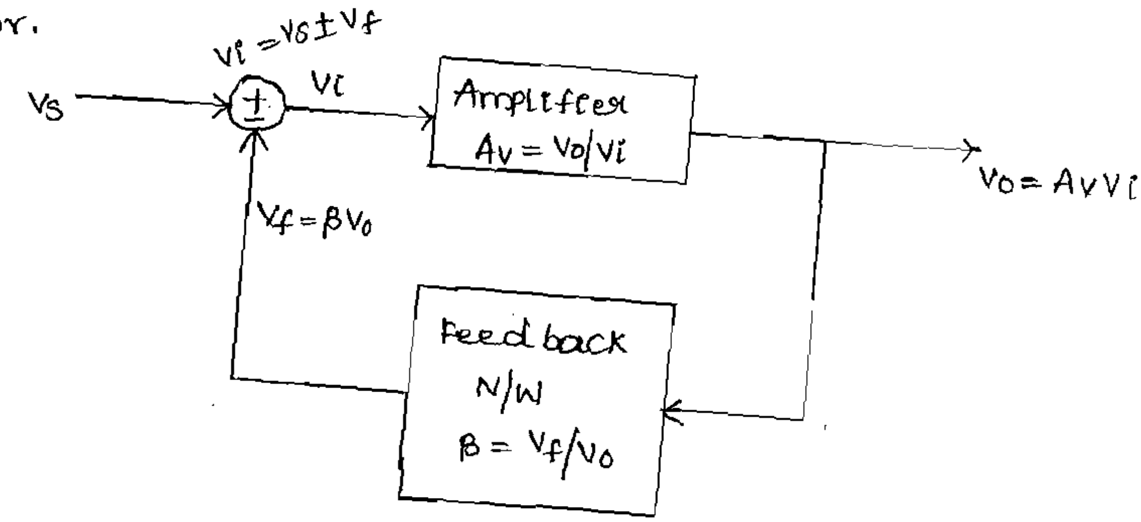
UNIT - III

FEED BACK AMPLIFIERS

Introduction:-

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



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

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

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

Types of feedback:-

1. positive feedback.
2. Negative feedback

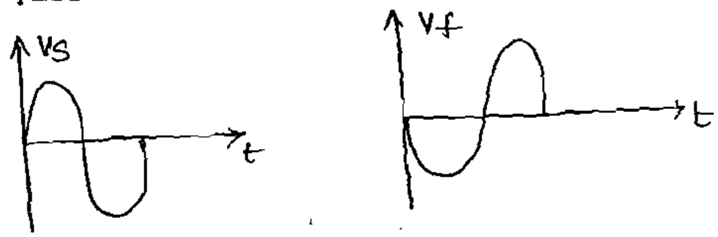
1. Positive feedback:-

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

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

2. Negative feedback:-

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



Gain of feed back Amplifier:-

The gain of feedback amplifier is given as

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

The input voltage to the amplifier with feedback is given as

$$V_i = V_s \pm V_f$$

$$V_s = V_i \mp V_f$$

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

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

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

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

From ① we have

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

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

From ②

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

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

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

Note:-

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

CHARATERISTICS OF NEGATIVE FEEDBACK

(OR)

ADVANTAGE OF NEGATIVE FEEDBACK OVER POSITIVE FEEDBACK

1. Increase stability:-

The expression for voltage gain with feedback is given as

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

as $\beta A_v >> 1$

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

2. Desensitivity of Transfer gain

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

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

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

Differentiate w.r.t A_v.

