

Unit-1 Feedback Amplifier

Basic Purpose of Basic Amplifier:-

The purpose of Amplifier is to amplify the signal without changing its characteristics except the magnitude.

The Amplifier are again divided into two types based on "Signal Variation".

Signal Variation:- The maximum change in current or voltage with respect to DC is called "Signal Variation".

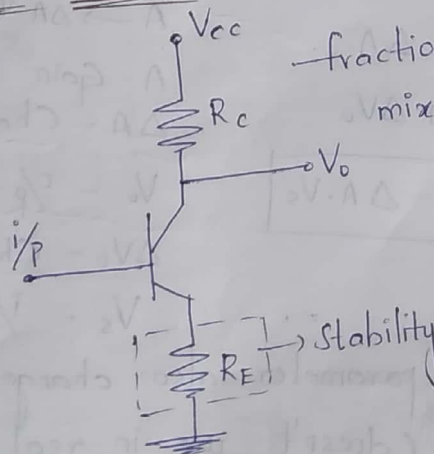
1. Small Signal Amplifier

2. Large Signal Amplifier

Small Signal Amplifier:- If the signal variation is much smaller than DC value then it is called "Small Signal Amplifier".

Large Signal Amplifier:- If the signal variation is comparable with DC value then it is called "Large Signal Amplifier".

Introduction to Feedback:-



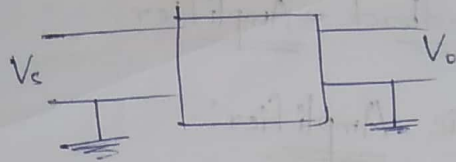
fraction of the o/p is mixed with the i/p

* R_E plays an important role in stability.

* R_E acts as feedback.

* The purpose of R_E is to stabilize the ckt. That means mathematically it brings stability.

* By the stability, the performance of ckt is not effective



where the o/p is the function of the i/p signal.

$$V_o = f(V_s)$$

Suppose, if the i/p signal is independent of o/p, then the o/p signal doesn't influence the i/p of the amplifier. Then the ckt is called "Open loop".

The above ckt is not good ckt because the ckt parameters will change due to,

1. Temperature change
2. Aging
3. Replacement of device
4. Voltage fluctuation.

⇒ Open loop amplifier doesn't have any feedback

$$\text{Gain } (A_v) = \frac{V_o}{V_s} \quad (\text{or}) \quad V_o = A_v \cdot V_s$$

Here, the gain will change due to any reason like temperature, aging---

if Gain changes then o/p also changes.

$$A = A + \Delta A$$

$$V_o = V_o + \Delta V_o$$

$$\therefore \Delta V_o = \Delta A \cdot V_s$$

$$A \rightarrow \Delta A$$

A - Gain

ΔA - Change in Gain

V_o - o/p voltage

ΔV_o - Change in o/p voltage

V_s - i/p voltage.

Then the system parameter also changes which is not our required o/p (doesn't use in real-time applications) that's why we move to feedback concept.

1. Why temperature changes:- When we operate the ckt, in the ckt having some power devices (transformer)

and semiconductor (which are more temperature sensitive) which changes the gain.

2. Aging:- Using of ckt for several years.

3. Replacement of device:- The behaviour of replaced device is not exactly equal to the before device.

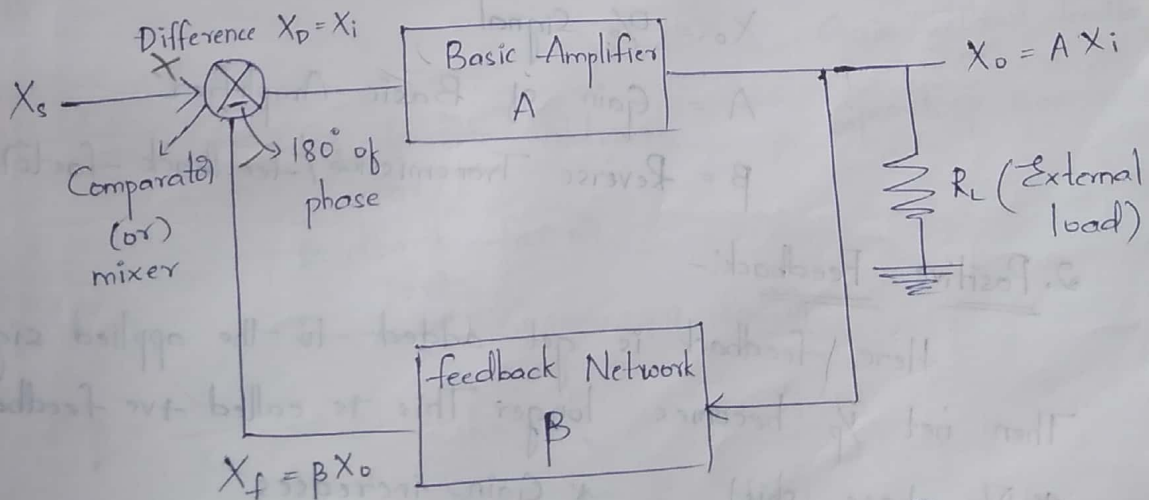
4. Voltage fluctuations:- These may change the performance of Amplifier. So, to overcome these problems we need to design a ckt without these problems. This is achieved only by feedback. Without feedback we can't achieve like this.

Feedback:- Feedback is nothing but it is a fraction of o/p is mixed with the i/p. (or) The function of the o/p voltage is mixed with the i/p. This is called "Feedback".

Simply, feedback is a process of allowing the part of the o/p to return to the i/p.

There are two types of feedback,

1. Negative feedback
2. Positive feedback



$$\left[\begin{array}{ll} X_s \rightarrow \text{i/p signal} & X_f \rightarrow \text{feedback signal} \\ X_o \rightarrow \text{o/p signal} & X_i \rightarrow X_s - X_f \end{array} \right]$$

1. Negative Feedback (180° phase Shift):-

Suppose if -feedback signal is applied to i/p signal then it makes the net ~~smaller~~ i/p smaller.

* Here feedback signal is get subtracted from applied i/p.

* -ve feedback is used to improve the system performance of Amplifier.

* In -ve feedback, gain is reduced. This is the drawback in -ve feedback.

Drawback of Basic Amplifier:-

1. Gain is unstable in Basic Amplifier

2. Device i/p & o/p resistance are not achieved

3. Higher harmonics & frequency distortion (due to limited bandwidth)

These are eliminated by using -ve feedback

from fig, $X_s = \text{Applied i/p}$

$X_i = \text{Net i/p}$

$X_f = \text{feedback signal}$

$X_o = \text{o/p signal}$

$A = \text{Gain of Basic Amplifier}$

$\beta = \text{Reverse Transmission / feedback factor}$

2. Positive Feedback:-

Here feedback is get added to the applied signal. Then net i/p becomes longer. This is called +ve feedback

* No phase shift * Gain increases

* if sufficient amount of feedback then it acts as oscillator

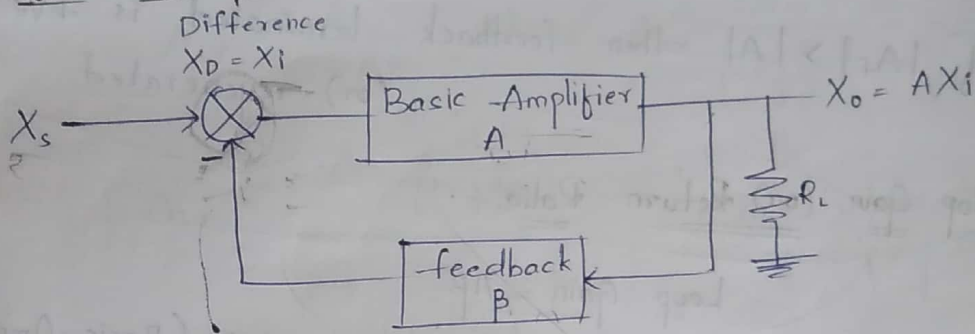
* Basic Amplifier converts to Oscillator (or) regenerative ckt.

Note:-

- * -ve feedback (or) degenerative ckt used in "Amplifier"
- * +ve feedback is used to convert the Amplifier to "Oscillator".

What are the effects of Negative feedback on characteristics of Basic Amplifier:-

1. Effect on Gain:-



Since Gain decreases due to -ve feedback by a factor $(1 + AB)$ times.

Here, $\frac{X_o}{X_s} = \frac{\%P}{i/P} = \text{Gain of feedback amplifier / Closed loop}$

$$\text{Closed loop gain } (A_{CL}) = A_f = \frac{X_o}{X_s} \rightarrow (1)$$

↓
feedback

$$\text{Open loop gain } (A_{OL}) = A = \frac{X_o}{X_i} \rightarrow \text{Gain of Basic Amplifier (or) Gain without feedback (or) Open loop gain}$$

→ (2)

$$\frac{X_f}{X_o} = \text{Gain of feedback Network (or)}$$

feedback factor

(or)
Reverse Transmission factor

$$\beta = \frac{X_f}{X_o} \rightarrow (3)$$

$$X_i = X_s - X_f$$

$$X_s = X_i + X_f = X_i + \beta X_o \text{ (from (3))}$$

$$= X_i + \beta (AX_i) \text{ (from (2))}$$

$$X_s = X_i(1 + AB) \rightarrow (4)$$

Eq ④ in Eq ①

$$A_{CL} = A_f = \frac{X_o}{X_i(1+A\beta)} = \frac{A \cancel{X_i}}{\cancel{X_i}(1+A\beta)} \quad (\text{from ②})$$

$$\therefore A_{CL} = A_f = \frac{A}{(1+A\beta)}$$

→ This is the closed loop gain of Amplifier with feedback.

if $|A_f| < |A|$ then feedback terminated is -ve

if $|A_f| > |A|$ then feedback terminated is +ve
(or) regenerated.

Loop Gain (or) Return Ratio:-

$$\text{Loop Gain} = A\beta$$

The product is nothing but $\rightarrow -1 \cdot A \cdot \beta$ (Basic Amplifier) $\downarrow$
-feedback

factor loop gain (or) return ratio = $-A\beta$

$$D = 1 + A\beta$$

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

$$\therefore D = 1 + A\beta$$

Since, the difference b/w unity(1) & the loop gain $(-A\beta)$ is called the "return difference". (indicated by 'D')

* The Amount of feedback is expressed in dB's (decibels)

$$\text{Amount of feedback (N)} = 20 \log \left| \frac{\text{Closed loop gain}}{\text{Open loop gain}} \right|$$

$$= 20 \log \left| \frac{A_f}{A} \right| = 20 \log \left| \frac{1}{1 + A\beta} \right|$$

$$(\because A_f = \frac{A}{1 + A\beta})$$

* The amount of feedback is indicated with 'N'.

$$\therefore N = 20 \log \left| \frac{A_f}{A} \right|$$

Suppose, $N = -ve$ number,

$$\text{Then } N = 20 \log \left| \frac{1}{1+A\beta} \right| = -20 \log (1+A\beta)$$

2. Effect on Cut-off frequencies:-

Case (i) :- Effect on Lower-Cut off frequency:-

We know that,

$$A_{Lf} = \frac{A_L}{1+A\beta} \quad \text{where, } A_L = \frac{A_m}{\left[1-j\frac{f_L}{f}\right]} = \frac{A_m}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}}$$

$$A_{Lf} = \frac{A_m \cancel{\left(1-j\frac{f_L}{f}\right)}}{1 + \frac{A_m}{\left(1-j\frac{f_L}{f}\right)} \cdot \beta}$$

↓
This is due to effect of coupling capacitor

$$= \frac{\cancel{A_m} \cancel{\left(1-j\frac{f_L}{f}\right)}}{\left(1-j\frac{f_L}{f}\right) + A_m \cdot \beta} = \frac{A_m}{1-j\frac{f_L}{f} + A_m \cdot \beta}$$

where, A_m = mid band gain

$$= \frac{A_m}{(1+A_m \cdot \beta) \left(1-j\frac{f_L}{f(1+A_m \cdot \beta)}\right)}$$

