PHASE SHIFT OSCILLATOR

Phase-shift oscillator or RC phase-shift oscillator is suitable to generate audio frequencies. Fig-1. shows a basic ckt. of transistorised phase-shift oscillator. When a sinusoidal voltage of frequency 'f' is applied to a circuit consisting of R and C, in series then alternating current in the circuit leads the applied voltage by certain angle known as phase-angle. The value of R and C may be selected in such a way that for the frequency 'f', the phase angle is 60°. So, using a ladder network of three R-C section (as shown in fig-1), we are able to produce 180° phase-shift.

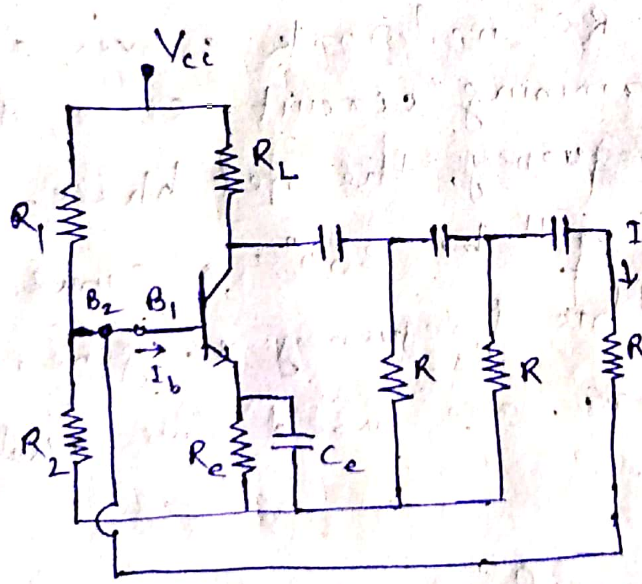

Fig-1(a)

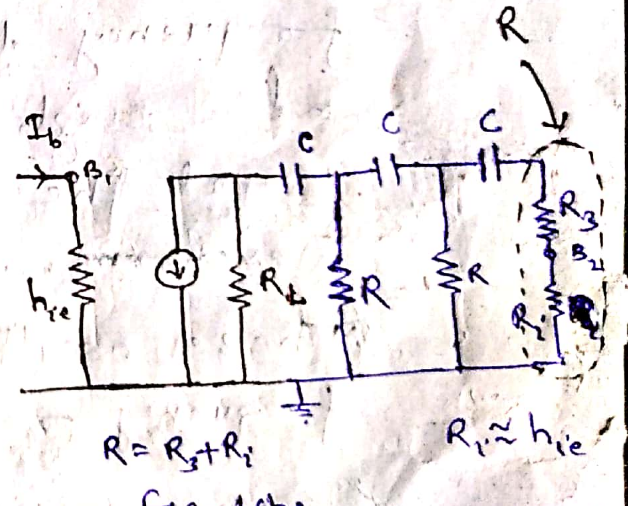

Fig-1(b)

Circuit arrangement :

ckt shown in fig-1(a) consist of NPN transistor in CE configuration. R_1, R_2 and R_E, C_e provides biasing and temperature stability. The output of amplifier goes to a feedback network which consist ~~a resistance~~

of three RC sections. It should be noted that the last section contain a resistance $R_3 = R - h_{ie}$ because this resistor is connected with the base of transistor, the input resistance h_{ie} of transistor is added to it to give total resistance R

Circuit action :-

Here the three RC - ladder circuit produces a phase shift of 180° between input and output voltages since CE amplifier produces a phase-shift of 180° due to transistor action, the total phase-shift becomes 360° (or 0°), which is the essential requirement of sustained oscillation. The RC network serves as frequency determining circuit, since only at a single frequency, the net phase-shift around the loop will be 360°, a sinusoidal waveform at this frequency is generated. These oscillators are used for audio frequency range.

Frequency of oscillation :-

There are following assumptions —

i) $1/h_{oe}$ is much larger than R_L,

ii) h_{re} is very small and $h_{re}V_o$ can be neglected

iii) In practice, R_L is taken equal to R i.e. $R_L \approx R$

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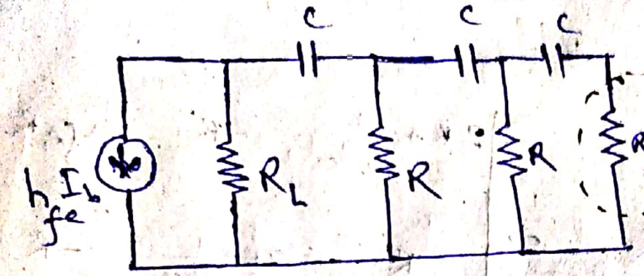
Now, the equivalent ckt (in h-parameter) of fig-1(a), which is drawn in fig-1(b), can be redrawn for mathematical analysis as shown in fig-2(a), (b)



