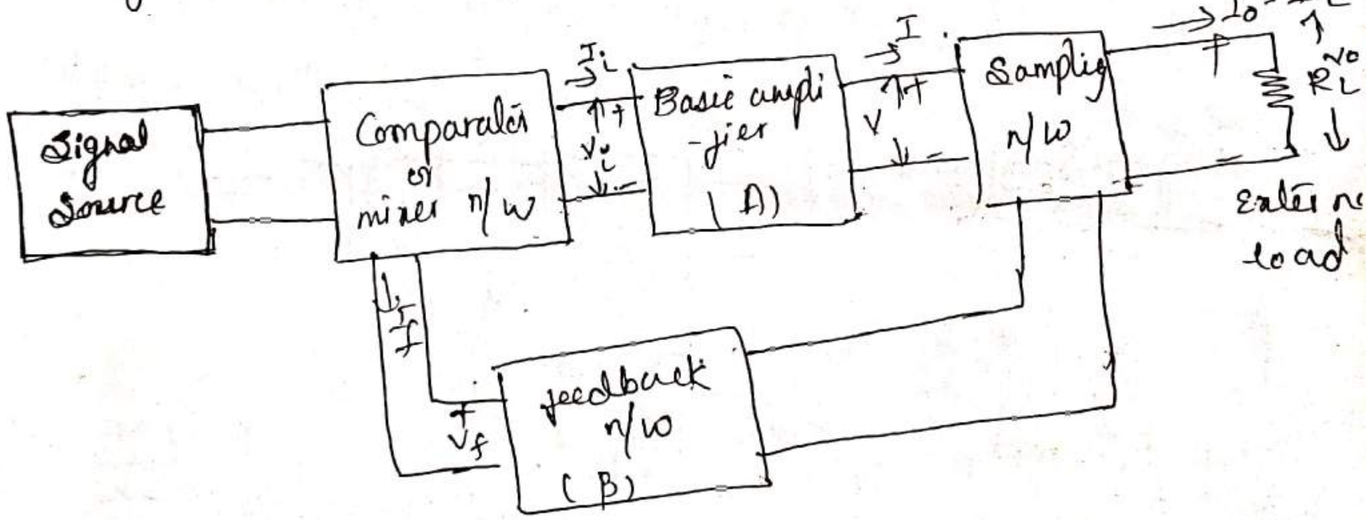
Feedback Concept:

Feedback is defined as some part of the output is added or subtractor with the input through a feedback network is called as feedback.

Feedback amplifiers are used when the magnitudes of impedances at input and output are to be varied. The four basic amplifiers with their impedances changing can be used as a feedback amplifiers.

Block diagram:



In the four basic amplifier circuits we may sample the o/p voltage or current by means of a suitable sampl n/w and apply this signal to the input through a feedb two-port n/w.

At the input the feedback signal is combined with the external signal (source) through a mixer n/w and is fed into the amplifier properly.

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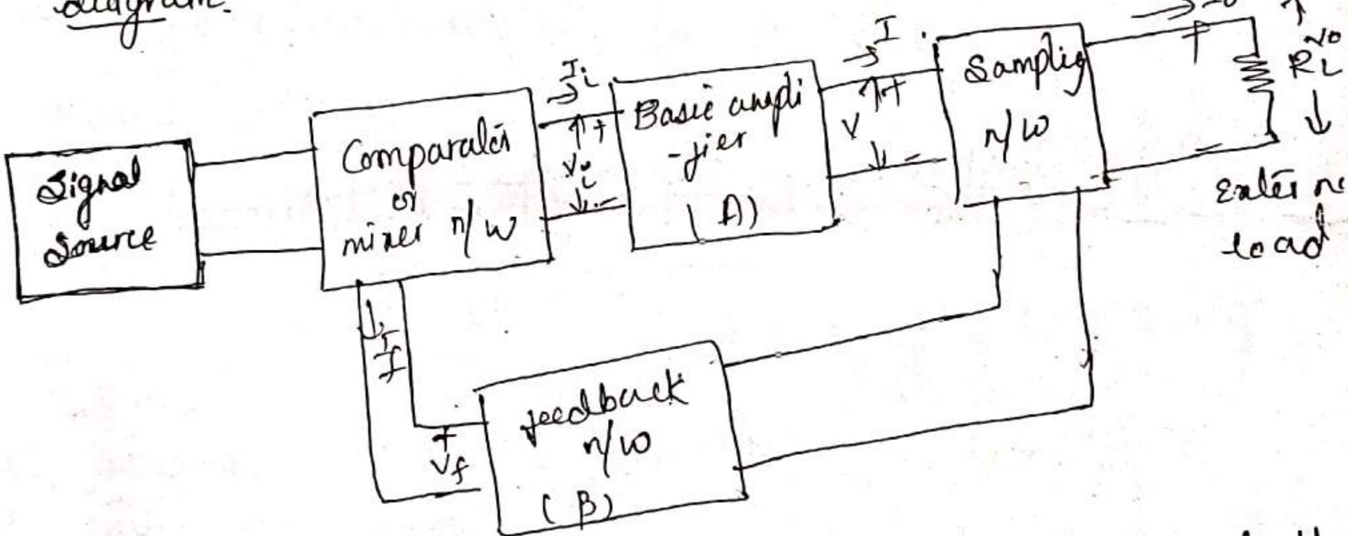

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two-port n/w.

At the input the feedback signal is combined with the external signal (source) through a mixer n/w and is fed into the amplifier properly.

Signal Source: This block is either a signal ... series with a resistor R_s (a Thevenin's representation) or a signal current I_s in parallel with a resistor R_s (a Norton's representation).

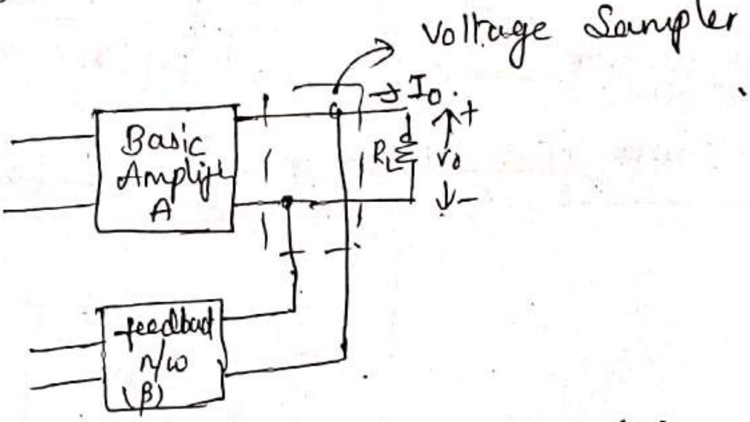
Feedback Network: This block is usually a passive 2-port n/w which may contain resistors, capacitors and inductors. or is simply a resistive configuration

Sampling Network:

Two types: 1) Voltage Sampler → means o/p voltage is fed i/p

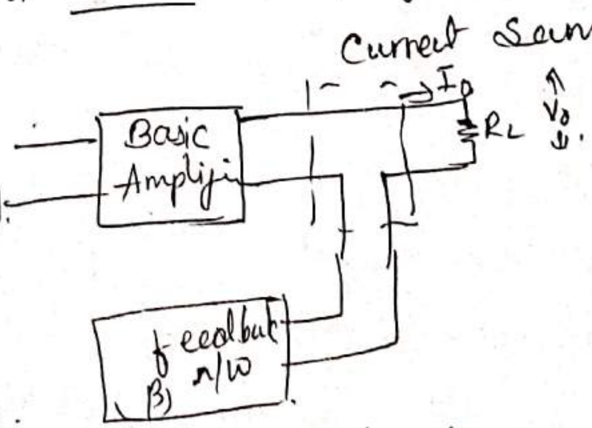
2) Current Sampler → means o/p current is fed i/p.

