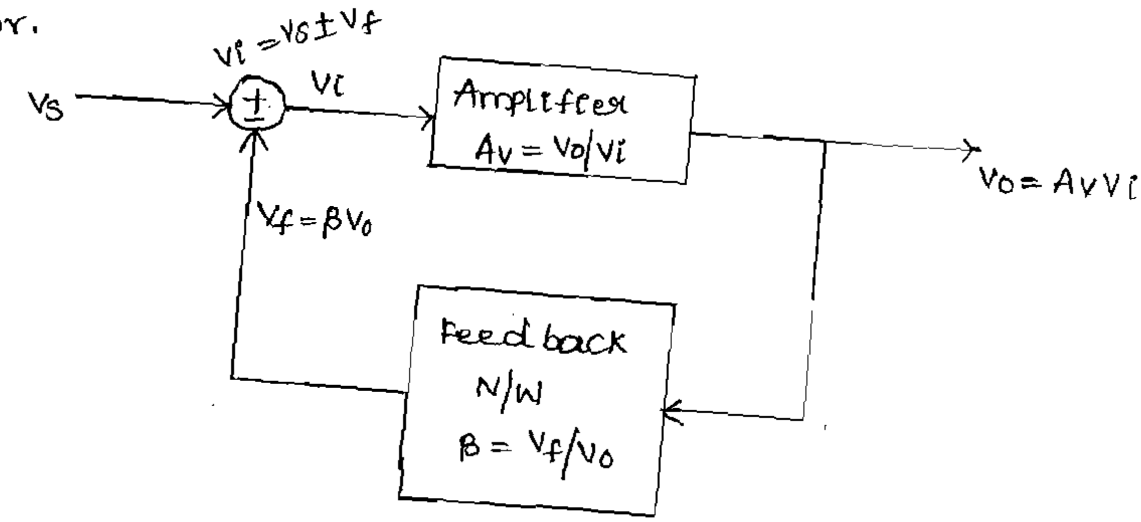
UNIT – III

FEED BACK AMPLIFIERS

Introduction:-

A feedback amplifier is a circuit in which the output signal is sampled and feedback to the input. The block diagram of a feedback amplifier is shown in fig 1. It consists of a basic Amplifier (or) having a voltage gain 'Av' and a feedback network. The gain of the gain of the feedback network is 'β' which is also known as feedback factor.



Amplifier:- An electronic circuit which increases the strength (voltage, power, current) of the gain input signal.

feedback:- A portion of sampled output signal is provided as an input is feedback.

The network which is used for feedback is known as feedback network.

Types of feedback:-

1. Positive feedback.
2. Negative feedback

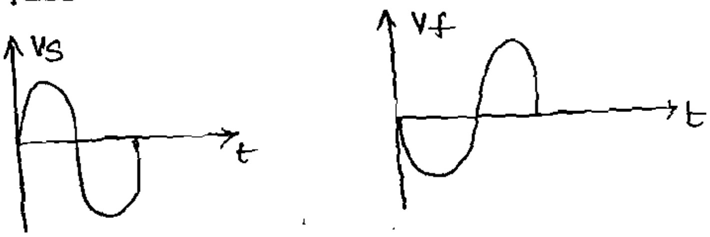
1. Positive feedback:-

If the feedback signal is in phase with the source signal then the feedback is known as positive feedback.

i.e., $V_i = V_s + V_f$

2. Negative feedback:-

If the feedback signal is out of phase with the source signal then the feedback (signal) is negative feedback i.e $V_i = V_s - V_f$



Gain of feed back Amplifier:-

The gain of feedback amplifier is given as

$$A_{vf} = \frac{V_o}{V_s}$$

The input voltage to the amplifier with feedback is given as

$$V_i = V_s \pm V_f$$

$$V_s = V_i \mp V_f$$

$$\Rightarrow V_s = V_i \mp \beta V_o$$

$$\Rightarrow V_s = V_i \mp \beta A_v V_i$$

$$\Rightarrow V_s = V_i \left[1 \mp \beta A_v \right]$$

$$\boxed{\frac{V_s}{V_i} = 1 \mp \beta A_v}$$

From ① we have

$$A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \times \frac{V_i}{V_s}$$

$$= A_v \cdot \frac{V_i}{V_s}$$

From ②

$$\Rightarrow A_{vf} = \frac{A_v}{1 \mp \beta A_v}$$

for +ve feedback, $A_{vf} = \dfrac{A_v}{1 - \beta A_v}$

for −ve feedback, $A_{vf} = \dfrac{A_v}{1 + \beta A_v}$

Note:-

1. Negative feedback is used for amplifiers
2. positive feedback is used for oscillators.

CHARATERISTICS OF NEGATIVE FEEDBACK

(OR)

ADVANTAGE OF NEGATIVE FEEDBACK OVER POSITIVE FEEDBACK

1. Increase stability:-

The expression for voltage gain with feedback is given as

$$A_{vf} = \frac{A_v}{1 + \beta A_v}$$

as $\beta A_v >> 1$

$$\Rightarrow A_{vf} = \frac{A_v}{\beta A_v} \Rightarrow \boxed{A_{vf} = \frac{1}{\beta}}$$

2. Desensitivity of Transfer gain

The fractional change of transfer gain with divided by fractional change of transfer gain without feedback is known as sensitivity of transfer gain

$$S = \frac{\left|\frac{dA_{vf}}{A_{vf}}\right|}{\left|\frac{dA_v}{A_v}\right|}$$

We know that $A_{vf} = \frac{A_v}{1+\beta A_v}$

Differentiate w.r.t A_v.

$$\Rightarrow \frac{d}{dA_v}(A_{vf}) = \frac{(1+\beta A_v)(1) - A_v(\beta)}{(1+\beta A_v)^2} = \frac{1+\beta A_v - \beta A_v}{(1+\beta A_v)^2}$$

$$\Rightarrow \frac{dA_{vf}}{dA_v} = \frac{1}{(1+\beta A_v)^2} \Rightarrow dA_{vf} = \frac{dA_v}{(1+\beta A_v)^2}$$

Dividing L.H.S & R.H.S by A_{vf}

$$\Rightarrow \frac{dA_{vf}}{A_{vf}} = \frac{dA_v}{A_{vf}(1+\beta A_v)^2}$$

$$= \frac{dA_v}{\left(\frac{A_v}{1+\beta A_v}\right)(1+\beta A_v)^2} = \frac{dA_v}{A_v} \cdot \frac{1}{(1+\beta A_v)}$$

$$\Rightarrow \frac{dA_{vf}}{dA_{vf}} = \frac{dA_v}{A_v} \cdot \frac{1}{1+\beta A_v}$$

$$\Rightarrow S = \frac{\left|\frac{dA_{vf}}{A_{vf}}\right|}{\left|\frac{dA_v}{A_v}\right|} = \frac{1}{1+\beta A_v}$$

Desensitivity is reciprocal of sentitivity

$$\Rightarrow D = \frac{1}{S} = 1+\beta A_v$$

$$\therefore \boxed{D = 1+\beta A_v}$$

3. Reduction in frequency distortion :-

We know that

$$A_{vf} = \frac{A_v}{1+\beta A_v} \Rightarrow A_{vf} = \frac{1}{\beta}$$

If the feedback network is made up of resistors but not with reactive elements like capacitor, Inducto[r] A_{vf} is independent of frequency. So distortions due to frequency is reduced.

4. Reduction in Noise :-

Let 'N_f' be the noise with feedback & 'N' be the noise without feedback then,

$$\therefore \boxed{N_f = \frac{N}{1+\beta A_v}} \quad \left(\because \begin{array}{l} A_{vf} < A_v \ \& \\ N_f < N_v \end{array}\right).$$

5. Reduction in distortion

If D_f is the distortion with feedback & 'D' is the distortion without feedback then,

$$\boxed{D_f = \frac{D}{1+\beta A_v}}$$

6. Increase in bandwidth :-

If $B \cdot W_f$ is the band width with feedback and $B \cdot W$ is the bandwidth without feedback then,

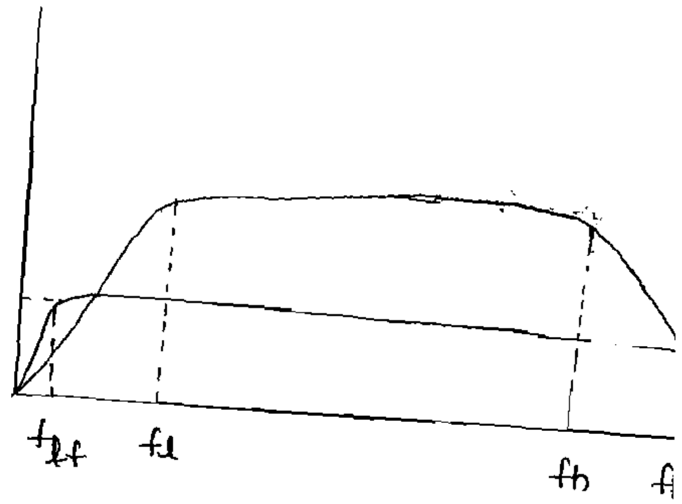
$$B \cdot W_f = BW(1+\beta A_v)$$

i.e $B \cdot W_f > B \cdot W$

$B \cdot W = f_h - f_l$

$B \cdot W_f = f_{hf} - f_{lf}$

$\therefore B \cdot W_f = f_{hf} - f_{lf}$



$B \cdot W = f_h - f_l$

$B \cdot W_f = f_{hf} - f_{lf}$

FEED BACK TOPOLOGIES :-

In feedback amplifiers, the output signal sampled may be either voltage (or) current and the sampled signal can be mixed either in series or in shunt with the input Based on the type of sampled signal (can be ~~mixed either~~) at the output side and the type of mixing at the input side the amplifiers are divided into four types. They are :

1. Voltage series feedback amplifier
2. Voltage shunt feedback amplifier.
3. current series feedback amplifier
4. current shunt feedback amplifier.

Note :-

1. If the sampled output signal is Voltage irrespective of type of input mixing the output impedance decreases.
2. If the sampled output signal is current irrespective of type of i/p mixing the o/p impedance increases.

3. If the type of mixing in input is in series irrespective of the type of sampled output the input impedance increases.
4. If the type of mixing the input is in shunt the type of sampled output the then irrespective of type of sampled output the input impedance decreases.

Voltage-series feedback Amplifier:-

If voltage is sampled and the mixing is in series then the type of feedback is known as voltage series. since the voltage is sampled, the output parameter monitored i.e voltage and since mixing at the input is series, the parameter that is affected is the input voltage& Av is stabilised.

The feedback factor β is the ratio of output signal of the feedback network to the input signal of the feedback network which is equal to

$$\beta = \frac{V_f}{V_o}$$

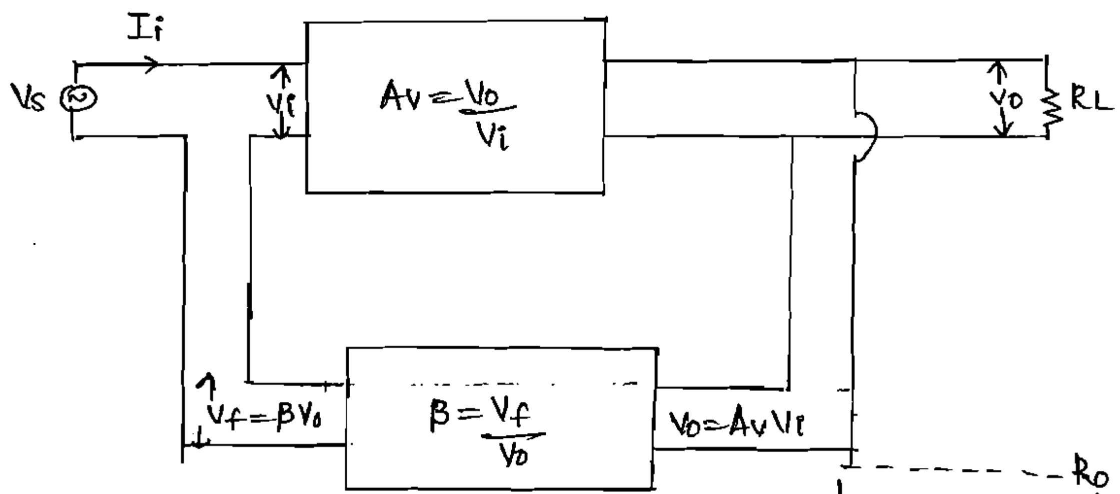
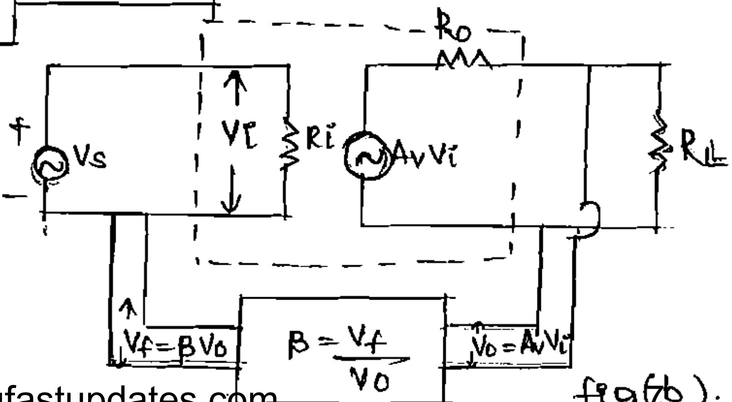


fig (a).



fig(b).

Gain with feedback (A_{vf}):-

From the circuit we have,

$$V_i = V_s - V_f$$

$$V_s = V_i + V_f = V_i + \beta V_o = V_i + \beta(A_v \cdot V_i) = V_i(1+\beta A_v)$$

$$\Rightarrow \frac{V_s}{V_i} = (1+\beta A_v) \rightarrow \frac{V_i}{V_s} = \frac{1}{1+\beta A_v}$$

$$A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \times \frac{V_i}{V_s} = A_v \cdot \frac{1}{1+\beta A_v}$$

$$\therefore \boxed{A_{vf} = \frac{A_v}{1+\beta A_v}}$$

Input impedance with feedback (R_{if}):-

We have,

$$V_i = V_s - V_f \Rightarrow V_s = V_i + V_f \ \& \ R_{if} = \frac{V_s}{I_i} \quad R_i = \frac{V_i}{I_i}$$

$$R_{if} = \frac{V_s}{I_i} = \frac{V_i + V_f}{I_i} = \frac{V_i + \beta V_o}{I_i} = \frac{V_i + \beta(A_v V_i)}{I_i}$$

$$\Rightarrow R_{if} = \frac{V_i}{I_i}(1+\beta A_v)$$

$$\Rightarrow \boxed{R_{if} = R_i(1+\beta A_v)}$$ [$R_{if} \uparrow$ $\because$ i/p mixing is series]

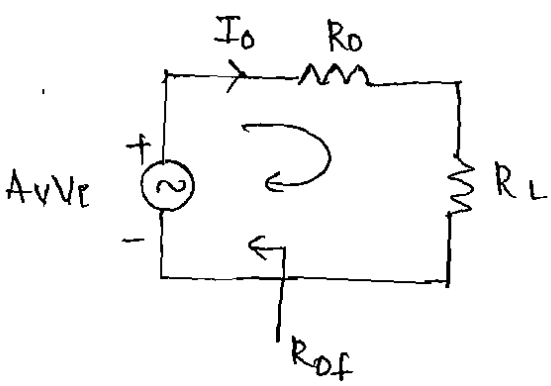
Output impedance with feedback (R_{of}):-

Output impedance is obtained by making source to 'zero'. i.e $V_s = 0$.

