuit.

Different types of oscillator

LC oscillator

1. Tuned collector oscillator
2. Hartley oscillator
3. Colpitt's oscillator

RC oscillator

- wein bridge
- phase shift

crystal oscillator

4.10 LC OSCILLATORS

The different types of LC oscillators circuit are explain below.

4.10.1 Tuned Collector Oscillator

Fig. 4.6 shows the circuit of tuned collector oscillator. The tank circuit ($L_1 - C_1$) is connected to the collector terminal of the transistor. The circuit uses a transformer. Primary of the transformer is connected in the tank circuit while the secondary is connected to the base. The biasing is provided by potential divider arrangement. The Biasing of transistor is done by resistor R_1, R_2 and R_E. Capacitor (C_E) is used as bye pass capacitor. Capacitor (C_2) is also used as a bye pass capacitor to bye pass R_2 form flow of a.c. Capacitor (C_2) allows a low resistance path to a.c. Hence there is no a.c. voltage drop across R_2.

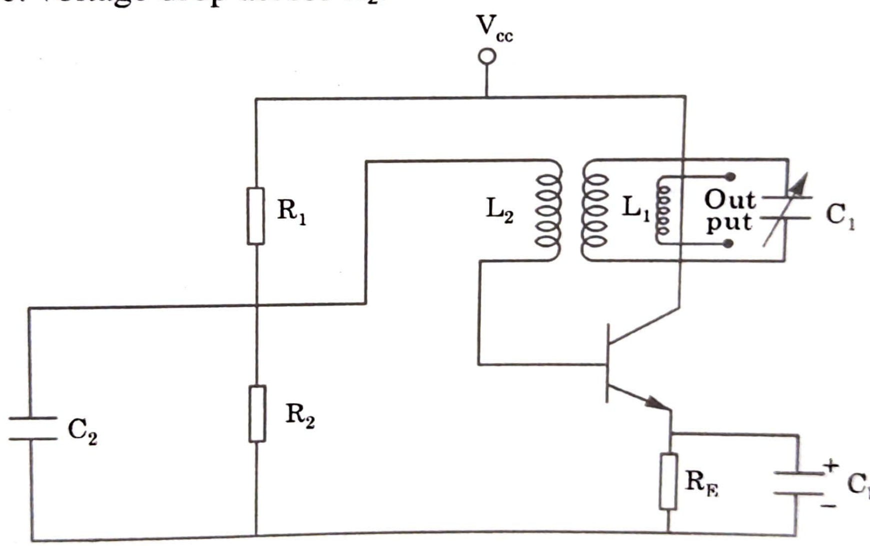


Fig. 4.6 : Tuned collector oscillator

Working : When supply is switched on, collector current starts increasing and charges the capacitor C_1. When this capacitor is fully charged it discharges through coil L_1, for setting up the oscillations of frequency $\left(f = \frac{1}{2\pi\sqrt{L_1C_1}}\right)$. These natural oscillation induce a small e.m.f. in L_2 by mutual induction. This voltage is applied to the transistor (between base and emitter) and amplified output appears across the collector circuit, thus overcoming the losses occurring in the tank circuit. Therefore, we can say that, part of the amplified voltage (or energy) is used to meet losses taking place in the oscillatory circuit and the balance is radiated out in the form of electromagnetic waves.

It may be noted that the phase of feedback is correct. The amplifier provides a phase difference of 180° between output at the collector and input at its base. Another phase difference of 180° is provided by the transformer . Thus the input and output has a phase difference of 360° or 0°. Hence the feed back is positive. As a result, the energy fed back to the tank circuit is in phase with the generated oscillations.

Example 4.1. The tuned collector oscillator circuit used in the local oscillation of a radio receiver makes use of an LC tuned circuit with L_1 = 58.6 μH and C_1 = 300pF. Calculated the frequency of oscillation.

Solution :

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

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

$$\text{Frequency of oscillation, } f = \frac{1}{2\pi\sqrt{L_1C_1}} = \frac{1}{2\pi\sqrt{58.6\times10^{-6}\times300\times10^{-12}}}$$

$$= 1199 \times 10^3\ Hz = 1199\ kHz\ \textbf{Ans.}$$

4.10.2 Hartley oscillator

Fig. 4.7 shows circuit of a Hartley oscillator. The circuit uses a radio frequency choke. It provides a low resistance path to d.c.; thus collector terminal is connected to Vcc through the coil. It provides a high impedance path to high frequency a.c. oscillations. Thus a.c. can not get grounded through Radio frequency choke (R.F.C) Capacitor C_{c2} acts as a coupling capacitor to block flow of d.c. in to the tank circuit while allowing a.c. to pass through it. R_1, R_2, R_E are used for biasing and C_E is used to bye pass a.c. preventing negative a.c. feed back through R_E. Output is taken across the tank circuit using transformer coupling. Tank circuit consists of two coils L_1 and L_2 wound on the same core. Thus there is mutual inductance between coils L_1 and L_2.

