Oscillator
Lecture 12

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Definition of Oscillator:

Oscillator is an electronic circuit that produces a periodic oscillating signal, it may be sine wave, square wave, triangle wave. Oscillator convert direct current from a power supply to an alternating current.

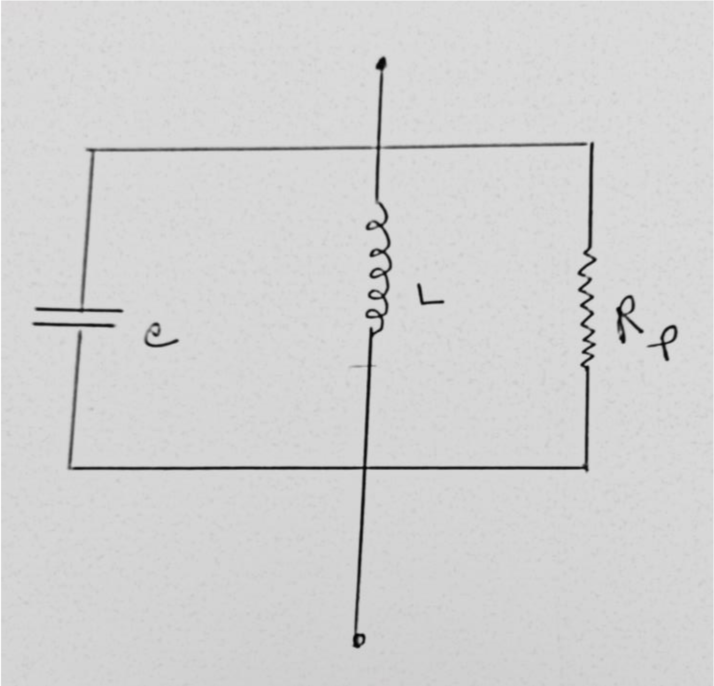

Fig 1

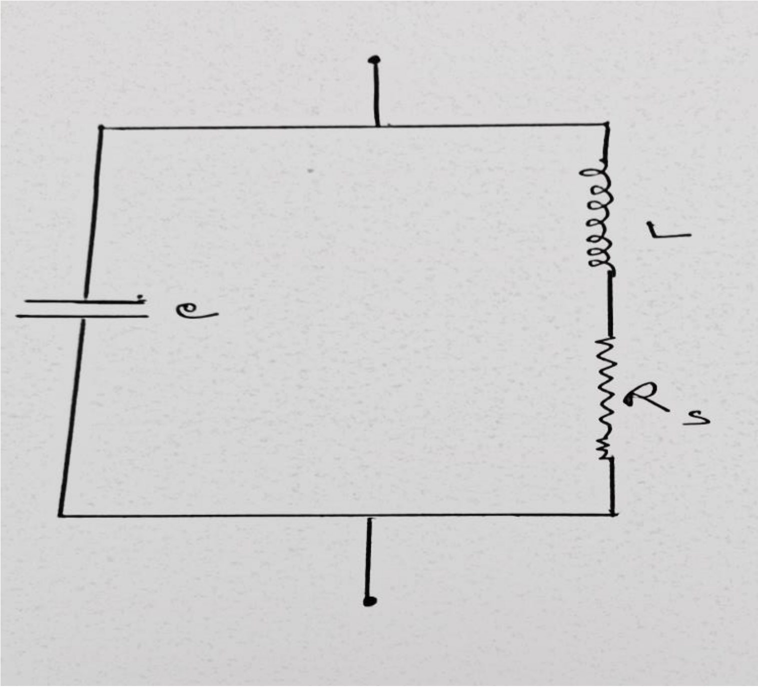

Fig 2

The fundamental oscillatory circuit is LCR circuit. R_S is the series resistance and R_P is parallel resistance. If R_S becomes zero, then resonant frequency f_0 can be defined as

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

But in practice R_S is not zero and so the above equation is expressed in a modified form as

