Distortion with feedback

$$D_f = \frac{D}{1+A\beta} \Rightarrow D_f = \frac{10}{5} = 2\%$$

Types of Negative feedback connections :

there are four different combinations in which negative feedback may be accomplished.

1) voltage series feedback
2) voltage shunt feed back
3) current series feedback
4) current shunt feedback.

series feedback connection increase the i/p resistance
shunt feedback connection decrease the i/p resistance
voltage " " decrease the o/p "
current " " increase " " "

1) voltage series feed back increases input impedance
decreases output "

2) voltage shunt feed back decreases the input resistance
decreases the output "

3) current series feed back increases the input resistance
increases the output "

4) current shunt feed back decreases the input "
increases the output "

It is desirable that most cascade Amplifiers need to have higher input ~~impedance~~ resistance and lower output resistance.

The voltage series type of feedback has the high input impedance and low output resistance, but it ~~decreases~~ suffers the highest degree in voltage gain.

On the other hand, current shunt feedback has the least desirable effects since it decreases input resistance and increases output resistance.

1) Voltage series feedback :

A block diagram of voltage series feedback is illustrated in figure below. Here the input to the feedback network is in parallel with the output of the amplifier. A fraction of the output voltage through the feedback n/w is applied in series with the input voltage of the amplifier. The shunt connection at the o/p reduces the output resistance R_o. The series connection at the input increases the input resistance.

In this case, the amplifier is a true voltage amplifier. The voltage feedback factor is given by

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

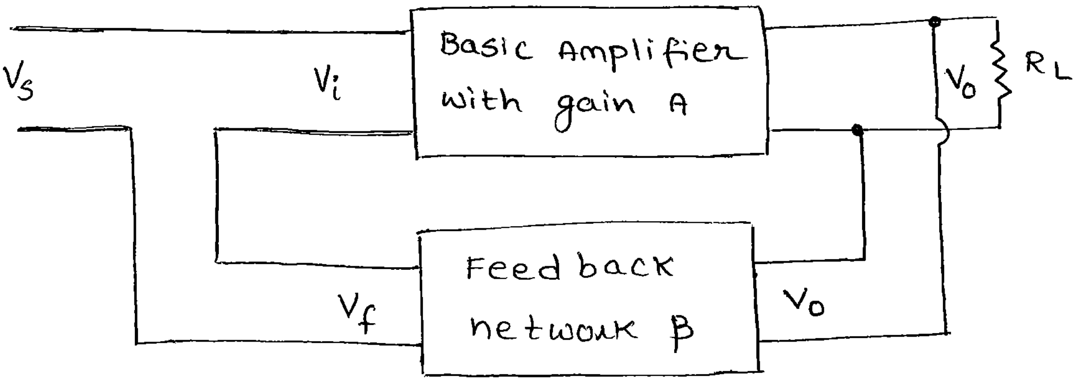


Fig: Block diagram of the voltage series feedback.

<u>Input and output resistances</u> :-

Figure below shows the voltage series feedback circuit used to calculate input and output resistances

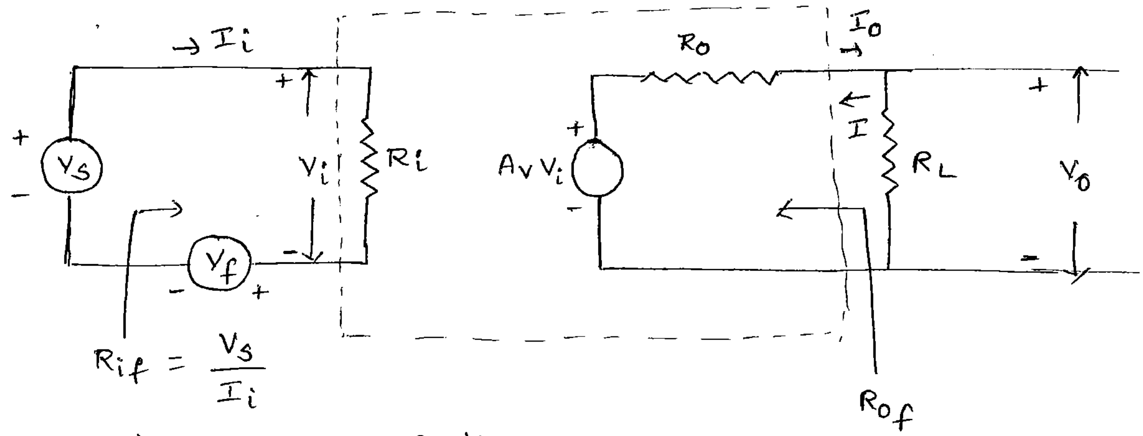


Fig: voltage series feedback circuit for the calculation of input and output resistances.