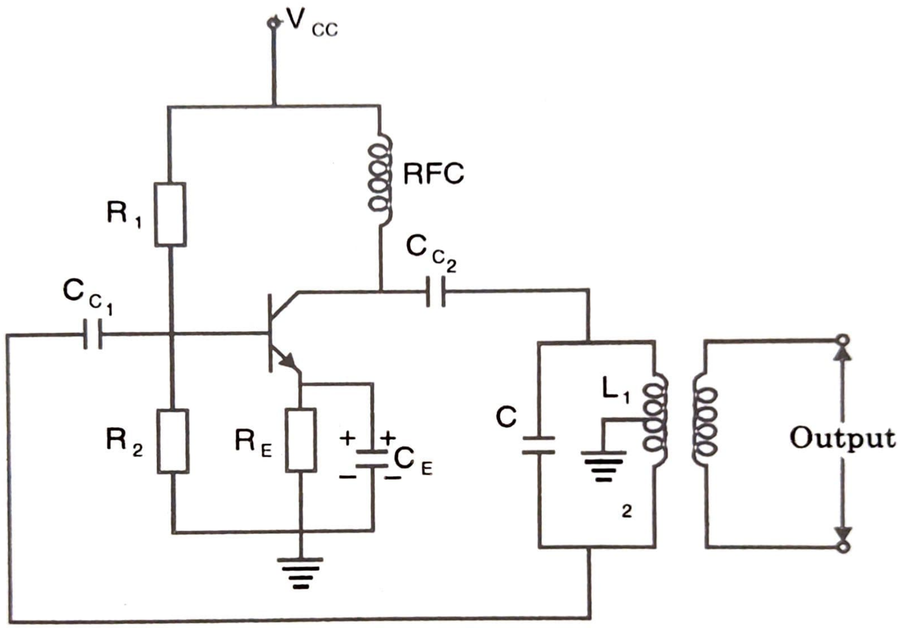


Fig. 4.7 : Hartley oscillator

Working : When V_{CC} is first switched ON, an initial bias is established by (R_1 –R_2) and oscillations are produced because of positive feedback form the LC tank circuit (L_1 and L_2 constitute L). e.m.f. induced in coil L_2 is fed back to base of transistor giving it a positive feed back. When the feedback is proper, it produce undamped oscillation.

The frequency of oscillation is given by

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad \ldots(4.6)$$

Where

$$L = L_1 + L_2 + 2M$$

Where M is the mutual inductance between L_1 and L_2.

4.10.3 Colpitts Oscillator

Colpitts oscillator is similar to Hartley oscillator. It uses a split tank capacitor while Hartle oscillator uses a split tank inductor. It is commonly used for generation of high frequenc oscillations above 1MHz. RFC serves the same function as in Hartley oscillator *i.e.* to provide low resistance path for d.c. and a high resistance path for a.c.