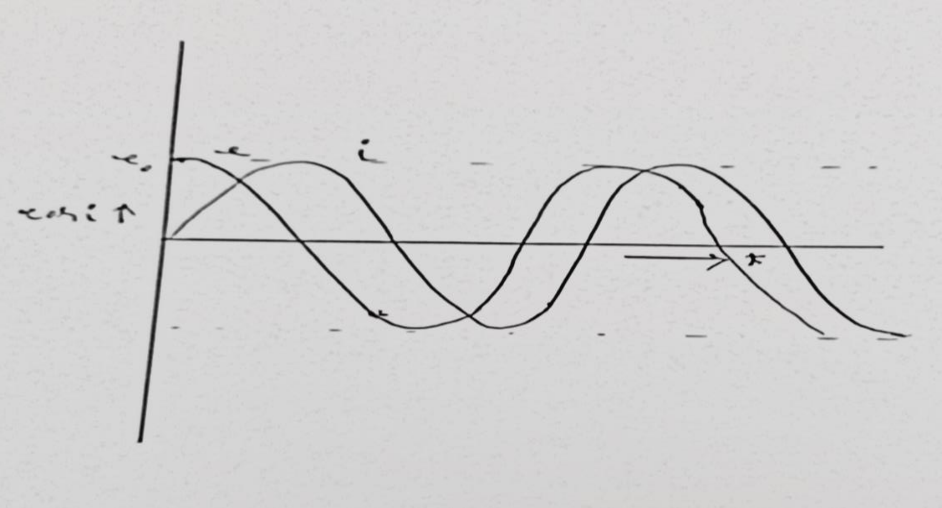

Fig 3

$$f_0 = \frac{1}{2\pi\sqrt{LC}}\left[\frac{1}{\sqrt{1+\left(\frac{RC^2}{\omega_0^2 L^2}\right)}}\right]$$

The fact is that some resistance is present in circuit and some of the energy stored in the reactive elements is dissipated as heat. The quality factor (Q) is

$$Q = \frac{Energy\ stored\ in\ system}{Energy\ discipated\ per\ cycle}$$

$$Q = \frac{X_L}{R_S} = \frac{\omega_0 L}{R_S}$$

If some initial energy is given in an ideal LC circuit it will oscillate indefinitely at resonance frequency as shown in Fig 3. The oscillatory or undamped condition gives

$$\frac{L}{C} < 4R_P^2$$

The in circuit for undamped condition i.e.

$$i = i_0 e^{-\alpha t}.cos\omega t$$

Where i_0 is initial current in L. The damping factor is

$$\alpha = \frac{1}{2R_P C}$$

The frequency is

$$\omega = \sqrt{\frac{1}{LC} - \frac{1}{4R_P^2C^2}}$$

When $\frac{L}{C} = 4R_P^2$, we get the critical damping. The critically damped circuit does not oscillate but within a very short time it dissipate the circuit energy.

If $\frac{L}{C} > 4R_P^2$, the overdamped condition happens.

It is important that in an oscillator the underdamped condition is desirable. If additional energy is periodically supplied to the circuit the amplitude of oscillation remains constant.

The logarithmic decrement is an important factor in any oscillator circuit. If $i_1\ and\ i_2$ are the successive peaks of the underdamped waveform then logarithmic decrement (δ) is given by

$$\delta = ln\left(\frac{i_1}{i_2}\right)$$

In terms of Q

$$\delta = \frac{\pi}{Q_P}$$

Barkhausen Criterion for Oscillation:

Before obtaining a steady state an oscillator must build up oscillation. For oscillation to be self sustain the following condition must satisfied;

1.An Amplifying Device

2.Regenerative Feedback

3.Some Circuit Non linearity

4.Some Energy Storage System

Generally a four terminal of feedback oscillator is regenerative feedback amplifier. Positive feedback results when the feedback factor βA is positive and less than unity.

If βA is increased to unity the gain with feedback becomes infinite and the amplifier functions as an oscillator. The condition $\beta A = 1$ is known as Barkhausen Criterion and it is true at a single and precise frequency at which the feedback signal operating at the input is exactly in phase with input signal. Oscillation occur even is $\beta A > 1$ and amplitude of oscillation increased without limit. For practical purpose nonlinearity limits the theoretically infinite gain to some finite value for both $\beta A = 1 \, and \, \beta A > 1$.

Hartlely Oscillator:

In this oscillator collector supply voltage is applied to the collector through inductor L. The reactance is higher than L_2. And may be omitted from the equivalent circuit

Here C_C acts as an open circuit at zero frequency. It prevents collector supply voltage V_{CC} from getting short circuited by L in series with L_2.