As, $V_i = V_s - V_f$

$\Rightarrow V_i = -V_f$ [$\because V_s = 0$]

Consider the o/p ckt $\rightarrow$



From the ckt,

$$V_o = I_o R_o + A_v V_i$$

$$\Rightarrow V_o = I_o R_o + A_v(-V_f) = I_o R_o - A_v(\beta V_o) \Rightarrow I_o R_o = V_o + A_v(\beta V_o)$$

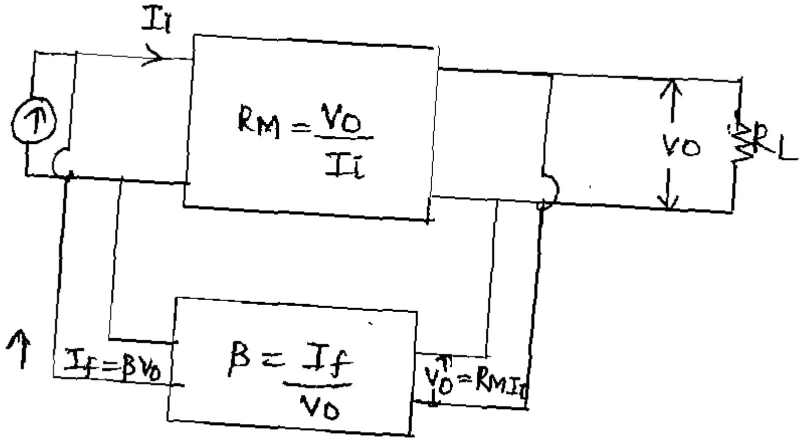
$$V_o(1+\beta A_v) = I_o R_o$$

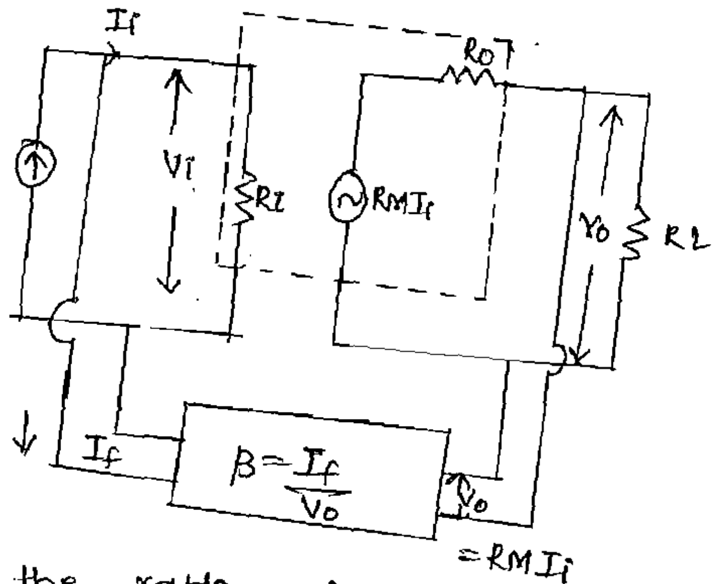
$$\Rightarrow \frac{V_o}{I_o} = \frac{R_o}{1+\beta A_v}$$

$$\Rightarrow \boxed{R_{of} = \frac{R_o}{1+\beta A_v}}$$

Voltage shunt feedback Amplifier:-

If voltage is sampled and the mixing is shunt then the type of feedback is known as voltage shunt since the mixing at the input is shunt then the parameter that is affected is the input current. The parameter that is stabilized in Voltage shunt feedback is $\frac{V_o}{I_i}$ which is known as transresistance denoted by 'R_M'.





→ The feedback factor 'β' is the ratio of feedback current to the output voltage, that is $\beta = \frac{I_f}{V_o}$.

→ In this amplifier, with feedback the o/p resistance & i/p resistance decrease.

Transresistance without feedback $R_M = \frac{V_o}{I_i}$

Transresistance with feedback $R_{Mf} = \frac{V_o}{I_s}$

∴ From the circuit

We have $I_i = I_s - I_f$

$\Rightarrow I_s = I_i + I_f$

$\Rightarrow I_s = I_i + \beta V_o = I_i + \beta(R_M I_i) = I_i(1+\beta R_M)$.

$\Rightarrow \frac{I_i}{I_s} = \frac{1}{1+\beta R_M}$

$\therefore R_{Mf} = \frac{V_o}{I_s} = \frac{V_o}{I_i} \times \frac{I_i}{I_s} = R_M \cdot \frac{1}{1+\beta R_M}$

$$\therefore \boxed{R_{Mf} = \frac{R_M}{1+\beta R_M}}$$

Input impedance:-

Input impedance without feedback is $R_i = \frac{V_i}{I_i}$

Input impedance with feedback is $R_{if} = \frac{V_i}{I_s}$

From the ckt we have,

$I_i = I_s - I_f$

$\Rightarrow I_s = I_i + I_f = I_i + \beta V_o = I_i + \beta R_M I_i = I_i(1+\beta R_M)$.

$\Rightarrow$ ~~$R_{if} = V$~~ $\Rightarrow \frac{I_s}{I_i} = 1+\beta R_M \Rightarrow \frac{I_i}{I_s} = \frac{1}{1+\beta R_M}$.

As, $R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i} \times \frac{I_i}{I_s} = R_i \cdot \frac{1}{1+\beta R_M}$.

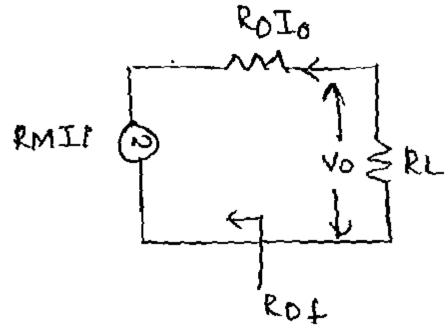
$$\therefore \boxed{R_{if} = \frac{R_i}{1+\beta R_M}}$$

Output impedance:-

To get o/p impedance make source to zero i.e $I_s = 0$

As, $I_i = I_s - I_f \Rightarrow I_i = -I_f$

considering the o/p ckt, →



Applying KVL,

$$V_o = R_oI_o + R_MI_i$$

$$= I_oR_o - R_MI_f$$

$$V_o = -I_oR_o - R_M\beta V_o.$$

$$\Rightarrow V_o + R_M\beta V_o = I_oR_o \Rightarrow V_o(1+R_M\beta) = I_oR_o \Rightarrow V_o = \frac{I_oR_o}{1+R_M\beta}$$

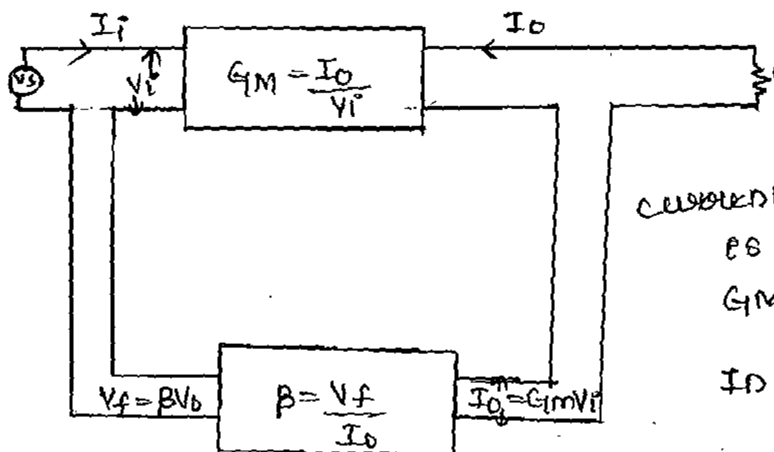
$$\Rightarrow \frac{V_o}{I_o} = \frac{R_o}{1+\beta R_M}$$

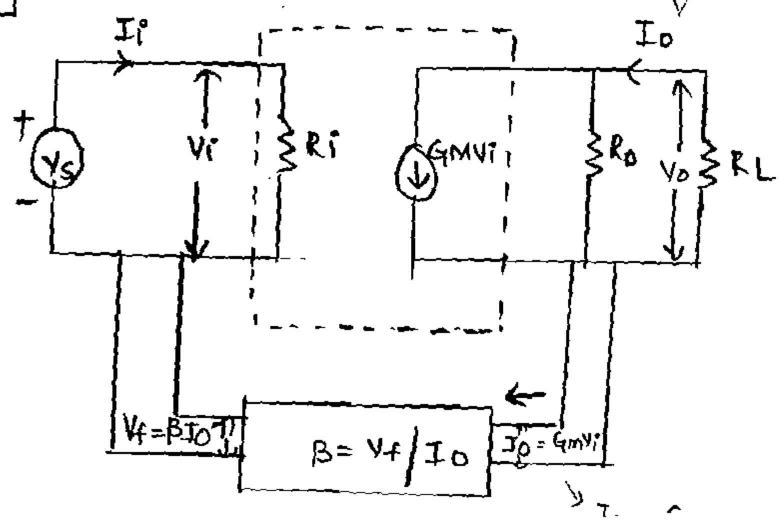
$$\Rightarrow \boxed{R_{of} = \frac{R_o}{1+\beta R_M}}$$

Current series feed back Amplifier:-

If current is sampled & the mixing is in series with the i/p then the type of feedback is known as current series. since the current gain without feedback is G_M & gain with feedback is G_M. $G_M = I_o/V_i$. & feedback factor $\beta = \frac{V_f}{I_o}$

In ckt, both o/p & i/p resistance increase





Transconductance without feedback $G_M = \frac{I_o}{V_i}$

Transconductance with feedback $G_{Mf} = \frac{I_o}{V_s}$

From the circuit

$V_i = V_s - V_f$

$V_s = V_i + V_f = V_i + \beta I_o = V_i + \beta(G_M V_i) = V_i(1+\beta G_M)$

$\Rightarrow \frac{V_s}{V_i} = 1+\beta G_M \Rightarrow \frac{V_i}{V_s} = \frac{1}{1+\beta G_M}$

$\therefore G_{Mf} = \frac{I_o}{V_s} = \frac{I_o}{V_i} \cdot \frac{V_i}{V_s} = G_M \cdot \frac{1}{1+\beta G_M}$

$\therefore \boxed{G_{Mf} = \frac{G_M}{1+\beta G_M}}$

Input impedance:-

Input impedance without feedback $R_i = \frac{V_i}{I_i}$

Input impedance with feedback $R_{if} = \frac{V_s}{I_i}$

from the circuit

$V_i = V_s - V_f$

$\Rightarrow V_s = V_i + V_f = V_i + \beta I_o = V_i + \beta(G_M V_i) = V_i(1+\beta G_M)$

$\Rightarrow \frac{V_s}{V_i} = 1+\beta G_M \Rightarrow \frac{V_i}{V_s} = \frac{1}{1+\beta G_M}$

$\therefore R_i = \frac{V_i}{I_i} = \frac{V_i}{V_s} \cdot \frac{V_s}{I_i} = \frac{1}{1+\beta G_M} \cdot R_{if}$

$\Rightarrow R_i = \frac{R_{if}}{1+\beta G_M}$

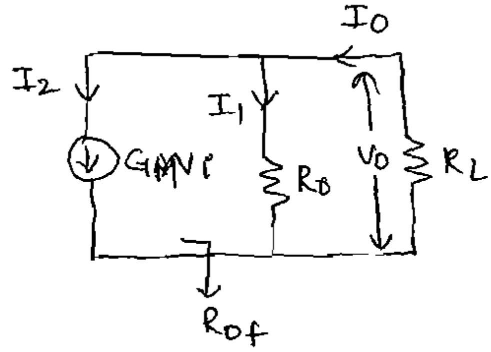
$\Rightarrow \boxed{R_{if} = R_i(1+\beta G_M)}$

Output impedance:-

To get the o/p impedance make source to zero i.e $V_s = 0$

$\Rightarrow V_i = V_s - V_f = -V_f$

consider the o/p ckt,



Applying KCL,

$$I_o = I_1 + I_2$$

$$= \frac{V_o}{R_o} + G_M V_i = \frac{V_o}{R_o} - G_M V_f$$

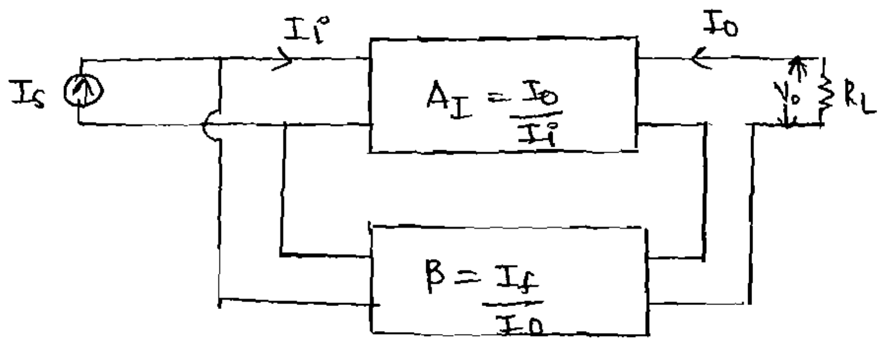
$$I_o = \frac{V_o}{R_o} - G_M \beta I_o$$

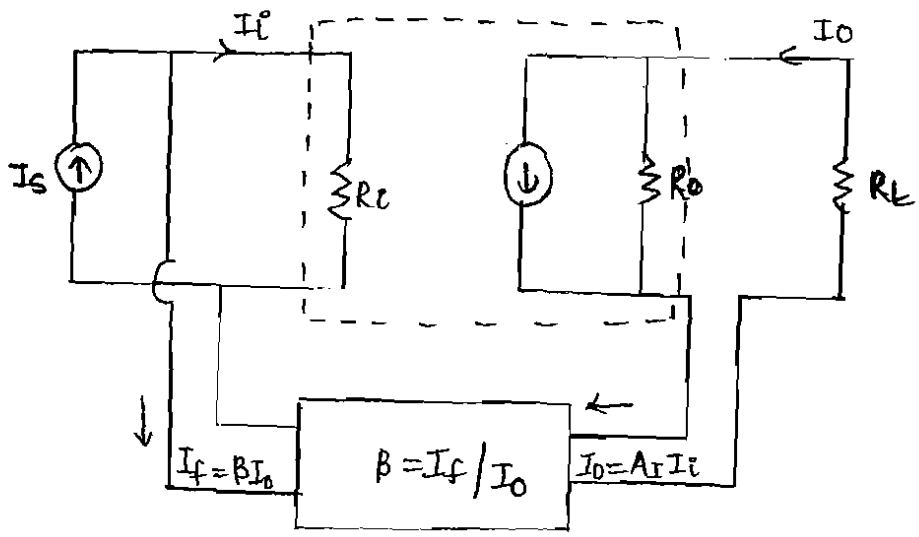
$$\Rightarrow I_o(1 + G_M \beta) = \frac{V_o}{R_o}$$

$$\Rightarrow \frac{V_o}{I_o} = R_o(1 + \beta G_M)$$

$$\Rightarrow \boxed{R_{of} = R_o(1 + \beta G_M)}$$

Current shunt feedback Amplifier:-





Current gain:-

current gain without feedback $A_I = \frac{I_o}{I_i}$

current gain with feedback $A_{If} = \frac{I_o}{I_s}$

From the ckt,

$$I_i = I_s - I_f$$

$$\Rightarrow I_s = I_i + I_f = I_i + \beta I_o = I_i + \beta(A_I I_i)$$

$$\Rightarrow I_s = I_i(1+\beta A_I) \Rightarrow \frac{I_i}{I_s} = \frac{1}{1+\beta A_I}$$

$$\Rightarrow A_{If} = \frac{I_o}{I_s} = \frac{I_o}{I_i} \cdot \frac{I_i}{I_s} = A_I \cdot \frac{1}{1+\beta A_I}$$

$$\Rightarrow \boxed{A_{If} = \frac{A_I}{1+\beta A_I}}$$

Input impedance:-

Input impedance without feedback $R_i = \frac{V_i}{I_i}$

Input impedance with feedback $R_{if} = \frac{V_i}{I_s}$

We have,

$$I_i = I_s - I_f$$

$$\Rightarrow I_s = I_i + I_f = I_i + \beta(A_I I_i) = I_i(1+\beta A_I)$$

$$\Rightarrow \frac{I_s}{I_i} = 1+\beta A_I \Rightarrow \frac{I_i}{I_s} = \frac{1}{1+\beta A_I}$$

$$\therefore R_{if} \quad R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i} \cdot \frac{I_i}{I_s} = \frac{R_i}{1+\beta A_I}$$

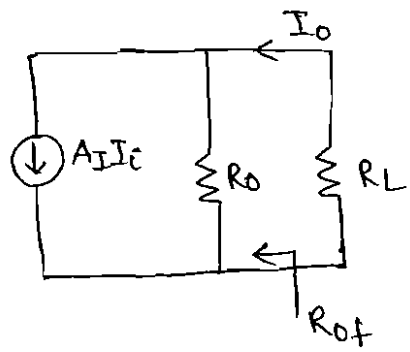
$$\therefore R_{if} = \frac{R_i}{1+\beta A_I}$$

Output impedance:-

To get o/p impedance,

$I_s = 0$ As, $I_i = I_s - I_f = -I_f$

considering O/P ckt:



8.