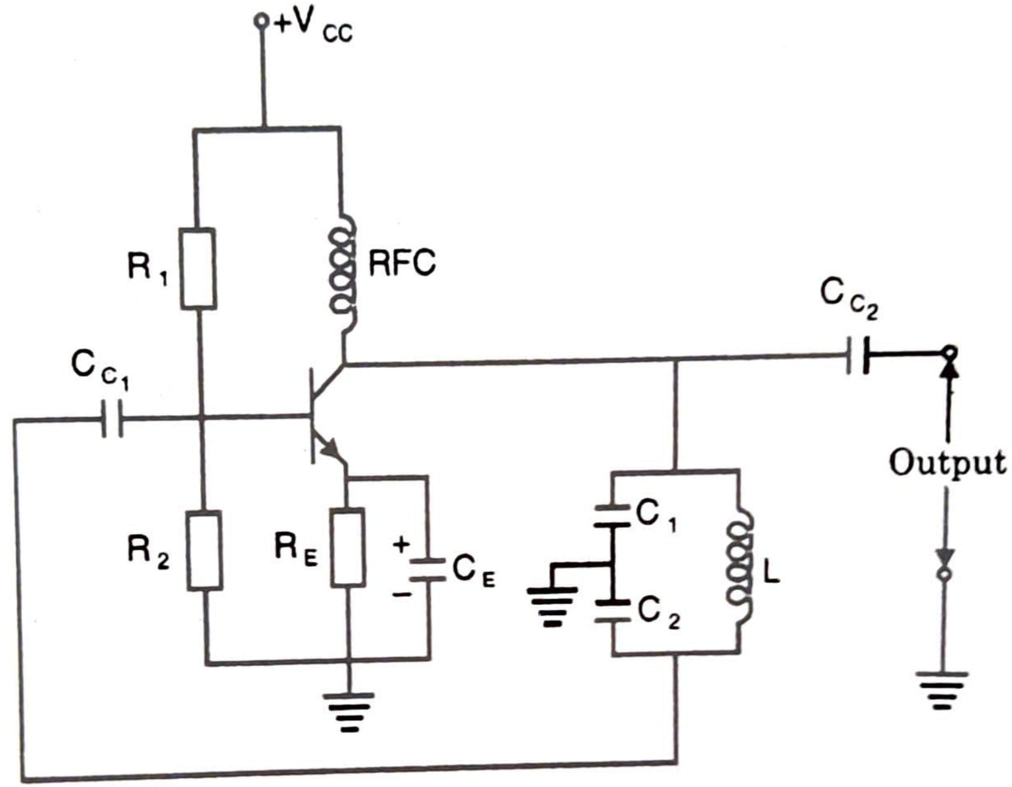


Fig. 4.8 : Colpitts oscillator

Frequency of oscillations depends upon values of L, C_1 and C_2.

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad ...(4.7)$$

Where C is series equivalent of capacitors C_1 and C_2

$$C = \frac{C_1 C_2}{C_1 + C_2} \qquad ...(4.8)$$

Output has been taken by using C_{C_2} as capacitor coupling. Output can also be obtained by using a coil across inductance to L shown in fig. 4.9.

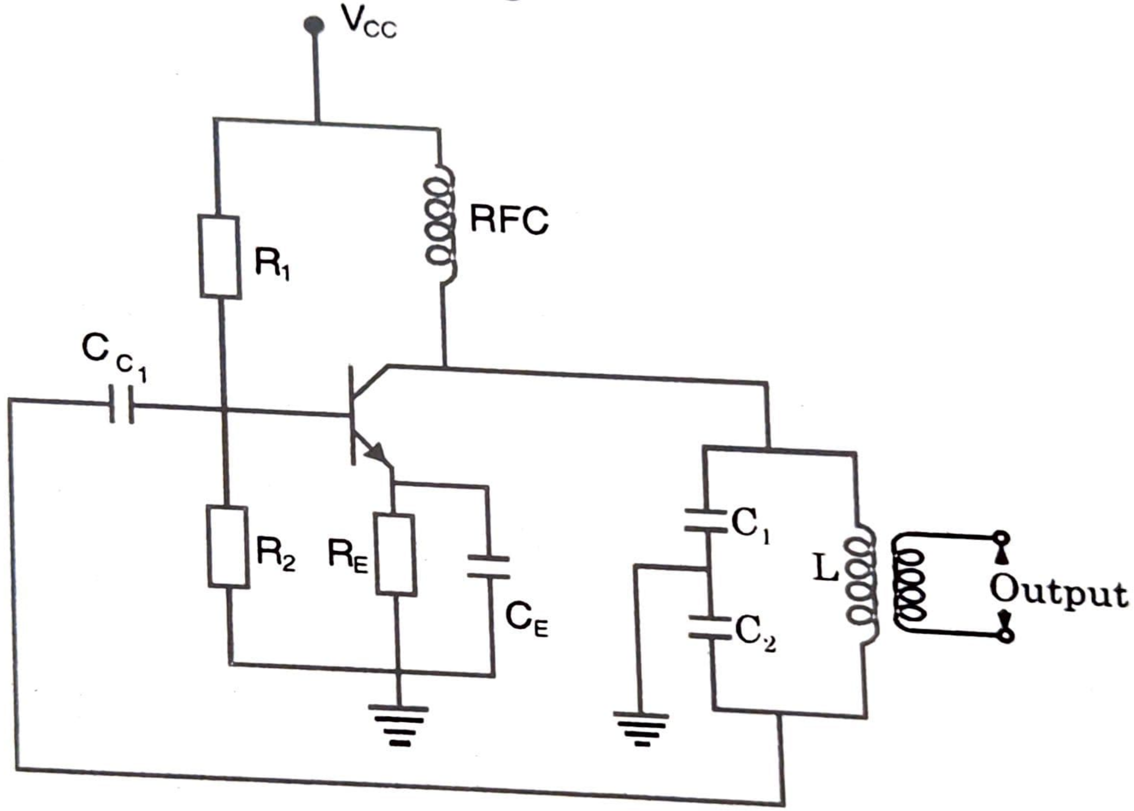


Fig. 4.9

4.11.2 Wein Bridge Oscillator

Wein bridge oscillator is used for generation of low frequencies of the order of 10 Hz to 50 KHz. Commercial audio signal generators use this circuit. As shown in Fig. 4.10 it essentially consists of two blocks of amplifiers and a feed back network for positive feed back.