Here $V_s = V_i + V_f$

$V_s = I_i R_i + \beta V_o$

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

$A = \frac{V_o}{V_i} \Rightarrow \frac{V_o}{I_i R_i}$

$V_o = A I_i R_i$

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

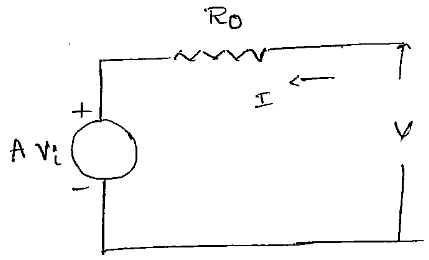
Hence the input resistance of a voltage series feedback amplifier is given by

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

where R_i is the input resistance of the amplifier without feedback.

For measuring the output resistance, R_L is disconnected and V_s is set to zero. Then external voltage V is applied across the output terminals and the current I delivered by V is calculated. Then $R_{of} = \frac{V}{I}$

Here $\cancel{I} = \frac{\cancel{V} - A\cancel{V_i}}{\cancel{R_o}}$



Due to feedback, input voltage V_f reduces output voltage AV_i which opposes V. Therefore

$$I = \frac{V - AV_i}{R_o} = \frac{V + \beta A V}{R_o}$$

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

Hence the output resistance of a voltage series feedback amplifier is given by

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

where R_o is the output resistance of the amplifier without feedback.

Problem: A voltage - series negative feedback amplifier has a voltage gain without feedback of $A = 500$, input resistance $R_i = 3k\Omega$, output resistance $R_o = 20k\Omega$ and feedback ratio $\beta = 0.01$. calculate the voltage gain A_f, input resistance R_{if} and output resistance R_{of} of the amplifier with feedback.

Solution: $A = 500$, $R_i = 3k\Omega$, $R_o = 20k\Omega$ and $\beta = 0.01$

voltage gain $A_f = \dfrac{A}{1+A\beta} = \dfrac{500}{1+(500\times 0.01)} = 83.3$

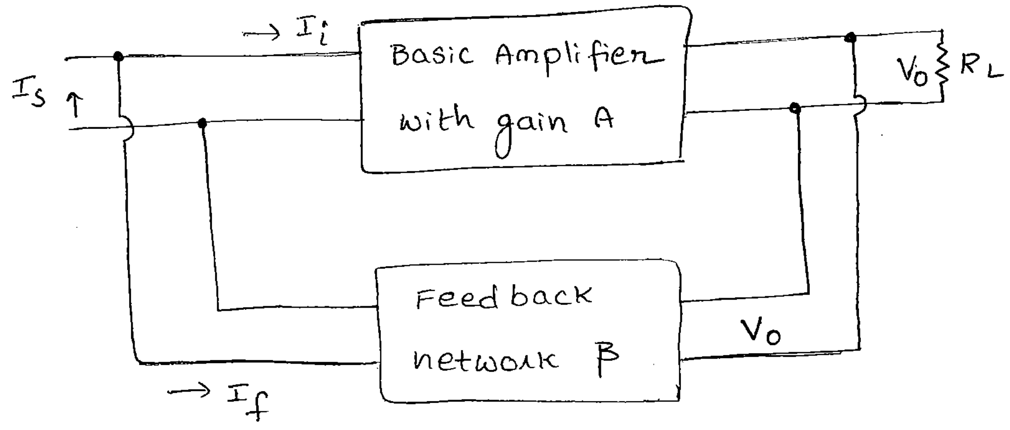
Input resistance $R_{if} = (1+A\beta)R_i = (1+500\times 0.01)\times 10^3$
$= 18k\Omega$.

output resistance $R_{of} = \dfrac{R_o}{1+A\beta} = \dfrac{20\times 10^3}{1+500\times 0.01} = 3.33k\Omega$