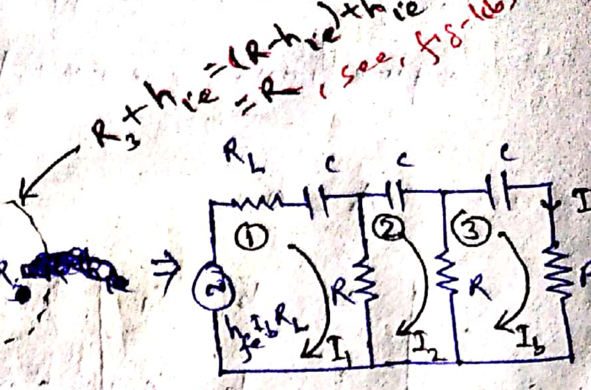


fig-2(a)

fig-2(b)

Let, $R_L = R$,

Apply KVL in loop-1 in fig-2(b)

$$h_{fe}I_bR_L + I_1\left(R + \frac{1}{j\omega c}\right) + (I_1 - I_2)R = 0$$

$$\text{or, } \left(2R + \frac{1}{j\omega c}\right)I_1 - RI_2 + h_{fe}RI_b = 0 \quad \text{———— (i)}$$

Again, Apply KVL in loop-2

$$(I_2 - I_b)R + (I_2 - I_1)R + I_2\left(\frac{1}{j\omega c}\right) = 0$$

$$\text{or } I_2R - I_bR + I_2R - I_1R + I_2\left(\frac{1}{j\omega c}\right) = 0$$

$$\text{or } -RI_1 + \left(2R + \frac{1}{j\omega c}\right)I_2 - RI_b = 0 \quad \text{———— (ii)}$$

similarly apply KVL in loop-3

$$I_bR + (I_b - I_2)R + I_b\left(\frac{1}{j\omega c}\right) = 0$$

$$\text{or } 0.I_1 - RI_2 + \left(2R + \frac{1}{j\omega c}\right) = 0 \quad \text{———— (iii)}$$

Here, there are three knowns as I_1, I_2, I_b for which we solve by using cramer's rule.

It is obvious from eq^n (i), (ii) & (iii), these equations are homogeneous,

$\therefore \Delta = 0.$

$$\therefore \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} = 0 \Rightarrow \begin{vmatrix} 2R + \frac{1}{j\omega C} & -R & h_{fe}R \\ -R & 2R + \frac{1}{j\omega C} & -R \\ 0 & -R & 2R + \frac{1}{j\omega C} \end{vmatrix} = 0$$

$$\text{or} \begin{vmatrix} 2R - jX_c & -R & h_{fe}R \\ -R & 2R - jX_c & -R \\ 0 & -R & 2R - jX_c \end{vmatrix} = 0, \quad \text{where } X_c = \frac{1}{j\omega C}$$

or, $(2R - jX_c)[(2R - jX_c)(2R - jX_c) - (-R)(-R)] - (-R)[(-R)(2R - jX_c) - 0]$

$+ h_{fe}R[(-R)(-R) - 0] = 0$

or, $(2R - jX_c)[3R^2 - j4RX_c - X_c^2] - R^2(2R - jX_c) + h_{fe}R^3 = 0$

or $6R^3 - j8R^2X_c - 2RX_c^2 - 3jR^2X_c - 4RX_c^2 + jX_c^3 - 2R^3 + jR^2X_c + h_{fe}R^3 = 0$

or $4R^3 + jX_c^3 - j10R^2X_c - 6RX_c^2 + h_{fe}R^3 = 0$

Equating imaginary part to zero

$X_c^3 - 10R^2X_c$ or $X_c^2 = 10R^2$, or $X_c = \sqrt{10}R$

or $\frac{1}{\omega C} = \sqrt{10}R$ or, $\omega C = \frac{1}{\sqrt{10}R}$ $\Rightarrow \boxed{f = \frac{1}{2\sqrt{10}\pi RC}}$

If $R_L \neq R$, then from above analysis, we can show that—

$$\boxed{f = \frac{1}{2\pi C\sqrt{4RR_L + 6R^2}}}$$

If $R_L << R$, then, $f = \frac{1}{2\sqrt{6}\pi CR}$

Now, equating real to zero, we get—

$$4R^3 - 6RX_c^2 + h_{fe}R^3 = 0$$

$\because X_c = 10R^2$, (from above discussion),

$$\therefore 4R^3 - 6R(10R^2) + h_{fe}R^3 = 0$$

or $R^3(4 - 60 + h_{fe}) = 0$ $\Rightarrow$ $\boxed{h_{fe} = 56}$

Thus, for sustained oscillation, $h_{fe} = 56$.