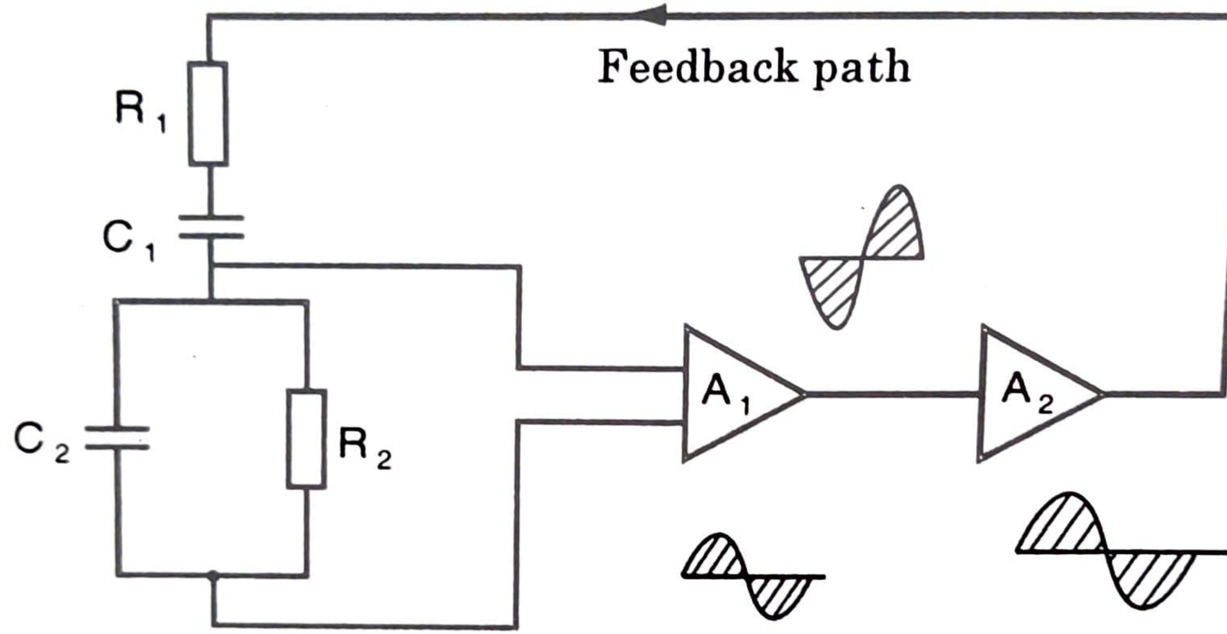


Fig. 4.10 : Block diagram of wein bridge oscillator

Blocks A_1 and A_2 represent two stages of amplifiers. As shown, the output of A_2 is in phase with input of A_1. Thus there is positive feed back. The amount of feed back is varied by the components R_1, C_1, R_2 and C_2 of feed back net work. Voltage developed across R_2, C_2 is fed back to A_1.

Frequency of oscillation

$$f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}} \quad \ldots(4.9)$$

If

$$R_1 = R_2, = R, C_1 = C_2 = C$$

$$\boxed{f = \frac{1}{2\pi RC}} \quad \ldots(4.10)$$

The value of feed back factor β should be $\frac{1}{3}$ and hence gain should be equal to 3 so as to satisfy the condition $A\beta = 1$. To reduce gain of the amplifier, a negative feed back is provided in the circuit. Negative feed back not only reduces gain of the amplifier, but it also improves stability of frequency of oscillations. This is done by using resistors R_3 and R_4 in the feed back net work as shown in Fig. 4.11.

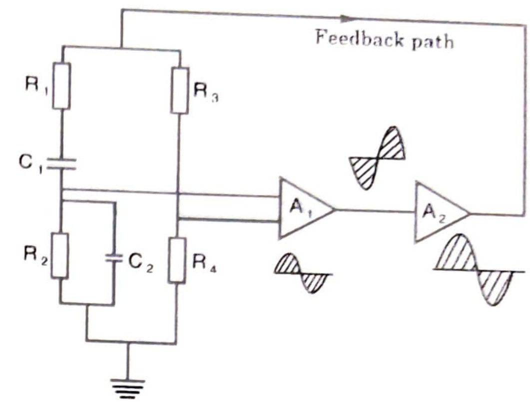


Fig. 4.11 : Circuit for positive as well as negative feed back

Capacitors C_1 and C_2 are generally ganged variable capacitors. Their value can be changed to change the frequency of oscillation. The feed back network can be drawn in a slightly different manner to show formation of a bridge as shown in Fig. 4.12. A practical circuit of Wein bridge oscillator is shown in Fig. 4.13.