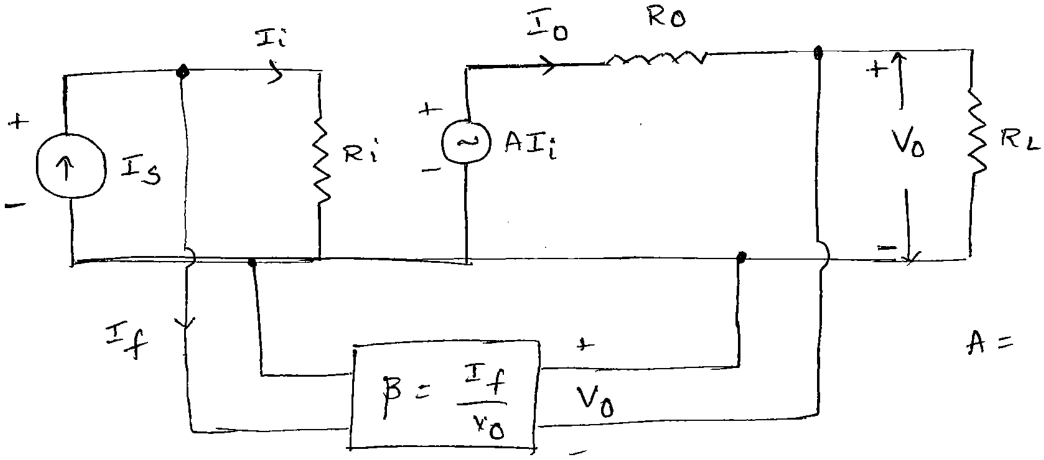
2) Voltage shunt feedback :-

A voltage shunt feedback is illustrated in figure below. Here a fraction of the output voltage is supplied in parallel with the input voltage through the feedback network. The feedback signal I_f is proportional to the output voltage V_o. Therefore the feedback factor is given by $\beta = \dfrac{I_f}{V_o}$. this type of amplifier is called a trans resistance amplifier. The voltage - shunt feedback provides a stabilised overall gain and decreases both input and output resistances by a factor $(1+A\beta)$

$$R_{if} = \frac{R_i}{1 + A\beta} \quad \text{and} \quad R_{of} = \frac{R_o}{1 + A\beta}$$



Input and output resistances :-



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

Fig : Equivalent circuit of voltage shunt feedback.

$$R_{if} = \frac{V_i}{I_s} = \frac{V_i}{I_i + I_f} = \frac{V_i}{I_i + \beta V_o} = \frac{V_i / I_i}{1 + \beta \frac{V_o}{I_i}}$$

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

thus the input impedance gets reduced by a factor $(1 + A\beta)$

$\cancel{-AI_i + I_o R_o + V_o = 0}$

$\cancel{V_o =}$

output Impedance :

