IV. FEEDBACK AMPLIFIERS

Types of Basic Amplifiers and their Ideal charecteristics:

Generally, Amplifiers without feedback are referred as basic amplifiers.

As we know the charecteristics of Amplifiers as Gain, Band width, input and output impedances etc....

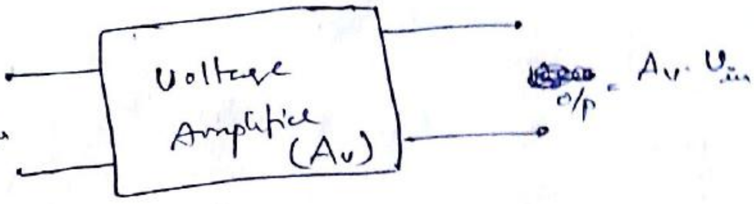
* Basic Amplifiers have been classified into four broad Categories.

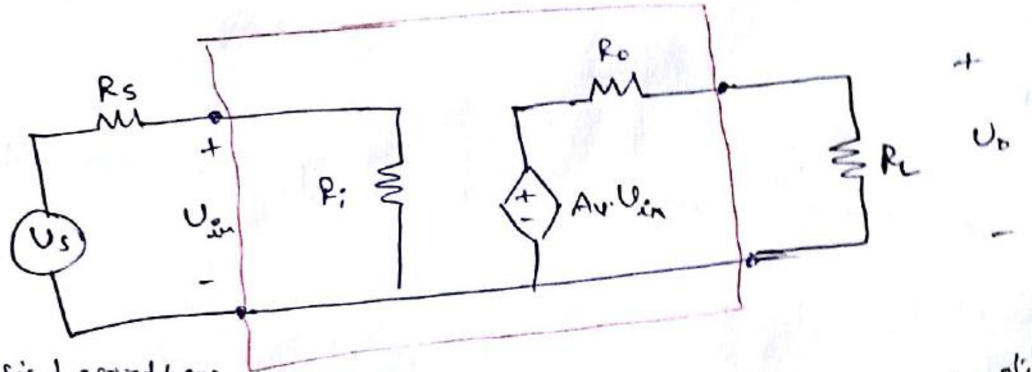
The relative Magnitude of i/p impedance as compared to the source impedance, and that of output impedance as compared to load impedance are the factors which determine the category of the amplifier.

1. Voltage Amplifiers
2. Current Amplifiers
3. Transconductance Amplifiers
4. Transresistance Amplifier

1. <u>Voltage Amplifier</u> :

which takes voltage as input signal and produces ~~o/p~~ output as voltage signal.





V_s = original i/p signal applied to amp

V_{in} = effective i/p signal across i/p terminal of amp

$A_v V_{in}$ = o/p voltage generated by the amp

V_o = effective o/p voltage fed to load R_L

<u>Fig</u>: equivalent ckt of voltage amplifier.

$$V_{in} = \frac{R_i}{R_i + R_s} \times V_s \quad \text{and} \quad V_o = \frac{R_L}{R_L + R_o} \times A_v \cdot V_{in}$$

if $R_i \gg R_s$ then $V_{in} \simeq V_s$

$$\therefore V_o = \frac{R_L}{R_L + R_o} \times A_v \cdot V_s$$

and if $R_o \ll R_L$ then $V_o \simeq A_v \cdot V_s$

→ <u>Charact. of voltage Amps</u>:

	Pract	ideal
A_v		
Stability		
R_i		
R_o		
BW		

Characteristics of Voltage Amps. are

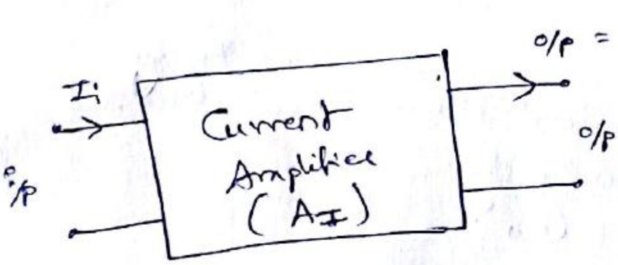
* Ideal characteristics

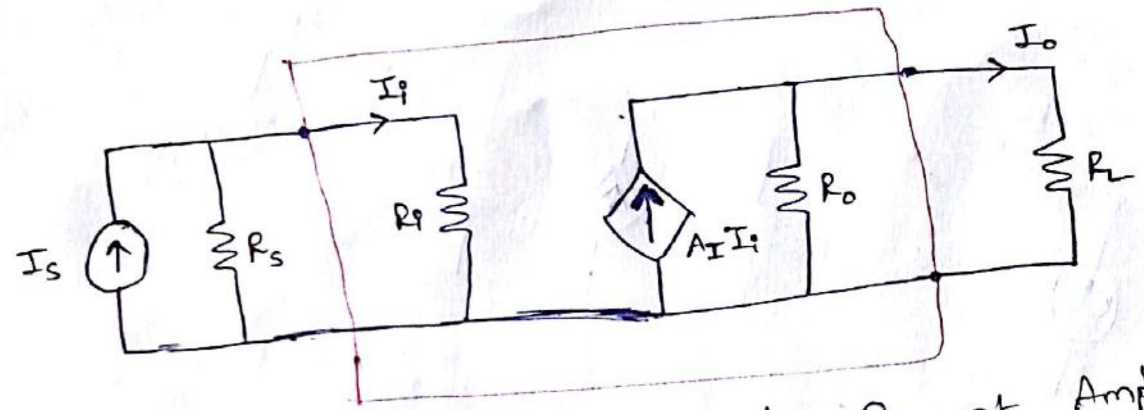
1. $A_v = \infty$
2. A_v must be stable
3. $BW = \infty$
4. $R_i = \infty$
5. $R_o = 0$.

* Ideal Voltage Amp has infinite i/p resistance & zero o/p resistance

2. <u>Current Amplifier:</u>

which accepts Current as input signal and produces output signal as Current





<u>Fig</u>: Equivalent ckt of Current Amplifier.

Using Current division rule,

$$I_i = \frac{R_s}{R_s + R_i} \times I_s \quad \text{and} \quad I_o = \frac{R_o}{R_o + R_L} \times A_I \cdot I_i$$

if $R_i << R_s$ then $I_i \cong I_s$

So $I_o = \frac{R_o}{R_o + R_L} \times A_I I_s$

and if $R_o >> R_L$ then $I_o \cong A_I \cdot I_s$

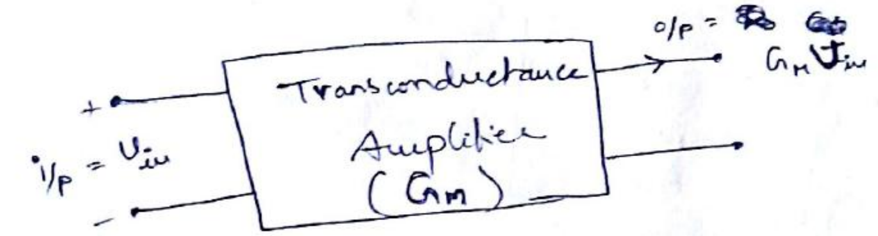
* Ideal charecteristics of Current Amplifier are:

1. $A_I = \infty$
2. A_I ~~[illegible]~~ must be stable
3. $BW = \infty$
4. $R_i = 0$
5. $R_o = \infty$

* Ideal Current Amp has zero i/p resistance & infinite o/p resistance

3. <u>Transconductance</u> <u>Amplifier</u>: $G_m = \frac{I_o}{V_{in}}$

It accepts voltage as input signal and provides current as output signal.