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

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

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

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

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

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

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

Desensitivity is reciprocal of sentitivity

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

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

3. Reduction in frequency distortion :-

We know that

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

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

4. Reduction in Noise :-

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

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

5. Reduction in distortion

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

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

6. Increase in bandwidth :-

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

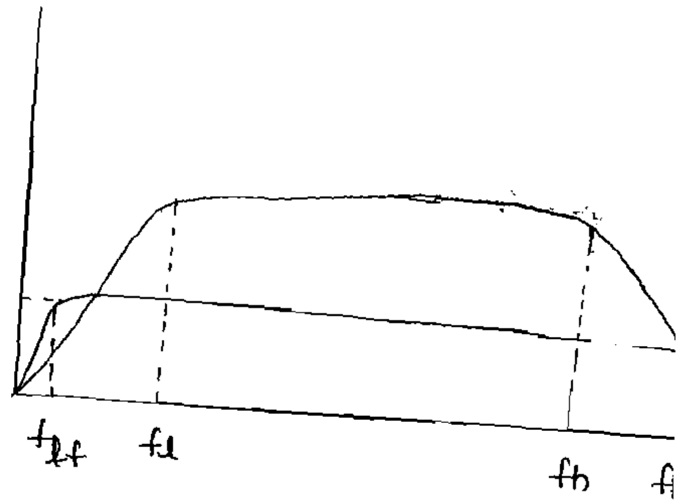
$$B \cdot W_f = BW(1+\beta A_v)$$

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

$B \cdot W = f_h - f_l$

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

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



$B \cdot W = f_h - f_l$

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

FEED BACK TOPOLOGIES :-

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

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

Note :-

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

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

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

<u>Voltage-series feedback Amplifier</u>:-

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

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

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

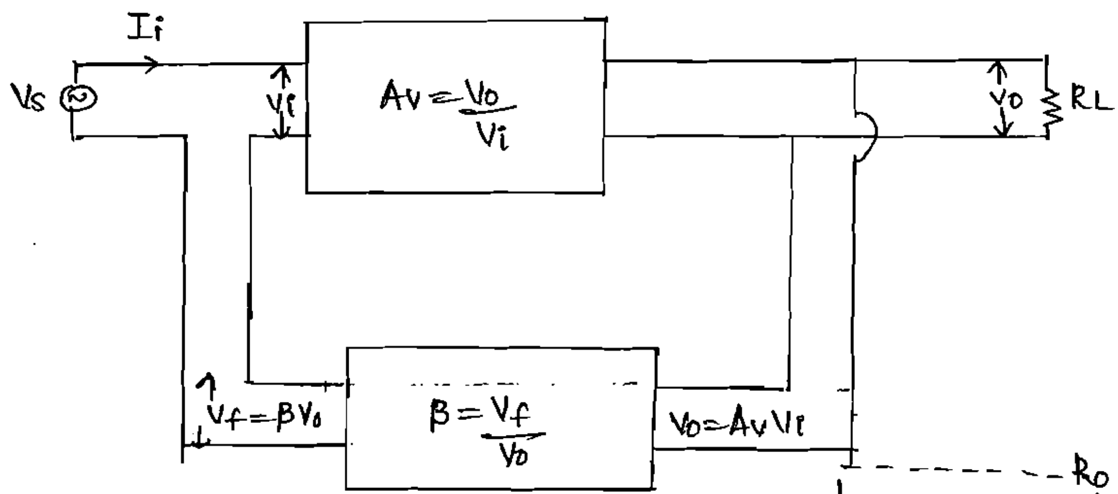


fig (a)

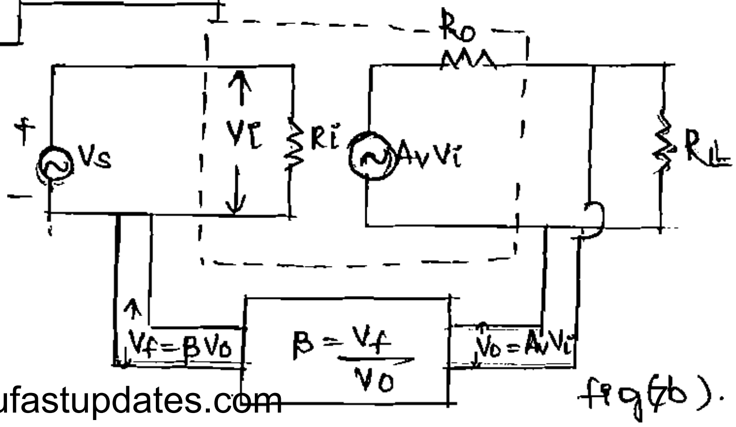


fig (b).

Gain with feedback (A_{vf}):-

From the circuit we have,

$$V_i = V_s - V_f$$

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

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

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

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

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

We have,

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

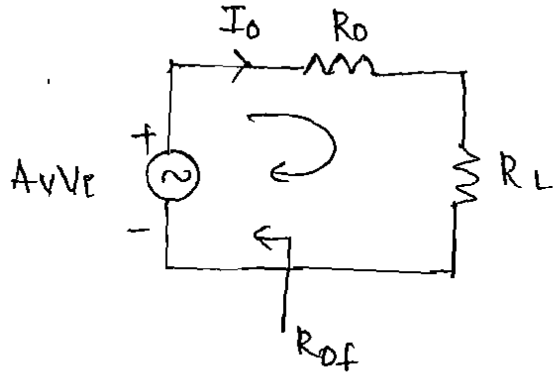
$$R_{if} = \frac{V_s}{I_i} = \frac{V_i + V_f}{I_i} = \frac{V_i + \beta V_o}{I_i} = \frac{V_i + \beta(A_v V_i)}{I_i}$$

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

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

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

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



As, $V_i = V_s - V_f$

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

Consider the o/p ckt $\rightarrow$

From the ckt,

$$V_o = I_oR_o + A_vV_i$$

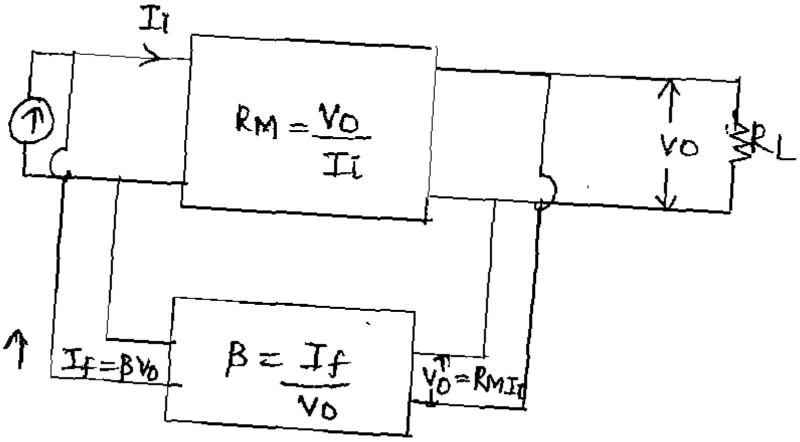
$$\Rightarrow V_o = I_oR_o + A_v(-V_f) = I_oR_o - A_v(\beta V_o) \Rightarrow I_oR_o = V_o + A_v(\beta V_o)$$

