FOUR BASIC FEEDBACK TOPOLOGIES

The amplifier output is to be sampled or connected (x_o) to a feedback network (β) and then "inserted" in input signal's path.

1. We can sample output voltage V_o or output current I_o or I_L as x_o.
2. We can "insert" the sampled feedback quantity (x_f) in "series" or "shunt" with input signal.

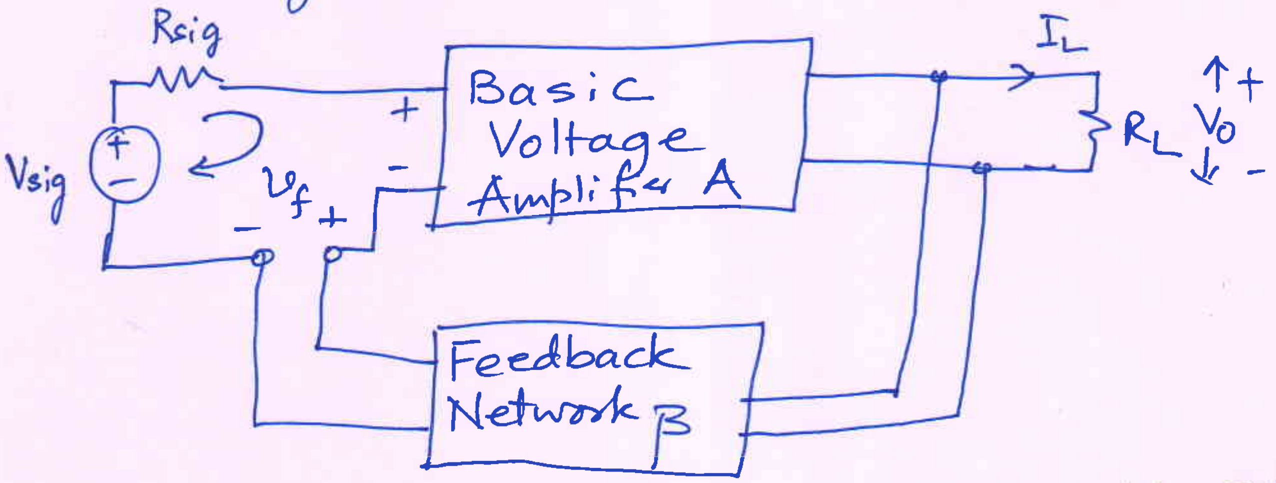
This gives us $2 \times 2 = 4$ possible combinations or circuit connection methods or topologies of providing negative feedback to any amplifier.

Case I : Voltage Amplifier.

($\underbrace{\text{Voltage Mixing}}$ $\underbrace{\text{Voltage Sampling}}$)

$\boxed{\text{SERIES — SHUNT feedback}}$

Consider a Voltage amplifier which works as a Voltage Controlled Voltage Source.



Note that polarity of V_f will oppose the flow of current in input loop. This is -ve f/b.

V_f is proportional to V_o.

$$V_f = V_o/\beta$$

Thus the 'opposition' to input current is proportional to output 'Voltage'. ∴ It is called Voltage sampling. Since β network is connected in parallel to R_L it is also called as SHUNT feedback. The quantity V_f is inserted in SERIES with signal generator hence the name "SERIES - SHUNT"

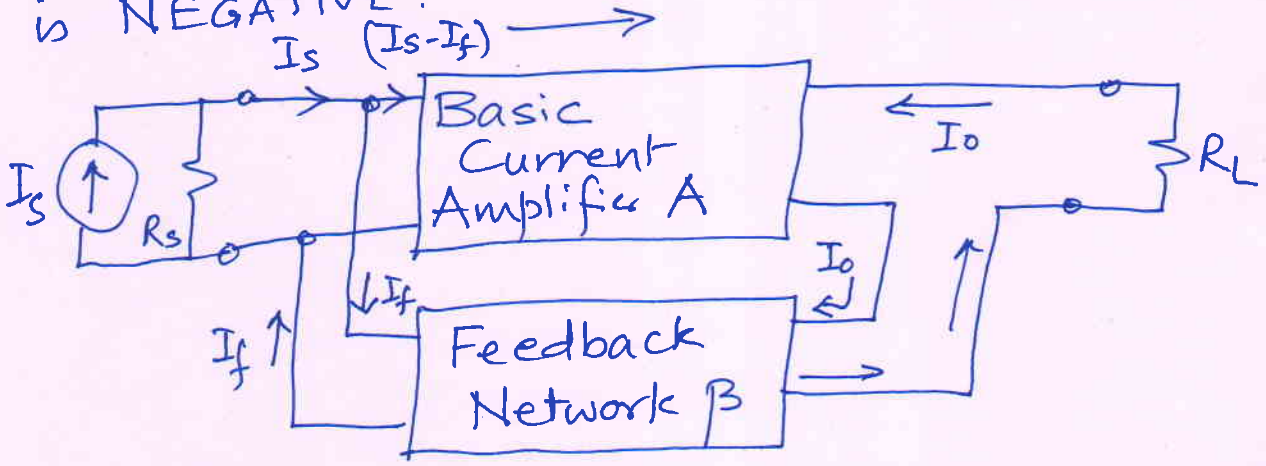
Output Impedance <u>reduces</u> input impedance "<u>increases</u>".

