U4ECB05 - Analog Electronic circuits

Unit - III Feedback Amplifiers.

Basic concepts of feedback, negative feedback positive feedback, Analysis of different types of negative feedback amplifier, Voltage shunt feedback, series feed back amplifier, Current shunt, current series feedback amplifier.

Amplifier is a device that increases the magnitude of a signal. It have the following drawbacks

1. value of Gain get changed due to the variation in temp, voltage etc.
2. wave form distored due to non linearities in the operating characteristics.
3. It may introduce noise.

The above seri drawbacks can be minimizing if we introduce feedback

Feedback Concept.

Some portion of output is feedback to the input is called feed back.

Types of feedback

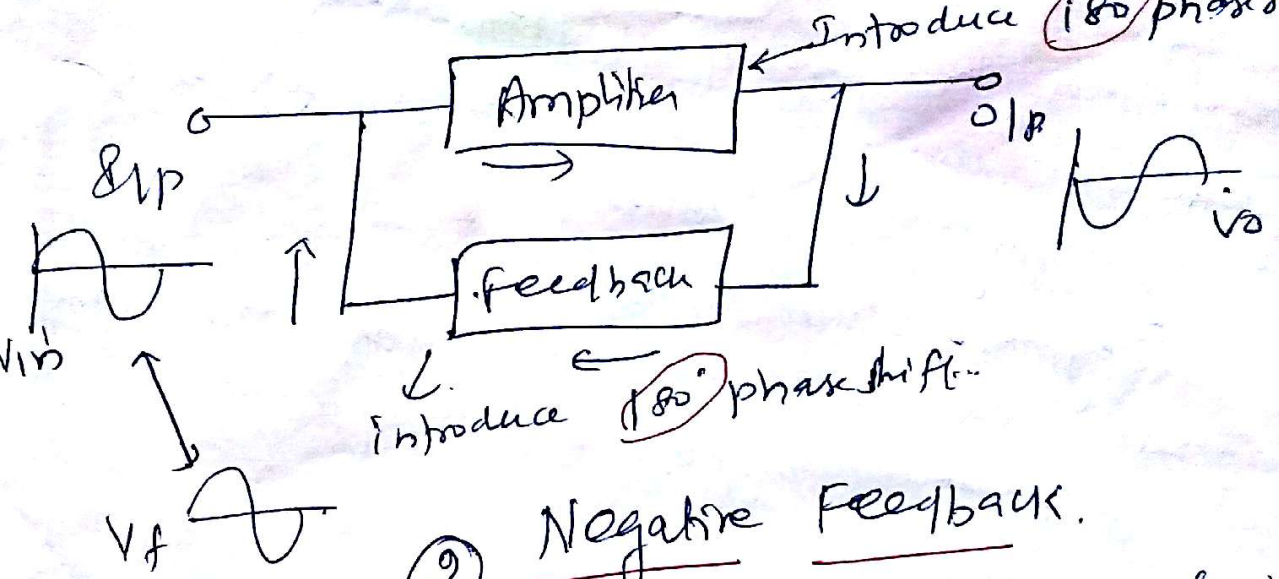
1. positive feedback 2. Negative feedback

Feedback

- ~~Positive~~ (Regenerative)
- Negative (Degenerative)
  - Voltage
    - Shunt
    - Series
  - Current
    - Voltage Shunt
    - Series

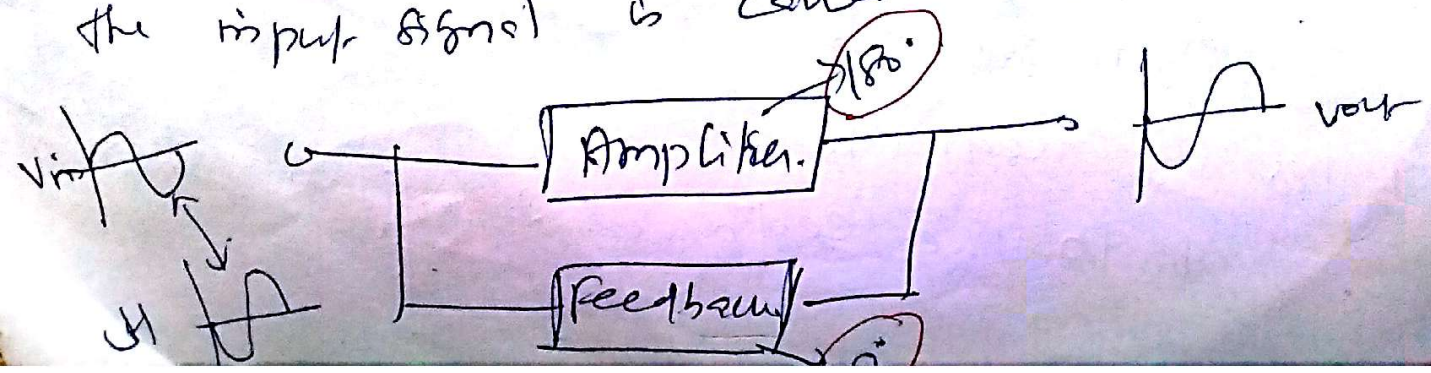
① Positive feedback

When the feedback signal is in phase with the input signal is called positive feedback.

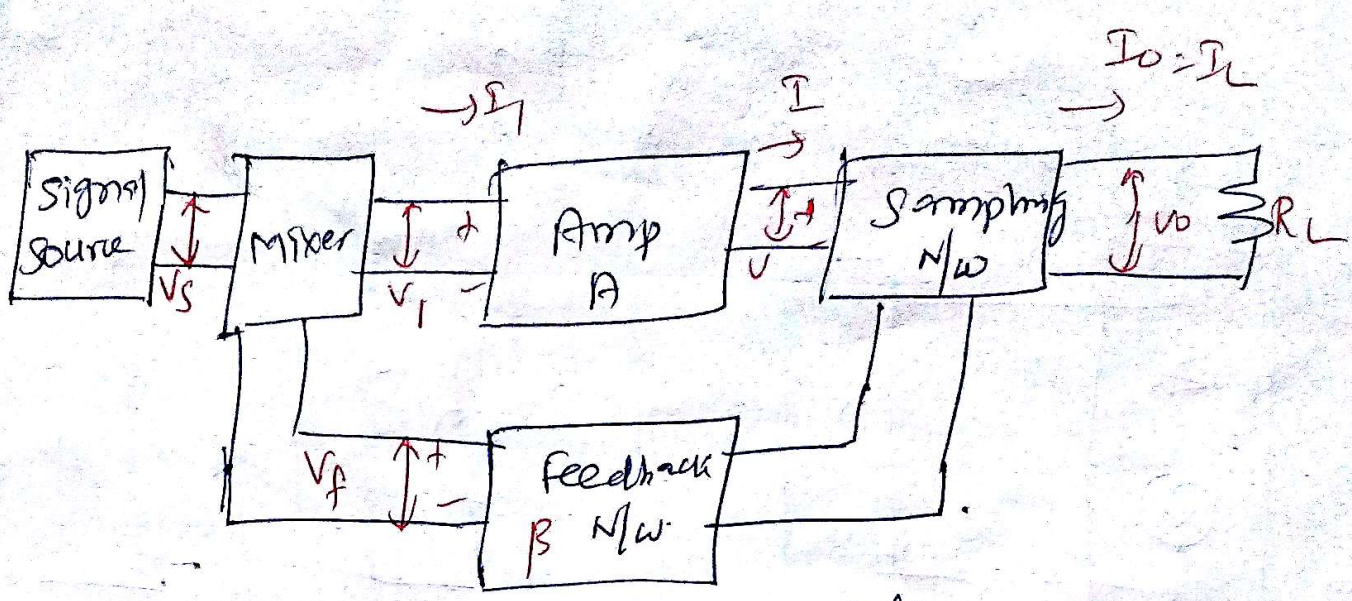


② Negative Feedback.

when the feedback signal is out of phase with the input signal is called Negative feedback.



Feedback Block Diagram



Feedback N/w consist of the following

1. Signal Source 2. Sampling N/w 3. Feedback N/w.
4. Mixer N/w.

1. Signal source.

It can be voltage source V_s or a current source I_s.

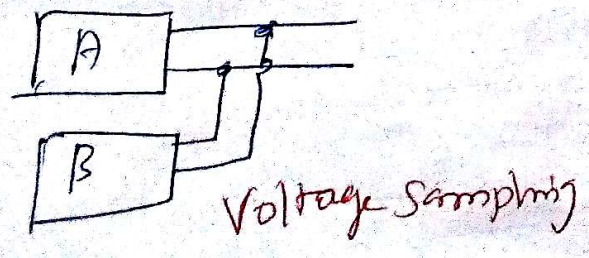
2. Feedback N/w

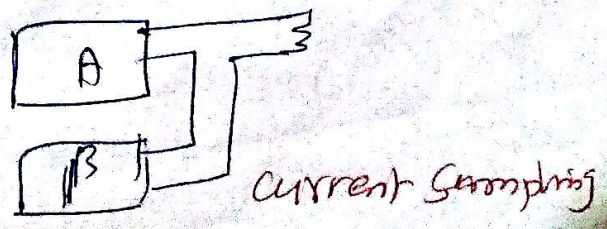
$$V_f = \beta V_{out}.$$

β = Reverse Transmission feedback factor or feedback ratio. $0 < \beta < 1$

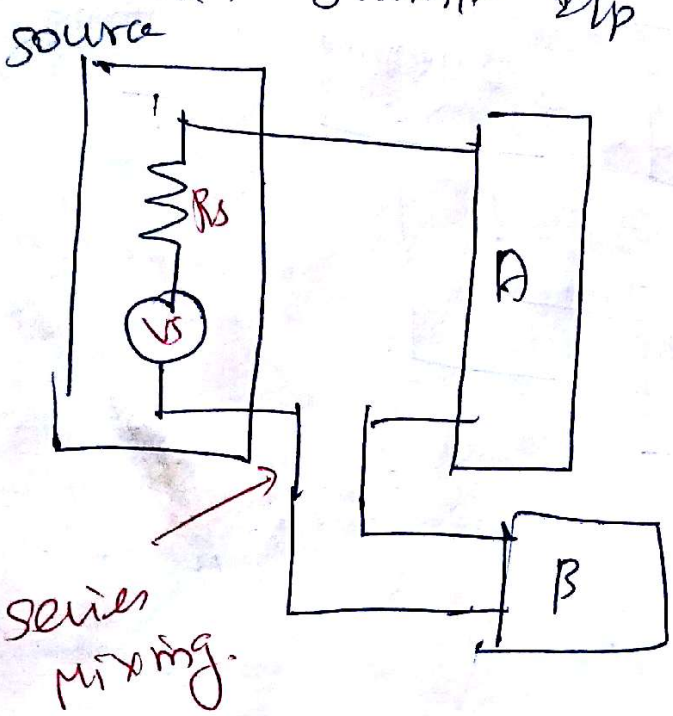
3. Sampling N/w.

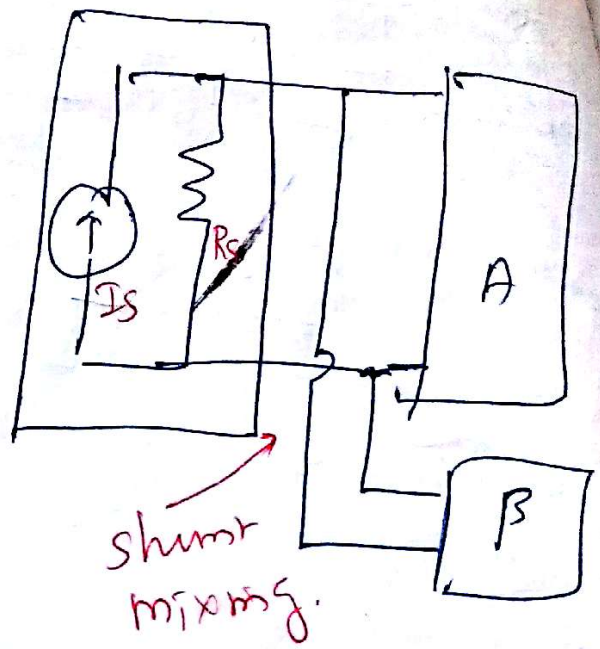
1. Voltage Sampling or Node Sampling
2. Current Sampling or Loop Sampling





1. Series I/p connection
2. Shunt I/p Connection.





Advantages of Negative feedback amplifier.

1. I/p impedance can be increased.
2. O/p impedance can be decreased.
3. Bandwidth increased
4. Distortion reduced
5. Noise reduces.

Properties of Negative feedback.

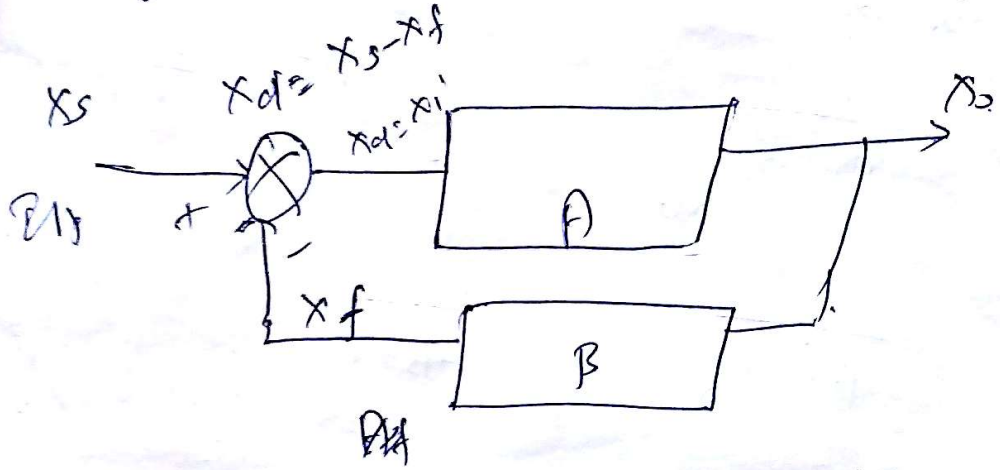
1. Desensitivity of Transfer Amplification

The variation due to ageing, temperature, replacement of ckt components & transistor

is reflected in lack of stability.

Fractional change without feedback is $\frac{dA_f}{A_f}$

Analysis of Ideal feedback amp



$X_d = X_s - X_f \Rightarrow X_s = X_d + X_f$

$X_d = X_i$

Forward Tx on gain $A = \frac{X_o}{X_i}$

~~Reverse~~ Tx on factor $\beta = \frac{X_f}{X_o}$ Transimission factor $\beta = X_f / X_o$

where $X_o = A X_i = A X_d$.

$A = \frac{X_o}{X_i} = \frac{X_o}{X_d}$.

$A_f = \frac{X_o}{X_s + X_f}$ WKT, the gain with feedback is expressed as follows

$$A_f = \frac{X_o}{X_s} = \frac{V_o}{V_s}$$ ⑥

$[\beta = X_f / X_o]$

$$A_f = \frac{X_o}{X_d + X_f} = \frac{X_o}{X_d + \beta X_o} = \frac{X_o}{X_d + \beta X_o}$$

Div Nr & Dr by X_o

$$A_f = \frac{1}{\beta + X_d / X_o} \qquad \left[A = \frac{X_o}{X_d} \right]$$

$$X_f = \frac{1}{\beta + 1/A} = \frac{A}{A\beta + 1}$$

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

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

Properties of Negative feedback

1. Desensitivity of Transfer Amplification.

The variation due to aging, temperature, replacement of ~~ckt~~ circuit components & transistor is reflected in corresponding lack of stability.

Fractional change to fractional change without feedback is given by. $\frac{dA_f}{A_f} \rightarrow (1)$

differentiate (1) w.r.to A.

$$\boxed{\text{where } A_f = \frac{A}{AB+1}}$$

$$\frac{dA_f}{dA} = \frac{d}{dA}\left(\frac{A}{1+AB}\right)$$

$$= \frac{(1+AB)\cdot 1 - A\cdot B}{(1+AB)^2} = \frac{1+\cancel{AB}-\cancel{AB}}{(1+AB)^2}$$

$$\boxed{\frac{du}{dv} = \frac{v\,du/dx - u\,dv/dx}{v^2}}$$

$$\frac{dA_f}{dA} = \frac{1}{(1+AB)^2}$$

$$dA_f = \frac{dA}{(1+AB)^2}$$

$\div$ both the sides by A_f, we get

$$\frac{dA_f}{A_f} = \frac{dA}{(1+AB)^2} \times \frac{1}{A_f}.$$

$$\left[A_f = \frac{A}{1+AB}\right]$$

$$\frac{dA_f}{A_f} = \frac{dA}{(1+AB)^{\cancel{2}}} \times \frac{\cancel{1+AB}}{A}$$

$$\frac{dA_f}{A_f} = \frac{1}{(1+AB)} \cdot dA/A.$$

$$S = \frac{dA_f/A_f}{dA/dA} = \frac{1}{1+AB} = \text{Sensitivity}$$

$$\boxed{\text{Desensitivity} : D = (1+A\beta)}$$

Due to -ve feedback 'D' get improved $(1+A\beta)$ times. So stability get improved.

② Cutoff frequencies with feedback.