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

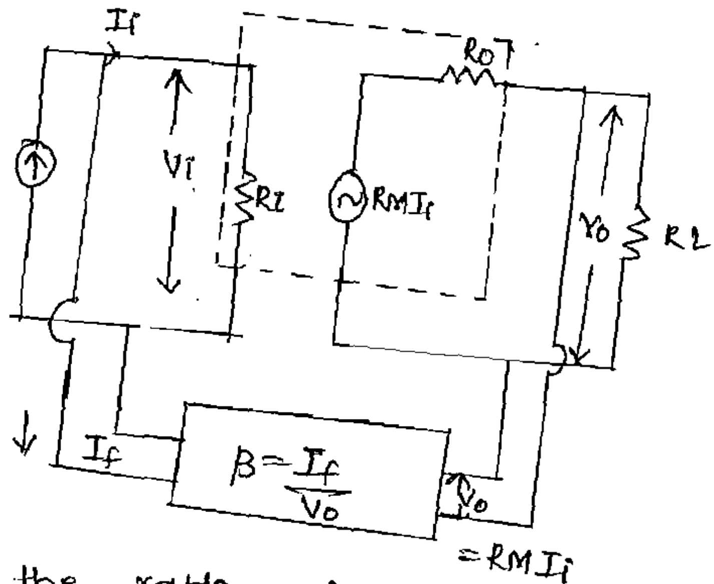
$$\Rightarrow \frac{V_o}{I_o} = \frac{R_o}{1+\beta A_v}$$

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

Voltage shunt feedback Amplifier :-



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



→ The feedback factor 'β' is the ratio of feedback current to the output voltage, that is

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

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

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

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

∴ From the circuit

We have $I_i = I_s - I_f$

$\Rightarrow I_s = I_i + I_f$

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

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

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

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

Input impedance:-

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

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

From the ckt we have,

$I_i = I_s - I_f$

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

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

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

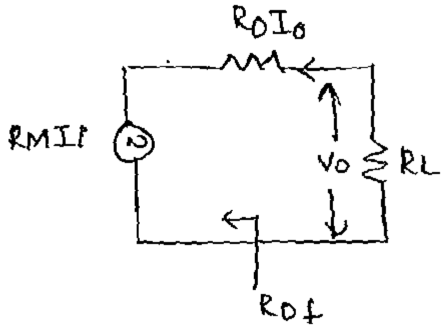
$$\therefore \boxed{R_{if} = \frac{R_i}{1+\beta R_M}}$$

Output impedance:-

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

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

considering the o/p ckt, →



Applying KVL,

$V_o = R_oI_o + R_MI_i$

$= I_oR_o - R_MI_f$

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

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

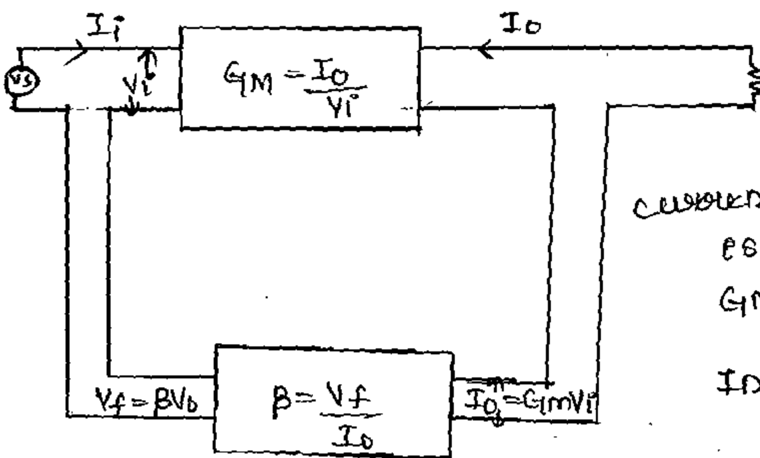
$\Rightarrow \frac{V_o}{I_o} = \frac{R_o}{1+\beta R_M}$

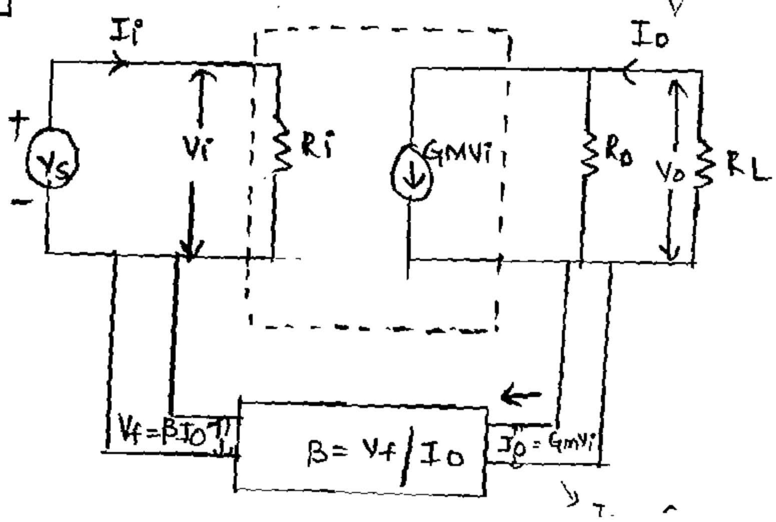
$\Rightarrow \boxed{R_{of} = \frac{R_o}{1+\beta R_M}}$