Case II : Current Amplifier

($\underbrace{\text{Current Mixing}}$ – $\underbrace{\text{Current Sampling}}$)

" $\boxed{\text{SHUNT — SERIES}}$ " F/B

Consider an ideal current amplifier. We sample output current I_o. It passes through feedback network β. It generates output which is applied in SHUNT or parallel to input terminals. The purpose of β network is to 'divert' or 'steal' a part of signal current which was entering the amplifier input. This way input current is <u>reduced</u> and the effect of β network is NEGATIVE.



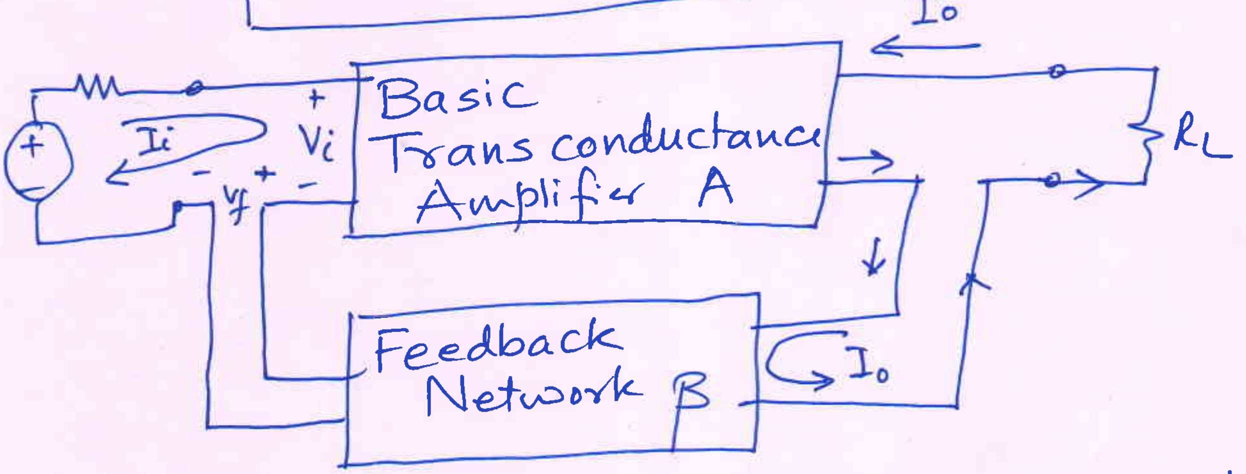
Stabilizes current gain, decreases input resistance and increases output resistance, both desirable properties for a CURRENT SOURCE.

Case III. : Transconductance Amplifier

In this type of amplifier, input is a voltage signal and output is current proportional to it.
Output current is 'sampled' by putting β network in SERIES. The fed back signal x_f is "inserted" in series with voltage signal to oppose input current. Hence it is known as

Voltage Mixing Current Sampling

$\boxed{\text{SERIES (insertion)} \quad \text{SERIES}}$ (β network) F/B



This topology increases input and output resistances both.

Most BJT amplifiers can be viewed as transconductance amplifiers.