Voltage Sampler:



The output voltage is sampled by connecting the feedback n/w in shunt across the output. This type of connection is referred to as voltage or node sampling.

Current Sampler:



The output current is sampled where the feedback n/w is connected in series with the output. This type of connection is referred to as current or loop sampling.

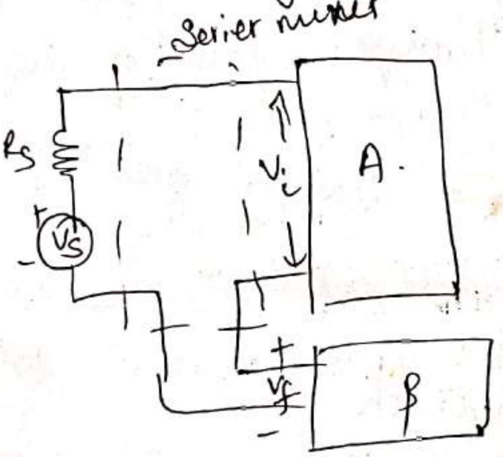
Comparator or Mixer n/w:

A comparator or mixer where the feedback output is mixed with input source.

Two types of mixers:

1) Series Mixing
2) shunt Mixing

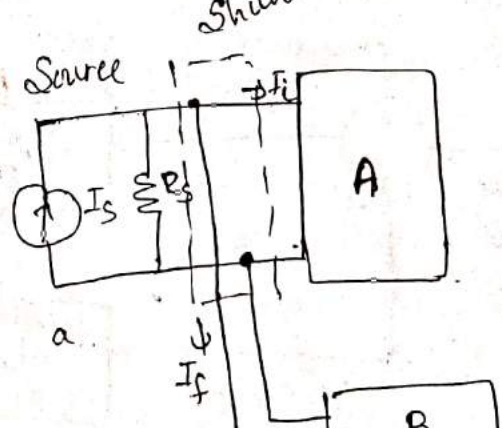
Series mixing: The feedback output from the feedback n/w is in series with the signal source. Therefore the signal source is thevenins source. In Series mixing the o/p of the feedback n/w is voltage.



Shunt Mixing:

The feedback output from the feedback n/w is in shunt with the signal source. Therefore, the signal source is a Nortons source.

In shunt mixing the o/p of the feedback n/w is current.



Transfer Ratio, or Gain.

The symbol A represents the ratio of the output signal to the input signal of the basic amplifier. The transfer ratio V_o/V_i is the voltage gain A_V. Illy I_o/I_i is the current amplification or current gain A_I, for the amplifier.

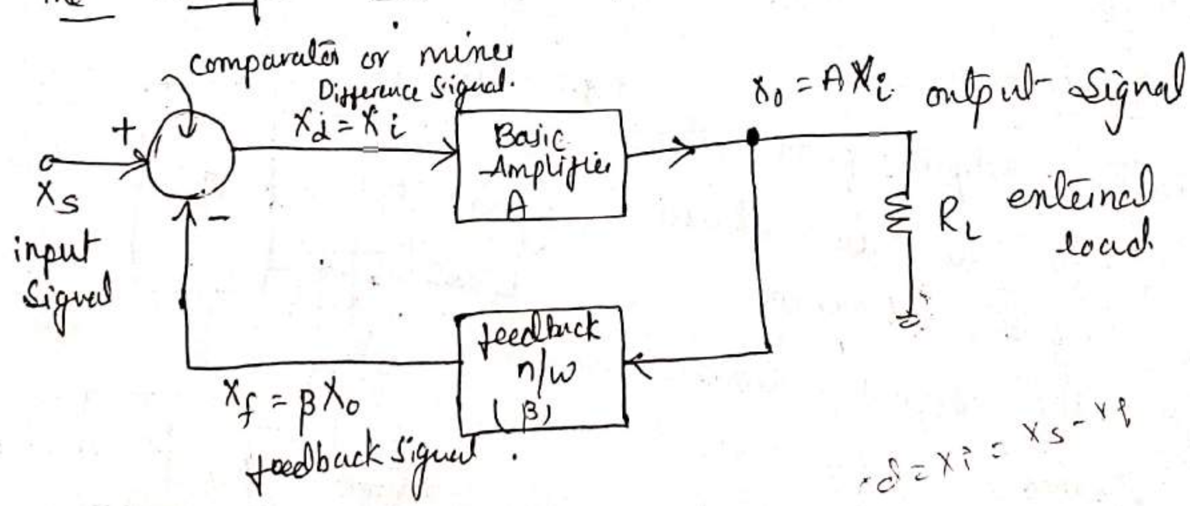
The ratio I_o/V_i of the amplifier is the transconductance G_M.

V_o/I_i is the trans-resistance R_M.

→ $A_V, A_I, G_M, \& R_M$ as a transfer gain of the basic amp without feedback.

→ $A_{V_f}, A_{I_f}, G_{M_f} \& R_{M_f}$ as a transfer gain of the amplifier with feedback.

The Transfer Gain With feedback:



$X_d = X_i = X_s - X_f$

from fig: $X_d = X_i = X_s - X_f$.

feedback factor $\beta = \dfrac{X_f}{X_o} \Rightarrow X_f = X_o\beta$.

transfer gain $A = \dfrac{X_o}{X_i}$

5

The gain with feedback $A_f = \dfrac{X_o}{X_s}$

$$A_f = \frac{X_o}{X_i + X_f} \qquad [\text{from } X_i = X_s - X_f]$$

$$A_f = \frac{X_o}{X_i + \beta X_o}$$

Divide Nr & Dr by X_i

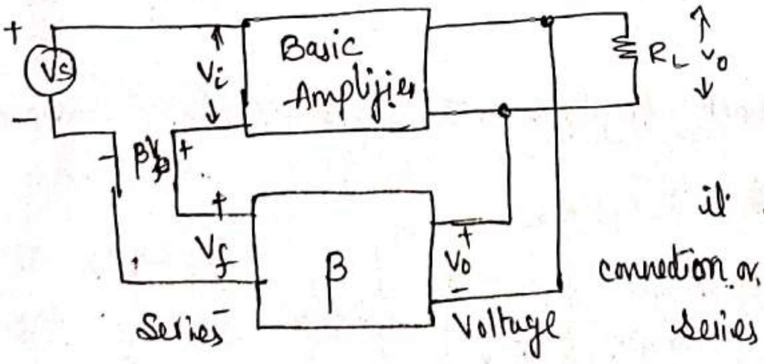
$$A_f = \frac{X_o / X_i}{1 + \beta \frac{X_o}{X_i}}$$

w.k.t $\dfrac{X_o}{X_i} = A$

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

→ Types of feedback amplifiers!

1) Voltage Series feedback amplifier (or) voltage amplifier with voltage series feedback



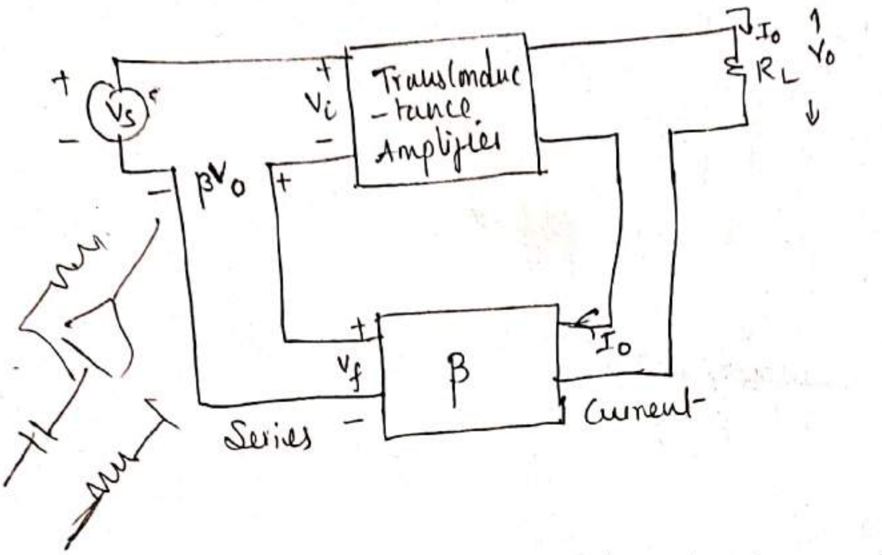
Voltage series means o/p shunt or node connection as it is voltage and i/p series connection or voltage source as it is series mixing.

