LECTURE SERIES-03

DATE 03-05-2020	B.Sc(H)-II PAPER-IV	* PHYSICS * ELECTRONICS	By. Dr. M.K. THAKUR A.P.S.M. College, Barauni

Amplifier as Oscillator: An amplifier converts an external small A.C. voltage (Input) into a large A.C. voltage (output) at the expense of D.C. plate supply. If the correct portion of the output voltage is fed back into the input circuit in the proper phase (positive feed back) to be amplified again, then amplifier can maintain its operation without external A.C voltage signal. The amplifier then becomes an oscillator.

Barkhausen Criterion for sustained oscillation: Let us consider a feed back amplifier whose voltage gain without feed back is A. Let E_g be the input and V_0 be the output voltage of the amplifier with feed back.

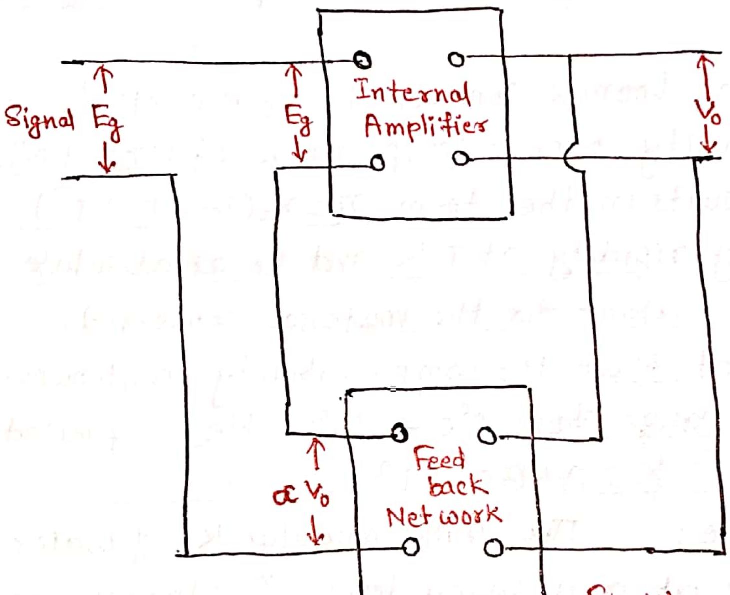

Fig.(1)

Let α be the fraction of the output voltage V_0 which is fed back into the input. If the feed back is positive, the actual input to the amplifier is $E_g' = E_g + \alpha V_0$. This on being amplifier A times by the amplifier gives the output V_0. Thus

$$(E_g + \alpha V_0) A = V_0$$

$$\therefore \quad E_g A + \alpha V_0 A = V_0$$

$$\text{or} \quad E_g A = -\alpha V_0 A + V_0$$

$$\therefore \quad E_g A = V_0 (1 - \alpha A)$$

$$\therefore \quad E_g = \frac{(1-\alpha A) V_0}{A} \qquad \text{—— (1)}$$

If $\alpha A = 1$, then $E_g = 0$, that is, the amplifier will operate without external A.C. input voltage. This process becomes self-sustaining and amplifier behaves as an oscillator. Thus the condition for sustained oscillation is

$$\alpha A = 1 \quad \therefore \quad \alpha = 1/A \quad \text{—— (2)}$$

If Z_L be the load impedance in the plate circuit of the amplifier, then its gain is given by

$$A = -\frac{\mu Z_L}{r_p + Z_L} \quad \text{—— (3)}$$

where μ = amplification factor
r_p = plate resistance

The minus sign indicates that the amplifier produces a phase shift of 180° in the output compared to the input.

Thus the condition of sustained oscillation can be written as

$$\alpha = -\frac{r_p + Z_L}{\mu Z_L} = -\left(\frac{r_p}{\mu Z_L} + \frac{1}{\mu}\right)$$

$\because \mu = r_p \times g_m$

$$\frac{r_p}{\mu} = \frac{1}{g_m}$$

$$\therefore \quad \alpha = -\left(\frac{1}{g_m Z_L} + \frac{1}{\mu}\right) \quad \text{—— (4)}$$

This equation is known as 'Barkhausen Criterion' for sustained oscillation.

Hartley oscillator:

This is the most suitable oscillator widely used in radio. The circuit diagram is shown in fig.(1). In this oscillator a single coil tapped in the middle is used. A part L_2 of this coil is in the collector circuit and the remaining part L_1 is in the base circuit. The variable condensor C is connected across both L_1 and L_2. The resistance R_1 and R_2 are used to bias the transistor to a suitable value of collector current. The feed back takes place through the mutual coupling M and inductances L_1 and L_2. For simplicity, the effect of M will be neglected in making analysis. The a.c equivalent circuit is shown in fig.(2)