Apply KCL,

$$I_o = \frac{V_o}{R_o} + A_I I_i$$

$$= \frac{V_o}{R_o} + A_I(-I_f)$$

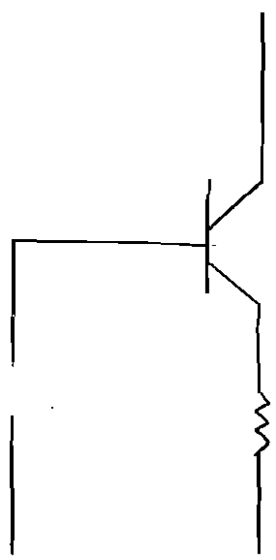
$$I_o = \frac{V_o}{R_o} - A_I \beta I_o \Rightarrow I_o + A_I \beta I_o = \frac{V_o}{R_o}$$

$$\Rightarrow I_o(1 + A_I\beta) = \frac{V_o}{R_o} \rightarrow \frac{V_o}{I_o} = R_o(1+\beta A_I)$$

$$\Rightarrow \boxed{R_{of} = R_o(1+\beta A_I)}$$

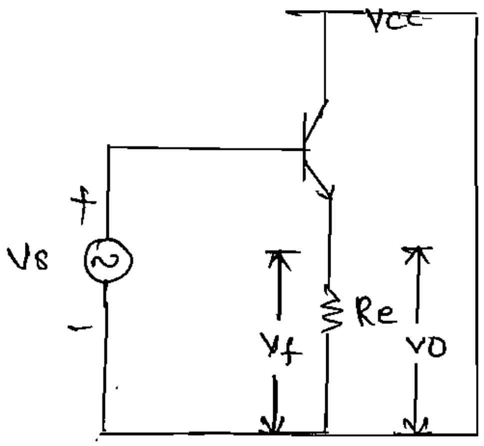
Practical ckt for voltage series feedback Amplifier

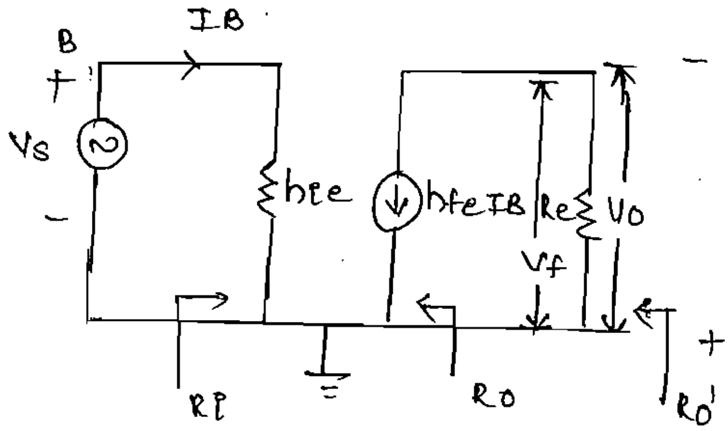
Emitter follower (CC Amplifier)



Practical ckt for voltage series feedback Amplifier

Emitter follower or CC Amplifier.





As, the signal sampled at Re is voltage and the voltage drop across Re is provided as feedback and it gets subtracts with the source voltage Vs.

∴ Emitter follower acts as voltage series feedback amplifier.

As, $V_0 = V_f$

feedback factor, $\beta = \frac{V_f}{V_0} = \frac{V_0}{V_0} = 1$

$$\Rightarrow \boxed{\beta = 1}$$

Voltage gain (AV):-

$$A_V = \frac{V_0}{V_S} = \frac{I_C R_e}{I_B h_{ie}} = \frac{h_{fe} I_B R_e}{I_B h_{ie}}$$

$$A_V = \frac{h_{fe} R_e}{h_{ie}}$$

Input impedance R_{ie}

$R_{ie} = h_{ie}$

output impedance R_{oe}:- make source to zero to get o/p impedance

ie $V_S = 0$.

If $V_S = 0 \Rightarrow I_B = 0$

$$\Rightarrow R_O = \frac{V_O}{I_C} = \frac{V_O}{h_{fe} I_B} = \frac{V_O}{0} = \infty.$$

$$\boxed{R_O = \infty}$$

R_O':-

$$R_O' = R_O \,//\, R_e = \frac{R_O R_e}{R_O + R_e} = R_e \quad \left[\because R_O = \infty \text{ i.e } R_O >> R_e\right]$$

* Voltage gain with feedback (A_{Vf}):-

$$A_{Vf} = \frac{A_V}{1+\beta A_V} = \frac{A_V}{1+A_V} \quad [\because \beta = 1]$$

$$A_{Vf} = \frac{\frac{h_{fe} R_e}{h_{ie}}}{1 + \frac{h_{fe} R_e}{h_{ie}}} = \frac{h_{fe} R_e}{h_{ie} + h_{fe} R_e}$$

$$\Rightarrow \boxed{A_{Vf} = \frac{h_{fe} R_e}{h_{ie} + h_{fe} R_e}}$$

* Input impedance with feedback (R_{if}):-

$$R_{if} = R_i (1+\beta A_V) = R_i (1+A_V) = h_{ie}\left(1 + \frac{h_{fe} R_e}{h_{ie}}\right)$$

$$\boxed{R_{if} = h_{ie} + h_{fe} R_e}$$

* Output impedance with feedback (R_{of} & R_{of}'):-

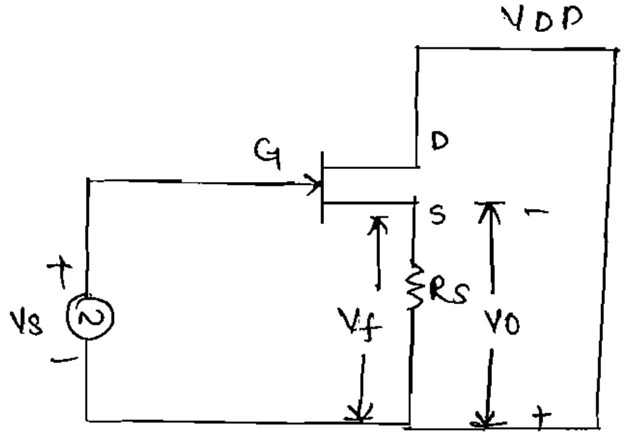
$$R_{of} = \frac{R_O}{1+\beta A_V} = \frac{R_O}{1+A_V} = \frac{\infty}{1+A_V} = \infty.$$

$$\boxed{R_{of} = \infty.}$$

$$R_{of}' = \frac{R_o'}{1+\beta A_v} = \frac{R_e}{1+\beta A_v} = \frac{R_e}{1+\frac{h_{fe}R_e}{h_{ie}}} = \frac{h_{ie}R_e}{h_{ie}+h_{fe}R_e}$$

$$\boxed{R_{of}' = \frac{h_{ie}R_e}{h_{ie}+h_{fe}R_e}}$$

* Source Amplifier



As, the output voltage and feedback signal are calucated across Rs

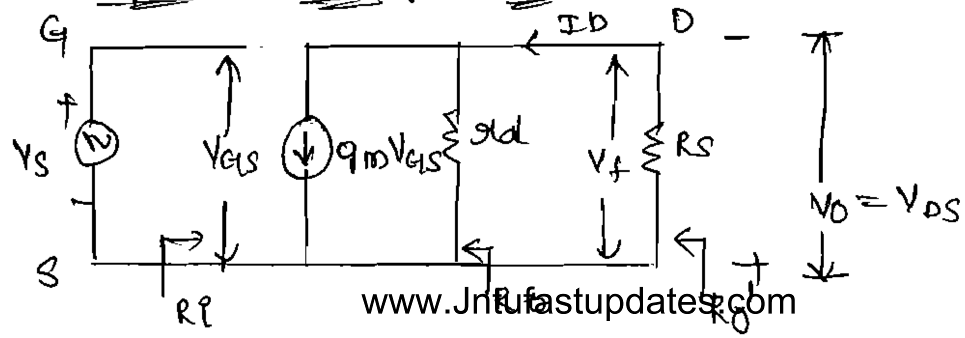
∴ $V_f = V_0$ and the feedback signal gets subtracts with the source signal.

∴ source follower acts as voltage series feedback amplifier.

Amplification factor $= \beta = \frac{V_f}{V_0} = \frac{V_0}{V_0} = 1$

$$\therefore \boxed{\beta = 1}$$

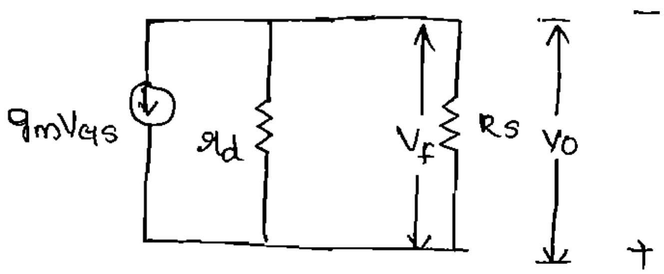
small signal Analysis for FET:-



Voltage gain $A_V = \frac{V_{DS}}{V_{GS}}$

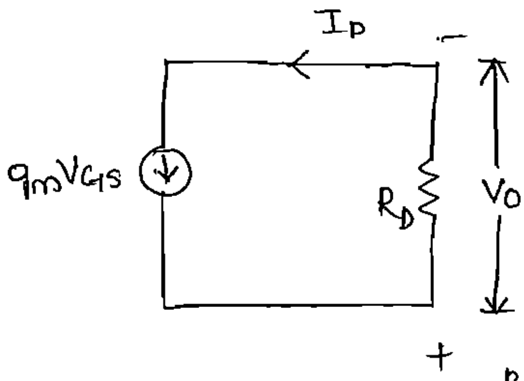
$$A_V = \frac{V_O}{V_S} = \frac{V_{DS}}{V_{GS}}$$

considering the o/p ckt



$$V_{DS} = I_d \times R_D$$

$$\therefore A_V = \frac{I_d R_D}{V_{GS}}$$



$$\Rightarrow A_V = \frac{g_m V_{GS} R_D}{V_{GS}}$$

$$\Rightarrow A_V = g_m R_D$$

substitute value of R_D

$R_D = r_d // R_S$

$R_D = \frac{r_d R_S}{r_d + R_S}$

$$A_V = \frac{g_m r_d R_S}{r_d + R_S}$$

$\boxed{A_V = \frac{\mu R_S}{R_S + r_d}}$, where, $\mu = g_m r_d$

* Input impedance (R_i) :-

As the input current of fet is zero the input impedance $R_i = \infty$.

* output impedance (R_O) :-

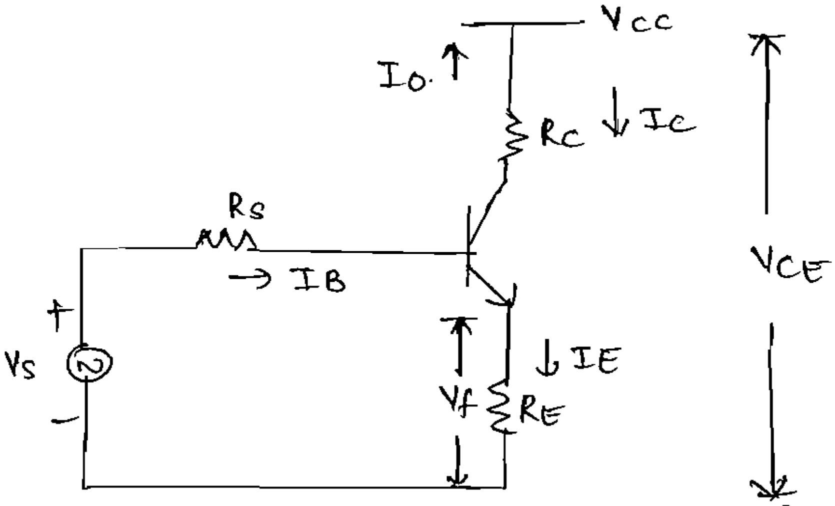
$$R_O = r_d$$

$$R_O' = R_O // R_S = \frac{R_O R_S}{R_O + R_S} = \frac{r_d R_S}{r_d + R_S}$$

$$\boxed{R_{of}' = \frac{r_d R_S}{r_d + R_S[1+\mu]}}$$

Current-series feedback Amplifier:-

CE-Amplifier with unbypassed emitter Resistor.



the feedback voltage is provided across 'R_E'

$$V_f = I_E R_E = (I_B + I_C) R_E$$

$\Rightarrow I_E = I_B + I_C$

$I_C >> I_B \quad \therefore V_E = I_C$

$$\therefore \boxed{V_f = I_C R_E}$$

$\Rightarrow V_f = -I_o R_e$

As, the feedback voltage is related to o/p current and current the output signal sampled. is current and the drop across 'R_e' gets subtracts with source voltage V_S. Hence, the mixing is in series. Hence common emitter amplifier with unbypassed emitter resistor acts as current series feed back amplifier

Voltage gain with feedback (A_{vf})

$$A_{vf} = \frac{A_v}{1+\beta A_v} = \frac{\dfrac{\mu R_s}{R_s+r_d}}{1+\dfrac{\mu R_s}{R_s+r_d}}$$

$$A_{vf} = \frac{\mu R_s}{R_s+r_d+\mu R_s}$$

$$\Rightarrow \boxed{A_{vf} = \frac{\mu R_s}{r_d+R_s[1+\mu]}}$$

* Input impedance with feedback (R_{if}):-

$$R_{if} = R_i(1+\beta A_v)$$

$$= \infty\,(1+\beta A_v) = \infty.$$

$$\Rightarrow \boxed{R_{if} = \infty.}$$

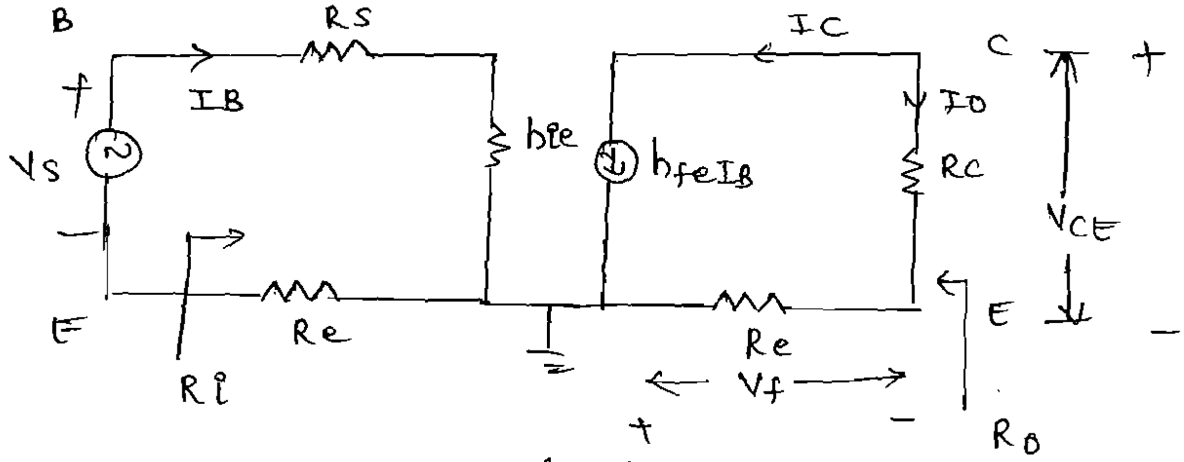
* Output impedance with feedback (R_{of}):-

$$R_{of} = \frac{R_o}{1+\beta A_v} = \frac{r_d}{1+\dfrac{\mu R_s}{r_d+R_s}}$$

$$\boxed{R_{of} = \frac{r_d(r_d+R_s)}{r_d+R_s[1+\mu]}}$$

$$R_{of}' = \frac{R_o'}{1+\beta A_v} = \frac{\dfrac{r_d R_s}{r_d+R_s}}{1+1\cdot\dfrac{\mu R_s}{r_d+R_s}}$$

Practical circuit:-



* Trans conductance (gm):-

$$G_M = \frac{I_O}{V_S} = \frac{-I_C}{V_S} = \frac{-h_{fe} I_B}{I_B[R_S + h_{ie} + R_e]}$$

$$\Rightarrow G_M = \frac{-h_{fe}}{R_S + h_{ie} + R_e}$$

* Input impedance (Ri):-

$$R_i = \frac{V_S}{I_B} = \frac{\cancel{I_B}[R_S + h_{ie} + R_e]}{\cancel{I_B}}$$

$$\beta = \frac{V_f}{V_O} = \frac{-I_O R_e}{I_O}$$

$$\Rightarrow \boxed{\beta = -R_e}$$

$$\Rightarrow \boxed{R_i = R_S + h_{ie} + R_e}$$

* Output impedance (Ro):-

To get Ro, make source to zero i.e $V_S = 0$.