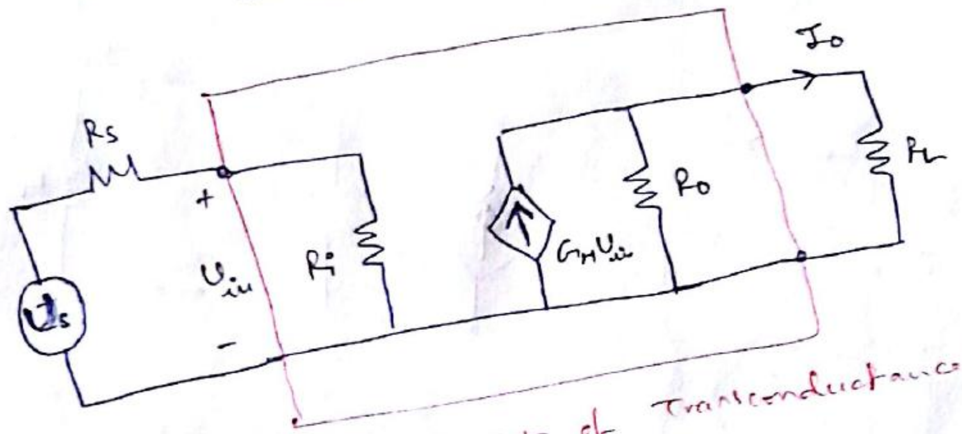


Fig: Equivalent ckt of Transconductance Amp

$$V_{in} = \frac{R_i}{R_i + R_s} \times V_s \quad \text{and} \quad I_o = \frac{R_o}{R_o + R_L} \times G_m V_{in}$$

if $R_i \gg R_s$ and $R_o \gg R_L$ then $I_o \equiv G_m V_s$

* Charecteristics of Transconductance Amp:

1. Very High & stable Transconductance gain (G_m)
2. Very high B/W
3. Very high i/p & o/p resistances.

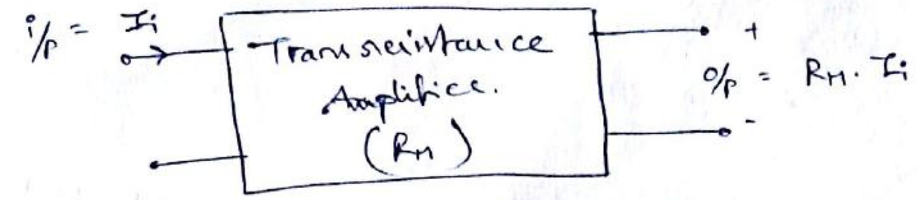
* Ideal charecteristics of Transconductance Amp:

1. $G_M = \infty$
2. G_M must be stable
3. $B/W = \infty$
4. $R_i = \infty$
5. $R_o = \infty$

* Ideal Transconductance Amp has infinite input and infinite output impedances.

4. Transresistance Amplifier: $\left(R_M = \frac{V_o}{I_i}\right)$

This accepts Current as input signal and produces voltage as output signal.



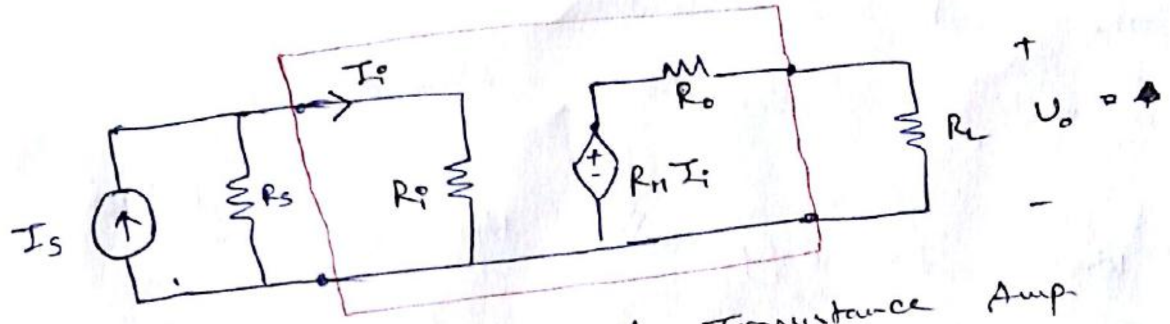


Fig: equivalent ckt of Transistance Amp.

$$I_i = \frac{R_s}{R_s + R_i} \times I_s \quad \text{and} \quad V_o = \frac{R_L}{R_L + R_o} \times R_M I_i$$

if $R_i << R_s$ and $R_o << R_L$ then $V_o \approx R_M \cdot I_s$

* Charecteristics of Transresistance Amp:

1. Very high & stable transresistance gain (R_M)
2. Very high B/W
3. very low R_i & R_o.

* Ideal charecteristics of Transresistance Amp:

1. $R_M = \infty$
2. stable R_M
3. $B/W = \infty$
4. $R_i = 0$ and $R_o = 0$

* Ideal Transresistance Amp has ~~infinite~~ zero input and ~~infinite~~ zero o/p impedances.

Disadvantages of Basic Amplifier.

1. The instability of a.c. gain is due to
   - (a) change in power Supply (i.e. drift in Supply)
   - (b) Changes in h-parameters
   - (c) Aging of the device

2. The input and output impedances are not according to the requirement.

3. Large Frequency and Harmonic distortions.

4. Noise is large.

5. Bandwidth is not Sufficient

Remedy: By using feedback, we can improve the performance of Basic amplifier.

Feedback: Def. is a process of application of a part of the o/p giving back to the input.

Feedback is of two types: +ve FB and -ve FB.

* If the feedback Signal gets added to the applied i/p Signal, such that the magnitude of effective input Signal to the amp increases, then it is called +ve FB.

+ve FB in a Controlled form if applied, amplifier behaves as oscillator.

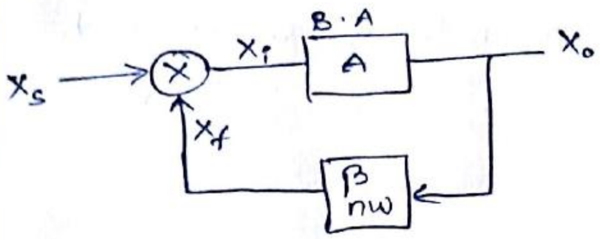
* If the feedback signal gets ~~[illegible]~~ subtracted from the applied input signal, such that the magnitude of effective input signal to the amplifier reduces, then it is called as -ve FB.

-veFB is used in amplifiers, to overcome the disadvantages of basic amplifier.