→ i/p to the feedback n/w is Voltage and feedback voltage (feedback) is added at i/p

$$\beta = \frac{V_f}{V_o} \; ; \quad A_v = \frac{V_o}{V_i}$$

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

2, Current Series feedback amplifier or Trans... amplifier with current series feedback.

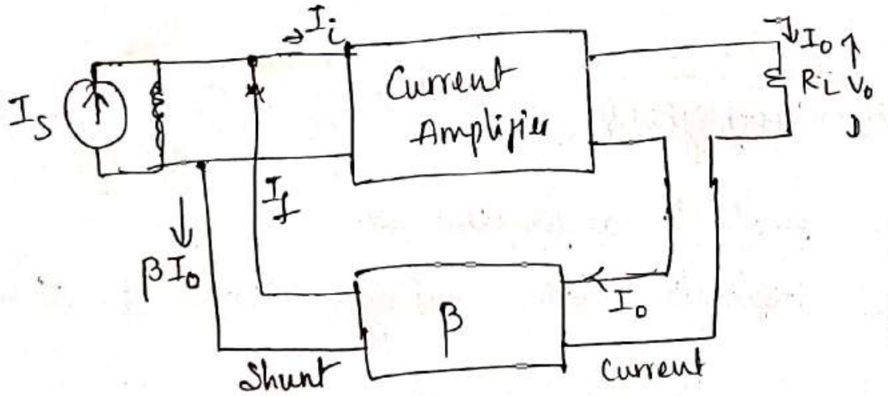


$$\beta = \frac{V_f}{I_o}$$

$$G_M = \frac{I_o}{V_i}$$

$$G_{M_f} = \frac{I_o}{V_s}$$

3, Current Amplifier with current shunt feedback (or) Current shunt feedback Amplifier:

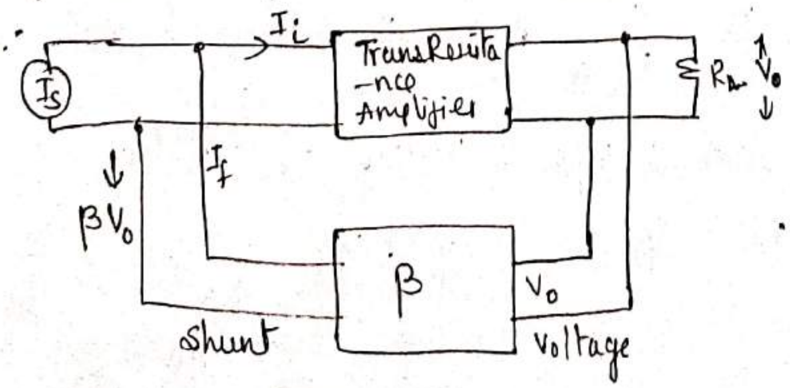


$$\beta = \frac{I_f}{I_o}$$

$$A_I = \frac{I_o}{I_i}$$

$$A_{I_f} = \frac{I_o}{I_s}$$

4) Voltage Shunt feedback Amplifier (or) Transresistance Amplifier with voltage shunt feedback:



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

$$R_M = \frac{V_i}{I_i}$$

$$R_{M_f} = \frac{V_o}{I_s}$$

Comparision :

Signal or Ratio	Voltage Series	Current Series	Current Shunt	Voltage shunt
X_0 (o/p)	Voltage	Current	Current	Voltage
X_s, X_f, X_d	Voltage	Voltage	Current	Current
A	A_V	G_M	A_I	R_M
β	V_f/V_o	V_f/I_o	I_f/I_o	I_f/V_o

ADVANTAGES OF NEGATIVE FEEDBACK :

1, Stability of gain

2, Reduction in Distortion

3 Reduction in Noise

4, Increased Bandwidth

5, Increased input impedance

6, Decreased output impedance.

1, Gain Stabilization !

The gain of an amplifier may change because of so many reasons. change in power supply voltage, or change in the parameters of the active device (FET or transistor) may change the gain.

This adversely effects the performance of the amplifier. It would have been ideal, if the gain of the amplifier was independent of these changes.

Negative feedback acheives this object to a great extent.

The gain of a negative feedback amplifier is given as

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

but $A\beta >> 1$ then in the denominator unity can be neglected compared to $A\beta$

$$\therefore \quad A_f = \frac{A}{A\beta} = \frac{1}{\beta}$$

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

→ Thus, the gain A_f of the feedback amplifier is made independent of the internal gain A.

→ The gain A_f depends only on β which in turn depends on passive elements such as resistors.

→ The values of the resistors remain fairly constant and hence the gain is stabilized.

→ Even if $A\beta >> 1$ Condition is not fully met, some improvement occurs in the stability of the gain.

→ Suppose a certain change in the internal gain of the amplifier takes place. we can find the Corresponding % change in the overall gain of the feedback amplifier.

w.k.T $$A_f = \frac{A}{1+A\beta}$$

Differentiating w.r.t A

6

$$\frac{dA_f}{dA} = \frac{(1+A\beta)\times(1) - A\beta}{(1+A\beta)^2}$$

$$\frac{dA_f}{dA} = \frac{1}{(1+A\beta)^2} \Rightarrow \frac{dA_f}{dA} = \frac{1}{1+A\beta} \times \frac{1}{1+A\beta}$$

$$\frac{dA_f}{dA} = \frac{A_f}{A} \times \frac{1}{1+A\beta} \quad \left[\because \frac{1}{1+A\beta} = \frac{A_f}{A}\right].$$

$$\boxed{\frac{dA_f}{A_f} = \frac{1}{(1+A\beta)} \frac{dA}{A}} \quad -(1)$$

since $(A\beta+1) > 1$, the % change in A_f is seen to be much less than the % change in A.

Desensitivity: It can be defined as change in voltage gain without feedback to the change in voltage gain with feedback.

$$D = (1+A\beta) = \frac{\frac{dA}{A}}{\frac{dA_f}{A_f}} \quad [\text{from (1) equation}]$$

It can be def

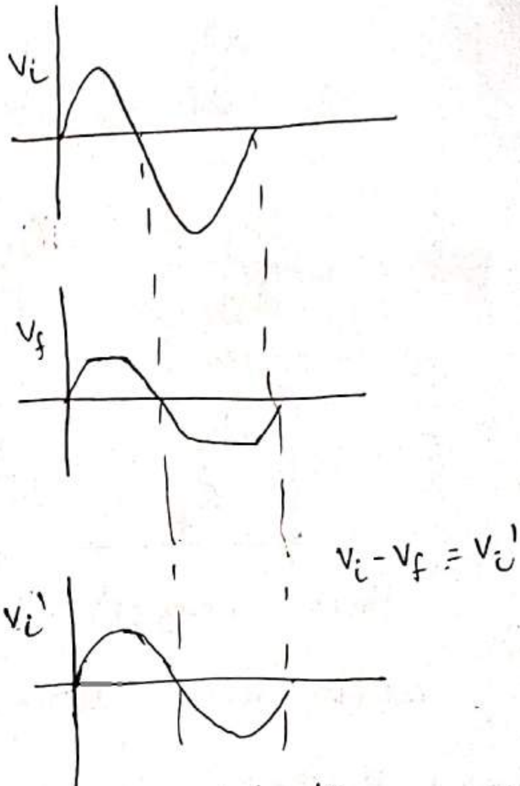
Sensitivity: It is defined as inverse of desensitivity. ratio of change in voltage gain with feedback to the change in voltage gain without feedback

$$S = \frac{1}{1+A\beta} = \frac{\frac{dA_f}{A_f}}{\frac{dA}{A}}$$

Reduction in Distortion & Noise:

In negative feedback the harmonic distortion is reduced.