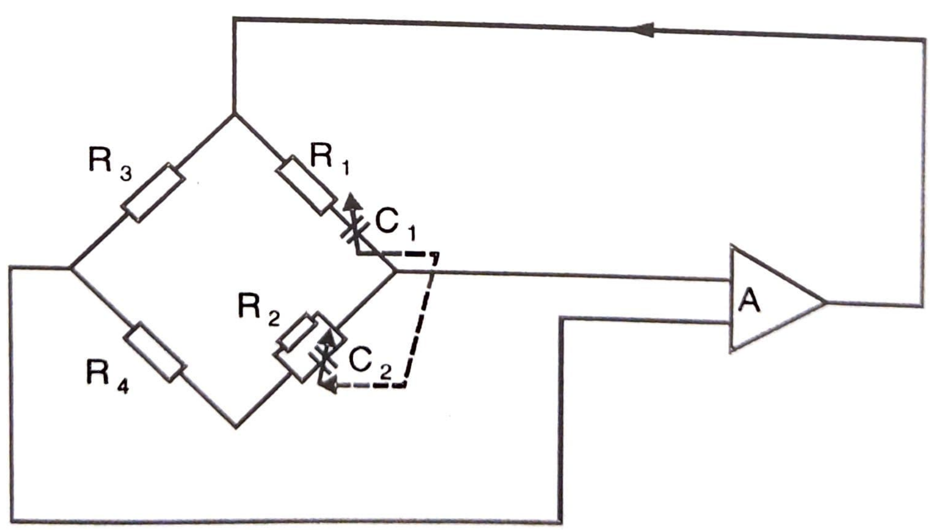


Fig. 4.12 : Formation of bridge

When V_{CC} is switched ON the noise voltage is amplified by amplifier A_1. It is further amplified by amplifier A_2 which shifts the phase of input by another 180°. When this output is fed back, through feed back network of R_1 C_1 R_2 and C_2, a positive feed back takes place.

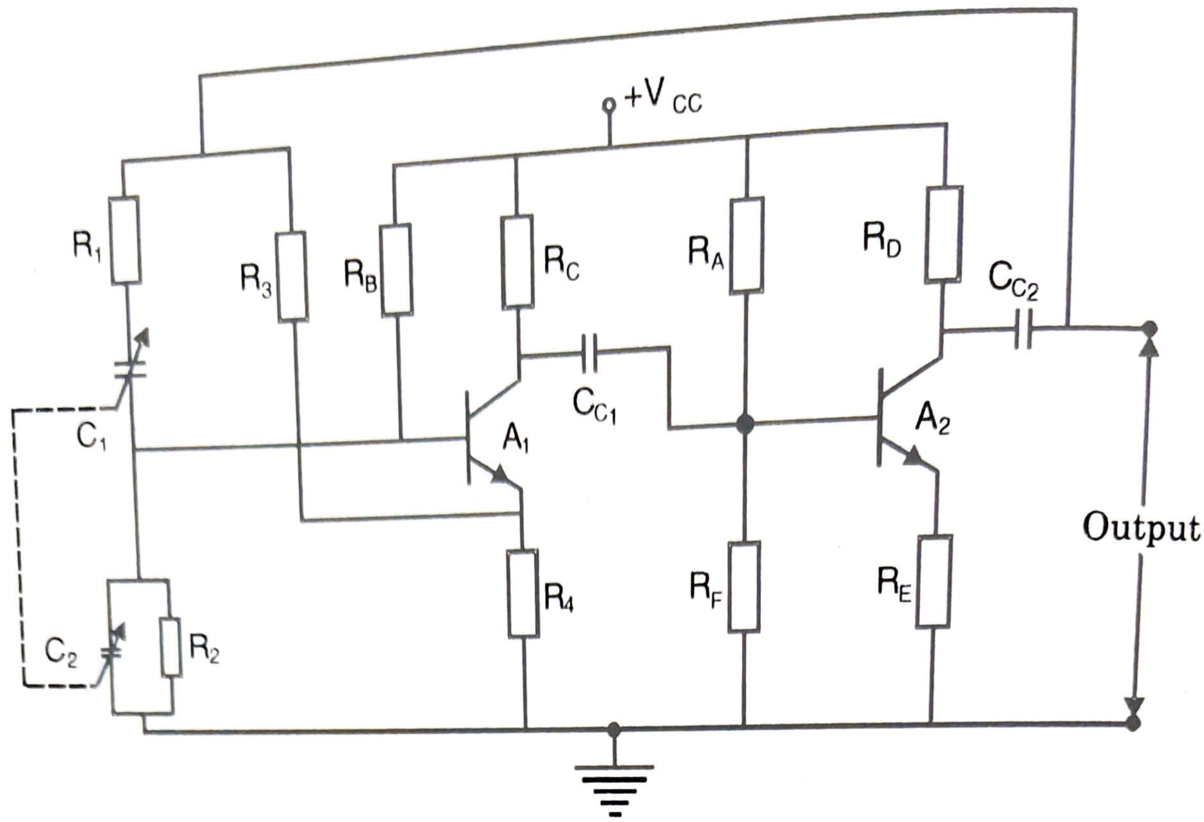


Fig. 4.13 : Transistorised Wein bridge oscillator circuit

Negative feedback has been provided by :

(*a*) Removing C_E across R_E

(*b*) By resistive network R_3 and R_4. Voltage drop across R_4 acts as negative feed back. R_4 also acts as R_E for first stage of amplifier.