Current series feed back Amplifier:-

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

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





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

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

From the circuit

$$V_i = V_s - V_f$$

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

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

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

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

Input impedance:-

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

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

From the circuit

$$V_i = V_s - V_f$$

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

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

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

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

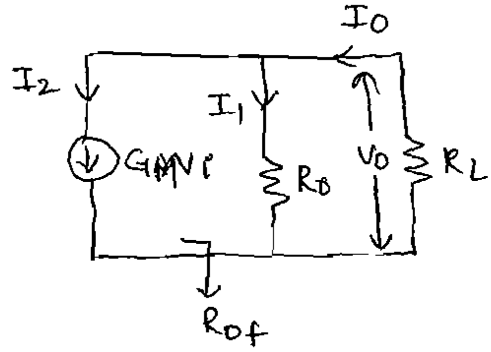
$$\Rightarrow \boxed{R_{if} = R_i(1+\beta G_M)}$$

Output impedance:-

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

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

consider the o/p ckt,



Applying KCL,

$$I_o = I_1 + I_2$$

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

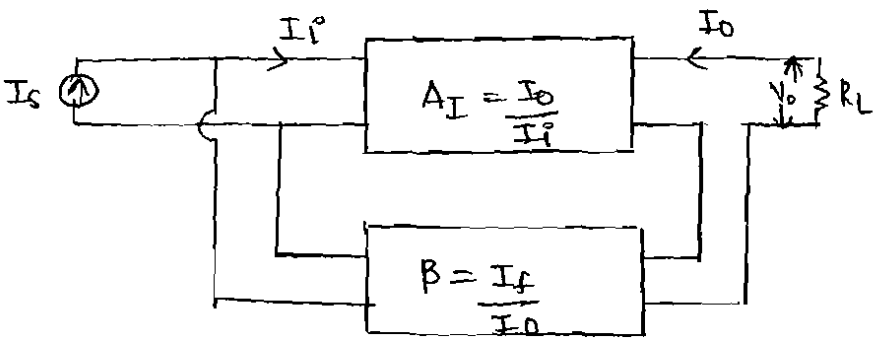
$$I_o = \frac{V_o}{R_o} - G_M \beta I_o$$

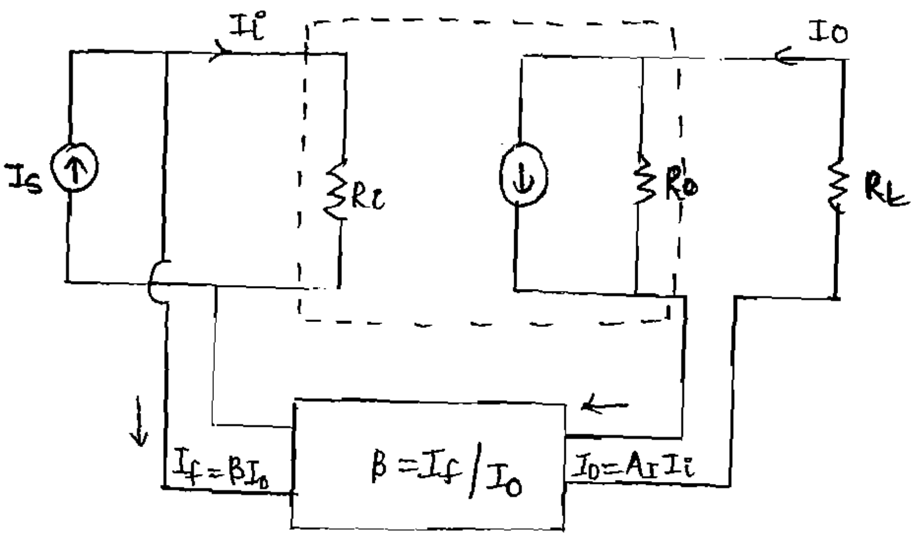
$$\Rightarrow I_o (1 + G_M \beta) = \frac{V_o}{R_o}$$

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

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

Current shunt feedback Amplifier:-





Current gain:-

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

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

From the ckt,

$$I_i = I_s - I_f$$

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

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

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

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

Input impedance:-

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

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

We have,

$$I_i = I_s - I_f$$

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

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

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

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

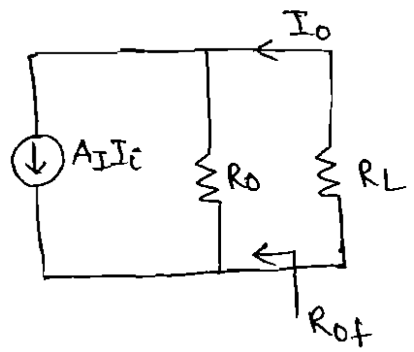
Output impedance:-

To get o/p impedance,

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

Considering o/p ckt :

8.



Apply KCL,

$$I_0 = \frac{V_0}{R_0} + A_I I_i$$

$$= \frac{V_0}{R_0} + A_I(-I_f)$$

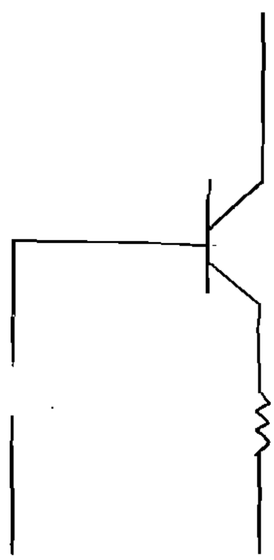
$$I_0 = \frac{V_0}{R_0} - A_I \beta I_0 \Rightarrow I_0 + A_I \beta I_0 = \frac{V_0}{R_0}$$

$$\Rightarrow I_0(1 + A_I\beta) = \frac{V_0}{R_0} \rightarrow \frac{V_0}{I_0} = R_0(1+\beta A_I)$$