WKT $A_f = \dfrac{A}{1+A\beta}$

we can write

$$A_{fmid} = \frac{A_{mid}}{1+A_{mid}\beta} \rightarrow ① \quad ; \quad A_{flow} = \frac{A_{low}}{1+A_{low}\beta} \rightarrow ②$$

$$A_{fhigh} = \frac{A_{high}}{1+A_{high}\beta} \rightarrow ③$$

2.1 Lower cutoff frequency

WKT, the relation b/w gain at low frequency & gain at mid frequency, is given as.

$$\frac{A_{low}}{A_{mid}} = \frac{1}{1-j\left(\frac{f_L}{f}\right)} \quad \therefore A_{low} = \frac{A_{mid}}{1-j\left(\frac{f_L}{f}\right)}$$

Sub A_{low} in ②

$$A_{flow} = \frac{\dfrac{A_{mid}}{1-j(f_L/f)}}{1+\beta\left[\dfrac{A_{mid}}{1-j(f_L/f)}\right]} = \frac{A_{mid}}{1-j\left(\frac{f_L}{f}\right)+A_{mid}\beta}.$$

$$A_{flow} = \frac{A_{mid}}{1 + A_{mid}\beta - j\left(f_L/f\right)}$$

$\Rightarrow$ Nr & Dr by $(1 + A_{mid}\beta)$

$$A_{flow} = \frac{A_{mid}/(1 + A_{mid}\beta)}{1 - j\left(\frac{f_L}{(1 + A_{mid}\beta) f}\right)}$$

$$\left[\because A_{fmid} = \frac{A_{mid}}{1 + A_{mid}\beta}\right]$$

$$A_{flow} = \frac{A_{fmid}}{1 - j\left(\frac{f_L}{(1 + A_{mid}\beta) f}\right)}$$

$$\frac{A_{flow}}{A_{fmid}} = \frac{1}{1 - j\left(\frac{f_{Lf}}{f}\right)}$$

where $\boxed{f_{Lf} = \frac{f_L}{1 + A_{mid}\beta}}$

From this, we can say that lower cutoff frequency with feedback is less than lower cutoff frequency without feedback by factor $(1 + A_{mid}\beta)$.

2.2 Upper cutoff frequency

WKT A_{fhigh} $\frac{A_{high}}{A_{mid}} = \frac{1}{1 - j\left(f/f_H\right)}$

$$A_{high} = \frac{A_{mid}}{1 - j(f/f_H)}$$

$$A_{f\,high} = \frac{A_{high}}{1 + A_{high} \cdot \beta} = \frac{\frac{A_{mid}}{1 - j(f/f_H)}}{1 + \frac{A_{mid}}{1 - j(f/f_H)} \cdot \beta}$$

$$A_{f\,high} = \frac{A_{mid}}{1 - j(f/f_H) + A_{mid}\beta} = \frac{A_{mid}}{(1 + A_{mid}\beta) - j(f/f_H)}$$

÷ Nr & Dr by $(1 + A_{mid}\beta)$

$$A_{f\,high} = \frac{\frac{A_{mid}}{1 + A_{mid}\beta}}{1 - j\frac{f}{f_H(1 + A_{mid})\beta}}$$

$$A_{f\,high} = \frac{A_{f\,mid}}{1 - j\frac{f}{f_H(1 + A_{mid})\beta}} = \frac{A_{f\,mid}}{1 - j\left(\frac{f}{f_{Hf}}\right)}$$

where $\boxed{f_{Hf} = f_H(1 + A_{mid})\beta}$

Upper cutoff freq with feedback is greater than upper cutoff frequency without feedback by factor $(1 + A_{mid}\beta)$.

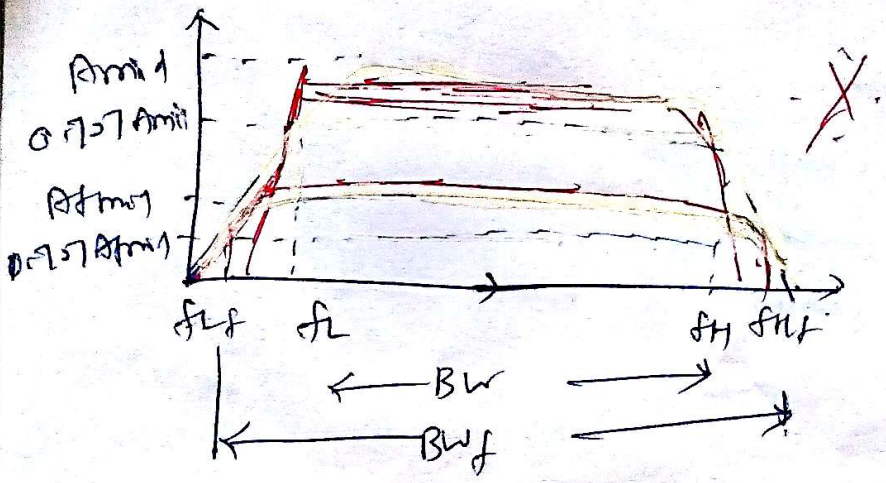
Bandwidth.

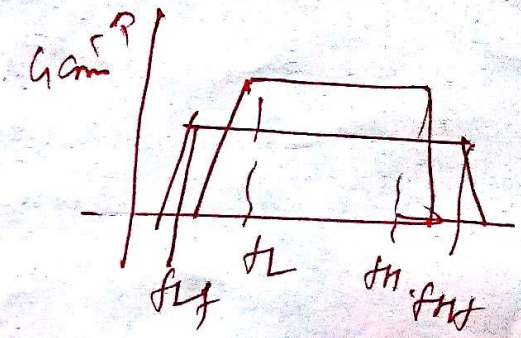
BW = Upper cutoff freq - Lower cutoff freq.

BW of the amplifier with feedback is given as,

$BW_f = f_{Hf} = f_{Lf}$.

$$BW_f = (1 + A_{mid}\beta) f_H - \frac{f_L}{(1 + A_{mid}\beta)}$$





3) Distortion with feedback.

3.1. Frequency Distortion.

$A_f = 1/\beta$ The overall gain is not a function of frequency. Under this condition, the frequency & phase distortion gets reduced.

If β is made up of reactive components, the reactance of these components will change with frequency changing the β. As a result, the gain will also change with frequency. For the tuning freq $\beta \to 0$ & at other freq $\beta \to \infty$. As a result, amplifier provides high gain for signal tuned freq & relatively reject all other frequencies.

② Noise & Nonlinear Distortion.

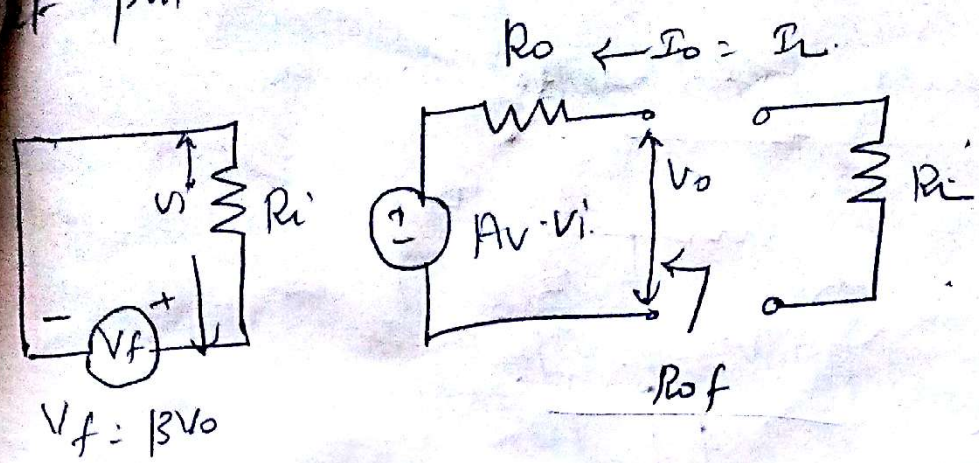
Signal feedback reduces the amount of noise signal & non-linear distortion.

4. Input & o/p Resistance

Classification of amplifiers.

1. Voltage series
2. Voltage shunt.
3. Current series
4. Current shunt.

Output Resistance



$V_f = \beta V_o$

Apply KVL to output side

$A_{vo} \cdot V_i + I_L R_o = V_o$

$I_L = \dfrac{V_o - A_{vo} \cdot V_i}{R_o}$ $= \dfrac{V_o + A_{vo} \cdot \beta V_o}{R_o}$

Since $V_s = 0$; so $V_i = -V_f = -\beta V_o$

$I_L = R_{of} = \dfrac{V_o}{I_L}$; then $R_{of} = \dfrac{V_o \cdot R_o}{V_o - A_{vo} \cdot V_i}$

$R_{of} = \dfrac{V_o R_o}{V_o (1 + A_{vo} \cdot \beta)}$

$$\boxed{R_{of} = \frac{R_o}{1 + \beta A_{vo}}}$$

o/p resistance with feedback R'_{of} includes R_L

$R'_{of} = R_{of} \,//\, R_L = \dfrac{R_{of} \cdot R_L}{R_{of} + R_L}$

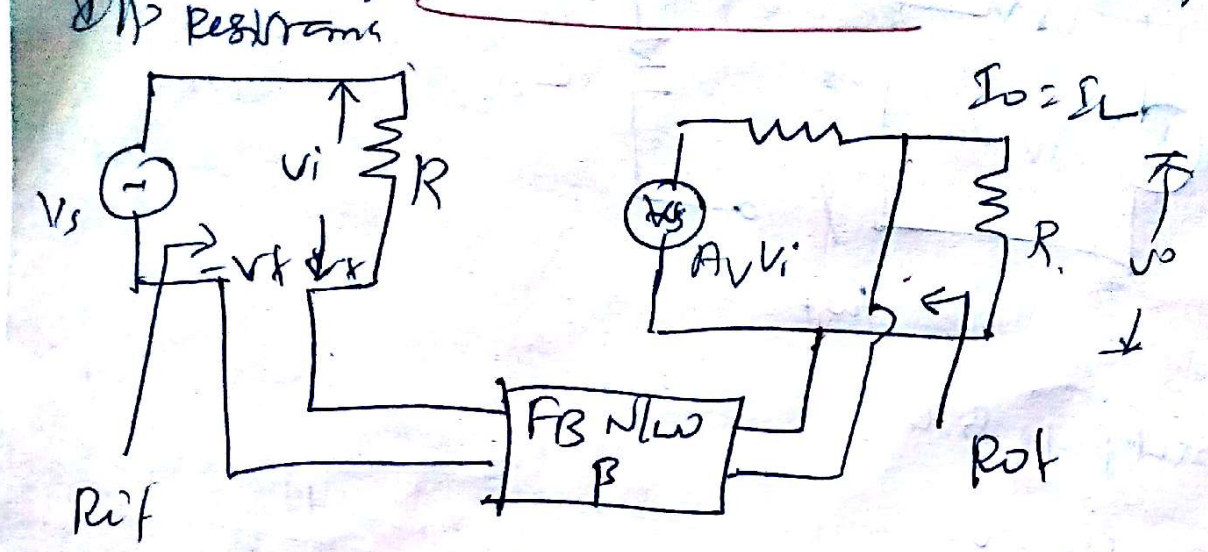
$R'_{of} = \dfrac{\dfrac{R_o}{1+\beta A_{vo}} \times R_L}{\dfrac{R_o}{1+\beta A_{vo}} + R_L} = \dfrac{\dfrac{R_o R_L}{1+\beta A_{vo}}}{\dfrac{R_{of} + R_L (1+\beta A_{vo})}{(1+\beta A_{vo})}}$

$R'_{of} = \dfrac{R_o R_L}{R_{of} + R_L + \beta A_{vo} R_L}$

$R'_{of} = \dfrac{R_o R_L / R_o + R_L}{1 + \beta A_{vo} R_L / R_o + R_L} = \dfrac{R'_o}{1 + \beta A_{vo}}$

Arjun Sai
Aditya
Bhavani
Chandu
Sai Ram
Deepak Reddy
Sai Sam
Dheeraj

1. Voltage Series feedback Amplifier



I/p Series-S

$R_{if} = \frac{V_s}{I_s}$

Apply KVL

$V_s - I_i R_i - V_f = 0$

$V_s = V_f + I_i R_i$

$V_f = \beta V_o$

o/p voltage is expressed as

$V_o = \frac{A_v V_i}{R_o + R_L} \times R_L = A_V \cdot V_i$

$A_V = \frac{A_v R_L}{R_o + R_L}$

A_v = open loop voltage gain without feedback

A_V = voltage gain without feedback taking R_L into account

$V_o = A_V \cdot V_i$

$= A_V \cdot I_i R_i$ since $V_i = I_i \cdot R_i$

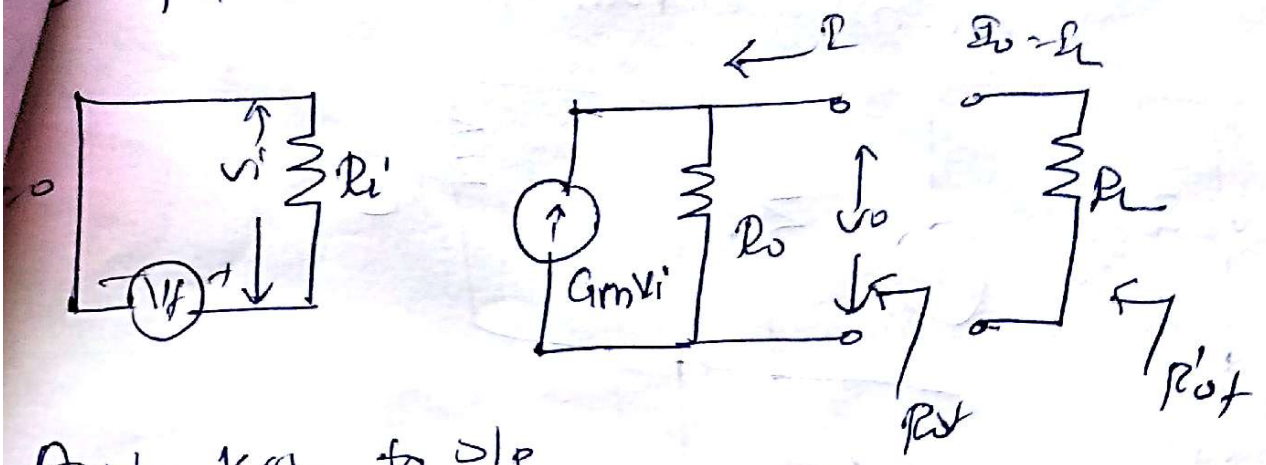
$R_{if} = \frac{V_f + I_i R_i}{I_s} = \frac{\beta V_o + I_i R_i}{I_s}$

$R_{if} = \beta \cdot \cancel{\frac{A_v V_i}{R_o}} \frac{\beta \cdot A_V \cdot V_i + I_i R_i}{I_s}$

$R_{if} = \frac{\beta A_V \cdot \cancel{V_i} R_i + \cancel{I_i} R_i}{\cancel{I_s}} = \frac{\cancel{I_s} R_i}{R_i + \beta A_V R_i}$

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

Output Resistance.



Apply KCL to o/p

$G_m V_i = I + \frac{V_o}{R_o}$

$G_m V_i + I = V_o / R_o$

$\Rightarrow I = \frac{V_o}{R_o} - G_m V_i$

$I = \frac{V_o}{R_o} + \beta G_m I$

$I(1 + \beta G_m) = V / R_o$

$$\boxed{R_{of} = V/I = R_o(1 + \beta G_m)}$$

$V_i = -V_f$

$V_f = \beta I$

since $I_o = -I$.

