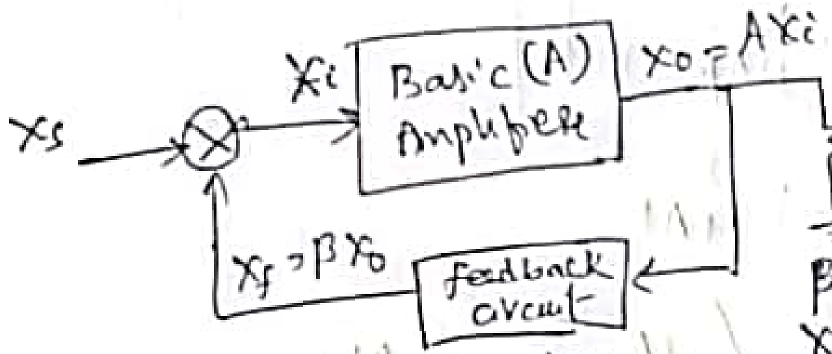
Negative feedback Amplifiers

Advantages.

1. Improves stability
2. Increases Bandwidth.
3. Increases I/p Impedance
4. Decreases o/p Impedance
5. Reduces Noise and distortion.

But Gain decreases.

Negative feedback amplifiers



$$\beta = \frac{x_f}{x_o}$$

These signals cause voltage or current

β - feedback factor

x_s - Source signal

x_i - I/p signal to amplifier

x_f - feedback signal

x_o - o/p signal

A - gain without feedback

$$x_i = x_s - x_f.$$

$$A = \frac{x_o}{x_i}$$

$$A_f = \frac{x_o}{x_s} = \frac{x_o}{x_i + x_f} = \frac{Ax_i}{x_i + \beta x_o} = \frac{Ax_i}{x_i + A\beta x_i}$$

A_f - gain with negative feedback

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

o/p current so gain

Stabilization of Gain in Negative feedback Amplifier

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

Differentiate w.r.t A

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

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

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

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

Sensitivity $\frac{dA_f}{A_f} \Big/ \frac{dA}{A} = \frac{1}{1+A\beta}$.

Desensitivity $= (1+A\beta)$

The % change in gain with feedback (due to temperature variations) reduced by $(1+A\beta)$ Times compared to without feedback.

R_{if} – Input Impedance with feedback

R_i – " without feed back

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

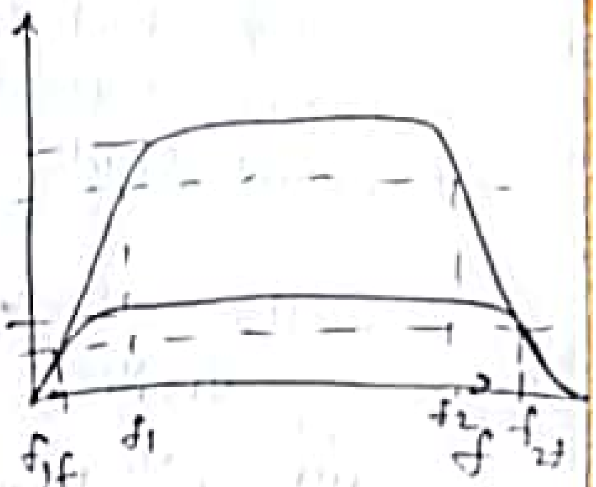
lly $R_{of} - \frac{R_o}{1+A\beta}$ where R_{of} – o/p Impedance with feedback

R_o – o/p Impedance without feed back

Frequency Response of Negative feedback Amplifier

$f_2 - f_1$ - Bandwidth with out feedback

$f_{2f} - f_{1f}$ - Bandwidth with feedback



So with feedback the gain decreases (Af) but Bandwidth increases.

Distortion reduces $D/(1+A\beta)$

Noise produced within an amplifier is also reduced by negative feedback again by a factor $(1+A\beta)$

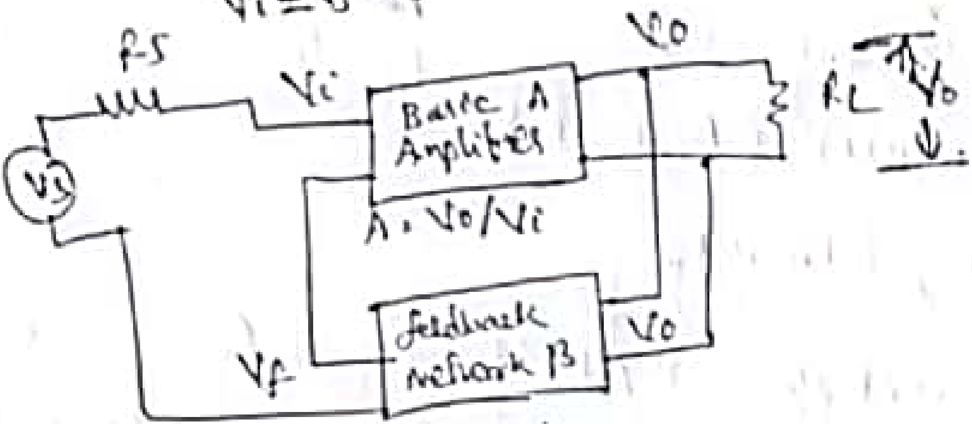
Ulp... current ... So Gain ...

Four Basic feedback topologies are

1. Voltage series feedback Amplifier.
2. Voltage shunt feedback Amplifier.
3. Current series feedback Amplifier
4. Current shunt feedback Amplifier.

1) Voltage series feedback Amplifier

$V_i = V_s - V_f$



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

Sampling signal o/p voltage V_o (I/p to feedback n/w)

mixing signal V_f voltage (o/p from feedback n/w)

A part of o/p voltage feedback to i/p decreases i/p voltage V_i ($V_i = V_s - V_f$) known as voltage series feedback Amplifier. In this Gain decreases as i/p voltage is decreased due to feedback.

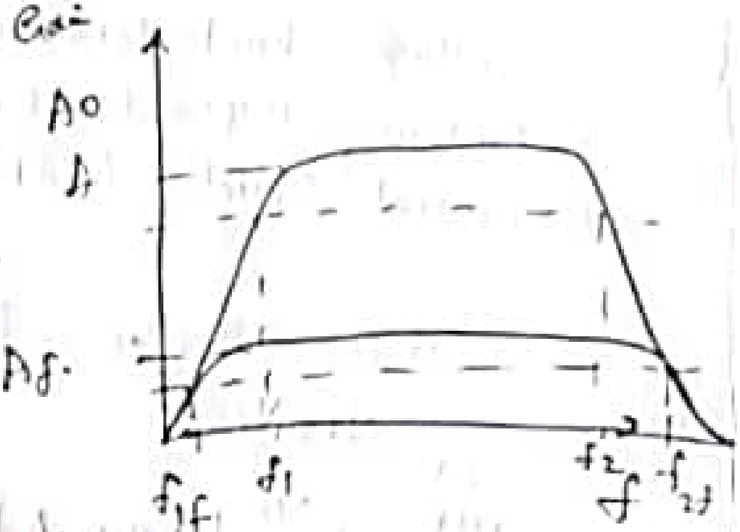
→ R_{if} Increases

R_{of} decreases.