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It would be clear from equivalent circuit that sustained oscillation will continue in the circuit provided the feed back current i_3 is greater than or equal to, the originally assumed base current i_b. we have

$$V_o = \frac{i_1}{h_{oe}} - \frac{h_{fe} i_b}{h_{oe}} \quad \text{——— (1)}$$

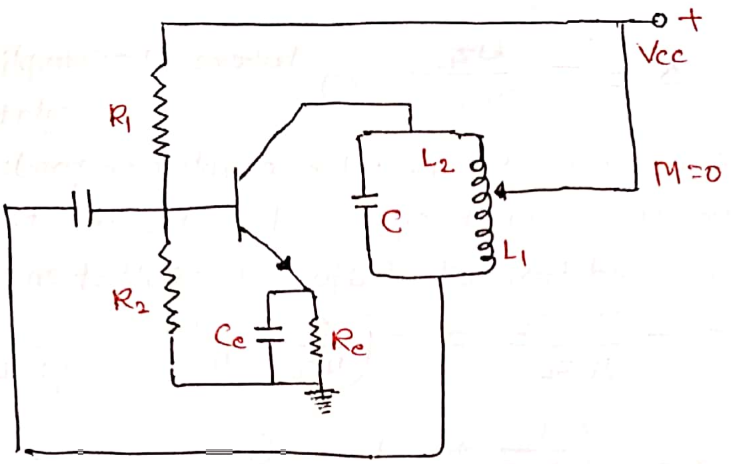

Fig.(1)

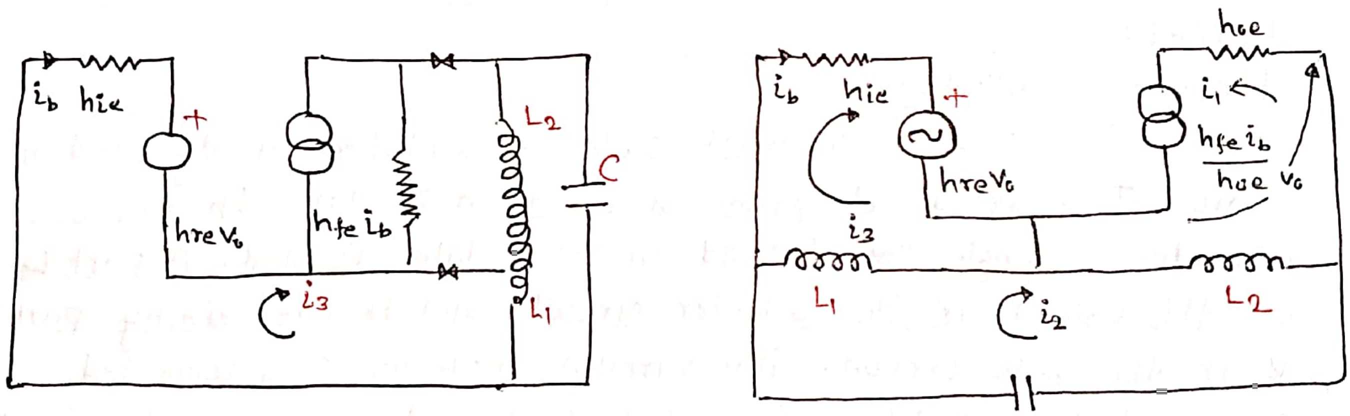

Fig.(2)

Let us consider i_1, i_2 and i_3 are the loop current flowing in the three loops. The loop equ^n may be written as

$$\frac{h_{fe} i_b}{h_{oe}} = i_1\left(\frac{1}{h_{oe}} + jX_{L2}\right) + i_2\, jX_{L2} \quad \text{——— (2)}$$

$$0 = i_1 j X_{L_2} + i_2 (jX_{L_1} + jX_{L_2} - jX_c) - i_3 j X_{L_1} \quad \text{--- (3)}$$

Multiplying equ^n (1) by $-hre$, we get

$$-hre\,V_o = \frac{hfe\,hre\,i_b}{hoe} - \frac{hre}{hoe} i_1$$

$$= -i_2 j X_{L_1} + i_3 (hie + jX_{L_1}) \quad \text{--- (4)}$$

From equ^n (3)

$$i_2 = \frac{-j i_1 X_{L_2} + i_3 j X_{L_1}}{jX_{L_1} + jX_{L_2} - jX_c}$$

$$\therefore \; i_2 = \frac{i_3 X_{L_1} - i_1 X_{L_2}}{X_{L_1} + X_{L_2} - X_c} \quad \text{--- (5)}$$

Using equ^n (5) in equ^n (2) and (4), we get

$$\frac{hfe\,i_b}{hoe} = i_1\left(\frac{1}{hoe} + jX_{L_2}\right) + jX_{L_2} \frac{i_3 X_{L_1} - i_1 X_{L_2}}{X_{L_1} + X_{L_2} - X_c}$$

$$\frac{hfe\,i_b}{hoe} = i_1\left(\frac{1}{hoe} + jX_{L_2} - \frac{jX_{L_2}^2}{X_{L_1}+X_{L_2}-X_c}\right) + \frac{i_3 j X_{L_2}}{X_{L_1}+X_{L_2}-X_c} \quad \text{--- (6)}$$

$$\frac{hre\,hfe\,i_b}{hoe} = i_1\left(\frac{hre}{hoe}\right) - \frac{(i_3 X_{L_1} - i_1 X_{L_2})\, jX_{L_1}}{X_{L_1} + X_{L_2} - X_c} + i_3(hie + jX_{L_1})$$

$$\frac{hre\;hfe\;i_b}{hoe} = i\left(\frac{hre}{hoe} + \frac{jX_{L_1}X_{L_2}}{X_{L_1}+X_{L_2}-X_c}\right) + i_3\left(hie + jX_{L_1} - \frac{jX_{L_1}^2}{X_{L_1}+X_{L_2}-X_c}\right) \quad \text{--- (7)}$$