∴ Divide & Multiply with $(1+A_m \cdot \beta)$ in denominator

$$\frac{A_m}{(1+A_m \cdot \beta) \left(1-j\frac{f_L}{f(1+A_m \cdot \beta)}\right)} = \frac{A_m}{(1+A_m \cdot \beta) \left(\frac{(1+A_m \cdot \beta) - j\frac{f_L}{f}}{(1+A_m \cdot \beta)}\right)} = \frac{A_m}{(1+A_m \cdot \beta) \left(1-j\frac{f_L}{f(1+A_m \cdot \beta)}\right)}$$

$$A_{Lf} = \frac{A_m f}{1-j\frac{f_L}{f}} \quad \left(\because \frac{A_m}{1+A_m \cdot \beta} = A_{mf} ; \frac{f_L}{1+A\beta} = f_{Lf} \right)$$

$$f_{Lf} = \frac{f_L}{1+A\beta}$$

due to -ve feedback it reduces the lower cutoff frequencies

Case (ii) :- Effect on higher cut-off frequency :-

$$A_{Hf} = \frac{A_H}{1 + A_H \beta} \quad \text{where} \quad A_H = \frac{A_m}{(1 + j \frac{f}{f_H})}$$

$$A_{Hf} = \frac{\frac{A_m}{(1 + j \frac{f}{f_H})}}{1 + \left(\frac{A_m}{(1 + j \frac{f}{f_H})} \right) \beta} = \frac{A_m}{1 + j \frac{f}{f_H} + A_m \cdot \beta}$$

$$A_{Hf} = \frac{A_m}{(1 + A_m \cdot \beta) \left(\frac{1 + j \frac{f}{f_H} + A_m \cdot \beta}{(1 + A_m \cdot \beta)} \right)} = \frac{A_m}{(1 + A_m \cdot \beta) \left(\frac{(1 + A_m \cdot \beta) + j \frac{f}{f_H}}{(1 + A_m \cdot \beta)} \right)}$$

$$A_{Hf} = \frac{A_m}{(1 + A_m \cdot \beta) \left(1 + \frac{j \frac{f}{f_H}}{(1 + A_m \cdot \beta)} \right)} = \frac{A_m}{(1 + A_m \cdot \beta) \left(1 + j \frac{f}{f_H (1 + A_m \cdot \beta)} \right)}$$

$$A_{Hf} = \frac{A_{mf}}{1 + j \frac{f}{f_{Hf}}} \quad \left(\because \frac{A_m}{1 + A_m \cdot \beta} = A_{mf} ; f_H (1 + A_m \cdot \beta) = f_{Hf} \right)$$

Here,

$$\therefore f_{Hf} = f_H (1 + A \cdot \beta)$$

due to -ve feedback it increases the higher cutoff frequency

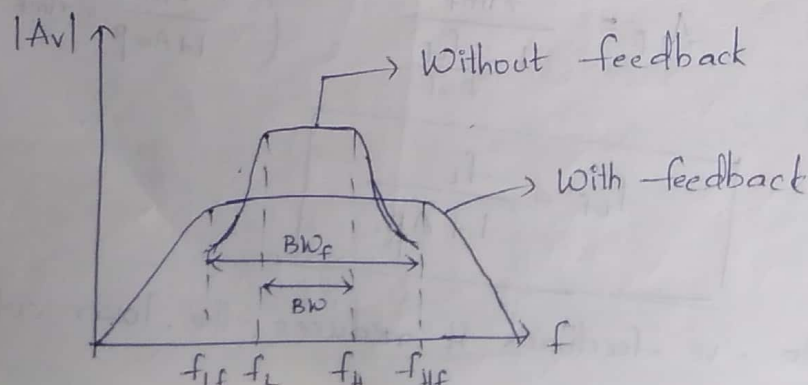
$$\text{Bandwidth (BW)} = f_H - f_L$$

$$BW_f = f_{Hf} - f_{Lf} \approx f_{Hf}$$

$$\therefore BW_f = BW (1 + A \cdot \beta)$$

where, BW_f = with feedback

BW = without feedback



Thus, due to -ve feedback, LCF is decreased by $(1+A\beta)$ times and higher cutoff freq (HCF) is increased by $(1+A\beta)$ times. Then obviously, the Bandwidth becomes increased with feedback. This means the freq distortion is reduced $(1+A\beta)$ times because due to -ve feedback midband ranges are more.

3. Effect on frequency distortion:-

* In any amplifier, the o/p waveform is less than perfect reproduction of i/p waveform because the process of Amplification introduces some distortion.

* The changes introduced can be due to one or more of the following effects.

a) Amplitude distortion b) freq distortion c) phase distortion.

frequency distortion:-

* frequency distortion describes the condition where different frequencies within the amplifier's bandwidth are amplified by different amounts.

* The gain over the bandwidth is no longer flat.

* Under these conditions the various frequency components of complex wave amplified by different amounts & the wave becomes distorted.

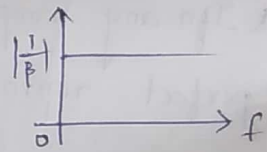
* freq distortion can be caused by the frequency dependent effects of reactive components (capacitances & inductances) in the ckt. Thus -ve feedback has an important role in helping prevent frequency distortion.

By applying -ve feedback keeps the closed loop gain at a constant level for even large changes in open loop gain. And the effect of -ve feedback helps to produce a flat response curve. So, gain becomes flatter for all frequencies.

* Since, due to decrease in the lower cutoff freq & increase in higher cutoff freq which will reduce in the percentage of tilt (Error).

% of tilt = $\frac{\pi f_L}{f}$ which indicates decrease in lower frequency distortion. Similarly due to -ve feedback HCF & rise & fall time will decrease. i.e., $(t_r = \frac{0.35}{f_H \uparrow}) \downarrow$ s
($\therefore t_r$ indicates higher freq distortion).

$\therefore A_f = \frac{1}{\beta} \rightarrow \text{Constant freq.}$



4. Effect on Stability:-

* By using -ve feedback we can stabilize the gain of amplifier by reducing its dependence on the transmission parameters.

$$A_f = \frac{A}{1 + A\beta} \quad A\beta \text{ is } \gg 1$$

Therefore, closed loop gain = $A_f = \frac{1}{\beta}$ ($\because \beta$ - feedback factor)

β - depends on resistor used in the feedback network.

* Resistors are less temperature sensitive, aging & replacement of the device and gain remains stable in -ve feedback.

* Suppose the feedback is removed then the amplifier works as basic amplifier.

Note:-

* In -ve feedback, the feedback signal & applied signal are 180° phase shift. But not in +ve feedback.

5. Effect on Sensitivity (S):-

* Sensitivity means, it is the ratio of relative change in gain with feedback to relative change in gain without feedback.

(or)

$$S = \frac{\text{The fractional change in Amplification with feedback}}{\text{The fractional change in Amplification without feedback}}$$

$$\text{i.e., } S = \frac{dA_f/A_f}{dA/A}$$

$$\left(\because A_f = \frac{A}{1+A\beta} \right) \rightarrow \text{Closed loop gain of feedback Amplifier.}$$

Now differentiate w.r.t 'A'

$$\frac{dA_f}{dA} = \frac{d}{dA} \left(\frac{A}{1+A\beta} \right) \quad \left(\because \frac{d(u/v)}{dA} = \frac{vu' - uv'}{v^2} \right)$$

$$= \frac{(1+A\beta)(A') - (A)(1+A\beta)'}{(1+A\beta)^2}$$

$$= \frac{(1+A\beta)(1) - (A)(0+\beta)}{(1+A\beta)^2} = \frac{1+A\beta - A\beta}{(1+A\beta)^2}$$

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

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

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

Take feedback one side remaining to other.

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

where, $\frac{dA_f}{A_f}$ = Relative change in gain with feedback

$\frac{dA}{A}$ = Relative change in gain without feedback

$$\therefore S = \frac{dA_f/A_f}{dA/A} = \frac{1}{1+A\beta} \rightarrow \text{Sensitivity}$$

We conclude that,

Gain without feedback changes by large amount &
Gain with feedback changes in a small amount i.e.;
sensitivity.

$$\therefore \text{for -ve feedback } \frac{dA_f}{A_f} < \frac{dA}{A}$$

6. Effect on Desensitivity (D):-

* Desensitivity is the reciprocal of sensitivity.

$$D = \frac{1}{S} = \frac{1}{\frac{1}{1+AB}} = 1+AB$$

* This desensitivity is the measure of ability of a
-ve feedback to stabilize the gain.

* Higher desensitivity indicates higher stability because
of desensitivity is the measure of ability of -ve feedback
to stabilize the gain.

7. Effect on Harmonic distortion (D_{HF}):-

* Due to -ve feedback reduces the harmonic distortion.
How much amount is reduced?

$$D_{HF} = \frac{D_H}{1+AB} \quad \text{This amount is reduced.}$$

* Harmonic distortion is more in "power amplifiers".
Because power amplifier is a large signal amplifier.

* These are the effects of on characteristics on Basic
Amplifier.

Classification of Amplifiers:-

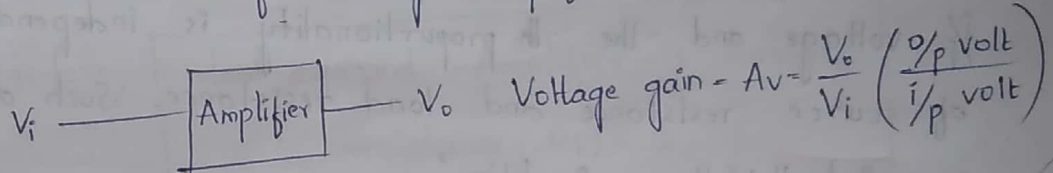
There are 4 types of Amplifiers. Classified based on
magnitude of i/p & o/p impedance of an amplifier
related to source & load impedances.

Suppose if we connect voltage source it is series connection
if we connect current source it is parallel connection

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

1. Voltage Amplifier:-

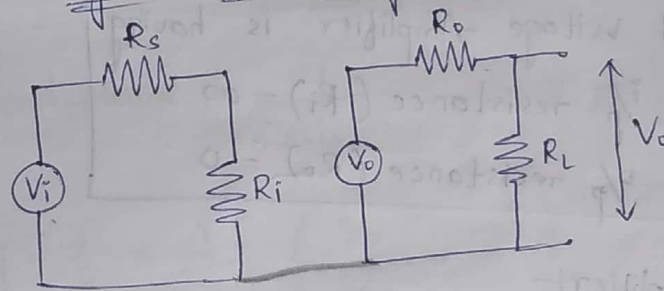
Voltage Amplifier is a thevenin's equivalent ckt of voltage Amplifier.



i/p - we are connecting voltage

o/p - we are connecting voltage

Rough diagram of voltage Amplifier:-



R_s - Source Resistance

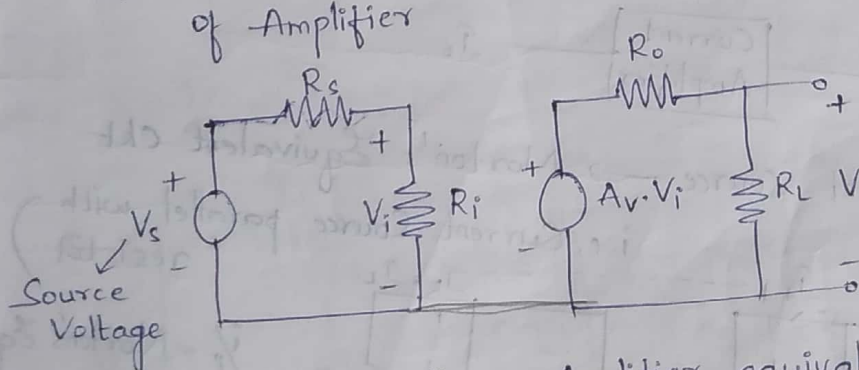
V_i - i/p Voltage

R_i - internal resistance of Amplifier

V_o - o/p voltage

R_o - o/p resistance

R_L - Load resistance (External load)



This is our voltage Amplifier equivalent ckt.

