OM SAKTHI

UNIT- I

Introduction

* Ideal Amplifier given stable o/p of the given I/p signal.

* But gain and stability of practical amplifier is not good, because of ambient temp, device parameter and non-Linearity of the devices.

They are avoided by Feedback Amplifier.

Feedback

A portion of the o/p signal is feedback to the I/p and combined with the I/p signal to produce the desired o/p is called feedback.

Types:-

(1) Negative F.B (Degenerative):

The portion of o/p signal is substracted from the I/p signal to produce desired o/p.

(2) Positive F.B (Regenerative):

The portion of the o/p signal is Added to the I/p signal to produce desired o/p.

Adv. of -ve F.B

(1) Higher I/p & lower O/p Impedance.

(2) Improved gain sensitivity.

(3) Reduced Noise

(4) Increased BW

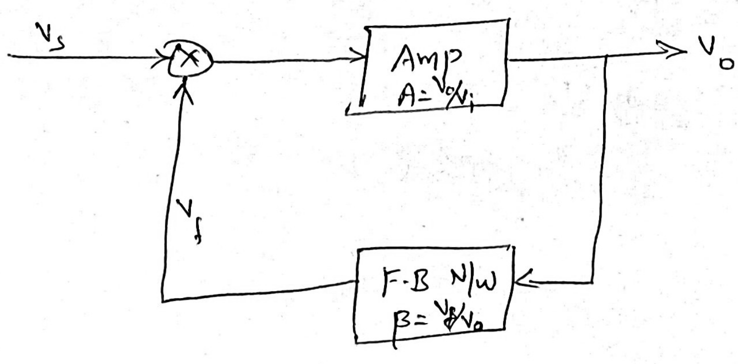
(5) Reduced Distortion.

Dis:-

(1) Reduced ckt overall gain

(2) Reduced stability at high freq.

Block Diagram of F.B Ckt :-



where, V_s - I/p signal

V_o - O/p signal ($V_o = AV_i$)

V_f - F.B signal ($V_f = \beta V_o$)

* Gain of the amplifier without F.B

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

* I/p signal applied to the amplifier is,

$$V_i = V_s \pm V_f$$

(or)

$$V_i = V_s \pm \beta V_o$$

(or)

$$V_s = V_i \pm A\beta V_i \qquad [\because V_o = AV_i$$

$$\boxed{V_s = V_i(1 + A\beta)}$$

where, $A\beta$ - loop gain of the amplifier.

* The Gain of the amplifier with F.B is,

$$A_f = \frac{V_o}{V_s} = \frac{AV_i}{V_i(1 \pm A\beta)} = \frac{A}{1 \pm A\beta}$$

Note

* -ve sign for +ve F.B, ie; $A_f = \frac{A}{1 - A\beta}$

* +ve sign for -ve F.B, ie; $A_f = \frac{A}{1 + A\beta}$

* $1 \pm A\beta$ – desensitivity Factor.

* Densensitivity Factor : The Reciprocal of sensitivity is called Densensitivity.

* Sensitivity :- It is the ratio of fractional change in amplifier with F.B to the fractional changes in amplifier without F.B $\left(\because S = \frac{1}{1+A\beta}\right)$

Positive F.B

* Volt gain of a F.B is greater than the open loop gain.
* If $A\beta$ - approaches unity then the closed loop gain becomes infinity.
* Ckt should given an o/p without any I/p.
* Dis: Increased distortion and Instability and noise.

Negative F.B

* O/p signal out of phase with I/p, i.e; I/p signal is decreases, It is called -ve F.B.
* If $(1+A\beta) > 1$ then the closed loop gain reduces from the o/p open loop gain A. So they called degenerative F.B.
* If $(1+A\beta) >> 1$,

$$A_{vf} = \frac{A}{1+A\beta} \approx \frac{A}{A\beta} \approx \frac{1}{\beta}$$

* F.B gain depends on β, i.e; A_{vf} inversely proportional to F.B factor β.

Properties of Negative Feedback:-

Performance Measurement of Negative Feedback Amplifiers

Advantages

(1) Improved stability

(2) Reduction in gain

(3) Reduction in distortion

(4) Reduction in noise

(5) Increase the I/p Impe.

(6) Decrease the O/p Impe.

(6) Increase in BW.

Proof

(1) Improved stability:-

The gain of the amplifier negative F.B is given by,

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

If $1+A\beta \simeq A\beta$ then $A_f = \frac{A}{A\beta} = \frac{1}{\beta}$

$\therefore A_f$ depends on β

ie; A_f (F.B amplifier gain) does not affected by changes in temp, transistor parameters and frequency. So A_f (gain) of the amplifier is extremely stable.

(2) Reduction in forward Gain :-

The Forward gain of the -ve F.B can be calculated as follows.

Let, $V_i = V_s - V_f$

$V_f = \beta V_o$ and $V_o = AV_i$

$\therefore V_o = AV_i = A(V_s - V_f)$

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

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

$$A_f = \frac{V_o}{V_s} = \frac{A}{1+A\beta}$$ [$\because$ Closed loop gain is less than of open loop gain A

ie; A_f is depends on densisitivity factor of $(1+A\beta)$

(3) Reduction in Distortion

D = Distortion in amplifier without F.B

D' = Distortion in amplifier with F.B

Assume, $D' = xD$. ——— (1)

* Therefore the fraction of O/p distortion which is fed back to I/p is,

$$\beta D' = \beta x D$$

* After amplification the distortion becomes $\beta x DA$, it is antiphase with original distortion D.

* hence the new distortion $D' = D - \beta x DA$ ——— (2)

Date: 04-01.12

Compare now the Equ. ① & ②,

$$xD = D - \beta x D A$$

(or)

$$xD + \beta x D A = D$$

(or)

$$x = \frac{D}{D(1+\beta A)} = \frac{1}{1+\beta A}$$

Thus, $D' = xD = \dfrac{D}{1+\beta A}$

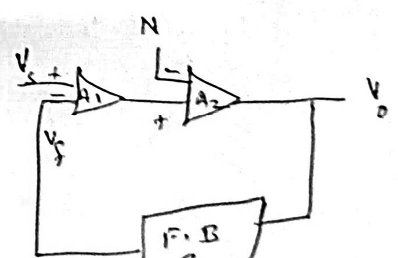
However the Improvement in the distortion is possible only if the distortion produced by the amplifier itself, not when it is already present in the i/p signal.

(4) Reduction in Noise :-

* considered F.B ckt with two amplifier (A_1 & A_2)
* N is noise introduced after stage-1. Therefore o/p volt. can be expressed as,

$$V_o = \overset{A}{A_1 A_2} \overset{V_f}{V_s} - A_2 N - A_1 A_2 \beta V_o$$

$A_2 = \frac{V_o}{N}$ $\quad \beta = \frac{V_f}{V_o}$



$$V_o [1 + A_1 A_2 \beta] = A_1 A_2 V_s - A_2 N$$

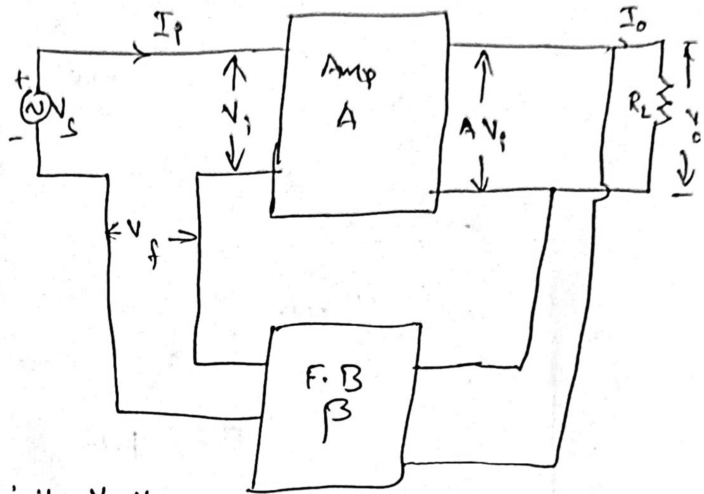
$$= A_1 A_2 \left[V_s - \frac{N}{A_1} \right]$$

$$V_o = \frac{A_1 A_2}{1+A_1 A_2 \beta} \left[V_s - \frac{N}{A_1} \right] = \frac{A_1 A_2 V_s}{1+A_1 A_2 \beta} - \frac{N A_2}{1+A_1 A_2 \beta}$$

∴ The overall noise of the two stage amplifier is reduced by the factor of $(1 + A_1 A_2 \beta)$

(5) Increased I/p resistance :-

$R_i = \frac{V_i}{I_i}$ [I/p impe. of Amplifier without F.B]



$R_{if} = \frac{V_s}{I_i}$ [I/p impe of Amplifier with F.B]

From fig,

$V_s = V_i + V_f = V_i + \beta A V_i$ ← βV_o or AV_i

[∵ $V_i = V_s - V_f$

$V_s = V_i + V_f$

but,

$V_i = I_i R_i$

$V_s = I_i R_i [1 + \beta A]$

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

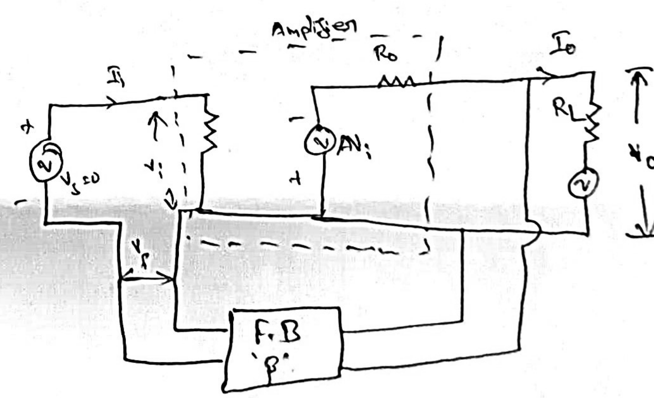
R_{if} = R_i multiplied by the desensitivity factor $(1 + A\beta)$, hence it is increased by $(1 + \beta A)$.