$$V_o = I_o R_o + A I_i$$

For $I_s = 0$ $\quad I_i = -I_f$, then

$$V_0 = I_0 R_0 - A I_f$$

$$V_0 = I_0 R_0 - A \beta V_0$$

$$V_0 (1 + A\beta) = I_0 R_0$$

$$R_{of} = \frac{V_0}{I_0} = \frac{R_0}{1 + A\beta}$$

3. Current series feedback Amplifier

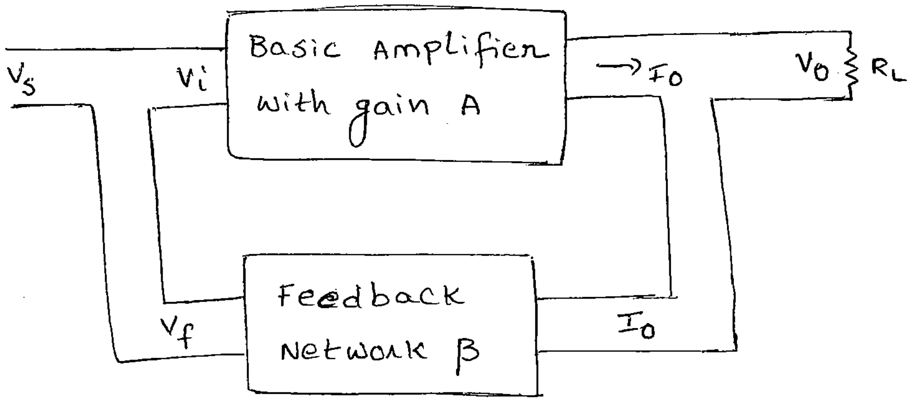
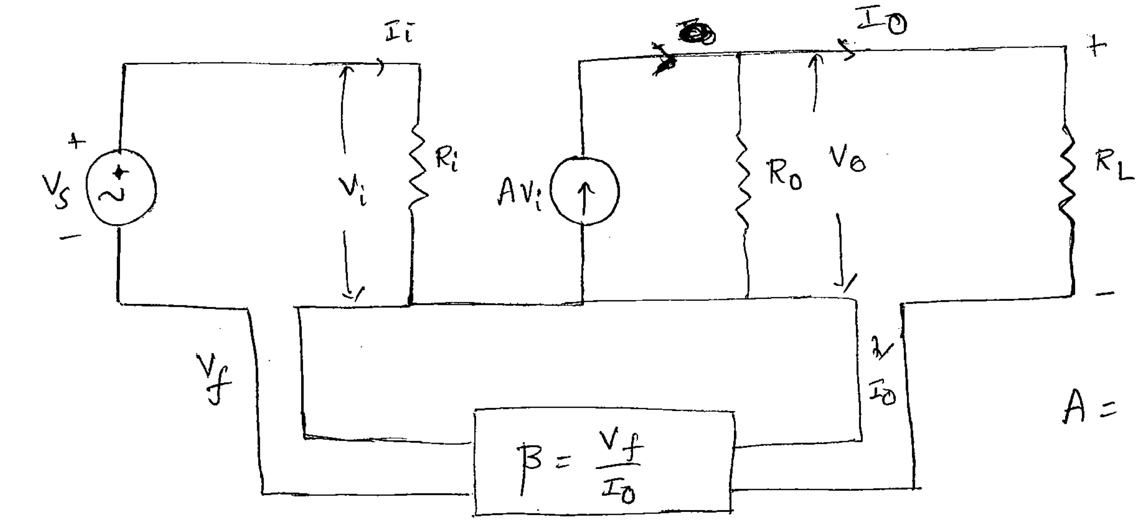


Fig: Block diagram of the current series feedback.

A block diagram of a current series feedback is illustrated in figure above. In current series feedback, a voltage is developed which is proportional to the output current. This is called current feedback even though it is a voltage that subtracts from the input voltage. Because of the series connection at the input and output, the input and output resistances get increased. This type of amplifier is called transconductance amplifier. The transconductance feedback factor β is given by $\beta = V_f / I_0$

Input and output resistances :



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

$$V_s = V_i + V_f = I_i R_i + \beta I_o$$

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

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

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

To obtain the output impedance assume that source voltage is transfered to output terminals, with V_s short circuited ie $V_s = 0$, resulting in a current I_o in to the circuit.

$$V_s = V_i + V_f \quad \text{if } V_s = 0 \text{ then } V_i = -V_f$$

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

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

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

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

4) Current - shunt feedback :

The block diagram of current shunt feedback is shown in figure below

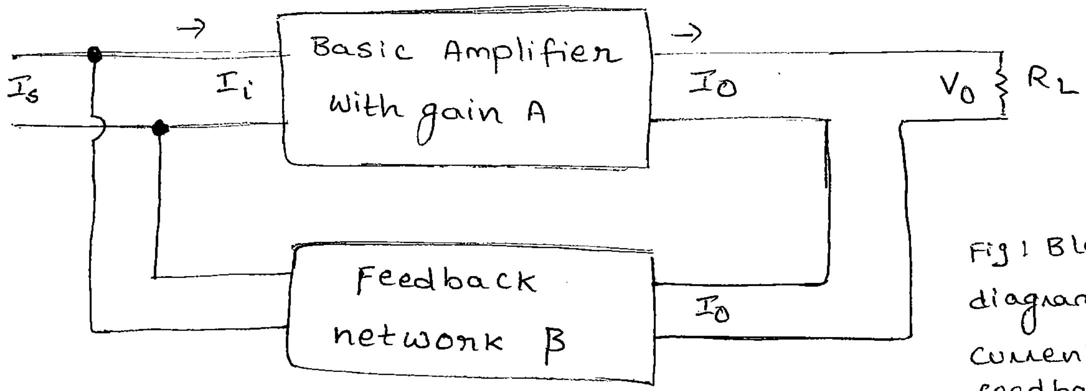


Fig 1 Block diagram of current shunt feedback

The shunt connection at the input reduces the input resistance and the series connection at the output increases the output resistance. This is a true current amplifier. The current feedback factor is given by
$$\beta = \frac{I_f}{I_o}$$

Here Amplifier gain $A = \frac{I_o}{I_i}$

Input and output resistances :