Frequency Response of Negative feedback Amplifier

$f_2 - f_1$ – Bandwidth without feedback

$f_{2f} - f_{1f}$ – Bandwidth with feedback



So with feedback the gain decreases (A_f) but Bandwidth increases.

Distortion reduces $D/(1+A\beta)$

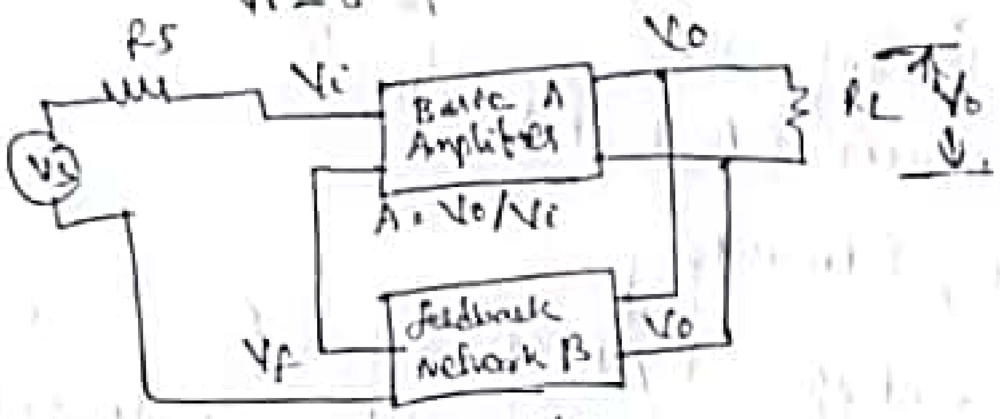
Noise produced within an amplifier is also reduces by negative feedback again by a factor $(1+A\beta)$

Four Basic feedback topologies are

1. Voltage series feedback Amplifier.
2. Voltage shunt feedback Amplifier.
3. Current series feedback Amplifier
4. Current shunt feedback Amplifier.

1) Voltage series feedback Amplifier

$V_i = V_s - V_f$



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

Sampling signal — o/p voltage Vo (I/p to feedback n/w)

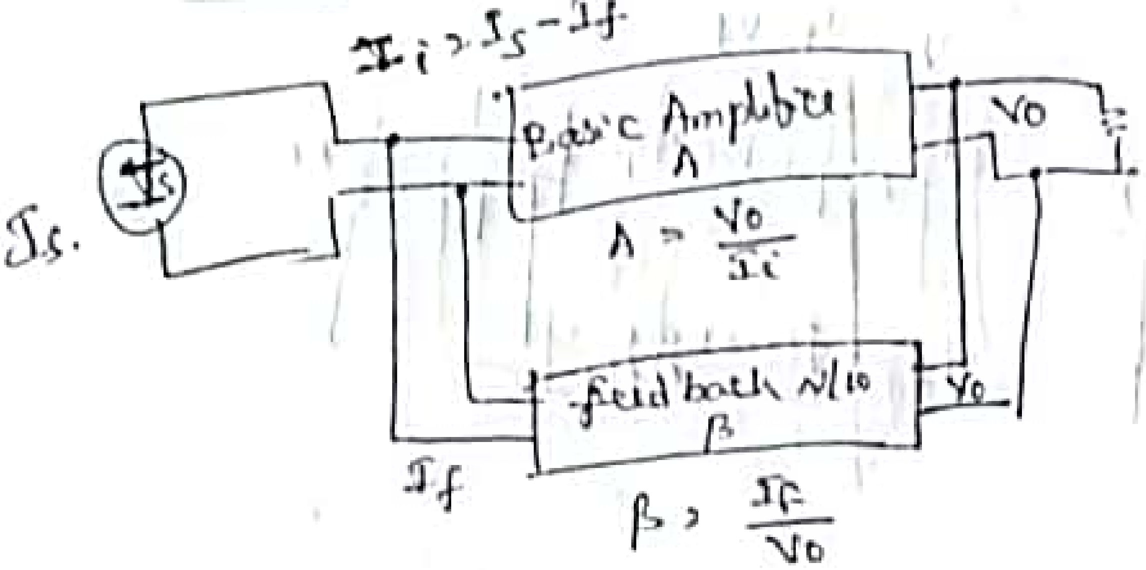
mixing signal — Vf voltage (o/p from feedback n/w)

A part of o/p voltage feedback to i/p decreases i/p voltage Vi ($V_i = V_s - V_f$) known as voltage series feedback Amplifier. In this Gain decreases as i/p voltage is decreased due to feedback.

→ Rif Increases

Rof decreases.

2. Voltage shunt feedback Amplifier



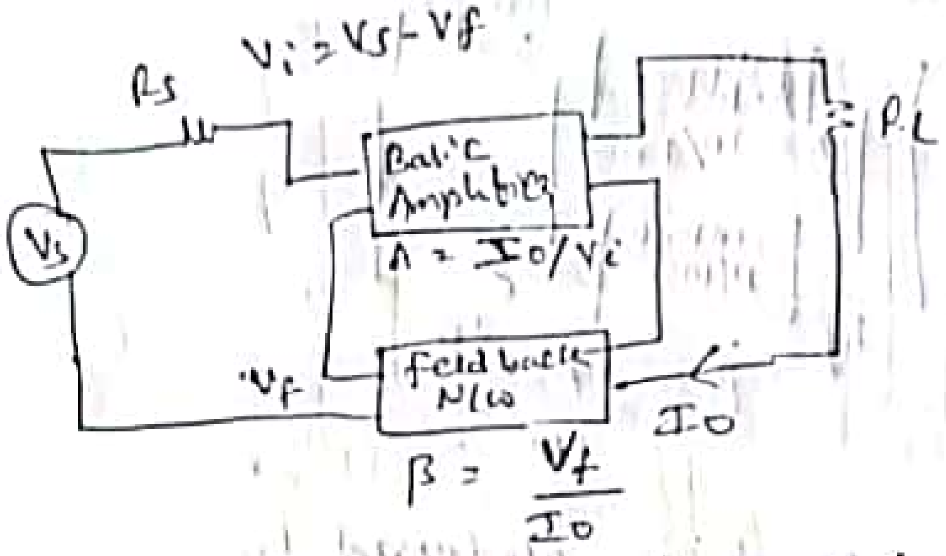
Sampling signal - voltage V_o
mixing signal - current I_f
Gain A - Transresistance - V_o/I_i
β - Trans conductance $\frac{I_f}{V_o}$

o/p Resistance decreases.
i/p Resistance decreases
(Note: Both sides shunt connection)

I_s - Source current
I_f - feedback current
V_o - o/p voltage

A part of o/p voltage fedback to i/p decreases i/p current known as voltage shunt feedback amplifier. As I/p current decrease o/p ~~current~~ current decreases o/p voltage V_o also decreases so Gain decreases.