Differences between +veFB and -veFB

+veFB	-veFB
1. Def	1. Def
2. effective input to basic amp ~~[illegible]~~ increases.	2. effective input to Basic amp ~~[illegible]~~ reduces
3. gain ↑	3. Gain ↓
4. BW ↓	4. BW ↑
5. Input & Output impedances degraded	5. Input and Output impedances improves.
6. Noise & distortion ↑	6. Noise & distortion ↓
7. Stability in gain ↓	7. Stability in Gain ↑
8. feedback network is frequency sensitive	8. feedback nw. (β nw) is independent of frequency.
9. β nw consists of L, C ~~[illegible]~~ or both components	9. β nw consists of only resistors.
10. +ve FB is useful only when it is applied in a controlled manner ie. $A\beta = 1$ ie. $\angle A\beta = 0°$ or $180°$ and $\lvert A\beta \rvert = 1$.	10. No condition exists for -veFB ie. any amount of o/p can be feedback to output.
11. oscillators uses +veFB.	11. Amplifiers use -veFB.

General Block diagram of Feedback Amplifiers:



A = gain of Basic Amplifier
gain of Amp w/o Feedback.

$A = \frac{X_o}{X_i}$ = open loop gain

A_f = gain of amp with FB = Closed loop gain = $A_f = \frac{X_o}{X_s}$

β = gain of Feedback network (or) feedback factor
= reverse transmission factor = $\frac{X_f}{X_o}$

X_s = applied input Signal
X_f = feed back Signal = βX_o
X_i = effective input signal = $X_s \pm X_f$

if $X_i = X_s + X_f$ then positive FB.
if $X_i = X_s - X_f$ then Negative FB

(a) for +ve FB: (Derivation of closed loop gain)

we know for +ve FB, $X_i = X_s + X_f = X_s + \beta X_o$

$X_i = X_s + \beta(AX_i) = X_s + A\beta X_i$

$X_i(1 - A\beta) = X_s$

Closedloop gain = $A_f = \frac{X_o}{X_s} = \frac{X_o}{X_i(1-A\beta)} = \frac{A}{1-A\beta}$

for -ve FB, $A_f > A$ i.e. gain increases.

(b) Closed loop gain for -ve FB:

for -ve FB, $X_i = X_s - X_f = X_s - \beta X_o = X_s - \beta(AX_i) = X_s - A\beta X_i$

$X_i(1+A\beta) = X_s$ $\therefore$ Closed loop gain = $A_f = \frac{X_o}{X_s} = \frac{X_o}{X_i(1+A\beta)}$

$A_f = \frac{A}{1+A\beta}$ $\therefore$ $A_f < A$ ie gain reduces when -veFB is used.

Effects of -ve FB: (Adv of -VeFB)

(1) effect of -ve FB on Gain stability.

$$\text{closed loop gain} = A_f = \frac{A}{1+A\beta} \approx \frac{A}{A\beta} = \frac{1}{\beta}$$

. closed loop gain depends only on β n/w, since β n/w is resistive, which is independent of h-parameters, temp. and ageing. Hence closed loop gain is more stable.

Another View:

$$A_f = \frac{A}{1+A\beta} \Rightarrow \text{Differentiate w.r.t. } A$$

$$\frac{dA_f}{dA} = \frac{d}{dA}\left[\frac{A}{1+A\beta}\right] = \frac{(1+A\beta)(1) - (A)(\beta)}{(1+A\beta)^2} = \frac{1}{(1+A\beta)^2}$$

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

multiply & Divide with 'A'.

$$\frac{dA_f}{dA} = \frac{A}{A} \cdot \frac{1}{(1+A\beta)} \cdot \frac{1}{(1+A\beta)} = \frac{A_f}{A}\left(\frac{1}{1+A\beta}\right)$$

re arrange the equation.

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

where $\frac{dA_f}{A_f}$ = relative change in gain with FB

$\frac{dA}{A}$ = (Fractional change) " in gain without FB.

* for -ve FB, $\left|\frac{dA_f}{A_f}\right| << \left|\frac{dA}{A}\right|$

ex:

(2) Sensitivity factor of FB (S): is defined as

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

Desensitivity factor (D) is reciprocal of Sensitivity.

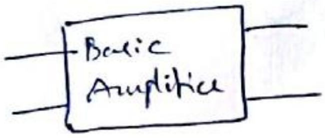
$$D = \frac{1}{S} = 1 + A\beta$$

Ideal value of Desensitivity factor $= \infty$
Ideal Value of Sensitivity factor $= 0$

* Desensitivity (D) Measures the stability of -veFB ie how much the gain is desensitive (stable) w.r.t. temprature, ageing and frequency.

Higher the value of D, More stability.

Effect of -ve FB on Bandwidth (i.e. on f_L and f_H).



Let
A = Gain of B.A. at MF
A_L = Gain of B.A at LF
A_H = Gain of B.A. at HF
f_L = lower Cutoff frequency of B.A.
f_H = Upper Cutoff frequency of B.A

we know Amplifier behaves as HP RC ckt (HPF) at Low freq, and as LPF at High freq.

So, the value of A_L and A_H Can be expressed as

$$A_L(f) = \frac{A}{1 - j\,(f_L/f)} \quad \text{and}$$

$$A_H(f) = \frac{A}{1 + j\,(f/f_H)}$$

Let
A_f = Gain of Amp with FB at MF
A_{Lf} = Gain of Amp with FB at LF
A_{Hf} = Gain of Amp with FB at HF
f_{Lf} = lower Cutoff freq. of amp with FB
f_{Hf} = Upper Cutoff freq of amp with FB

we know Gain of amplifier reduces ~~by (1+Aβ) times~~ when -veFB is used.

So
at MF, $A_f = \dfrac{A}{1 + A\beta}$

at LF, $A_{Lf}(f) = \dfrac{A_L}{1 + A_L\beta}$

at HF, $A_{Hf}(f) = \dfrac{A_H}{1 + A_H\beta}$

(a) effect of -veFB on lower Cutoff frequency:

we know, the gain of an amplifier with FB at LF is

$$A_{Lf}(f) = \frac{A_L(f)}{1 + A_L(f)\beta} =$$

$$= \frac{\left(\frac{A}{1 - jf_L/f}\right)}{1 + \left(\frac{A}{1 - j(f_L/f)}\beta\right)} = \frac{A}{1 + A\beta - jf_L/f} = \frac{(A/1+A\beta)}{1 - j\frac{f_L}{f(1+A\beta)}} = \frac{A_f}{1 - j\frac{f_{Lf}}{f}}$$

where f_{Lf} = lower cutoff frequency of amp with FB = $f_L/(1+A\beta)$

$$\boxed{f_{Lf} = \frac{f_L}{1+A\beta}} \quad \text{so} \quad f_{Lf} < f_L$$

i.e. −ve FB reduces the the magnitude of lower cutoff freq by $(1+A\beta)$ times when compared to Basic Amplifier

(b) Effect of −ve FB on Upper cutoff frequency:

we know the gain of an amp with FB ~~with~~ at HF is

$$A_{Hf}(f) = \frac{A_H(f)}{1+A_H(f)\beta} = \frac{\left(\frac{A}{1+jf/f_H}\right)}{1+\frac{A}{1+jf/f_H}\cdot\beta}$$

$$A_{Hf}(f) = \frac{A}{1+A\beta+j(f/f_H)} = \frac{(A/1+A\beta)}{1+j\frac{f}{f_H(1+A\beta)}} = \frac{A_f}{1+jf/f_{Hf}}$$

where f_{Hf} = Upper cutoff frequency of amp with FB

$$\boxed{f_{Hf} = f_H(1+A\beta)} \quad \text{So} \quad f_{Hf} > f_H.$$

i.e. −ve FB increases the magnitude of upper cutoff frequencies by $(1+A\beta)$ times compared to Basic Amp.