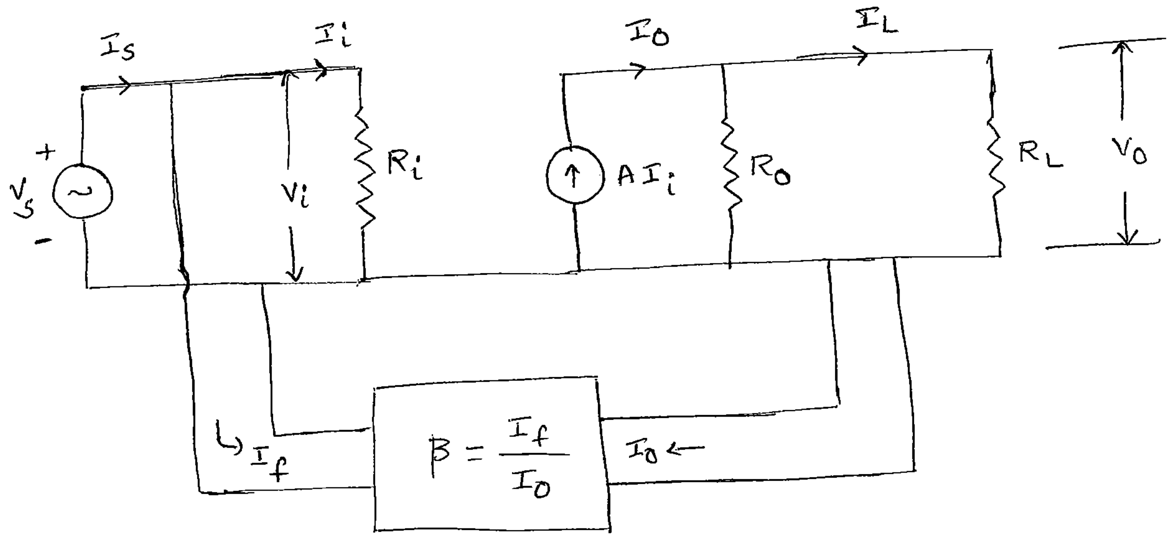


Fig : Equivalent circuit of current shunt feedback connection

Input Resistance

From the Equivalent circuit

$$I_s = I_i + I_f$$

$$I_s = \frac{V_i}{R_i} + \beta I_o \qquad \left[\because \beta = \frac{I_f}{I_o}\right]$$

$$I_s = \frac{V_i}{R_i} + \beta A I_i \qquad \left[\because A = \frac{I_o}{I_i}\right]$$

$$I_s = \frac{V_i}{R_i} + \beta A \frac{V_i}{R_i} \qquad \left[\because I_i = \frac{V_i}{R_i}\right]$$

$$I_s = \frac{V_i}{R_i}\left[1 + A\beta\right]$$

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

Output resistance:

we know that

$$I_s = I_i + I_f$$

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

From the equivalent circuit $I_o = A I_i + \frac{V_o}{R_o}$

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

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

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

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

Problem:

When a negative feedback is applied to an Amplifier of gain 100, the overall gain falls to 50. calculate (i) the feedback factor β (ii) If the same feedback factor maintained, the value of the amplifier gains required if the overall gain is to be 75

Solution: (i) $A = 100$, $A_f = 50$

$$A_f = \frac{A}{\cancel{A} + A\beta} \Rightarrow \beta = 0.01$$

(ii) $A_f = 75$

$$A_f = \frac{A}{1 + A\beta} \Rightarrow 75 = \frac{A}{1 + 0.01 A}$$

$$\Rightarrow A = 300.$$

Problem:

The gain of the amplifier without feedback is 50 whereas with~~out~~ -ve feedback ~~is~~ it falls to 25. If due to ageing, the amplifier gain falls to 40. Find the percentage reduction in gain

i) without feedback (ii) with negative feedback.

Solution: $A_f = \frac{A}{1+A\beta}$ Given $A_f = 25$, $A = 50$

then $\beta = 0.02$

(i) without feedback % reduction in gain $= \frac{50-40}{50} \times 100$

$= 20\%$

when the gain without feedback was 50, the gain with feedback was 50. Now the gain without feedback falls to 40

then $A_f = \frac{A}{1+A\beta} = \frac{40}{1+0.02\times 40} = 22.2$ | % reduction in gain $= \frac{25-22.2}{25} \times 100 = 11.2\%$