This can be shown as:

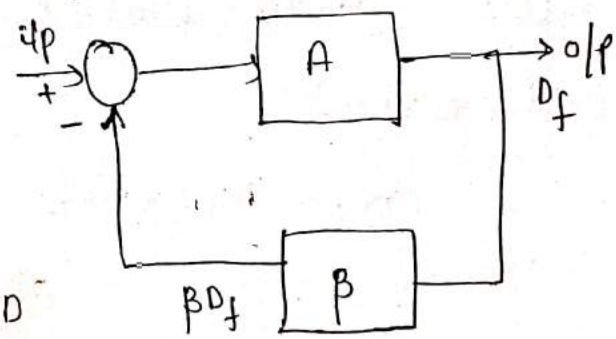


→ v_f is distorted since o/p of amplifier is distorted.

- A flattened o/p when subtracted from the i/p becomes a resulting o/p v_o' of more peaked.

→ Thus the net i/p v_i' is predistorted in such a way so as to partially compensate for the flattening caused by the amplifier.

→ We can find the amount of reduction in the distortion caused by -ve feedback.



Suppose the amplifier with gain A produces a distortion D without feedback.

After f.b applied this distortion D appears as D_f.

D_f gets multiplied with β and βD_f part of distortion D_f is feedback to the input.

This gets amplified A times by the basic amplifier and becomes $A\beta D_f$. This gets added up (in reverse polarity) to the original distortion D to make the net distortion D_f. Thus

$$D_f = D - A\beta D_f$$

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

The distortion is reduced by the same factor as gain

Illy Noise $N_f = \dfrac{N}{1+A\beta}$

4) Increased Bandwidth:

→ W.K.T due to -ve f.b the gain is reduced by a factor of $(1+A\beta)$.

→ also negative feedback reduces the f_1 lower cut off frequency by a factor of $(1+A\beta)$ & increases the f_2 higher cutoff freq by a factor of $(1+A\beta)$

but $BW_f = f_{2_f} - f_{1_f}$

as $f_2 >> f_1$

$\therefore BW_f \simeq f_2$

$\therefore$ Bandwidth increases by a factor of $(1+A\beta)$

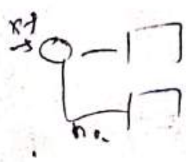
$$\Rightarrow \boxed{BW_f = BW(1+A\beta)}$$

i) f_{L_f} → lower cut off frequency with feedback:

W.K.T $A_{V_L} = \dfrac{A_{V_m}}{1-j\left(\frac{f_L}{f}\right)}$ [gain in LFR]

$A_{V_{L_f}} = \dfrac{A_{V_L}}{1+A_{V_L}\beta}$ [in the form of $A_f = \dfrac{A}{1+A\beta}$]

gain in LFR with feedback



$$A_{V_{L_f}} = \dfrac{\dfrac{A_{V_m}}{1-j\left(\frac{f_L}{f}\right)}}{1+\left(\dfrac{A_{V_m}}{1-j\left(\frac{f_L}{f}\right)}\right)\beta}$$

$$A_{V_{L_f}} = \frac{\dfrac{A_{V_m}}{1-j\left(\frac{f_L}{f}\right)}}{\dfrac{1-j\left(\frac{f_L}{f}\right)+A_{V_m}\beta}{\left[1-j\left(\frac{f_L}{f}\right)\right]}}$$

$\Rightarrow$

$$A_{V_{L_f}} = \frac{A_{V_m}}{1-j\left(\frac{f_L}{f}\right)+A_{V_m}\beta}$$

taking $(1+A_{V_m}\beta)$ common.

$$A_{V_{L_f}} = \frac{\dfrac{A_{V_m}}{1+A_{V_m}\beta}}{1-j\,\dfrac{f_L}{f(1+A_{V_m}\beta)}}$$

$$A_{V_{L_f}} = \frac{A_{V_{m_f}}}{1-j\,\dfrac{f_L}{f(1+A_{V_m}\beta)}} \qquad \left[\because A_{V_{m_f}} = \frac{A_{V_m}}{1+A_{V_m}\beta}\right]$$

gain w. f.b in midband region

$$A_{V_{L_f}} = \frac{A_{V_{m_f}}}{1-j\left(\frac{f_{L_f}}{f}\right)} \quad \text{where} \quad f_{L_f} = \frac{f_L}{1+A_{V_m}\beta}$$

$\Rightarrow$ f_{L_f} = lower cutoff freq with feedback $= \dfrac{f_L}{1+A_{V_m}\beta}$

reduces by a factor of $(1+A_V\beta)$

(ii) IIIly $f_{H_f} = f_H(1+A_{V_m}\beta) \Rightarrow$ increases by a factor of $(1+A_V\beta)$

5) Increased input impedance: 2, 20, 36, 52, 690 (8)

It is desirable to have a high input impedance for an amplifier

Then it will not load the preceeding stage or the input voltage source. Such a desirable characteristic can be acheived with the help of negative ~~p~~ series voltage feedback.

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

The input impedance in increased by a factor of $(1+A\beta)$

6) Decrease in output impedance;

Low impedance at o/p is advantageous for an amplifier. An amplifier with low impedance is capable of delivering power (or voltage) to the load without much loss. Such a desirable characteristics is achieved by employing negative series - voltage feedback in the amplifier.

$$R_{of} = \frac{R_0}{1+A\beta}$$

The output impedance is reduced by a factor of $(1+A\beta)$.

(1) E.C.E(A)

METHOD OF ANALYSIS OF A FEEDBACK AMPLIFIER

6 Analysis of feedback amplifiers involves determination of the four parameters, namely voltage gain, current gain, input impedance and output impedance of the amplifier with feedback.

In order to determine these parameters, the type of the amp the type of feedback involved in the circuit the transfer ratio of the amplifier without feedback is to be established. with the help of these parameters the analysis of the amplifier can be performed.

The analysis of any type of feedback amplifier can be consolidated as following steps:

(1) Redraw the ckt and identify the active devices ~~and the terminals.~~

2. Identify the topology
a. Is the feedback signal X_f a voltage or current? Is the feedback signal applied in series or in shunt In other words, is X_f applied in series with the external excitation?
b. Is the sampled signal X_o a voltage or current? or Is the sampled signal taken at the o/p In other words, Is the sampled signal node or from the o/p loop?

(3) Draw the ckt of the amplifier without feedback by using following steps:
a. To find the input ckt
Set $V_0 = 0$ for voltage sampling / short the o/p node
Set $I_0 = 0$ for current sampling / open the o/p loop

3. To find the output ckt

Set $V_i = 0$ for shunt comparision / short the i/p node

Set $I_i = 0$ for series comparision / open the i/p loop

4. Use a thevenin's source if x_f is a voltage a Norton's source if x_f is a current

5. Replace each active device by its appropria equivalent model.

6. By applying KCL & KVL to the equivalent circu determines the transfer ratio A of the amplifier witha feedback

---

7. Indicate X_f & X_o in the ckt & evaluate β val

8. From the values of A & β, find D, A_f, R_{if} & R_o

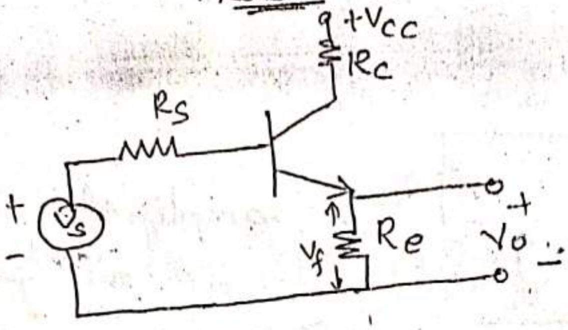
6/1

85, 91, 104, 110

~~112~~, 113, 131

PROBLEMS

(1)



(i) Identifying the topology:

(a) The feedback element is R_e
As R_e is not connected directly to the input terminal base it is a series mixing.

or

(b) the feedback output is voltage seri.
∴ series mixing.

