Feedback Amplifiers

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Feedback amplifiers: The amplifier in which a part of output is fed back to the input of amplifier is ca feedback amplifiers. Therefore at the input we have two signals one is source signal and part of output whi fed back to input.

Feedback: *Feedback* is a portion of the output is returned to the input to form part of the system excitation.
There are two types of feedback:

(a) *Negative (degenerative)* feedback and

(b) *Positive (regenerative)* feedback.

Negative (degenerative) feedback: If the signal fed back is of opposite polarity or out of phase by 180° (or odd integer multiples of 180°) with respect to the input signal, the feedback is called *negative feedback*.

The feedback signal reduces the magnitude of the amplifier input signal.
It decreases the voltage gain.
It is principally applied in amplifiers.

Positive (regenerative) feedback: If the signal fed back is of the same polarity or in phase with the input signal, the feedback is called *positive feedback*. So, the feedback signal increases the magnitude of the amplifier input signal.

It increases the voltage gain and causes the instability of an amplifier.
It is mainly used in oscillators.

A feed back is sometimes referred to as a closed loop because the feedback forms a closed loop between the input and output.

S.No	Parameter	Positive feedback	Negative feedback
1	Phase shift between input and feedback signal	0 or 360^0	180^0
2	input and feedback signal	Both are in phase	Are out of phase
3	Input voltage	Increase	Decrease
4	Output Voltage	Increase	Decrease
5	Voltage gain	Increase	Decrease
6	Distortion	Increase	Decrease
7	Stability	Decrease	Increase
8	Applications	Used in oscillators and Schmitt triggers	Used in amplifiers

A feedback amplifier consists of a basic amplifier and a feedback network.
The representation of any single-loop feedback connection around a basic amplifier is shown in **Fig. 13-5**.

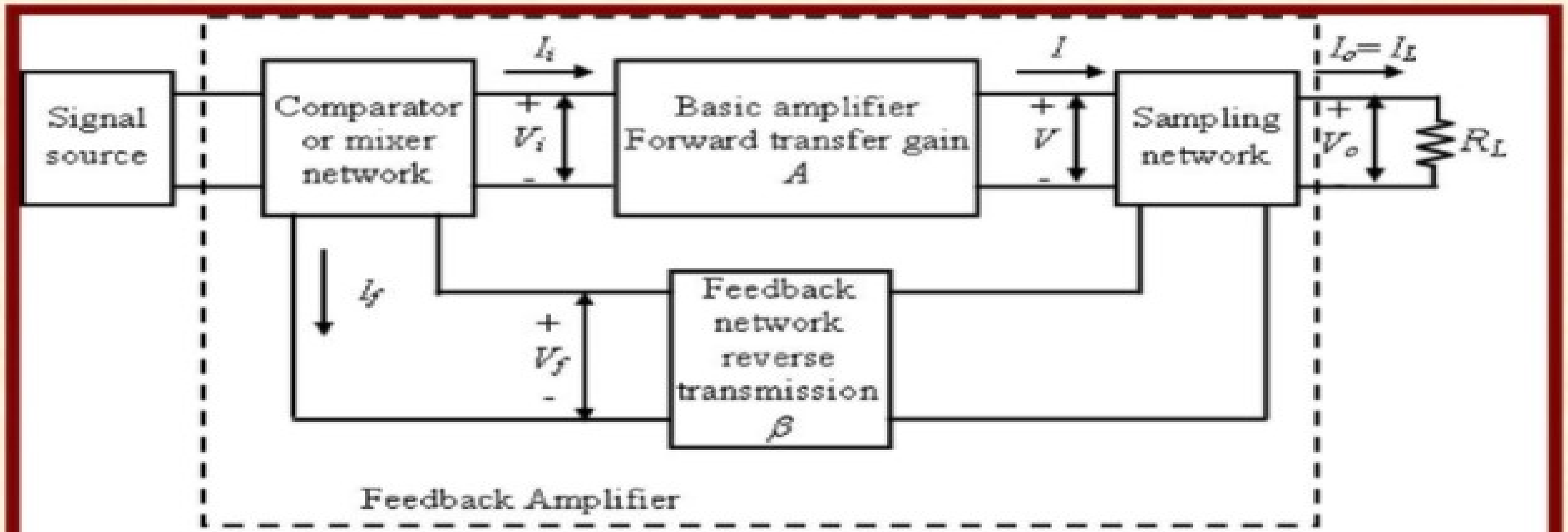


Fig. 13-5 Representation of any single-loop feedback connection around a basic amplifier. The transfer gain A may represent A_V, A_I, G_M, or R_M.

The basic parts of a single-loop feedback connection around a basic amplifier are as follows:

(a) Signal source, **(b) Feedback network with reverse transmission,**
(c) Sampling network, **(d) Comparator or mixer network, and**
(e) Basic amplifier with forward transfer gain.

Signal Source:

Signal source is either a signal voltage V_s in series with a resistor R_s (a Thevenin's representation) or a signal current I_s in parallel with a resistor R_s (a Norton's representation).