(c) effect of −ve FB on Bandwidth:

Def: Bandwidth is a range of frequencies over which the gain is greater than or equal to 70.7% of its maximum value.

Gain falls to 70.7% of its Max. value at upper and lower cutoff frequencies. (or) the frequency at which gain reduces to 70.7% ($1/\sqrt{2}$) of its Max. value is called cutoff frequency.

Bandwidth of Basic Amp = $f_H - f_L$

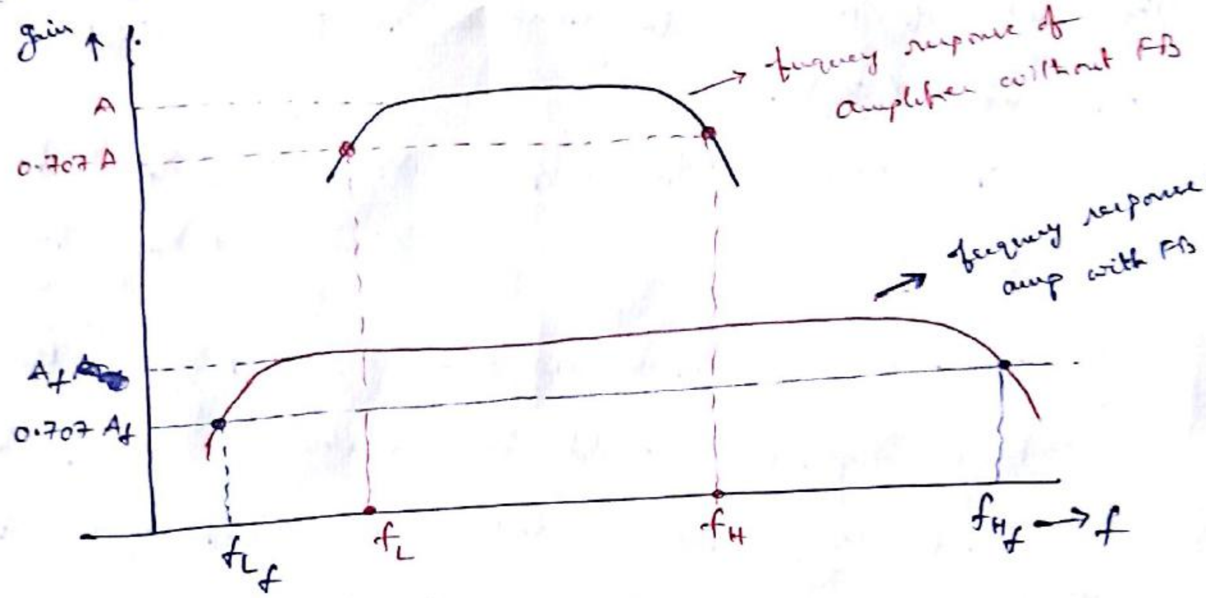
Since $f_H \gg f_L$, So BW of B.A $\simeq f_H$.

Bandwidth of Amp with FB = $f_{H_f} - f_{L_f}$

Since $f_{H_f} \gg f_{L_f}$, So $(BW)_f = f_{H_f} = f_H(1+A\beta)$

$= BW(1+A\beta)$

Hence BW of an amplifier increases with -ve FB by $(1+A\beta)$ times compared to Basic amplifier.



By using FB, Gain Bandwidth product of Amplifier doesn't change i.e it remains Constant

proof: Gain BW product of B.A = (A) (BW)

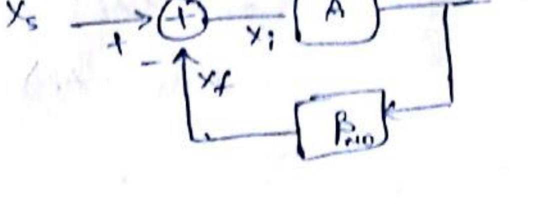
Gain BW product of Amp with FB = $A_f.(BW)_f$

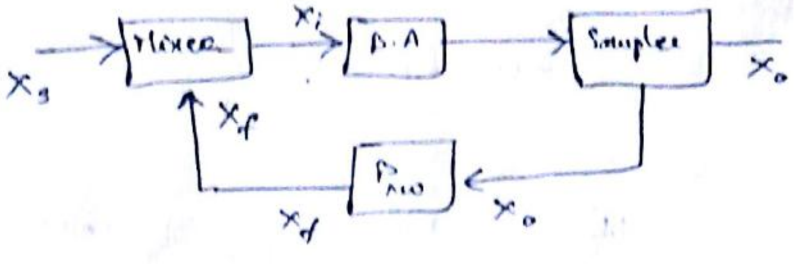
$= \left(\frac{A}{1+A\beta}\right)((BW)(1+A\beta)) = (A)(BW).$

$$\boxed{\therefore \quad A_f \cdot (BW)_f = A \cdot (BW)}$$

TYPES of FEEDBACK TOPOLOGIES:

The general block diagram of -ve FB amplifier is





The fuction of Mixer is to ~~Combine~~ Add/subtract feedback signal (X_f) with applied input signal (X_s).

o/p of Mixer = effective i/p = $X_i = X_s - X_f$ for -veFB

$X_i = X_s + X_f$ for +veFB

The function of Sampler is that it will provide the entire o/p of Basic amplifier should be available at the i/p of β N/W,

Such that β N/W selects how much part of o/p should be given as feedback (X_f = o/p of β N/W = βX_o).

Feedback topology is a method of providing feedback based on how the o/p signal is sampled and how the feedback signal is combined at i/p of amp.

There are four different feedback topologies.

1) Voltage - series (or) series - shunt
2) Voltage - shunt (or) shunt - shunt
3) Current - series (or) series - series
4) Current - shunt (or) shunt - series

Feedback Topologies

Based on Mixing n/w

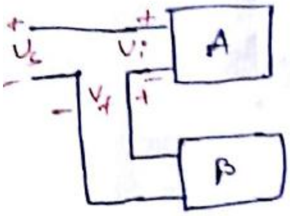
If X_s, X_f and X_i are

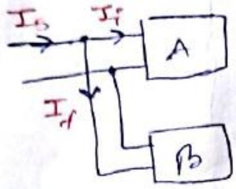
- Voltage Signals → They must be combined in series, so that $V_i = V_s - V_f$. → Series Mixing
- Current Signals → They must be combined in shunt. So $I_i = I_s - I_f$ → Shunt Mixing

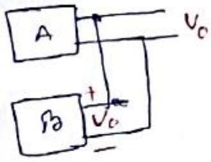
Based on Sampling n/w

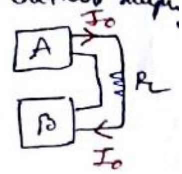
If X_o is

- Voltage → It must be given in parallel to the β n/w input. → Shunt Sampling (or) Voltage Sampling
- Current → It must be given in series to the β n/w input → Series Sampling (or) Current Sampling





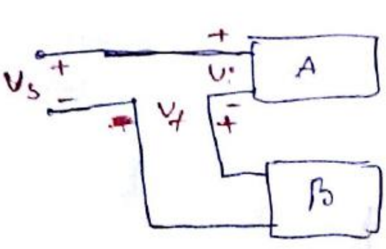




Identification of Mixing Networks:

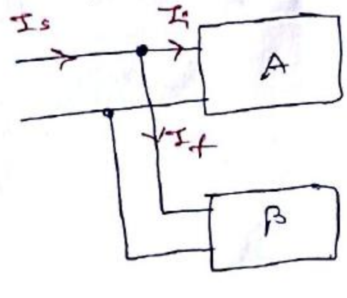
(a) If the feedback signal is in series with the external i/p signal, then it is series mixing.