(b) as $V_f \propto V_o$

or $V_f = I_e R_e$
where $I_e R_e = V_o$

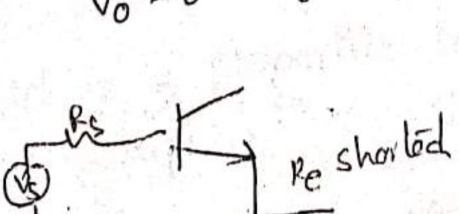
∴ $V_f \simeq V_o$
or $V_f \propto V_o$

∴ Voltage sampling amplifier.

⇒ Voltage Series

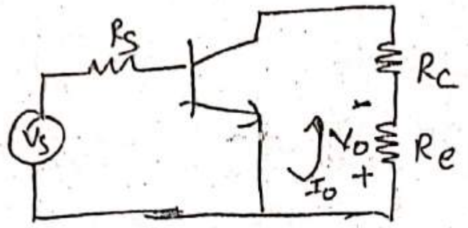
(ii) i/p loop:
for drawing i/p loop of this amplifier set $V_o = 0$ [as voltage sampling]

ckt becomes ⇒



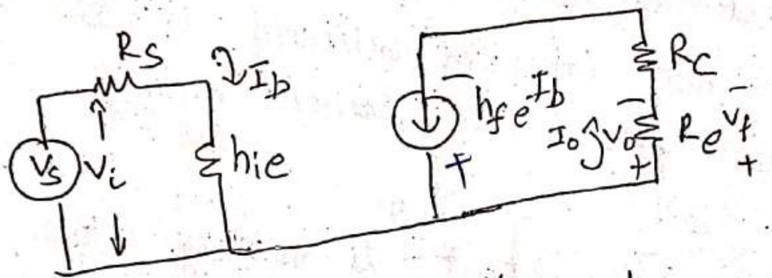
for o/p loop set $I_i = 0$ [for series mixing]

Signal from o/p to i/p from β n/w is zero.



amplified circuit with out feedback

(iii) Replacing transistor by approximate model.



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

$$A_v = \frac{V_0}{V_i} \qquad V_i = V_s = (h_{ie} + R_s) I_b$$

$$V_0 = h_{fe} I_b R_e$$

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

$$\boxed{A_v = \frac{h_{fe} R_e}{h_{ie} + R_s}}$$

$$\rightarrow D = 1 + A_v \beta = 1 + A_v = 1 + \frac{h_{fe} R_e}{h_{ie} + R_s}.$$

$$\rightarrow A_{vf} = \frac{A_v}{D}$$

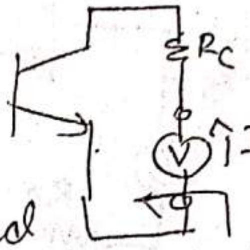
$$\rightarrow R_{if} = R_i D \Rightarrow R_i = h_{ie} + R_s.$$

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

$\Rightarrow R_{of} \rightarrow$ o/p impedance without R_L.

to find o/p impedance open R_e and connect V with current I

for looking from open R_e



$R_o \rightarrow \infty$

$\therefore R_{of} \rightarrow \infty$. as it is inderminned value so we have to find R_{of}' then find R_{of}.

$R_o = \infty$.

$R_{of}' = R_o \| R_e$

$R_{of}' \simeq R_e$.

$$R_{of}' = \frac{R_o'}{D} = \frac{R_e}{D} = \frac{R_e(R_s + h_{ie})}{R_s + h_{ie} + h_{fe} R_e}.$$

$$R_{of} = \lim_{R_e \to \infty} R_{of}' = \frac{R_s + h_{ie}}{\frac{R_s + h_{ie}}{R_e} + h_{fe}} = \frac{R_s + h_{ie}}{h_{fe}}.$$

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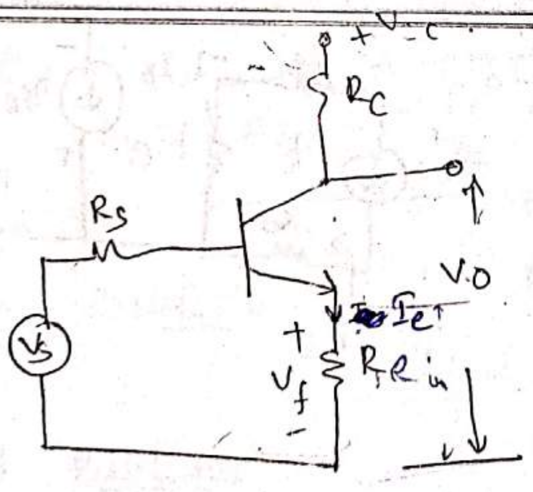
(2)



i) Identifying the topology

i) as feedback resistor Re is not connected to base series mixing.

or

as feedback o/p is V_f. series mixing.

ii) $V_f = R_e I_e$

$I_e \simeq I_o$.

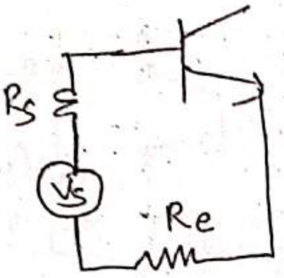
$V_f = R_e I_o$

$V_f \propto I_o$ as V_f is proportion to o/p current.

$\therefore$ current Sampling i.e. Current Series Amplifier

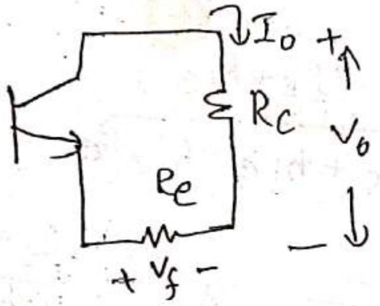
3. i/p loop.

$I_o = 0$ [as current sampling]

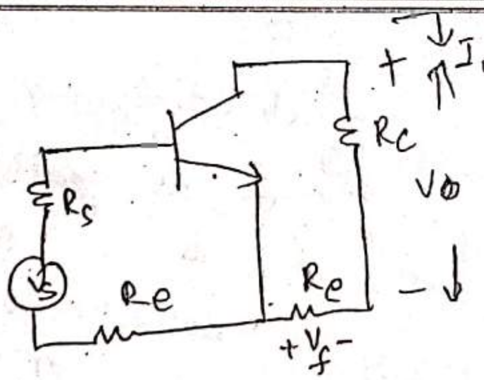


3. o/p loop

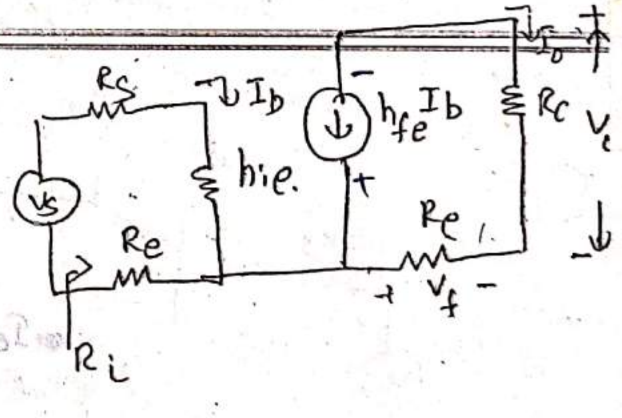
$I_i = 0$ (as series mixing).