Here, $R_i \gg R_s$

$R_o \ll R_L$

→ if R_i is large, -than R_s , -then

$$V_i \cong V_s$$

Let $R_s = 10\Omega$, voltage drop is negligible across R_s

→ if $R_L \gg R_o$, -then

$$V_o \cong A_v \cdot V_i$$

* This Amplifier provides o/p voltage is proportionality to i/p voltage. and the proportionality is independent of source resistance and load resistance. Such a ckt is called "Voltage Amplifier".

$$\therefore A_v (\text{Voltage Gain}) = \frac{\text{o/p volt}}{\text{i/p volt}} \quad \left| \text{with } R_L \text{ tends to } \infty \right.$$

-that means o/p ckt voltage gain.

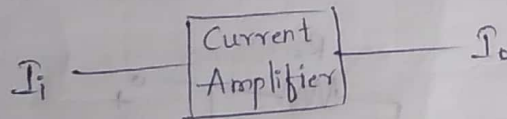
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So, ideal Voltage Amplifier is having
i/p resistance (R_i) = ∞
o/p resistance (R_o) = 0

Most Imp
for Competitive
Exams

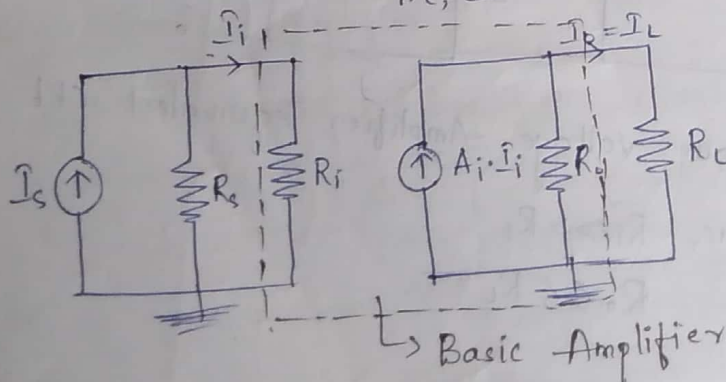
2. Current Amplifier:-

In Current Amplifier,

$$\text{Current Gain } (A_i) = \frac{I_o}{I_i} \left(\frac{\text{o/p Current}}{\text{i/p Current}} \right)$$



($\therefore$ for Current source $\rightarrow$ Norton's Equivalent ckt
i.e, Current Source parallel with resistor)



i/p - Norton's Equi
o/p - Norton's Equi

* if $R_i \ll R_s$ then $I_i \cong I_s$

* if $R_o \gg R_L$ then $I_L \cong A_i \cdot I_i$

* Therefore o/p current (I_L) is proportional to signal current ' I_i '

$$\text{Short ckt Current Gain } (A_i) = \left. \frac{I_L}{I_i} \right|_{\text{with } R_L \rightarrow 0}$$

Therefore, ideal current Amplifier is having
i/p resistance (R_i) = 0
o/p resistance (R_o) = ∞

This is the Current Amplifying Equivalent Ckt.

3. Transconductance Amplifier:-

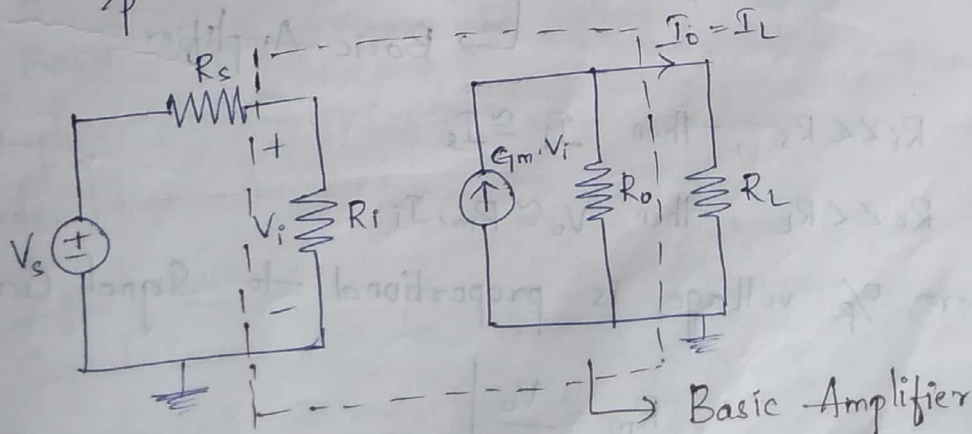
$$\text{Conductance} = \frac{1}{\text{Resistance}} \quad V_i \rightarrow \boxed{\text{Transconductance Amp}} \rightarrow I_o$$

$$G = \frac{1}{R} = \frac{I}{V} \left(\frac{\text{o/p Current}}{\text{i/p Voltage}} \right)$$

$$G_m = \frac{\text{o/p Current}}{\text{i/p Voltage}}$$

→ This is "Transconductance Gain".

i/p - Thevenin's Equi o/p - Norton's Equi.



* if $R_i \gg R_s$, then $V_i \cong V_s$

* if $R_o \gg R_L$, then $I_L \cong G_m \cdot V_i$

* Here % current is proportional to Signal Voltage

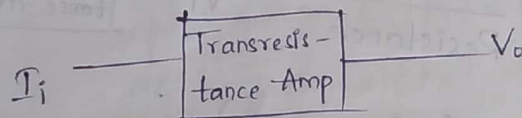
$$\therefore G_m = \frac{I_L}{V_i} \rightarrow \text{Transconductance Gain}$$

Therefore, ideal Transconductance Amplifier,
i/p Resistance (R_i) = ∞
o/p Resistance (R_o) = ∞

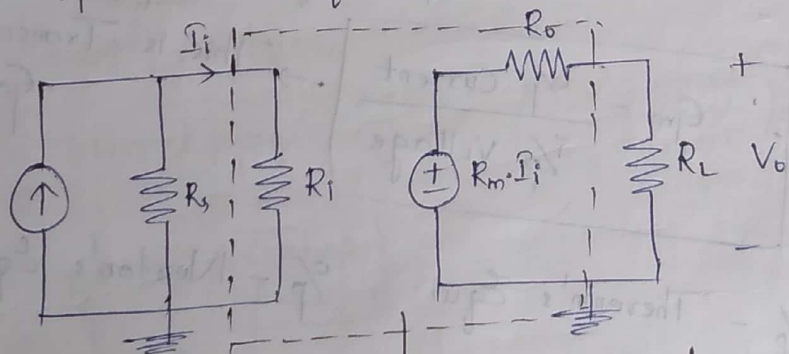
4. Transresistance Amplifier:-

$$\text{Resistance (R)} = \frac{V}{I}$$

$$\text{Transresistance Gain (R}_m\text{)} = \frac{\text{o/p voltage}}{\text{i/p Current}}$$



i/p - Norton's Equi o/p - Thevenin's Equi



Basic Amplifier.

* if $R_i \ll R_s$, then $I_i \cong I_s$

* if $R_o \ll R_L$, then $V_o \cong R_m \cdot I_i$

* Here, % voltage is proportional to Signal Current

$$R_m = \left. \frac{V_o}{I_i} \right|_{\text{with } R_L \rightarrow \infty}$$

Therefore, ideal Transresistance Amplifier,

$$i/p \text{ Resistance } (R_i) = 0$$

$$o/p \text{ Resistance } (R_o) = 0$$

Ideal Amplifier Characteristics:-

Parameters

Amplifiers

Voltage Amplifier

Current Amplifier

Transconductance Amplifier

Transresistance Amplifier

1. i/p resistance (R_i)

$$\infty$$

$$0$$

$$\infty$$

$$0$$

2. o/p resistance (R_o)

$$0$$

$$\infty$$

$$\infty$$

$$0$$

3. Transfer Characteristics

$$V_o = A_v \cdot V_s$$

$$I_L = A_i \cdot I_s$$

$$I_L = G_m \cdot V_s$$

$$V_o = R_m \cdot I_s$$

Block diagram of feedback Amplifier:-

Signal Source

Basic Amplifier

Sampling Network

Feedback Network

i) Basic Amplifier:-

* Basic Amplifier is the amplifier without feedback.

* Basic Amplifiers may be Voltage Amplifier (or) Current Amplifier (or) Transconductance Amplifier (or) Transresistance Amplifier.

ii) Signal Source:-

* Signal Source can be Voltage Source (Thevenin's Equi) (or) Current Source (Norton's Equi), depending upon the type of Basic Amplifier.



* if Basic Amplifier is,

→ Voltage Amplifier (or) Transconductance Amplifier - we require Thevenin's Equivalent Ckt.

→ Current Amplifier (or) Transresistance Amplifier - we require Norton's Equivalent Ckt.

iii) Feedback Network:-

* It is a two port passive network.

* In -ve feedback, this network consists only one resistor.

* In +ve feedback, this network consists combination of resistors, inductors & capacitors.

What is the function of feedback Network?

Ans:- It collects some samples from the o/p & passed to feedback network and multiplied with (p) feedback factor & produces the proportional feedback system.

$$X_f = \beta X_o$$

X_f - o/p of feedback Network

X_o - o/p of feedback Network

This is the function of feedback Network.

iv) Sampling Network:-

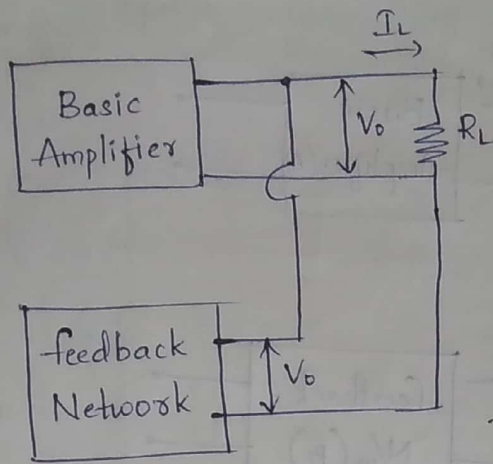
* This sampling network is connected to feedback Network.

What is the function of Sampling Network?

Ans:- It represents the way of feedback Network is connected to the o/p side of Basic Amplifier.

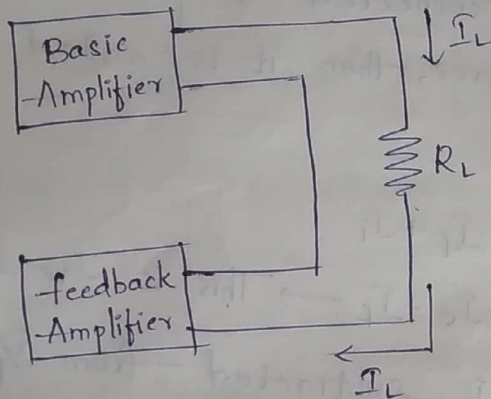
i.e., Series, parallel.

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Suppose, if this feedback Network connected in parallel to load resistor ' R_L ' then o/p voltage will directly appears to i/p of feedback Network (V_o).

*



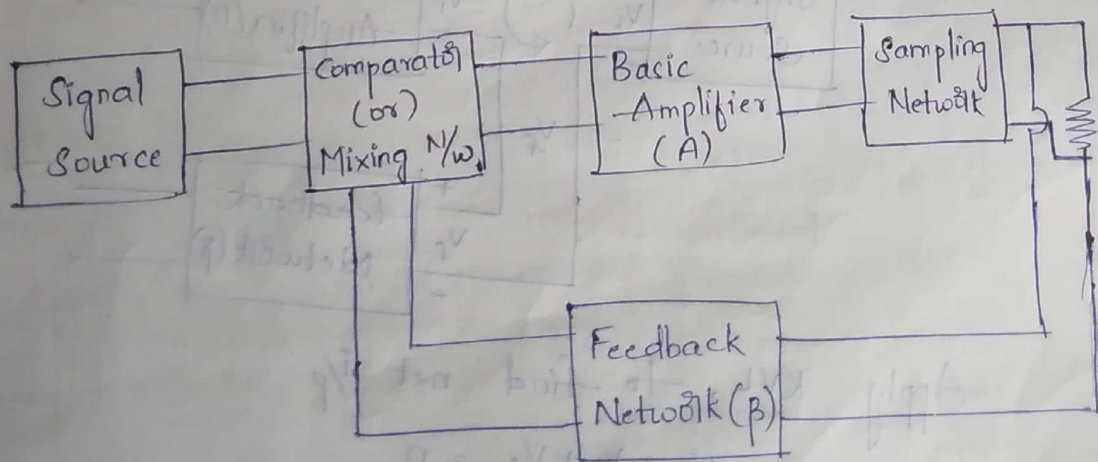
Suppose, if this feedback Network connected in series to load resistor ' R_L ' then o/p Current will directly appears to i/p of feedback Network (I_L). Then it is called "Current Sampling N/w" (or) "Loop Sampling".