If $= V_S = 0 \rightarrow I_B = 0 \Rightarrow h_{fe} I_B = 0 \Rightarrow I_C = 0$

As the o/p current is zero, output impedance is infinity.

$$\therefore \boxed{R_O = \infty}$$

* Trans conductance with feedback

$$G_{Mf} = \frac{G_M}{1 + \beta G_M}$$

$$= \frac{\dfrac{-h_{fe}}{R_s + h_{ie} + R_e}}{1 + R_e \dfrac{h_{fe}}{R_s + h_{ie} R_e}}$$

$$G_{Mf} = \frac{-h_{fe}}{R_s + R_e [h_{ie} + h_{fe}]}$$

* Input impedance (R_{if})

$$R_{if} = R_i (1 + \beta G_M)$$

$$= (R_s + h_{ie} + R_e) \left[1 + \frac{(-R_e)(-h_{fe})}{R_s + h_{ie} + R_e} \right]$$

$$= R_s + h_{ie} + \cancel{R_e} + R_e + R_e h_{fe}$$

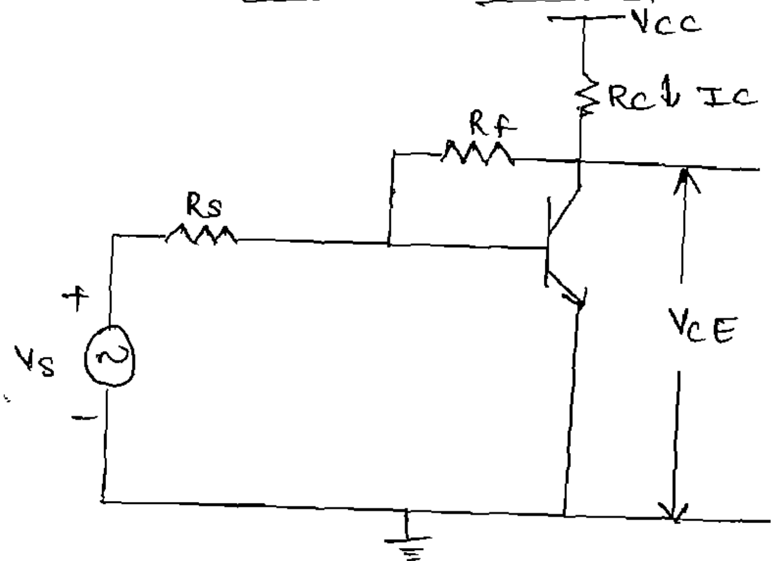
$$\boxed{R_{if} = R_s + h_{ie} + R_e [1 + h_{fe}]}$$

Output impedance with feedback (R_{of})

$$R_{of} = R_o (1 + \beta G_M)$$

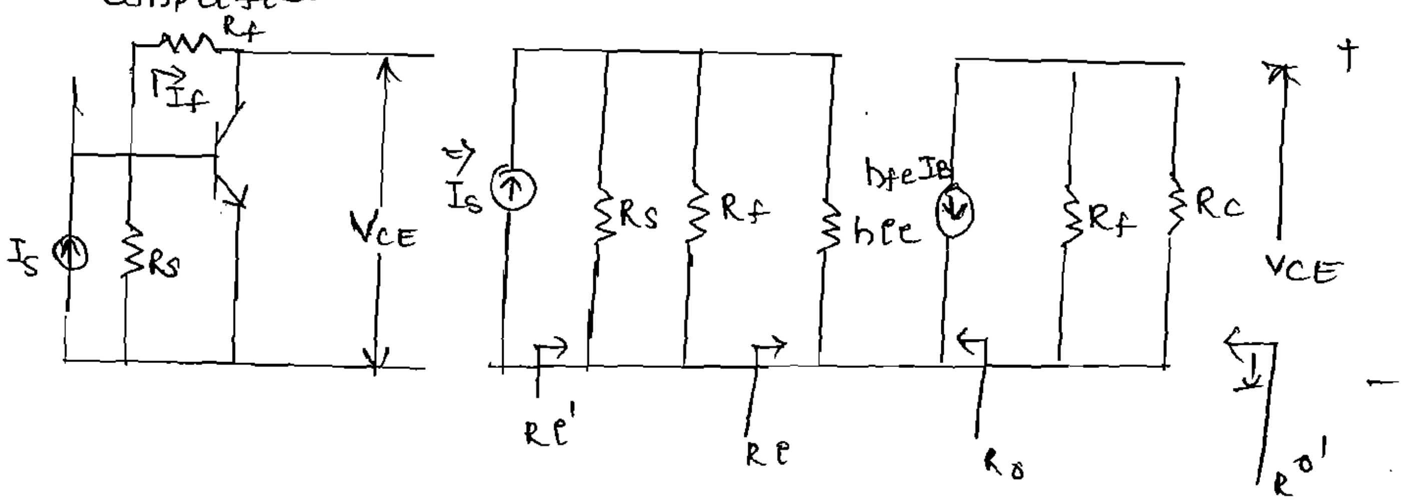
$$\Rightarrow \boxed{R_{of} = \infty.}$$

Voltage shunt feedback Amplifier.



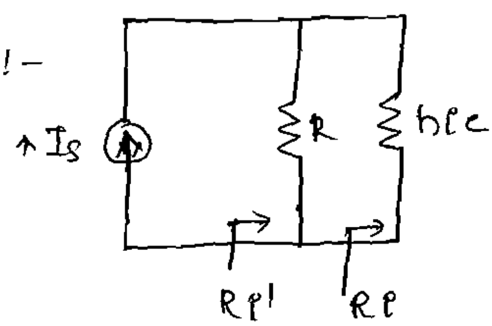
As $I_f = 0$ when $V_{CE} = 0$ and the mixing at the input is $I_i = I_s - I_f$

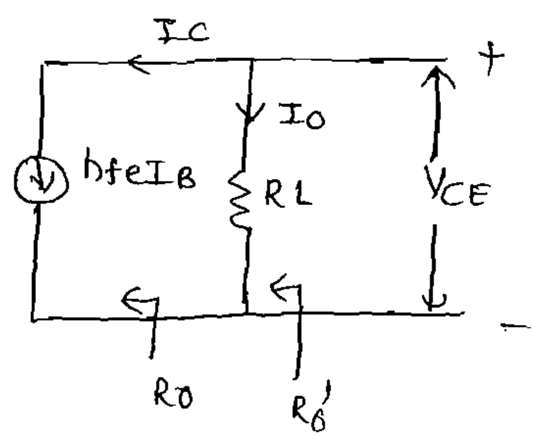
∴ The ckt acts as voltage shunt feedback amplifier.



Without feedback:-

Input impedance:-





$$R_i = \frac{V_o}{I_i}$$

$$\boxed{R_i = h_{ie}}$$

$$R = \frac{R_s R_f}{R_s + R_f}$$

$R_i' = R \parallel R_i$

$= R \parallel h_{ie}$

$$\boxed{R_i' = \frac{R h_{ie}}{R + h_{ie}}} \quad \text{where } R = \frac{R_S R_f}{R_s + R_f}$$

* Trans resistance (R_M):-

$$R_M = \frac{V_o}{I_i} = \frac{V_{CE}}{I_S} = \frac{I_o R_L}{I_B} = \frac{-h_{fe} I_B R_L}{I_B}$$

$$\therefore \boxed{R_M = -h_{fe} R_L} \qquad \left[\because I_o = -I_c \;\; \& \;\; I_c = -h_{fe} I_B\right]$$

* output impedance (R_o & R_o')

To get o/p impedance make source zero

i.e $I_S = 0 \Rightarrow I_B = 0 \Rightarrow h_{fe} I_B = 0 \Rightarrow I_c = 0.$

$\therefore R_o = \infty$

$R_o' = R_o \parallel R_L = R_L \qquad [\because R_o >> R_L]$

where, $R_L = \frac{R_f R_c}{R_f + R_c}$

* Trans resistance with feedback:-

$$R_{Mf} = \frac{R_M}{1 + \beta R_M}$$

Where, $I_f = \frac{V_{in} - V_{CE}}{R_f} = \frac{-V_{CE}}{R_f}$

$$\beta = \frac{I_f}{V_o} = \frac{-\cancel{V_{CE}}}{R_f \cancel{V_o}} = \frac{-1}{R_f}$$

$$R_{Mf} = \frac{-h_{fe}R_L}{1-\frac{1}{R_f}\left[-h_{fe}R_L\right]} = \frac{-h_{fe}R_LR_f}{R_f+h_{fe}R_L}$$

$$\Rightarrow \boxed{R_{Mf} = \frac{-h_{fe}R_LR_f}{R_f+h_{fe}R_L}}$$

* Input impedance (R_{if}) with feedback

$$R_{if} = \frac{R_i}{1+\beta R_M} = \frac{h_{ie}}{1+\frac{1}{R_f}(h_{fe}R_L)} = \frac{h_{ie}R_f}{R_f+h_{fe}R_L}$$

$$R_{if}' = \frac{R_i'}{1+\beta R_M} = \frac{\frac{Rh_{ie}}{R+h_{ie}}}{1+\frac{h_{fe}R_L}{R_f}}$$

$$= \frac{\frac{Rh_{ie}}{R+h_{ie}}}{\frac{R_f+h_{fe}R_L}{R_f}} \Rightarrow R_{if}' = \frac{RR_fh_{ie}}{(R+h_{ie})(R_f+h_{fe}R_L)}$$

* Output impedance with feedback

$$R_{of} = \frac{R_o}{1+\beta R_M} = \infty.$$

$$R_{of}' = \frac{R_o'}{1+\beta R_M} = \frac{R_L}{\frac{1+h_{fe}R_L}{R_f}} = \frac{R_LR_f}{R_f+h_{fe}R_L}$$

$$\Rightarrow \boxed{R_{of}' = \frac{R_fR_L}{R_f+h_{fe}R_L}}$$

FEED BACK AMPLIFIERS

1. If an input of 0.028V peak to peak given to an open loop amplifier it gives fundamental frequency output of 36 V peak to peak, but it is associated with 7% distortion.

i, If the distortion is to be reduced to 1% how much feed back is to be introduced and what will be required input voltage ?

ii, If 1.2% of output is feed back and the input is maintained at the same level, what is the output voltage ?

Sol Given; $V_i = 0.028\,V$

$V_o = 36\,V$

Voltage gain of amplifier is $A_v = \frac{V_o}{V_i}$

$= \frac{36}{0.028}$

$= 1285.7.$

i, Distortion without feed back $= 7\%$

$= 0.07.$

Distortion with feedback $= 1\% \Rightarrow 0.01$

$A_v = 1285.7.$

$$A_v = \frac{V_o}{V_{in}}$$

$$V_{in} = \frac{V_o}{A_{vf}}$$

$$V_{in} = \frac{36}{183.67}$$

$$\boxed{V_{in} = 0.19\,V.}$$

where $A_{vf} = \frac{AV}{1+\beta AV}$

$$= \frac{1285.7}{1+\beta[1285.7]} \Rightarrow \frac{1285.7}{1+(0.04)(1285.7)} \Rightarrow 183.67.$$

To find β ;

$$D_f = \frac{D}{1+\beta AV}.$$

$$\beta = \left[\frac{D}{D_f} - 1\right] \cdot \frac{1}{AV}$$

$$= \left[\frac{0.07}{0.01} - 1\right] \frac{1}{1285.7}$$

$$\boxed{\beta = 0.004.}$$

iii) Given ; $\beta = 12\% \Rightarrow 0.012$

o/p voltage $V_0 = A_{vf} \cdot V_{in}$

$$A_f = \frac{AV}{1+\beta AV} \Rightarrow \frac{1285.7}{1+0.012[1285.7]}$$

$$\Rightarrow 78.26.$$

$$V_0 = 78.26 * 0.028$$

$$\boxed{V_0 = 2.19\,V}$$

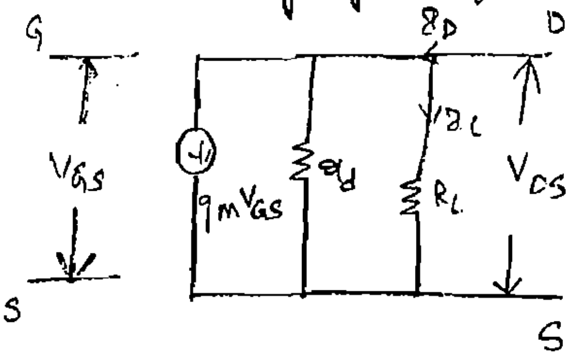
2. A common source FET amplifier has a load resistance of 500kΩ. The ac drain resistance of the device is 100kΩ and the trans conductance is 0.8 mAV^{-1}. Calculate the voltage gain of the amplifier

Sol Given;

$R_L = 500k\Omega$

$r_d = 100k\Omega$

$g_m = 0.8\ mA/V$.



$$A_V = \frac{V_o}{V_i}$$

$$= \frac{V_{DS}}{V_{GS}} \Rightarrow \frac{i_D \cdot R_D}{V_{GS}} \qquad \{\therefore R_D = r_d \| r_L\}$$

$$A_V = \frac{-i_L \cdot R_D}{V_{GS}}$$

$$= \frac{-i_D \cdot R_D}{V_{GS}}$$

$$= \frac{-g_m \cancel{V_{GS}} R_D}{\cancel{V_{GS}}} \qquad \{\therefore i_D = g_m V_{GS}\}.$$

$$A_V = -g_m \cdot R_D$$

$$= -0.8\times10^{-3}\left[500k \| 100k\right]$$

$$= -0.8m\left[\frac{100k \times 500k}{100k+500k}\right] \Rightarrow -66.6\ V.$$

3. An amplifier has an open loop voltage gain of 1000 delivers 10 watts output with 10% second harmonic distortion when the input is 10mV. If 40dB of negative feedback is applied, what is the value of distortion? How much input voltage should be applied to get 10 watts of output power?

Sol Given;

gain $[A_v]$: 1000.

Distortion without feed back $[D] = 10\% = 0.1$.

Input voltage $= 10\,mV$.

$\beta = 40dB$.

i) input signal voltage $V_s' = V_s[1+\beta A]$

$= V_s[1+100]$

∴ Here β is given in dB so;

Antilog$\left(\frac{40}{20}\right)$

$\Rightarrow 100.$

$\Rightarrow 10m[1+100]$

$\Rightarrow 1.01\ V.$

ii) Value of second harmonic distortion;

$$D_f = \frac{D}{1+\beta A}$$

$$= \frac{10\%}{1+100} \Rightarrow 0.99 \times 10^{-3}.$$

4. An amplifier with negative feedback gives an output of 12.5 V with an input of 1.5 V. When feedback is removed, it requires 0.25 V input for the same output. Find

i, value of voltage gain without feedback

ii, value of β, if the input and output are in phase and β is real.

Sol Given ;

$$V_{of} = 12.5$$

$$V_{in} = 1.5V.$$

$$\therefore A_{vf} = \frac{V_{of}}{V_{in}} = \frac{12.5}{1.5}$$

$$= 8.333.$$

i, $A_v = \frac{V_o}{V_{in}} = \frac{12.5}{0.25}$

$$= 50.$$

ii, $A_{vf} = \frac{A}{1+A_v\beta}$

$$8.33 = \frac{50}{1+50\beta}.$$

$$\therefore 1+50\beta = \frac{50}{8.33}$$

$$50\beta = \frac{50}{8.33} - 1 \Rightarrow \beta = \frac{5.002}{50} \rightarrow \boxed{0.1 = \beta}$$

5. An amplifier has a mid band gain of 125 and bandwidth of 250 kHz. If 4% negative feedback is introduced and the new bandwidth and gain.