Output can be taken by capacitive coupling using capacitor C_{C_2}.

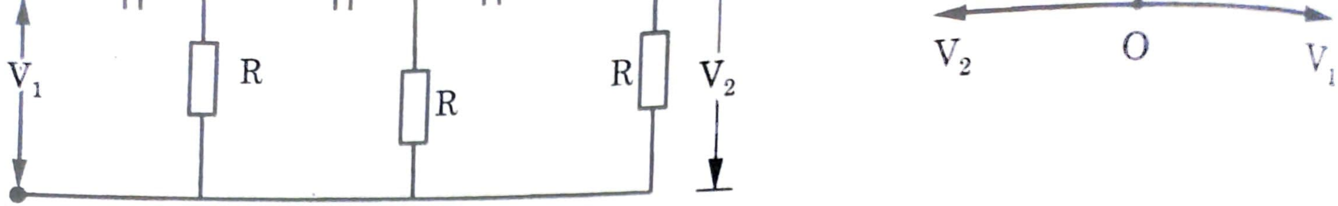
In practice R_4 is replaced by a filament lamp which is sensitive to temperature. The resistance of lamp increases with currents it helps to keep the output constant.

Advantages :

1. It gives constant output.
2. Highly stabilized amplitude and voltage amplification
3. It is most suitable for fixed frequencies Audio frequency range.
4. The overall gain is high because of two transistor amplifier stages.
5. The frequency of oscillations can be easily changed by using a potentiometer or changing value of ganged capacitor C_1C_2.

Disadvantage:

1. It requires two transistors and a large number of components.
2. It cannot generate very high frequencies.



(a) RC circuit

(b) Vector diagram

Fig. 4.15

4.11.3 Phase Shift Oscillator

Fig. 4.16 shows the circuit of a phase shift oscillator. It consists of a conventional sing stage transistor amplifier and a three-section R-C phase shift network. The three phase sh network are $R_1 C_1$, $R_2 C_2$, $R_3 C_3$. It produces a total phase shift of 180° (*i.e.* 60° per section) in t signal feed back to the base.