Current Series feedback Amplifier

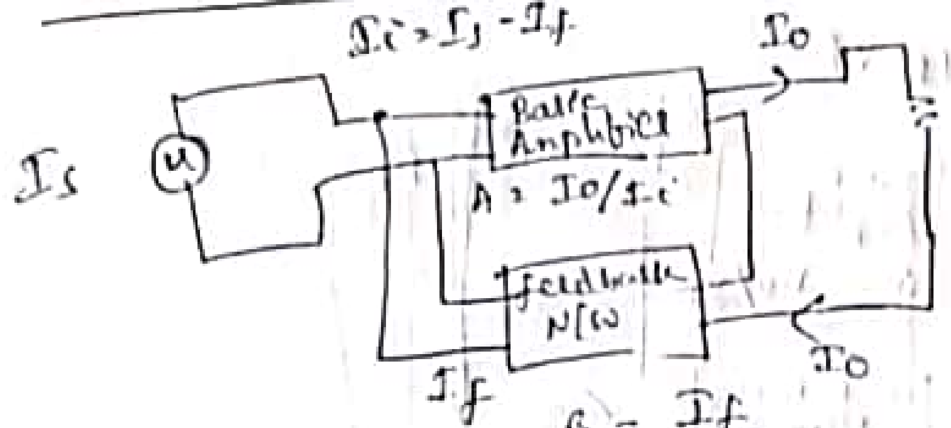


A part of o/p current feedback to i/p decreases I/p voltage known as current series feedback amplifier. Gain in current series feedback amplifier is $A = I_o/V_i$ known as ~~Trans~~ Transconductance. β reciprocal of A. In current series feedback

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

Input Resistance and o/p Resistance both Increases.

Current shunt feedback Amplifier



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

The sampling signal is o/p current I_o
mixing signal is I_f.

A part of o/p current feedback to I/p decreases I/p current ($I_i = I_s - I_f$) and gain so it is known as current shunt feedback amplifier.

O/p resistance increases.
I/p resistance decreases with feedback

(Note at o/p series connection, at i/p shunt connection)

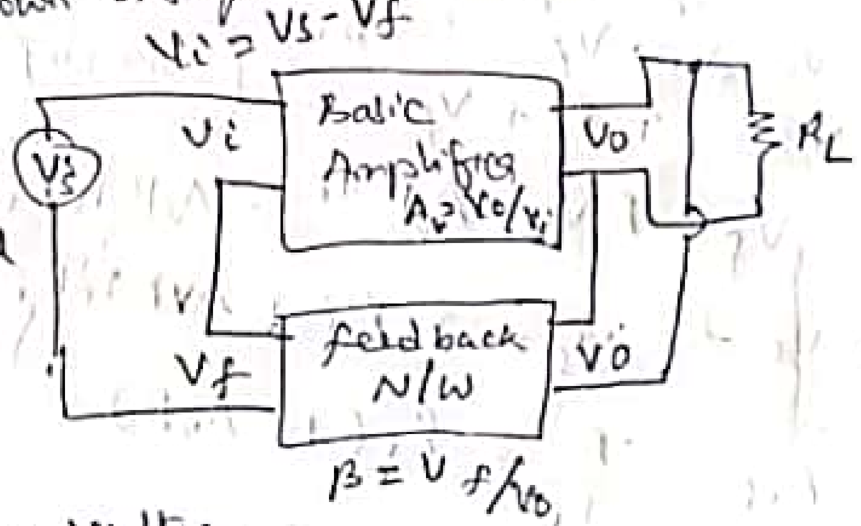
Voltage Series feedback Amplifier

In voltage series feedback Amplifier a part of the output voltage feedback to i/p decreases i/p voltage and voltage gain (V_o/V_s).

The block diagram of voltage series feedback amplifier shown in fig.

Sampling signal voltage V_o

Mixing signal voltage V_f



V_s - Source voltage

V_o - o/p voltage

V_i - i/p voltage to the Amplifier.

A_v - The gain of the amplifier without feedback

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

A_{vf} - the voltage gain of the amplifier with feedback

$$V_s = V_i + V_f. \qquad A_v = \frac{V_o}{V_i} \qquad \beta = \frac{V_f}{V_o}$$

$$A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{V_i + V_f} = \frac{A_v V_i}{V_i + \beta V_o} = \frac{A_v V_i}{V_i + A_v \beta V_i}$$

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

The Thevenin Equivalent circuit to find R_{if}

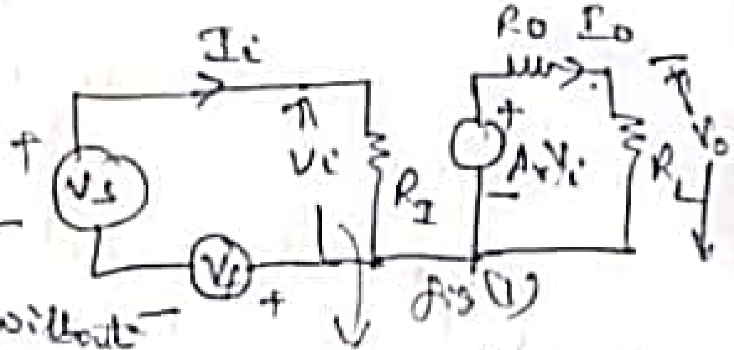


fig (1)

R_{if} — I/p Impedance with feedback

R_i — I/p Impedance without feedback

$V_s = V_i + V_f$

$V_s = I_i R_i + V_f$ — (The drop across $R_I = V_I$ $V_i = I_i R_i$)

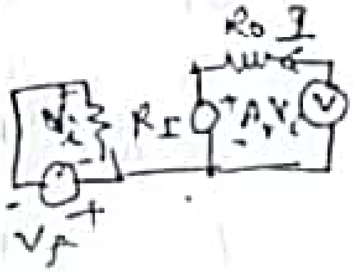
$V_f = \beta V_o = A_v \beta V_i = A_v \beta I_i R_i$

so $V_s = \;\; V_s = I_i R_i + A_v \beta I_i R_i$

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

R_{of} — o/p Impedance with feedback

In the above dig remove R_L. connect Voltage source V at o/p and set $V_s = 0$



$V_i = -V_f$; $V_o = V$

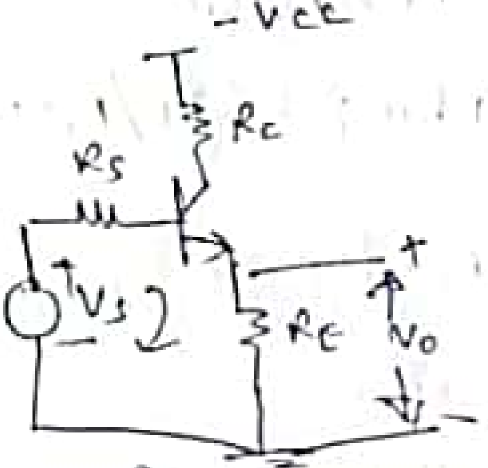
$$I = \frac{V - A_v V_i}{R_o} = \frac{V + A_v V_f}{R_o}$$

$$I = \frac{V + A_v \beta V}{R_o} = \frac{V(1 + A_v\beta)}{R_o} \Rightarrow R_{of} = \frac{V}{I}$$

$$\boxed{R_{of} = \frac{R_o}{1 + A_v\beta}}$$ with feedback R_{of} decreased.