$V_i = -\beta I$

$V_f = +\beta I_o$

$V_i = -V_f = -\beta I_o$

since $I = I_o$

$V_f = +\beta I_o$

$R'_{of} = R_{of} // R_L = \frac{R_{of} \times R_L}{R_{of} + R_L}$

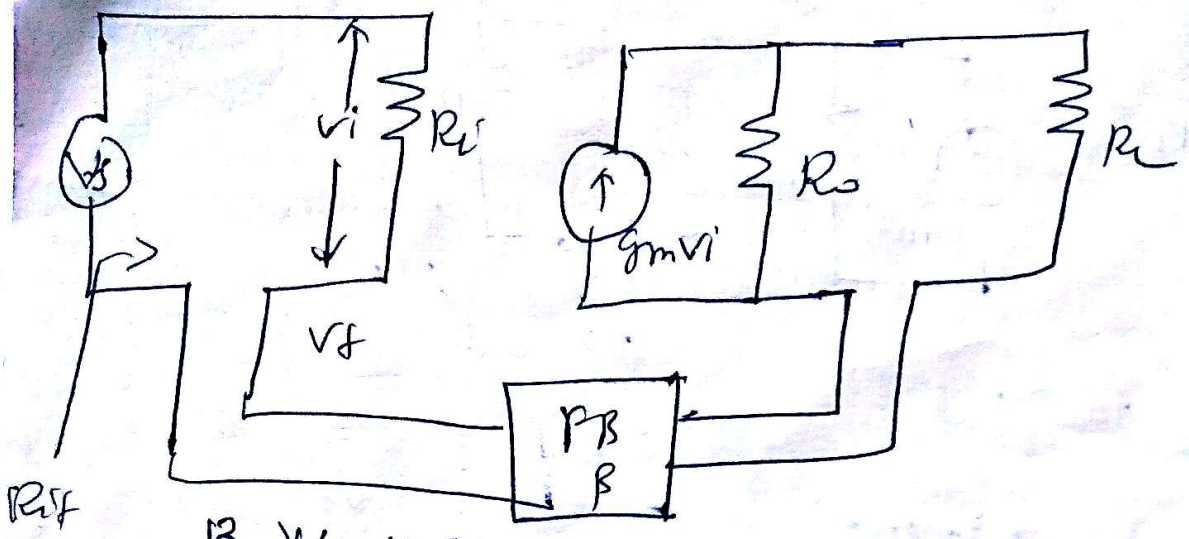
$\frac{R_o(1+\beta G_m) \cdot R_L}{R_o(1+\beta G_m) + R_L} =$

$\div$ N.r & Dr by $R_o + R_L$

$R'_{of} = \frac{\frac{R_o R_L}{R_o + R_L}(1+\beta G_m)}{R_o \cdot 1 + \frac{\beta G_m R_o}{R_o + R_L}}$

Current Series Feedback Amplifier

(or) Transconductance Amplifier



$V_f = \beta . I_o$

$R_{if} = V_s / I_s$ $\qquad V_f = -\beta I_o$

Apply KVL to I/p loop

$V_s = I_i R_i + V_f = I_i R_i - \beta I_o$

O/p current I_o is expressed as

$$I_o = \frac{G_m V_i R_o}{R_o + R_L} = G_M . V_i$$

where $G_M = \dfrac{G_m R_o}{R_o + R_L}$ $\qquad G_m$: Open loop transconductance without feedback

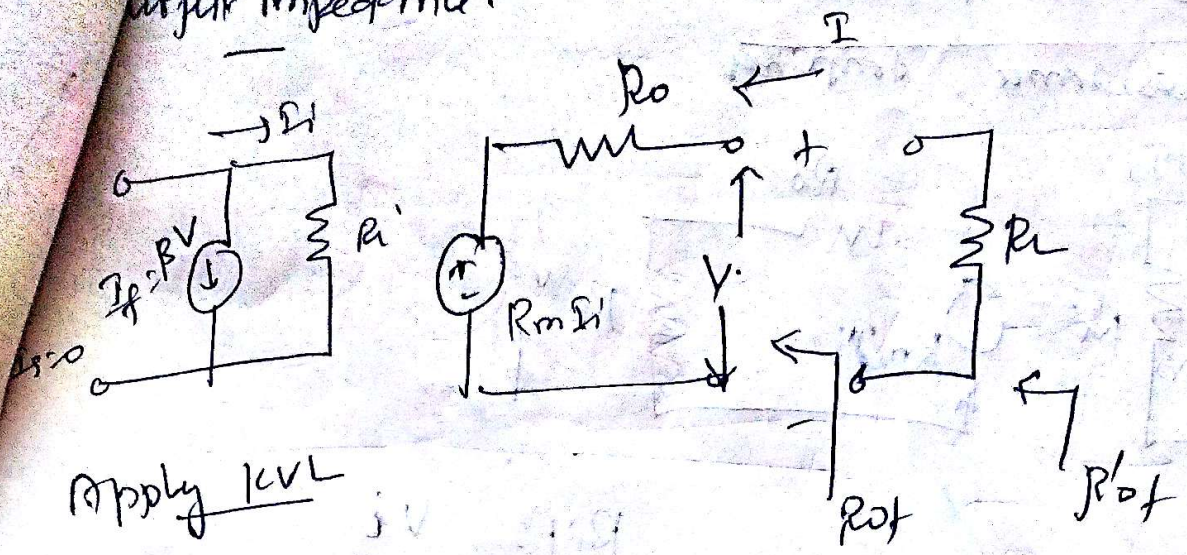
G_M : " " taken R_L in account

$V_s = I_i R_i + \beta - G_M . I_i R_i$

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

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

Output impedance.



Apply KVL

$$V = R_m I_i + I \cdot R_o$$

$$R_{of} = V/I.$$

$$I = \frac{V - R_m I_i}{R_o}$$

I/p ckt given by

$$I_i = -I_f = -\beta V.$$

$$I = \frac{V + \beta R_m \cdot V}{R_o}$$

$$I = \frac{V(1+\beta R_m)}{R_o}$$

$$\boxed{R_{of} = V/I = \frac{R_o}{1+\beta R_m}}$$

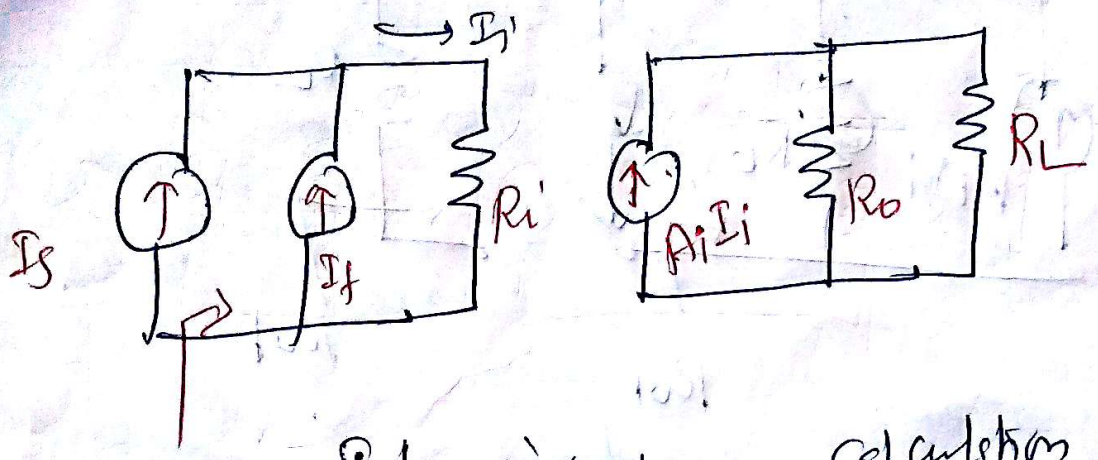
$$R'_{of} = R_{of} \,||\, R_L = \frac{R_{of} R_L}{R_{of} + R_L} = \frac{R_o/(1+\beta R_m)}{\frac{R_o}{1+\beta R_m} + R_L}$$

$$R'_{of} = \frac{R_o}{R_o + R_L(1+\beta R_m)}$$

$\div$ by $(R_o + R_L)$

$$R'_{of} = \frac{R'_o}{1 + \frac{R_L \beta R_m}{R_o + R_L}} = \frac{R'_o}{1+\beta R_m}$$

(a) Current Gain Amplifier



R_{if} I/p impedance calculation

Apply KCL

$$R_{if} = \frac{V_i}{I_s}$$

$$I_s = I_f + I_i \quad \Big| \quad I_f = \beta \cdot I_o$$

$$I_s = \beta I_o + I_i$$

unknown term I_o

$$I_o = \frac{A_i \cdot I_i R_o}{R_o + R_L} = A_I \cdot I_i \quad \left[\frac{A_i R_o}{R_o + R_L} = A_I \right)$$

$$I_o = A_I \cdot I_i$$

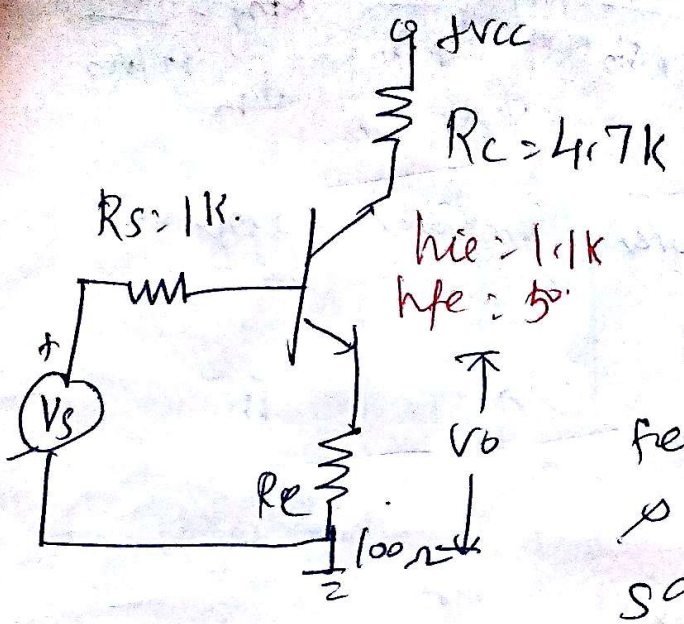
$$I_s = \beta A_I \cdot I_i + I_i = I_i (1 + \beta A_I)$$

$$R_{if} = \frac{V_i}{I_s} = \frac{\cancel{I_i} R_i}{\cancel{I_i}(1 + \beta A_I)}$$

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

Analysis of Feedback Amplifiers.

Transistor Emitter follower



Step: 1

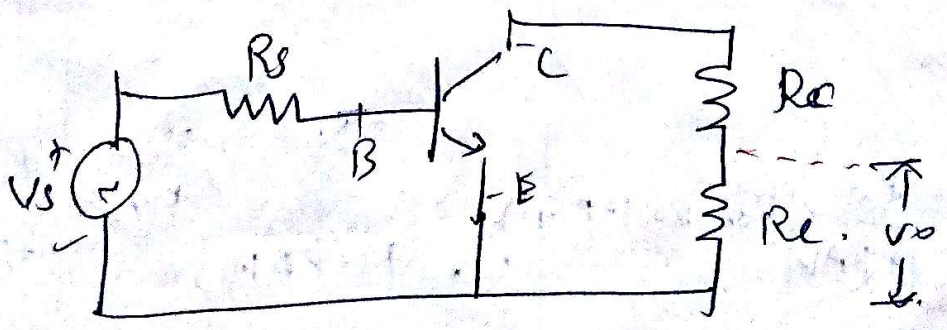
Identify the topology.

By shorting o/p voltage ($V_o = 0$) feedback signal becomes zero. & hence it is voltage sampling. Voltage feedback is subtracted from the source Vs & hence it is series mixing

Step2 & Step3 Find I/p & o/p circuit

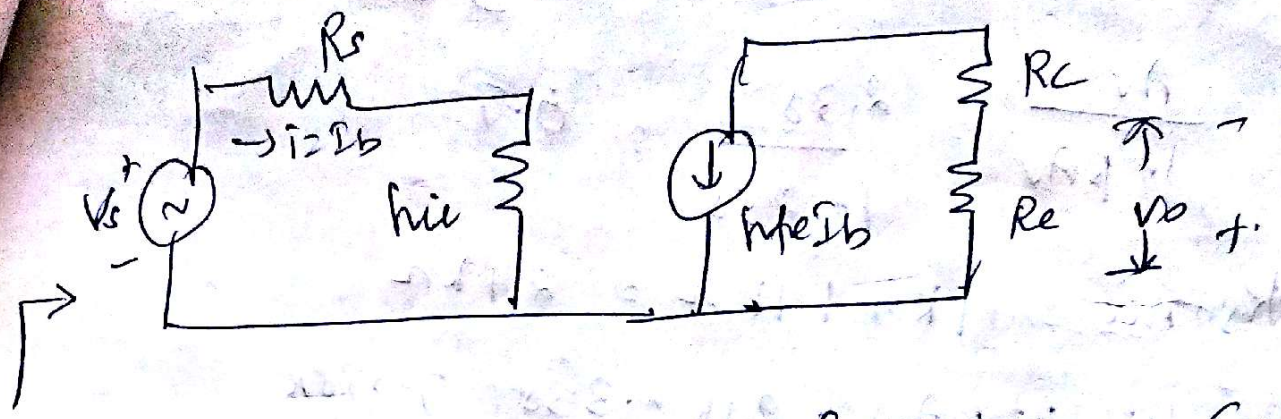
To find the I/p circuit set $V_o = 0$ & hence Vs is series with Rs appears

To find the O/P ckt, set $I_i = I_b = 0$ & hence Re appears only in the output loop



Parameter	Voltage series	Current series	Current shunt	Voltage shunt
Gain with feedback.	$A_{vf} = \frac{A_v}{1+\beta A_v}$ ↓ses	$A_{mf} = \frac{G_m}{1+\beta G_m}$ ↓ses	$A_{if} = \frac{A_i}{1+\beta A_i}$ ↓ses	$R_{mf} = \frac{R_m}{1+\beta R_m}$ ↓se
Stability	Improves	Improves	Improves	Improves
Frequency response	Improves	↑se	↑se	↑se
Frequency distortion	decreases	↓se	↓se	↓se
Noise & Non linear distortion	reduces	↓se	↓se	↓se
I/p resistance	$R_{if} = R_i(1+\beta A_v)$ ↑ses	$R_{if} = R_i(1+\beta G_m)$ ↑ses	$R_{if} = \frac{R_i}{1+\beta A_i}$ ↓se	$R_{if} = \frac{R_i}{1+\beta R_m}$ ↓se
O/p resistance	$R_{of} = \frac{R_o}{1+\beta A_v}$	$R_{of} = R_o(1+\beta G_m)$	$R_{of} = R_o(1+\beta A_s)$	$R_{of} = \frac{R_o}{1+\beta R_m}$

Step:4 Replace transistor by its h-parameters equivalent Circuit.



Step:5 Find open loop voltage Gain

$$A_v = \frac{V_o}{V_s} = \frac{h_{fe} I_b \cdot R_e}{V_s}$$

Apply KVL in the I/p side.

$$V_s = I_b (R_s + h_{ie})$$

$$A_v = \frac{h_{fe} \cancel{I_b} \cdot R_e}{\cancel{I_b}(R_s + h_{ie})}$$

$$A_v = \frac{h_{fe} R_e}{R_s + h_{ie}} = \frac{50 \times 100}{1K + 1.1K} = 2.38$$

Step:6 Indicate V_o & V_f & calculate β.

$$\beta = V_f / V_o = 1$$ [Both Voltage present across Re]

Step: 7 calculate D, A_{vf}, R_{if}, R_{of} & R'_{of}

$$D = 1+\beta A_v = 1+1\times 2.38 = 3.38$$

$$A_{vf} = \frac{A_v}{1+\beta A_v} = \frac{2.38}{1+2.38} = 0.7$$

$$R_i = R_s + h_{ie} = 1k + 1.1k\Omega = 2.1k\Omega$$

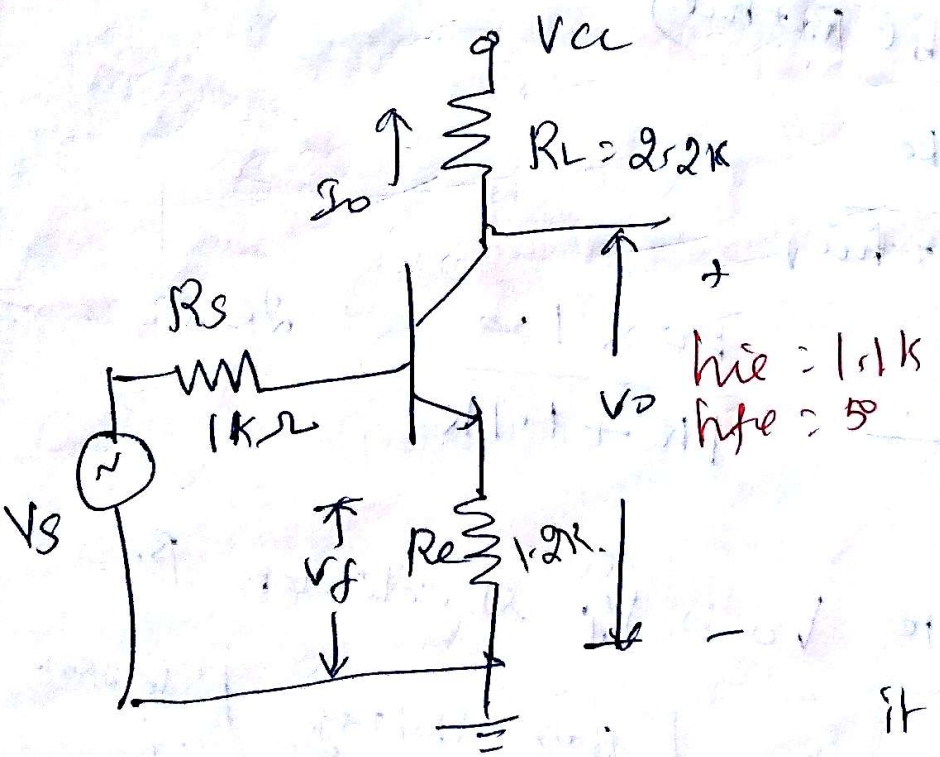
$$R_{if} = R_i(1+\beta A_v) = 2.1k \times 3.38 = 7.098k$$

$$R_o = \infty.$$

$$R'_{of} = \frac{R_o}{1+\beta A_v} = \frac{\infty}{3.38} = \infty$$

Current Series FeedBack

Common Emitter Configuration with unbypassed Re



Analysis

Step: 1)

By opening the output loop, (o/p ckt $I_o = 0$), feedback signal becomes zero & hence it is current sampling.