Sol

Given ;

$A_V = 125$;

$B.W = 250\,kHz$;

$\beta = 4\% \Rightarrow 0.04$.

$$A_{vf} = \frac{A_v}{1+\beta A_v}$$

$$= \frac{125}{1+(0.04)(125)}$$

$$= 20.83.$$

$$BW_f = BW * [1+\beta A_v]$$

$$= 250\,k * [1+0.04 * 125]$$

$$= 1.5\,MHz.$$

6. The open loop voltage gain of the amplifier is 50. Its input impedence is 1kΩ. What will be the input impedence where a negative feedback of 10% is applied to the amplifier?

Sol:- Given;

$A_v = 50.$

$R_i = 1k\Omega;$

$\beta = 10\% \Rightarrow 0.1.$

$D = 1+\beta A_v$

$= 1+(0.1 * 50)$

$= 6.$

$R_{if} = R_i * D$

$= 1K * 6.$

$= 6K.$

7. The open loop gain of an amplifier is 50db. A negative feedback factor is 0.004 is applied to it. If the open loop gain is thereby reduced by 10% find the change in overall gain.

Sol Gain of amplifier is given as $50dB = 20 \log \frac{V_o}{V_i}$

$AV_1 = \text{antilog}\left(\frac{50}{20}\right)$

$= 316.22$

$\beta = 0.004.$

when it is reduced by 10% of AV_1.

$= Av_1 \times \frac{10}{100}.$

$= 316.22 \times \frac{1}{10}$

$= 31.622.$

$A_{V_2} = A_{V_1} - 10\%$ of A_{V_1}.

$= 316.22 - 31.622$

$= 284.5$

$$A_{f_1} = \frac{A_{V_1}}{1+\beta A_{V_1}} = \frac{316.22}{1+(0.004 * 316.22)}$$

$$= 139.61.$$

$$A_{f_2} = \frac{A_{V_2}}{1+\beta A_{V_2}} = \frac{284.5}{1+(0.004 * 284.5)}$$

$$= 133.08$$

$$\%\ \text{change in over all gain} = \frac{A_{f_1} - A_{f_2}}{A_{f_1}} \times 100$$

$$= \frac{139.61 - 133.08}{139.61} \times 100$$

$$= 4.08\%$$

8. A single stage CE amplifier has a voltage gain of 600 without feedback. When feedback is employed, its gain reduced to 50. Calculate the percentage of output which is fed back to the input.

Sol

$A_V = 600$

$A_{Vf} = 50$;

$\beta = ?$

$$A_{vf} = \frac{A_v}{1+\beta A_v}$$

$$50 = \frac{600}{1+\beta\, 600}$$

$$1+\beta(600) = \frac{\cancel{600}^{12}}{\cancel{50}}$$

$$\beta = \frac{11}{600}.$$

$$\%\beta = \frac{11}{600} \times 100$$

$$\boxed{\beta = 1.83\%}$$

$\therefore$ The % of the o/p which is fed back to i/p is 1.83%.

9. Calculate the voltage gain, input impedence and output impedence of a voltage series feed back amplifiers having an open loop gain $A = 300$; $R_i = 1.5k$; $R_o = 50k$; $\beta = +1/20$?

Sol Given $A_v = 300$;

$R_i = 1.5K$;

$R_o = 50K$;

$\beta = -1/20$;

input impedence $R_{if} = R_i[1+\beta A_v]$

$= 1.5K\left[1+\left(+1/20\right)300\right]$

$= 24K$

Out put impedence : $R_{of} = \frac{R_o}{1+\beta A_v}$

$= \frac{50K}{1+(1/20)(300)}$

$= 3.125K.$

Voltage gain : $A_f = \frac{A_V}{1+\beta A_V}$

$= \frac{300}{1+(1/20)(300)}$

$= 18.75.$

10. For voltage series feed back amplifier with parameters of the internal amplifier as $A_V = -200$; $R_{in} = 5K$; $R_o = 20K$; Bandwidth $= 50KHz$ and having feedback factor $\beta = -0.02$. Calculate

i, Voltage gain A_{vf}

ii, input impedence R_{inf}

iii, output impedence R_{of} and

iv, Bandwidth

Sol Given; $A_V = -200$;

$R_{in} = 5K$;

$R_o = 20K$;

$B.W = 50KHz$;

$\beta = -0.02$.

i, voltage gain $A_{vf} = \frac{A_V}{1+\beta A_V}$

$= \frac{-200}{1+(-0.02)(-200)}$

$= -40.$

ii, input impedence $R_{if} = R_i[1+\beta A_V]$

$= 5K[1+(-0.02)(-200)]$

$= 25K.$

iii, output impedence $R_{of} = \frac{R_o}{1+\beta A_V}$

$= \frac{20K}{1+[-0.02][-200]}$

$= 4K.$

iv, Bandwidth$_f$ $= A_V * B.W.$

$= (-200)(50K)$

$= -10M.$

11) An amplifier circuit has a gain of 60dB and an output impedence $Z_o = 10k\Omega$; it is required to modify its output impedence to 600Ω by applying -ve feed back. Calculate the value of the feedback factor. Also find the percentage change in overall gain, for 10% change in the gain of the internal amplifier.

Sol :- Given;

Gain of the amplifier is $60dB = 20 \log A_V$.

$A_V = \frac{V_o}{V_i}$

we know that ; $= 1000$.

$R_{of} = \frac{R_o}{1+\beta A_V}$

Given ;

output impedence $R_o = 10K$;

$R_{of} = 500\Omega$;

$\beta = ?$

$R_{of} = \frac{R_o}{1+\beta A_V}$.

$500 = \frac{10K}{1+\beta 1000}$

$1000\beta + 1 = \frac{10K}{500}$

$1000\beta = 20 - 1$

$\beta = \frac{19}{1000} \Rightarrow 0.019$.

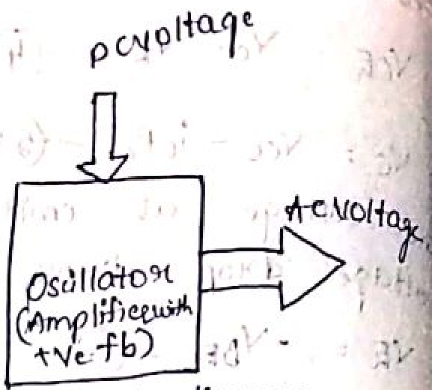
(ii) % change in overall gain $= \frac{10}{1+\beta A_V} \Rightarrow \frac{10}{1+0.019 * 1000}$

$= 0.5\%$

4 - Oscillators

Oscillator :-

An oscillator is an electronic ckt which produces Ac o/p voltage without any Ac input, to produce an Ac voltage it is energized with DC power supply.



Simple block diagram representation of oscillator.

It is an electronic ckt which converts D.C voltage to A.C voltage. Then it is also called DC to AC converter. An amplifier with +ve feed back is called an oscillator.

Principle of Oscillations :-

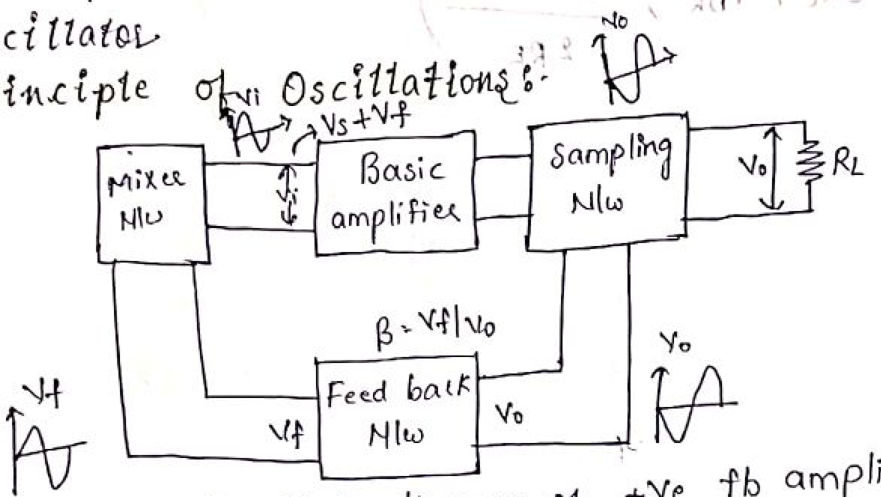


fig: Block diagram of +ve fb amplifier

The above figure shows an amplifier with +ve feed back. When dc power supply is switched on, noisy current is developed in the amplifier circuit and it is considered as the input of amplifier. Now the amplifier amplifies that noise input with 180° phase shift. The sampling N/w is used to take the part of the output voltage and it is back to the input of amplifier through a feed back N/w.

The feed back N/w is so designed to provide another 180° phase shift. So that the total phase shift around the closed loop is 360°.

Now the feed back signal is inphase with the input signal and it is added to the i/p of amplifier i.e., $V_i = V_s + V_f$. It is further amplified by the basic amplifier. This process will be continues untill sustained oscillations are generated.

Expression for gain with +Ve fb:

The gain of an amplifier without fb is given by

$$A = \frac{V_o}{V_i} = \frac{V_o}{V_s} \quad \text{--(1)}$$

By providing +Ve fb, $V_i \rightarrow V_s + V_f$

$$A = \frac{V_o}{V_s + V_f}$$

$$AV_s + AV_f = V_o$$

$$AV_s + A\beta V_o = V_o$$

$$AV_s = V_o - A\beta V_o = V_o(1 - A\beta)$$

$$A_f = \frac{V_o}{V_s} = \frac{A}{1 - A\beta} \quad \text{--(2)}$$

If the product of $A\beta = 1$

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

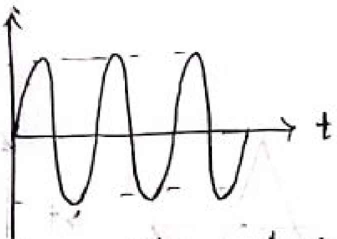
This indicates that the circuit produces an output without external input just by feeding its own input

Barkhausen Criterion:-

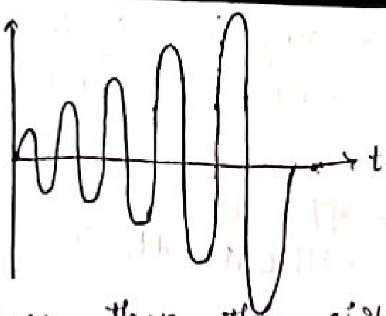
The barkhausen criterion states that an amplifier with +Ve feed back by satisfying the total phase shift around the closed loop is 360° and the product of A & β = 1, then the circuit works as an oscillator.

In general, an amplifier with +Ve feedback, the total phase shift around the closed loop is 360°.

1. If $A\beta = 1$, then the circuit generates sustained oscillations (or) undamped oscillations. and it is shown in fig(a).

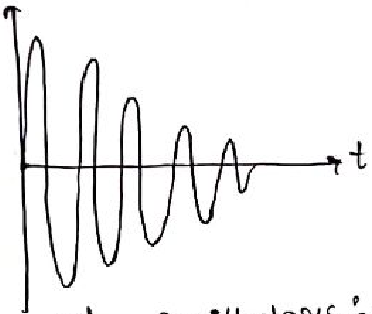


2) If $A\beta > 1$, then the circuit generates continuously increasing types of oscillations and it is shown in fig.



Over damped Oscillations

3) If $A\beta < 1$, then the circuit generates continuously decreasing type of oscillations (or) undamped oscillations. It is as shown in fig.



Under damped oscillations

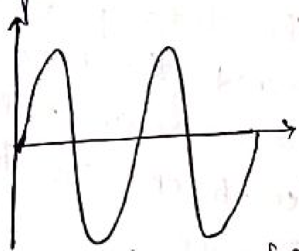
· Classification of Oscillators :-

Oscillators are classified based on four criterias.

I According to waveforms generated :-

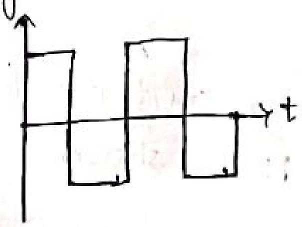
1. Sinusoidal Oscillators
2. Non Sinusoidal Oscillators.

→ The Sinusoidal Oscillators generates sinusoidal voltages (or) currents as shown in fig (a).

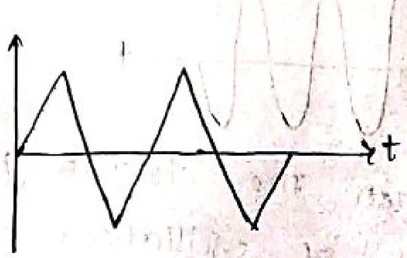


Sinusoidal waveform

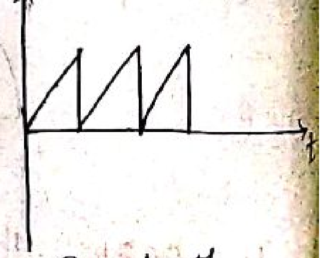
→ Non sinusoidal Oscillators generates nonsinusoidal waveforms which are vary one or more times in a given cycle of time as shown in figures



Square waveform



triangular wave form



Sawtooth waveform

II. According to Fundamental Mechanisms used :-

1. Negative Resistance Oscillators
2. Positive feedback Oscillators

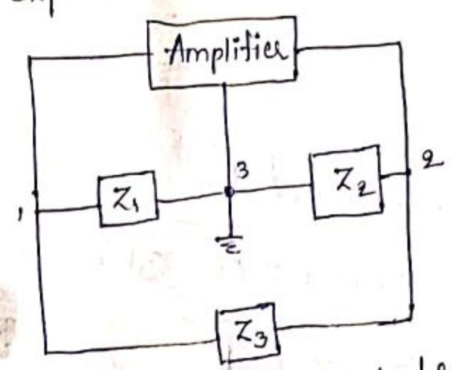
III. According to Frequency Range :-

1. Audio frequency Oscillators - upto 20kHz
2. Radio frequency Oscillators - 20kHz - 30MHz
3. Very high frequency Oscillators : 30MHz - 300MHz
4. Ultra high frequency Oscillators : 300MHz - 3GHz
5. Micro wave Oscillators : > 3GHz

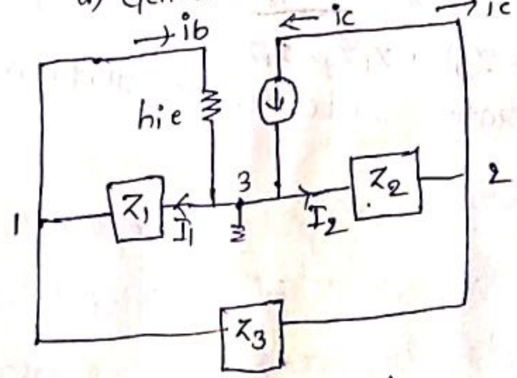
IV. According to Circuit Components: Sinusoidal oscillators are further classified into 2 types.

1. LC Oscillators
   a) Hartley Oscillator
   b) colpitts Oscillator
2. RC Oscillators
   a) RC Phase shift Oscillator
   b) Weinbridge Oscillator

General Expression for LC Oscillator :-



a) General form of LC Oscillator



b) Equivalent ckt

fig(a) shows general form of LC oscillator. It consists of an amplifier with feedback N/w. As shown in fig(a), the feed back N/w is formed by 3 reactive elements Z_1, Z_2 & Z_3. The reactive elements Z_1 & Z_2 acts as voltage divider N/w i.e., the voltage across Z_1 is feedback voltage & the voltage across Z_2 is o/p voltage. To determine condition to generate sustained oscillations fig(a) is replaced by fig(b).