Feedback Network:

Feedback network design with R,L,C. Feedback factor 'β' is lies between 0 to 1 in –ve feed back an

The feedback network is usually a passive two-port network which may contain resistors, capacitors, and inductors.

Sampling Network:

Two types of sampling networks can be used. These two sampling networks are:

Voltage or node sampling: In this type of sampling system the output is sampled by connecting the feedback network in *shunt* across the output. **Fig. 13-6(a)** shows the representation of voltage or node sampling network.

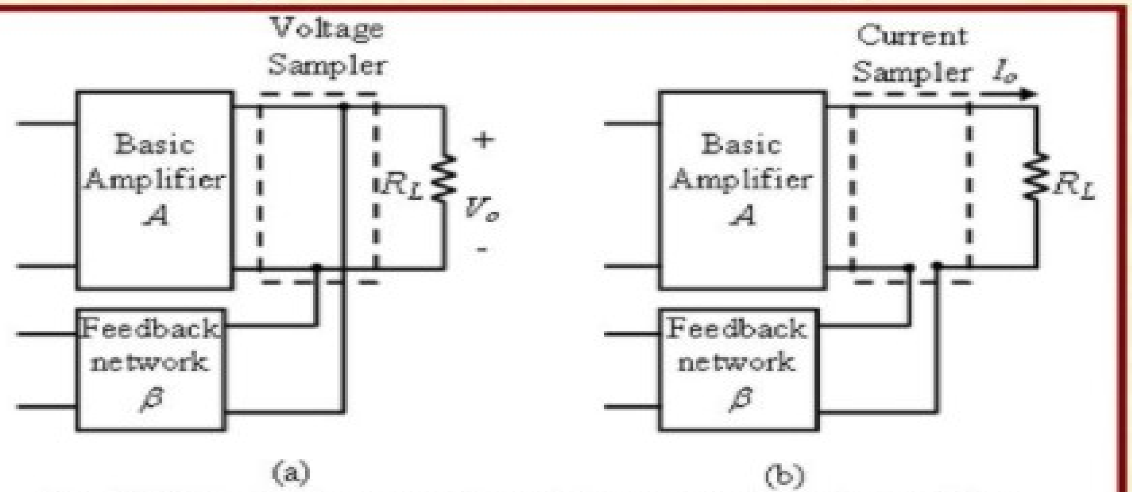


Fig. 13-6 Feedback connections of the output of a basic amplifier, sampling the output. (a) Voltage (b) Series.

Current or loop sampling: In this type of sampling system the output is sampled by connecting the feedback network in *series* with the output. **Fig. 13-6(b)** shows the representation of current or loop sampling network.

Comparator or mixer network:

Mixer network circuit is either *series* (*loop*) input or *shunt* (*node*) input connections.

Figs. 13 –7 (a) and (b) show the representation of series and shunt connections, respectively.