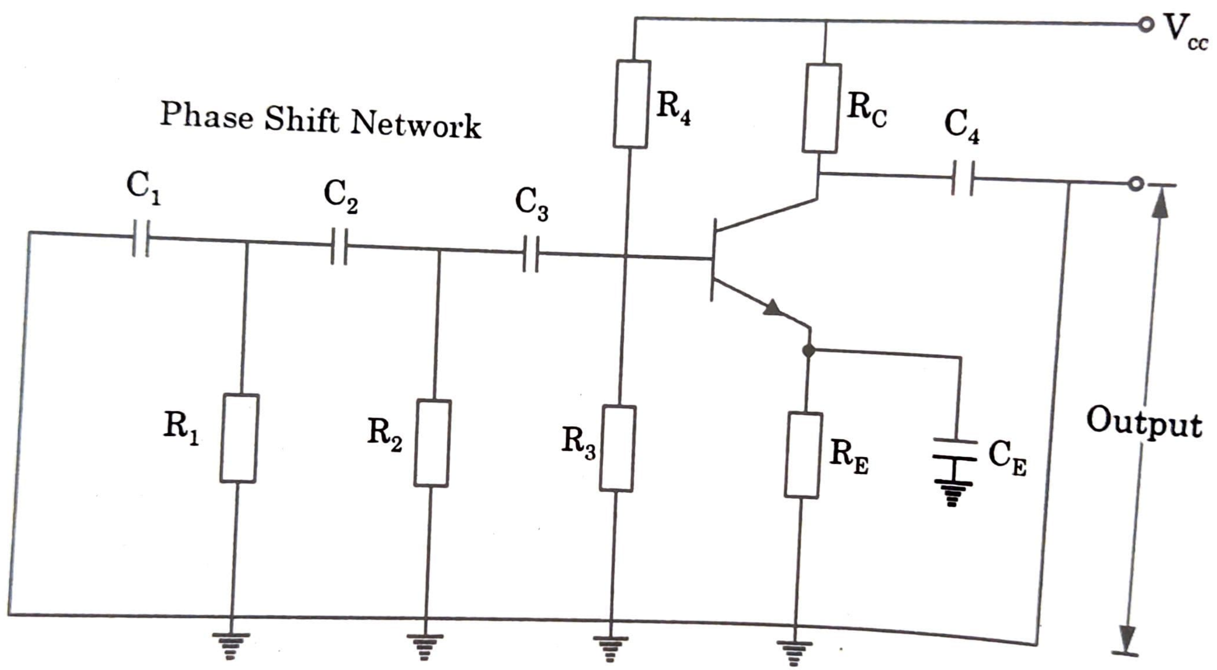


Fig. 4.16 : Block diagram of phase shift oscillator

The frequency of oscillation is given by

$$f = \frac{1}{2\pi RC\sqrt{6}}\ \text{Hz} \qquad \ldots(4.11)$$

where $R_1 = R_2 = R_3 = R$

$C_1 = C_2 = C_3 = C$

Working: When the circuit is switched on, it produces oscillation of frequency f. The output (e_o) of the amplifier is feedback to the RC feedback network. This network produces a phase shift of 180° and a voltage (e_i) appears at its output which is applied to the transistor. Obviously, the circuit will stop oscillating the moment phase shift differs form 180°.

Advantages:

1. Since they do not require any bulky and expensive high value inductors, such oscillator are well-suited for frequency below 10kHz.
2. It does not require transformer or inductor. Thus cost is reduced.
3. In this, positive feedback occurs only for one frequency. Hence pure sine wave output is possible.

Disadvantage:

1. It produces a distortion level of nearly 5% in the output signal,
2. The feedback or output is small, so it is difficult to start oscillation.
3. It necessitates the use of a high β transistor to overcome losses in the RC network.

4.13 INTRODUCTION TO PIEZO -ELECTRIC CRYSTAL

Basically, Piezo-electric crystal uses as a resonant tank circuit in the oscillators (c oscillator). Certain Crystalline materials, namely Rochelle salts, ammonium dihyd phosphate, lithium sulphate, quartz., and ceramics, which exhibit the piezoeleectric effe called **Piezolectric crystal.** Except for quartz and ceramics, A and B are manmade crystal ceramic materials do not have piezoelectric properties in their original state but these prop are produced by special polarizing treatment.

The quartz crystal is most commonly used because it is inexpensive and readily availa nature. It also has control of frequency in oscillator which comes from its permance, low tem efficient and high mechanical strength of quartz.

4.13.1 Piezoelectric Effect

When the mechanical stresses are applied on the opposite faces of quartz like (piezoelec crystal, electrical charges appear at some other faces and vice-versa. It is called **piezoelec effect**. Thus, when an alternating voltage is applied to appropriate faces, mechanical vibra are produced at some other faces. If the frequency of the applied ac voltage matches the na frequency of vibrations of the crystal, the amplitude of vibration will be maximum.

4.13.2 Properties of Pizo-Electric Crystals

The desirable properties of piezo-electric materials are stability, high output, insensitivi temperature humidity and ability to be formed into most desirable shape. Quartz is most suit piezo-electric material. However, its output is quite small.

4.13.3 Quartz Crystal

It is normally used material for crystal oscillator because of its stability, their h mechanical strength and also of its frequency control in oscillators. The shape of quartz crys hexagonal. It contains three axis x – axis, y – axis and z – axis. The x –axis is known as electr axis, y – axis is called mechanical axis and z – axis is called optical axis. Many different cuts be made from it depending on the application.

Working: In order to use crystal in an electronic circuit, a crystal is suitably cut and mounted between two metallic plates. The crystal behaves like a dielectric, placed between conducting plates. Mechanical vibrations are produced in the crystal when a.c. voltage is app to it. Frequency of vibration depends upon.

(a) Size of crystal

(b) Orientation of crystal surfaces with respect to its axis

(c) Mounting of crystal.

Equivalent Circuit : When the frequency of a.c. voltage is equal to the natural frequency of crystal, resonance takes place and then vibrations reach its maximum value. Electromechanically resonance of crystal can be represented by an equivalent electrical resonant circuit. Figure 4.17 (a) shows a crystal mounted between plates while its equivalent circuit is shown in figure 4.17 (b).

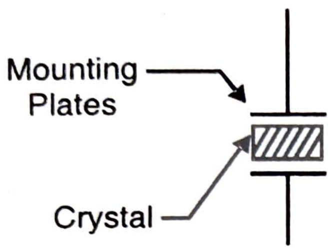


Fig. 4.17 (a) : Mounting of Crystal

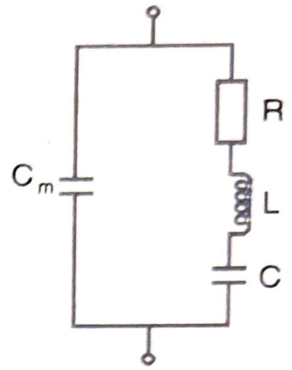


Fig. 4.17(b) : Electrical Equivalent Circuit of a Crystal

It consists of two cases

(i) When the crystal is not vibrating, It is equivalent to capacitance C_m. This capacitance is known as mounting capacitance.

(ii) When the crystal is vibrating, it is equivalent to R -L - C series circuit. In this case, it is shunted by the mounting capacitance C_m. The value of C is much lower than that of C_m.