If R_L included $R_{of}' = \frac{R_o'}{1 + A_v\beta}$ where $R_o' = R_o \| R_L$

The Emitter follower is an example for voltage series feedback amplifier.



Draw the hybrid model of this circuit. Connect $-V_{cc}$ to Ground

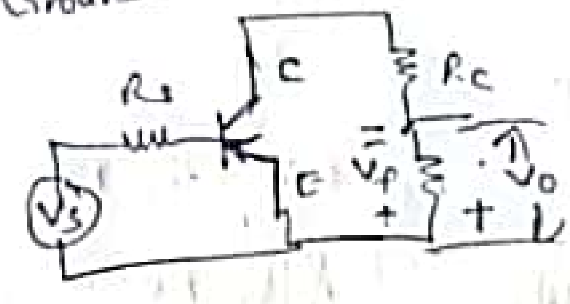
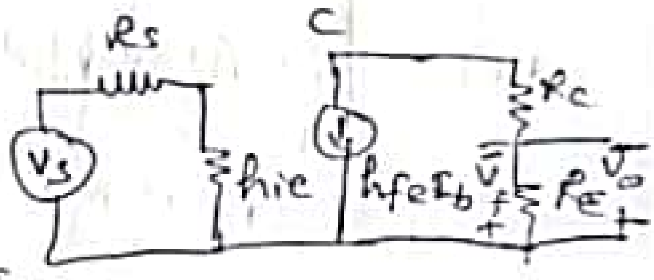


Fig. 1

The voltage drop across R_E is V_o as well as V_f

In Fig (1)



$$V_s = I_B R_s + V_{BE} + I_E R_E$$

$$V_{BE} = V_s - I_B R_s - I_E R_E$$

so — $I_E R_E = V_o \uparrow$ $V_{BE} \downarrow$ this is voltage series feedback principle.

The voltage gain $A_V = \frac{V_o}{V_s}$ — (1)

$V_o = h_{fe} I_b R_E$ — (2)

$V_s = I_b (R_s + h_{ie})$ — (3)

(2) & (3) substitute in eq. (1)

$$A_V = \frac{V_o}{V_s} = \frac{h_{fe} R_E}{R_s + h_{ie}}$$

$$\beta = \frac{V_f}{V_o} ; \quad V_f = V_o \quad \beta = 1$$

$$D = 1 + A_V\beta = 1 + \frac{h_{fe} R_E}{R_s + h_{ie}}$$

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

The gain with feedback A_{vf}

$$A_{vf} = \frac{A_v}{D} = \frac{h_{fe}R_E / R_s + h_{ie}}{R_s + h_{ie} + h_{fe}R_E / R_s + h_{ie}}$$

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

$$A_{vf} = \frac{h_{fe}R_E}{R_s + h_{ie} + h_{fe}R_E}$$

$R_s + h_{ie} << h_{fe}R_E$

$$A_{vf} = \frac{h_{fe}R_E}{h_{fe}R_E} = 1$$

$R_o = R_s + h_{ie}$

from this side

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

$$R_{if} = (R_s + h_{ie})\, D = \cancel{(R_s + h_{ie})}\,\frac{(R_s + h_{ie} + h_{fe}R_E)}{\cancel{(R_s + h_{ie})}}$$

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

$$R_{of}' = \frac{R_o'}{D} \qquad R_o' = R_E$$

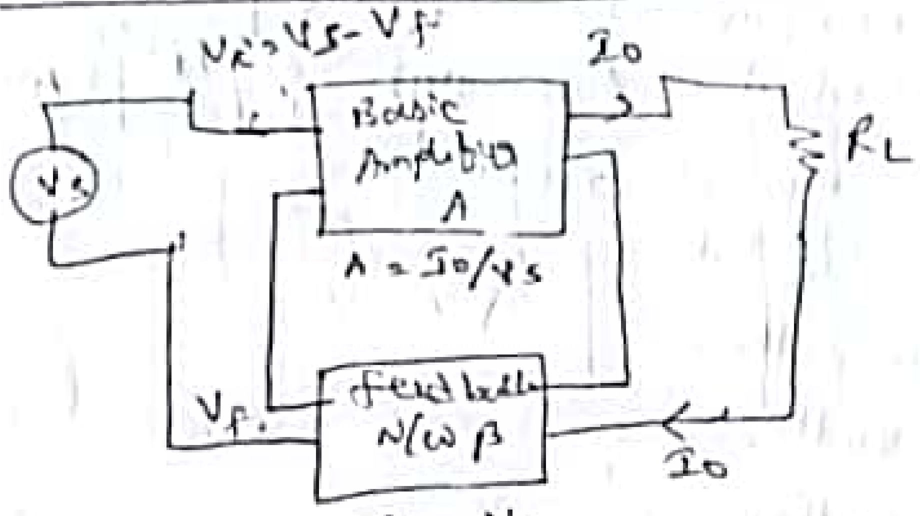
$$R_{of}' = R_E(R_s + h_{ie}) / R_s + h_{ie} + h_{fe}R_E$$

$$\lim_{R_E \to \infty} R_{of}' = \frac{R_E(R_s + h_{ie})}{R_s + h_{ie} + h_{fe}R_E}$$

$$= \frac{\cancel{R_E}(R_s + h_{ie})}{\cancel{R_E}\left(\frac{R_s + h_{ie}}{\cancel{R_E}} + h_{fe}\right)} = \frac{R_s + h_{ie}}{h_{fe}}$$

So in Emitter follower I/p impedance increases and O/p impedance decreases.

Current series feedback amplifier



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

In current series feedback amplifier a part of output current feedback to i/p i.e. decreases i/p voltage and transconductance $I_o/V_s = G_{Mf}$

Sampling signal is current

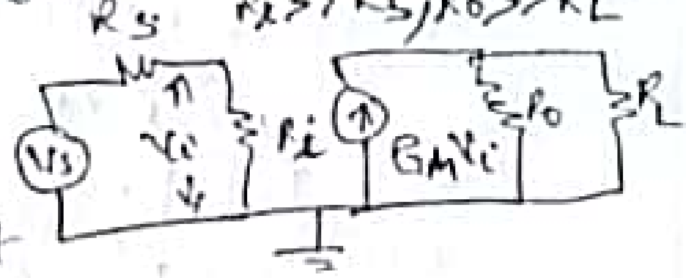
mixing signal is voltage.

The characteristics of current series feedback amplifier are

1. G_{Mf} decreases
2. Bandwidth increases.
3. I/p Impedance and output impedance both increases.
4. Noise / distortion decreases.
5. Stability improves.

It is also known as Transconductance amplifier.