Feedback signal V_f is subtracted from the externally applied signal V_s & subtracting

R_{of}

$$G_M = \frac{-h_{fe}}{R_s + h_{ie} + R_e} = -0.015$$

Step:6 Calculate β

$$\beta = \frac{V_f}{I_o} = \frac{I_e R_e}{I_o} = \frac{-I_o R_e}{I_o} \quad [\because I_e = -I_o]$$

$$\boxed{\beta = -1.2k}$$

Step:7 Calculate D, G_{Mf}, A_{vf}, R_{if}, R_{of} & R'_{of}

$$D = 1 + \beta G_M = 19.18$$

$$G_{Mf} = \frac{G_M}{D} = -0.782 \times 10^{-3}$$

Voltage Gain $A_{vf} = \frac{V_o}{V_s} = \frac{I_o R_L}{V_s}$

$$= G_{Mf} \cdot R_L$$

$$= -1.72$$

$$R_i = R_s + h_{ie} + R_e = 3.3k$$

$$R_{if} = R_i(1+D) = 63.3k$$

$$R_o = \infty \qquad R_{of} = \infty$$

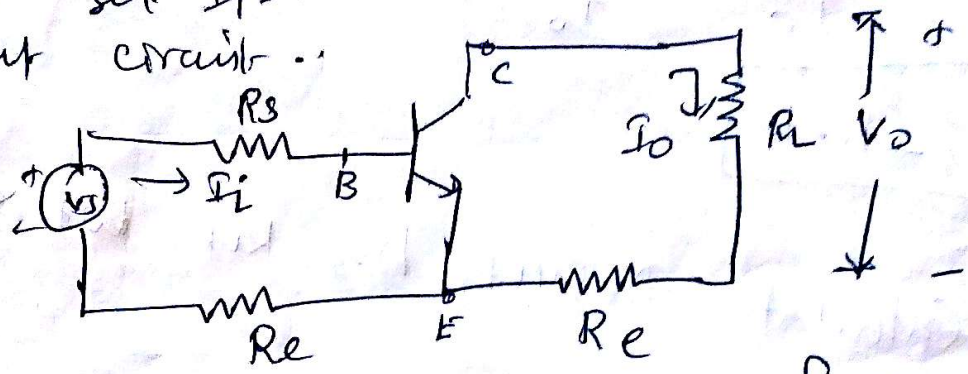
$$R'_{of} = \infty \cdot R'_o \left[\frac{1+\beta G_M}{1+\beta G_M}\right]$$

$$R'_{of} = R_L = 2.2k$$

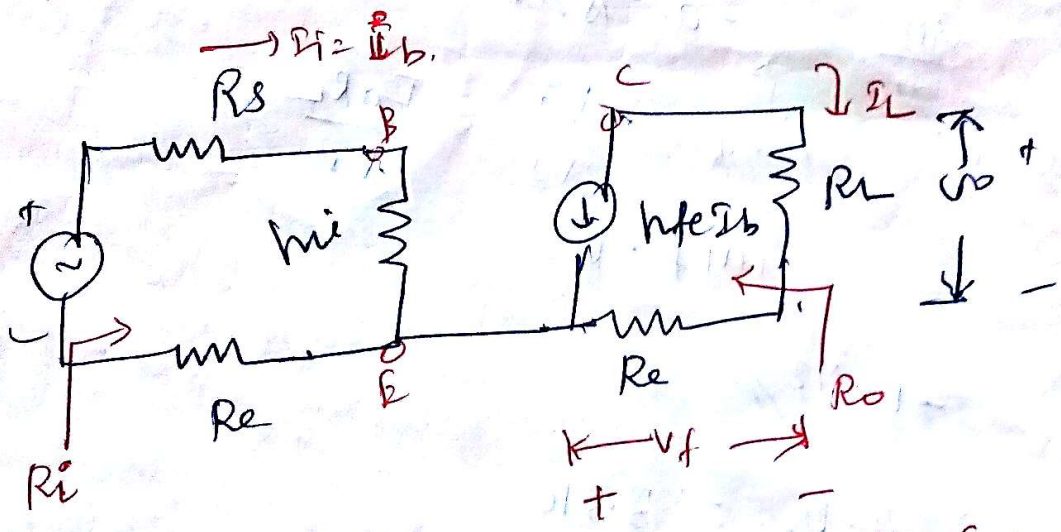
∴ hence it is Series Mixing.

Step 2 & Step: 3 Find I/p & o/p Circuit

To find input circuit set $I_o = 0$, then R_e appears at the input side. To find output circuit set $I_i = 0$, then R_e appears in the output circuit..



Step: 4 Replace the transistor with h-parameter



Step: 5 Find open loop transfer Gain

$$G_m = \frac{I_o}{V_i} = \frac{-h_{fe} I_b}{V_i} \quad \because I_o = -h_{fe} I_b$$

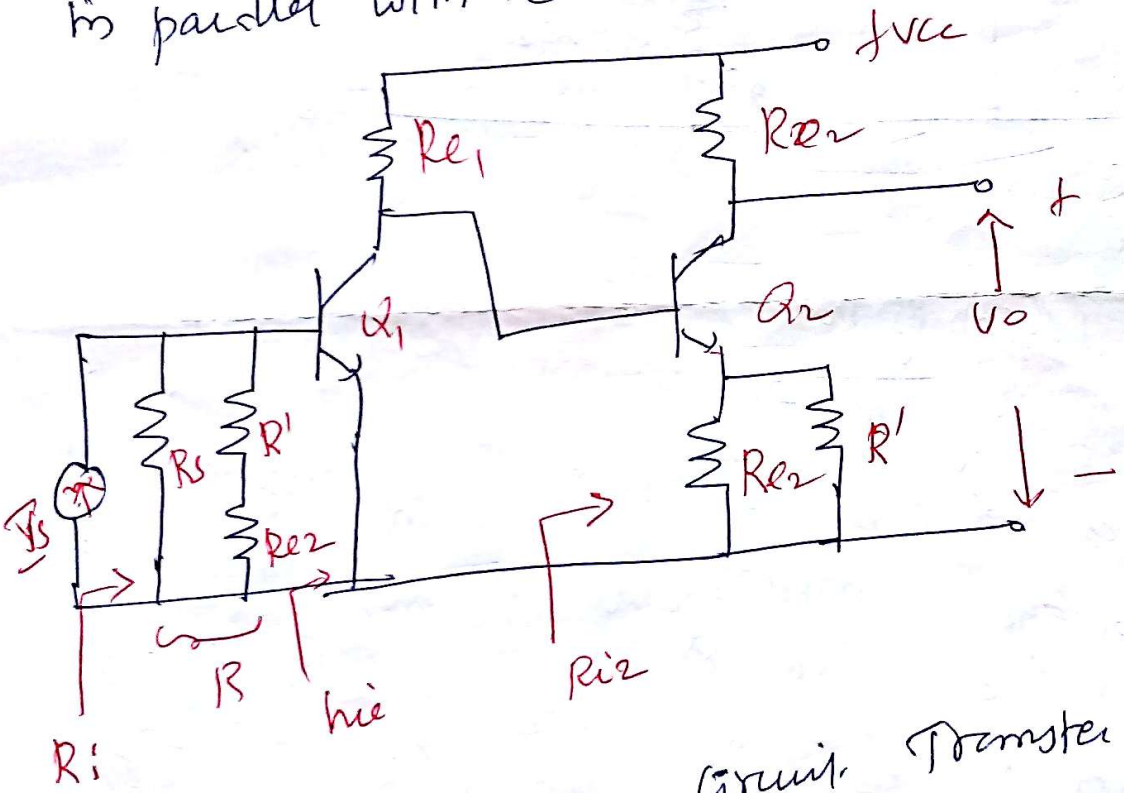
I/p signal V_i without feedback is V_o

∴ with $V_i = V_s$

$$G_M = \frac{-h_{fe} I_b}{V_s} = \frac{-h_{fe} I_b}{I_b (R_s + h_{ie} + R_e)}$$

Step 2 & Step:3 Find the I/p and o/p ckt.

The input ckt of the amp without feedback is obtained by opening the output loop at the emitter of Q_2 ($I_o = 0$). This places R' in series with R_e from base to emitter of Q_1. The o/p ckt is formed by shorting the I/p node (the base of Q_1). ie making $V_i = 0$. This places R' in parallel with R_e'.



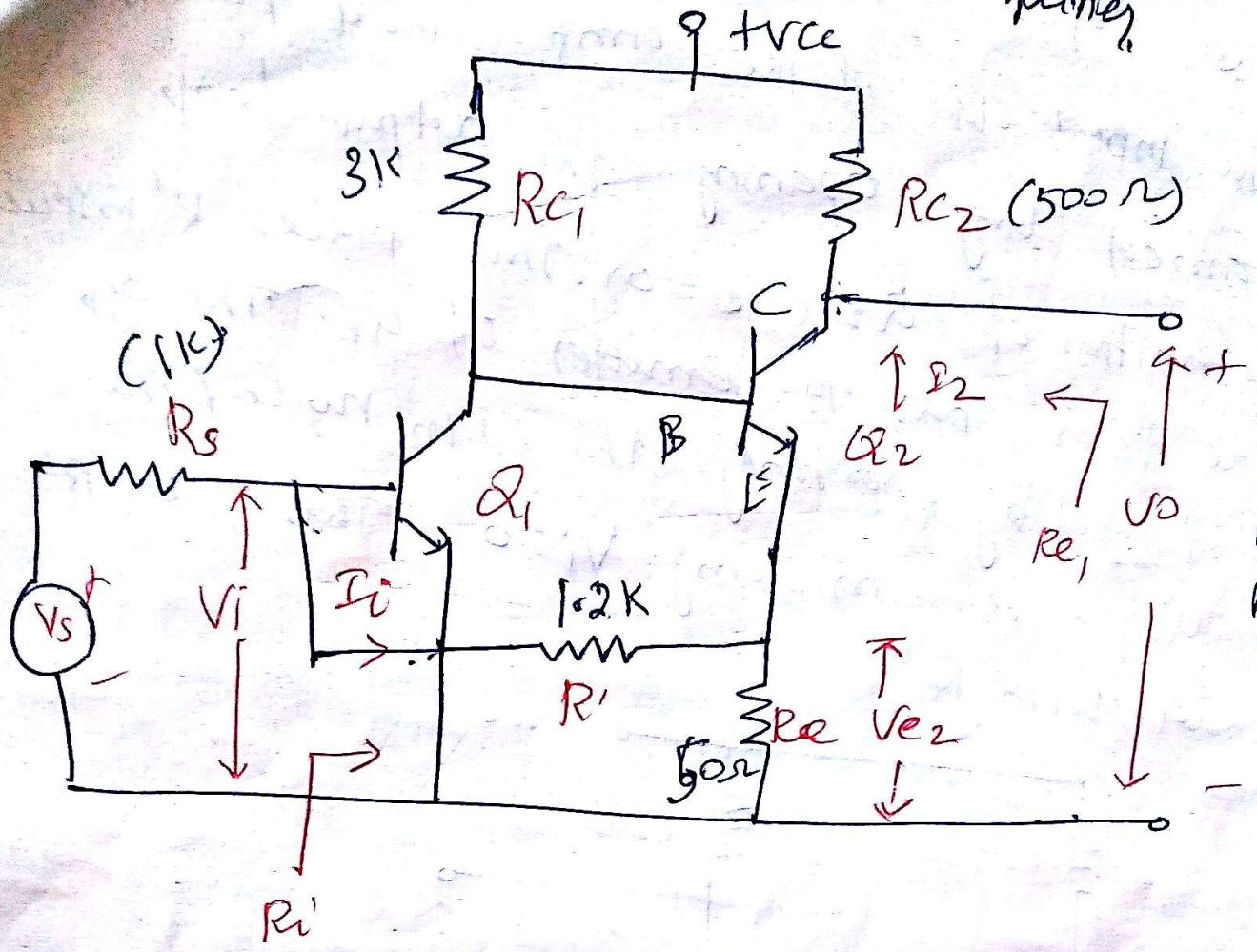
Step:4 Find the open Circuit Transfer Gain

$$A_I = \frac{-I_{c2}}{I_s} = \frac{-I_{c2}}{I_{b2}} \cdot \frac{I_{b2}}{I_{c1}} \cdot \frac{I_{c1}}{I_{b1}} \cdot \frac{I_{b1}}{I_s}$$

WKT $\frac{-I_{c2}}{I_{b2}} = A_{i2} = -h_{ie} = -50$ &

$\frac{-I_{c1}}{I_{b1}} = A_{i1} = -h_{fe} = -50$

Current Shunt feedback Amplifier



Step: 1 Identify the topology.

By sorting the o/p voltage ($V_o = 0$) feedback signal does not becomes zero so hence it is not voltage sampling. By opening the o/p loop ($I_o = 0$). feed back signal becomes zero. So it is current sampling. The feedback signal appears in shunt with input ($I_i = I_s - I_f$) hence the topology is current shunt feedback amplifier

$$\frac{I_{c1}}{I_{b1}} = 50$$

From ~~ग्रि~~ $\frac{I_{b2}}{I_{c1}} = \frac{-R_{e1}}{R_{e1} + R_{i2}}$

where $R_{i2} = h_{ie} + (1+h_{fe})(R_{e2} \| R')$

$$R_{i2} = 1.1 + (1+50) \cdot \left(\frac{50 \times 1.2k}{50 + 1.2k} \right)$$

$$R_{i2} = 3.55k.$$

$$\frac{I_{b2}}{I_{c1}} = \frac{-3k}{3k + 3.55k} = -0.457$$

$$\frac{I_{b1}}{I_s} = \frac{R}{R + h_{ie}} =$$

where $R = R_s \| (R' + R_e) = \frac{1.2k \times 1.25k}{1.2k + 1.25k}$

$$R = 0.612k$$

$$\therefore \frac{I_{b1}}{I_s} = \frac{0.612k}{0.612 + 1.1k} = 0.358$$

$$A_1 = (-50)(-0.457)(50)(0.358)$$

$$A_1 = 40b.$$

Step: 5 Calculate β

$$I_f = \frac{-I_e R_{e2}}{R_{e2}+R'} \qquad [\because I_e = I_c]$$

$$I_f = \frac{I_o R_{e2}}{R_{e2}+R'}$$

$$\beta = I_f / I_o = \frac{R_{e2}}{R_{e2}+R'} = \frac{50}{50+12k} = 0.04$$

Step: 6 Calculate $D, R_i, R_{if}, A_{if}, A_{vf} \& R_{of}$

$$D = 1+\beta A_I = 1+(0.04)\,406$$

$$D = 17.2$$

$$A_{if} = \frac{A_i}{1+\beta A_I} = \frac{406}{17.2} = 23.6$$

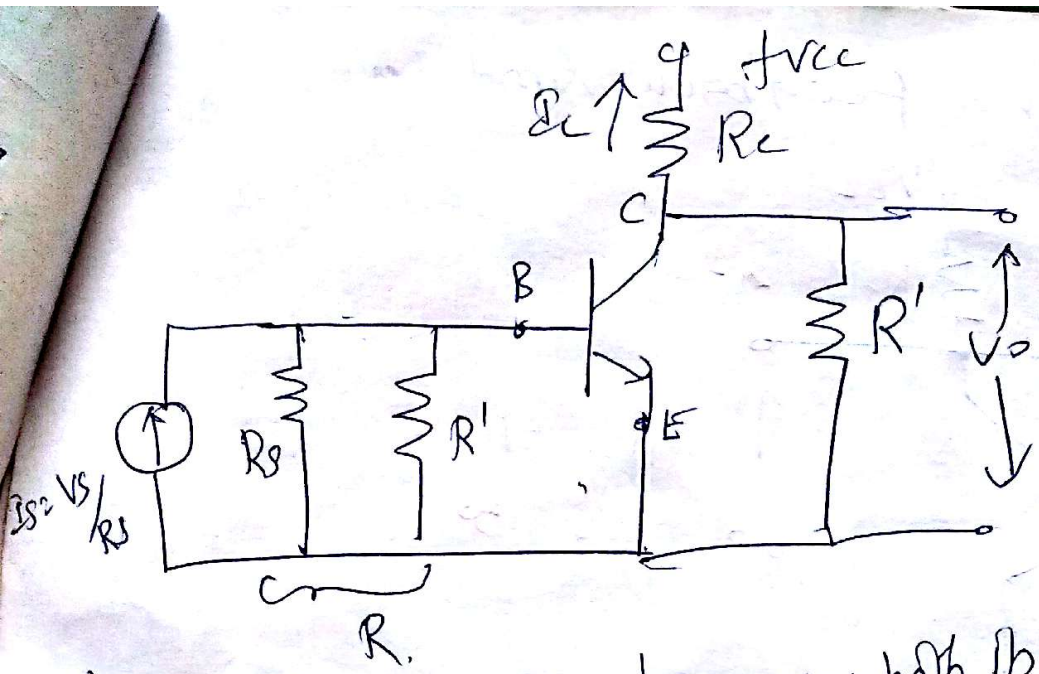
$$R_i = R \,||\, h_{ie} = \frac{0.612k \times 1.1k}{0.612k + 1.1k} = 0.394k$$

$$R_{if} = \frac{R_i}{D} = \frac{0.394k}{17.2} = 23\Omega$$

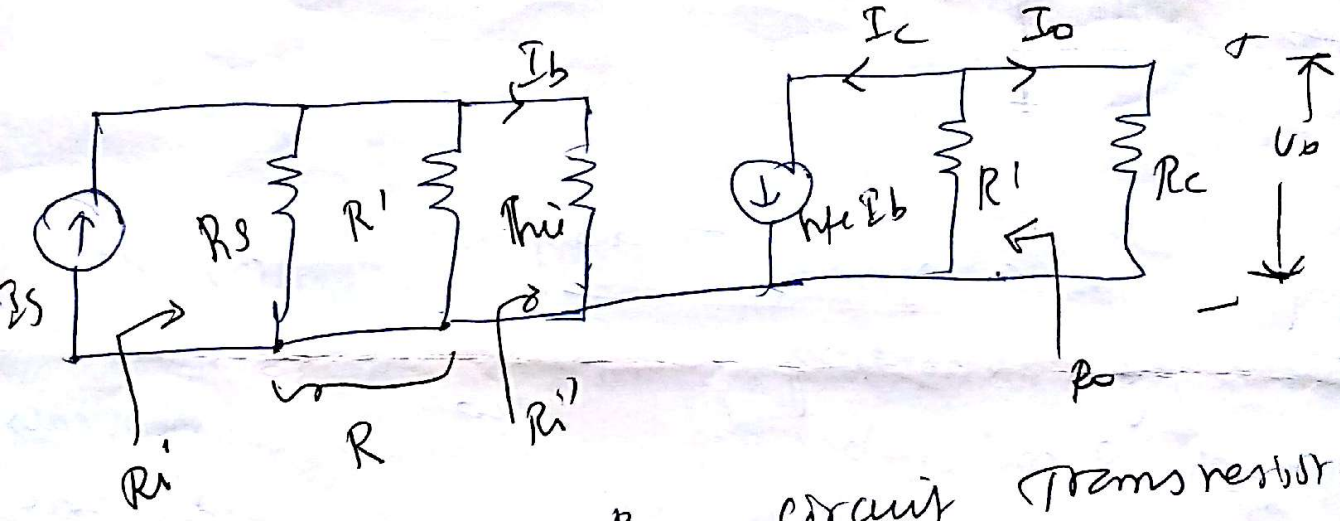
$$R_o = \infty, \quad \because h_{oe} = 0$$