In series mixing, X_s, X_f and X_i are all voltage signals, because currents can't be mixed up in series.



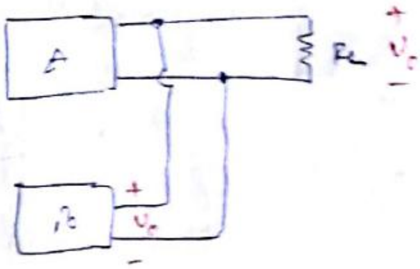
(b) If the feedback signal is in ~~shunt~~ parallel with the external i/p signal, then it is shunt mixing.

In shunt mixing, X_s, X_f and X_i are all current signals, because voltages can't be mixed up in parallel.

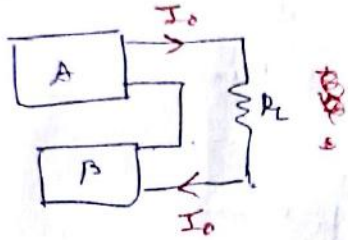


Identification of Sampling network:

(a) If the Sampled Signal is taken at the o/p node itself, then it is a voltage Sample i.e. If the load and the β n/w are connected to the same node, then o/p Sampling is Shunt.



(b) If the Sampled Signal is taken from the o/p loop, then it is a Current Sample i.e. if one terminal of the output active device is driving the load and the other terminal is attached to the feedback network then the output Sampling is Series.

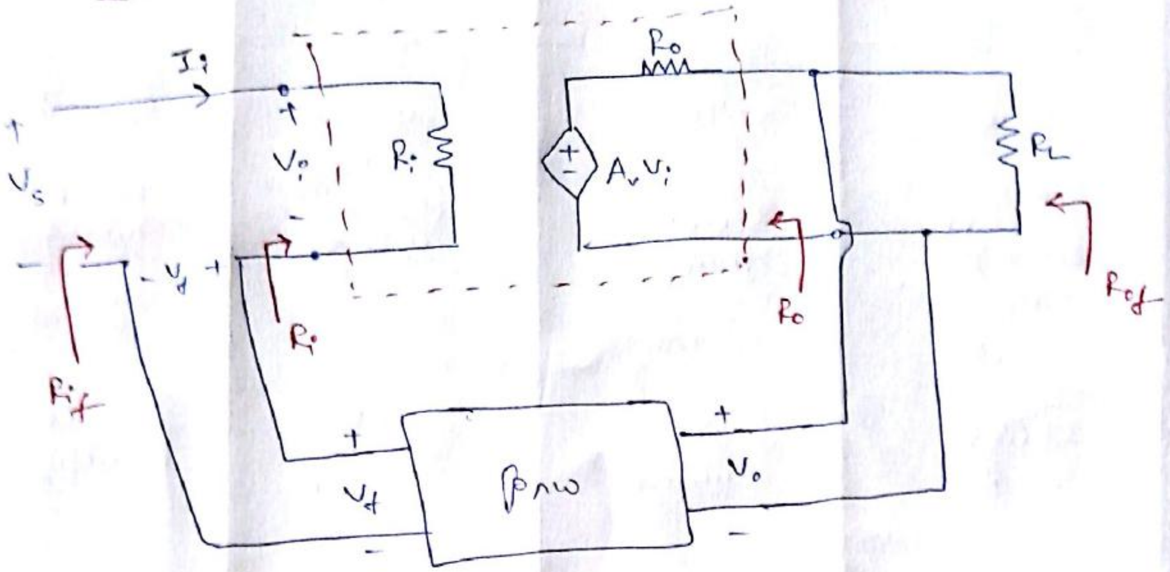


Comparison of Different topologies :

1. X_f, X_s, X_i	Voltage	Voltage	Current	Current
2. Type of Mixing	Series Mixing	Series Mixing	Shunt Mixing	Shunt Mixing
3. X_o	Voltage	Current	Voltage	Current
4. Type of Sampling	Shunt Sampling	Series Sampling	Shunt Sampling	Series Sampling
5. feed topology				
(a) output - input	Voltage - Series	Current - Series	Voltage - Shunt	Current - Shunt
(b) input - output	Series - Shunt	Series - Series	Shunt - Shunt	Shunt - Series
6. Basic Amp. Type $\left(\frac{X_o}{X_i}\right)$	Voltage amp (A_v)	Transconductance Amp (G_M)	Transresistance Amp (R_M)	Current Amp (A_I)
7. Ideal value of				
(a) input impedance ($R_{i\,ideal}$)	∞	∞	0	0
(b) output impedance ($R_{o\,ideal}$)	0	∞	0	∞
8. (a) R_{if}	$R_i(1+A_v\beta)$	$R_i(1+G_M\beta)$	$R_i/(1+R_M\beta)$	$R_i/(1+A_I\beta)$
(b) R_{of}	$R_o/(1+A_v\beta)$	$R_o(1+G_M\beta)$	$R_o/(1+R_M\beta)$	$R_o(1+A_I\beta)$
9. Drawing Basic Amp				
(a) To find input loop, set	$V_o = 0$	$I_o = 0$	$V_o = 0$	$I_o = 0$
(b) To find O/P loop, set	$I_i = 0$	$I_i = 0$	$V_i = 0$	$V_i = 0$
10. practical feedback ckt	CC amp, CD amp, (emitter follower, Source follower)	CE amp, CS amp,	CE amp, CS amp with FB resistor from C (D) to B (G).	Cascade of Two CE stages with FB from 2nd emitter to first base through resistor, R'.

Effect of -ve FB on Input and Output resistances.

(1) Voltage - Series Feedback:



(a) Since the feedback signal, V_f opposes V_s, the input current I_i is less than it would be if V_f were absent. Hence the i/p resistance with feedback, $R_{if} \simeq \frac{V_s}{I_i}$ is greater than the i/p resistance without feedback, $R_i \cdot (= \frac{V_i}{I_i})$

Let A_v = open ckt voltage gain (taking R_s into account).

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

$$R_{if} = \frac{I_i R_i + \beta(A_v \cdot I_i R_i)}{I_i} = \frac{I_i(R_i + A_v \beta R_i)}{I_i}$$

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

Hence i/p resistance with series mixing is increased.

(b) Effect of FB on o/p resistance :

* Negative Feedback which samples the o/p voltage, regardless of how this O/p signal is returned to the input, tends to decrease the o/p resistance.

Let R_{of} = output resistance with FB, looking into the o/p terminals but with R_L disconnected.