4. ~~the~~ The amplified ckt w.o.f.b. and with approximate model.



⇒



$$V_f = -I_o R_e$$

$$\beta = \frac{V_f}{I_o} = \frac{-I_o R_e}{I_o} = -R_e$$

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

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

$$G_M = \frac{I_o}{V_s} = \frac{I_o}{V_i}$$

$$I_o = -h_{fe} I_b.$$

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

$$D = 1 + G_M \beta = 1 + \frac{h_{fe} R_e}{R_s + h_{ie} + R_e}$$

$$D = \frac{R_s + h_{ie} + R_e + h_{fe} R_e}{R_s + h_{ie} + R_e}$$

$$G_{Mf} = \frac{G_M}{D} = \frac{-h_{fe}}{(R_s + h_{ie}) + R_e(1 + h_{fe})}$$

$$= \frac{-\cancel{h_{fe}}}{R_e \cancel{h_{fe}}} \simeq \frac{-1}{R_e}.$$

To calculate voltage gain:

$$A_{vf} = \frac{V_o}{V_s} = \frac{I_o R_c}{V_s} = G_{Mf} R_c.$$

$$\boxed{A_{vf} = -\frac{R_c}{R_e}}$$

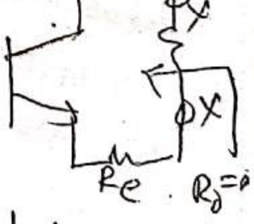
Input Resistance: $R_{if} = R_i D$.

$$R_i = (R_s + h_{ie} + R_e).$$

output Resistance:

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

R_o to find open R_c.



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

$R_{of}' = R_{of}' (1 + G_M \beta)$ $R_L || R_{of}$ ∵ with R_L

$R_o' = R_o || R_c \simeq R_c$.

$R_{of}' = R_c (1 + G_m \beta)$.

or $R_{of}' = \frac{R_o' (1 + \beta G_m)}{(1 + \beta G_M)}$

G_m reps shortcircuited transconductance then $G_m = \lim_{R_L \to 0} G_M$

from G_M equ it is indep of R_L & hence $G_m = G_M$ & $R_{of}' = R_o' = R_L = R_c$ where $R_o' = R_o || R_c \simeq R_c$.

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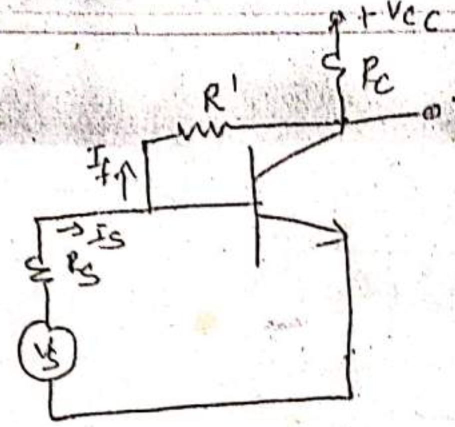
(3)



i) Identifying the topology:

as feedback resistor R' is Connected directly to the base shunt mixing

or the feedback o/p or signal is I_f ∴ shunt mixing.

ii) $I_f = \frac{V_i - V_o}{R'} \simeq \frac{-V_o}{R'}$ since V_i is in mV ~~two~~ for ampl. when compared to V_o which is in volts $V_o >> V_i$

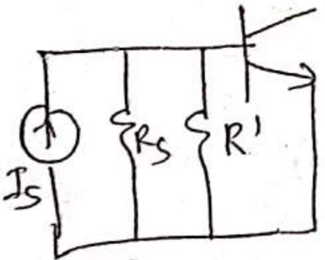
$I_f \propto V_o$.

As $I_f \propto V_o$ it is voltage sampling

∴ voltage shunt feedback amplifier.

3) i/p loop:

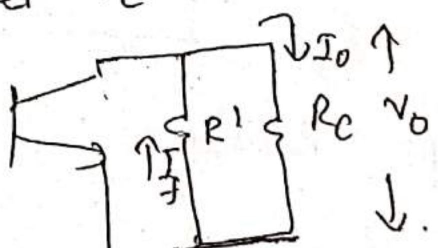
set $V_o = 0$ [as voltage sampling]



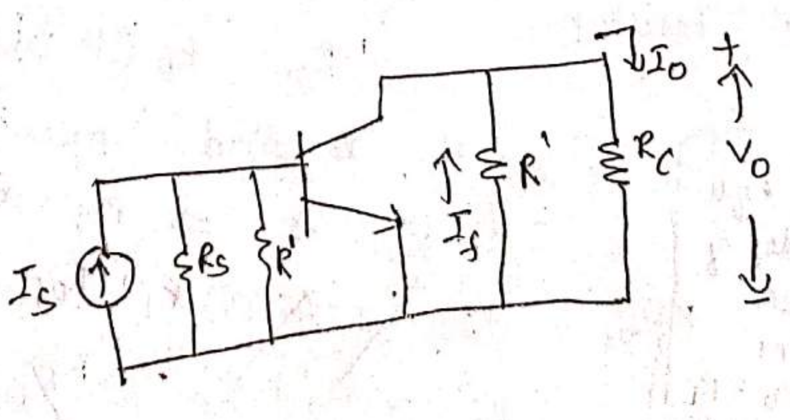
Replacing thevenins of i/p as Nortons. ∵ shunt mixing

3) o/p loop

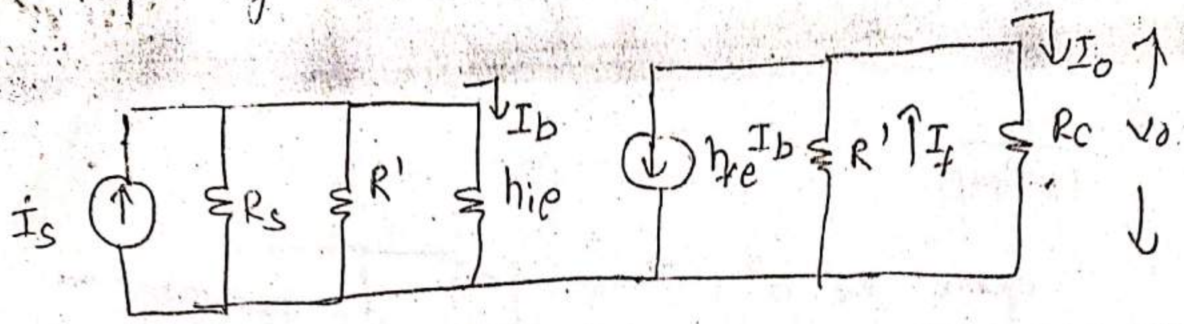
set $V_i = 0$ (as shunt mixi



⇒



(4) Replacing transistor with its approximate model



$$\beta = \frac{V_f}{V_o} = \frac{I_f}{-R' I_f} = \frac{-1}{R'}$$

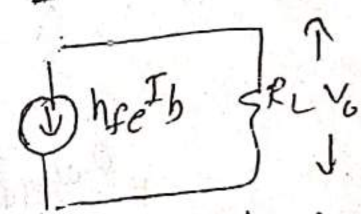
$V_o = I_o R_C$
or
$V_o = -R' I_f$.

$$\boxed{\beta = -\frac{1}{R'}}$$

$R_L = R' \parallel R_C$.