$$\Rightarrow \boxed{R_{of} = R_0(1+\beta A_I)}$$

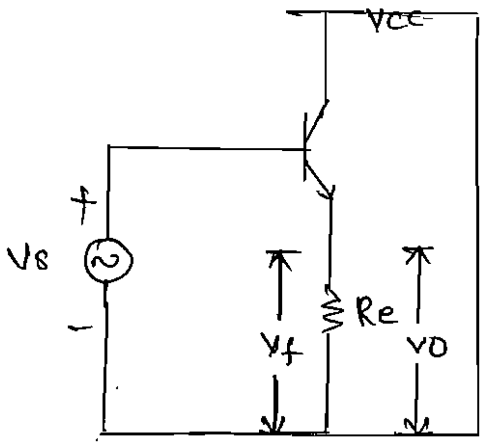
Practical ckt for voltage series feedback Amplifier

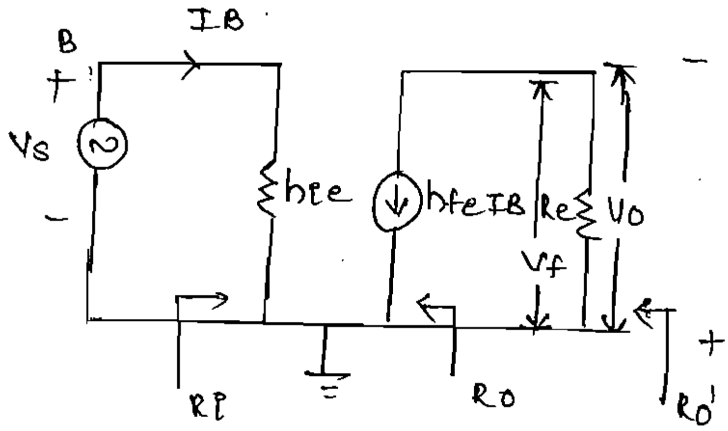
Emitter follower (CC Amplifier)



Practical ckt for voltage series feedback Amplifier

Emitter follower o/CC Amplifier.





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

∴ Emitter follower acts as voltage series feedback amplifier.

As, $V_0 = V_f$

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

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

Voltage gain (AV):-

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

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

Input impedance Rie

$R_{ie} = h_{ie}$

output impedance Roe:.

make source to zero to get o/p impedance

ie $V_S = 0$.

If $V_S = 0 \Rightarrow I_B = 0$

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

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

R_O':-

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

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

$$A_{vf} = \frac{A_v}{1 + \beta A_v} = \frac{A_v}{1 + A_v} \quad [\because \beta = 1]$$

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

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

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

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

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

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

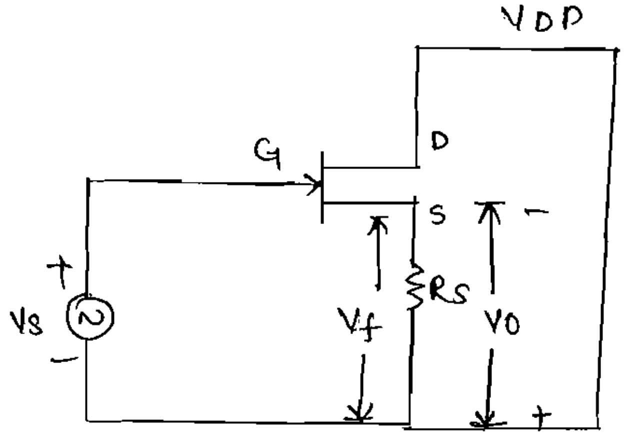
$$R_{of} = \frac{R_O}{1 + \beta A_v} = \frac{R_O}{1 + A_v} = \frac{\infty}{1 + A_v} = \infty.$$

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

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

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

* Source Amplifier



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

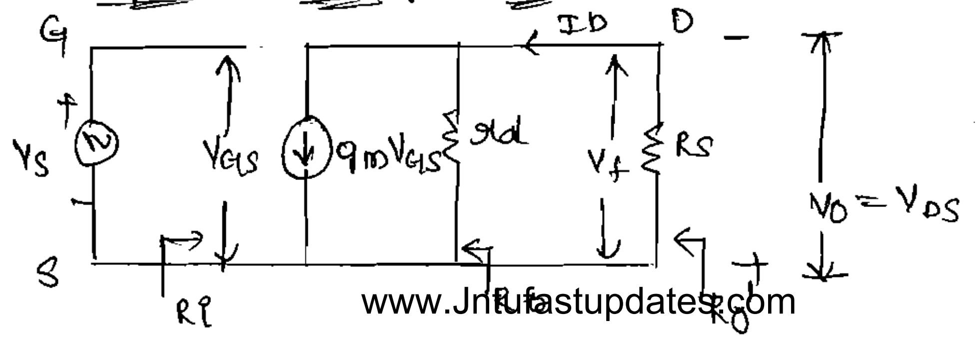
$\therefore$ $V_f = V_o$ and the feedback signal gets subtracts with the source signal.

$\therefore$ source follower acts as voltage series feedback amplifier.