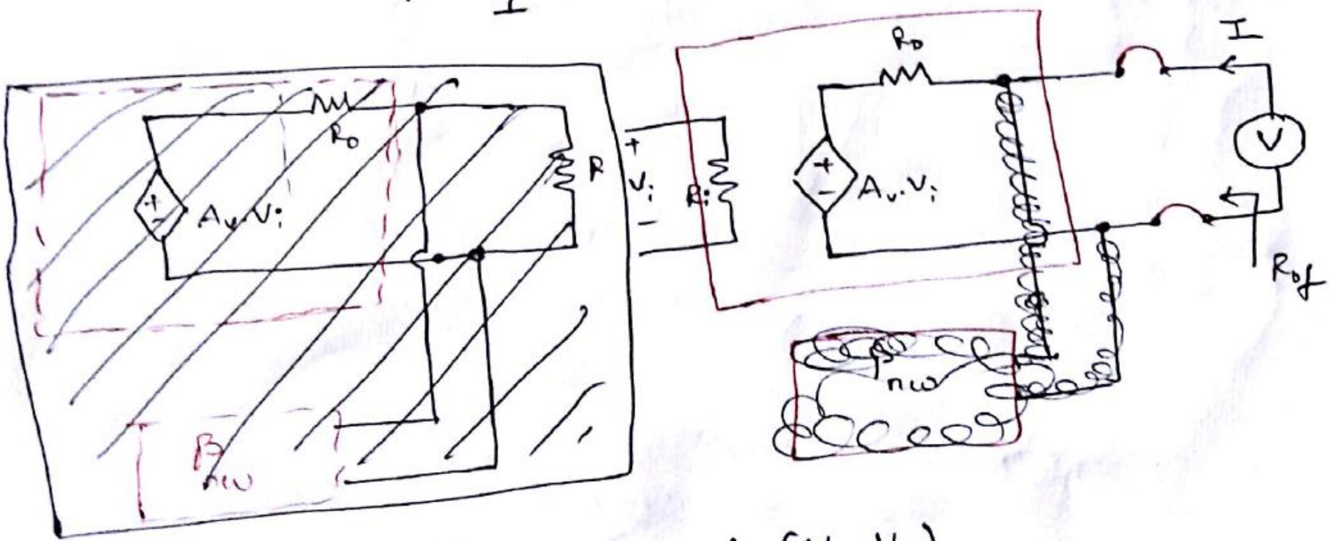
To find R_{of},

(i) we must remove externally applied i/p signal i.e. set $V_s = 0$.

(ii) remove R_L (ie. $R_L = \infty$).

(iii) Apply a voltage V across the o/p terminals, and calculate the current I delivered by V.

Then $R_{of} = \frac{V}{I}$



$$I = \frac{V - A_v V_i}{R_o} = \frac{V - A_v(V_s - V_f)}{R_o}$$

Since $V_s = 0$, $I = \frac{V - A_v V_f}{R_o} = \frac{V - A_v(-\beta V)}{R_o} = \frac{V(1 + A_v\beta)}{R_o}$

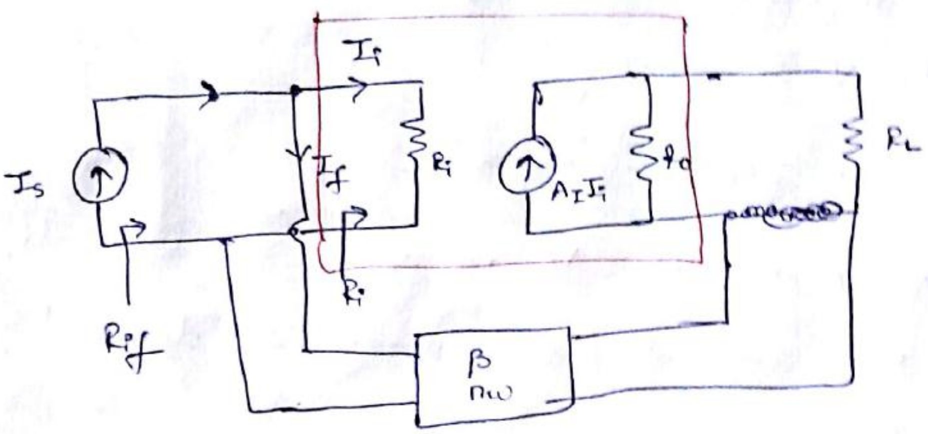
Hence $R_{of} = \frac{V}{I} = \frac{R_o}{1 + A_v\beta}$

and R_{of}' = output resistance with FB ~~which~~ including R_L

$R_{of}' = R_{of} \parallel R_L$

~~In other way, $R_{of}' = \frac{R_o'}{1 + A_v\beta}$ where $R_o' = R_o \parallel R_L$~~

(2) Current - Shunt Feedback:



(a) R_{if} = input impedance with FB = $\frac{V_i}{I_s}$

R_i = input impedance of B.A = $\frac{V_i}{I_i}$

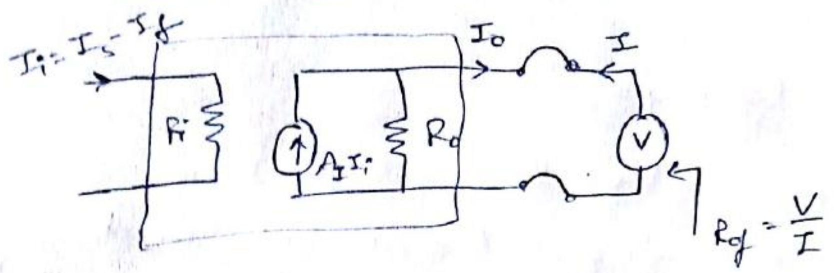
$I_s = I_i + I_f = I_i + A_I I_o = I_i + A_I \beta I_i$

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

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

Hence shunt mixing reduces the i/p resistance of B.A by $(1 + A_I\beta)$ times.

(iii) effect of -ve FB on o/p impedance :



from KCL at output node, $I + A_I I_i - \frac{V}{R_o} = 0$

$$I = \frac{V}{R_o} - A_I I_i = \frac{V}{R_o} - A_I(I_s - I_f)$$

Since $I_s = 0$, ~~for~~ while calculating o/p impedance,

$$I = \frac{V}{R_o} - A_I(-I_f) = \frac{V}{R_o} + A_I(\beta I_o)$$

but $I_o = -I$, so $I = \frac{V}{R_o} - A_I \beta I$

$$I + A_I \beta I = \frac{V}{R_o}$$

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

$$\therefore \quad R_{of} = \frac{V}{I} = R_o(1 + A_I \beta).$$

Hence o/p impedance of Basic amplifier with shunt Sampling increases by a factor of $(1 + A_I \beta)$.

ANALYSIS OF A FEEDBACK AMPLIFIER:

procedure:

1. Identify the topology

2. Draw the basic amplifier ckt without FB, but taking the loading of the β nw into account, which is obtained by applying following rules.

   (a) To find the input ckt:

   (i) Set $V_o = 0$ for voltage Sampling ie. short the o/p node.

   (ii) Set $I_o = 0$ (open the o/p loop) for Current Sampling

   (b) To find the Output ckt:

   (i) Set $V_i = 0$ (short the i/p node) for Shunt Mixing

   (ii) Set $I_i = 0$ (open the i/p loop) for Series Mixing.