$$R_{of} = R_o D = \infty$$

$$R'_{of} = R'_o \frac{1+\beta A_i}{1+\beta A_I} = 500\Omega$$



Step: 4 Replace the transistor with its equivalent h-parameter



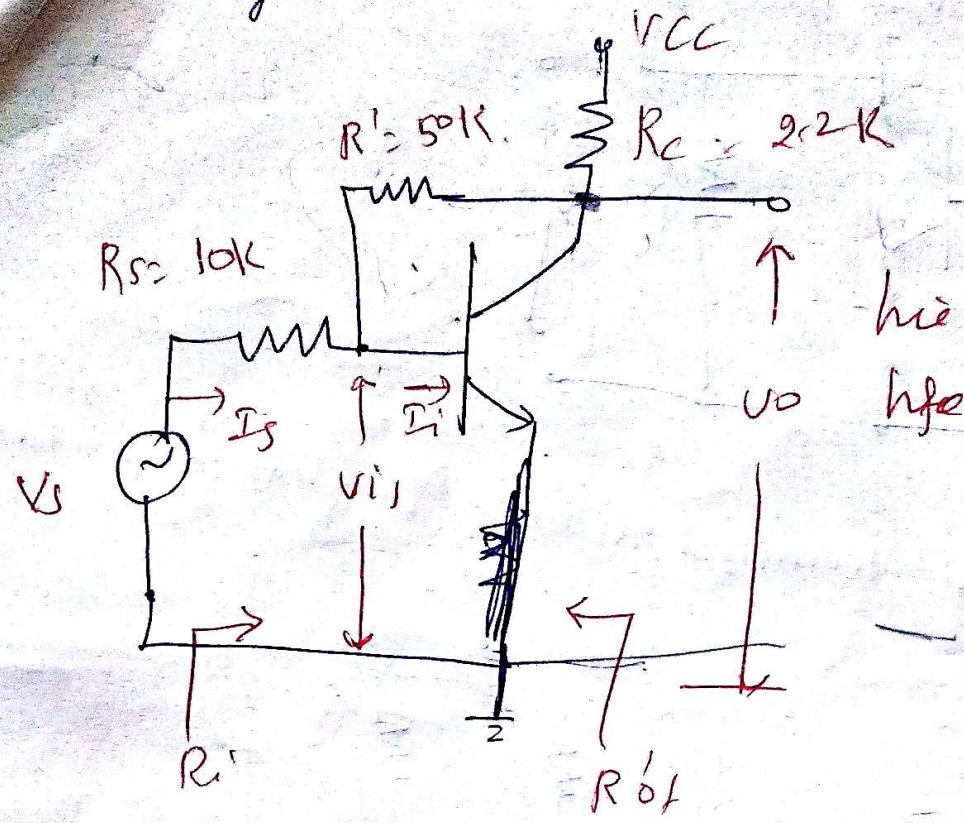
Step: 5 Find the open circuit transresistance

$$R_M = \frac{V_o}{I_s} = \frac{I_o R_c}{I_s}$$

$$\frac{I_o}{I_s} = \frac{I_o}{I_c} \times \frac{I_c}{I_b} \times \frac{I_b}{I_s}$$

$$\frac{I_o}{I_c} = \frac{-R'}{R' + R_c} = -0.895$$

Voltage shunt feedback Amplifier



Step: 1 Identify the topology

By shorting the output voltage, the feedback signal becomes zero. So it is Voltage sampling. The feedback signal appears in shunt. So it is Voltage shunt feedback amplifier.

Step 2, find the input & output circuit.

To find the i/p, we short the o/p. So Resistance R' is in ||el with Rs. ||el, to find the o/p, open the i/p. (Apply Norton's theorem). So R' appears in the o/p side.

$$\frac{I_b}{I_s} = \frac{R}{R + h_{ie}} =$$ where $R = R_s \| R' = 10 \| 4K = 8 \cdot K.$

$$I_b / I_s = 0.879$$

$$\therefore R_M = -184.87K$$ $\because V_o \gg V_i$

Step: 6 Calculate β.

$$I_f = \frac{V_i - V_o}{R'} = \frac{-V_o}{R'}$$

$$\beta = \frac{I_f}{V_o} = \frac{-1}{R'} = \frac{-1}{40K} = -2.5 \times 10^{-5}$$

Step: 7 Calculate D, R_{Mf}, A_{vf}, R_{if}, R_{of} & R'_{of}

$$D = 1 + \beta R_M = 5.62$$

$$R_{Mf} = R_M / D = -32.89K$$

$$A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{I_s R_s} = \frac{R_{mf}}{R_s} = \frac{-32.89K}{10K} = -3.289.$$

$$R_i = R \| h_{ie} = \frac{R h_{ie}}{R + h_{ie}} = \frac{8K \times 1.1K}{8K + 1.1K} = 0.967K.$$

$$R_{if} = \frac{R_i}{D} = 172\Omega$$

$$R_{of} = \frac{R_o}{1 + \beta R_m} =$$ where $R_m = \lim_{R_c \to \infty} R_M$

$$\therefore R_m = \frac{V_o}{I_s} \Big/ R_c \to \infty$$

where $V_o = I_o \times R'$

$[\because R_o = -\infty]$

$$R_m = \frac{I_o R'}{I_s} = \frac{I_o}{I_c} \times \frac{I_c}{I_b} \times \frac{I_b}{I_s} \times R'$$

Since $R_c \to \infty$; $I_o = -I_c$; $\therefore \frac{I_o}{I_c} = 1$

Sub the values of I_c/I_b & $\frac{I_b}{I_s}$, we have

$$R_m = -1 \times 50 \times 0.879 \times 40 \times 10^3 = -1758\,k$$

$$1+\beta R_m = 44.95$$

$$R_{of} = \frac{R_o}{1+\beta R_m} = 889.88\,\Omega$$

$$R'_{of} = R_{of} \parallel R_c = 748.2\,\Omega$$

Simple way to calculate R'_{of}

$$R'_o = R' \parallel R_c = 4.2\,k$$

$$R'_{of} = R'_o/D = 748.36\,\Omega$$

5/2/16

HOD/ECE

Unit - III - Oscillators

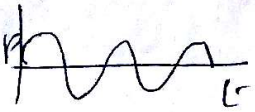
Oscillators.

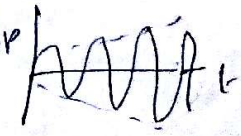
It is a circuit which basically act as a generator, generate the o/p signal which oscillates with constant amplitude and constant desired frequency. positive feedback applied to the circuit to get oscillation

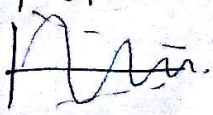
Barkhausen Criterion:

① The total phase shift around a loop, is 0° (or) 360°

② $|A\beta| = 1$ ie The magnitude of product of the open loop gains of the Amplifier (A) and the feedback factor β is unity.

$|A\beta| = 1$ 

$|A\beta| > 1$ 

$|A\beta| < 1$ 

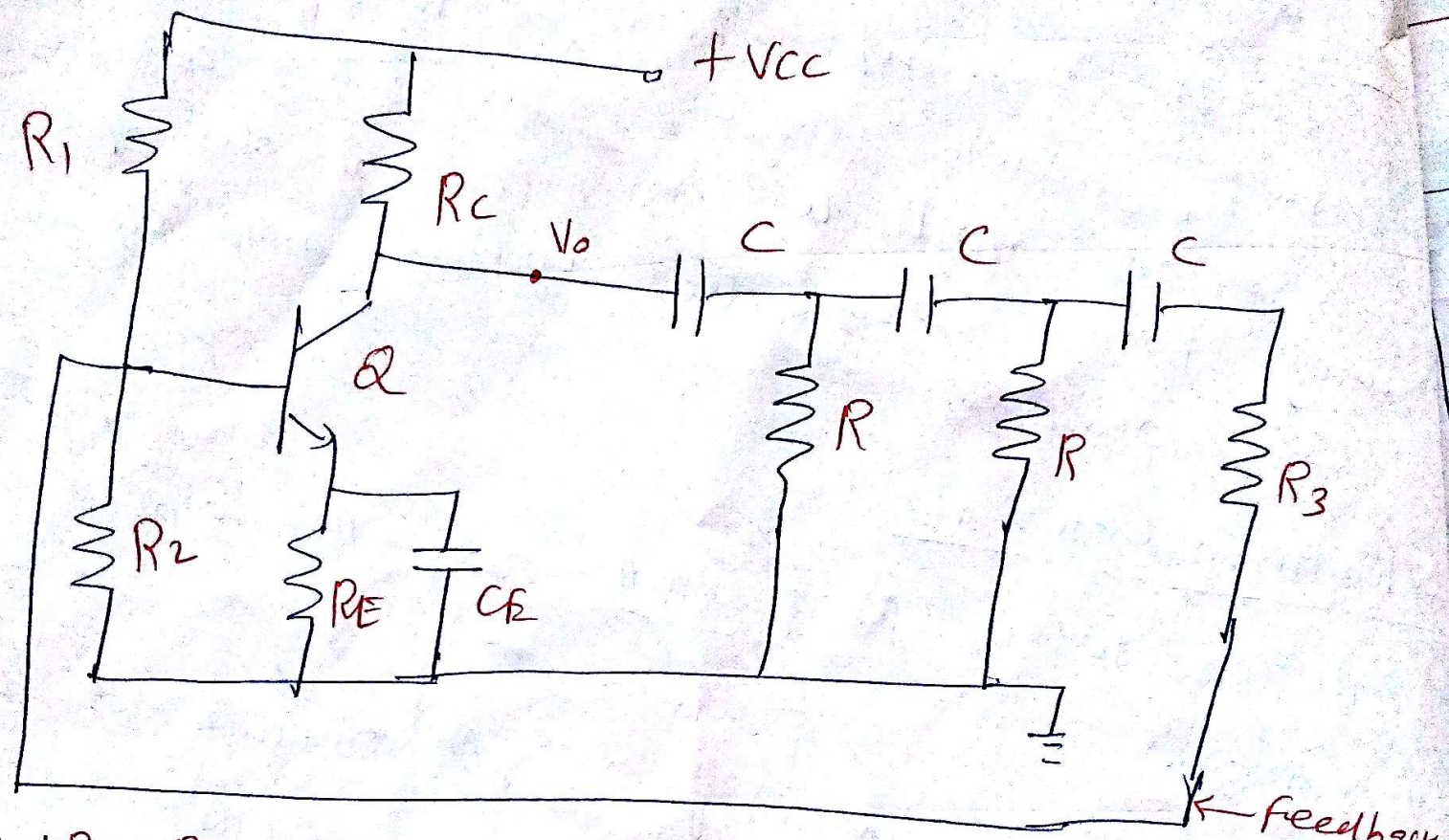
Classification of oscillators.

Based on

- O/p waveform
  - Sinusoidal
  - Non sinusoidal.
- Circuit Components
  - RC
  - LC
  - Crystal
- operating frequency
  - LF
  - HF
  - RF
- Whether feedback used or not
  - Feedback
    - all type
  - No FB
    - UJT Relaxation osc

Transistorised.

RC Phase Shift Oscillator



hie + R3 = R.

Derivation for the frequency of oscillations

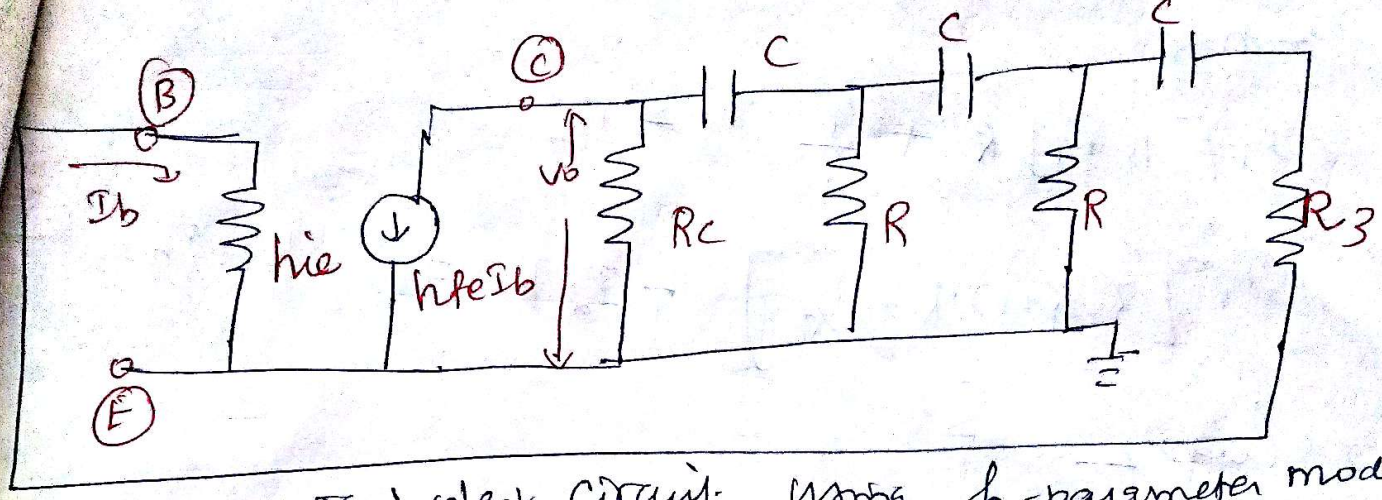


Fig: Equivalent circuit using h-parameter model.

Replace Re + hie as R [hie + R_3 = R]

|||ly replace the current source $h_{fe}I_b$ by its equivalent voltage source. So assume the ratio of the resistance Rc to R, be K.

$$K = R_c / R.$$

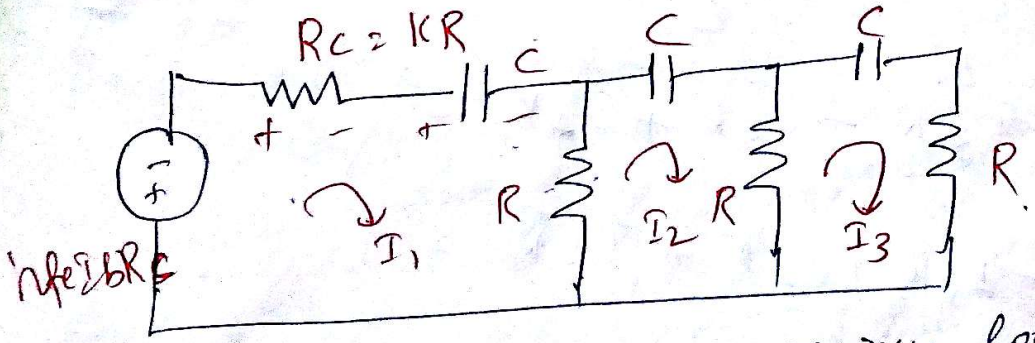


Fig: 3. Modified Equivalent circuit

Apply KVL for the various loops.

For Loop1

$$-I_1R_c - \frac{1}{j\omega C}I_1 - I_1R - h_{fe}I_bR_c + I_2R = 0$$

Replace Rc by KR & jω by s, we get

$$-h_{fe} I_b R_c = I_1 KR + \frac{1}{sC} I_1 + I_1 R + I_2 R.$$

$-h_{fe}$

$$I_1 [K+1] R + \frac{1}{sC} I_1 - I_2 R$$

$$I_1 \left[(K+1) \cdot R + 1/sC \right] - I_2 R = -h_{fe} I_b R_c$$

For loop:2

$$-\frac{1}{j\omega C} I_2 - I_2 R + I_3 R - I_2 R + I_1 R = 0$$

$$-I_1 R + \frac{1}{sC} I_2 + I_2 R - I_3 R + I_2 R = 0$$

$$I_2 \left[2R + 1/sC \right] - I_1 R - I_3 R = 0 \longrightarrow (2)$$

For loop:3

$$-\frac{1}{j\omega C} I_3 - I_3 R - I_3 R + I_2 R = 0$$

$$\frac{1}{sC} I_3 + I_3 R + I_3 R - I_2 R = 0$$

$$-I_2 R + I_3 \left[2R + 1/sC \right] = 0 \longrightarrow (3)$$

ing Cramer's Rule

$$D = \begin{bmatrix} (K+1)R + 1/sC & -R & 0 \\ -R & 2R + 1/sC & -R \\ 0 & -R & 2R + 1/sC \end{bmatrix}$$

$$D = (K+1)R + 1/sC \left[\left[2R + 1/sC \right]^2 - R^2 \right] - R \left[-R \left[2R + 1/sC \right] - 0 \right] + 0$$

$$D = \frac{[sRC[K+1]+1][2sCR+1]^2}{s^3C^3} - \frac{R^2(2sCR+1)}{sC} - \frac{R^2[(K+1)sRC+1]}{sC}$$

$$D = \frac{s^3C^3R^3[4K+4] + s^2C^2R^2[4K+8] + sRC[5+K] + 1 - [2R^2 + 3sR^3C + KsR^3C]s^2C^2}{s^3C^3}$$

$$\boxed{D = \frac{s^3C^3R^3[3K+1] + s^2C^2R^2[4K+6] + sRC[5+K] + 1}{s^3R^3}}$$

Now $D_3 = \begin{bmatrix} (K+1)R + 1/sC & -R & -h_{fe} \\ -R & [2R + 1/sC] & 0 \\ 0 & -R & 0 \end{bmatrix}$

$$D_3 = -R^2(h_{fe} I_b KR) = -KR^3 h_{fe} I_b$$

$$I_3 = \frac{D_3}{D} = \frac{-KR^3 h_{fe} I_b \times s^3c^3}{s^3c^3R^3(3K+1)+s^2c^2R^2[4K+6]+scR[5+K]+1}$$

$$I_3 = \frac{-K h_{fe} I_b s^3R^3c^3}{s^3c^3R^3(3K+1)+s^2c^2R^2(4K+6)+scR(5+K]+1}$$

where I_3 = O/p ct of FB ckt.