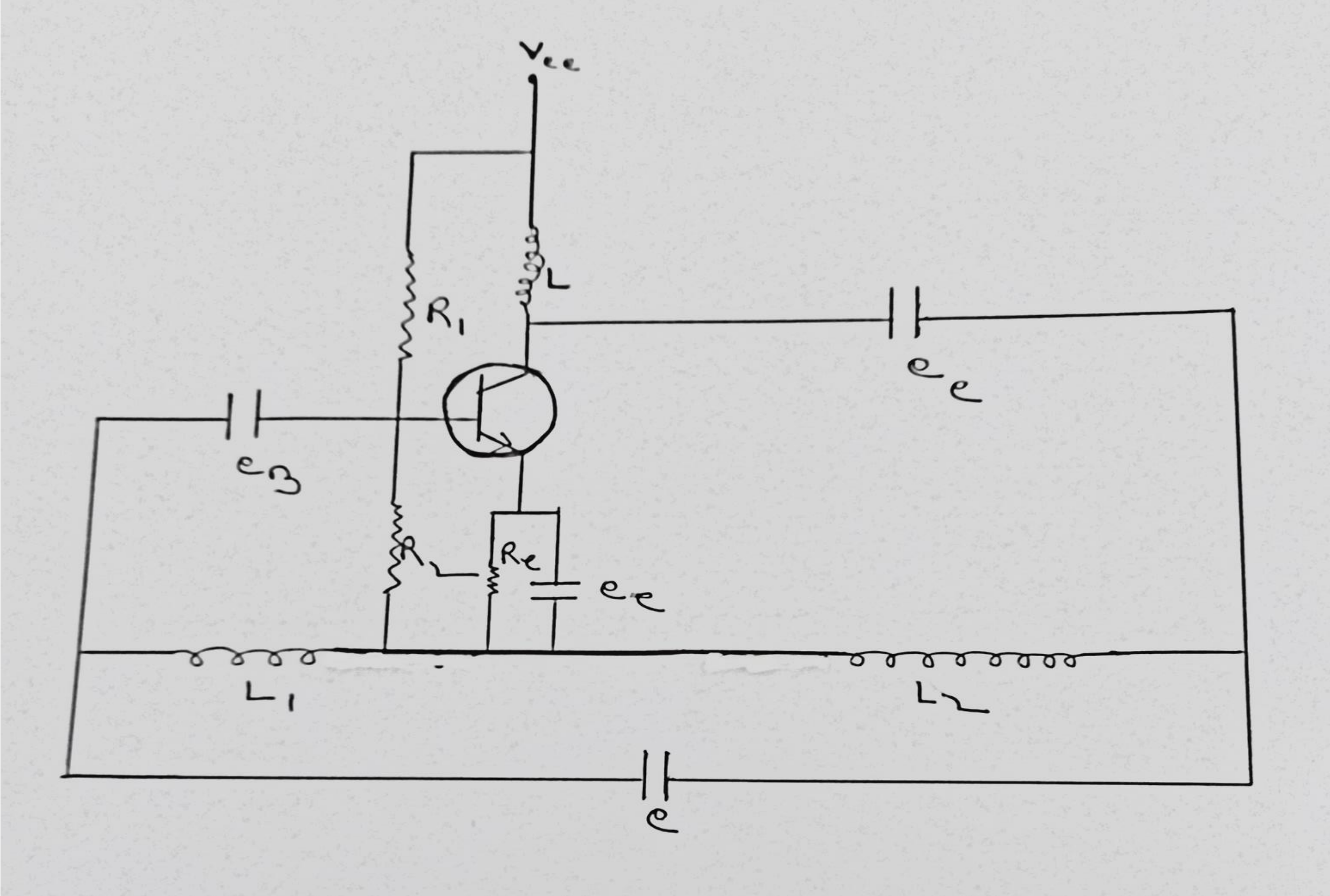

Fig 4

The parallel combination of R_e and C_e in conjunction with R_1 and R_2 combination provides stabilized self bias. The frequency of oscillation is determined by tuned circuit L_1, L_2 and C.