(6) O/p Impedance

R_o = O/p Impe. of the amplifier without F.B

R_{of} = " " " with F.B

from figure,



$V_o = AV_i + I_o R_o$

(or)

$I_o R_o = V_o - AV_i$

we know, $V_s = V_i + V_f$

Assume $V_s = 0$ ∴ $V_i = -V_f$

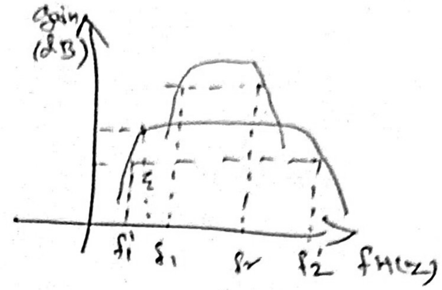
$I_o R_o = V_o + A V_f = V_o + A\beta V_o = V_o (1 + A\beta)$

(or)

$$\boxed{\frac{V_o}{I_o} = \frac{R_o}{1 + A\beta}}$$

[o/p impe. is decreased by the factor of $(1 + \beta A)$

(6) Increased BW:-



* BW is difference b/w two cut off freq.

i; $BW = f_2 - f_1$

* BW is increased in F.B ckt & gain of the amplifier is decreased.

- Thus the gain BW product is remains the same ~~(proof)~~

Proof

(a) Lower cut-off freq. of without F.B amplifier:

$$\text{gain}, A_L = \frac{A_m}{1 - j(f_1/f)}$$

A_m - Voltage gain in mid freq range
f_1 = Lower cut-off freq. of amplifier without F.B.

The gain of the amplifier with feedback (at lower cut-off freq.) can be written as,

$$A_{vf} = \frac{A_L}{1 + A_L\beta} = \frac{\frac{A_m}{1-j(f_1/f)}}{1 + \beta\frac{A_m}{1-j(f_1/f)}} = \frac{A_m}{1 - j(f_1/f) + \beta A_m}$$

$$= \frac{A_m}{1 + \beta A_m - j(f_1/f)} = \frac{A_m}{1+\beta A_m}\left[\frac{1}{1 - j\left(\frac{f_1}{f(1+A_m\beta)}\right)}\right]$$

$$A_{vf} = \frac{A_{mf}}{1 - j\left(\frac{f_1'}{f}\right)} \qquad \left[\because f_1' = \frac{f_1}{1 + A_m\beta} \;\&\; A_{mf} = \frac{A_m}{1+\beta A_m}\right.$$

* Equ. shows $f_1' < f_1$

i; -ve F.B decreases Lower cut-off freq by the factor of $(1+A_m\beta)$

(b) Upper cut-off freq of a F.B amplifier

$$\text{gain, } A_{vf} = \frac{A_m}{1+j(f/f_2)}$$

$$A_{vf} = \frac{A_{vf}}{1+A_{vf}\beta} = \frac{\frac{A_m}{1+j(f/f_2)}}{1+\left(\frac{A_m}{1+j(f/f_2)}\right)\beta} = \frac{A_m}{1+j(f/f_2)+A_m\beta}$$

$$A_f = \frac{A_m}{1+A_m\beta}\left(\frac{1}{1+j\left(\frac{f}{f_2(1+A_m\beta)}\right)}\right) = \frac{A_{mf}}{1+j\,(f/f'_2)}$$

where, $f'_2 = f_2(1+A_m\beta)$ = upper cut off freq with F-B.

$A_{mf} = \frac{A_m}{1+A_m\beta}$ = midband gain of the amplifier with F.B

* equ. show that $f'_2 > f_2$

is; upper cut-off freq. is increased in -ve F.B.

∴ BW is high is -ve F.B

Basic - Feedback Topologies

In F.B amplifier, sample o/p volt. (or) Ct by means of sampling (or) feedback N/W and applied ~~at~~ the I/p of the Amplifier.

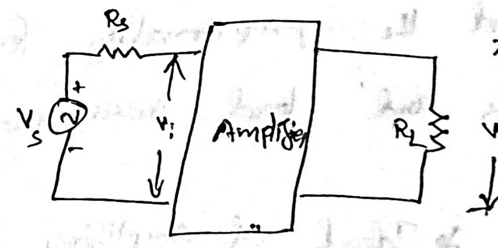
Based on the quantity to be amplified the amplifiers are classified into 4 types.

(1) Volt. Amplified (2) Ct Amplifier

(3) Trans conductance Amplifier (4) Trans resistance Amplifier.

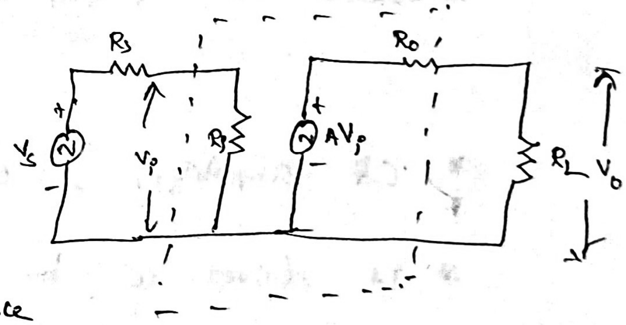
(1) Voltage Amplifier (or) Voltage Controlled Volt. Source (VVS)

In this amplifier,



V_i - I/P Volt.

V_o = O/P Volt.



* ideal Volt. Sources (or) Volt. Amplifier

$R_i >> R_s$ thus $V_i \simeq V_s$

where

* R_i, R_s are I/P & Source resistance

and also If $R_L >> R_o$, thus

$V_o = A_v V_i$ (or) $V_o \simeq A_v V_s$

Note: * O/P V_o is directly proportional to I/p Volt. and proportionality factor is independent of the magnitudes of the source and load resistances. It is called 'Voltage Amplifier'

* Ideal Volt. Amplifier → R_i - Infinite

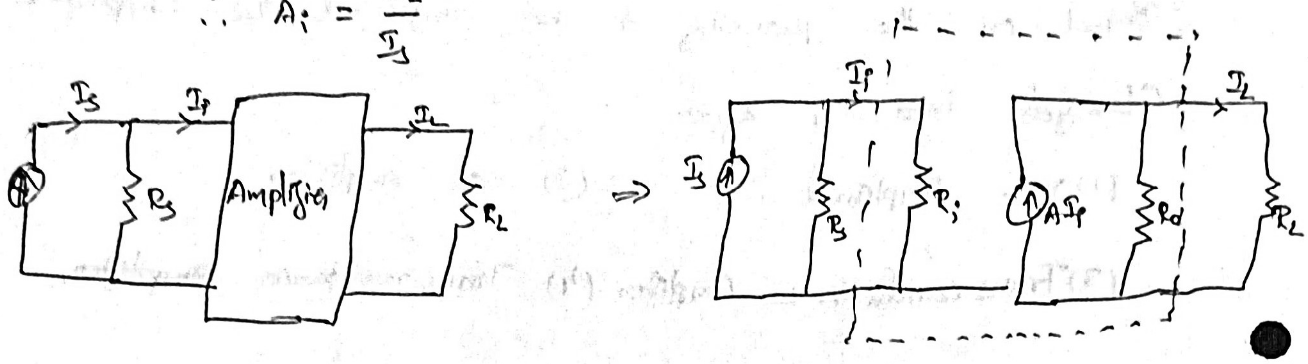
R_o - zero

(2) Current Amplifier (or) Voltage Controlled Current Sources (VCS)

* In this ckt, o/p signal & F.B signals are current.

* $R_i << R_s$ & $I_i \simeq I_s$ and also $R_o >> R_L$ then $I_L \simeq A_i I_i$

$$\therefore A_i = \frac{I_L}{I_s}$$



* O/p Ct is directly proportional to the I/p signal current I_s, and the proportionality factor is independent of source resistance R_s and load resistance R_L.

* Ideal Ct Amplifier $\rightarrow$ $R_i = 0$

$R_o = \infty$ (Infinite)

* Ct amplifier is opposite to that of Voltage Amplifier

* It drives a low resistance load and Volt. amplifier driven by a high resistance source.

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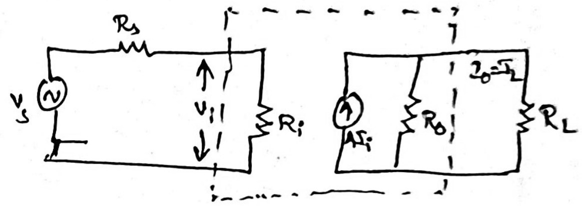
(3) Transconductance Amplifier (or) Cr Controlled volt. Source :-

* It is the ratio of Cr in one loop to volt. in some other loop.

* In this amplifier, volt is given I/p (V_i) and Cr is taken o/p.

* $I_o \propto V_i$

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



* In this case, $R_i \gg R_s$ then $V_i \simeq V_s$ ~~and If $R_o \ll R_L$~~

then, $I_o = G_m V_i \simeq G_m V_s$

Since $R_o \gg R_L$, it drives a low resistive load.

(4) Transresistance Amplifier (or) Current Controlled Current Source (CCS)

* It is the ratio of volt. in one loop to current in some other second loop.