$$R_M = \frac{V_o}{I_i} = \frac{V_o}{I_s}.$$

$$= \frac{-h_{fe} I_b \times R_L}{I_s}$$



$R_L = R' \parallel R_C$

where $R = R_s \parallel R'$

$$I_b = I_s \times \frac{R}{R + h_{ie}}$$

$$I_s = \frac{I_b (R + h_{ie})}{R}.$$

$$R_M = \frac{-h_{fe} R_L \cancel{I_b} \times R}{\cancel{I_b} (R + h_{ie})} = \frac{-h_{fe} R_L R}{R + h_{ie}}.$$

$$D = 1 + R_M \beta$$

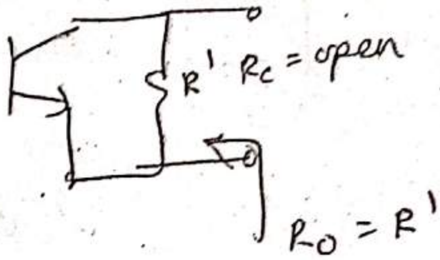
$$R_{Mf} = \frac{R_M}{D} = \frac{V_o}{I_s}$$

$$A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{I_s R_s} = A_{vf} = \frac{R_{Mf}}{R_s}$$

$R_{if} = \frac{R_i}{D}$ $\quad R_i = R \| h_{ie} = \frac{R h_{ie}}{R + h_{ie}}$

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

$\underline{R_o}$: open R_c



$R_o = R'$

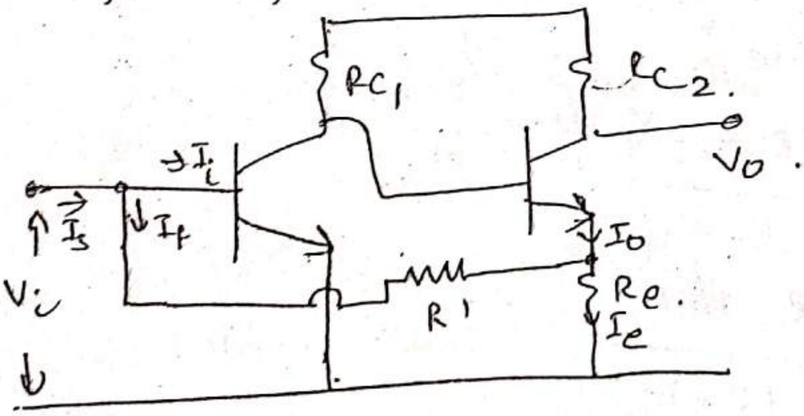
$R_m =$ ~~if $R_L \to \infty$~~ R_M when $R_c \to \infty$ $R_L = R'$

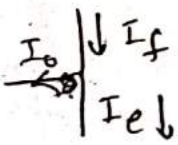
$\therefore R_M = \frac{-h_{fe} R' R}{R + h_{ie}}$ when $R_C \to \infty$
$R_L = R'$

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

~~$R_{of}' = R_{of} \| R_C$.~~

(4)





$I_o + I_f = I_e$

$I_f = I_o + I_e$

$-I_f + I_o$

i) Identifying the topology:

i) as feedback resistor R' is directly connected to the base shunt mixing

or

as feedback signal is I_f $\therefore$ shunt mixing

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$$I_f = \frac{(V_{i,1} - V_e)}{R'}$$

$$I_f = \frac{-V_e}{R'}$$

$$\simeq \frac{(I_o - I_f)R_e}{R'}$$

$$I_f(R_e + R') = I_o R_e$$

$$I_f = \frac{R_e}{R_e + R'} I_o$$

$I_o = I_f + I_e$

$I_f = -\frac{(I_o + I_f)R_e}{R'}$

$I_f = \frac{-I_oR_e - I_fR_e}{R'}$

$I_f(R' + R_e) = -R_e I_o$

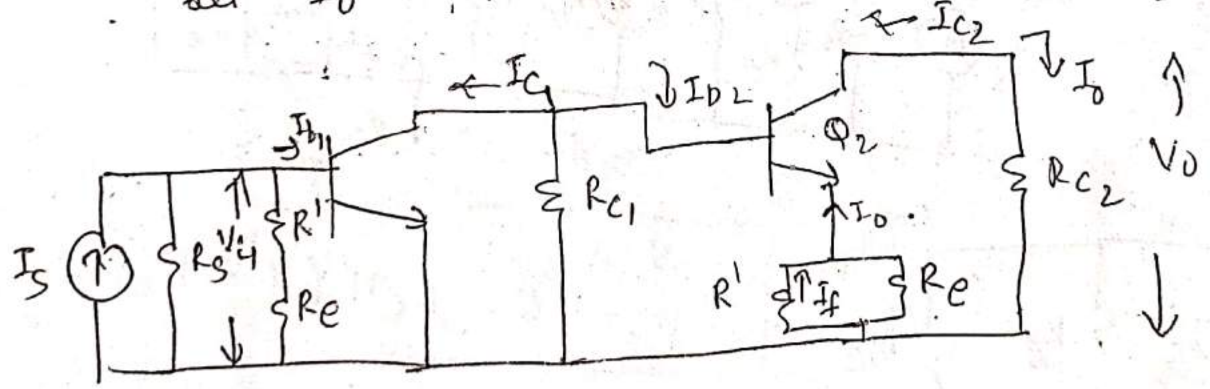
$I_f = \frac{-R_e}{R_e + R'} I_o$

$\Rightarrow \quad I_f \propto I_o$

$\therefore$ current sampling

$\Rightarrow$ Current shunt feedback amplifier.

② for draw i/p loop set $I_o = 0$ o/p loop set $v_{i_1} = 0$



$$I_f = I_o \times \frac{R_e}{R' + R_e}$$

$$\frac{I_f}{I_o} = \frac{R_e}{R' + R_e}$$

$$\Rightarrow \beta = \frac{R_e}{R' + R_e}$$

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$$A_I = \frac{I_o}{I_s} = \frac{-I_{c_2}}{I_s}$$

$$= \frac{-I_{c_2}}{I_{b_2}} \times \frac{I_{b_2}}{I_{c_1}} \times \frac{I_{c_1}}{I_{b_1}} \times \frac{I_{b_1}}{I_s}$$

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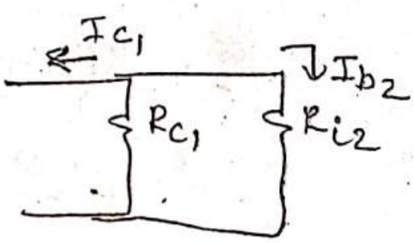
2500

$$\Rightarrow \frac{-I_{c_2}}{I_{b_2}} = \frac{-h_{fe} I_{b_2}}{I_{b_2}} = -h_{fe}.$$

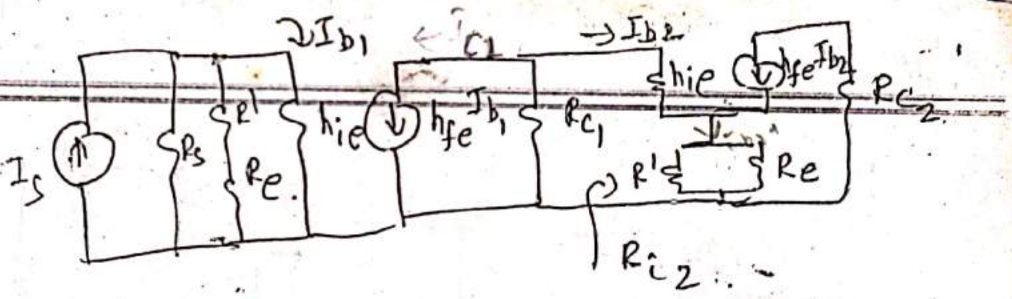
$$\Rightarrow \frac{I_{c_1}}{I_{b_1}} = \frac{h_{fe} I_{b_1}}{I_{b_1}} = h_{fe}.$$