03/04/21

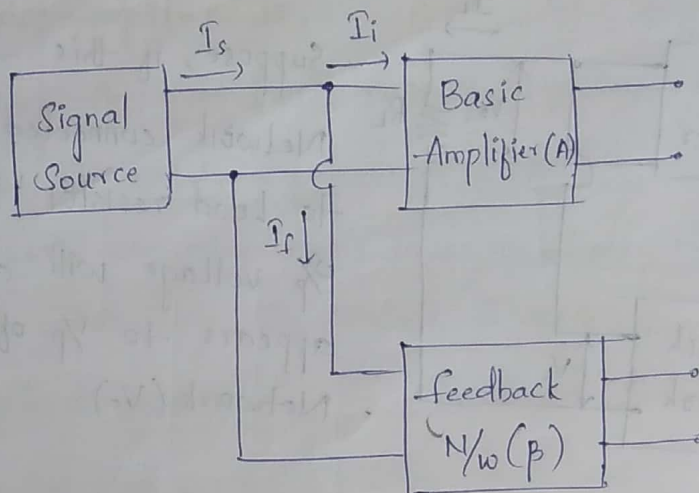
iv) Comparator (or) Mixing Network:-

* This is also like "Sampling Network".

* Suppose the o/p of feedback N/w is Voltage Signal, is connected to comparator.



i)



* If the feedback N/w connected in parallel (or) shunt with signal source, then it is called "Shunt Mixing".

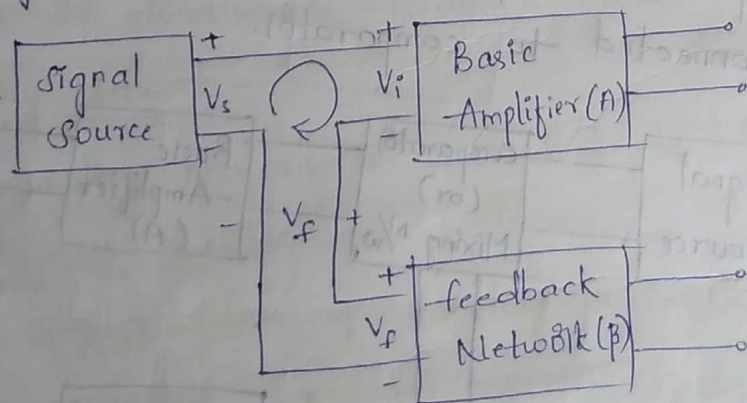
$$\text{Net i/p } I_s = I_f + I_i$$

$$I_i = I_s - I_f \rightarrow \text{This is -ve feedback.}$$

Because this feedback is subtracted from i/p.

* Shunt mixing is used for mixing of current signal. This is "Shunt Mixing".

ii) * If the feedback N/w is connected in series with signal source, then it is called "Series Mixing".



Apply KVL, to find net i/p

$$-V_s + V_i + V_f = 0$$

$$V_i = V_s - V_f \rightarrow \text{This is the Net i/p.}$$

* It is -ve feedback, because feedback signal is subtracted from applied i/p.

Transfer Ratio (or) Gain:-

$$\left(\begin{array}{l} \therefore \text{Voltage Amplifier - Voltage Gain} \Rightarrow A_v = \frac{V_o}{V_i} \\ \therefore \text{Current Amplifier - Current Gain} \Rightarrow A_i = \frac{I_o}{I_i} \end{array} \right)$$

In Block diagram, 'A' represents the ratio of o/p signal to i/p signal.

$$\text{Transconductance Gain } (G_m) = \frac{I_o}{V_i}$$

$$\text{Transresistance Gain } (R_m) = \frac{V_o}{I_i}$$

* These are the transfer gain of Basic Amplifier without feedback.

* A_f - is called the transfer gain of the Amplifier with feedback.

$$\text{Voltage gain} = A_{vf} = \frac{V_o}{V_s}$$

$$\text{Current gain} = A_{if} = \frac{I_o}{I_s}$$

($\therefore V_s$ - here 's' means including source (with feedback))

$$\text{Transconductance gain} = G_{mf} = \frac{I_o}{V_s}$$

$$\text{Transresistance gain} = R_{mf} = \frac{V_o}{I_s}$$

Samplers: Part of o/p is fed to the i/p of f/bk. voltage samp. current samp.

Feedback Topologies:-

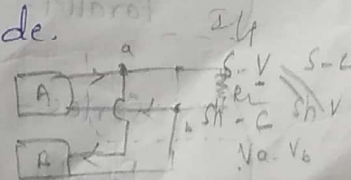
* Based on type of mixing & sampling N/w. There are 4 types of topologies are possible.

1. Series - Series feedback:-

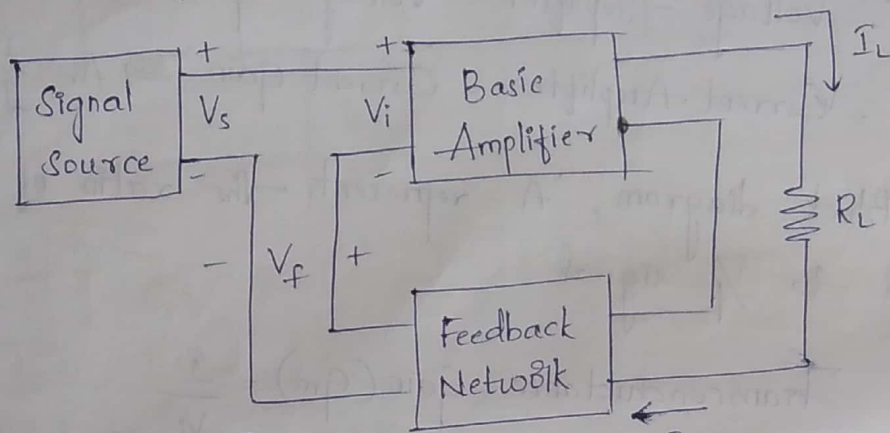
* i/p side - series o/p side - series

* This is also called as "Current - Series - feedback"

(In series, Current is same).



* Wkt, mixing N/w is i/p to Basic Amplifier, & o/p is sampling Network.



($\therefore$ i/p - voltage)
o/p - Current)

* Here, feedback signal,

$$X_f = \beta X_o$$

$$V_f = \beta I_L$$

$$\therefore \beta = \frac{V_f}{I_L}$$

* So, this feedback N/w is Transconductance gain.

* This feedback N/w stabilize the Transconductance gain.

2. Series-Shunt feedback:-

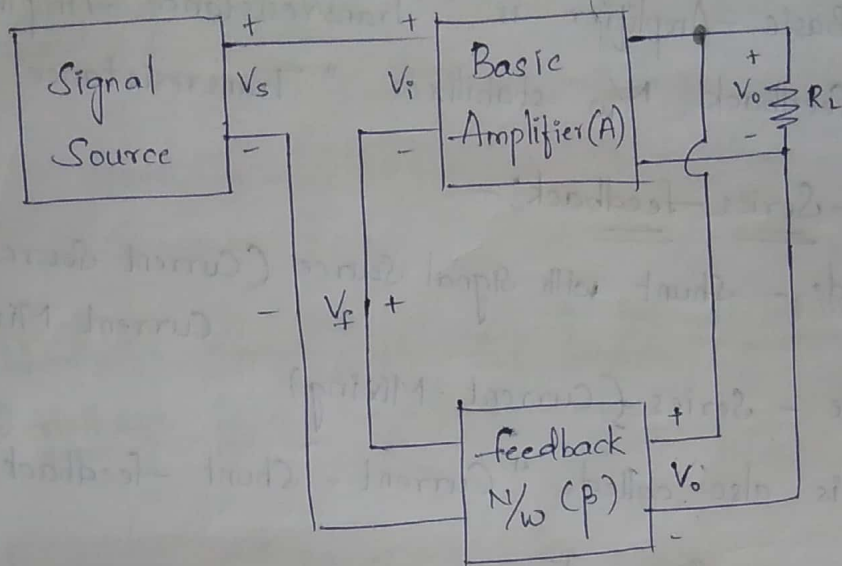
* i/p side - series (Voltage mixing)

* o/p side - Shunt (or) parallel (Voltage mixing)

($\therefore$ Series - Voltage mixing only in i/p side)
Parallel - Current mixing

($\therefore$ Series - Current mixing only in o/p side)
Parallel - Voltage mixing

* This is also called "Voltage-Series feedback".



$$X_f = \beta X_o$$

$$V_f = \beta V_o$$

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

* Therefore, this Basic Amplifier is "Voltage Amplifier".

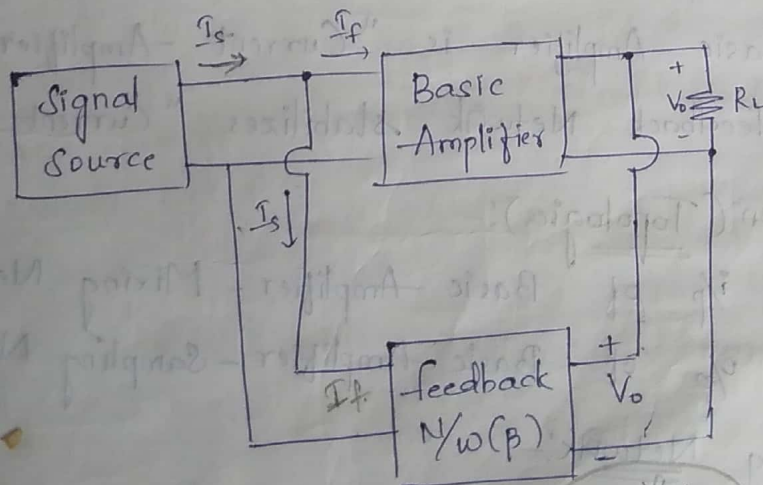
* This feedback N/w stabilizes the "Voltage gain".

3. Shunt - Shunt feedback:-

* i/p side - shunt (Current Mixing)

* o/p side - ~~series~~ shunt (Voltage Mixing)

* This is also called "Voltage-Shunt Amplifier".



$$X_f = \beta X_o$$

$$I_f = \beta V_o$$

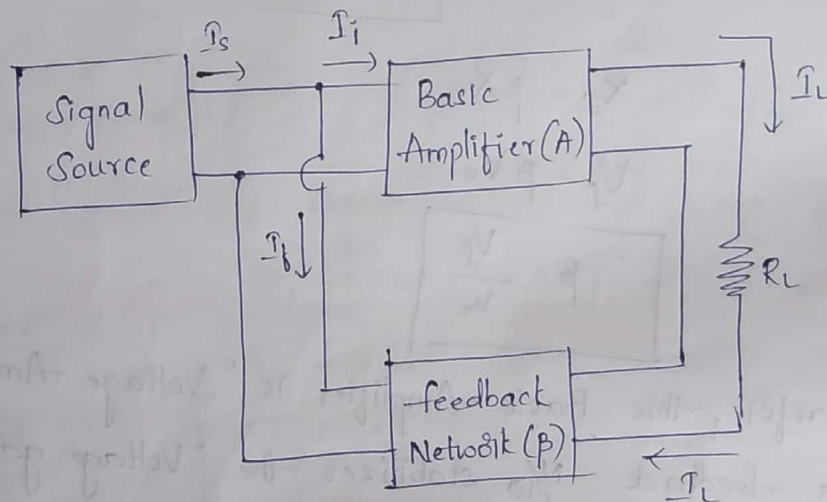
$$\therefore \beta = \frac{I_f}{V_o}$$

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

- * This Basic Amplifier is "Transresistance Amplifier".
- * This feedback N/w stabilizes "Transresistance gain".