I_b = I/p ct of the Amp

$I_c = h_{fe} I_b$ = I/p ct of the feedback ckt

$$\beta = \frac{\text{O/p of FB}}{\text{I/p of FB}} = \frac{I_3}{I_c} = \frac{I_3}{h_{fe} I_b}$$

$$A = \frac{\text{O/p of Amp}}{\text{I/p of Amp}} = \frac{I_c}{I_b} = \frac{h_{fe} I_b}{I_b} = h_{fe}$$

$$A\beta = \frac{I_3}{h_{fe} I_b} \times h_{fe} = \frac{I_3}{I_b}$$

$$A\beta = \frac{I_3}{I_b} = \frac{-K h_{fe} \cancel{I_b} s^3R^3c^3}{\cancel{I_b}\left[s^3c^3R^3[3K+1)+s^2c^2R^2(4K+6)+scR(5+K)+1\right]}$$

hfe Sub $j = \omega$ $s = j\omega$; $s^2 = -\omega^2$; $s^3 = -j\omega^3$

SCR [5

$$A\beta = \frac{+K\, h_{fe}\, j\omega^3 R^3 C^3}{-j\omega^3 C^3 R^3 (3K+1) - \omega^2 C^2 R^2 (4K+6) + j\omega CR (5+K) + 1}$$

$$= \frac{j K h_{fe} \omega^3 C^3 R^3}{[1 - 4K\omega^2 C^2 R^2 - 6\omega^2 C^2 R^2] - j\omega [3K\omega^2 C^3 R^3 + \omega^2 C^3 R^3 + 5RC + KRC]}$$

$\div$ Nr & Dr by $j\omega^3 R^3 C^3$ [Replace $-1/j = j$]

$$A\beta = \frac{K h_{fe}}{\frac{1 - 4K\omega^2 R^3 C^3 - 6\omega^2 C^2 R^2}{j\omega^3 R^3 C^3} - \frac{j\omega [3K\omega^2 C^3 R^3 + \omega^2 R^3 C^3 + 5RC + KRC]}{j\omega^3 R^3 C^3}}$$

$$A\beta = \frac{K h_{fe}}{-j\left\{\frac{1}{\omega^3 C^3 R^3} - \frac{4K}{\omega RC} - \frac{6}{\omega RC}\right\} - \left[3K + 1 - \frac{5}{\omega^2 R^2 C^2} - \frac{K}{\omega^2 C^2 R^2}\right]}$$

Replace $\frac{1}{\omega RC} = \alpha$ for simplicity.

$$\boxed{A\beta = \frac{K h_{fe}}{[-3K - 1 + 5\alpha^2 + K\alpha^2] - j(\alpha^3 - 4K\alpha - 6\alpha)}}$$

As per Barkhausen Criterion, $\angle A\beta = 0°$

Imaginary part must be equal to zero

$$\alpha^3 - 4K\alpha - 6\alpha = 0$$

$$\alpha\left[\alpha^2 - 4K - 6\right] = 0$$

$$\alpha^2 = 4K + 6$$

$$\alpha = \sqrt{4K+6}$$

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

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

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

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

As per Barkhausen Criterion, $|A\beta| = 1$

Sub $\alpha = \sqrt{4K+6}$

$$A\beta = \frac{K h_{fe}}{-3K - 1 + (4K+6)(5+K)} = \frac{K h_{fe}}{-3K - 1 + 20K + 30 + 4K^2 + 6K}$$

$$A\beta = \frac{K h_{fe}}{4K^2 + 23K + 29} = 1$$

$$\left.\frac{K h_{fe}}{4K^2+23K+29}\right| = 1$$

$$K h_{fe} = 4K^2+23K+29$$

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

This must be the value of h_{fe} for the oscillations.

Minimum Value of h_{fe} for the oscillations

To get minimum value of h_{fe}.

$$\boxed{\frac{dh_{fe}}{dK} = 0}$$

$$4 - \frac{29}{K^2} = 0 \Rightarrow 4 = 29/K^2$$

$$K^2 = 29/4$$

$$\boxed{K = 2.6925}$$ for minimum h_{fe}.

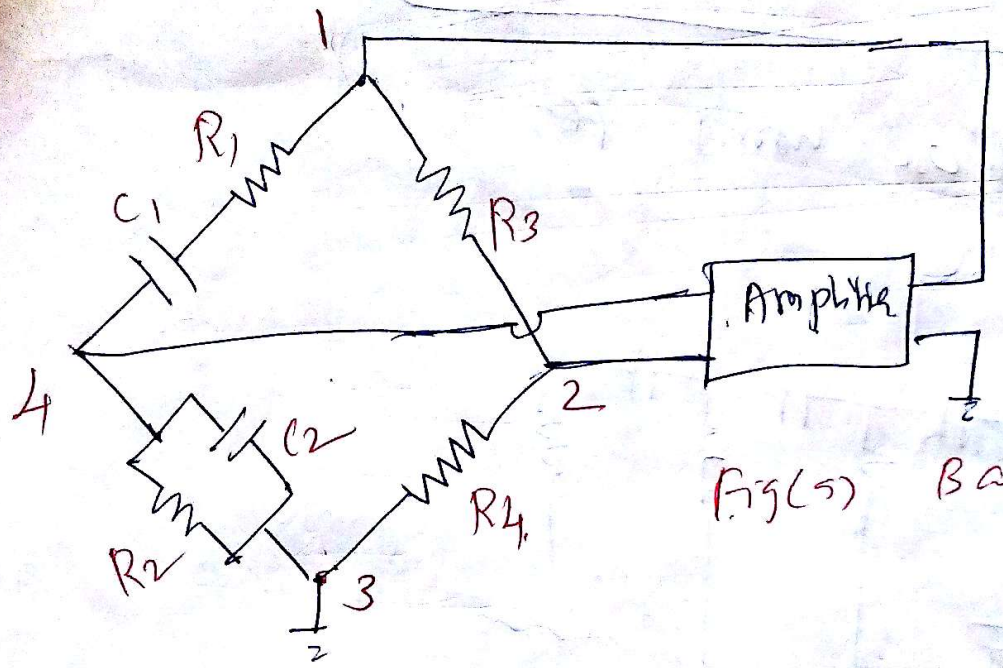
$$h_{fe} = 4K + 23 + 29/K = 44.54$$

$$\boxed{h_{fe} = 44.54}$$

Thus for the circuit to oscillate, must select the transistor whose (h_{fe}) min should be greater than 44.54.

Wein Bridge Oscillator (or) Zero phase shift osc (or) Lead - Lag osc.

To maintain Barkhausen criterion principle, the overall phase shift around the loop is 0° (or) 360°. Here Non-inverting Amplifier is applied & hence does not provide any phase shift.



Fig(5) Basic circuit.

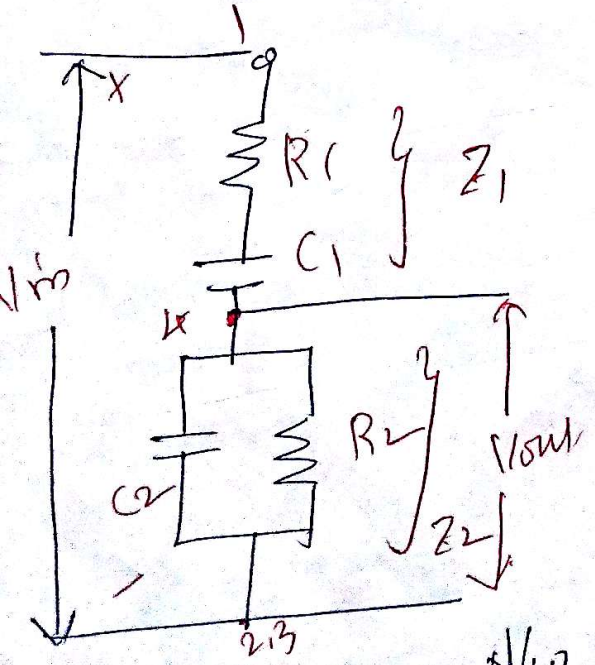
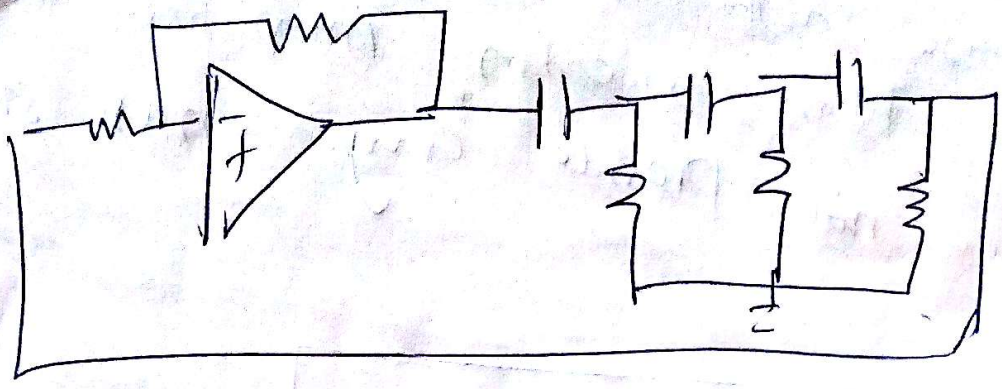


Fig: Feedback N/w

R_1C_1 - series } Freq sensitive arms
R_2C_2 - parallel

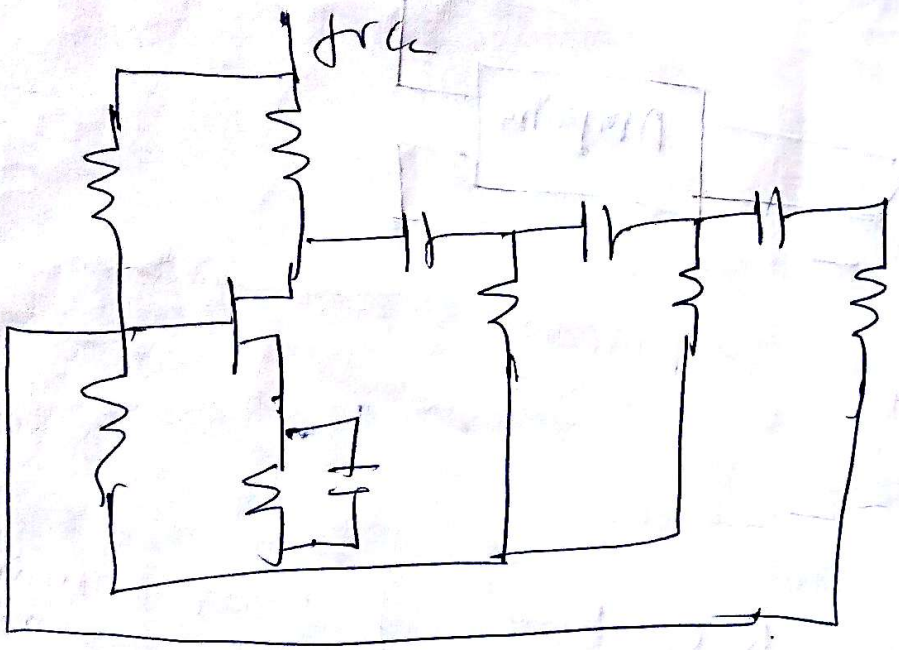
For very low freq - lead N/w
For very high freq - Lag N/w

RC phase shift osc using op-amp



$f = \frac{1}{2\pi RC\sqrt{6}}$

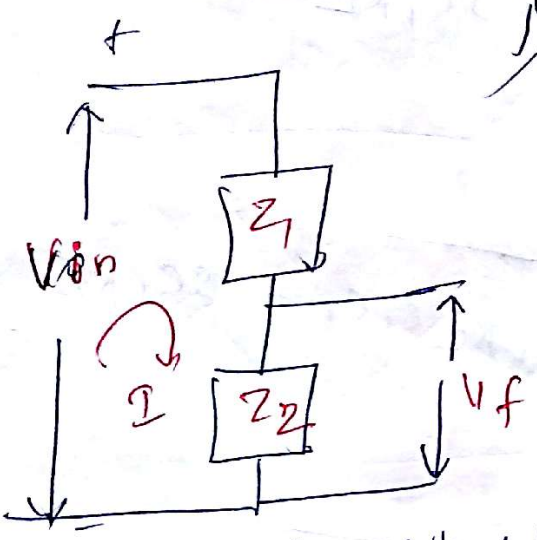
RC phase shift osc using FET



$$Z_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1 + j\omega C_1 R_1}{j\omega C_1}$$

$$Z_2 = R_2 \,||\, \frac{1}{j\omega C_2} = \frac{R_2 \times 1/j\omega C_2}{R_2 + 1/j\omega C_2}$$

$$= \frac{R_2 / j\omega C_2}{\frac{j R_2 \omega C_2 + 1}{j\omega C_2}} = \frac{R_2}{1 + j\omega C_2 R_2}$$



Fig(3) Simplified Circuit

Replacing $j\omega = s$.

$$Z_1 = \frac{1 + sR_1C_1}{sC_1}$$

$$Z_2 = \frac{R_2}{1 + sC_2R_2}$$

$$I = \frac{V_{in}}{Z_1 + Z_2} \quad \& \quad V_f = I \cdot Z_2$$

$$V_f = \frac{V_{in}}{Z_1 + Z_2} \cdot Z_2$$

$$\boxed{\beta = \frac{V_f}{V_{in}}} = \frac{V_{in} Z_2}{(Z_1 + Z_2) V_{in}} = \frac{Z_2}{Z_1 + Z_2}$$

Sub the value of Z_1 & Z_2

$$\beta = \frac{\dfrac{R_2}{1+sR_2C_2}}{\dfrac{1+sC_1R_1}{sC_1} + \dfrac{R_2}{1+sR_2C_2}}$$

$$\beta = \frac{sC_1R_2}{(1+sC_1R_1)(1+sR_2C_2) + sC_1R_2}$$

$$\beta = \frac{sC_1R_2}{1+s(R_1C_1+R_2C_2)+s^2R_1R_2C_1C_2 + sC_1R_2}$$

$$\beta = \frac{sC_1R_2}{1+s(R_1C_1+R_2C_2+C_1R_2)+s^2R_1R_2C_1C_2}$$

Replace $s = j\omega$ & $s^2 = -\omega^2$

$$\beta = \frac{j\omega C_1R_2}{(1-\omega^2R_1R_2C_1C_2) + j\omega(R_1C_1+R_2C_2+C_1R_2)}$$

rationalize the expression.

$$\beta = \frac{j\omega C_1 R_2 \left[(1-\omega^2 R_1 R_2 C_1 C_2) - j\omega (R_1 C_1 + R_2 C_2 + C_1 R_2) \right]}{(1-\omega^2 R_1 R_2 C_1 C_2)^2 + \omega^2 (R_1 C_1 + R_2 C_2 + C_1 R_2)^2}$$

$$\beta = \frac{\omega^2 C_1 R_2 (R_1 C_1 + R_2 C_2 + C_1 R_2) + j\omega C_1 R_2 (1-\omega^2 R_1 R_2 C_1 C_2)}{(1-\omega^2 R_1 R_2 C_1 C_2)^2 + \omega^2 (R_1 C_1 + R_2 C_2 + C_1 R_2)^2}$$

To have zero phase shift of the feedback network, its imaginary part must be zero.