3. Replace each active device by the proper model ie. the hybrid-π Model for a Tr. at HF and h-parameter (or) r-parameter (or) Hybrid π LF Model at low frequencies

4. Indicate X_f and X_o then calculate $\beta = \frac{X_f}{X_o}$

5. Evaluate 'A' by using KCL (or) KVL to the equivalent ckt

6. From A and β values,

   find $D = 1 + A\beta$

   $A_f = A / 1 + A\beta$

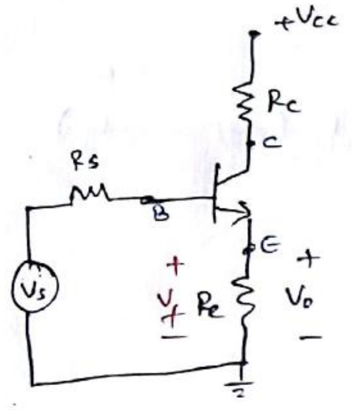
   $R_{if} =$

   $R_{of} =$

VOLTAGE - SERIES FB:

ex: emitter follower, Source follower

(1) EMITTER FOLLOWER (Common Collector Amplifier):



$\underline{S_1}$: For the given ckt,

the feedback signal is the voltage across Re (V_f), which is in series with applied input signal, U_s.

So Series Mixing.

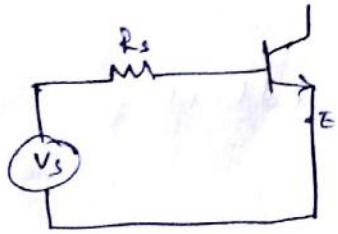
Since the o/p and feedback are taken at same node, the output sampling is shunt (or) voltage sampling.

Hence the topology involved is <u>Voltage - Series</u> (or) <u>Series - Shunt</u>.

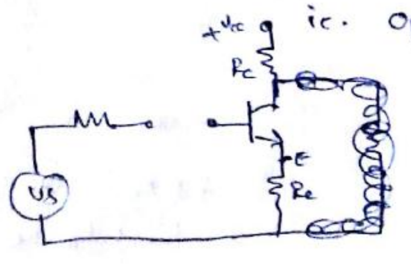
$\underline{S_2}$: Draw the Basic Amplifier ckt without FB, but taking the loading of β nw into account

(a) To find input ckt, set $V_o = 0$ for voltage sampling.

then Re will not appear in the input loop, hence V_s in series with Rs, appears between B and E.

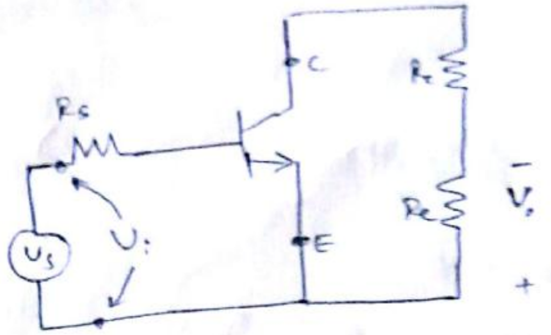


(b) To find the output ckt, set $I_i = 0$ for Series Mixing. ie. Open the input loop formed by the voltages - ie. $I_b = 0$



Now Re appears in o/p side only, as there is no i/p current ($I_b = I_i = 0$) is flowing

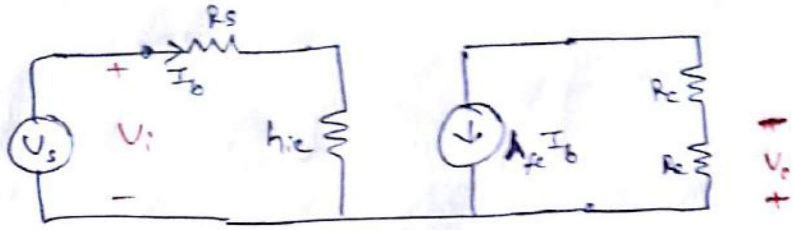
Now the ~~[illegible]~~ ckt represents is equivalent



Assume Rs is part of amp.

$\therefore \quad V_i = V_s$

$\underline{S_3}$: Replace BJT with h-parameter model. (approximate).



$$A_v = \frac{V_o}{V_i} = \frac{h_{fe} I_b R_e}{V_s} = \frac{h_{fe} I_b R_e}{I_b (R_s + h_{ie})} = \frac{h_{fe} R_e}{R_s + h_{ie}}$$

$$\beta = \frac{X_f}{X_o} = \frac{V_f}{V_o} = 1$$

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

$$A_{vf} = \frac{A_v}{D} = \frac{A_v}{1 + A_v \beta} = \frac{h_{fe} \cdot R_e}{R_s + h_{ie}} \times \frac{R_s + h_{ie}}{R_s + h_{ie} + h_{fe} R_e}$$

$$A_{vf} = \frac{h_{fe} \cdot R_e}{R_s + h_{ie} + h_{fe} \cdot R_e} \simeq 1. \quad \text{i.e. emitter follower}$$

R_i = input impedance without feedback (i.e. from the equivalent ckt)

$$R_i = R_s + h_{ie}$$

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

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

Since we used Simplified h-parameter, $h_{oe} = 0$ i.e. $R_o = \infty$

$$\therefore \quad R_o' = R_e \parallel R_o = R_e \qquad \therefore \quad R_{of}' = \frac{R_o'}{1 + A_v \beta} = \frac{R_e (R_s + h_{ie})}{R_s + h_{ie} + h_{fe} \cdot R_e}$$

* The Voltage Series FB desensitizes voltage gain w.r.t. changes in h_{fe} and also increases the input resistance, and decreases the o/p resistance.

Fundamental Assumptions for feedback Amp Analysis:

1. The input Signal is transmitted to the o/p through the amplifier 'A' but not through the β network.

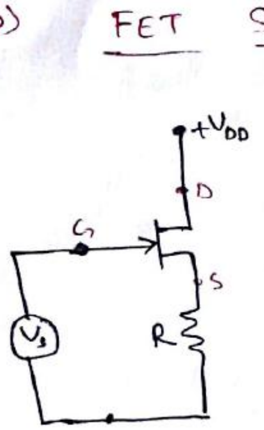
   i.e. If the Amplifier (A) is deactivated, (say, Set $A=0$ by reducing ~~h_{fe}~~ $h_{fe}=0$ for BJT, $g_m=0$ for FET) then the output Signal must drop to zero.

2. The feedback Signal is transmitted from the o/p to the i/p through βnw, but not through the amplifier.

   i.e. the basic amplifier is Unilateral from input to output, and the reverse transmission is zero.

3. The reverse transmission factor, β of the ~~network~~ feedback network is independent of the load and the Source resistances (R_L and R_s).

(b) FET Source Follower:



S1: Identify the topology.

Since the feedback Signal, V_f is the voltage across 'R', which is in Series with applied i/p voltage, V_s, So Series Mixing.

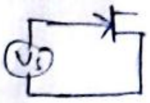
Since the o/p and βnw are at the same node it is Voltage Sample (or) Shunt Sample.

Hence the topology is "Voltage - Series" (or) "Series - Shunt".

S. To Draw Basic amplifier with loading of β n/w,

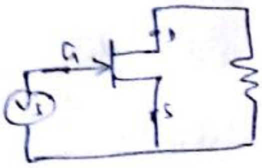
(a) To find the input ckt, Set $V_o = 0$ (Short the o/p node).