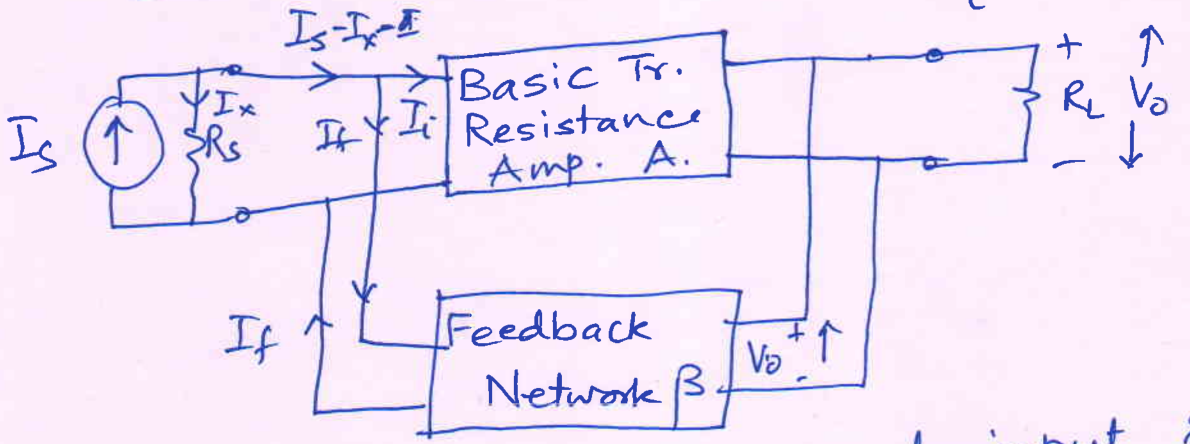
Case IV : Transresistance Amplifier

Here the input signal is current and output is Voltage. So we 'sample' output parameter voltage by putting β network in "shunt" with the load. Since input is current, to steal a part of it, β network must provide a path parallel to input of amplifier ∴ the insertion of x_f must be in "shunt" to stead away a part of input current.

Hence it is

$$\underbrace{\underbrace{\text{Current Mixing}}_{\text{SHUNT}}\ \underbrace{\text{Voltage Sampling}}_{\text{SHUNT}}}\ \text{Feedback}$$