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

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

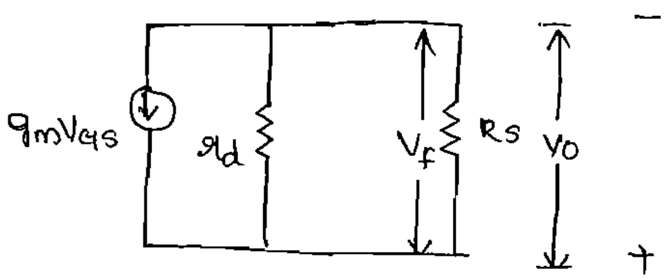
small signal Analysis for FET :-



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

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

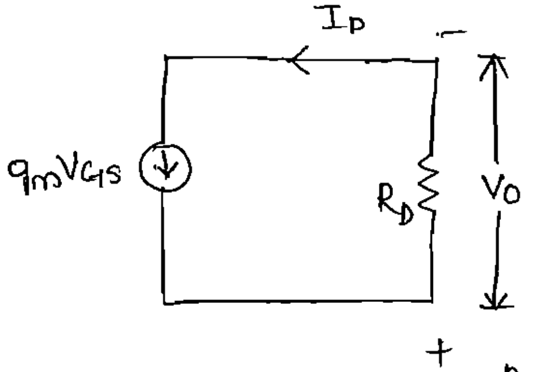
considering the o/p ckt



$V_{DS} = I_d \times R_D$

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

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



$\Rightarrow A_V = g_m R_D$

Substitute value of R_D

$R_D = r_d \| R_S$

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

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

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

* Input impedance (R_i) :-

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

* output impedance (R_O) :-

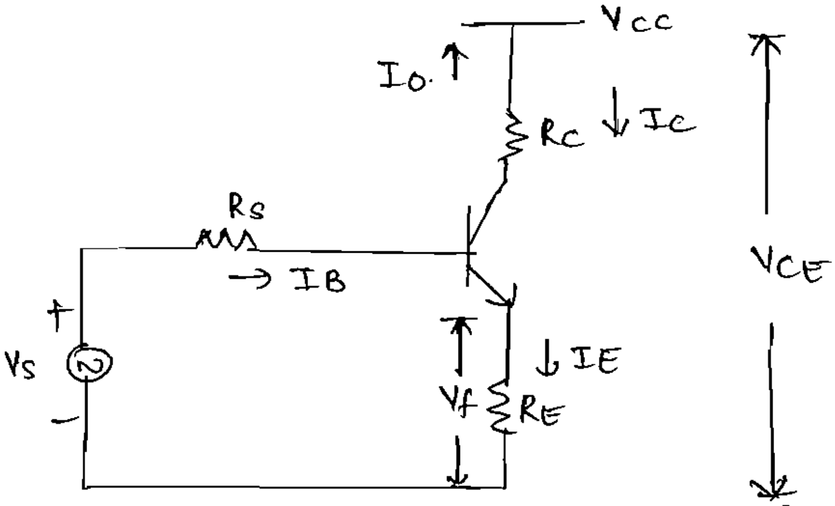
$R_O = r_d$

$R_O' = R_O \| R_S = \frac{R_O R_S}{R_O + R_S} = \frac{r_d R_s}{r_d + R_s}$

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

<u>current-series feedback Amplifier</u> :-

CE-Amplifier with unbypassed emitter Resistor.



the feedback voltage is provided across 'R_E'

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

$\Rightarrow I_E = I_B + I_C$

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

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

$\Rightarrow V_f = -I_o R_e$

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

Voltage gain with feedback (A_{vf})

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

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

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

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

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

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

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

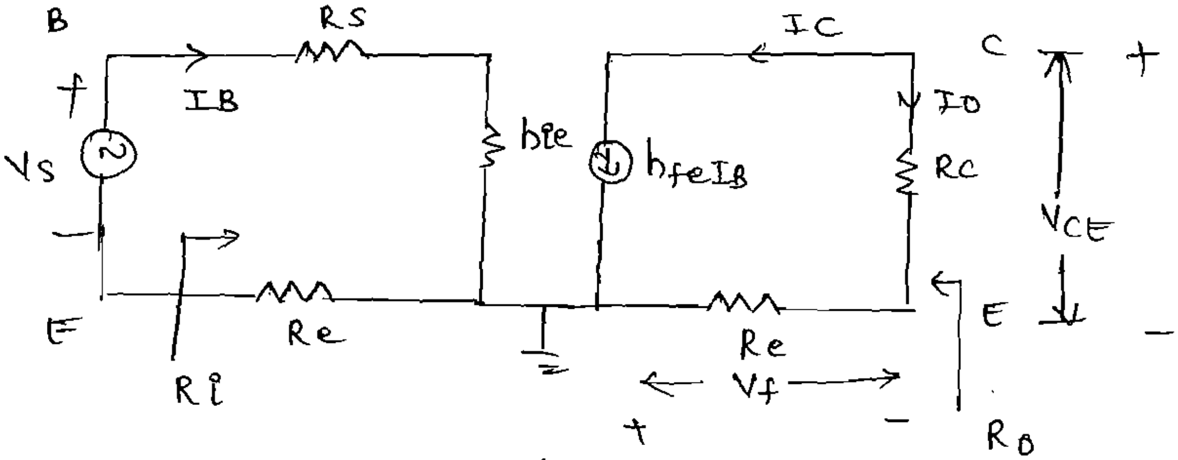
* Output impedance with feedback (R_{of}):-

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

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

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

Practical circuit:-



* Trans conductance (g_m):-

$$G_M = \frac{I_o}{V_s} = \frac{-I_c}{V_s} = \frac{-h_{fe} I_B}{I_B[R_s + h_{ie} + R_e]}$$

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

* Input impedance (R_i):-

$$R_i = \frac{V_s}{I_B} = \frac{\cancel{I_B}[R_s + h_{ie} + R_e]}{\cancel{I_B}}$$

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

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

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

* Output impedance (R_o):-

To get R_o, make source to zero i.e $V_s = 0$.