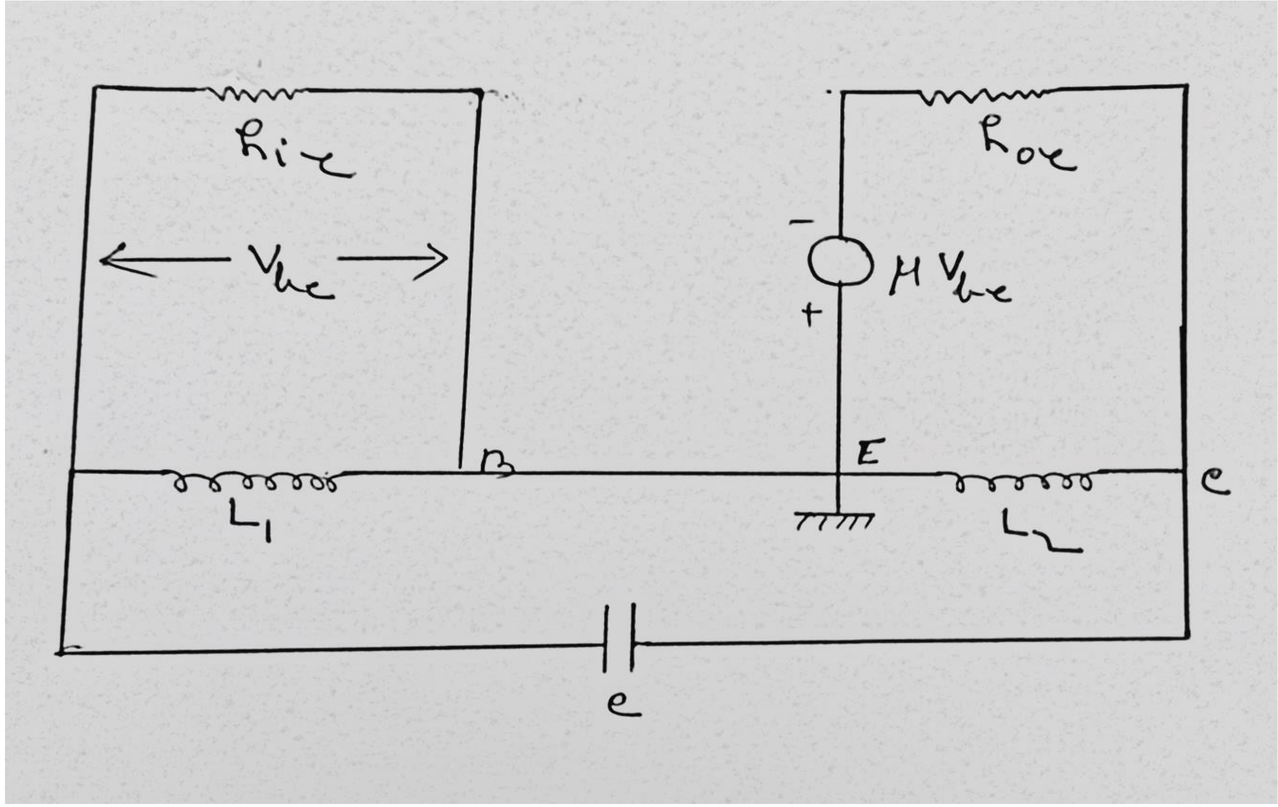

Fig 5

Since the circuit extends from collector circuit to base circuit the feedback needed for sustained oscillation takes place through the tuned circuit itself. The frequency

$$\omega = \omega_0 \sqrt{1 - \frac{X_1 X_2}{h_{ie} h_{oe}}}$$

Where $X_1 = \omega L_1 \; and \; X_2 = \omega L_2$

Thus frequency of oscillation ω is slightly less than the frequency of series resonance ω_0 of $L_1 , L_2 \; and \; C$. And

$$h_{fe} = \frac{\omega L_1}{\omega L_2} = \frac{L_1}{L_2}$$

This equation gives the condition for sustained oscillation. If there exist mutual inductance M between coils $L_1 \; and \; L_2$, then this equation gets the modified as

$$h_{fe} = \frac{L_1 + M}{L_2 + M}$$

Phase Shift Oscillator:

If a transistor is used for active element, the output R of the feedback network would be shunted by the relatively low input resistance of transistor. Hence instead of employing voltage source feedback, here one can use voltage shunt feedback for a transistor phase shift oscillator.

For the circuit we assume that $h_{oe}R_C < 0.1$, so that we may use the approximate hybrid parameter model to characterize the low frequency small signal behaviour of the transistor.