From equ^n (6)

$$i_1 = \left(\frac{hfe\,i_b}{hoe} - \frac{i_3 j X_{L_1} X_{L_2}}{X_{L_1}+X_{L_2}-X_c}\right) \Big/ \frac{i}{hoe} + jX_{L_2} \frac{jX_{L_2}^2}{X_{L_1}+X_{L_2}-X_c} \quad \text{--- (8)}$$

After Solving above equ^n, we get

$$-\frac{hie}{hoe} + X_{L_1}X_{L_2} - \frac{X_{L_1}^2 X_{L_2}}{X_{L_1}+X_{L_2}-X_c} - \frac{X_{L_1}X_{L_2}^2}{X_{L_1}+X_{L_2}-X_c} = 0 \quad \text{--- (9)}$$

$$hfe = (hie\,hoe - hfe\,hre)\frac{L_2}{L_1} \quad \text{--- (10)}$$

In equ^n (10), we neglected those terms whose co-efficients is $(X_{L_1} + X_{L_2} - X_c)$

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From equ^n (9) $$\frac{h_{ie}}{h_{oe}} = X_{L_1}X_{L_2} - \frac{X_{L_1}X_{L_2}(X_{L_1}+X_{L_2})}{X_{L_1}+X_{L_2}-X_C}$$

$$\frac{h_{ie}}{h_{oe}} = X_{L_1}X_{L_2} - \frac{X_{L_1}X_{L_2}(X_{L_1}+X_{L_2})}{X_{L_1}+X_{L_2}-X_C}$$

$$\frac{h_{ie}}{h_{oe}} \cancel{\times} (X_{L_1}+X_{L_2}-X_C) = X_{L_1}X_{L_2}(X_{L_1}+X_{L_2}-X_C) - X_{L_1}X_{L_2}(X_{L_1}+X_{L_2})$$

or $$\frac{h_{ie}}{h_{oe}}(X_{L_1}+X_{L_2}-X_C) = X_{L_1}X_{L_2}(X_{L_1}+X_{L_2}-X_C-X_{L_1}-X_{L_2})$$

or $$\frac{h_{ie}}{h_{oe}}(X_{L_1}+X_{L_2}-X_C) = -X_C X_{L_2} X_{L_1}$$

or $$X_{L_1}+X_{L_2}-X_C = \frac{-h_{oe}}{h_{ie}}\omega L_1 \omega L_2 \times \left(\frac{1}{\omega C}\right)$$

or $$\left(\omega L_1 + \omega L_2 - \frac{1}{\omega C}\right) = \frac{-h_{oe}}{h_{ie}}\omega^2 L_1 L_2 \frac{1}{\omega C}$$

or $$\omega(L_1+L_2) - \frac{1}{\omega C} = -\omega^2 L_1 L_2 \frac{h_{oe}}{h_{ie}} \times \frac{1}{\omega C}$$

or $$\frac{\omega^2 C(L_1+L_2)-1}{\omega C} = -\omega^2 L_1 L_2 \frac{h_{oe}}{h_{ie}} \times \frac{1}{\omega C}$$

or $$\omega^2\left[(L_1+L_2)C + L_1L_2\frac{h_{oe}}{h_{ie}}\right] = 1$$

$$\therefore \quad \omega^2 = \frac{1}{C(L_1+L_2)+L_1L_2\frac{h_{oe}}{h_{ie}}} \simeq \frac{1}{C(L_1+L_2)} \quad \text{—— (11)}$$

$$\left[\because L_1L_2\frac{h_{oe}}{h_{ie}} \text{ is small}\right]$$

$$\therefore \quad \omega = \frac{1}{\sqrt{C(L_1+L_2)}} \quad \therefore f = \frac{1}{2\pi\sqrt{C(L_1+L_2)}} \quad \text{—— (12)}$$

This is the frequency of Hartley oscillator. If mutual induction is considered, then

$$f = \frac{1}{2\pi\sqrt{C(L_1+L_2+2M)}} \quad \text{—— (13)}$$

From eqn (10)

$$\frac{h_{fe}}{h_{ie} h_{oe} - h_{fe} h_{re}} = \frac{L_2}{L_1} \quad \text{——— (14)}$$

This is the condition of oscillation if mutual inductance M is considered, then the condition is

$$\frac{h_{fe}}{h_{ie} h_{oe} - h_{fe} h_{re}} = \frac{L_2 + M}{L_1 + M} \quad \text{——— (15)}$$

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