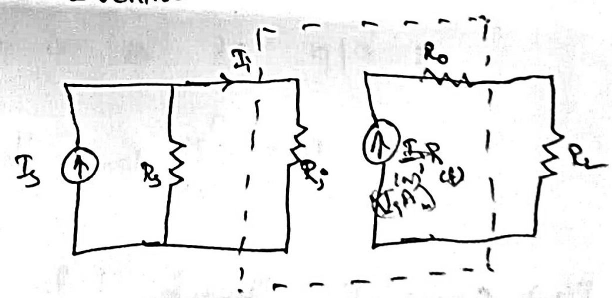
* Cr source act as I/p signal & volt. is taken as o/p

* I/p is represent as norton equ. ckt

o/p is " as thevenins "

* $R_s \gg R_i$, then $I_i \simeq I_s$

If $R_o \ll R_L$



then $V_o = R_m I_i \simeq R_m I_s$

$A_m I_i \approx A_m I_s$

R_m (or) $A_m = \frac{V_o}{I_i}$, with $R_L = \infty$

$\therefore R_m$ is the open-ckt mutual (or) transfer resistance.

I/p & O/p resistance with F.B

* There are 4- basic ways to connecting F.B signal.

* Both Ct (or) Volt. can be F.B to the I/p either in series (or) parallel.

* It is classified as, (1) Volt. Series F.B Connection
(2) Volt. Shunt F.B Connection
(3) Current Series F.B Connection
(4) Current Shunt F.B Connection.

(1) Volt. Series F.B :-

* O/p Volt. directly proportional to the I/p Volt., thus it is used as Volt. Amplifier.

$$A = \frac{V_o}{V_i} \quad (or) \quad V_o = AV_i$$

(2) Volt. Shunt F.B

* O/p Volt. $\propto$ I/p Ct, is also called Trans resistance Amplifier.

$$A = \frac{V_o}{I_i} \quad (or) \quad V_o = AI_i$$

(3) Current Series F.B

* O/p Ct is $\propto$ to I/p Volt. (Trans conductance)

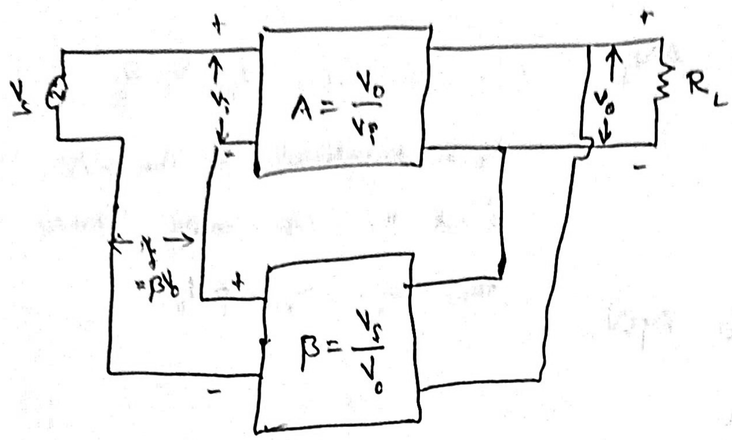
i.e; $A = \frac{I_o}{V_i}$ (or) $I_o = AV_i$

(4) Current Shunt F.B

* O/p Ct $\propto$ I/p Ct (Ct Amplifier)

i.e; $A = \frac{I_o}{I_i}$ (or) $I_o = AI_i$

Voltage Series Feedback [Series - Shunt F.B]



Let, $A_V = \frac{V_o}{V_i}$ = gain of the amplifier without F.B (or) $V_o = V_i A$

If F.B is connected then $V_s = V_i + V_f$ (or) $V_i = V_s - V_f$

$$V_s = V_i + \beta V_o = V_i + \beta A V_i = (1+A\beta) V_i$$

$$A_{Vf} = \frac{V_o}{V_s} = \frac{V_i A}{V_i (1+A\beta)} = \frac{A}{(1+A\beta)}$$

I/p Impedance:

$$V_i = V_s - V_f = R_i I_i$$

Assuming R_o to be negligible,

$$V_s = V_i + V_f = R_i I_i + \beta V_o = R_i I_i + \beta A V_i$$

$$V_s = R_i I_i + I_i R_i \beta A = Z_i I_i + I_i Z_i A\beta$$

$$V_s = Z_i I_i (1 + A\beta)$$

$$\boxed{Z_{if} = \frac{V_s}{I_i} = Z_i (1+\beta A)}$$

Output Impe.

from figure, $V_o = I_o Z_o + AV_i$ Assume $[R_o = Z_o]$

$= I_o Z_o - AV_f$ [as we know $V_i = V_s - V_f$,

$V_s = 0 \Rightarrow V_i = -V_f$

V_s is transferred, to the O/P side to find the O/P impe hence $V_s = 0$

thus $V_i = -V_f = \beta V_o$

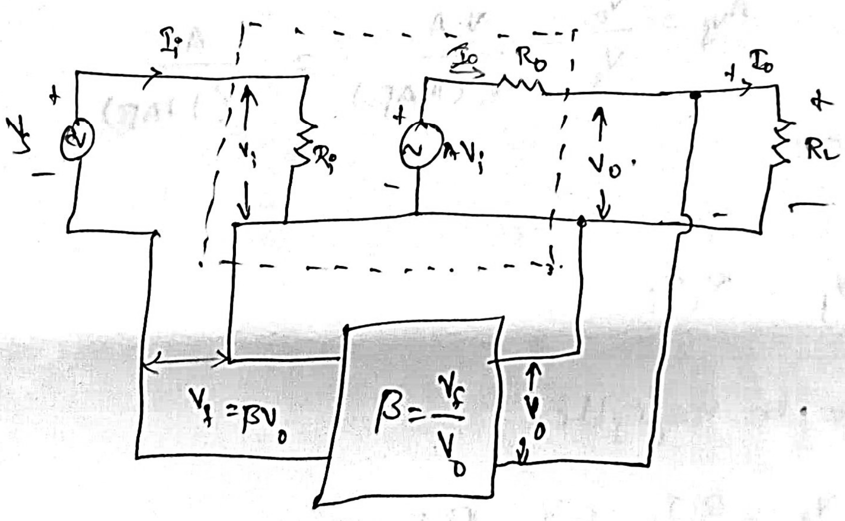
$$V_o = I_o Z_o - A\beta V_o$$

$$V_o(1 + A\beta) = I_o Z_o$$

$$Z_{of} = \frac{V_o}{I_o} = \frac{Z_o}{1 + A\beta}$$ = O/P impe of the amplifier with FB

where, Z_o = O/P impe. of the amplifier without F.B.

Thus the O/P impe. is reduced by a factor of $(1+A\beta)$ from the O/P impe of the amplifier without F.B



9 Voltage Shunt Feedback [Shunt - Shunt F.B]

* o/p signal is fed in parallel with the I/p ckt, thus it is called as volt. shunt F.B.
* I/p ct is varied by o/p volt. because of shunt connection.

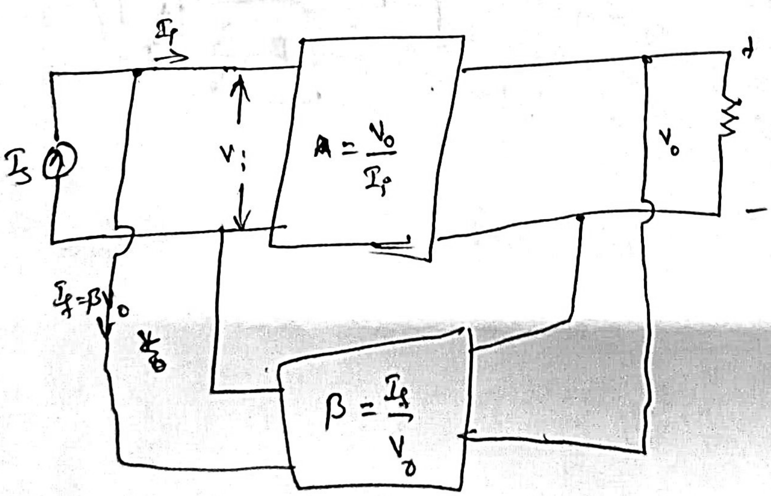
∴ ratio of V_o/I_s, it is called transistance.

Let, * $A = \frac{V_o}{I_i}$ = gain of amplifier without F.B and $\beta = \frac{I_f}{V_o}$

* $I_s = I_i + I_f = I_i + \beta V_o = I_i + \beta A I_i = I_i(1 + A\beta)$

* $A_f = \frac{V_o}{I_s} = \frac{V_o}{I_i + \beta A I_i} = \frac{A I_i}{(1+A\beta)I_i} = \frac{A}{1+A\beta}$

Thus, $\boxed{A_f = \frac{A}{1+\beta A}}$ = gain of the Amplifier with F.B



I/p Impedance:-

* A volt. shunt F.B connection with basic amplifier modelled as a dependent volt. source (shown in fig.)

* The I/p impe. with F.B is given by,

$$Z_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i + I_f} = \frac{V_i}{I_i + \beta V_o} = \frac{V_i}{I_i + \beta A I_i} = \frac{V_i}{I_i(1+A\beta)}$$

$$\boxed{Z_{if} = \frac{Z_i}{1+A\beta}} \qquad \left[\because Z_i = \frac{V_i}{I_i}\right.$$

* I/p Impe. reduced by $(1+A\beta)$. This is true for both volt. shunt and ct shunt F.B connections.

O/p Impe.

From fig.

$$V_o = I_o R_o + A I_i = I_o R_o - A I_f$$

$I_s = I_i + I_f$

$0 = I_i + I_f$

$I_i = -I_f = -\beta V_o$

we know, $I_i = I_s - I_f$

I_s is transferred to o/p side,

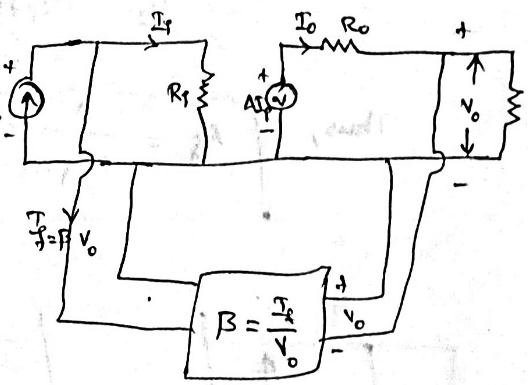
then $I_s = 0$

then $I_i = -I_f = -\beta V_o$

$$V_o = I_o R_o - A\beta V_o$$

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

$$R_{of} = \frac{V_o}{I_o} = \frac{R_o}{1+A\beta}$$



* R_{of} reduced by $(1+A\beta)$, from the amplifier without F.B $Z_o = R_o$.