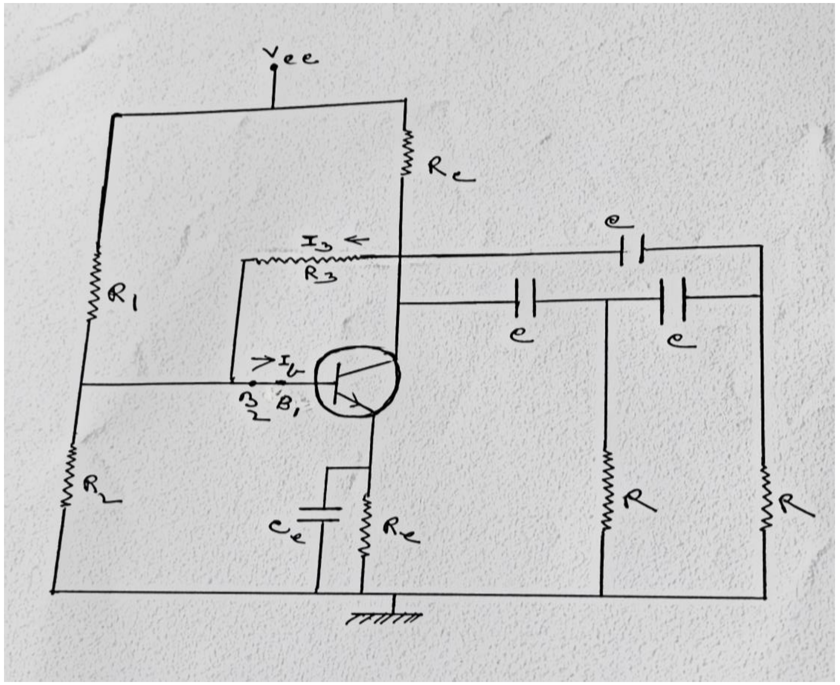

Fig 6

The resistor $R_3 = R - R_i$, where $R_i \cong h_{ie}$ is the input resistance of the transistor. This choice makes the three RC sections of the phase shifting network alike and simplifies the calculation.