The circuit has two resonant frequencies.

(a) **Series resonant frequency :** It is the resonant frequency of RLC branch of electrical equivalent circuit of crystal shown in fig. 4.17 (a)

$$\text{Series resonant frequency, } f_s = \frac{1}{2\pi\sqrt{LC}} \text{ Hz} \quad ...(4.12)$$

(b) **Parallel resonant frequency :** The series branch RLC has parallel resonance with capacitor C_m.

$$\text{Parallel resonant frequency, } f_p = \frac{1}{2\pi\sqrt{LC'}} \text{ Hz} \quad ...(4.13)$$

Where C′ is equivalent capacitance of C parallel with C_m

$$C' = \frac{C.C_m}{C + C_m} \quad ...(4.14)$$

Parallel resonant frequency f_p is always greater than f_s. However, difference between f_p and f_s is small. When a crystal is used as an oscillator, its resonant frequency lies between f_p and f_s.

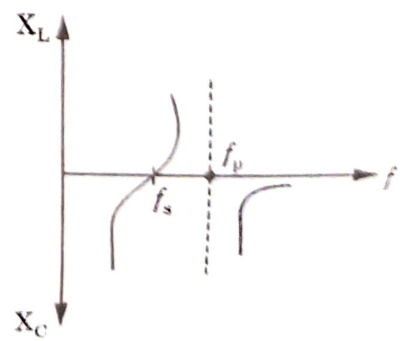


Fig. 4.18 : Frequency Response of Crystal.

4.14 CRYSTAL OSCILLATOR

Figure 4.19 shows the circuit diagram of transistor crystal oscillator. In this crystal is used to stabilize the frequency of a tuned -collector oscillator which has a crystal in the feedback circuit.

When V_{CC} is switched on, the capacitor C_1 gets charged. Discharging of C_1 through L_1 produces oscillations in tank circuit. It induces an e.m.f. in L_2 by mutual induction. This is positively fed back to the amplifier and the oscillations build up. Crystal provided in the base circuit makes the oscillations to sustain at resonant frequency of the crystal and also provides positive feedback with necessary phase shift. RFC coil provides dc collector load and also prevents any ac signal form entering the dc supply.

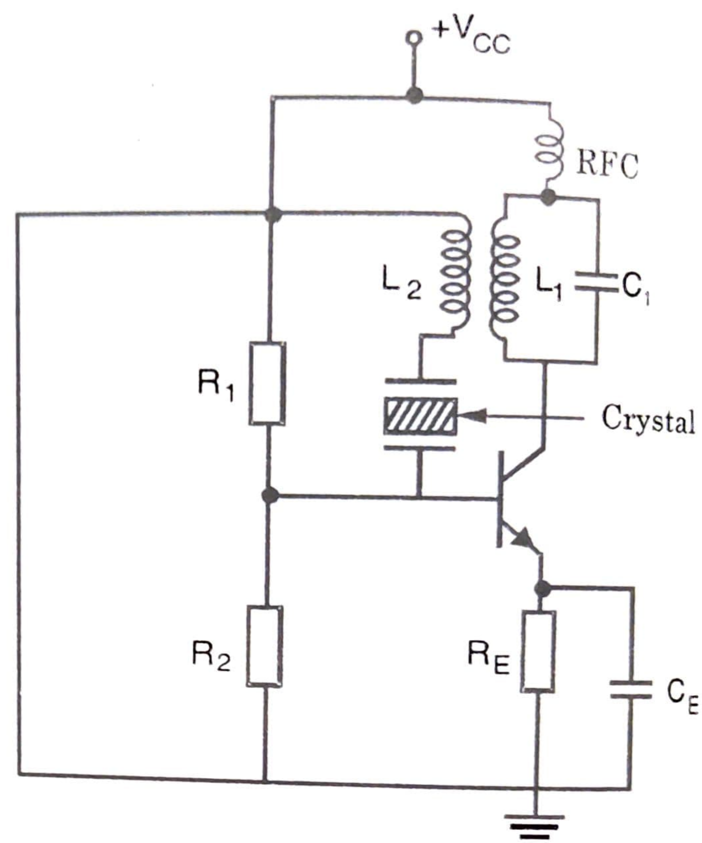


Fig. 4.19 : Crystal oscillator circuit using transistor

Here, the crystal is excited in the series resonance mode because it is connected as a series element in the feedback path form collector to the base. Since, in series-resonance, crystal impedance is the smallest, the amount of positive feedback is the largest. The crystal not only provides the feedback but also provides the necessary phase shift. Here, R_1, R_2 and R_E provide voltage - divider dc bias circuit. The capacitor C_E is shunted across R_E to avoid degeneration.

Example 4.7. A crystal has **L = 3H, C = 0.05pF, R =** 2kΩ and C