In current series feedback amplifier $R_i >> R_S$; $R_o >> R_L$



The thevenin's equivalent circuit preferred at i/p side

The Norton's equivalent circuit preferred at o/p side.

V_s - Source voltage

V_i - i/p voltage

V_o - o/p voltage

R_s - Source Resistance

R_i - I/p Resistance without feedback

R_o - o/p Resistance without feedback

G_M - I_o / V_i Transconductance

$R_i = \infty$ $V_i = V_s$

$R_o = \infty$ $I_o = I_L = G_M V_i$

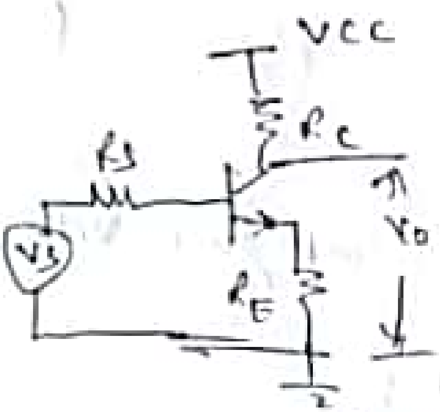


fig CE amplifier without bypass capacitor

This works as current series feed back amplifier.

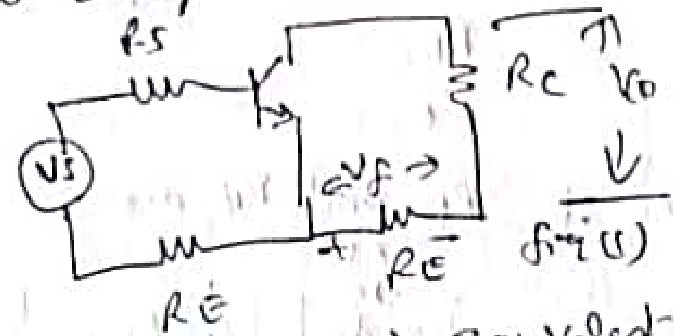
The current flowing through R_E is I_E produces $I_E R_E = V_f$ decreases i/p voltage V_{BE} (V_i)

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

where β is feedback factor.

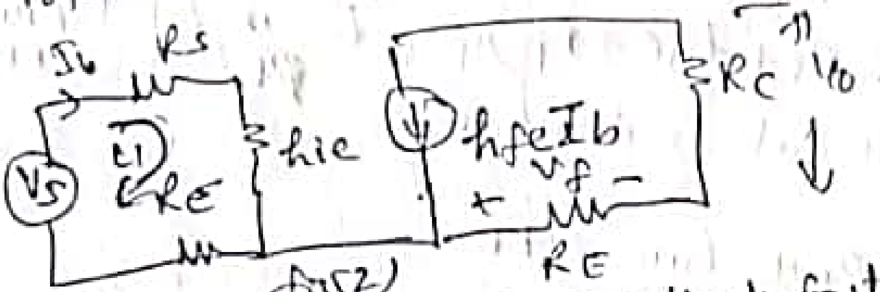
As V_i decreases the Gain known as Transconductance G_{Mf} with feedback decreases.

To analyze this Equivalent circuit



fig(1)

The Hybrid model Equivalent of this is



fig(2)

$\beta = -R_E$ where β Feedback factor.

when $R_i = \infty$ $R_s = 0$ $V_i = V_s$.

Trans conductance $G_M = \frac{I_o}{V_i} = \frac{-h_{fe} I_b}{V_s}$

In loop L1 $V_s = I_b (R_s + h_{ie} + R_E)$

$G_M = \frac{I_o}{V_s} = \frac{-h_{fe}}{R_s + h_{ie} + R_E}$ —(1) ; $\beta = -R_E$

$D = 1 + \beta G_M = 1 + \frac{h_{fe} R_E}{R_s + h_{ie} + R_E}$ (2)

$G_{Mf} = \frac{G_M}{D}$;

$G_{Mf} = (1)/(2)$

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

If $R_s + h_{ie} << (1 + h_{fe}) R_E$ then $G_{Mf} = \frac{-1}{R_E}$

So R_E stable resistor the transconductance G_{Mf} stabilized with feedback.

In fig(2) $I_o = G_M V_s = \frac{-h_{fe} V_s}{R_s + h_{ie} + (1 + h_{fe}) R_E} = \frac{-V_s}{R_E}$

So o/p current depends on V_s and R_E.

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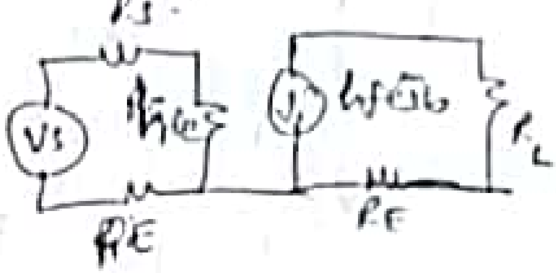
The voltage gain with feedback $A_{vf} = \frac{I_o R_L}{V_s}$

$$A_{vf} = \frac{G_m V_s R_L}{V_s} = -\frac{R_L}{R_E}$$

Voltage gain is stable if R_E and R_L are stable.



In i/p loop

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

R_i without feedback is

$$\frac{V_s}{I_b} = R_s + h_{ie} + R_E$$

$$R_{if} = R_i (1 + G_M \beta) = R_i D = (R_s + h_{ie} + R_E) \times D$$

$$= \cancel{R_s + h_{ie} + R_E} \times \frac{R_s + h_{ie} + (1+h_{fe}) R_E}{\cancel{R_s + h_{ie} + R_E}}$$

So $R_{if} = R_s + h_{ie} + (1+h_{fe}) R_E$

with feedback I/p impedance increases.

R_{of} — o/p resistance with feedback

$$R_o = \infty \quad R_o' = R_L$$

$$R_{of}' = R_o' \frac{1+\beta G_m}{1+\beta G_M} \qquad G_m = \lim_{R_L \to 0} G_M$$

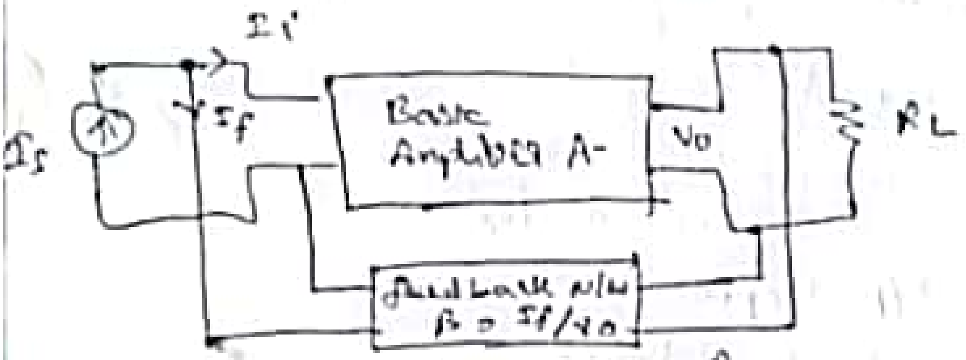
$$= \lim_{R_L \to 0} \frac{-h_{fe}}{R_s + h_{ie} + R_E} = G_M$$