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

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

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

* Trans conductance with feedback

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

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

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

* Input impedance (R_{if})

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

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

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

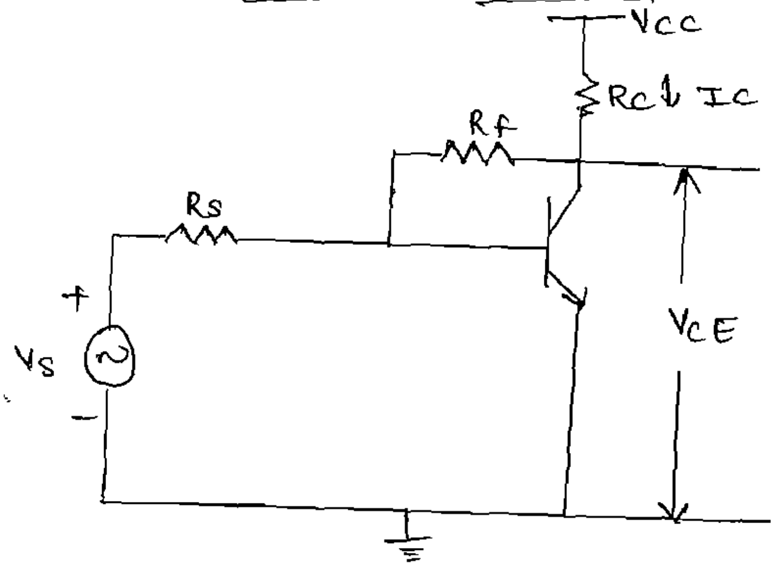
$$\boxed{R_{if} = R_s + h_{ie} + R_e(1 + h_{fe})}$$

Output impedance with feedback (R_{of})

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

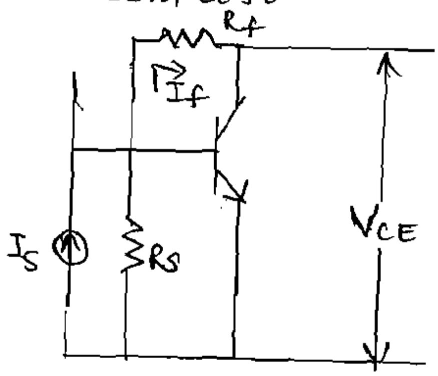
$$\Rightarrow \boxed{R_{of} = \infty.}$$

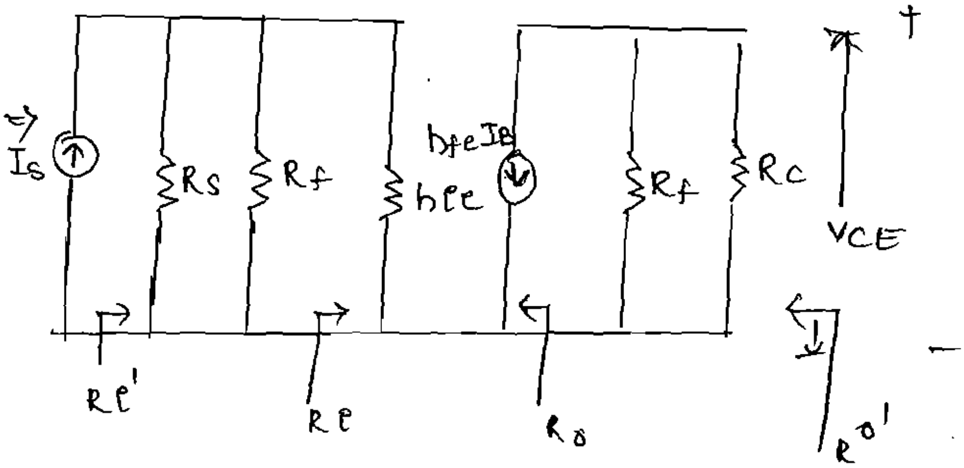
Voltage shunt feedback Amplifier.



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

∴ The ckt acts as voltage shunt feedback amplifier.





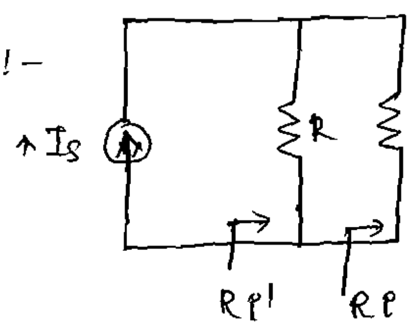
Without feedback:-

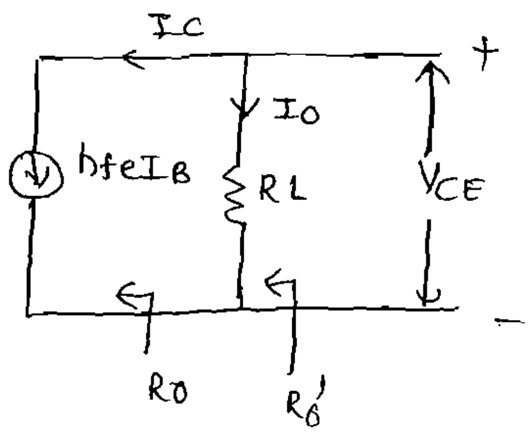
Input impedance:-

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

$\boxed{R_i = h_{ie}}$ ≅

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





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

* Trans resistance (R_M):-

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

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

* output impedance (R_o & R_o')