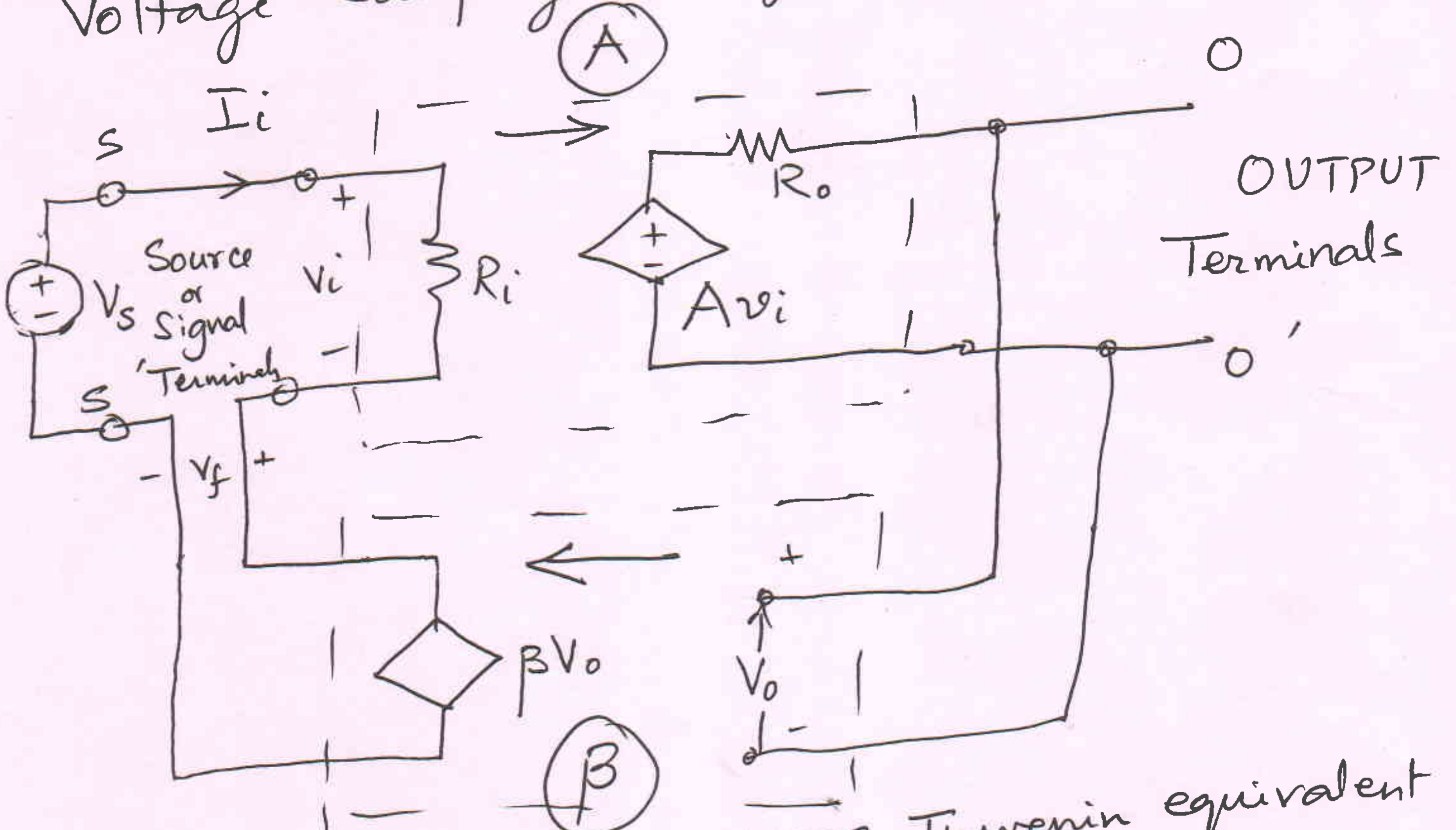
$$I_i = I_s - I_x - I_f$$



Note that both output and input resistances decreases due to negative feedback.

INPUT & OUTPUT RESISTANCE OF AMPLIFIER WITH FEEDBACK

We will calculate input and output resistance of an amplifier with Feedback assuming ideal conditions First and later with practical situation. Let us take case of Voltage Sampling Voltage Feedback amplifier.



Note: Amplifier output is VCVS Thevenin equivalent with an OC voltage of ~~Av_i~~ $A.v_i$ and series or source impedance of R_o. β network does not load V_o. The "inserted" feedback voltage is V_f coming from an ideal Voltage source with zero R_{TH}.

The signal generator source ~~a~~ resistance R_{sig} is included inside the amplifier A block and any load side resistors like R_C, r_o etc. are also included in R_o or R_{TH} shown.

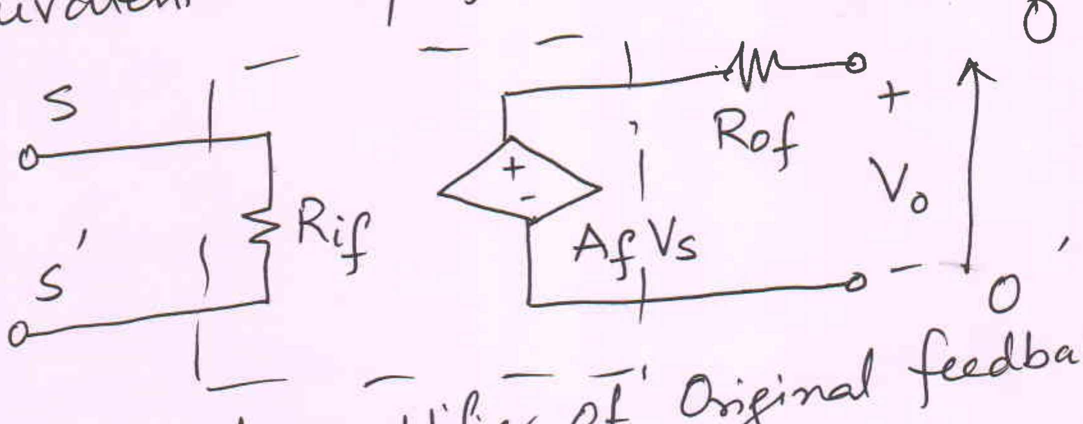
Closed Loop Voltage Gain

= Voltage Gain with feedback

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

Note that A & β have reciprocal units. Hence $A\beta$ becomes DIMENSIONLESS ENTITY.

We can replace whole circuit between S & O terminals by an equivalent amplifier model as below:



Equivalent amplifier of Original feedback block.