Thevenin's - Volt. Source
- Ct source
(12) Norton

Method of Identifying Feedback Topology And Basic Amplifier with loading Effect of Feedback:-

Rules For To Identify the Feedback Topology following rules are followed

(1) Identify the Whether the feedback signal applied is a Volt. (or) ~~Circuit~~ Current (or) Identify the Feedback signal is applied in series (or) Shunt with the external excitation.

(2) Identify the sampled signal is a volt. (or) Ct (or) Identify whether the sampled signal is taken at the O/p node (or) loop.

To find the O/p ~~mixing~~ Sampling Circuits

(a) If making $V_0 = 0$ results in the F.B signal $V_f = 0$ then it is known as Volt. Sampling. (or) (Short output node)

(b) If the outer loop $I_0 = 0$ if F.B signal becomes zero then it is known as Current sampling (or) open the output loop

To find the mixing Circuits

(i) If the F.B signal is subtracted from the I/p Volt. Then it is known as Series mixing.

(ii) If the F.B signal is subtracted from the I/p Ct then it is known as Shunt mixing.

To find the I/P Equ. Ckt

(1) for Volt. Sampling set $V_o = 0$

(2) for Ct Sampling set $I_o = 0$

To find the O/P equivalent Circuit

(1) for Series mixing set $I_i = 0$

(2) for Shunt mixing set $V_i = 0$

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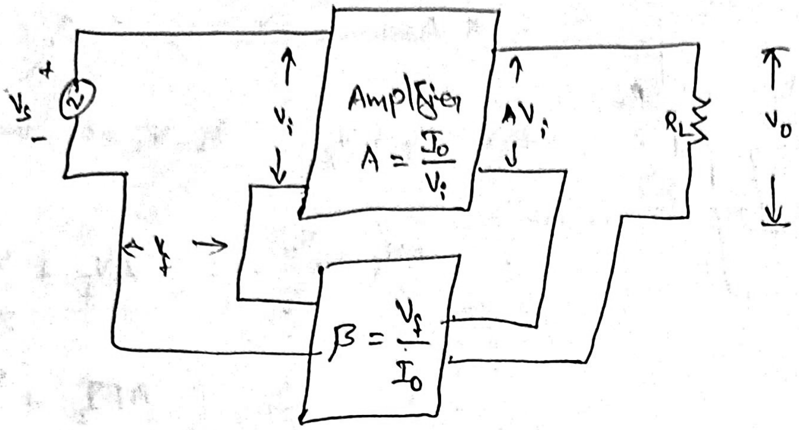
10 Current Series F·B [series - Series F·B]



* O/P ckt is F·B to Series with I/p ckt

∴ I/p Volt is ∝ to I_o.

* The ratio of I_o/V_i is known as transconductance amplifier.

* $R_i >> R_s$ and $R_o >> R_L$ thus, $I_o = I_L$

* without F·B, $A = \frac{I_o}{V_i}$, ~~β=~~

* F·B factor $\beta = \frac{V_f}{I_o}$

* $V_s = V_i + V_f$.

$$\therefore A_f = \frac{I_o}{V_s} = \frac{I_o}{V_i + V_f} = \frac{AV_i}{V_i + V_f} = \frac{AV_i}{V_i + \beta A V_i} = \frac{A}{1+A\beta}$$

* gain reduced by $(1+A\beta)$, when F·B is provided

__I/p Impe__ (from fig)

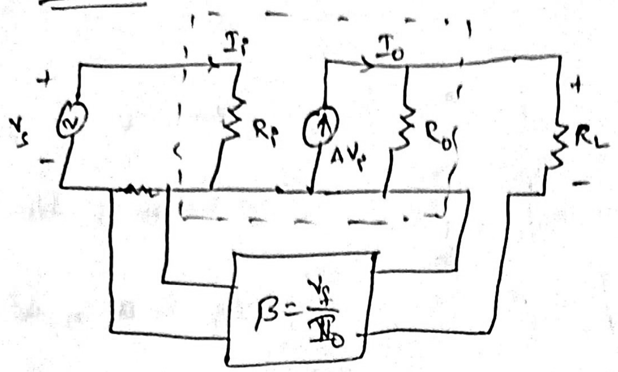
$$V_s = \underbrace{I_i R_i}_{V_i} + V_f = I_i R_i + \beta I_o \cancel{= I_i R_i + \beta A V_i}$$
$$= I_i R_i + \beta A V_i$$

where, $\boxed{I_o = AV_i}$ $= I_i R_i + A\beta I_i R_i$ [where, $V_i = I_i R_i$

$$V_s = I_i R_i (1+A\beta)$$

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

O/p Impe.



* O/p Impe depends on I/p source volt

* Assume $V_s = 0$, $\therefore I_o = ?$

$V_s = V_i + V_f$ If $V_s = 0$, then $V_i = -V_f$

$$I_o = AV_i + \frac{V_o}{Z_o} = -AV_f + \frac{V_o}{Z_o}$$

$$I_o = -A\beta I_o + \frac{V_o}{Z_o}$$

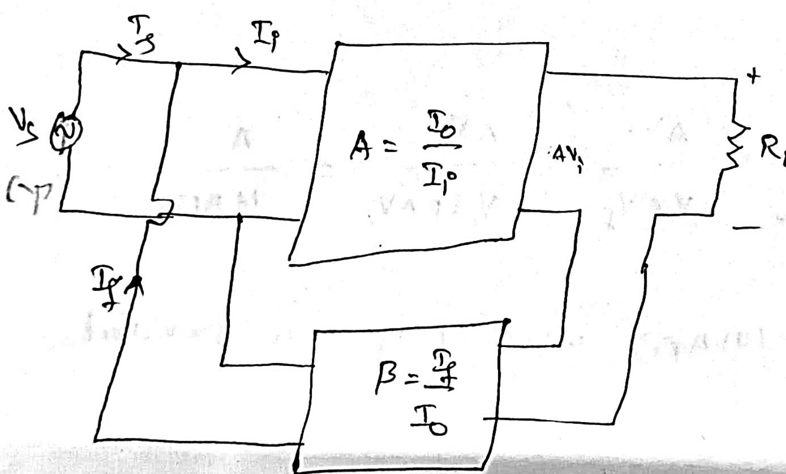
$$I_o(1+A\beta) = \frac{V_o}{Z_o}$$

hence,

$$Z_{of} = \frac{V_o}{I_o} = Z_o(1+A\beta)$$

$\therefore$ O/p Impeed $\uparrow$ by $(1+A\beta)$.

Current Shunt F.B [Shunt Series F.B]



* O/p ~~ckt~~ is F.B paral with I/p ckt

* $\therefore$ ratio of I_o/I_i becomes CF gain thus, this Configurati behave like a CF Amplifier.

* Let the gain of the amplifier without F.B is $A = \frac{I_o}{I_i}$

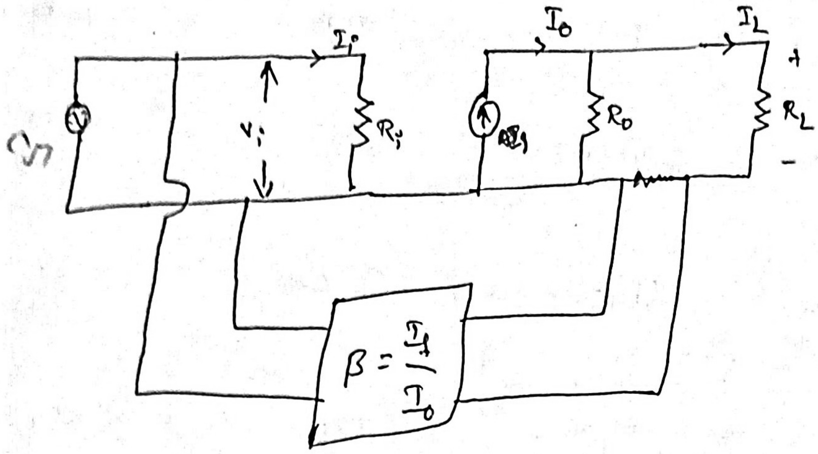
F.B factor, $\beta = \frac{I_f}{I_o}$

* $$A_f = \frac{I_o}{I_s} = \frac{I_i A}{I_i + I_f} = \frac{I_i A}{I_i(1+A\beta)}$$

$I_f = \beta I_o = \beta A I_i$

10

I/p Impe.