4. Shunt-Series-feedback:-

- * i/p side - Shunt with Signal Source (Current Source - Current Mixing)
- * o/p side - Series (Current Mixing)
- * This is also called "Current-Shunt-feedback".



$$X_f = \beta X_o$$

$$I_f = \beta I_o$$

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

- * This Basic Amplifier is "Current Amplifier".
- * This feedback Network stabilizes "Current Gain".

Conclusion (Topologies):-

- * Always i/p of Basic Amplifier - Mixing Network
- * o/p of Basic Amplifier - Sampling Network

1. Mixing Network:-

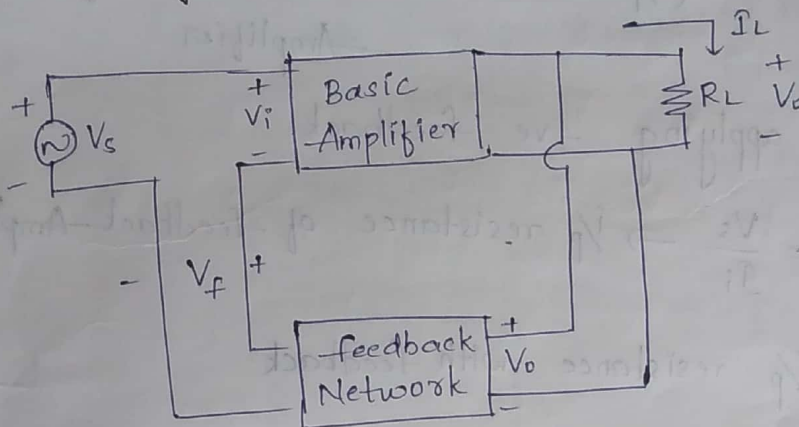
- Series :- Voltage mixing
- Shunt/Parallel :- Current dominating

2. Sampling Network:- $\frac{O/P}{I/P} \leftarrow$ shunt current
 Series :- Current mixing $\rightarrow$ voltage
 Shunt / Parallel :- Voltage dominating

4/06/21

Effect of feedback on i/p & o/p resistances:-

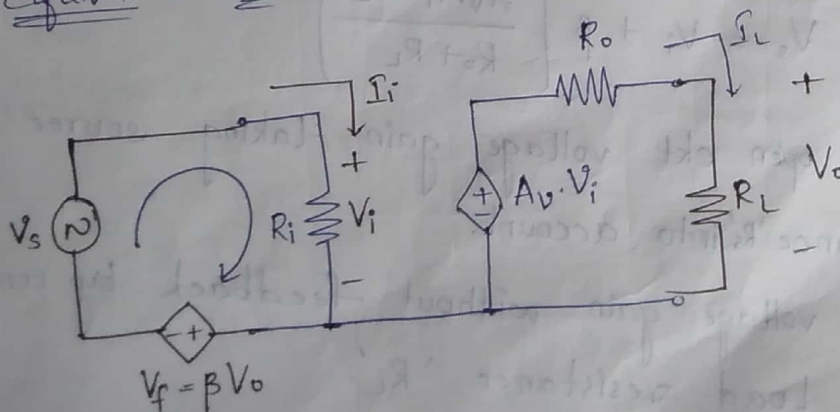
✓ (a) Voltage Series Feedback:-



o/p - Voltage Sample (Parallel with load resistor)
 * feedback N/w is connected in parallel with load resistor.

i/p - Mixing Network.
 * feedback N/w is connected in series with voltage source.

In Voltage series feedback, Basic Amplifier is voltage Amplifier, which amplifies voltage signal.
Equivalent ckt:-



* Here, internal resistance is negligible.

* $V_f = \beta V_o \rightarrow$ i/p side. (feedback signal)

(i) Effect on i/p resistance:-

* i/p - resistance ' R_i '.

$$R_i = \frac{V_i}{I_i} \quad \begin{array}{l} \text{(i/p Voltage)} \\ \text{(i/p Current)} \end{array} \rightarrow \text{This is the i/p resistance of basic Amplifier.}$$

We are applying -ve feedback.

$$R_{if} = \frac{V_s}{I_i} \rightarrow \text{i/p resistance of feedback Amplifier}$$

R_{if} - i/p resistance with feedback

Apply KVL in i/p loop,

$$-V_s + V_i + V_f = 0$$

$$V_s = V_i + V_f$$

$$\boxed{V_s = V_i + \beta V_o} \quad \left(\because V_f = \beta V_o \right)$$

We have to calculate ' V_o ' to find ' V_s '.

Apply Voltage division rule

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

$$\therefore V_s = V_i + \beta \left[\frac{A_v \cdot V_i \cdot R_L}{R_o + R_L} \right]$$

A_v = open ckt voltage gain taking source resistance ' R_s ' into account.

A_v = voltage gain without feedback by considering Load resistance ' R_L '.

Replace $\frac{A_v \cdot R_L}{R_o + R_L}$ with A_v .

$$V_s = V_i + A_v \cdot V_i \cdot \beta$$

$$V_s = V_i (1 + A_v \beta)$$

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

$$\therefore R_{if} = \frac{V_s}{I_i} = R_i (1 + A_v \beta) \rightarrow \text{i/p resistance of Voltage Series feedback}$$

$$\left(\because R_i = \frac{V_i}{I_i} \rightarrow \text{i/p resistance of basic amplifier} \right)$$

* due to -ve feedback, R_{if} is increasing by the factor of $(1 + A_v \beta)$.

* i/p resistance with feedback $>$ i/p resistance without feedback.

$$R_{if} > R_i$$

ii) Effect on o/p resistance:-

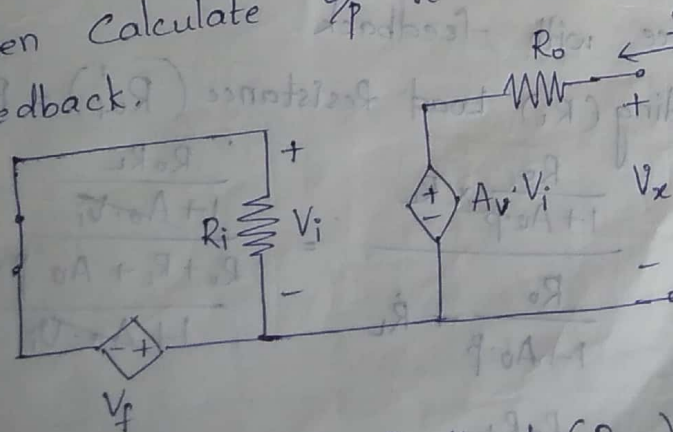
* To find o/p resistance, we have to modify equivalent ckt.

→ Replace source voltage ' V_s ' with short ckt

→ Disconnect external load ' R_L '

→ Apply test voltage ' V_x ' at the o/p side

Then Calculate o/p resistance of Voltage Series feedback.



$$\text{o/p resistance with feedback } (R_{of}) = \frac{V_x}{I_x}$$

* $\%$ resistance with feedback
without including (R_L) Load Resistance

$$R_{of} = \frac{V_x}{I_x}$$

$$I_x = \frac{V_x - A_v \cdot V_i}{R_o}$$

In i/p loop,

$$V_i + V_f = 0$$

$$V_i = -V_f \rightarrow \textcircled{1}$$

$$I_x = \frac{V_x - A_v \cdot (-V_f)}{R_o} \quad (\because V_f = \beta V_x)$$

$$I_x = \frac{V_x - A_v \cdot (-\beta V_x)}{R_o}$$

$$= \frac{V_x + A_v \cdot \beta \cdot V_x}{R_o}$$

$$= \frac{V_x (1 + A_v \cdot \beta)}{R_o}$$

$$\frac{I_x}{V_x} = \frac{1 + A_v \cdot \beta}{R_o}$$

$$R_{of} = \frac{V_x}{I_x} = \frac{R_o}{1 + A_v \cdot \beta}$$

($\because A_v$ - open ckt voltage gain)

* $\%$ resistance with feedback
after including (R_L) Load Resistance (R_{of}') = $R_{of} \parallel R_L$

$$R_{of}' = \frac{\frac{R_o}{1 + A_v \cdot \beta} \times R_L}{\frac{R_o}{1 + A_v \cdot \beta} + R_L} = \frac{\frac{R_o R_L}{1 + A_v \cdot \beta}}{\frac{R_o + R_L + A_v \cdot \beta \cdot R_L}{1 + A_v \cdot \beta}}$$

$$= \frac{R_o R_L}{R_o + R_L + A_v \cdot \beta \cdot R_L}$$

Now, multiply $\frac{1}{R_o + R_L}$ in Numerator & denominator

$$= \frac{\frac{R_o R_L}{R_o + R_L} \rightarrow R_o'}{1 + \beta \frac{A_v R_L}{R_o + R_L} \rightarrow A_v'}$$

$$\left(\because A_v = \frac{A_v R_L}{R_o + R_L} \right) \left(\because R_o' = \text{output resistance without feedback} \right)$$

$$\therefore R_o' = \frac{R_o}{1 + \beta A_v}$$

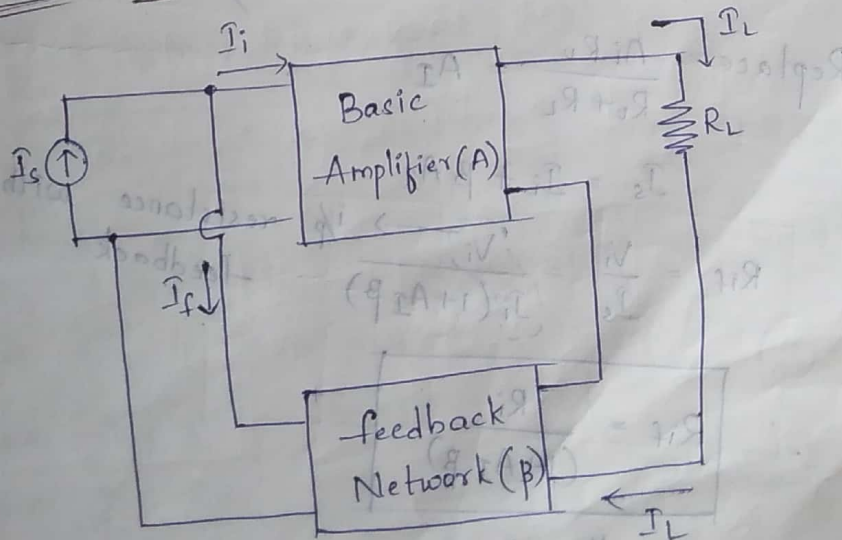
from $A_v = \frac{A_v R_L}{R_o + R_L}$

if $R_L \rightarrow \infty$ then, $\frac{V}{I} = R_o'$

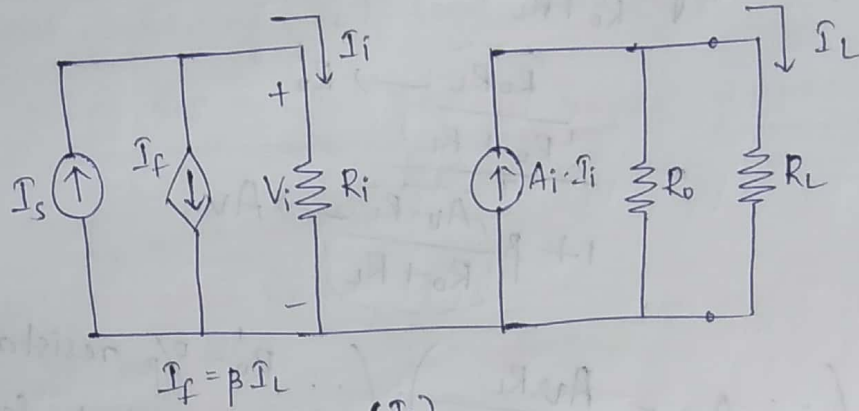
$$A_v = \frac{A_v R_L}{R_L \left(\frac{R_o}{R_L} + 1 \right)} = A_v \left(\because \frac{R_o}{\infty} = 0 \right)$$

$$\therefore A_v = A_v$$

5/6/21
ii) Current Shunt feedback Amplifier:-



Equivalent Ckt.:-



* The $\%$ of Amplifier (Basic) is multiplied with feedback Network (β) and the $\%$ of feedback N/w is mixed with the i/p .