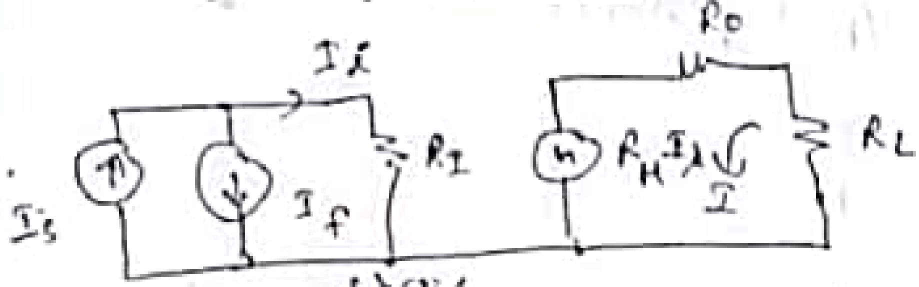
$$\boxed{R_{of}' = R_L \frac{1+\beta G_M}{1+\beta G_M} = R_L}$$

R_{of}' o/p resistance with feedback including R_L.

R_L - Load Resistance

Voltage Shunt feedback Amplifier. ①





fig(1)

with feedback Transresistance $= \frac{V_o}{I_s} = \frac{V_o}{I_i + I_f}$

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

$\frac{V_o}{I_i} = R_M$ – Transresistance without feed back

$R_m = \underset{R_L \to \infty}{Lt} R_M$ — open circuit Transresistance

Input Resistance with feed back (R_{if})

$$R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i + I_f} = \frac{V_i}{I_i + \beta V_o} = \frac{V_i}{I_i + \beta R_M I_i}$$

$$R_{if} = \frac{V_i}{I_i} \Big/ 1 + \beta R_M = \frac{R_i}{1 + \beta R_M}$$

. R_i – I/p Resistance without feed back

. R_{of} o/p Resistance with feedback. At $I_s = 0$ $R_L = \infty$ connect V at o/p in fig(2)

$$I = \frac{V - R_M I_i}{R_o}$$

$I_s = 0$

$I_i = -I_f$

Voltage shunt feedback amplifier (1)

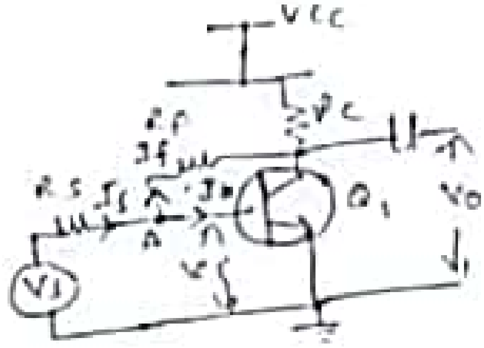
Collector to base-bias in CE amplifier works as voltage shunt feedback amplifier.

The transistor in CE configuration.

i/p applied b/w Base and emitter

o/p taken b/w collector and emitter.

R_C collector Resistor R_s source resistor. R_f feedback resistor b/w collector and ~~emitter~~ Base of the transistor.



As V_o increases the i/p current I_b decreases.

At node A Kirchhoff's current law applied. $I_s = \frac{V_s}{R_s}$

$I_b = I_s - I_f$

V_i small $V_i \approx 0$

$\frac{V_i - V_o}{R_f} = I_f$

$\frac{-V_o}{R_f} = I_f$

$V_o \uparrow - I_f \uparrow$. $I_b \downarrow$

$$\boxed{\beta = \frac{I_f}{V_o} = -\frac{1}{R_f}} \quad -(1)$$

β = feedback factor

If has gain A reciprocal of β ($A = \frac{1}{\beta}$ for good stabilization)

A gain of the amplifier $= \frac{V_o}{I_i}$

without feedback - Transresistance amplifier

$A = R_M$

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

$A = R_M$

$A_f = R_{Mf}$

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

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

R_{Mf} - Transresistance with feedback

R_M - Transresistance without feedback

To analyze this hybrid model is used.

R_f can be split towards i/p side and o/p side using Miller theorem.

fig (1)

For simplification R_f connected towards i/p and o/p side in fig 2

$$\frac{V_s}{R_s} = I_s$$

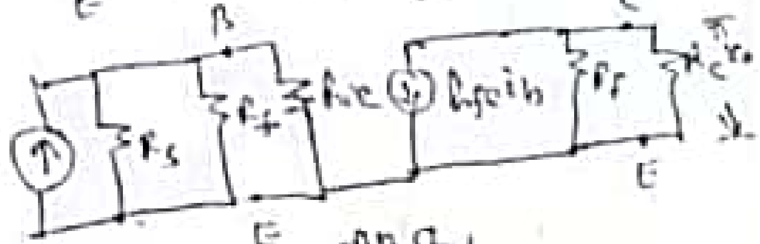


fig (2)

Now to analyze it

R_M, β, R_{Mf}, R_{If}, R_{of}, A_{vf} derivation from Hybrid represented.

β = is feedback factor $\frac{I_f}{V_o}$

$$\beta = -\frac{1}{R_f} \quad -(1)$$

To find R_M

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

$$R_f \parallel R_c = R_c' = \frac{R_f R_c}{R_f + R_c}$$

$$V_o = -h_{fe}\, i_b R_c' \quad -(2)$$

current Division Rule

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

$$i_b = \frac{I_s \cdot R}{R + h_{ie}} \quad -(3)$$

Substitute (3) in (2)

$$V_o = \frac{-h_{fe} I_s R R_c'}{R + h_{ie}}$$

$$\boxed{R_M = \frac{V_o}{I_s} = \frac{-h_{fe} R_c' R}{R + h_{ie}}} \quad -(4)$$

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

$$= \frac{\frac{-h_{fe} R_c' R}{R + h_{ie}}}{1 + \left(\frac{-h_{fe} R_c' R}{R + h_{ie}}\right)\left(\frac{-1}{R_f}\right)}$$

$$R_{Mf} = \frac{-h_{fe} R_c' R R_f}{(R + h_{ie}) R_f + h_{fe} R_c' R} \quad -(5)$$

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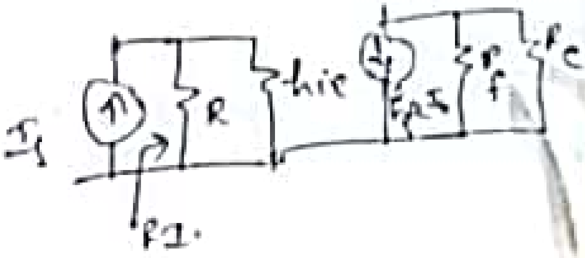
To find R_{if} at i/p side

$R = R_f \| R_s$

$R_i = R \| h_{ie} = \dfrac{R\,h_{ie}}{R + h_{ie}}$ — (6)



with feedback $R_{if} = \dfrac{R_i}{1+\beta R_M}$ — (7)

To find R_{of} $\quad R_C \to \infty$

$R_m = \lim_{R_C \to \infty} R_M = \dfrac{-h_{fe}\, R_C'\, R}{R + h_{ie}}$ — (8)

(Note:- R_C open) $R_C' = R_f$ only.