To get o/p impedance make source zero

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

$$\therefore R_o = \infty$$

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

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

* Trans resistance with feedback:-

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

where, $I_f = \dfrac{V_{in} - V_{CE}}{R_f} = \dfrac{-V_{CE}}{R_f}$

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

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

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

* Input impedance (R_{if}) with feedback

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

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

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

* Output impedance with feedback

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

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

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

FEED BACK AMPLIFIERS

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

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

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

Sol Given;

$V_i = 0.028\,V$

$V_o = 36\,V$

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

$= \frac{36}{0.028}$

$= 1285.7.$

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

$= 0.07.$

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

$A_v = 1285.7.$

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

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

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

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

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

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

To find β ;

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

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

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

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

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

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

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

$$\Rightarrow 78.26.$$

$$V_o = 78.26 * 0.028$$

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

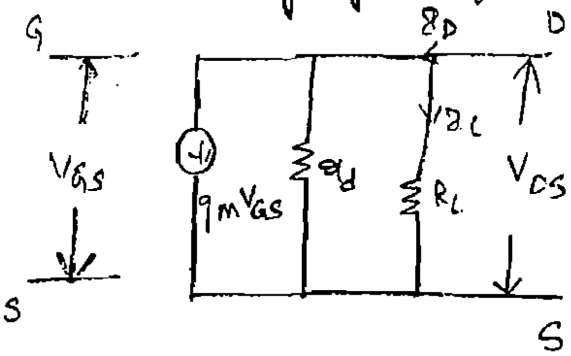
2. A common Source FET amplifier has a load resistance of 500kΩ. The ac drain resistance of the device is 100kΩ and the trans Conductance is $0.8\, mAV^{-1}$. Calculate the voltage gain of the amplifier

Sol Given;

$R_L = 500k\Omega$

$r_d = 100k\Omega$

$g_m = 0.8\, mA/V$.



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

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

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

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

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

$$A_V = -g_m \cdot R_D$$

$$= -0.8 \times 10^{-3} [500k // 100k]$$

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

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

Sol Given;

gain $[A_v]$: 1000.

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

Input Voltage $= 10\,mV$.

$\beta = 40\,dB$.

i, input signal voltage $V_s' = V_s[1+\beta_A]$

$= V_s[1+100]$

$\therefore$ Here β is given in dB so;

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

$\Rightarrow 100.$

$\Rightarrow 10m[1+100]$

$\Rightarrow 1.01\ V.$

ii, Value of second harmonic distortion;

$$D_f = \frac{D}{1+\beta_A}$$

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

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

i, Value of voltage gain without feedback

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

Sol Given ;

$$V_{of} = 12.5$$

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

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

$$= 8.333.$$

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

$$= 50.$$

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

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

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

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

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

Sol

Given ;

$A_v = 125$;

$B.W = 250\,kHz$;

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

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

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

$$= 20.83.$$

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

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

$$= 1.5\,MHz.$$

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

Sol:- Given;

$A_v = 50.$

$R_i = 1k\Omega;$

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

$D = 1+\beta A_v$

$= 1+(0.1 * 50)$

$= 6.$

$R_{if} = R_i * D$

$= 1K * 6.$

$= 6K.$

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

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

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

$= 316.22$

$\beta = 0.004.$

when it is reduced by 10% of AV_1.

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

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

$= 31.622.$

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

$$= 316.22 - 31.622$$

$$= 284.5$$

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

$$= 139.61.$$

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

$$= 133.08$$

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

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

$$= 4.08\%$$

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

Sol

$A_V = 600$

$A_{Vf} = 50$;

$\beta = ?$

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

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

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

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

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

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

∴ The % of the o/p which is fed back to i/p is 1.83%.

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

Sol Given $A_v = 300$;

$R_i = 1.5K$;

$R_o = 50K$;

$\beta = -1/20$;

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

$$= 1.5K\left[1+\left(+\tfrac{1}{20}\right)300\right]$$

$$= 24K$$

Out put impedence : $R_{of} = \frac{R_0}{1+\beta A_v}$

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

$= 3.125K$.

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

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

$= 18.75$.

10. For voltage series feed back amplifier with parameters of the internal amplifier as $A_V = -200$; $R_{in} = 5K$; $R_0 = 20K$; Bandwidth = 50KHz and having feedback factor $\beta = -0.02$. Calculate

i, Voltage gain A_{vf}

ii, input impedence R_{inf}

iii, output impedence R_{of} and

iv, Bandwidth

sol Given; $A_V = -200$;

$R_{in} = 5K$;

$R_o = 20K$;

$B.W = 50KHz$;

$\beta = -0.02$.

i) voltage gain $A_{vf} = \frac{A_v}{1+\beta A_v}$

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

$= -40.$

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

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

$= 25K.$

iii) output impedence $R_{of} = \frac{R_o}{1+\beta A_v}$

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

$= 4K.$

iv) Bandwidth$_f$ $= A_v * B.W.$

$= (-200)(50K)$

$= -10M.$

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

Sol :- Given;

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

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

we know that; $= 1000$.

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

Given;

output impedence $R_o = 10K$;

$R_{of} = 500\Omega$;

$\beta = ?$

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

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

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

$$1000\beta = 20 - 1$$

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

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

$= 0.5\%$