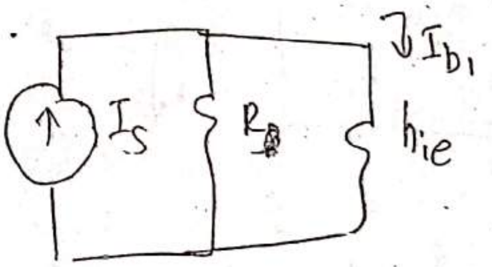
$$I_{b_2} = -I_{c_1} \times \frac{R_{c_1}}{R_{c_1} + R_{i_2}}.$$



$$\rightarrow \frac{I_{b_2}}{I_{c_1}} = \frac{-R_{c_1}}{R_{c_1} + R_{i_2}}$$

$$R_{i_2} = h_{ie} + (1 + h_{fe}) R' \| R_e$$





$$R = R_s \| (R' + R_e)$$

$$R_{i_2} = \frac{V_2}{I_2} = \frac{h_{ie} I_{b_2} + (R' \| R_e)(h_{fe} I_{b_2})}{(I_{b_1} + h_{fe} \ldots)}$$

$$I_{b_1} = I_s \times \frac{R}{R + h_{ie}} \Rightarrow \frac{I_{b_1}}{I_s} = \frac{R}{R + h_{ie}}.$$

$$\Rightarrow A_I = (-h_{fe})(h_{fe}) \left(\frac{-R_{c_1}}{R_{c_1} + R_{i_2}} \right) \left(\frac{R}{R + h_{ie}} \right)$$

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$$D = 1 + A_I\beta$$

$$A_{I_f} = \frac{A_I}{D}$$

$$A_{v_f} = \frac{V_o}{V_s} = \frac{-I_{c_2}R_{c_2}}{I_s R_s}$$

$$A_{v_f} = A_{I_f}\frac{R_{c_2}}{R_s}$$

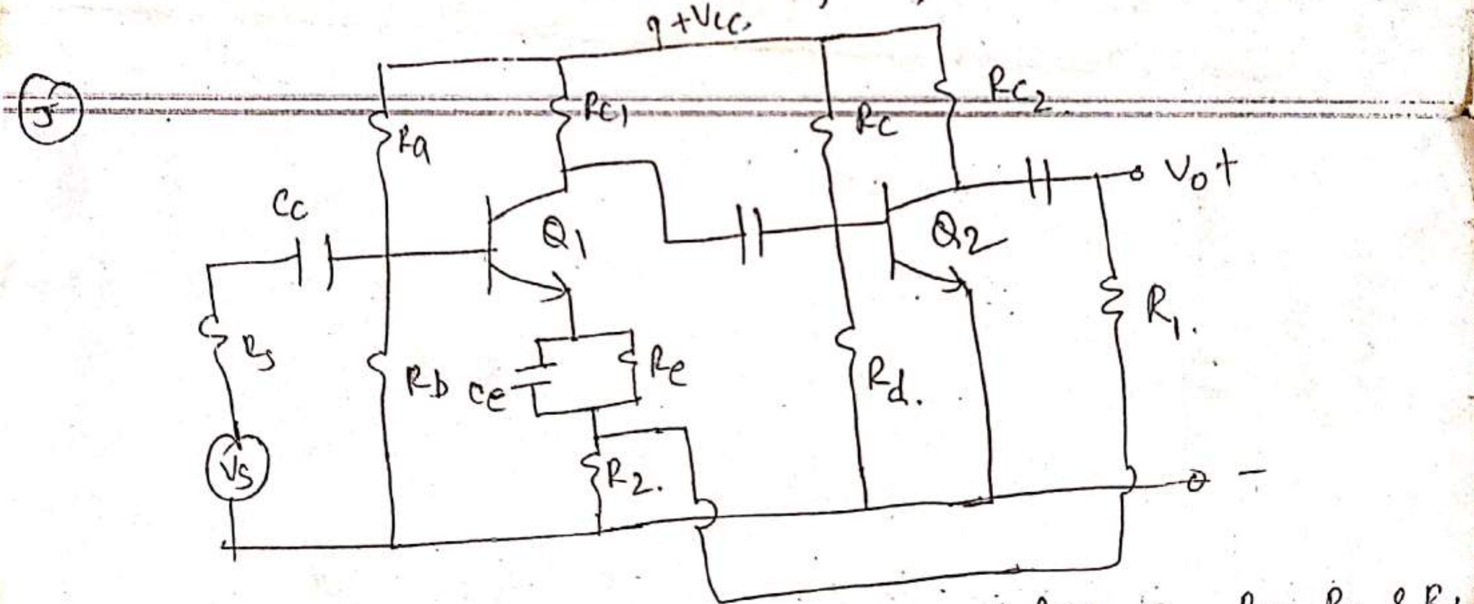
$$R_{if} = \frac{R_i}{D} \Rightarrow R_i = R_s \parallel (R' + R_e) \parallel h_{ie}$$

$$R_{of} = R_o(1 + A_i\beta) \Rightarrow R_0 = \infty \qquad R_{of}' = \frac{R_o'(1 + A_i\beta)}{1 + A_I\beta}$$

$$R_o' = R_{c_2}$$

$$\Rightarrow R_{of}' \simeq R_{c_2}$$

5

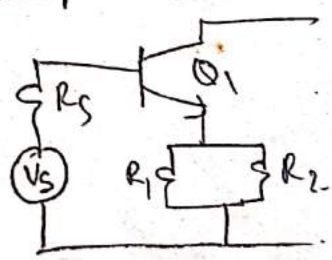


Neglecting R_a, R_b, R_c & R_d

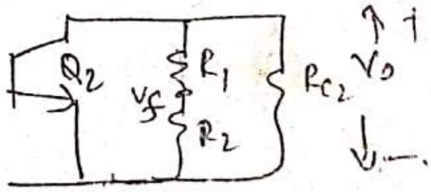
$C_e \parallel R_e$ acts as short ckt.

Voltage Series:

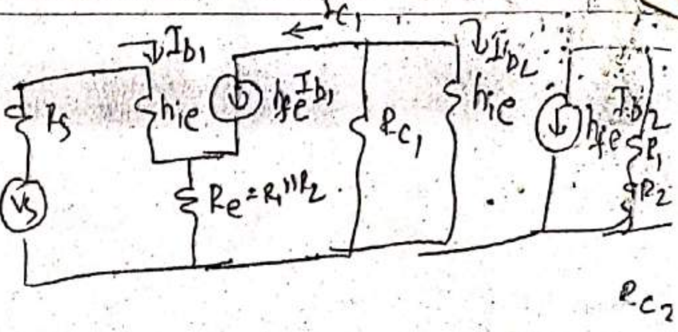
i/p loop $\quad V_o = 0$



o/p loop $\quad I_i = 0$



$$\beta = \frac{V_f}{V_0}$$



$$V_f = V_0 \times \frac{R_2}{R_1 + R_2}$$

$$\Rightarrow \beta = \frac{V_f}{V_0} = \frac{R_2}{R_1 + R_2}.$$

$$A_V = \overset{R_{L_2}}{A_{V_1}} \times A_{V_2}$$

$$A_{V_1} = A_{I_1} \times \frac{R_{L_1}}{R_{i_1}}$$

$$\boxed{A_{V_1} = -h_{fe}\frac{R_{L_1}}{R_{i_1}}}$$ where $R_{i_1} = h_{ie} + (1 + h_{fe})R_e$

where $R_e = R_1 \| R_2$.

$$A_{V_2} = A_{I_2} \times \frac{R_{L2}}{R_{i2}}$$

$$R_{L_2} = (R_1 + R_2) \| R_{C2}.$$

$$R_{i_2} = h_{ie}$$

$$\Rightarrow \boxed{A_{V_2} = -h_{fe} \times \frac{R_{L_2}}{h_{ie}}}$$

$$R_i = R_s + h_{ie} + (1 + h_{fe})(R_1 \| R_2)$$

$$R_{if} = R_i D.$$

$$R_{of} = \frac{R_0}{1 + A_V\beta}$$

R_{C_2} open

then $R_0 = R_1 + R_2$.

$$R_{of}' = R_{of} \| R_{C_2}.$$