Hence $V_s = V_i$ i.e. V_s appears directly between Gate and Source

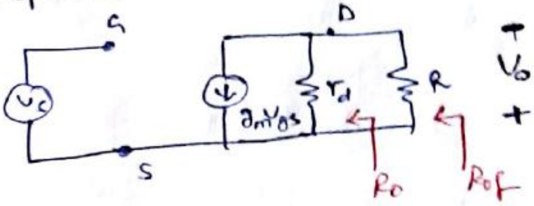


(b) To find the o/p ckt, Set $I_i = 0$ ~~or~~ i.e. break the input loop formed at input side now R appears only in the output loop.

Now Draw the equalent ckt.



S_3: Replace FET with equalent model.



S_4: Calculate A_v, β, A_{vf}, R_{if}, R_{of}.

$$A_v = \frac{V_o}{V_s} = \frac{g_m V_{gs}(r_d // R)}{V_{gs}} = g_m(r_d // R) = \frac{g_m r_d R}{r_d + R} = \frac{\mu \cdot R}{r_d + R}$$

$$\beta = \frac{V_f}{V_o} = 1.$$

$$1 + A_v\beta = 1 + \frac{\mu \cdot R}{r_d + R} = \frac{r_d + R + \mu \cdot R}{r_d + R} = \frac{r_d + (1+\mu)R}{r_d + R}$$

$$A_{vf} = \frac{A_v}{1 + A_v\beta} = \frac{\mu \cdot R}{r_d + R(1+\mu)} \simeq 1.$$

Since R_i of FET is very large bcz RB G-S Junction,

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

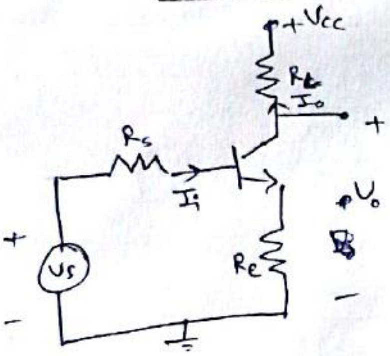
$$R_o = r_d \quad \text{and} \quad R_{of} = R // r_d$$

$$R_{of}' = \frac{R_{of}}{1 + A_v\beta} = \frac{(R // r_d)}{1 + \frac{\mu \cdot R}{r_d + R}} = \frac{R \cdot r_d}{r_d + R(1+\mu)}$$

Hence Voltage - Series FB desensitizes Voltage gain and increases i/p resistance and decreases the o/p resistance.

2. CURRENT- SERIES Feedback:

(a) CE amplifier with emitter resistor, Re (CE with Re)



S_1: The feedback signal is the voltage, V_f, across Re, which is in series with the applied input signal, V_s.

Hence series mixing.

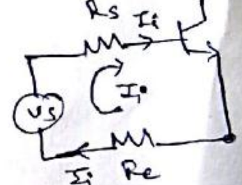
$V_o = V_{CE} + I_e R_e = V_{CE} + V_f$

Since the feedback signal is a part of output loop, the type of sampling is Current sample.

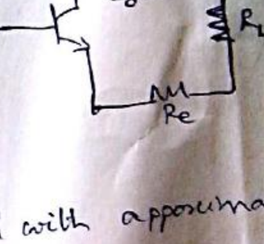
The topology is Current - Series (or) Series - Series feedback.

S_2: Draw Basic amp by considering the loading of β nw.

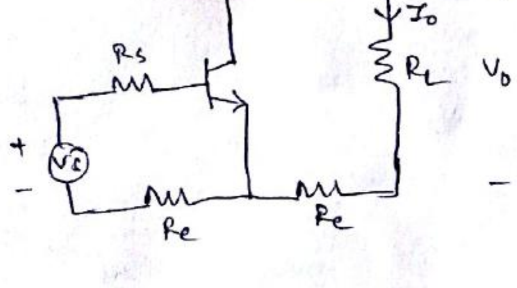
(a) To draw i/p side, set $I_o = 0$ for current sampling. So no o/p current flows in the Re, the current that flows in Re is the input current ie. I_i or I_b.



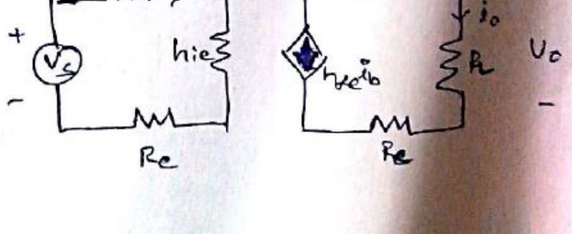
(b) To draw o/p side, set $I_i = 0$ ie. break the loop at input for series mixing. So only output current flows in Re ie Re should present in only outputside.

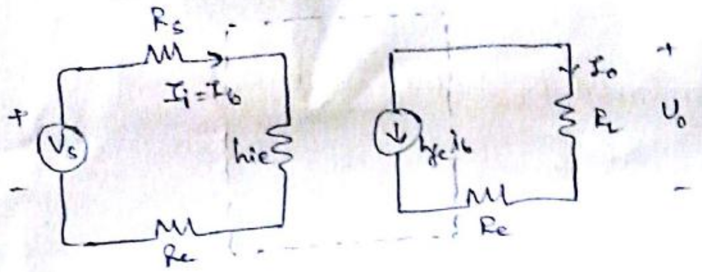


Combine both ckts. to get Basic amp with loading of β nw.



S_3: replace Tr symbol with approximate h-parameter model.





$\underline{S_4}$ A = gain of B. $A = \frac{V_o}{V_i}$

$$A = \frac{I_o R_L}{I_i\, hie} = \frac{-h_{fe} i_b R_L}{I_i\, hie}$$

$$A = \frac{-h_{fe} R_L}{hie}$$

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

V* If we think, ~~V_o then (i.e. voltage sample)~~ I_o is proportional to V_o, it is not correct to conclude that this is a Voltage-Series feedback. Thus, if the o/p signal is taken as the Voltage V_o, then $\beta = \frac{V_f}{V_o} = \frac{-I_o R_e}{I_o R_L} = \frac{-R_e}{R_L}$

Since β is now a function of the load R_L, but the assumption of β now should be independent of R_L and R_s is going wrong.

Current Series FB has basic amplifier is Transconductance amp, whose gain is $G_M = \frac{X_o}{X_i} = \frac{I_o}{V_i} = \frac{-h_{fe} i_b}{i_b(R_s + hie + R_e)}$

$$G_M = \frac{-h_{fe}}{R_s + hie + R_e} \quad \text{and} \quad \beta = -R_e$$

$$D = \text{Desensitivity factor} = 1 + G_M \cdot \beta = 1 + \frac{h_{fe} R_e}{R_s + hie + R_e}$$

$$D = \frac{R_s + hie + R_e(1 + h_{fe})}{R_s + hie + R_e}$$

G_{Mf} = gain of Transconductance with FB $= \frac{G_M}{D} = \frac{G_M}{1 + G_M \beta}$

$$G_{Mf} = \frac{-h_{fe}}{R_s + hie + R_e(1 + h_{fe})} = \frac{X_o}{X_s} = \frac{I_o}{V_s}$$

$$\therefore I_o = G_{Mf} \cdot V_s = \frac{-h_{fe} \cdot V_s}{R_s + hie + R_e(1 + h_{fe})}$$

Since $R_e(1 + h_{fe}) \gg R_s + hie$ and $h_{fe} \gg 1$, $I_o = \frac{-V_s}{R_e}$.