As shown in fig(b) hie & Z_1 are in parallel & their equivalent resistance is given by $Z' = \frac{Z_1 hie}{Z_1 + hie}$ — (1)

The load impedance in b/w terminals 2 & 3 is the equivalent impedance of Z_2 in parallel with the series combination of Z' & Z_3.

$$Z_L = Z_2 \| (Z' + Z_3)$$

$$Z_L = \frac{Z_2(Z' + Z_3)}{Z_2 + Z' + Z_3} = \frac{Z_2 Z' + Z_2 Z_3}{Z_2 + \frac{Z_1 hie}{Z_1 + hie} + Z_3}$$

$$Z_L = \frac{Z_2\left(\frac{Z_1 hie}{Z_1 + hie}\right) + Z_2 Z_3}{Z_2 + \left(\frac{Z_1 hie}{Z_1 + hie}\right) + Z_3}$$

$$= \frac{Z_1 Z_2 hie + Z_2 Z_3 Z_1 + Z_2 Z_3 hie}{Z_1 Z_2 + Z_2 hie + Z_1 hie + Z_1 Z_3 + Z_3 hie}$$

$$Z_L = \frac{Z_2\left[Z_1 hie + Z_3 Z_1 + Z_3 hie\right]}{hie(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3} \quad \text{— (2)}$$

The condition to generate sustained oscillations is

$A\beta = 1$ — (3)

wkt $A = \frac{V_o}{V_i}$ — (4)

where $V_o = I_L Z_L$

$= -i_c Z_L$

$V_o = -h_{fe} i_B Z_L$ — (5)

$V_i = h_{ie} i_B$ — (6)

$$A = \frac{-h_{fe} \cancel{i_B} Z_L}{h_{ie} \cancel{i_B}}$$

$$\boxed{A = \frac{-h_{fe} Z_L}{h_{ie}}} \quad — (7)$$

$\beta = V_f / V_0$ — (8)

$V_f = -I_1 Z'$ — (9)

The o/p voltage V_0 in b/w terminals 2 & 3 in terms of current I_1 is given by

$V_0 = -I_1 (Z' + Z_3)$ — (10)

$$\beta = \frac{-\cancel{I_1} Z'}{-\cancel{I_1}(Z' + Z_3)}$$

$$\beta = \frac{\dfrac{Z_1 h_{ie}}{Z_1 + h_{ie}}}{\dfrac{Z_1 h_{ie}}{Z_1 + h_{ie}} + Z_3} = \frac{Z_1 h_{ie}}{Z_1 h_{ie} + Z_1 Z_3 + Z_3 h_{ie}}$$

$$\beta = \frac{Z_1 h_{ie}}{Z_1 Z_3 + h_{ie}(Z_1 + Z_3)} \quad — (11)$$

Now A & β are sub. in eq (3)

$$\frac{-h_{fe} Z_L}{\cancel{h_{ie}}} \cdot \frac{Z_1 \cancel{h_{ie}}}{Z_1 Z_3 + h_{ie}(Z_1 + Z_3)} = 1$$

$$\frac{-h_{fe} Z_L Z_1}{Z_1 Z_3 + h_{ie}(Z_1 + Z_3)} = 1$$

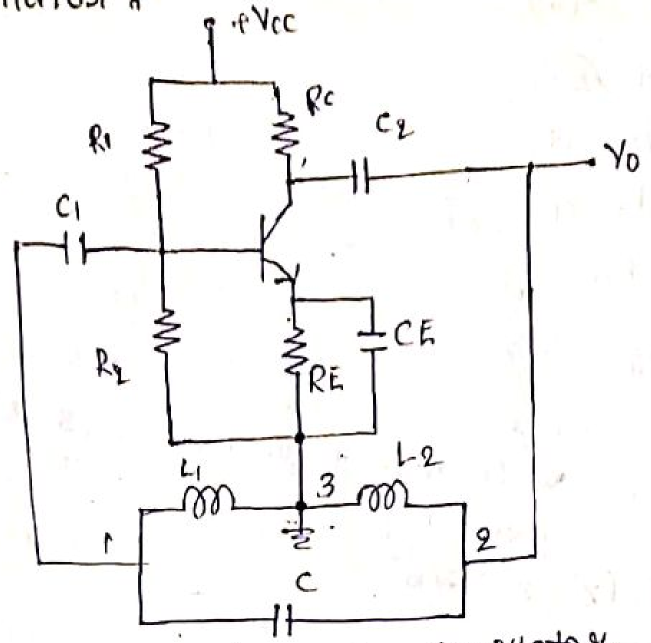
$$\frac{-h_{fe} Z_1 \dfrac{Z_2 [Z_1 h_{ie} + \cancel{Z_1 Z_3 + Z_3 h_{ie}}]}{h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3}}{Z_1 Z_3 + \cancel{h_{ie}}(Z_1 + Z_3)} = 1$$

$\Rightarrow -h_{fe} Z_1 Z_2 = h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3$

$\Rightarrow h_{ie}(Z_1 + Z_2 + Z_3) + Z_1(Z_2 + Z_3) + h_{fe} Z_1 Z_2 = 0$ — (12)

The above eq. is general expression of LC oscillator. By using this we can determined the frequency of LC oscillator

Hartley Oscillator :-



ckt diagram of Hartley Oscillator

The above fig shows the circuit diagram of Hartley oscillator. It consists of an amplifier with feedback network. Here feedback network is formed by two inductors and one capacitor i.e., The reactive elements Z_1 and Z_2 are inductors and Z_3 is capacitor.

Operation :-

when power supply +Vcc is switched on, noisy currents developed within the amplifier circuit and it will be considered as input for same amplifier. Then amplifier amplifies noise inputs and this amplified noise output back to the feedback network. Due to this, oscillatory currents developed across L_1 & L_2. The terminal 3 is grounded and it is at Zero potential. If terminal 1 is at +Ve potential with respect to terminal 3 at any instant and terminal 2 is at -Ve potential with respect to terminal 3 at the same instant. Thus the phaseshift b/w terminal 1 and terminal 2 is 180° and another 180° phase shift is provided by amplifier. The total phase shift around the closed loop is 360° i.e., one of the condition is satisfied and other condition $A\beta = 1$ is also satisfied by designing the Feedback N/w. Then the ckt works as an Oscillator

Frequency of Oscillation :
WKT, the general expression of LC Oscillator is given by $h_{ie}(Z_1+Z_2+Z_3)+Z_1Z_2(1+h_{fe})+Z_1Z_3=0$ —(1)

The reactance of inductor L_1

$Z_1 = j\omega L_1 + j\omega M = j\omega(L_1+M)$ —(2)

The reactance of L_2

$Z_2 = j\omega L_2 + j\omega M = j\omega(L_2+M)$ —(3)

The reactance of C

$Z_3 = \frac{1}{j\omega C}$ —(4)

Substitute eq (2),(3),(4) in (1)

~~hie (jωL₁~~

$$h_{ie}\left[j\omega(L_1+M)+j\omega(L_2+M)+\frac{1}{j\omega C}\right]+j\omega(L_1+M)(j\omega(L_2+M)(1+h_{fe})+\frac{\cancel{j\omega}(L_1+M)}{\cancel{j\omega}C}=0$$

$$h_{ie}j\omega\left[L_1+L_2+2M+\frac{1}{j^2\omega^2C}\right]+j^2\omega^2(L_1+M)(L_2+M)(1+h_{fe})+\frac{L_1+M}{C}=0.$$

$$\Rightarrow h_{ie}j\omega\left[L_1+L_2+2M-\frac{1}{\omega^2C}\right]-\omega^2(L_1+M)\left[(L_2+M)(1+h_{fe})\cancel{+\frac{L_1+M}{}}\frac{-1}{\omega^2C}\right]=0$$

To determine the frequency of oscillation, the imaginary part of above eq. equate to zero.

$$h_{ie}j\omega\left[L_1+L_2+2M-\frac{1}{\omega^2C}\right]=0$$

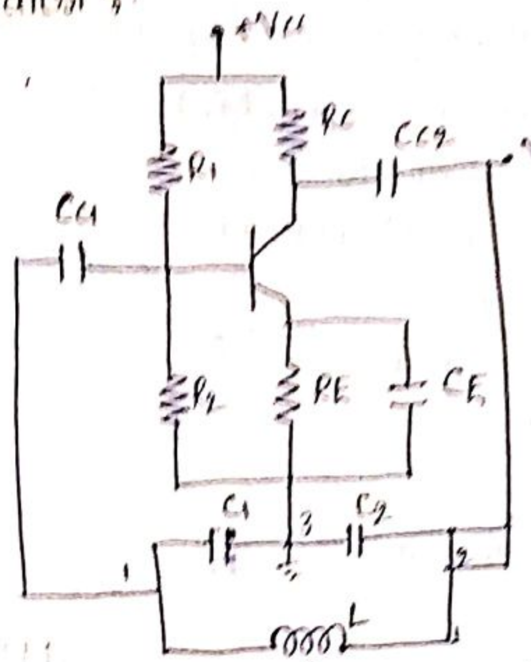
$$\Rightarrow L_1+L_2+2M=\frac{1}{\omega^2C}.$$

$$\omega^2=\frac{1}{(L_1+L_2+2M)C}$$

$$\omega=\frac{1}{\sqrt{(L_1+L_2+2M)C}}$$

$$\boxed{f=\frac{1}{2\pi\sqrt{(L_1+L_2+2M)C}}}$$ —(5)

Colpitts Oscillator :



CKt diagram of colpitts Oscillator

→ Same theory as per Hartley Oscillator.

Frequency of oscillation :

The General expression of LC oscillator is given by $h_{ie}(Z_1+Z_2+Z_3) + Z_1Z_2(1+h_{fe}) + Z_1Z_3 = 0$ —①

From the ckt diagram, The reactance of capacitor C_1, C_2 is given by

$$Z_1 = \frac{1}{j\omega C_1} \quad \text{—②}$$

$$Z_2 = \frac{1}{j\omega C_2} \quad \text{—③}$$

$$Z_3 = j\omega L \quad \text{—④}$$

Substitute eq 2,3,4 in eq ①

$$h_{ie}\left[\frac{1}{j\omega C_1} + \frac{1}{j\omega C_2} + j\omega L\right] + \frac{1}{j\omega C_1}\cdot\frac{1}{j\omega C_2}(1+h_{fe}) + \frac{1}{j\omega C_1} j\omega L = 0$$

$$\Rightarrow \frac{h_{ie}}{j\omega}\left[\frac{1}{C_1} + \frac{1}{C_2} + (j\omega)^2 L\right] - \frac{1}{\omega^2 C_1 C_2}(1+h_{fe}) + \frac{L}{C_1} = 0$$

$$\Rightarrow -h_{ie}j\frac{1}{\omega}\left[\frac{1}{C_1} + \frac{1}{C_2} - \omega^2 L\right] - \frac{1}{\omega^2 C_1 C_2}(1+h_{fe}) + \frac{L}{C_1} = 0$$

To determine the frequency of oscillation, The imaginary part of above eq. is equating to zero.

$$\Rightarrow \frac{-h_{ie}j}{\omega}\left[\frac{1}{C_1}+\frac{1}{C_2}-\omega^2 L\right]=0$$

$$\frac{1}{C_1}+\frac{1}{C_2}=\omega^2 L.$$

$$\omega^2=\frac{1}{L}\left[\frac{1}{C_1}+\frac{1}{C_2}\right]$$

$$\omega=\sqrt{\frac{1}{L}\left[\frac{1}{C_1}+\frac{1}{C_2}\right]}$$

$$f=\frac{1}{2\pi}\sqrt{\frac{1}{L}\left(\frac{C_1+C_2}{C_1C_2}\right)}$$

$$C_{eq}=\frac{C_1C_2}{C_1+C_2}$$

$$f=\frac{1}{2\pi}\sqrt{\frac{C_1+C_2}{LC_1C_2}}=\frac{1}{2\pi\sqrt{LC_{eq}}} \quad \text{—(5)}$$

1. In a Hartley Oscillator, if $L_1 = 0.2mH$, $L_2 = 0.3mH$ and $C = 0.003\mu F$, calculate the freq. of its oscillation.

Given, $L_1 = 0.2mH$, $L_2 = 0.3mH$, $C = 0.003\mu F$

$(\because M=0)$

WKT $$f=\frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

$$f=\frac{1}{2\pi\sqrt{(0.2+0.3)\times10^{-3}\times0.003\times10^{-6}}}$$

$$=\frac{1}{2\pi(1.224\times10^{-6})}$$

$f = 0.130MHz.$ (or) $130KHz.$

2. In the Hartley Oscillator, $L_2 = 0.4mH$ & $C = 0.004\mu F$. if the freq of oscillation is 120 KHz. Find the value of L_1. (Neglect M)

WKT $$f=\frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

$$120\times10^{3}=\frac{1}{2\pi\sqrt{(L_1+0.4\times10^{-3})(0.004\times10^{-6})}}$$

$$240\pi\times10^{3}=\frac{1}{\sqrt{(L_1+0.4\times10^{-3})(0.004\times10^{-6})}}$$

$$\Rightarrow 5.68\times10^{11}=\frac{1}{(L_1+0.4\times10^{-3})(0.004\times10^{-6})}$$

$\Rightarrow 2272 = \frac{1}{(L_1 + 0.4 \times 10^{-3})}$

$\Rightarrow 2272 L_1 + 0.9088 = 1$

$2272 L_1 = 0.0912$

$L_1 = 4.01 \times 10^{-5}\ H$

$L_1 = 0.04 mH$

3) In a transisterized hartley oscillator, the 2 inductors are 2mH, 20μH. while the freq. is to be changed from 950 KHz to 2050 KHz. Calculate the range over which the capacitor is to be varied.

Given, $L_1 = 2mH$, $L_2 = 20 \mu H$

$f_1 = 950 KHz$, $C_1 = ?$

$f_2 = 2050 KHz$; $C_2 = ?$

WKT $f = \frac{1}{2\pi \sqrt{(L_1 + L_2)C}}$

$\Rightarrow \sqrt{(L_1 + L_2)C_1} = \frac{1}{2\pi f_1}$

$\sqrt{(2 \times 10^{-3} + 20 \times 10^{-6})} \cdot \sqrt{C_1} = \frac{1}{2\pi (950 \times 10^3)}$

$0.0449 \sqrt{C_1} = 1.67 \times 10^{-7}$

$\sqrt{C_1} = 3.719 \times 10^{-6}$

$C_1 = 13.83 PF$

$\Rightarrow \sqrt{(L_1 + L_2)C_2} = \frac{1}{2\pi f_2} = \frac{1}{2\pi \times 2050 \times 10^3}$

$0.0449 \sqrt{C_2} = 7.76 \times 10^{-8}$

$\sqrt{C_2} = 1.728 \times 10^{-6}$

$C_2 = 2.98 PF$

The range of capacitance is from 2.98PF to 13.83PF

4) $L_1 = 38\mu H$, $L_2 = 12\mu H$, $C = 500PF$. Find the freq of oscillation and feed back factor 'β'.

wkt $$f = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$

$$= \frac{1}{2\pi\sqrt{(38+12)\times10^{-6}\times500\times10^{-12}}}$$

$$= \frac{1}{2\pi\sqrt{2.5\times10^{-14}}} = \frac{1}{2\pi\times1.58\times10^{-7}} = 0.10\times10^{7}$$
$$= 1\times10^{6}$$

$f = 1MHz.$

$$\beta = \frac{L_1}{L_2} = \frac{38}{12} = 3.16$$

5) A colpitts Oscillator is designed with $C_1 = 100PF$, $C_2 = 7500PF$. The inductance is variable, determine the range of inductance values, if the freq. of oscillator is to vary b/w 950 KHz, and 2050 KHz.

wkt $$f = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

$$C_{eq} = \frac{C_1C_2}{C_1+C_2} = \frac{(100\times7500)\times10^{-24}}{(100+7500)10^{-12}}$$

$C_{eq} = 98.6$ PF

$$f_1 = \frac{1}{2\pi\sqrt{L_1 eq}}$$

$$950\times10^{3} = \frac{1}{2\pi\sqrt{L_1}(9.92\times10^{-6})}$$

$$\Rightarrow 59.21 = \frac{1}{\sqrt{L_1}}$$

$\sqrt{L_1} = 0.016$

$L_1 = \cancel{28.5}\ 2.85\times10^{-4}$

$L_1 = 0.285mH$

$$127.90 = \frac{1}{\sqrt{L_2}}$$

$\sqrt{L_2} = 7.81\times10^{-3}$

$$\Rightarrow 2050\times10^{3} = \frac{1}{\sqrt{L_2}\cdot6.23\times10^{-5}}$$

$\Rightarrow \sqrt{L_2} = 7.82\times10^{-3}$

$L_2 = 61.3\mu H$

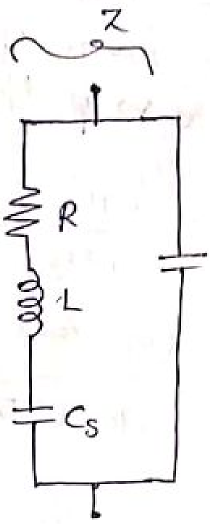
The inductance value changes from 0.28mH to 0.061mH

Why LC oscillators are not used at low frequencies.