* Effect on i/p resistance:-

i/p resistance (R_i) = $\frac{V_i}{I_i}$ of Basic Amplifier. (or) without feedback.

i/p resistance (R_{if}) = $\frac{V_i}{I_s}$ with feedback

We need to calculate I_s ,

Apply KCL at i/p side,

$$I_s = I_f + I_i$$

$$I_s = I_i + \beta I_L \quad (\because I_i = \beta I_L)$$

$$I_s = I_i + \beta \left[A_i \cdot I_i \cdot \frac{R_o}{R_o + R_L} \right] \quad (\text{from } o/p \text{ side})$$

Replace $\frac{A_i R_o}{R_o + R_L} = A_I$

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

$$R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i (1 + A_I \beta)} \quad \text{--- } i/p \text{ resistance without feedback}$$

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

$$A_i = \lim_{R_L \rightarrow \infty} A_I$$

$$A_I = \frac{A_i \cdot R_o}{R_o + R_L} = \frac{A_i \cdot R_o}{R_o \left(1 + \frac{R_L}{R_o}\right)} \quad \left(\because R_L \rightarrow 0 \right)$$

$$1 + \frac{R_L}{R_o} = 1$$

$$\therefore A_I = A_i$$

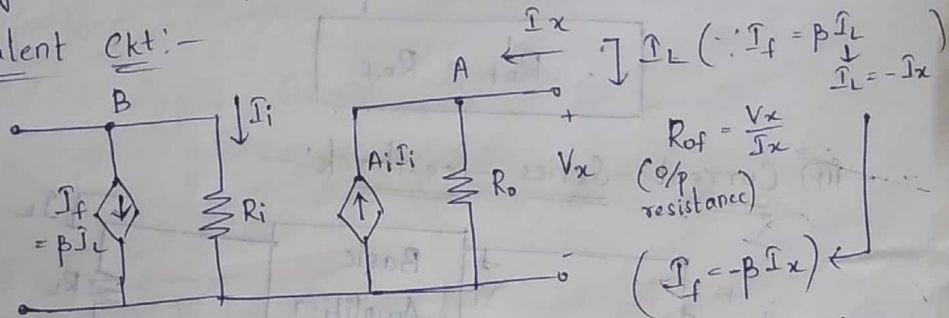
($\because A_i$ = Short ckt, Current gain (or) maximum current gain).

* finally due to -ve feedback, i/p resistance (R_i) is decreased.

* Effect on o/p resistance:-

* In the above equi ckt, disable the current source (open ckt), disconnect the external load resistance & apply test voltage.

Equivalent ckt:-



Apply KCL at 'A' i.e., o/p node

$$I_x = \frac{V_x}{R_o} - A_i I_i \quad \left(I_x + A_i I_i = \frac{V_x}{R_o} \right)$$

$$\frac{V_x}{R_o} = I_x + A_i (-I_f) = I_x + A_i (-(-\beta I_x)) \quad \left(\begin{array}{l} \text{KCL at B} \\ I_i + I_f = 0 \\ I_i = -I_f \end{array} \right)$$

$$\frac{V_x}{R_o} = I_x + A_i \cdot \beta I_x = I_x (1 + A_i \beta)$$

$$\therefore R_{of} = \frac{V_x}{I_x} = R_o (1 + A_i \beta)$$

→ This is o/p resistance of feedback without load.

* This Current Shunt f/b amplifier o/p resistance with f/b is increased.

* This Amplifier converts into more ideal Amplifier.

Effective o/p Resistance including R_L (load):-

$$R_{of}' = R_{of} \parallel R_L = \frac{R_{of} \times R_L}{R_{of} + R_L}$$

$$R_{of}' = \frac{R_o (1 + A_i \beta) R_L}{R_o (1 + A_i \beta) + R_L} = \frac{R_o R_L (1 + A_i \beta)}{R_o + R_o A_i \beta + R_L}$$

$$= \frac{R_o R_L (1 + A_i \beta)}{R_o + R_L + R_o A_i \beta} = \frac{R_o R_L}{(R_o + R_L)} \cdot \frac{(1 + A_i \beta)}{\left(1 + \frac{R_o A_i \beta}{R_o + R_L}\right)}$$

$$\left(\therefore R_o' = \frac{R_o R_L}{R_o + R_L} ; A_i = \frac{A_i R_o}{R_o + R_L} \right) \rightarrow \text{if } R_L = \infty \text{ then}$$

$$A_i = \frac{A_i \cdot \cancel{R_o}}{\cancel{R_o} \left(1 + \frac{R_L}{R_o}\right)}$$

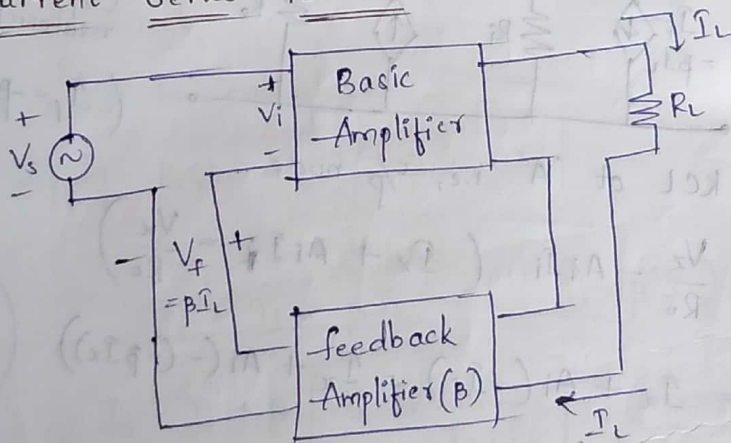
$$\therefore R_{of}' = R_o' \cdot \frac{(1 + A_i \beta)}{1 + \beta A_i} \rightarrow \textcircled{1} \quad \boxed{A_i = 0}$$

if $A_i = 0$ in eq. ①,

$$\text{then, } R_{of}' = \frac{R_o' (1 + \beta A_i)}{1 + \beta (0)} = R_o' (1 + \beta A_i)$$

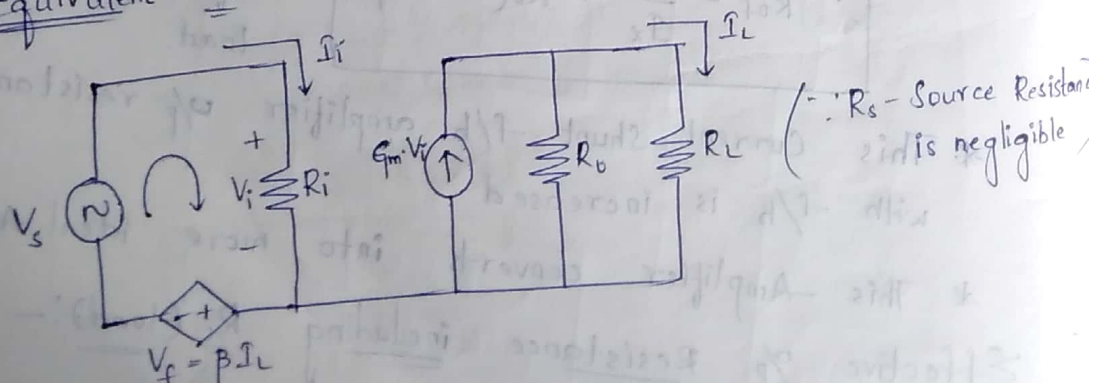
$$\therefore R_{of}' = R_{of}$$

iii) Current-Series feedback:-



This is the basic Amplifier is Transconductance Amplifier.

Equivalent ckt:-



This is the equivalent ckt of Current Series feedback.

* Effect on i/p resistance:-

* i/p resistance $R_i = \frac{V_i}{I_i} = \frac{i/p \text{ volt}}{i/p \text{ current}} \rightarrow i/p \text{ resistance of Basic Amplifier without feedback.}$

* i/p resistance with feedback (R_{if}) $= \frac{V_s}{I_i} \rightarrow i/p \text{ resistance of feedback amplifier.}$

Apply KVL in i/p loop;

$$-V_s + V_i + V_f = 0$$

$$V_s = V_i + \beta I_L \quad (\because V_f = \beta I_L)$$

This is the i/p signal V_s in terms of I_L . We need to find I_L .

On i/p loop;

Apply Current division,

$$I_L = \frac{G_m \cdot V_i \times R_o}{R_o + R_L}$$

$$V_s = V_i + \beta \left[\frac{G_m \cdot V_i \times R_o}{R_o + R_L} \right]$$

(Replace $\frac{G_m \cdot R_o}{R_o + R_L} = G_M$)

$$V_s = V_i + \beta \cdot V_i \cdot G_M$$

$$V_s = V_i (1 + \beta G_M) \rightarrow \text{This is Source Voltage}$$

Now, i/p resistance with feedback (R_{if}) $= \frac{V_s}{I_i} = \frac{V_i (1 + \beta G_M)}{I_i} \rightarrow i/p \text{ resistance without feedback.}$

* i/p resistance with feedback is $(1 + \beta G_M)$ times the i/p resistance without feedback.

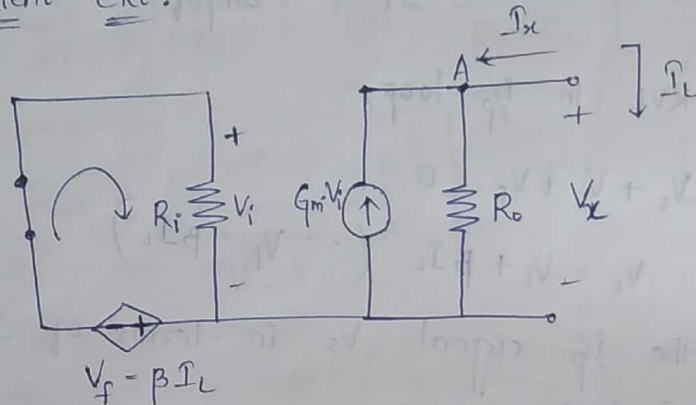
* Therefore, $R_{if} > R_i$

($\because G_m = \text{Transconductance gain taking } R_s \text{ into account}$
 $G_M = \text{Transconductance gain without } R_L$)

* Effect on o/p resistance:-

For finding o/p resistance we need to modify ckt
Remove the voltage source by its internal resistance
and disconnect load resistor and apply test voltage.

Equivalent ckt:-



Apply KCL at A,

$$G_m \cdot V_i + I_x = \frac{V_x}{R_o}$$

$$\frac{V_x}{R_o} = I_x + G_m (-V_f)$$

$$= I_x + G_m (\beta I_x)$$

$$= I_x (1 + \beta G_m)$$

$$\therefore R_{of} = \frac{V_x}{I_x} = R_o (1 + \beta G_m)$$

$$\left[\begin{array}{l} \therefore \text{from i/p,} \\ V_i + V_f = 0 \\ V_i = -V_f \end{array} \right]$$

$$\left[\begin{array}{l} \therefore V_f = \beta I_x \\ (\quad I_x = -I_x) \\ V_f = -\beta I_x \end{array} \right]$$

* This is the o/p resistance with feedback without load.

* For Current Series feedback o/p resistance also increased by ' $(1 + \beta G_m)$ ' times.