$$\omega (1 - \omega^2 R_1 R_2 C_1 C_2) = 0$$

[If $R_1 = R_2 = R$, $C_1 = C_2 = C$]

$$\omega^2 = \frac{1}{R_1 R_2 C_1 C_2}$$

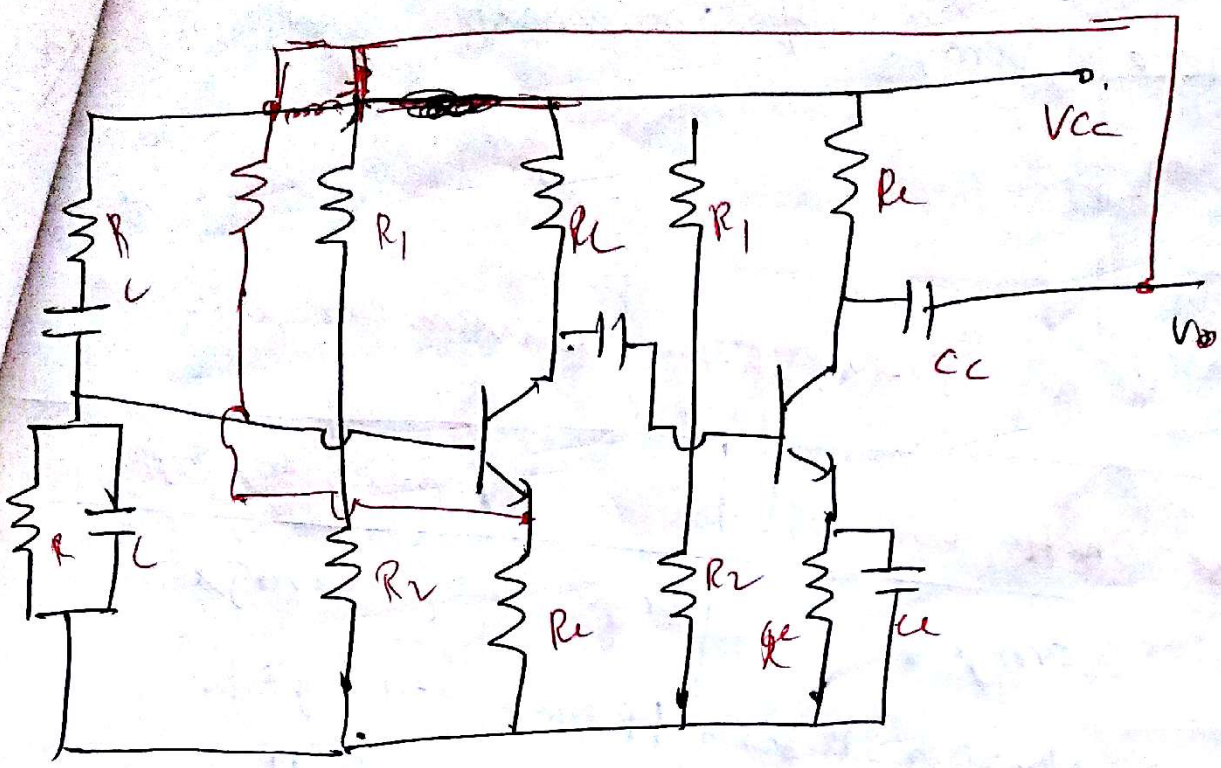
$$\omega^2 = \frac{1}{R^2 C^2}$$

$$\omega = \frac{1}{RC}$$

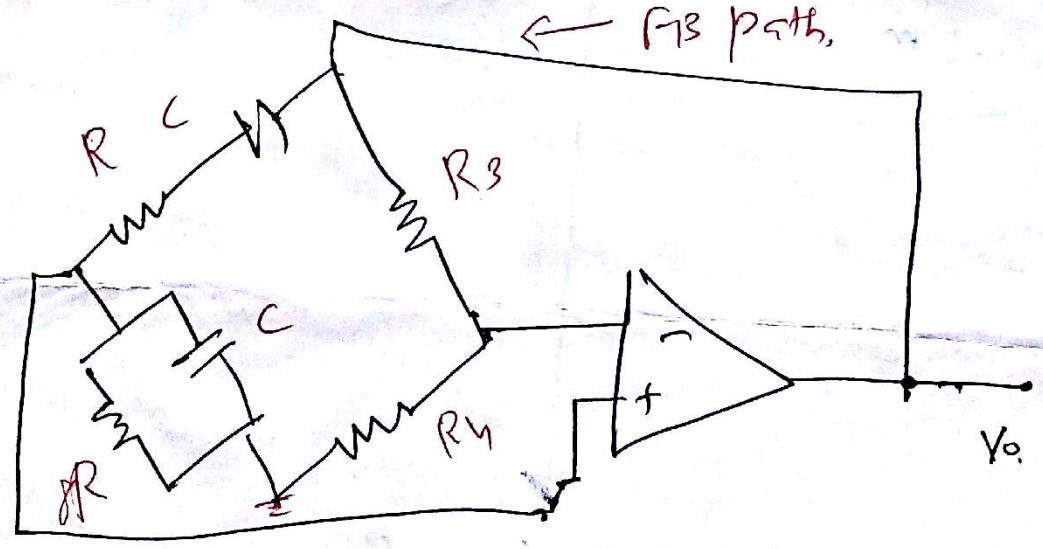
$$\boxed{f = \frac{1}{2\pi RC}.}$$

Transistorized Wein Bridge OSC.

(using FET
Replace
Trans
FET



Wein Bridge osc using op-amp.



Adv

- Freq can be varied as per our requirement.
- Gain high.
- stability high
- Low distortion
- Freq Range can be selected by using decade resistors

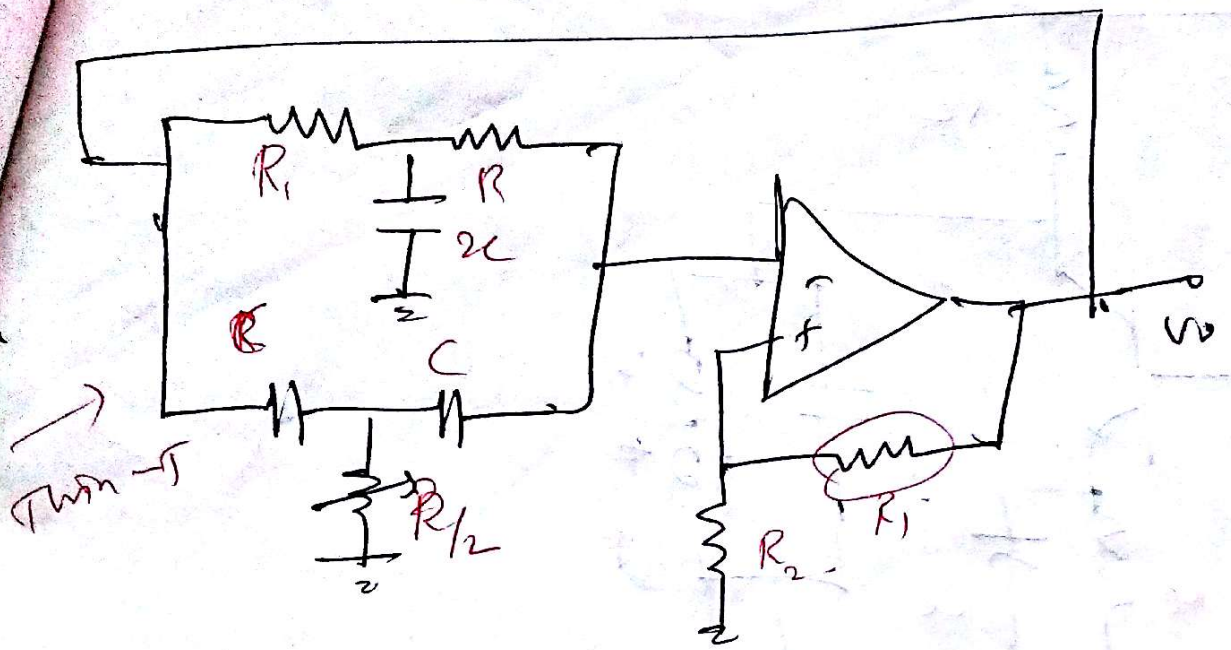
Dis Adv

1. High freq generation is not possible
2. Need More number of components.
3.

Comparison of RC phase shift & wein bridge osc.

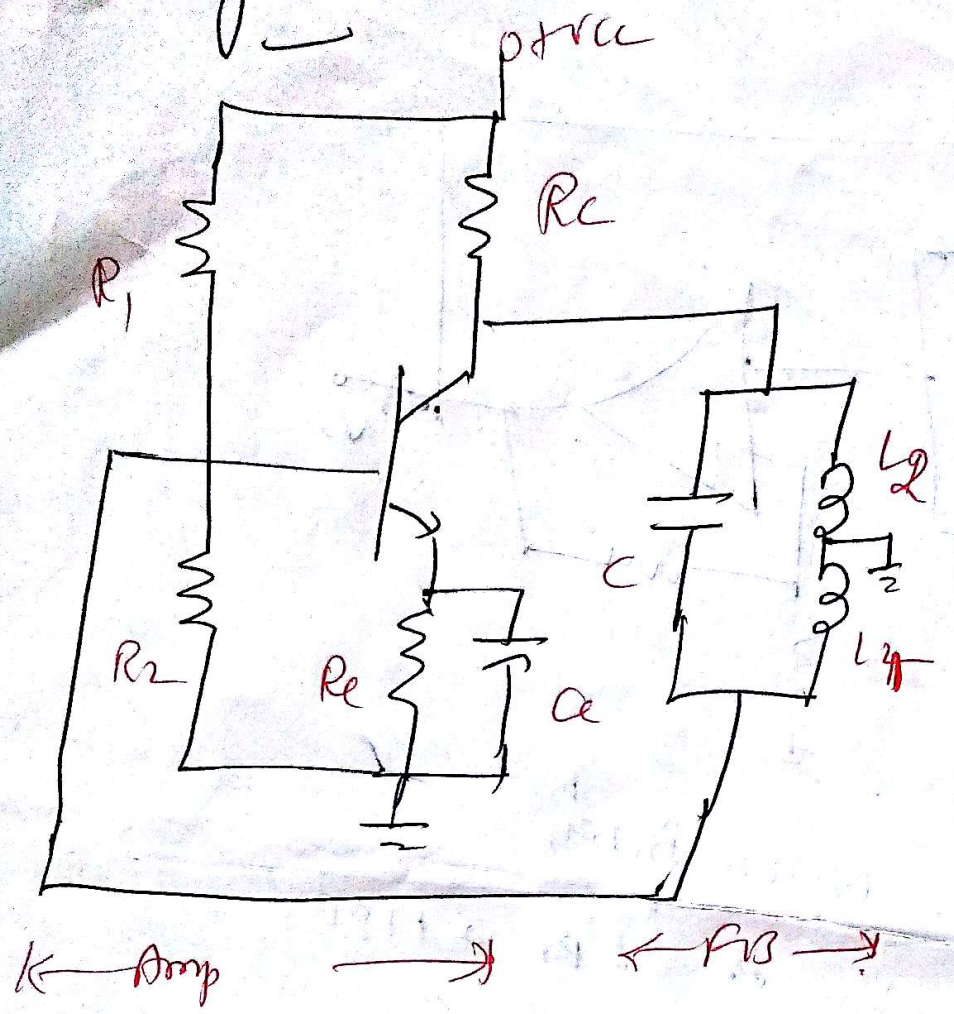
RC phase shift osc	Wein Bridge osc.
1. Low freq range	Low freq range
2. FB N/W is RC N/W with 3 RC section	FB N/W is Lead-lag N/W
3. FB N/W introduce 180° phase shift	No phase shift
4. Op-amp is used in	

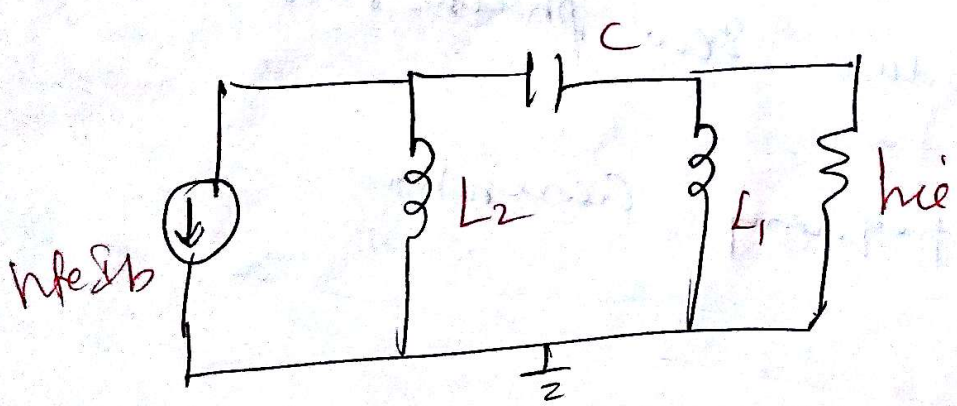
Twin-T Oscillator

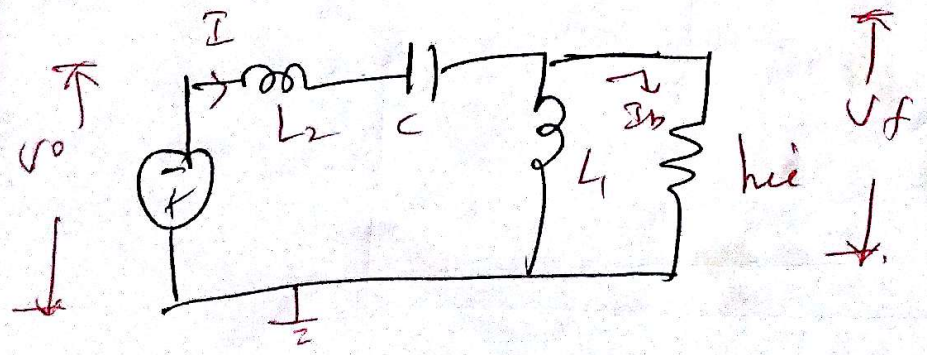


- Other Name - Notch filter
- It is a combination of LPF & HPF.
- It can produce zero phase shift during $f = f_r$
- Only one frequency generation
- Rarely used

Hartley osc


+Vcc
Rc
R1
R2
Re
Ce
C
L2
L1
Amp
FB


C
L2
L1
hie
hfeIb


I
L2
C
L1
Ib
hie
Vo
Vf

$$V_o = h_{fe} I_b X_{L_2}$$
$$= h_{fe} I_b \cdot j\omega L_2$$

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

$$X_{L_2} + X_C = j\omega L_2 + \frac{1}{j\omega C} = \frac{j^2\omega^2 L_2 C + 1}{j\omega C}$$

$$X_{L_1} \| h_{ie} = \frac{j\omega L_1 \cdot h_{ie}}{j\omega L_1 + h_{ie}}$$

Replace $j\omega = s$

$$I = \frac{-h_{fe} I_b \cancel{X_{L_2}} s L_2}{\frac{1 + s^2\omega^2 L_2 C}{sC} + \frac{s h_{ie} L_1}{h_{ie} + sL_1}}$$

$$I = \frac{-s^2 h_{fe} I_b L_2 C (sL_1 + h_{ie})}{s^3 L_1 L_2 C + s^2 C h_{ie} (L_1 + L_2) + sL_1 + h_{ie}}$$

According to current division in $\|^{el}$ ckt

$$I_b = I \times \frac{X_{L_1}}{X_{L_1} + h_{ie}}$$

$$\cancel{I_b} = \frac{-s^2 h_{fe} \cancel{I_b} L_2 C \cancel{(sL_1 + h_{ie})}}{s^3 L_1 L_2 C + s^2 C (L_1 + L_2) + sL_1 + h_{ie}} \times \frac{sL_1}{\cancel{sL_1 + h_{ie}}}$$

$$I_b = \frac{-s^3 h_{fe} I_b L_1 L_2 C (sL_1 + h_{ie})}{s^3 L_1 L_2 C + s^2 C (L_1 + L_2) + sL_1 + h_{ie}}$$

$$1 = \frac{-s^3 h_{fe} C L_1 L_2}{s^3 L_1 L_2 C + s^2 C h_{ie} (L_1 + L_2) + s L_1 h_{ie}}$$

Sub $s = j\omega$; $s^2 = -\omega^2$, $s^3 = -j\omega^3$

$$1 = \frac{+ j\omega^3 h_{fe} C L_1 L_2}{-j\omega^3 L_1 L_2 C - \omega^2 C h_{ie} (L_1 + L_2) + j\omega L_1 h_{ie}}$$

$$1 = \frac{j\omega^3 h_{fe} C L_1 L_2}{h_{ie} - \omega^2 C h_{ie} (L_1 + L_2) + j\omega L_1 [1 - \omega^2 L_2 C]}$$

Rationalize the eqn

$$1 = \frac{j\omega^3 h_{fe} C L_1 L_2 \left[h_{ie} - \omega^2 C h_{ie} (L_1 + L_2) - j\omega L_1 (1 - \omega^2 L_2 C) \right]}{\left[h_{ie} - \omega^2 C h_{ie} (L_1 + L_2) \right]^2 + \omega^2 L_1^2 (1 - \omega^2 L_2 C)^2}$$

To satisfy this eqn, imaginary part must be equate to zero.

$$\omega^3 h_{fe} C L_1 L_2 \left[h_{ie} - \omega^2 C h_{ie} (L_1 + L_2) \right] = 0$$