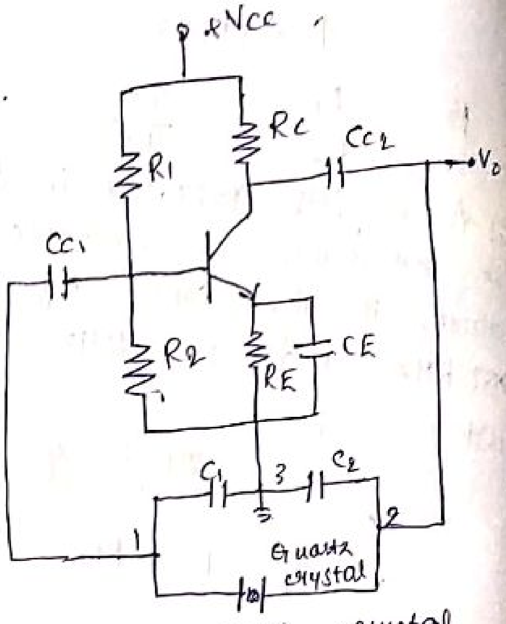
For LC oscillators, the frequency of oscillation is given by $f = \frac{1}{2\pi\sqrt{LC}}$. It clearly shows that the frequency of oscillation is inversely proportional to inductance and capacitance i.e., $f \propto \frac{1}{LC}$. If we design LC oscillators at low frequencies, it requires large values of inductors and capacitors which ~~occupies~~ i.e. having large space size and high cost.

This is the reason the LC oscillators are not used at low frequencies.

Crystal Oscillator:



B) Equivalent ckt of crystal



a) ckt diagram of crystal oscillator

Fig (a) shows the circuit diagram of crystal oscillator. It is similar to the colpitts oscillator except inductor is replaced by Quartz crystal in feedback network. This oscillator works on the principle of piezo electric effect which states that when mechanical force is applied at one phase of crystal and it develops ac voltage at opposite phase of the crystal and in reverse when ac voltage is applied at one phase of the crystal and it develops mechanical vibrations at opposite phase of the crystal.

To determine the frequency of oscillation, Quartz crystal is replaced by its equivalent circuit as shown in fig(b).

When crystal is not vibrating just it is represented by capacitor symbol (C_p) and when it is vibrating it is represented by series RLC circuit i.e., the internal losses are represented by resistor symbol, the magnetic field around the crystal is represented by inductor and the ac voltage which is developed by crystal is represented with the capacitor (C_s).

Frequency of oscillation :-

As shown in fig (6), the equivalent impedance 'Z' is given by (neglecting internal losses)

$$Z = \left(j\omega L + \frac{1}{j\omega C_s}\right) \parallel \frac{1}{j\omega C_p}$$

$$= \frac{\left(j\omega L + \frac{1}{j\omega C_s}\right)\frac{1}{j\omega C_p}}{j\omega L + \frac{1}{j\omega C_s} + \frac{1}{j\omega C_p}}$$

$$= \frac{\cancel{j}\left(\omega L - \frac{1}{\omega C_s}\right)\frac{1}{j\omega C_p}}{\cancel{j}\left(\omega L - \frac{1}{\omega C_s} - \frac{1}{\omega C_p}\right)}$$

$$Z = \frac{\frac{\omega}{L}\left(\omega L - \frac{1}{\omega C_s}\right)\frac{1}{j\omega C_p}}{\frac{\omega}{L}\left(\omega L - \frac{1}{\omega C_s} - \frac{1}{\omega C_p}\right)}$$

$$= \frac{\left(\omega^2 - \frac{1}{LC_s}\right)\frac{1}{j\omega C_p}}{\left[\omega^2 - \left(\frac{1}{LC_s} + \frac{1}{LC_p}\right)\frac{1}{L}\right]}$$

$$Z = \frac{\left(\omega^2 - \omega_s^2\right)\frac{1}{j\omega C_p}}{\omega^2 - \omega_p^2}$$

From the above equation, $\omega_s^2 = \frac{1}{LC_s}$

$$\Rightarrow \omega_s = \frac{1}{\sqrt{LC_s}}$$

$$\boxed{f_s = \frac{1}{2\pi\sqrt{LC_s}}}$$

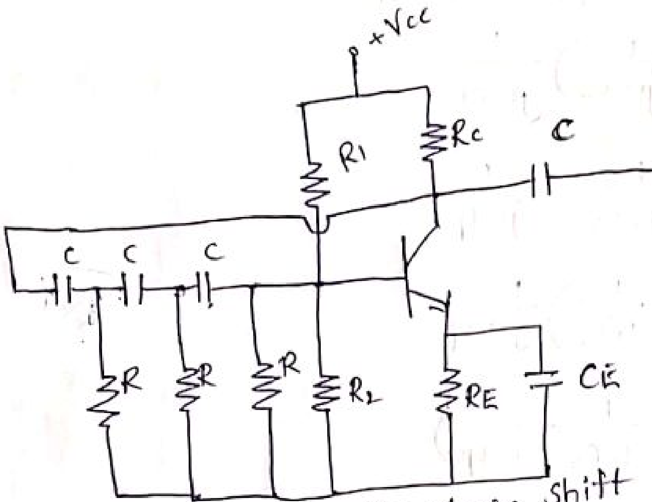
where $\omega_p^2 = \left(\frac{1}{C_s} + \frac{1}{C_p}\right) \cdot \frac{1}{L} = 1/LC_{eq}$.

$$\omega_p = \sqrt{\left(\frac{1}{C_s} + \frac{1}{C_p}\right)\frac{1}{L}}$$

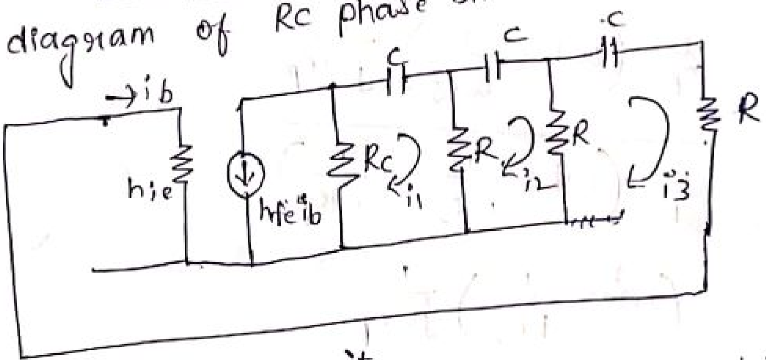
$$\omega_p = \sqrt{\frac{C_p + C_s}{C_s C_p L}} = \frac{1}{\sqrt{LC_{eq}}}$$

$$f_p = \frac{1}{2\pi\sqrt{LC_{eq}}}$$

RC - Phase shift Oscillator :-



a) ckt diagram of Rc phase shift Oscillator.



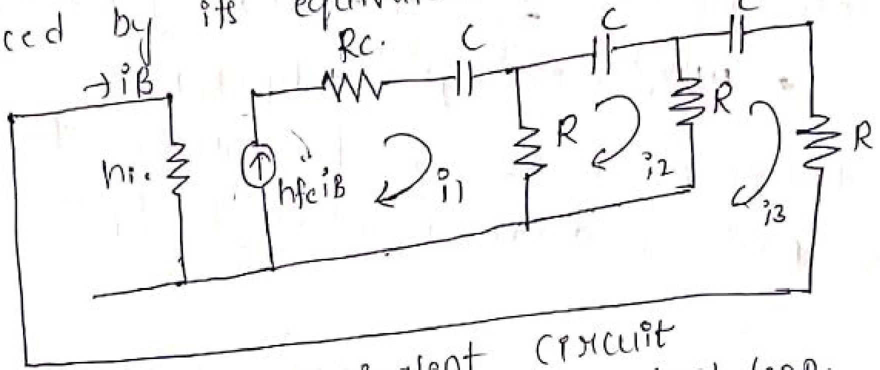
b) Equivalent Circuit

Fig(a) shows the Circuit diagram of Rc phase shift oscillator. It consists of a CE amplifier and feed back network which is formed by 3 RC networks. when a power supply +Vcc is switched ON, noisy current is developed within the amplifier circuit and it will be considered as input for the amplifier circuit. Thus, an amplifier amplifies it with 180° phase shift and this amplified noise output back to the input of the amplifier, through a feedback network.

In a feedback network, Each RC network provides 60° phase shift i.e., the phase shift provided by RC ladder network is 180°. Thus, the total phase shift around the closed loop is 360° and by designing feedback network if $A\beta = 1$ then above circuit works as an oscillator.

Frequency of Oscillation :-

To determine the frequency of oscillation, fig (a) is replaced by its equivalent circuit as shown in fig(b).



c) Simplified Equivalent Circuit

From fig(c), apply KVL to the first loop. $(i_B = i_3)$

$\Rightarrow h_{fe} i_B R_C + i_1 R_C - i_1 j X_C + R(i_1 - i_2) = 0$

$\Rightarrow i_1 (R_C - jX_C + R) + i_2(-R) + i_3 h_{fe} R_C = 0$ —— ①

Apply KVL to the second loop.

$\Rightarrow R(i_2 - i_1) - i_2 j X_C + R(i_2 - i_3) = 0$

$\Rightarrow -Ri_1 + i_2 (R - jX_C + R) - Ri_3 = 0$ —— ②

Apply KVL to the third loop.

$R(i_3 - i_2) - i_3 j X_C + i_3 R = 0$ —— ③.

$\Rightarrow -Ri_2 + i_3 (R + R - jX_C) = 0$

From 1, 2, 3.

$$\Delta = \begin{bmatrix} (R_C + R) - jX_C & -R & h_{fe} R_C \\ -R & 2R - jX_C & -R \\ 0 & -R & 2R - jX_C \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = 0$$

$$\begin{vmatrix} R_C + R - jX_C & -R & h_{fe} R_C \\ -R & 2R - jX_C & -R \\ 0 & -R & 2R - jX_C \end{vmatrix} = 0$$

$\Rightarrow (R_c + R - jX_c)\left[(2R - jX_c)^2 - R^2\right] + R\left[-R(2R - jX_c)\right] + h_{fe}R_c(R^2)$
$= 0$

$\Rightarrow (R_c + R - jX_c)\left[4R^2 - j4RX_c - X_c^2 - R^2\right] - 2R^3 + jR^2X_c + h_{fe}R_cR^2 = 0$

$\Rightarrow (R_c + R - jX_c)(3R^2 - X_c^2 - j4RX_c) - 2R^3 + jR^2X_c + h_{fe}R_cR^2 = 0$

$\Rightarrow 3R^2R_c - R_cX_c^2 - j4RX_cR_c + 3R^3 - RX_c^2 - j4R^2X_c - j3R^2X_c + jX_c^3$
$- 4RX_c^2 - 2R^3 + jR^2X_c + h_{fe}R_cR^2 = 0$

$\Rightarrow$ To determine frequency of oscillation, the imaginary part of above equation is equal to zero.

$\Rightarrow -4RX_cR_c - 4R^2X_c - 3R^2X_c + X_c^3 + R^2X_c = 0$

$\Rightarrow -6R^2X_c + X_c^3 - 4RX_cR_c = 0$

$\Rightarrow X_c(X_c^2 - 6R^2 - 4RR_c) = 0$

$\Rightarrow X_c^2 = 6R^2 + 4RR_c$

$X_c^2 = R(R6 + 4R_c)$

$X_c = \sqrt{R^2\left(6 + 4\frac{R_c}{R}\right)}$

$\frac{1}{\omega C} = \sqrt{R^2\left(6 + \frac{4R_c}{R}\right)}$

$\omega = \frac{1}{RC\sqrt{6 + \frac{4R_c}{R}}}$

$\boxed{f = \frac{1}{2\pi RC\sqrt{6 + 4\frac{R_c}{R}}}}$ $\qquad \frac{R_c}{R} = K$

$f = \frac{1}{2\pi RC\sqrt{6 + 4K}}$ $\qquad f = \frac{1}{2\pi\sqrt{LC}}$

Wein bridge Oscillator :-

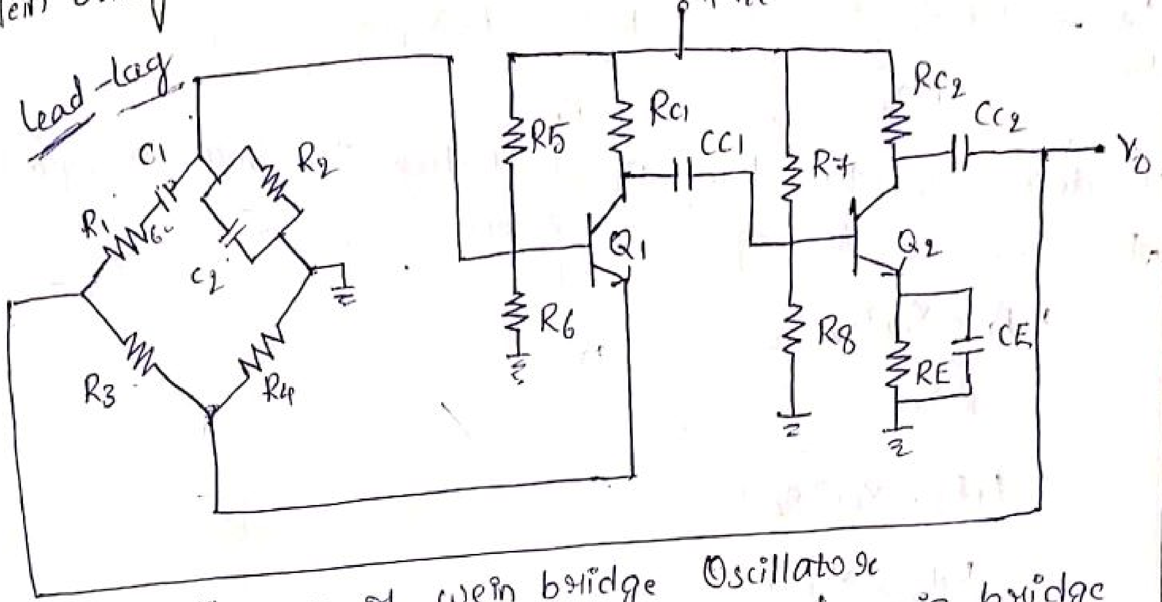


fig: ckt diagram of wein bridge Oscillator

The above fig. shows the ckt diagram of wein bridge oscillator, it consists of two amplifier sections in CE mode and balanced bridge network each CE - amplifier stage provides 180° phase shift and the total phase shift by the two amplifier sections is 360° and hence no need to introduce any additional phase shift by the balanced bridge N/w. The lead - lag N/w which is formed by $R_1 - C_1$ & $R_2 - C_2$ provides the +ve feedback to the i/p of 1st stage of amplifier and the voltage divider N/w which is formed by R_3 & R_4 provides -ve fb to the emitter of I stage of transistor. This balanced bridge N/w provides stability of oscillations in both amplitude & frequency.