Effective o/p resistance including Load (R_L):-

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

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

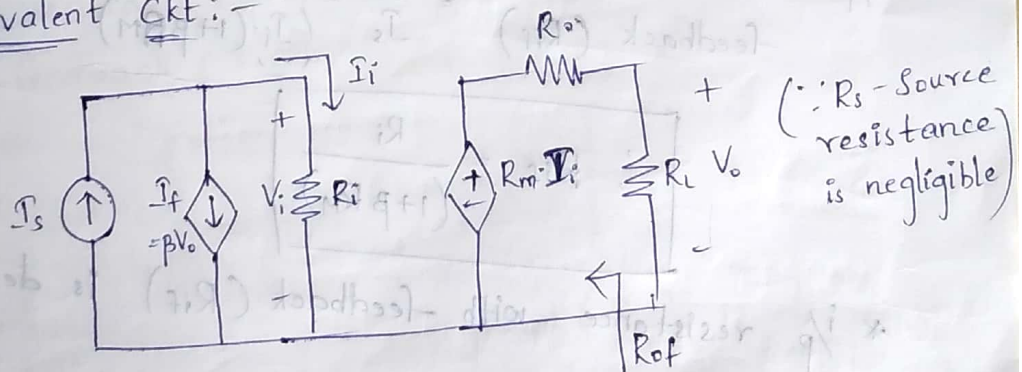
$$= \frac{R_o (1 + \beta G_m) R_L}{R_o (1 + \beta G_m) + R_L} = \frac{R_o R_L (1 + \beta G_m)}{R_o + \beta G_m R_o + R_L}$$

$$\left(\therefore R_o' = \frac{R_o R_L}{R_o + R_L}, G_M = \frac{G_m \cdot R_o}{R_o + R_L} \right) \rightarrow \text{if } R_L \rightarrow \infty \text{ then } G_M = \frac{G_m \cdot R_o}{R_o \left(1 + \frac{R_L}{R_o}\right)}$$

$$GM = 0$$

The diagram illustrates a feedback amplifier system. It consists of two main blocks: a 'Basic Amplifier' and a 'feedback Network'. A current source I_s is connected to the input of the 'Basic Amplifier'. The output of the 'Basic Amplifier' is connected to a load resistor R_L , which has a voltage V_o across it. The output V_o is also connected to the input of the 'feedback Network'. The output of the 'feedback Network' is connected back to the input of the 'Basic Amplifier'. The feedback signal is labeled $I_f = \beta V_o$.

Equivalent Ckt:-



* Effect on i/p resistance:-

* i/p resistance (R_i) = $\frac{V_i}{I_i}$ = $\frac{\text{i/p volt}}{\text{i/p current}}$ $\rightarrow$ i/p resistance of Basic Amplifier without feedback



We need to find I_s ,

Apply KCL at i/p node,

$$I_s = I_f + I_i \quad (\because I_f = \beta V_o)$$

$$I_s = \beta V_o + I_i$$

i/p signal (I_s) is in terms of V_o . We need to find V_o . Apply KVL at o/p loop,

$$V_o = \frac{R_m \cdot I_i \times R_L}{R_o + R_L}$$

$$I_s = I_i + \beta \left(\frac{R_m \cdot I_i \times R_L}{R_o + R_L} \right)$$

$$\left(\text{Replace } \frac{R_m \cdot R_L}{R_o + R_L} = R_M \right)$$

$$I_s = I_i + \beta \cdot R_M \cdot I_i$$

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

$$i/p \text{ Resistance with feedback } (R_{if}) = \frac{V_i}{I_s} = \frac{V_i}{I_i (1 + \beta R_M)} \quad \begin{matrix} i/p \text{ resistance} \\ \text{without } -f/b \end{matrix}$$

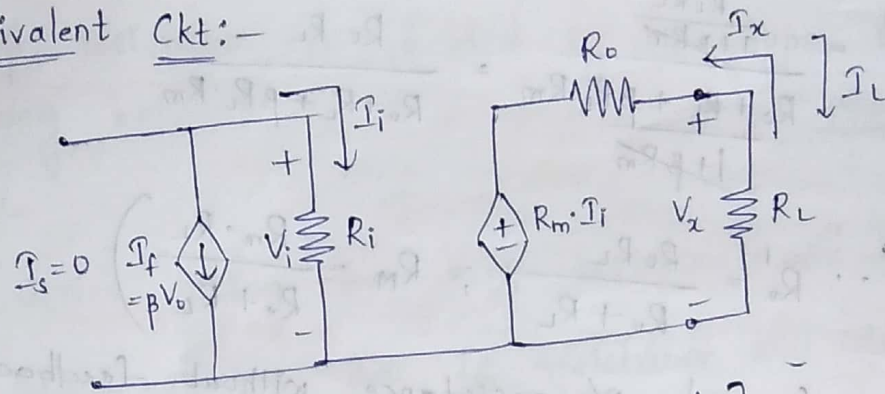
$$\therefore R_{if} = \frac{R_i}{(1 + \beta R_M)}$$

* i/p resistance with feedback (R_{if}) is decreased.

* Effect on o/p resistance:-

To find o/p resistance we need to modify the ckt.
Remove Current Source by its internal resistance,
remove load resistance & apply test voltage

Equivalent Ckt:-



o/p resistance with feedback without including load resistance (R_L) $\left. \vphantom{\begin{matrix} \text{with feedback} \\ \text{without including load resistance} \end{matrix}} \right\} = R_{of} = \frac{V_x}{I_x}$

$$I_x = \frac{V_x - R_m \cdot I_i}{R_o}$$

from i/p, KCL at A,

$$I_f + I_i = 0$$

$$I_i = -I_f \Rightarrow I_i = \beta V_x \quad (\because I_f = -\beta V_x)$$

$$I_x = \frac{V_x - R_m (-\beta V_x)}{R_o}$$

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

o/p resistance with feedback (R_{of}) $= \frac{V_x}{I_x} = \frac{R_o}{(1 + \beta R_m)}$

$$\therefore R_{of} = \frac{R_o}{(1 + \beta R_m)}$$

* o/p resistance with feedback (R_{if}) is decreased

Effective o/p resistance (R_{of}') including load resistance (R_L):

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

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

$$= \frac{\frac{R_o}{1 + \beta R_m} \times R_L}{\frac{R_o}{1 + \beta R_m} + R_L}$$

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

$$\left(\because R_o' = \frac{R_o R_L}{R_o + R_L} ; R_M = \frac{R_M \cdot R_L}{R_o + R_L} \right)$$

($\because R_o'$ - o/p resistance without feedback)

Now, multiply $\frac{1}{R_o + R_L}$ in Numerator & denominator

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

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

from, $R_M = \frac{R_M \cdot R_L}{R_o + R_L}$

if $R_L \rightarrow \infty$ then, $R_M = \frac{R_M \cdot R_L}{R_L \left(\frac{R_o}{R_L} + 1 \right)} = R_M$

$$\therefore R_M = R_M$$

Shortcut: -

We can find R_i & R_o increased (or) decreased without doing Analysis: -

* o/p resistance is decided by the Sampling Network

Ex:-
if o/p is Current Sample then o/p resistance will increase.

if o/p is Voltage Sample then o/p resistance will decrease.

* i/p resistance is decided by the type of mixing network.

Ex:-

if series mixing then i/p resistance will increase.

if shunt mixing then i/p resistance will decrease

- (a) O/P side to i/p side
- Voltage (sampling) & series mixing $\Rightarrow$ (sampling - mixing)
 - Current (sampling) & series mixing $\Rightarrow$ (mixing - sampling)
 - Voltage (sampling) & shunt mixing
 - Current (sampling) & shunt mixing

(b) Shunt - Series

Voltage - shunt mixing
current - series

7/06/21

Problems:-

① An amplifier has voltage gain 200, i/p resistance $10\text{ k}\Omega$ and o/p resistance $50\text{ k}\Omega$. If 2% of the o/p voltage is returned to the i/p in series opposition then calculate modified values of gain, i/p & o/p resistance.

Sol:- Given data,

Voltage gain without feedback (A) = 200

i/p resistance of Basic Amplifier (R_i) = $10\text{ k}\Omega$

o/p " " " " (R_o) = $50\text{ k}\Omega$

feedback signal excess (X_f) = 2% of X_o (o/p)

$$X_f = 0.02 \times X_o = 0.02 X_o$$

$$\Rightarrow \beta = \frac{X_f}{X_o} = 0.02$$

We have to find gain, i/p resistance & o/p resistance of amplifier with feedback.

The given feedback is Voltage - Series feedback

$$A_f = ? \quad R_{if} = ? \quad R_{of} = ?$$

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

$$D = 1 + (0.02)(200) \quad \left(\because \begin{array}{l} \beta = 0.02 \\ A = 200 \end{array} \right)$$

$$D = 5$$

$$\rightarrow A_f = \frac{A}{1 + A\beta} = \frac{A}{D} = \frac{200}{5} = 40$$

$$\boxed{\therefore A_f = 40}$$

$$\rightarrow R_{if} = R_i (1 + A\beta) = R_i (D) = 10\text{ k}\Omega (5) = 50\text{ k}\Omega$$

($\because$ Series mixing - i/p resistance increases by a factor 'D')

$$\therefore R_{if} = 50 K\Omega$$

→ % resistance is decided by Sampling Network.

The % resistance is decreased by a factor 'D'
($\therefore$ Series mixing).

$$R_{of} = \frac{R_o}{D} = \frac{50K}{5} = 10K\Omega$$

$$\therefore R_{of} = 10K\Omega$$

Q. An amplifier has open loop gain 500, cut off frequency 50 Hz & 40 KHz. If 4% of the % return to the i/p in opposition. Then Calculate

- (i) Closed loop gain
- (ii) Cut-off frequencies
- (iii) Amount of feedback.

Sol:- Given data,

Open loop gain (A) = 500

Lower Cut-off freq (f_L) = 50 Hz

Higher (or) Upper Cut-off freq (f_H) = 40 KHz

$$X_f = 4\% \text{ of } X_o$$

$$X_f = 0.04 X_o$$

$$\Rightarrow \beta = \frac{X_f}{X_o} = 0.04$$

$$\text{Desensitivity (D)} = 1 + A\beta = 1 + (500)(0.04) = 21$$

$$(i) \text{ Closed loop gain } (A_f) = \frac{A}{D} = \frac{500}{21} = 23.8$$

$$\therefore A_f = 23.8$$

(ii) Cut-off frequencies,

Due to -ve feedback, f_{Lf} decreases

$$f_{Lf} = \frac{f_L}{D} = \frac{50}{21} = 2.38 \text{ Hz}$$

$$\therefore f_{Lf} = 2.38 \text{ Hz}$$

Higher Cut-off freq,

Due to -ve feedback, f_{Hf} increases by a factor 'D'

$$f_{Hf} = f_H \cdot D = 40K(21) = 840 KHz$$

$$\therefore f_{Hf} = 840 KHz$$

$\therefore$ Bandwidth also increases by a factor of 'D'.

Due to -ve feedback, mid-band is expanded.

(iii) Amount of feedback is measured in decibels (dB)

$$= 20 \log \left(\frac{1}{1+A\beta} \right) (dB) = 20 \log (1+A\beta)$$

$$= -20 \log (D) = -20 \log (21)$$

$$= -26.44 \text{ dB}$$

$$\therefore \text{Amount of feedback in dB} = -26.44$$

Imp ③ If an i/p of 0.028V peak to peak to an open loop amplifier, it gives fundamental frequency o/p of 36V peak to peak, but if it is associated with 7% harmonic distortion. Then Calculate.

(i) If the distortion is to be reduced to 1%, how much feedback is to be introduced and what will be required i/p voltage

(ii) If 1.2% of o/p is feedback & the i/p is maintained at same level, what is o/p voltage?

Sol:- (i) Percentage of harmonic distortion ($\% D_{Hf}$) = $\frac{\% D_H}{1+A\beta}$

D_H - percentage of harmonic distortion without feedback

$$\% D_{Hf} = \frac{\% D_H}{1+A\beta} \Rightarrow 1+A\beta = \frac{\% D_H}{\% D_{Hf}}$$

$$1 + A\beta = \frac{\% D_H}{\% D_{Hf}} = \frac{7}{1} = 7$$

$$\therefore 1 + A\beta = 7$$

Due to -ve feedback, % voltage is reduced by '1 + Aβ' times. (∵ Gain is decreased)

To keep % voltage remains constant, ~~%~~ then i/p voltage is increased by '1 + Aβ' times.

$$A_f = \frac{A}{1 + A\beta} \quad \downarrow \quad A_f = \frac{V_o \downarrow (1 + A\beta) \text{ times}}{V_i \uparrow (1 + A\beta) \text{ times}}$$

$$\therefore V_o \Rightarrow \downarrow (1 + A\beta) \text{ times}$$

If we ^{should} maintain V_o constant, $V_i \Rightarrow \uparrow (1 + A\beta) \text{ times}$

$$\therefore \text{New i/p voltage} = (1 + A\beta) (0.028) =$$

$$(\because \text{initial i/p voltage} = 0.028 \text{ V})$$

$$\text{New i/p voltage} = (7) (0.028) = 0.196 \text{ V}$$

$$\boxed{\therefore \text{New i/p voltage} = 0.196 \text{ V}}$$

(ii) Here, in this case, the i/p is maintained at same level.

$$\beta = 1.2\% = 0.012$$

$$1 + A\beta = 1 + 0.012 (1285.714) = 16.428$$

$$\left(\because A = \frac{36 \text{ (o/p voltage)}}{0.028 \text{ (i/p voltage)}} = 1285.714 \right)$$

$$\therefore 1 + A\beta = 16.428$$

To maintain i/p at same level, o/p voltage is decreased by (1 + Aβ) times. (∵ ^{-ve feedback} Gain is decreased)

$$\text{New o/p voltage} = \frac{\text{Actual o/p voltage}}{(1 + A\beta)} = \frac{36}{16.428} = 2.19$$

$$\boxed{\therefore \text{New o/p voltage} = 2.19 \text{ V}}$$



④ An amplifier has ~~an~~ open loop gain 1000 ± 100 , it is considered into an amplifier whose gain doesn't vary by more than $\pm 0.1\%$. Then Calculate

- (i) Closed loop gain (A_f)
- (ii) Reverse Transmission factor (or) feedback factor
- (iii) Amount of feedback.