R_{if} = Input Resistance seen by Signal Generator

R_{of} = Output " " " load resistance R_L which will be connected at O-O'.

$$R_{if} = \frac{V_s}{I_i} = \frac{V_s}{(V_i/R_i)} = R_i \frac{V_s}{V_i}$$

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

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

$$= R_i \cdot D \quad (D = \text{AMOUNT OF FEEDBK} = \text{DESENSITIVITY FACTOR})$$

If $R_i = R_\pi = 1K$ & $A = 100$, $\beta = \frac{1}{10}$ & $1 + A\beta = 11$

then $R_{if} = 1K \cdot 11 = 11K$.

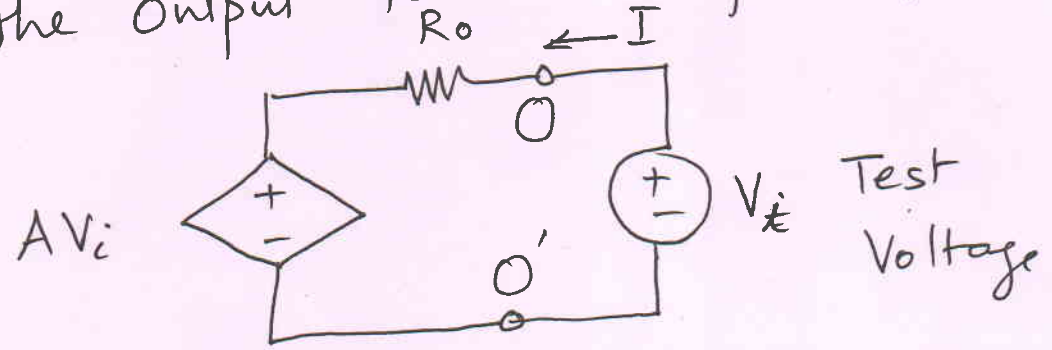
So having larger D, increases INPUT RESISTANCE by a factor of D

At high frequencies we can replace R by Z

$$Z_{if}(s) = Z_i(s)\left[1 + A(s)\beta(s)\right]$$

This equation allows us to create Z_{if} by suitably choosing frequency sensitive behaviour of $A(s)$ and more particularly $\beta(s)$. We can put β as low pass, high pass, band pass or band stop network and obtain desirable $Z_{if}(s)$ behaviour.

To measure output resistance R_{of}, we use a ~~current~~ voltage source from terminals O-O' and measure current flowing <u>into</u> the output terminals of amplifier.



defined as

$$R_{of} \equiv \frac{V_t}{I}$$

Before we do above, we ensure that $V_s = 0$.
So in input loop earlier there were 2 voltage terms — one V_s and second βV_o.
The first one vanishes & second still remains.

$$I = \frac{V_t - AV_i}{R_o}$$

We know from input that $\therefore$ $V_s = 0$ $\boxed{V_f = \beta V_t}$

$$V_s = V_f + V_i$$

$$\therefore V_i = -V_f$$

$$\therefore I = \frac{V_t - (A(-V_f))}{R_o} = \frac{V_t + A\beta V_t}{R_o}$$

~~$\therefore R_o$~~

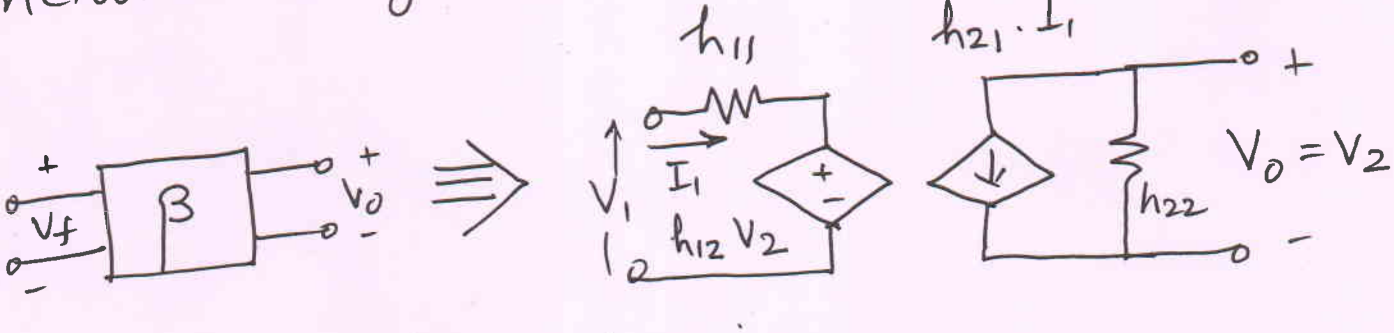
Practical Situation

Our calculations of R_{if} and R_{of} are based on assumption that β does not load the output V_o and that it behaves like an ideal voltage source (βV_o) with ZERO source resistance.