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

$$1 = \omega^2 C (L_1 + L_2)$$

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

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

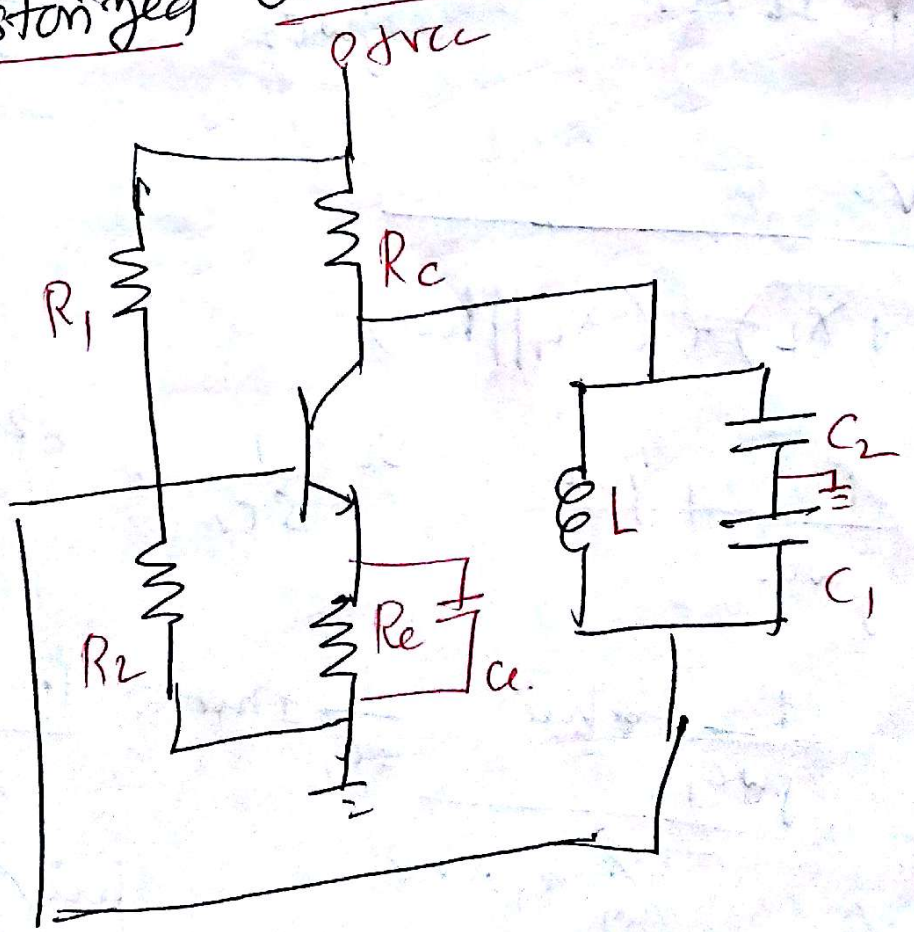
$$2\pi f = \frac{1}{\sqrt{C(L_1+L_2)}}$$

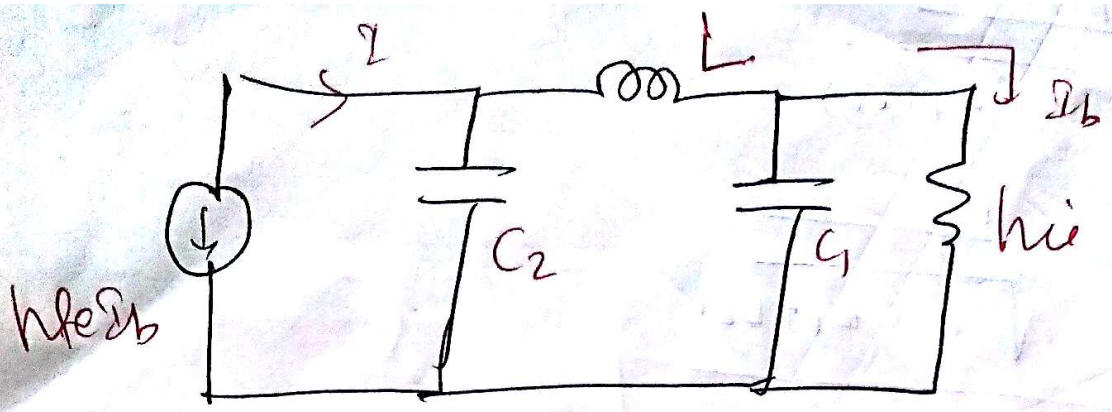
$$\boxed{f = \frac{1}{2\pi\sqrt{C(L_1+L_2)}}}$$

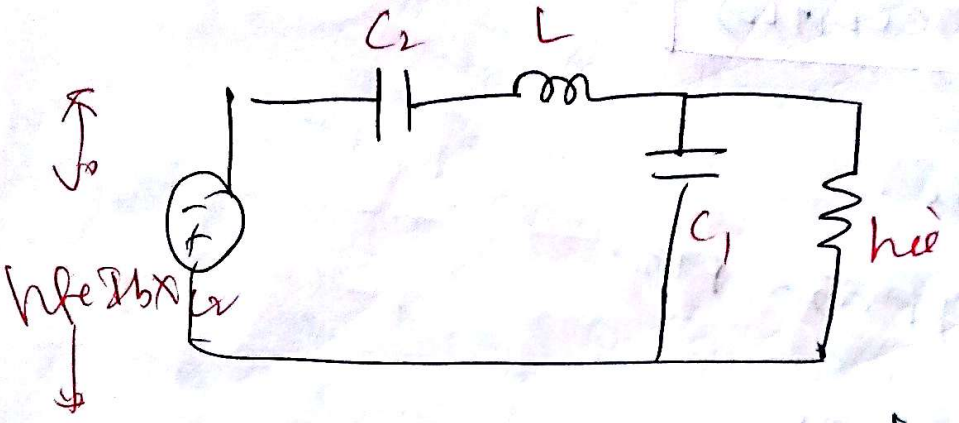
FET Hartley osc.

Replace Tr as a FET.

Transistorized Colpitts osc.







$$V_o = h_{fe} I_b X_{C_2} = \frac{h_{fe} I_b}{j\omega C_2} = \frac{h_{fe} I_b}{sC_2}$$

$$I = \frac{-V_o}{(X_{C_2} + X_L) + (X_{C_1} \| h_{ie})}$$

$$X_{C_2} + X_L = \frac{1}{j\omega C_2} + j\omega L = \frac{sL+1}{sC_2} = \frac{s^2 LC_2 + 1}{sC_2}$$

$$X_{C_1} \| h_{ie} = \frac{\frac{1}{j\omega C_1} \cdot h_{ie}}{1/j\omega C_1 + h_{ie}} = \cancel{\frac{1}{sC_1} \cdot h_{ie} = \frac{1 + h_{ie} sC_1}{sC_1}}$$

$$I = \frac{\frac{h_{fe} I_b}{sC_2}}{\frac{s^2 LC_2 + 1}{sC_2} + \frac{1 + h_{ie} sC_1}{sC_1}} = \frac{h_{ie}/sC_1}{\frac{1 + h_{ie} sC_1}{sC_1}} = \frac{h_{ie}}{1 + h_{ie} sC_1}$$

$$I = \frac{-\dfrac{h_{fe} I_b}{sC_2}}{\dfrac{1+s^2LC_2}{sC_2} + \dfrac{h_{ie}}{1+h_{ie}sC_1}}$$

$$I = \frac{h_{fe} I_b / \cancel{sC_2}}{\dfrac{1+s^2LC_2+h_{ie}sC_1+s^3LC_1C_2h_{ie}+sC_2h_{ie}}{\cancel{sC_2}(1+h_{ie}sC_1)}}$$

$$= \frac{-h_{fe} I_b (1+h_{ie}sC_1)}{s^3LC_1C_2h_{ie}+s^2LC_2+sC_1h_{ie}+1+sC_2h_{ie}}$$

$$\boxed{I = \frac{-h_{fe} I_b (1+h_{ie}sC_1)}{s^3LC_1C_2h_{ie}+s^2LC_2+sh_{ie}(C_1+C_2)+1}}$$

According to current division in the I/p ckt

$$I_b = I \times \frac{X_{C_1}}{X_{C_1}+h_{ie}}$$

$$\frac{X_{C_1}}{X_{C_1}+h_{ie}} = \frac{1/j\omega C_1}{1/j\omega C_1 + h_{ie}} = \frac{\dfrac{1}{sC_1}}{\dfrac{1}{sC_1}+h_{ie}} = \frac{\dfrac{1/\cancel{sC_1}}{\dfrac{1+h_{ie}sC_1}{\cancel{sC_1}}}}{}$$

$$= \frac{1}{1+h_{ie}sC_1}$$

$$\cancel{I_b} = \frac{-h_{fe}\cancel{I_b}(1+s h_{ie} C_1)}{s^3 L C_1 C_2 h_{ie} + s^2 L C_2 + s h_{ie}(C_1+C_2)+1}$$

$$1 = \frac{-h_{fe}}{s^3 L C_1 C_2 h_{ie} + s^2 L C_2 + s h_{ie}(C_1+C_2)+1}$$

Replace $j\omega = s$.

$$1 = \frac{-h_{fe}}{-j\omega^3 L C_1 C_2 h_{ie} - \omega^2 L C_2 + j\omega h_{ie}(C_1+C_2)+1}$$

$$1 = \frac{-h_{fe}}{(1-\omega^2 L C_2) + j\omega h_{ie}(C_1+C_2-\omega^2 L C_1 C_2)}$$

No need to go for Resonance.

when $(C_1+C_2-\omega^2 L C_1 C_2) = 0$

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

$$\omega^2 = \frac{1}{L\frac{C_1 C_2}{C_1+C_2}} = \frac{1}{L(C_1 \| C_2)}$$

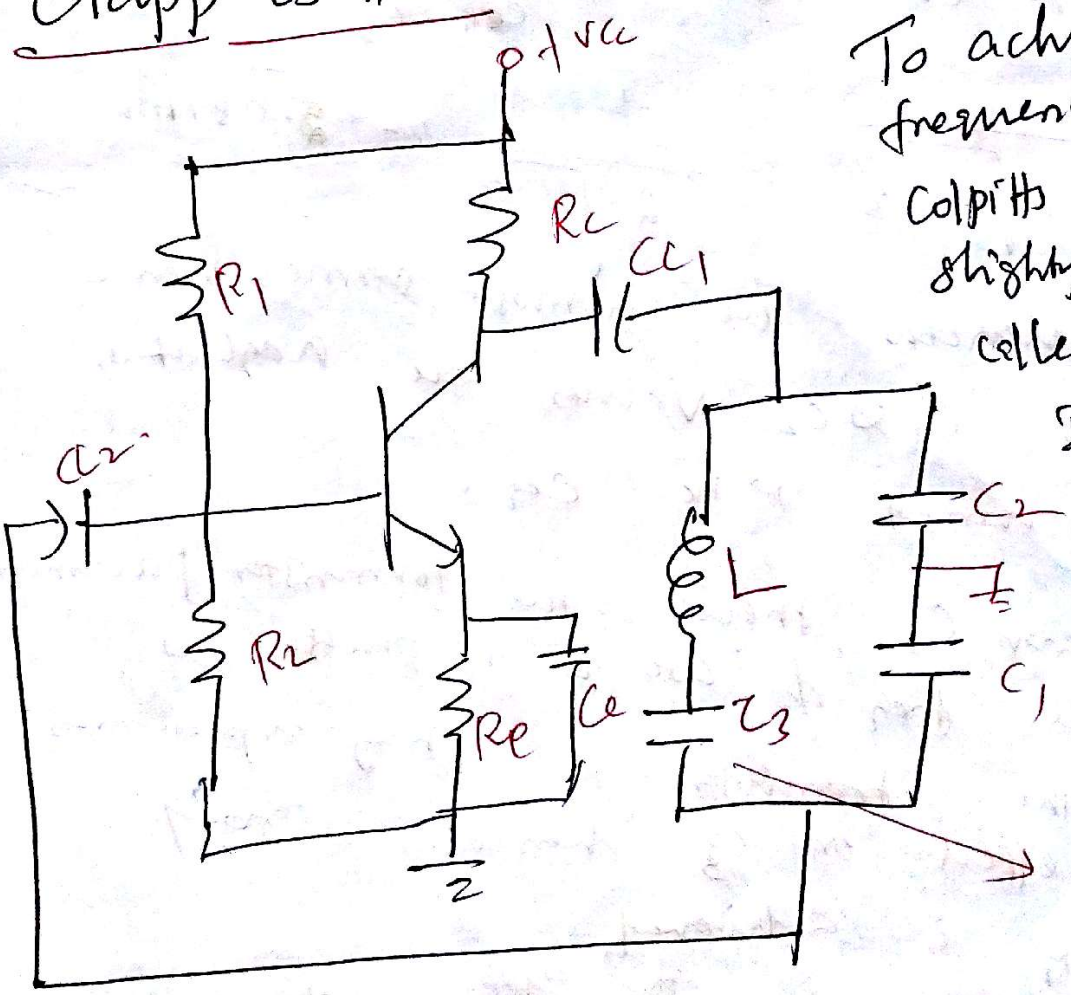
$$\omega = \frac{1}{\sqrt{L(C_1 \| C_2)}}$$

$$2\pi f = \frac{1}{\sqrt{L(C_1 \| C_2)}}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{L(C_1 \| C_2)}}}$$

This is the freq of osc. of colpitts osc

Clapp oscillator



To achieve the frequency stability, colpitts osc circuit is slightly modified is called clapp osc.

In this ckt add one more capacitor in the tank ckt.

This capacitor decides the frequency of oscillation

∴ The value of C_3 is much smaller than C_1 & C_2

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$f = \frac{1}{2\pi\sqrt{L \cdot C_{eq}}}$$

Let $C_1 = C_2 = 0.001\,\mu F$ & $L = 15\,\mu H$ $C_3 = 50\,pF$

$C_{eq} = 4.54 \times 10^{-11}$

$$f = \frac{1}{2\pi\sqrt{L \cdot C_{eq}}} = 6.09 \text{ MHz}.$$

If C_1 & C_2 neglected, then $C_{eq} = C_3$

$C_{eq} = C_3$

$$f = \frac{1}{2\pi\sqrt{L \cdot C_3}} = \frac{1}{2\pi\sqrt{L \cdot C_3}} = 5.83 \text{ MHz}$$

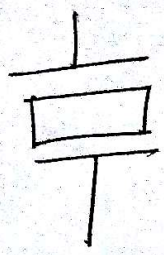
The frequencies are almost same, hence in practice C_1 & C_2 values are neglected, & C_3 assumed to be C_{eq}.

Now across C_3, there is no transistor parameters & hence the freq of osc is stable & accurate. The transistor & stray capacitances have no effect on C_3 hence good freq stability is achieved.

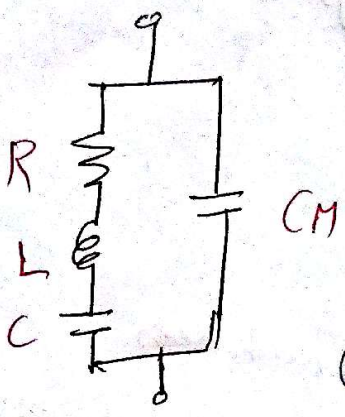
C_3 kept variable. As freq is dependent on C_3, the freq can be varied in the desired range.

Crystal Oscillator

Symbol



AC. equivalent circuit



R → Internal frictional loss

L → Inductance (Mass of the crystal).

C → Stiffness (during vibration).

CM → Mounting capacitance

The natural shape of the crystal is hexagonal prism. But in practice it is cut to the rectangular slab. This slab is then mounted between two metal plates.

When the crystal is not vibrating, it is equivalent to the mechanical mounting. Such a capacitance due to the mechanical mounting of the crystal. Such a capacitance existing due to the two metal plates separated by a dielectric like crystal slab is called, mounting capacitance denoted as C_M or C.

When it is vibrating, there are internal frictional losses which is denoted by 'R'. while the mass of the crystal, which is indication of inertia is represented by an inductance 'L', & stiffness represented by 'C'.

$$f_r = \frac{1}{2\pi\sqrt{LC}} \cdot \sqrt{\frac{Q^2}{1+Q^2}}$$ Q ⇒ Quality

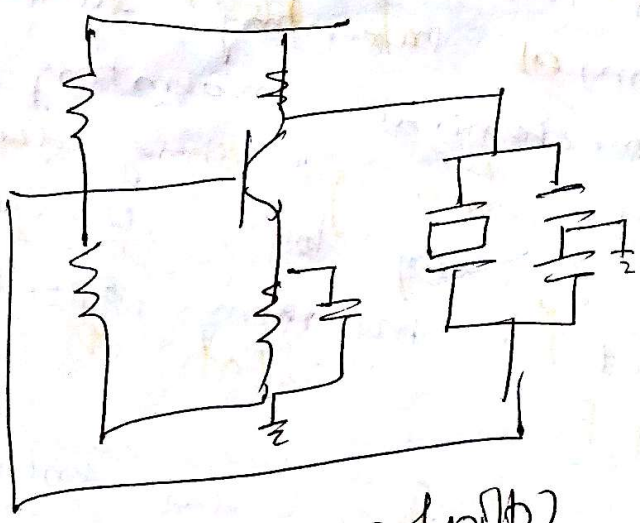
Q factor of crystal is very high i.e 20,000.

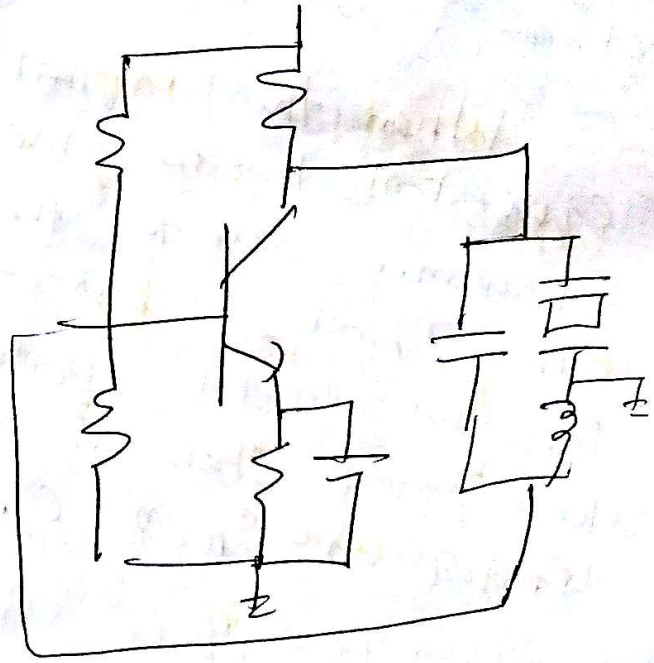
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$f \propto 1/t$. t ⇒ Thickness

So very high freq, thickness of the crystal should be very small.

Pierce crystal osc.



(Modified colpitts)

Miller crystal osc