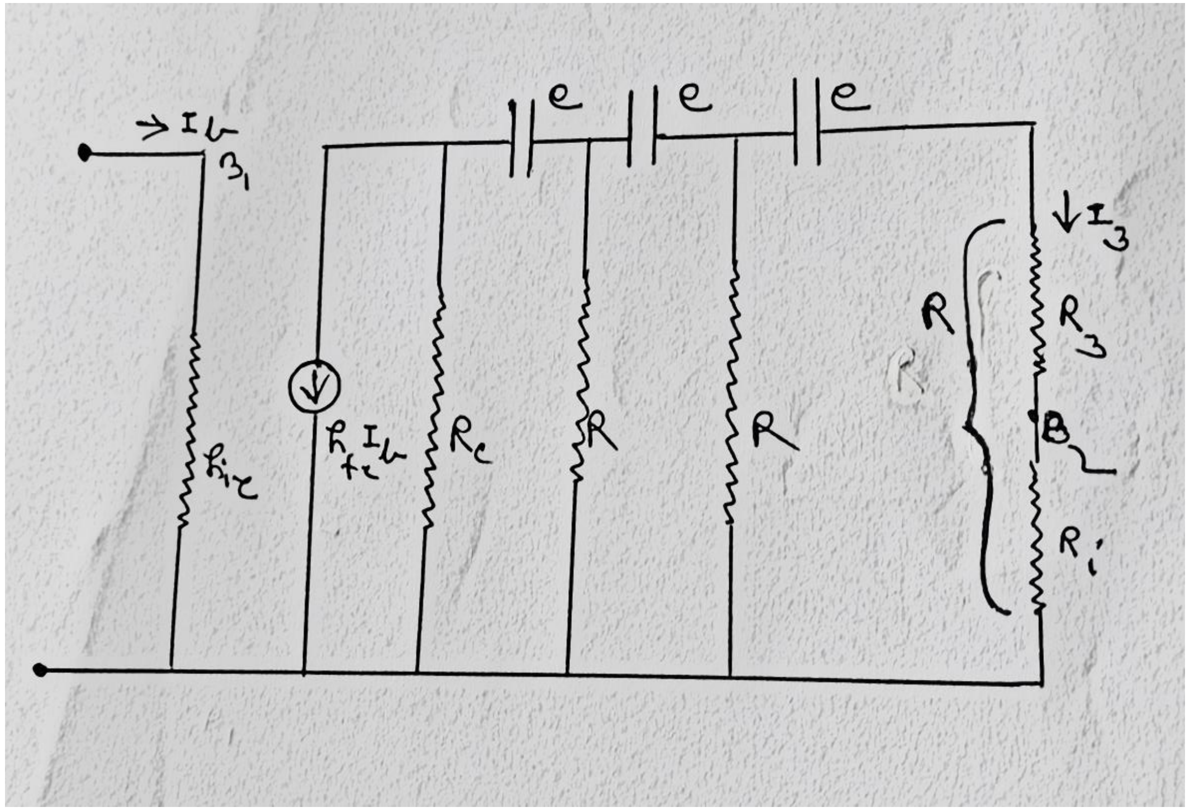

Fig 7

We assume that biasing resistor R_1 , R_2 and R_e have no effect on the signal operation and neglected these in analysis. The Barkhausen Criterion that the phase of $\left(\frac{I_3}{I_b}\right)$ must equal to zero , leads to the following expression for the frequency of oscillation.

$$f = \frac{1}{2\pi R_C} \frac{1}{\sqrt{6+4K}}$$

Where $K = \frac{R_C}{R}$, then requirement that the magnitude of $\left(\frac{I_3}{I_b}\right)$ must exceed unity in order for oscillation to start leads to the inequality

$$h_{fe} > 4K + 23 + \frac{29}{K}$$

The value of K which gives the minimum h_{fe} turns out to be 2.7 and for this optimum value of $\frac{R_C}{R}$ we find that $h_{fe} = 44.5$. A transistor with a small signal common emitter short circuit current gain less than 44.5 can not be used in this phase shift oscillator.

The phase shift oscillator is particularly suited to the range of frequencies from several $Hertz$ to several hundreds $Kilo\ Hertz$ and so includes the range of audio frequency. The frequency of oscillation may be varied by changing any of the impedance elements in the phase shifting network. For a variation of frequency over a large range of the three capacitances are usually varied simultaneously.

Such a variation keeps the input impedance to the phase shifting network constant and also keeps constant the magnitude of $\beta \; and \; A\beta$. Hence amplitude of oscillation will not be affected as frequency is adjusted. The phase shift oscillator is operated in $Class \; A$ in order to keep distortion to be a minimum value.

Wien-Bridge Oscillator:

An RC oscillator which uses a balanced bridge as the feedback network is Wein-Bride oscillator. The output voltage V_0 of the amplifier is the input voltage of the bridge. The output voltage V_i of the bridge is the input voltage of the amplifier. When the bridge is exactly balanced $V_i = 0$.

But for sustained oscillation V_i must be nonvanishing. The bridge is slightly makes unbalanced by adjusting the ratio between resistance R_1 and R_2.