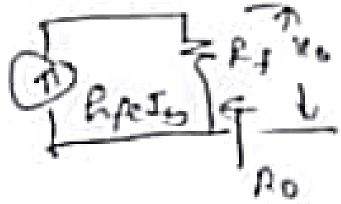
$R_C' = R_f \| R_C$

$R_C = \infty$ now

replace $R_C' = R_f$ in (8)

$R_m = \dfrac{-h_{fe} R_f R}{R + h_{ie}}$ — (9)

In o/p now



$\boxed{R_o = R_f}$

$\boxed{R_{of} = \dfrac{R_o}{1+\beta R_m}}$

substitute now
$R_o = R_f$
R_m from (9) in R_{of}
$\beta = -\dfrac{1}{R_f}$

$R_{of} = \dfrac{R_f}{1+\beta R_m} = \dfrac{R_f}{1 + \dfrac{1}{R_f}\dfrac{h_{fe} R_f R}{R + h_{ie}}}$

$\boxed{\downarrow R_{of} = \dfrac{R_f (R + h_{ie})}{R + h_{ie} + \underline{h_{fe} R}\uparrow}}$ $\quad h_{fe} R$ high

In voltage shunt feedback amplifier
$R_{if} \downarrow \quad R_{of} \downarrow$

$R_{of}' = R_{of} \| R_C$ (Including external resistance R_C)

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The gain of the amplifier

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

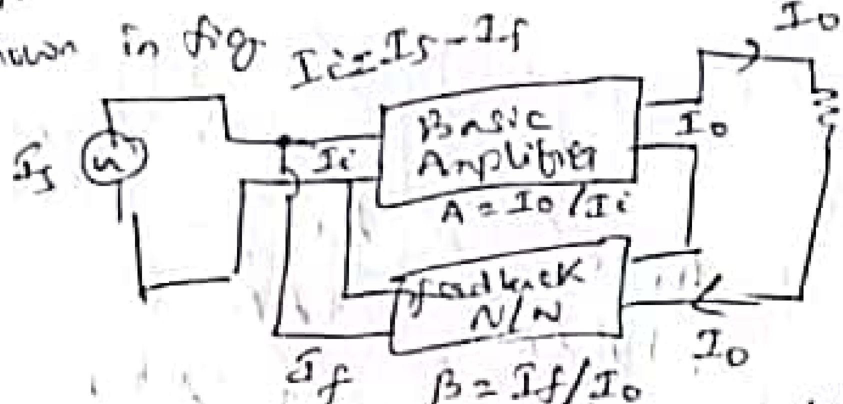
So in voltage shunt feedback amplifier
voltage gain decreases with feedback.
R_{if} and R_{of} decreases.
It is known as Transresistance Amplifier

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

Current shunt feedback amplifier

In current shunt feedback amplifier a part of o/p current feed back to i/p, decrease i/p current and current gain I_o/I_i.

The block diagram of current shunt feedback amplifier shown in fig



In current shunt feedback amplifier, the sampling current is I_o. mixing signal is current (I_f).

The current gain without feedback $A_I = I_o/I_i$

feedback factor $\beta = I_f/I_o$.

The o/p impedance increases and I/p impedance decreases.

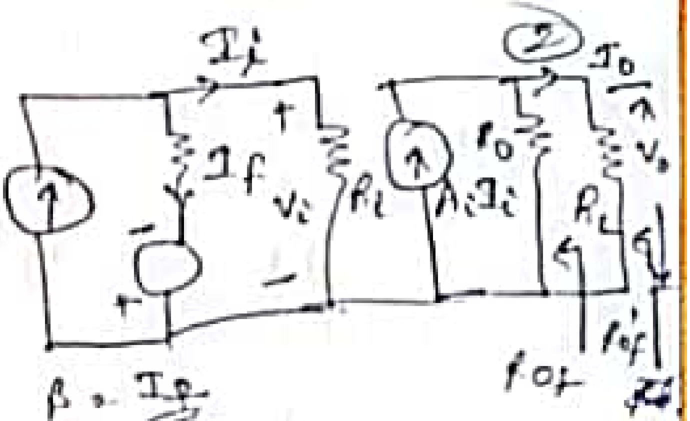
The characteristics of current shunt feedback amplifier

The sampling and mixing signal both are current.

1. Sampling and mixing signal both are current.
2. The current gain with feedback A_{If} decreases.
3. Bandwidth increases.
4. Noise / Distortion decreases.
5. Stability of gain
6. I/p Impedance decreases; o/p impedance increases.

A_i - shortcircuit current gain
A_I - The current gain without feedback

A_{If} - The current gain is with feedback



$$A_{If} = \frac{I_o}{I_s} \qquad A_I = \frac{I_o}{I_i} \qquad \beta = \frac{I_f}{I_o}$$

$$A_I I_i = I_o$$

$$I_s = I_i + I_f$$

$$A_{If} = \frac{A_i I_i}{I_i + I_f} = \frac{A_i I_i}{I_i + \beta A_i I_i} = \frac{A_i}{1 + A_i \beta}$$

from o/p loop $I_o = \frac{A_i I_i R_o}{R_o + R_L}$ $\left(R_L = 0 \quad I_o = \frac{A_i I_i R_o}{R_o} \quad A_I = \frac{I_o}{I_i} \right)$

$A_i = \underset{R_L = 0}{Lt} A_I$

$$\boxed{\text{If } R_L = 0 \quad A_{If} = \frac{A_I}{1 + A_I \beta}}$$

Input Impedance $R_{if} = \frac{V_i}{I_s} = \frac{I_i R_i}{I_i + I_f} = \frac{I_i R_i}{I_i + \beta A_I I_i}$

$$\boxed{\text{So } R_{if} = \frac{R_i}{1 + A_I \beta}}$$

Input impedance R_{if} decreases with feedback.

O/P Resistance with feedback (R_{of})

Set $I_s = 0$ remove R_L
Connect V at o/p.
Then o/p current $I_o = I$

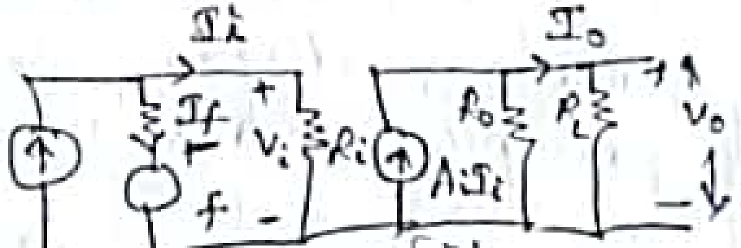


fig 1

$$I = \frac{V}{R_o} - A_I I_i \quad \text{from fig 2}$$

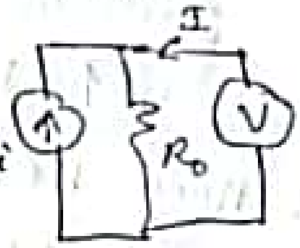


fig 2

Since $I_s = 0$ $I_i = -I_f$.