From fig,

$$I_s = I_i + I_f = \frac{V_i}{R_i} + \beta I_o = \frac{V_i}{R_i} + \beta A I_i$$

$$I_s = \frac{V_i}{R_i} + \frac{\beta A V_i}{R_i} = \frac{V_i}{R_i}(1+\beta A)$$

$$\therefore \boxed{R_{if} = \frac{V_i}{I_s} = \frac{R_i}{1+A\beta}}$$

O/p Impe

from fig, $I_s = I_i + I_f$ (or) $I_i = I_s - I_f = -I_f$ $[\because I_s = 0$

$$I_o = A I_i + \frac{V_o}{R_o} = \frac{V_o}{R_o} - A I_f = \frac{V_o}{R_o} - A\beta I_o$$

(or)

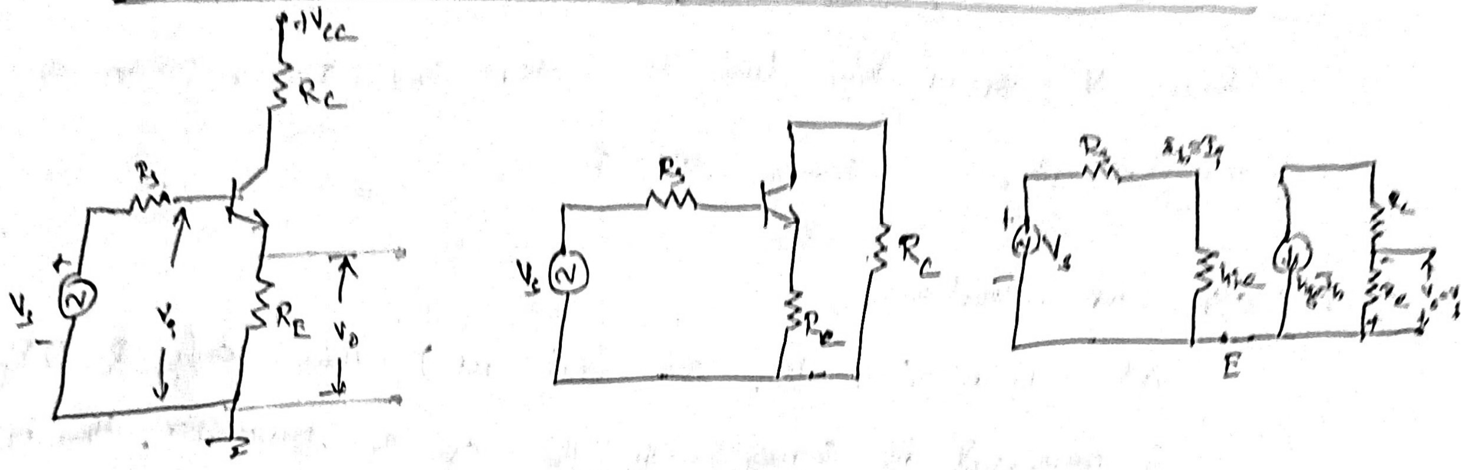
$$I_o(1+A\beta) = \frac{V_o}{R_o}$$

(or)

$$\boxed{R_{of} = \frac{V_o}{I_o} = R_o(1+A\beta}$$

	Volt. Series F.B	Volt. Shunt F.B	Cl Series F.B	Cl Shunt F.B
Gain	decreases	decreases	decr.	decre.
stability	Increases	Increases	Incr.	Incr.
Noise	decr.	decr.	decr.	decr.
Distortion	decr.	decr.	decr.	decr.
I/p Impe.	Incr.	decr.	Incr.	dec.
O/p Impe.	decr	decr.	Incr.	Incr.

13 Voltage Series F.B Amplifier – Emitter Follower



- **Step-1** : Method of identify the topology.

(1) * Voltage drop across the resistor R_E is o/p Volt. it act as F.B Volt. V_f

$\therefore$ gain F.B CKT $\beta = \frac{V_f}{V_o} = 1$

(2) ~~$V_f = 0$~~ F.B Volt. $V_f = V_o$ is connected in series with I/P CKT hence it is known as Volt. Series F.B amplifier. (also called

- Emitter follower).

→ In this CKT, R_E act as F.B element, which is connected in series with the I/P CKT refer.

Step-2 (Find the I/P & O/P CKT)

(3) In this amplifier, V_o = O/P Volt. & V_f = F.B Volt.

without F.B is $A = \frac{V_o}{V_s}$

with F.B is $A_f = \frac{V_o}{V_i}$

The F.B signal $V_f = \beta V_o$ (or) $\beta = \frac{V_o}{V_f}$ $\frac{V_f}{V_o}$

(4) from Equ. CKt, (I/p CKt Analysis)

$V_0 = 0 \Rightarrow R_E = 0$; I/p side hie series with Rs.

Assume, $V_o = 0$ (or) short CKt , $\therefore R_E = 0$

- hence V_s appear b/w base & emitter, and I/p resistance of transistor hie is series with R_s.

(5) O/P CKt Analysis :-

- set $I_i = 0$ (I/p loop is open CKt), thus only R_c & R_E is connected in series with ~~the~~ of the transistor, thus in the O/p CKt transistor is replaced by Ct sources which is connected in series with R_c & R_E.

(6) - I/p signal $V_i = V_s - V_o$

- O/P volt. $V_o >> V_s$, hence -ve F.B, which makes the base emitter junction becomes less ~~FB~~ Forward bias as a result of the gain is decreased.

(7) Ideal CKt, $R_i \uparrow$ & $R_o \downarrow$

Voltage gain

from equ. ckt

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

$$V_o = h_{fe} \underset{I_b}{I_b} R_e$$

Gain of the amplifier without F.B,

$$A_{vs} = \frac{V_o}{V_s} = \frac{h_{fe} I_i R_e}{(R_s + h_{ie}) I_i} = \frac{h_{fe} R_e}{R_s + h_{ie}}$$

~~The gain~~

14 The gain of the amplifier with F.B is,

$$A_{VSF} = \frac{A_{VS}}{1+\beta A_{VS}} = \frac{\frac{h_{fe} R_e}{R_s + h_{ie}}}{1 + \frac{h_{fe} R_e}{R_s + h_{ie}} \beta} = \frac{h_{fe} R_e}{R_s + h_{ie} + h_{fe} R_e}$$ [where, $\beta = 1$

If $R_s + h_{ie} << h_{fe} R_e$ then $A_{vsf} \simeq 1$

Input Impedance

we know the I/P impe. of the volt. series FB is,

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

we know, $A_{vs} = \frac{h_{fe} R_e}{R_s + h_{ie}} \simeq \frac{h_{fe} R_e}{h_{ie}}$ [$R_s << h_{ie}$ (or) R_i

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

$R_{if} = (h_{ie} + h_{fe} R_e)$ [$\beta = 1$ due to unity gain

Output Impe.

* O/P impe. without F.B is, $R_o = \frac{V_o}{I_{sc}}$ [V_o - open ckt volt. ; I_{sc} - short ckt ct

* The O/P impe. of amplifier is given as,

$$R_o = \frac{V}{I} = \lim_{R_e \to \infty} R_e \text{ (Ideal)}$$

we know the o/p impe. of the voltage series F.B connection is,

$$R_{of} = \frac{R_o}{1+A\beta} = \frac{\underset{R_e \to \infty}{Lt} R_e}{1 + \frac{h_{fe} R_e}{h_{ie}+R_s} \cdot \beta} = \underset{R_e \to \infty}{Lt} \frac{(h_{ie}+R_s) \cdot R_e}{h_{ie}+R_s+h_{fe}R_e\beta}$$

$$= \underset{R_e \to \infty}{Lt} \frac{(h_{ie}+R_s) R_e}{\left(\frac{h_{ie}+R_s}{R_e} + h_{fe}\beta\right) R_e}$$

$$\boxed{R_{of} = \frac{h_{ie}+R_s}{h_{fe}\beta}}$$ if $\beta = 1$ then, then, $R_{of} = \frac{h_{ie}+R_s}{h_{fe}}$

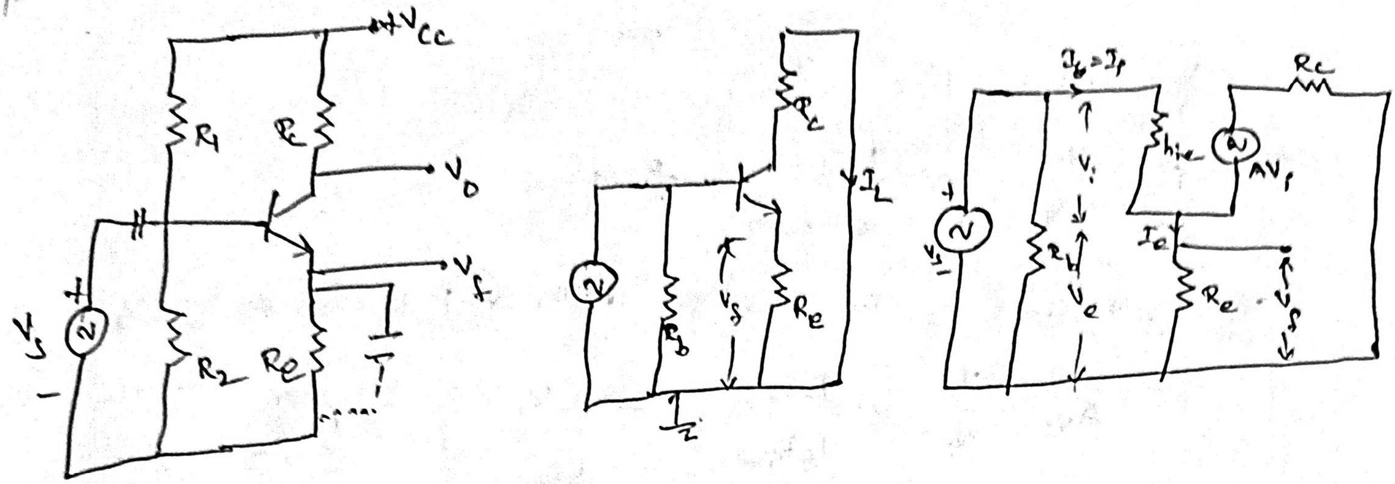
Current Series F-B Amplifier

* In DC bias: Re provide stabilization ~~but~~ there is no ac F.B.
* In AC bias: without C_E capacitor, R_E volt. drop across R_E act as Feedback volt., Thus Re is act as F.B element.
* – R_E connected b/w I/p & O/p, (I_b+I_c) ct flow through in R_E.

– In Re $\Rightarrow V_f = (I_b+I_c)R_e$

$$R_e \simeq I_c R_e = -I_L R_e$$

* o/p ct I_c given to I/p, i.e; sample ct I_c subtracted from I/p V_s. Thus it is known as ct series F.B.