Sol:- Without feedback Gain (or) } (A) = 1000
Open loop gain

Change in gain due to some } (ΔA) = ± 100
reasons

The percentage of change in gain,

$$\% \Delta A = \frac{\Delta A}{A} \times 100 = \frac{\pm 100}{1000} \times 100 = \pm 10\%$$

Retat

10/06/21 Due to ~~the~~ $\pm 10\%$ feedback, the gain is changed by $\pm 0.1\%$. The Basic Amplifier gain is changed by,

$$\frac{dA}{A} \times 100 = \frac{\pm 100}{1000} \times 100 = \pm 10\%$$

By using $\pm 0.1\%$ feedback, the gain is changed by $\pm 0.1\%$.

$$\frac{dA_f}{A_f} \times 100 = \pm 0.1\%$$

We know, $A_f = \frac{A}{1 + AB}$

$$\frac{dA_f}{A_f} = \left(\frac{1}{1 + AB} \right) \frac{dA}{A} \Rightarrow \left(\frac{dA_f}{A_f} \times 100 \right) = \left(\frac{1}{1 + AB} \right) \left(\frac{dA}{A} \times 100 \right)$$

$$0.1 = \left(\frac{1}{1 + AB} \right) 10$$

$$(1 + AB) = \frac{10}{0.1} = 100 //$$

$$i) A_f = \frac{A}{1+A\beta} = \frac{1000}{100} = 10 //$$

$$\therefore A_f = 10$$

$$ii) \text{Amount of -feedback} = -20 \log(1+A\beta) \\ = -20 \log(100) = -20 \log 10^2$$

$$\therefore \text{Amount of feedback} = -40 \text{ dB}$$

$$iii) \text{-feedback factor}(\beta) \Rightarrow 1+A\beta = 100$$

$$A\beta = 99 \Rightarrow \beta = \frac{99}{1000} = 0.099$$

$$\therefore \beta = 0.099$$

Imp 5) An amplifier has open loop voltage gain of 1000 and delivers 10 watts o/p power with 10% second harmonic distortion when the i/p is 10mV. If 40dB of -ve -feedback is applied, what is the value of distortion? How much i/p voltage should be applied to get 10 watts of o/p power?

Sol:- Open loop voltage gain (A_v) = 1000

The o/p power (P_o) = 10 watts

Distortion without -feedback = 10% = 0.1

(-feedback factor) $\beta = 40 \text{ dB}$

$$20 \log(\beta) = 40 \Rightarrow \log_{10} \beta = \frac{40}{20} = 2$$

$$\Rightarrow \beta = 10^2 = 100$$

$$\therefore \beta = 100$$

$$\text{Desensitivity } (D) = 1+A\beta = 1+(1000)(100) = 1+(10^3)(10^2) \approx 10^5$$

$$\therefore D \approx 10^5$$

(i) Distortion with feedback (D_{Hf}) = $\frac{D_H}{1+AB}$

$$= \frac{0.1}{10^5} = 10^{-6}$$

$$\therefore D_{Hf} = 10^{-6}$$

(ii) To maintain 10 watts of o/p power, how much i/p should be applied.

$A_f = \frac{V_o}{V_s}$ $\therefore$ We have to increase i/p voltage by $(1+AB)$ times

i/p voltage is $\therefore$ Actual i/p $\times$ initial i/p $(1+AB)$

$$\text{New i/p voltage} = (10\text{mV})(10^5) = 10 \times 10^{-3} \times 10^5$$

$$\therefore \text{New i/p voltage} = 10^3 \text{ V}$$

⑥ For Voltage series feedback amplifier with parameters of the internal amplifier as $A_v = -200$, $R_{in} = 5\text{ k}\Omega$, $R_o = 20\text{ k}\Omega$, $BW = 50\text{ KHz}$ & having feedback factor $\beta = -0.02$. Calculate.

(i) Voltage gain (A_{vf})

(ii) i/p impedance (R_{if})

(iii) o/p impedance (R_{of}) and

(iv) Bandwidth.

Sol:- (i) Voltage gain (A_{vf}) = $\frac{A_v}{1+AB}$

$$= \frac{-200}{1+(-200)(-0.02)} = -40$$

$$\therefore A_{vf} = -40$$

$$(1+AB) = (1+(-200)(-0.02)) = 5$$

$$(ii) \frac{1}{p} \text{ impedance } (R_{if}) = R_i(1+A\beta) \quad (\because \text{Series Mixing})$$

$$= 5K(5) = 25K\Omega$$

$$\therefore R_{if} = 25K\Omega$$

$$(iii) \frac{0}{p} \text{ impedance } (R_{of}) = \frac{R_o}{(1+A\beta)}$$

$$= \frac{20K}{5} = 4K\Omega$$

$$\therefore R_{of} = 4K\Omega$$

$$(iv) \text{ Bandwidth } (BW_f) = BW(1+A\beta)$$

$$= 50K(5) = 250K\Omega$$

$$\therefore BW_f = 250K\Omega$$

⑦ An amplifier has a mid band gain of 125 and Bandwidth (BW) = 250KHz. If 4% of -ve feedback is introduced & the new band width & gain.

Mid band gain of an amplifier (A) = 125

Bandwidth (BW) = 250KHz

$$X_f = 4\% \text{ of } X_o$$

$$X_f = 0.04 X_o$$

$$\beta = \frac{X_f}{X_o} = 0.04$$

$$i) A_f = \frac{A}{1+A\beta} = \frac{125}{1+(125)(0.04)}$$

$$= \frac{125}{6} = 20.83$$

$$\therefore A_f = 20.83$$

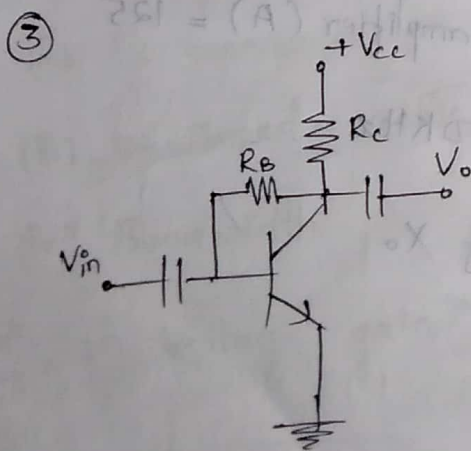
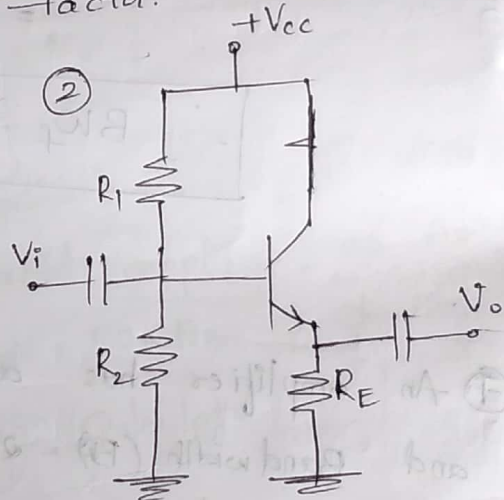
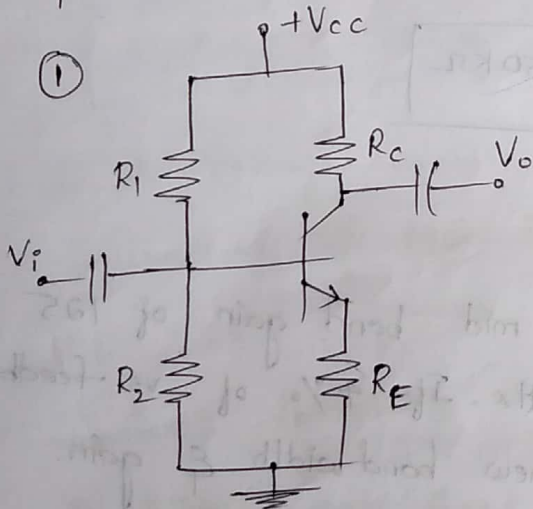
$$ii) \text{Bandwidth } (BW_f) = BW(1+A\beta)$$

$$= 250K(6) = 1.5 \text{ MHz}$$

$$\therefore BW_f = 1.5 \text{ MHz}$$

How to identify feedback topologies:-

In the following ckt's identify the type of feedback & calculate the feedback factor.



Steps to identify feedback topologies:-

- ① Identify the feedback component
- ② If the feedback ^{component} is directly connected to o/p node (X_o), It indicates Voltage Sampling otherwise Current Sampling.
- ③ i/p side $\rightarrow$ Mixing Network.
If the feedback component is directly to i/p node. It indicates Shunt Mixing otherwise Series Mixing.

Solution of Circuit ①:-

* feedback component is ' R_E '.

($\because R_E$ brings stability & causes feedback.)

R_E presents ϕ in i/p & o/p while writing eqn.

* But in ckt, R_E is not directly connected to o/p i.e., collector terminal.

$\therefore$ o/p is in Current Sampling.

* R_E is not directly connected to i/p node i.e., Base terminal.

$\therefore$ i/p is in Series Mixing.

Hence, Given ckt is "Current-Series feedback Amplifier."

Given ckt is CE Amplifier with unbypassed ' R_E '.

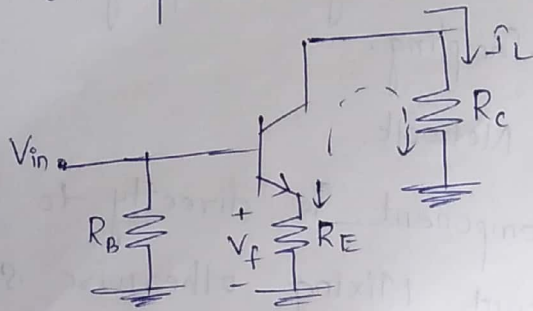
* Here, in this feedback Amplifier, the feedback signal is $(V_f) = \beta I_L$ ($\because$ o/p is Current Sampling)

$$V_f = \beta I_L \rightarrow (1)$$

The Equivalent Ckt:-

(i) DC Sources are grounded

(ii) Capacitors are short ckted.



from the Ckt,

$$V_f = -R_E \cdot I_L \rightarrow (2)$$

Compare (1) & (2)

$$\beta I_L = -R_E \cdot I_L$$

(-feedback factor) $\boxed{\therefore \beta = -R_E}$

$$\text{Gain of Amplifier } (A_f) = \frac{V_f}{V_o} = \frac{-I_L \cdot R_E}{I_L \cdot R_C} = -\frac{R_E}{R_C}$$

$$\boxed{\therefore A_f = -\frac{R_E}{R_C}}$$

Solution of Circuit (2):-

* feedback component is ' R_E '.

* In the ckt, R_E is directly connected to o/p terminal (Emitter).

$\therefore$ o/p is in Voltage Sampling.

* R_E is not directly connected to i/p i.e., Base terminal.

$\therefore$ i/p is in Series Mixing.

Hence, given ckt is "Voltage-Series feedback Amplifier".