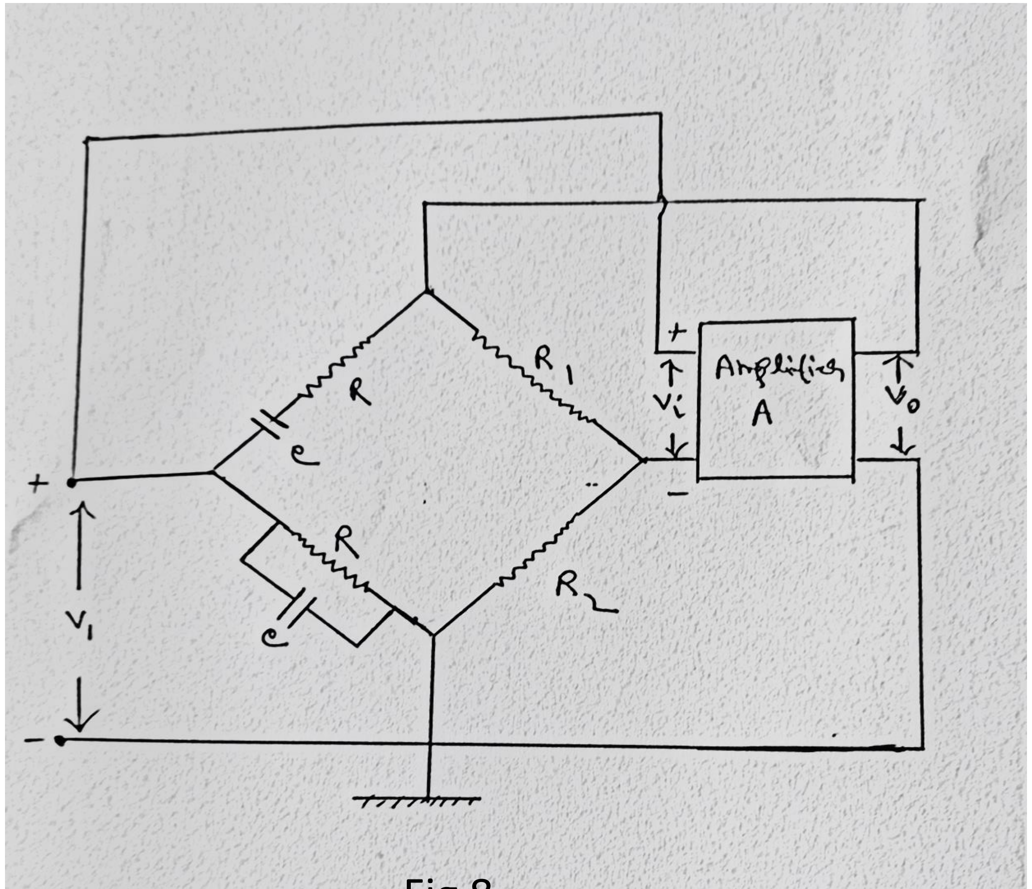

Fig 8

Thus the bridge does not give any phase shift between input and output voltage, the amplifier must not introduced any phase shift between its input and output voltage to achieve a net phase shift of zero around the loop. A two stage CE amplifier can serve the purpose when bridge is balanced.

$$\frac{R_1}{R_2} = \frac{\left(R + \frac{1}{j\omega C}\right)}{\frac{R/_{j\omega C}}{R + 1/_{j\omega C}}}$$

$$\frac{R_1}{R_2} = 2 + j\,\frac{R^2 - {}^{1}/_{\omega^2 C^2}}{{}^{R}/_{\omega C}}$$

Equating real and imaginary part we get

$$\frac{R_1}{R_2} = 2 \quad and \quad R^2 = \frac{1}{\omega^2 C^2}$$

Therefore

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi RC}$$

When the bridge is balanced the voltage of two lower arms of the bridge must be equal i.e.

$$V_1 = V_2 = \frac{R_2}{R_1 + R_2} V_0 = \frac{1}{3} V_0$$

Therefore at balanced condition we get

$$\frac{R_2}{R_1 + R_2} = \frac{1}{3} \quad and \quad \frac{V_1}{V_0} = \frac{V_2}{V_0} = \frac{1}{3}$$

Since $V_i \neq 0$ for oscillation occur, the ratio $\frac{R_2}{R_1+R_2}$ is taken to be less than $\frac{1}{3}$. If we get

$$\frac{R_2}{R_1+R_2} = \frac{1}{3} - \frac{1}{\delta}$$

Where δ is number greater than 3 the bridge is slightly unbalanced and give a feedback voltage V_i. As bridge is unbalanced by adjusting $\frac{R_1}{R_2}$ the ratio $\frac{V_1}{V_0}$ remains $\frac{1}{3}$, but ratio $\frac{V_2}{V_0}$ becomes

$$\frac{V_2}{V_0} = \frac{1}{3} - \frac{1}{\delta}$$

Now the feedback voltage is

$$V_i = V_1 - V_2 = \left(\frac{1}{3} - \frac{1}{3} + \frac{1}{\delta}\right) V_0 = \frac{V_0}{\delta}$$

Clearly V_i and V_o are in phase and feedback fraction is

$$\beta = \frac{V_i}{V_0} = \frac{1}{\delta}$$

The condition $A\beta = 1$, satisfied by making gain of amplifier

$$A = \delta > 3$$

Like phase shift oscillator Wien-Bridge oscillator is used in AF range.

Continuous variation of frequency is achieved by simultaneously varying the two capacitors, which is advantage over to be varied simultaneously. For wide variation different values of two identical resistor R employed.

It has following advantage

1.Overall gain is high since a two stage amplifier is used.

2.It gives very good sine wave output

3.Frequency stability is good

4.Frequency oscillation can easily varied

The disadvantage are

1.Large number of component needed for two stage amplifier

2.High frequency can not be generated