Step-1 : Method of Identifying the topology,

- I_f O/p ckt open, $I_L = 0$ ⇒ F.B signal also zero ⇒ called CR sampling

- F.B signal V_f is subtracted from the I/p signal V_s ⇒ series mixer

- Finally, Conclusion of this to condition is identifies the topology is CR series. F.B.

Step-2 (Find the I/p & O/p ckt)

- To Find I/p ckt, set $I_L = 0$ then R_E appear in I/p side

- " " O/p " , set $I_i = 0$, then R_E " " O/p side

* I/p Impedance :-

$\div I_e$ In numerator & denominator

$$R_{if} = \frac{V_s}{I_i} = \frac{V_f + V_e}{I_i} = \frac{V_i}{I_i} + \frac{V_e}{I_i} = R_i + \frac{I_e R_e}{I_i} = R_i + \frac{I_e R_e}{I_e - I_c} = R_i + \frac{R_e}{1 - \frac{I_c}{I_e}}$$

we know, $I_c = I_b h_{fe}$; $I_e = (\overset{\beta I_b}{I_c} + I_b) = I_b(1 + \overset{\beta}{h_{fe}})$

hence, $\frac{I_c}{I_e} = \frac{h_{fe}}{(1+h_{fe})}$ thus, $R_{if} = R_i + \frac{R_e}{1 - \frac{h_{fe}}{1+h_{fe}}} = R_i + R_e(1+h_{fe})$

If $R_i = h_{ie}$ and biasing resistors are parallel then $R'_{if} = R_{if} \| R_b$

where, $R_b = R_1 \| R_2$

Voltage gain:- we know, $V_0 = -I_L R_e \simeq -I_c R_e$

$$V_f = (I_b + I_c) R_e \simeq I_c R_e$$

$$= -\frac{I_c R_e}{I_c R_e} = -\frac{R_e}{R_e} = 1$$

$$\beta = \frac{V_f}{V_o} = -\frac{I_c R_e}{I_c R_e} = \cancel{} \neq -1$$

The volt gain of the amplifier without F.B is given by,

$$A_{VS} = \frac{V_o}{V_i} \simeq -\frac{I_c R_e}{I_b h_{ie}} = \frac{-h_{fe} R_e}{h_{ie}} \qquad \left[\beta = \frac{I_c}{I_B} \right.$$

h_{fe}

we know,

$$(A_{VS})_f = \frac{A_{VS}}{1 + A_{VS}\beta} = \frac{-\frac{h_{fe} R_e}{h_{ie}}}{1 - \frac{h_{fe} R_e}{h_{ie}}\left(-\frac{R_e}{R_e}\right)}$$

$= -1$

$$\boxed{(A_{VS})_f = -\frac{h_{fe} R_e}{h_{ie} + h_{fe} R_e}} \simeq -\frac{h_{fe} R_e}{h_{ie}}$$

O/P Impe

$$R_{of} = R_o(1 + A\beta) = R_o\left(1 + \frac{h_{fe} R_e}{h_{ie}}\left(-\frac{R_e}{R_e}\right)\right)$$

$$\boxed{R_{of} = R_o\left(1 + \frac{h_{fe} R_e}{h_{ie}}\right)}$$

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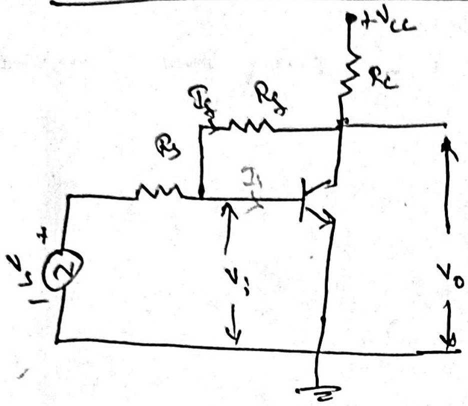
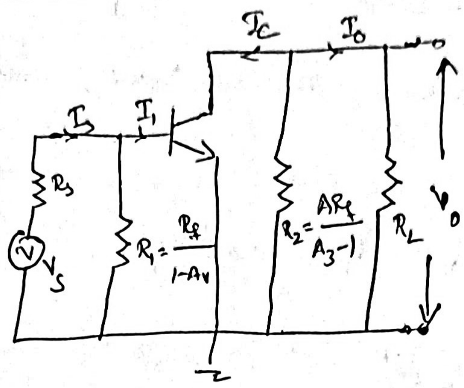
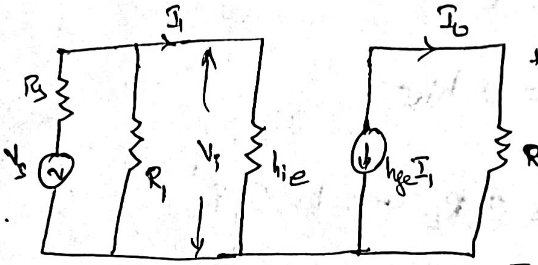
Voltage Shunt F.B Amplifier

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







$R_L' = R_L \parallel R_2$

* R_f b/w collector to base, it act as F.B resistance

* V_o is $>$ V_i and 180° out of phase with each other.

Hence, $I_f = \frac{V_i - V_o}{R_f} \simeq \frac{-V_o}{R_f}$

where, or $\beta = \frac{I_f}{V_o} = \frac{-1}{R_f}$ = Feedback factor.

* Method of Identifying the topology:-

The O/p volt. $V_o = 0$ then F.B signal reduced to zero thus it is known as volt. sampling.

- In this case, F.B signal I_f is substracted from the I/P signal V_s thus it is known as shunt mixing. hence this topology is known as volt. shunt F.B.

Step 2 :- ⇒ To find I/p ckt set $V_o = 0$,

so $R_f = 0$, and it has only source resistance.

⇒ To find o/p ckt $V_i = 0$, and it has only source resistance R_s.

* I/p Impe. :

$$R_{if} = Z_{if} = h_{ie} \| R_1 \| R_2$$

* $V_o = -h_{fe} I_1 R_L'$

Let $V_i = I_1 h_{ie}$

$$V_o = I_o R_L' = -h_{fe} I_1 R_L'$$

hence, $A_{vs} = \frac{V_o}{V_i} = -\frac{h_{fe} R_L'}{h_{ie}}$

where, $R_L' = R_2 \| R_L \approx R_L$

overall voltage gain,

$$\boxed{A_v = \frac{V_o}{V_i} = \frac{-h_{fe} I_1 R_L'}{h_{ie} I_1} = \frac{-h_{fe} R_L'}{h_{ie}}}$$

$$A_{vsf} = \frac{A_{vs}}{1 + A_{vs}\beta} = \frac{-\frac{h_{fe} R_L'}{h_{ie}}}{1 + \left(-\frac{h_{fe} R_L'}{h_{ie}}\right)\left(-\frac{1}{R_f}\right)}$$

$$= \frac{-h_{fe} R_L' R_f}{h_{ie} R_f + h_{fe} R_L'}$$

o/p Impe.

$$\boxed{R_{of} = \frac{R_f}{R_s} \left[\frac{R_s + h_{ie}}{h_{fe}}\right]}$$

$$R_{of} = \frac{R_o}{1 + A\beta} = \frac{R_o}{1 + \left(\frac{h_{fe} R_L'}{h_{ie}}\right)\left(-\frac{1}{R_f}\right)}$$

$$= \frac{R_o \cdot h_{ie} R_f}{h_{ie} R_f + h_{fe} R_L'} = R_f$$

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

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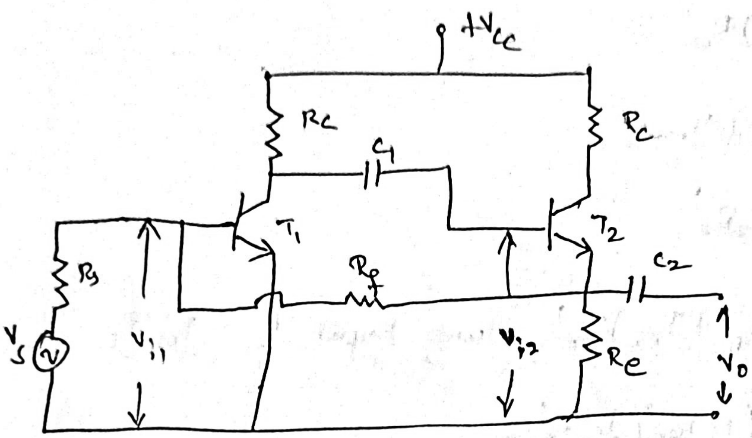
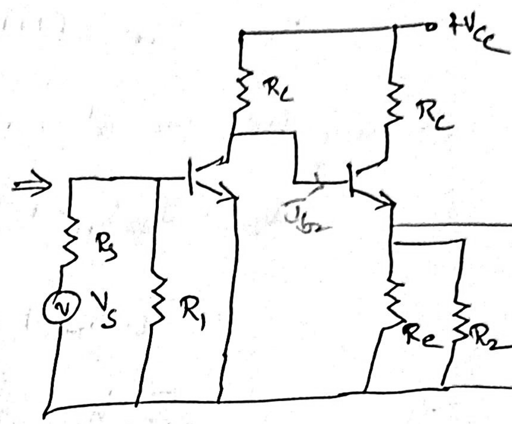
17 Current Shunt F.B Amplifier $A = \frac{I_o}{I_i}$ 16





Method of Identifying the topology

- If $V_o = 0$, F.B signal doesnot becomes zero, but $I_o = 0$, F.B signal becomes zero. (ct sampling
  - and F.B signal is connected in shunt with ct I/P signal i.e.; ~~ct~~ shunt mixing
  hence it is called 'ct shunt F.B amplifier'.