In practice β is just a pair of resistors or an attenuator so it violates both of above assumptions. We can take into account the imperfections of β network as follows:

We need to include the effect of R_{sig} and R_L also

We represent β network by a equivalent 2-port network using h parameters.



h_{21} = forward current gain

h_{12} = reverse conductance

h_{11} = input resistance

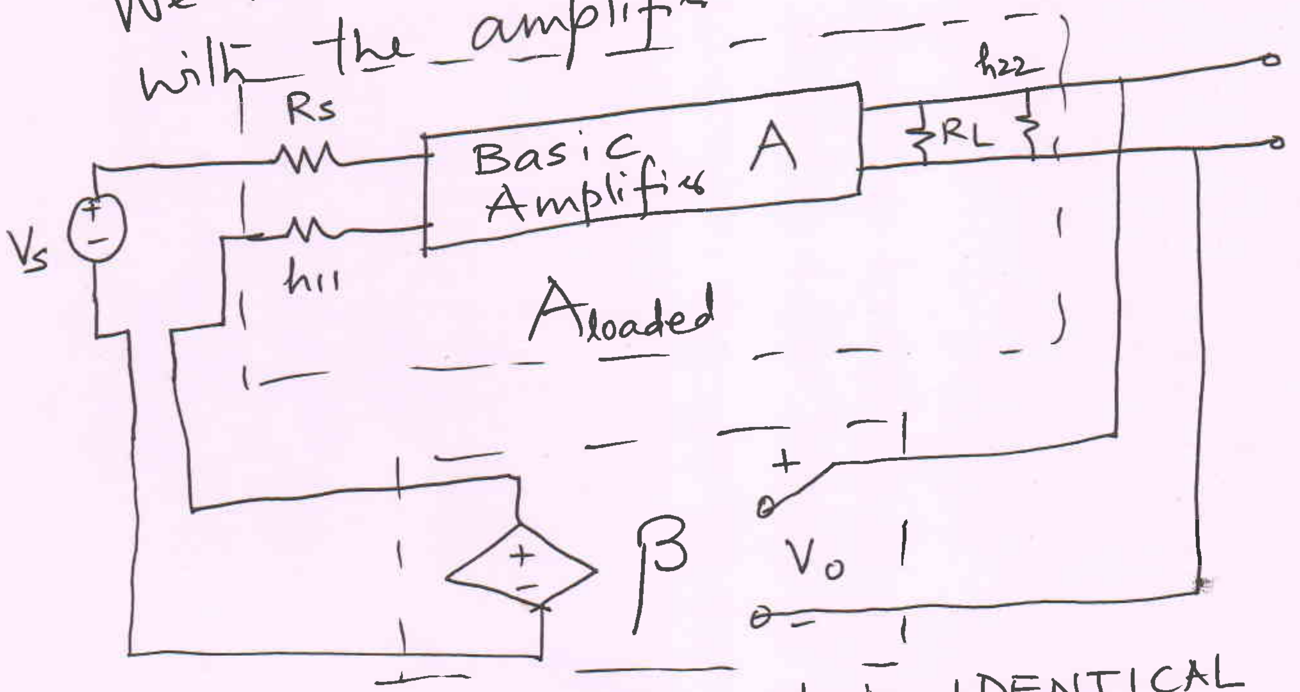
h_{22} = output resistance

In practical β circuits there is very little forward transmission and even if it is there it is in parallel with main amplifier of gain A which is much higher than h_{21} ∴ we neglect current source $h_{21} I_1$. So now we are left with 3 entities – h_{11} (resistive effect or loading of β network on input side)

– h_{22} (resistive effect or loading of β network on output side)

– V_f or voltage feedback $= h_{12} V_2 = \beta V_o$

We redraw the circuit lumping h_{11} and h_{22} with the amplifier.

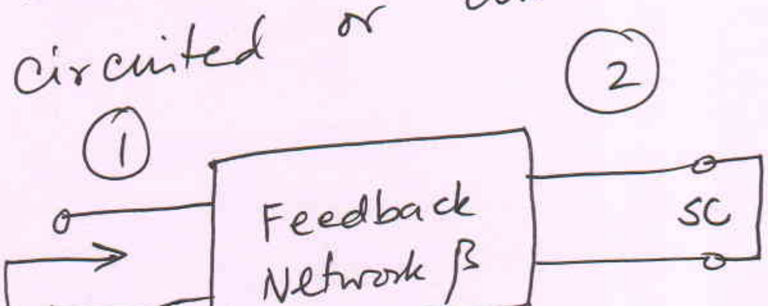


Now Practical Circuit is IDENTICAL TO IDEAL CKT with diff. that Basic Amp Gain will get loaded or reduced.