So $I = \frac{V}{R_o} + A_I I_f = \frac{V_o}{R_o} + A_i \beta I_o$

$$I = \frac{V}{R_o} - A_i \beta I$$

$$I(1 + A_i\beta) = \frac{V}{R_o} \Rightarrow \frac{V}{I} = R_o(1 + A_i\beta) = R_{of}$$

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

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

Divide N & D with $R_o + R_L$

$$R_{of}' = \frac{\frac{R_o R_L}{R_o + R_L}(1 + A_i\beta)}{1 + \frac{R_o A_i \beta}{R_o + R_L}} \qquad \left[\because \frac{A_i R_o}{R_o + R_L} = A_I\right]$$

If $R_L = \infty$ then $A_I = 0$

$$R_{of}' = \frac{R_o \| R_L (1 + A_i\beta)}{1 + A_I\beta} = \frac{R_o \| R_L (1 + A_i\beta)}{1 + 0}$$

$$= R_{of}' = R_o'(1 + A_i\beta) \text{ where}$$

$R_o' = R_o \| R_L$.

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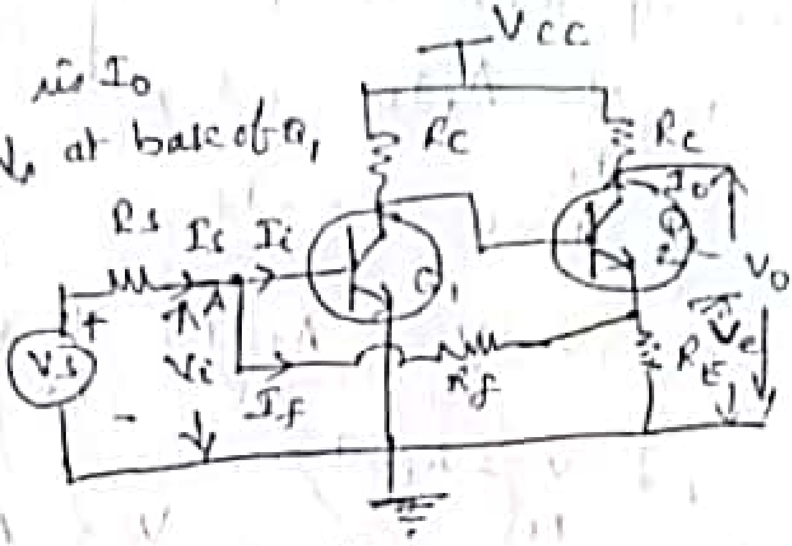
The two stage RC coupled amplifier with feedback (or) resistor R_f b/w Q_1(base) and Q_2(emitter) decrease the current gain ($A_I \uparrow$). The current passes through R_f decreases. i/p base current I_i as I_o o/p current increases.

Q_2. collector current is I_o

$I_o \uparrow$ $I_f \uparrow$ $I_b = I_i \downarrow$ at base of Q_1



At Node KCL apply

$I_s = I_i + I_f$

$I_i = I_s - I_f$.

I_f. current through R_f = $\frac{V_i - V_{e_2}}{R_f}$

where V_i - i/p voltage at base of Q_1

V_{e_2} - emitter voltage at Q_2.

I_f - feedback current.

V_i - is in millivolts.

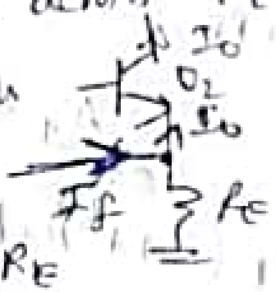
V_{e2} - o/p voltage at emitter of Q_2

If V_i neglected. $I_f = -\frac{V_{e_2}}{R_f}$

R_E - Emitter Resistance of Q_2

The voltage drop across R_E = $\underline{(I_o - I_f)R_E}$

Note: ~~I_f gain~~ is



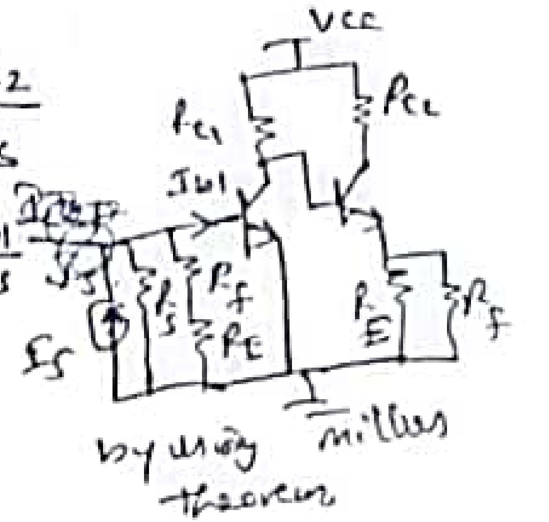
The current through R_E $I_o - I_f$

$$I_f = \frac{(I_o - I_f)R_E}{R_f}$$

$I_f R_f + I_f R_E = I_o R_E \Rightarrow I_f(R_f + R_E) = I_o R_E$

$$\boxed{\beta = \frac{I_f}{I_o} = \frac{R_E}{R_f + R_E}}$$

The current gain $A_I = -\frac{I_{c2}}{I_s}$



$$A_I = -\frac{I_{c2}}{I_{b2}} \times \frac{I_{b2}}{I_{c1}} \times \frac{I_{c1}}{I_{b1}} \times \frac{I_{b1}}{I_s}$$

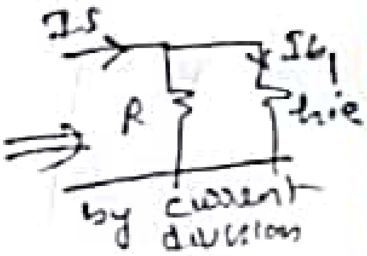
$$-\frac{I_{c2}}{I_{b2}} = -h_{fe} \quad -①$$

$$-②$$

$$\frac{I_{c1}}{I_{b1}} = h_{fe}$$

$$\frac{I_{b2}}{I_{c1}} = -\frac{R_{c1}}{R_{c1}+R_{i2}} \quad -③ \qquad R_{i2} = h_{ie} + (1+h_{fe})(R_E \| R_f)$$

$$\frac{I_{b1}}{I_s} = \frac{R}{R+h_{ie}} \quad -④ \quad \text{where } R = R_s \| (R_f + R_E) \Rightarrow$$



Substitute ①, ② ③. ④ in A_I Equation the gain of amplifier with out feedback is obtained

$$A_{If} = \frac{A_I}{1+A_I\beta} \qquad \beta = \frac{R_E}{R_f+R_E}$$

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

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

$$R_{of}' = R_o' \frac{1+\beta A_i}{1+\beta A_I} \qquad R_o' = R_{c2}$$

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