* 1st stage connected to 2nd stage amplifier (CE & CC amplif

* $V_{i2} > V_{i1}$

* V_{i2} - 180° outof phase with V_{i1}

*

* ~~tif~~ $I_f = \frac{V_{i1} - V_o}{R_f} \simeq \frac{-V_o}{R_f}$

$V_o = -I_o R_e$

hence, $I_f = \frac{I_o R_e}{R_f}$ (or) $\beta = \frac{I_f}{I_o} = \frac{R_e}{R_f}$

$\left[\begin{array}{l} V = IR_e \\ \therefore V_o = I_o R_e \\ V_f = R_f I_f \end{array} \right.$

* The I/p imped. of transistor T_2 is given by

$$R_{i2} = h_{ie} + (1+h_{fe}) R_e'$$

it can be proved as follows,

$$V_{i2} = I_{b2} h_{ie} + I_{e2} R_e'$$

$$= I_{b2} h_{ie} + (I_{b2} + I_{c2}) R_e' \quad \because \text{we know } I_c = h_{fe} I_b$$

$$= I_{b2} h_{ie} + (1+h_{fe}) I_{b2} R_e'$$

$$= I_{b2} [h_{ie} + (1+h_{fe}) R_e']$$

(or)

$$\boxed{\frac{V_{i2}}{I_{b2}} = R_{i2} = h_{ie} + (1+h_{fe}) R_e'} \quad [\text{where, } R_e' = R_e \| R_2$$

* The volt. gain of transistor T_1 is, $\boxed{A_1 = \frac{-h_{fe} R_L'}{h_{ie}}}$

ie; $V_o = -h_{fe} I_b R_L'$; $V_i = I_b h_{ie}$ thus $A_{v1} = \frac{-h_{fe} R_L'}{h_{ie}}$

* Total volt. gain

$$A_v = A_{v1} \cdot A_{v2}$$

where, $A_{v2} = \frac{-h_{fe} R_L'}{h_{i2}}$; $R_1 = \frac{R_f}{1-A}$; $R_2 = \frac{R_f A}{1-A}$

* O/p Impe

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

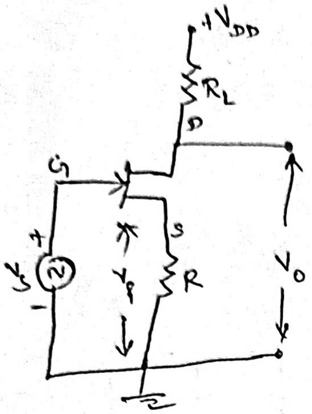
Total O/p Impe. $R_{of}' = R_{of} \| R_L$

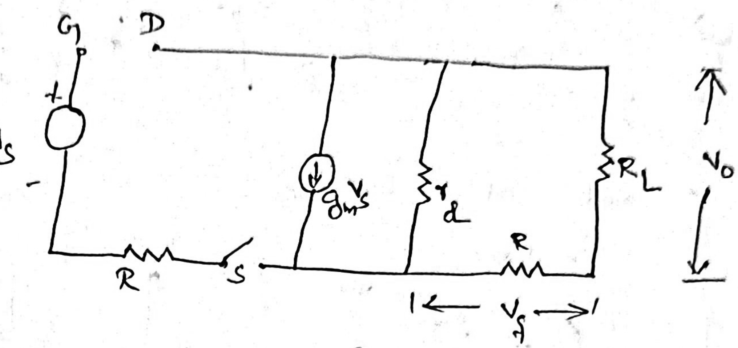
$$= R_{of} \| R_{c2}$$

$$= \infty \| R_{c2}$$

$$\boxed{R_{of}' = R_{c2}}$$

19) FET Amplifier using Current Series F.B :





* Volt. across 'R' constitute F.B signal,
* Load of I_o is same with the F.B signal hence it is named as Current Series F.B.
* $V_f = I_o R$
* I/p of the F.B = O/p of $= I_o$

hence,

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

* without F.B $V_i = V_s$

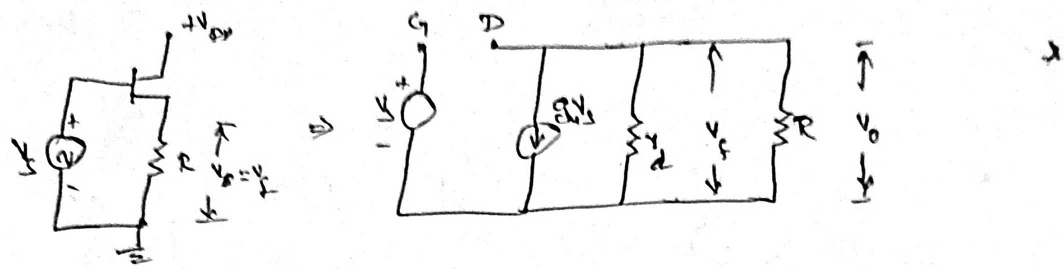
hence,

$$G_m = A = \frac{I_o}{V_i} = \frac{I_o}{V_s} = \frac{-g_m r_d}{r_d + R_L + R} = \frac{-\mu}{r_d + R_L + R}$$

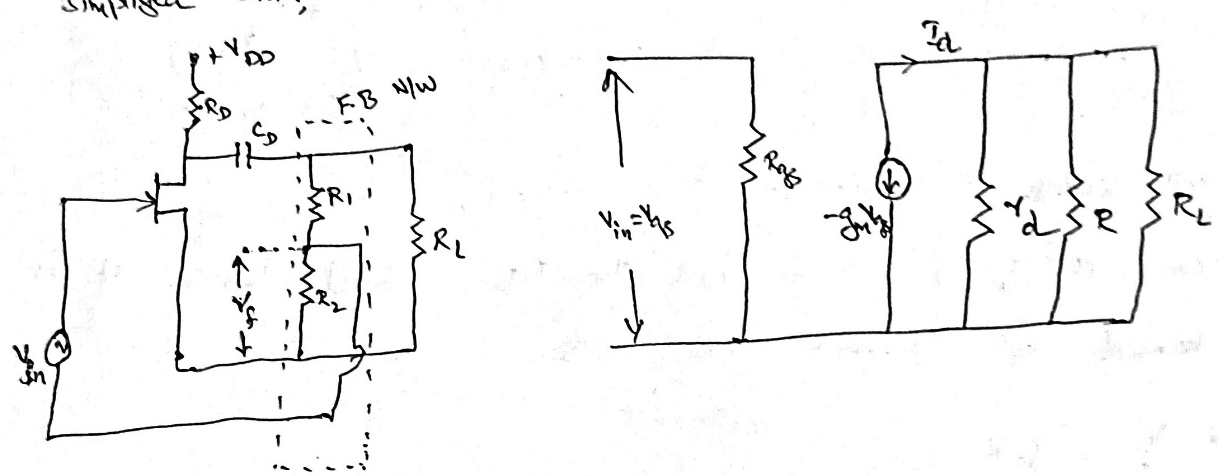
$$G_{mf} = A_f = \frac{G_m}{1 + G_m \beta} = \frac{-\mu}{r_d + R_L + R(\mu + 1)}$$

* $R_i = \infty$
* similiarly, $R_{if} = R_i D = \infty$ where $D = (1 + G_m \beta)$
* $R_o = r_d + R$
* since β is independence of $R_L \Rightarrow 1 + \beta G_m = \lim_{R_L \to 0} (1 + G_m \beta) = \frac{r_d + (\mu + 1)R}{r_d + R}$
* $R_{of} = R_o (1 + G_m \beta) = (r_d + R) \frac{r_d + (\mu + 1)R}{r_d + R}$ $\Rightarrow \therefore R_{of\,tot} = R_o \,||\, R_{of}$

FET Source Follower As Volt. series F.B



Simplified ckt :-



without F.B the amplifier gain is,

$V_o = I_d (r_d \| R \| R_L)$ where, $R = R_1 + R_2$

$I_d = -g_m V_{gs} = -g_m V_i$

$V_o = -g_m V_i (r_d \| R \| R_L)$

$$A_V = \frac{V_o}{V_i} = -g_m (r_d \| R \| R_L)$$

* The F.B N/w provides a F.B factor of

$$\beta = \frac{V_f}{V_o} = \frac{-R_2}{R_1 + R_2}$$ (using potential division rule)

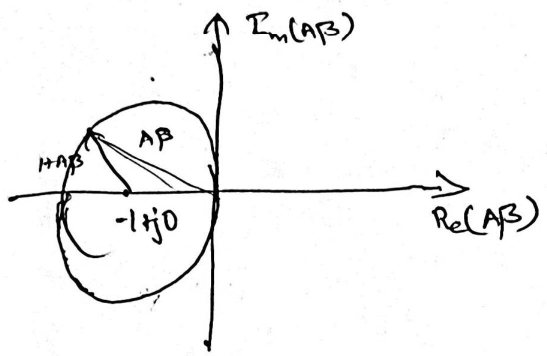
$\therefore$ gain with -ve F.B $A_f = \dfrac{A}{1 + A\beta}$

$$A_f = \frac{-g_m (r_d \| R \| R_L)}{1 + \left(\frac{R_2}{R_1 + R_2}\right) g_m (r_d \| R \| R_L)}$$

* $R_i = \infty$; $R_o = r_d$.

Nyquist Criterion

- Alternate approach to obtain the condition for stability.
- loop gain ($A\beta$), being a complex number, may be represented as a point in the complex 'S' plane.