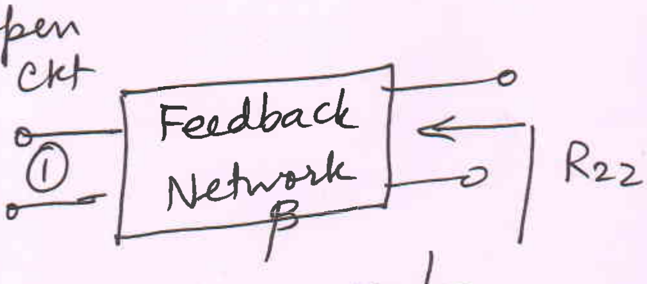
In general, to see the effect of loading of feedback (or β) network on Amplifier Gain A we should calculate h_{11} – input resistance seen into β network with port 2 i.e. input of β network short circuit, so as to render feedback zero. In case of another topology if β network gives V_f/I_o then Input port of β network must be open circuited to make feedback voltage or effect or $x_f = 0$.

To Calculate $\beta = h_{12} = \left.\dfrac{V_1}{V_2}\right|_{I_1=0}$ by definition

Apply voltage at port 2 i.e. at V_2 and measure voltage at V_1 when V_1 is open circuited or disconnected from Vs (i.e. $I_1 = 0$).



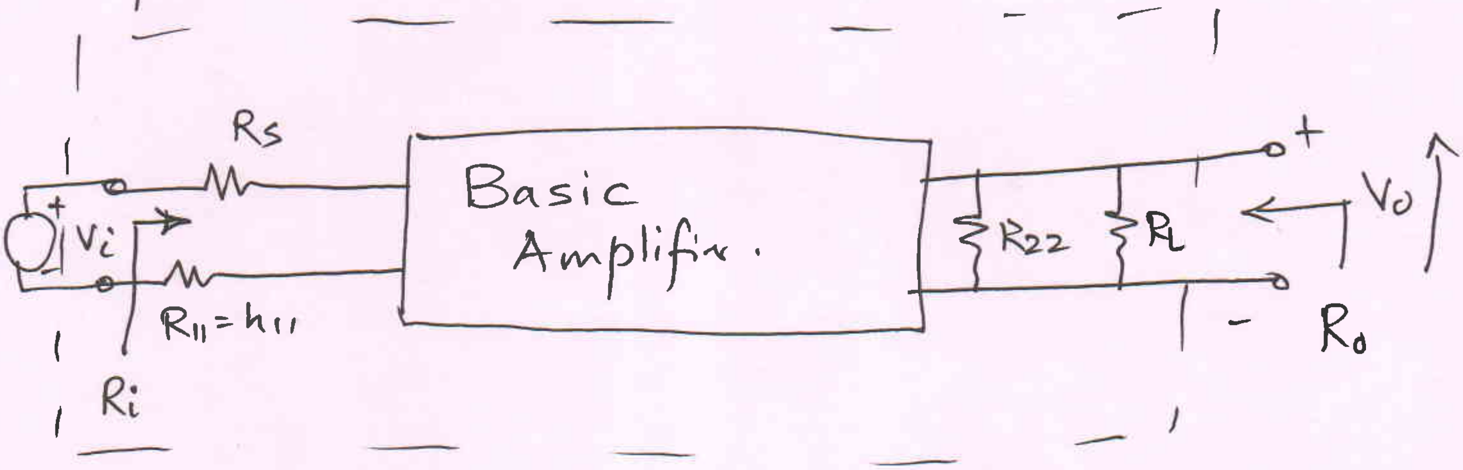
$R_{11} = h_{11}$



$= \dfrac{1}{h_{22}}$

$\because h_{22}$ = Conductance.

Measurement of R_i & R_o without F/B but taking into consideration loading of β network, Rsig and R_L.



1. R_i and R_o are the input & output resistance of Overall 'lumped' amplifier
2. When β network is added to above we get input as R_{if} and Output as R_{of} respectively