→ To determine freq. of oscillation we consider the condition for balancing the bridge.

i.e., $$\frac{R_3}{R_4} = \frac{R_1 + \frac{1}{j\omega C_1}}{R_2 \| \left(\frac{1}{j\omega C_2}\right)} \quad (\text{or}) \quad \frac{R_3}{R_4} = \frac{R_1 - jX_{C_1}}{R_2 \| (-jX_{C_2})}$$

$$= \frac{R_1 - jX_{C_1}}{\frac{R_2(-jX_{C_2})}{R_2 - jX_{C_2}}} = \frac{(R_1 - jX_{C_1})(R_2 - jX_{C_2})}{-jR_2X_{C_2}}$$

$$= \frac{R_1R_2 - jR_1X_{C_2} - jR_2X_{C_1} - X_{C_1}X_{C_2}}{-jR_2X_{C_2}}$$

$$= \frac{R_1R_2 - X_{C_1}X_{C_2}}{-jR_2X_{C_2}} + \frac{\cancel{-j}(R_1X_{C_2} + R_2X_{C_1})}{\cancel{-j}R_2X_{C_2}}$$

$$\frac{R_3}{R_4} \Rightarrow \frac{j(R_1R_2 - X_{C_1}X_{C_2})}{R_2X_{C_2}} + \frac{R_1X_{C_2} + R_2X_{C_1}}{R_2X_{C_2}}$$

To determine the freq. of oscillation, the imaginary part of above eq. is equal to zero.

$$\frac{R_1R_2 - X_{C_1}X_{C_2}}{R_2X_{C_2}} = 0$$

$$\Rightarrow \quad R_1R_2 - X_{C_1}X_{C_2} = 0$$

$$R_1R_2 = X_{C_1}X_{C_2}$$

$$R_1R_2 = \frac{1}{\omega C_1} \cdot \frac{1}{\omega C_2}$$

$$\omega^2 = \frac{1}{R_1R_2C_1C_2}$$

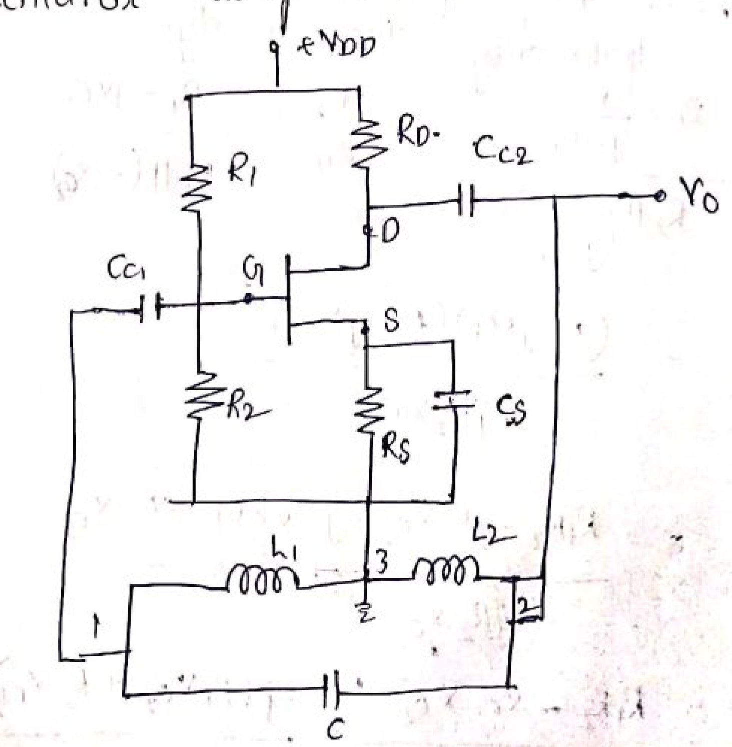
$$\omega = \frac{1}{\sqrt{R_1R_2C_1C_2}}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}}$$

if $R_1 = R_2 = R$ & $C_1 = C_2 = C$

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

Hartley Oscillator using JFET :-



G.E
$h_{ie}(Z_1+Z_2+Z_3)+(1+h_{fe})Z_1Z_2+Z_1Z_3=0$

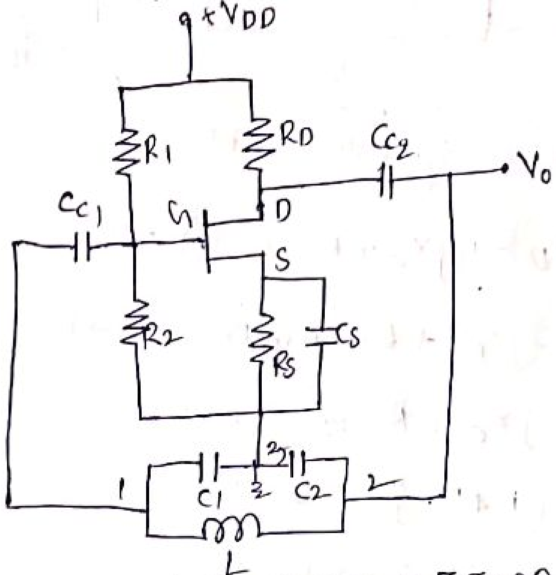
$\Rightarrow Z_1 = j\omega L_1 + j\omega M = j\omega(L_1+M)$

$Z_2 = j\omega L_2 + j\omega M = j\omega(L_2+M)$

$Z_3 = \frac{1}{j\omega C}$

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

Colpitts Oscillator using JFET :-



G.E — $h_{ie}(Z_1+Z_2+Z_3)+(1+h_{fe})Z_1Z_2+Z_1Z_3=0$

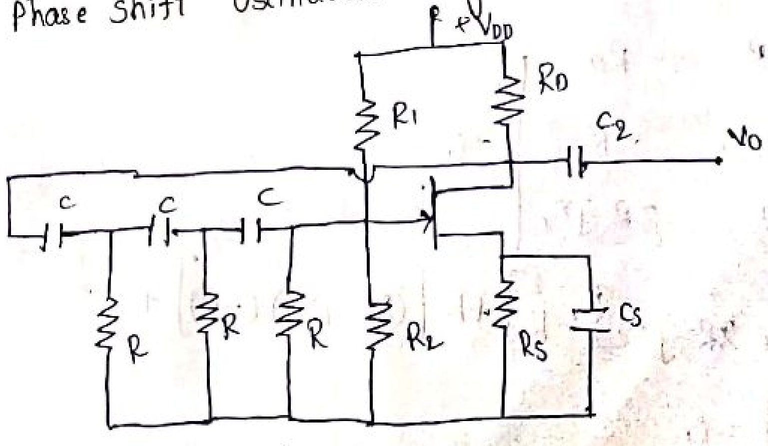
$Z_1 = \frac{1}{j\omega C_1}$ ← (4)

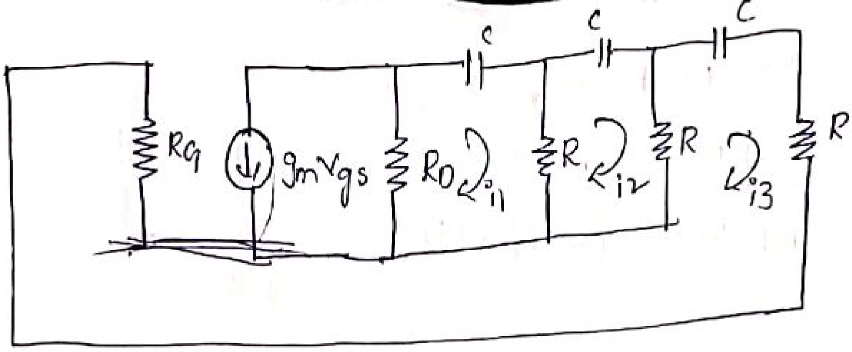
$Z_2 = \frac{1}{j\omega C_2}$

$Z_3 = j\omega L.$ $\qquad C_{eq} = \frac{C_1C_2}{C_1+C_2}$

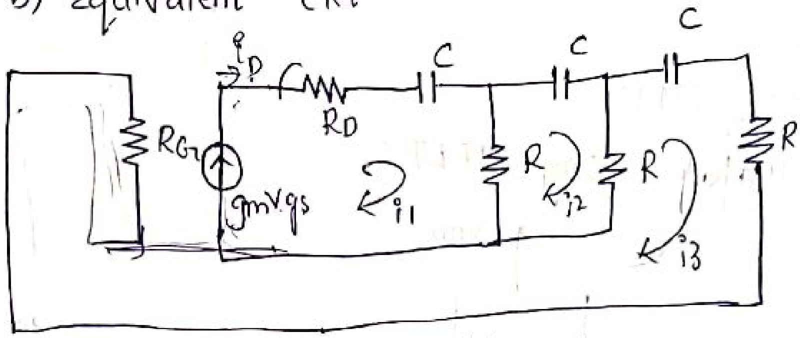
$f = \frac{1}{2\pi\sqrt{LC_{eq}}}$

RC Phase shift Oscillator using JFET :-





b) Equivalent ckt



c) Simplified Equivalent ckt

$g_m = \frac{i_D}{V_{gs}}$

$\rightarrow g_m V_{gs} R_D + i_1 R_D - i_1 j X_C + R(i_1 - i_2) = 0$

$\Rightarrow i_1(R_D + R - jX_C) + R i_2 + i_3 R_D = 0$ — (1)

$\rightarrow R(i_2 - i_1) - i_2 j X_C + R(i_2 - i_3) = 0$

$\Rightarrow -i_1 R + i_2(R + R - jX_C) + R i_3 = 0$

$-R i_1 + i_2(2R - jX_C) - i_3 R = 0$ — (2)

$\rightarrow R(i_3 - i_2) - j i_3 X_C + i_3 R = 0$

$\Rightarrow -R i_2 + i_3(2R - jX_C) = 0$ — (3)

$$\begin{bmatrix} R_D + R - jX_C & -R & R_D \\ -R & 2R - jX_C & -R \\ 0 & -R & 2R - jX_C \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{vmatrix} R_D + R - jX_C & -R & R_D \\ -R & 2R - jX_C & -R \\ 0 & -R & 2R - jX_C \end{vmatrix} = 0$$

$\Rightarrow (R_D + R - jX_C)\left[(2R - jX_C)^2 - R^2\right] + R\left[(2R - jX_C)(-R)\right] +$

$R_D \left[R^2\right] = 0$

$$\Rightarrow (R_D+R-jX_C)\left[4R^2-4RjX_C-X_C^2\}R^2\right]+R\left[-2R^2+jX_CR\right]+R_DR^2=0$$

$$\Rightarrow (R_D+R-jX_C)(3R^2-4RjX_C-X_C^2) + 2R^3+jX_CR^2+R_DR^2=0$$

$$\Rightarrow 3R^2R_D-4R_DRjX_C-R_DX_C^2+3R^3-4R^2jX_C+RX_C^2-3R^2jX_C+4RX_C^2+jX_C^3+2R^3+jX_CR^2+R_DR^2=0$$

To determine the frequency of oscillation, the imaginary part of above eq is zero.

$$jX_C^3+jX_CR^2-3R^2jX_C-4R^2jX_C-4R_DRjX_C=0$$

$$X_C^2+R^2-3R^2-4R^2-4R_DR=0$$

$$X_C^2-6R^2-4R_DR=0.$$

$$X_C^2=6R^2+4R_DR$$

$$X_C^2=R(6R+4R_D)$$

$$X_C=\sqrt{R^2\left(6+\frac{4R_D}{R}\right)}$$

$$\frac{1}{\omega C}=\sqrt{R^2\left(6+\frac{4R_D}{R}\right)}$$

$$\omega=\frac{1}{RC\sqrt{\left(6+\frac{4R_D}{R}\right)}}$$

$$f=\frac{1}{2\pi RC\sqrt{\left(6+\frac{4R_D}{R}\right)}} \qquad \boxed{K=\frac{R_D}{R}}$$

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

Frequency and amplitude stability of oscillator:

In the weinbridge oscillator, if the RC N/ws consists of resistors of 200KΩ and the capacitors of 300PF. Find its frequency of oscillation.

$$f=\frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

$R_1=R_2=200K\Omega$, $C_1=C_2=300PF$

$$f = \frac{1}{2\pi RC} = \frac{1}{2\pi \times 200 \times 10^{3} \times 300 \times 10^{-12}}$$

$$= \frac{10^{5}}{12\pi}$$

$$f = 2.652 \text{ kHz}$$

Frequency and amplitude stability of oscillator :-

Frequency stability of an oscillator :-

The frequency stability of an oscillator is a measure of its ability to maintain the required frequency over a long time interval. The main drawback in transistor oscillators is that the frequency of ~~oscillation~~ operation is not stable. during a long time operation. The following are the factors which contribute to the change in the value of the frequency.

i) Due to change in temperature the values of the frequency determining components such as resistor, inductor and capacitor changes.

ii) Due to variations in the power supply, change in climatic conditions and due to aging of components the transistor parameter changes.

iii) The effective resistance of the tank ckt is changed when the load is connected.

iv) Due to variations in biasing conditions and loading conditions.

In the absence of automatic temp. control, the effect of temp. on the LC ckt can be reduced by selecting the inductance 'L' with +Ve temperature coefficient and capacitance 'C' with -Ve temperature coefficient.

As ~~Piezo~~ Piezo-electric crystals have high 'Q' values of the order of 10^5, they can be used as parallel resonant circuits in oscillators to get very high frequency stability.

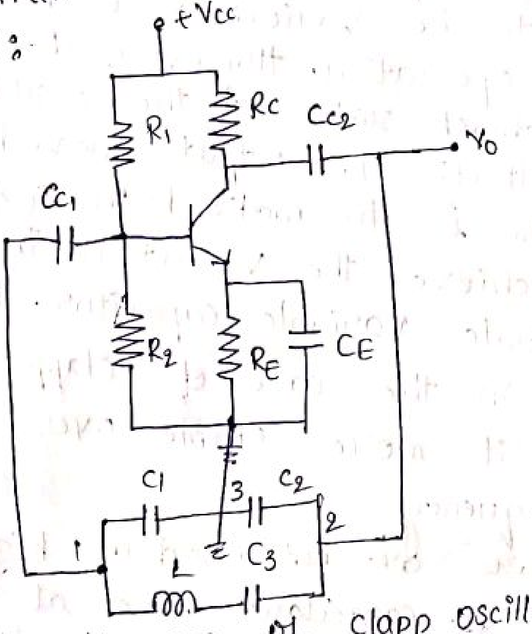
Amplitude stability of an Oscillator:

All oscillators not require +Ve feed back for their operation. If the +Ve resistance of the LC tank ckt is cancelled by introducing the right amount of -Ve resistance across the tank ckt, then the steady oscillation can be maintained.

There are several devices such as Thermister, UJT and tunnel diode exhibits a region of -Ve resistance in V-I characteristics. such devices operated in negative resistance region are placed across LC ckt as the frequency determining section.

In the case of RC oscillators, the amplitude against the variations due to aging of the transistors and other components can be stabilized by replacing the resistor in bridge by sensistors, which are temperature dependent resistors. Thus, the stability in amplitude of the RC oscillators can be easily maintained.

Clapp Oscillator:



a) ckt diagram of clapp oscillator

- Clapp Oscillator is a advanced version of colpitts oscillator in which an additional capacitor C_3 is added into the tank circuit to be in series with the inductor as shown in figure.

Apart from the presence of extra capacitor, all other components and their connections remains similar to that in the case of colpitts oscillator.

Hence, the working of this circuit is almost similar to that of the colpitts oscillator. However, the frequency of oscillation in the case of clapp oscillator is given by $\boxed{f = \frac{1}{2\pi\sqrt{L\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)}}}$

Usually, the value of C_3 is choosen that to be much smaller than the other two capacitors. This is because at higher frequencies, smaller the C_3, larger will be the inductor which simplifies the implementation as well as reduces the effect of leakage inductance.

However, is to be noted that when C_3 is choosen to be smaller with comparision in C_1 & C_2, the net capacitance will be more dependent on it. Thus, $\boxed{f = \frac{1}{2\pi\sqrt{LC_3}}}$

In the case of colpitts oscillator, the capacitor C_1 (or) C_2 need to be varied in order to vary its frequency of operation. However, during this process, even the feedback ratio of the oscillator changes which inturn effects its output waveform. One solution to this problem is to make both C_1 & C_2 to be fixed, while achieve the variation in frequency using a seperate variable capacitor. This is what the C_3 does in the case of clapp oscillator, which inturn makes it more stable over colpitts in terms of frequency

Why RC oscillators are not used at high frequency?

The 'C' in RC is capacitance and at high frequencies the capacitor reactance will decreases. than at low frequencies. As capacitor performance goes down, the circuit performance also goes down. Thus, RC oscillators performance is poor at high frequencies and not provides stable oscillations. This is the reason RC oscillators are not used at high frequencies