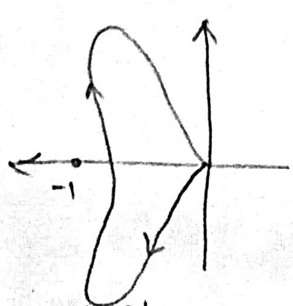


- Further $A\beta$ is a function of freq. (values is $-\infty$ to $+\infty$ points in the complex S-plane)

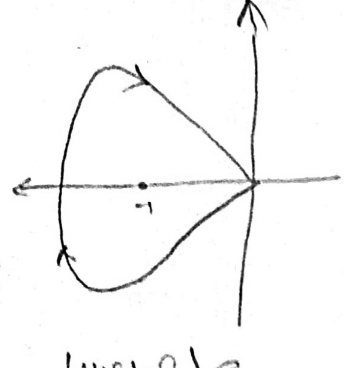
* Nyquist criterion state that, the amplifier is unstable if this curve encloses the point $-1+j0$ and the amplifier is stable, if the curve does not enclose this point.

* If $|1+A\beta|=1$ represent a circle of unit radius with its center at the point $-1+j0$.

* If for any freq $A\beta$ extends outside the circle, the FB is negative, since $|1+A\beta|>1$. on the other hand if $A\beta$ is lies entires within the circle then $|1+A\beta|<1$ and the FB is ~~negative~~ positive.



Stable



unstable

(1) When the -ve F.B is applied to an amplifier of gain 100, the overall gain falls to 50. Calculate (i) the F.B factor β

(ii) If the same F.B factor maintained, the value of the amplifier gains required if the overall gain is to be 75.

Sol

(i) $A_f = \dfrac{A}{1+A\beta}$ where, $A=100$ & $A_f = 50$

hence, $50 = \dfrac{100}{1+100\beta}$ (or) $1+100\beta = \dfrac{100}{50}$

$$100\beta = 2-1$$

$$\beta = \frac{1}{100} = 0.01$$

(ii) $A_f = 75$; $\beta = 0.01$ what is $A = ?$

$A_f = \dfrac{A}{1+A(0.01)} \Rightarrow A_f = \dfrac{75}{1-0.75} = 300$

(2) The gain of the amplifier without FB is 50 whereas with -ve F.B it falls to 25. If due to ageing, the amplifier gain falls to 40. Find the percentage reduction in gain (i) without F.B (ii) with -ve F.B.

Sol

$A_f = \dfrac{A}{1+A\beta}$; Given $A_f = 25$; $A = 50$

$25 = \dfrac{50}{1+50\beta}$ (or) $\beta = 0.02$ ✓

(i) without F.B % reduction in gain $= \dfrac{50-40}{50} \times 100 = 20\%$

(iii) with -ve F.B;

when the gain without F.B was 50, the gain with F.B was 25, Now the gain without F.B falls to 40.

$$A_f = \frac{40}{1+0.02\times 40} = 22.2$$

$$\%\ \text{reduction in gain} = \frac{25-22.2}{25} \times 100 = 11.2\ \%$$

---

(3) An amplifier has $A_v = 1000 \pm 100$. Determine the F.B needed to keep the gain with in ± 0.1 percent. Find A_{vf}.

Sol

$$\frac{dA_f}{A_f} = 0.1\% = \frac{0.1}{100} = 10^{-3}$$

$$\frac{dA}{A} = \frac{100}{1000} = 0.1$$

$$D = 1+A\beta = \frac{0.1}{10^{-3}} = 100$$

differentiation eqn of gain

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

After diff. $\Rightarrow$

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

If $A = 1000$,

$$\beta = \frac{99}{1000} = \frac{1}{10} \text{ approximately}$$

$$A_f = \frac{A}{D} = \frac{1000}{100} = 10.$$

---

(4) If an amplifier has a gain of 60 db, a F.B of $\beta = 0.005$ is applied what would be the change in overall gain of the F.B amplifier If the internal amplifier is subjected to a gain reduction of 12%

Sol: $A = 60\ db = 20 \log_{10} A = 1000$

$\beta = 0.005$; $\frac{dA}{A} = 12\%$

$$\frac{dA_f}{A_f} = \frac{dA}{A}\left(\frac{1}{1+A\beta}\right) = \frac{0.12}{1+1000(0.005)} = 0.02$$

Therefore, the overall gain of the F.B amplifier will be reduced by 2%

22 (6) Amplifier without F.B has an o/p volt. $V_0 = 50V$; with second harmonic distortion of 10% for $V_i = 0.5$ volt. Calculate

(1) the amount of F.B necessary to reduce distortion to 1%.

(2) The gain A_f (3) The new I/p Volt. required to restore V_0 to 50 Volt. with 1% distortion.

Sol

(1) $A = \frac{V_0}{V_i} = \frac{50}{0.5} = 100$

Distortion $D = 10\%$ of V_0

$= 0.1 \times 50 = 5$ volt.

Distortion with F.B $= D_f = 0.01 \times 50 = 0.5$ volt.

reduced to 1%.

(1) ∴ The amount of F.B factor 'β' necessary to reduce the D_f to 1%.

$D_f = x D$

is, $D_f = \frac{D}{1+A\beta} \Rightarrow 0.5 = \frac{5}{1+\beta 100}$

(or) $\beta = 0.09$

$A = \frac{V_0}{V_s} = \frac{50}{0.5}$

(2) $A_f = \frac{A}{1+A\beta} = \frac{100}{1+100\times 0.09} = 10$

(3) $V_{if} = \frac{V_0}{A_f} = \frac{50}{10} = 5$ Volts.

① Two amplifiers each with a gain of 100 are connected in cascade and negative F.B applied to provide an overall gain of 20. Determine (1) the required F.B factor (2) the percentage increases in the overall gain if the gain of each amplifier increases by 100%.

Sol

(a) $A_0 = A_1 \cdot A_2$ if $A_1 = A_2 = A$ then $A_0 = A^2$

hence gain with F.B $A_f = \dfrac{A^2}{1+A^2\beta}$

$$A_f = \frac{100^2}{1+\beta\, 100^2} = 20$$

$$\beta = 0.0499$$

(b) $A_f = \dfrac{200^2}{1+(0.0499)\,200^2} = 20.03$

∴ The increase in the overall gain $= \dfrac{20.03-20}{20} \times 100\ (\%)$

$= 0.15\ \%$

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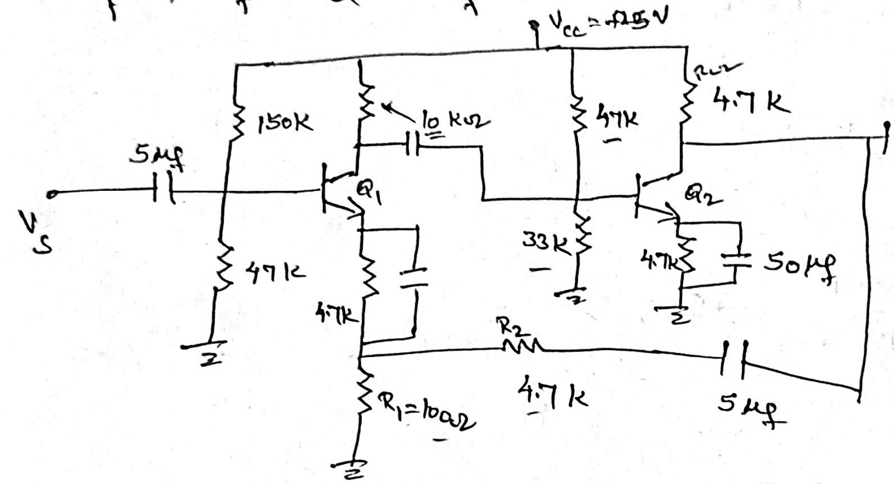
21 (5) Transistors in the F.B amplifier shown in figure are identical and their parameters are $h_{ie} = 1.1K$, $h_{fe} = 50$, $h_{re} = h_{oe} = 0$. Identify the F.B amplifier and calculate A_{vf}, R_{if} and R_{of}'.



* overall gain without F.B $A_v = A_{v1} \cdot A_{v2}$

* The effective load resistance R_{L1}' of Q_1 is,

$R_{L1}' = 10K \| 47K \| 33K \| 1.1K = 942\,K\Omega$ (or) $0.942\,K\Omega$

* $R_{L2}' \Rightarrow R_{C2} = 4.7K$; $(R_1 + R_2) = 4.8K$ (100Ω + 4.7K)

$R_{L2}' = 4.7K \| 4.8\,K = 2.37K$

* effective emitter resistance R_e of Q_1 is $R_1 \| R_2 = 100\Omega \| 4.7K\Omega$
$= 98\Omega$ (or) $0.098K$

* Volt. gain $A_{v1} = \dfrac{-h_{fe} R_{L1}}{h_{ie} + (1+h_{fe}) R_e} = \dfrac{-50 \times 0.942}{1.1 + (50+1)\,0.096} = -7.72$

$A_{v1} = \dfrac{V_o}{V_i} = \dfrac{-h_{fe} R_{L1}}{h_{ie} + (1+h_{fe}) R_e}$ R_{if}

$A_{v2} = \dfrac{-h_{fe} R_{L2}'}{h_{ie}} = \dfrac{-50 \times 2.37 \times 10^{3}}{1.1 \times 10^{-3}} = -108.$

$\therefore$ overall volt. gain $A_v = A_{v1} \cdot A_{v2} = (-7.72)(-108) = 834$

$* \ \beta = \dfrac{R_1}{R_1+R_2} = \dfrac{1000}{48000} = \dfrac{1}{48}$

loop gain $\rightarrow$ $A_v \cdot \beta = \dfrac{834}{48} = 17.4$

$D = 1 + A_v\beta = 18.4$

$* \ A_{vf} = \dfrac{A_v}{D} = \dfrac{834}{18.4} = 45.4$

$* \ R_i = h_{ie} + (1+h_{fe}) R_e$

$= 1.1 + (1+50)\, 0.098 \times 10^3 = 6.1k$

$R_{if} = R_i D = 6.1 \times 10^3 \times 18.4 = 112.2 k\Omega$

*The output resistance without F.B

$R_o' = R_{L2} = 2.37k$

$R_{of}' = \dfrac{R_o'}{D} = \dfrac{2.37k}{18.4k} = 129\ \Omega$