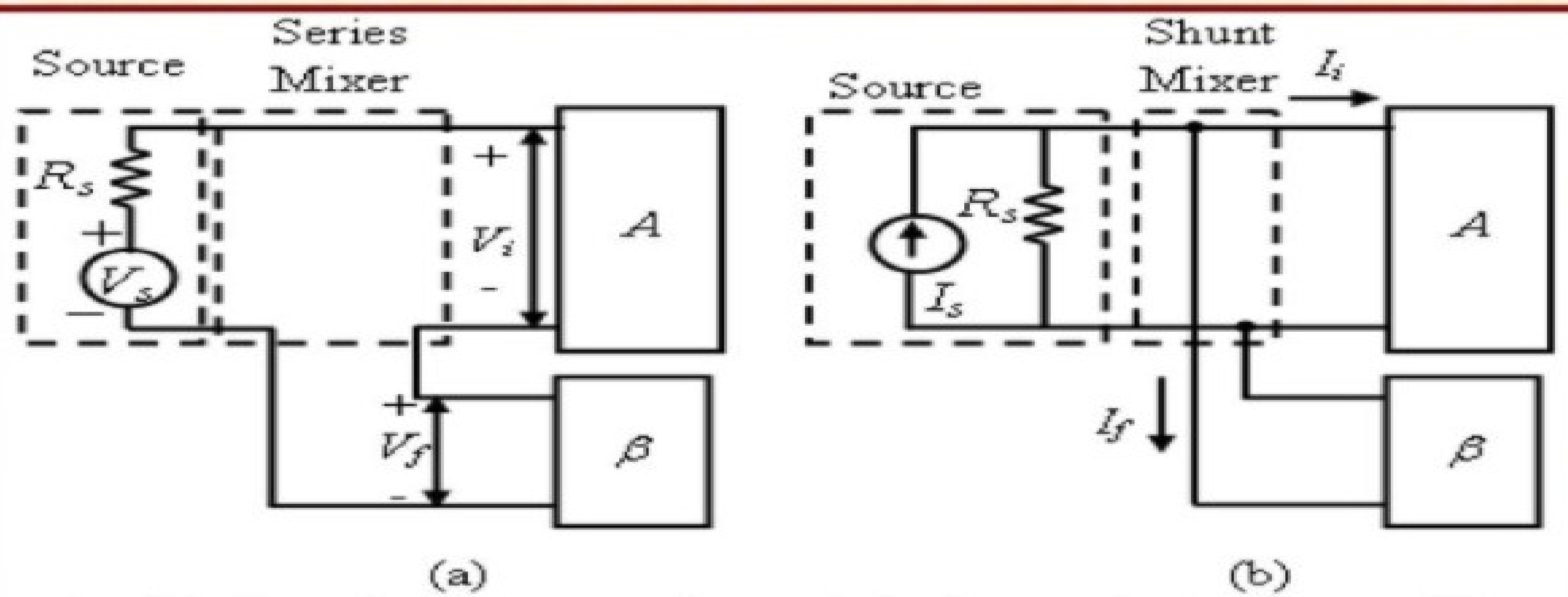
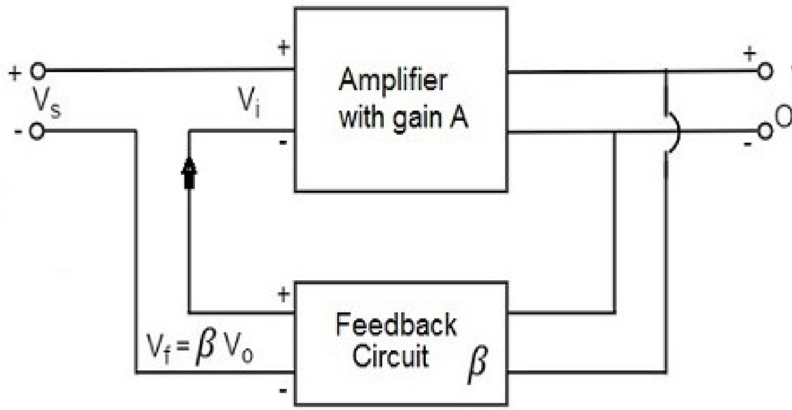


Fig. 13-7 Feedback connections of the input of a basic amplifier. (a) Series connection. (b) Shunt Mixing.

A differential amplifier is often also used as the mixer.
Such an amplifier has two inputs and gives an output proportional to the difference between the signals at the two inputs.

Principle of Feedback Amplifier

A feedback amplifier generally consists of two parts. They are the **amplifier** and the **feedback circui**
The feedback circuit usually consists of resistors. The concept of feedback amplifier can be understoo
from the following figure.



From the above figure, the gain of the amplifier is represented as A. the gain of the amplifier is the ratio of output voltage V_0 to the input voltage V_i. the feedback network extracts a voltage $V_f = \beta V_0$ from the output V_0 of the amplifier.

This voltage is added for positive feedback and subtracted for negative feedback, from the signal voltage V_S. Now,

$$V_i = V_s + V_f = V_s + \beta V_o$$

$$V_i = V_s - V_f = V_s - \beta V_o$$

The quantity $\beta = V_f/V_o$ is called as feedback ratio or feedback fraction.

Let us consider the case of negative feedback. The output V_o must be equal to the input voltage $(V_s - \beta V_o)$ multiplied by the gain A of the amplifier.

Hence,

$$(V_s - \beta V_o)A = V_o$$

Or

$$AV_s - A\beta V_o = V_o$$

Or

$$AV_s = V_o(1 + A\beta)$$

Therefore,

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

Let A_f be the overall gain (gain with the feedback) of the amplifier. This is defined as the ratio of output voltage V_o to the applied signal voltage V_s, i.e.,

$$A_f = \frac{Output\ voltage}{Input\ signal\ voltage} = \frac{V_o}{V_s}$$

So, from the above two equations, we can understand that,

The equation of gain of the feedback amplifier, with negative feedback is given by

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

The equation of gain of the feedback amplifier, with positive feedback is given by

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

These are the standard equations to calculate the gain of feedback amplifiers.

Negative Feedback

The feedback in which the feedback energy i.e., either voltage or current is out of phase with the input and thus opposes it, is called as **negative feedback**.

In negative feedback, the amplifier introduces a phase shift of 180^o into the circuit while the feedback network is so designed that it produces no phase shift or zero phase shift. Thus the resultant feedback voltage V_f is 180^o out of phase with the input signal V_{in}.

Though the **gain** of negative feedback amplifier is **reduced**, there are many advantages of negative feedback such as

- Stability of gain is improved
- Reduction in distortion
- Reduction in noise
- Increase in input impedance
- Decrease in output impedance
- Increase in the range of uniform application
- Improves the frequency response
- Increases the Bandwidth
- It is because of these advantages negative feedback is frequently employed in amplifiers.

Classification of negative feed back amplifiers is based on the method of mixing and sampling emplo

Voltage series feedback amplifier. **1. Series-Shunt Feedback (Voltage Amplifier)**

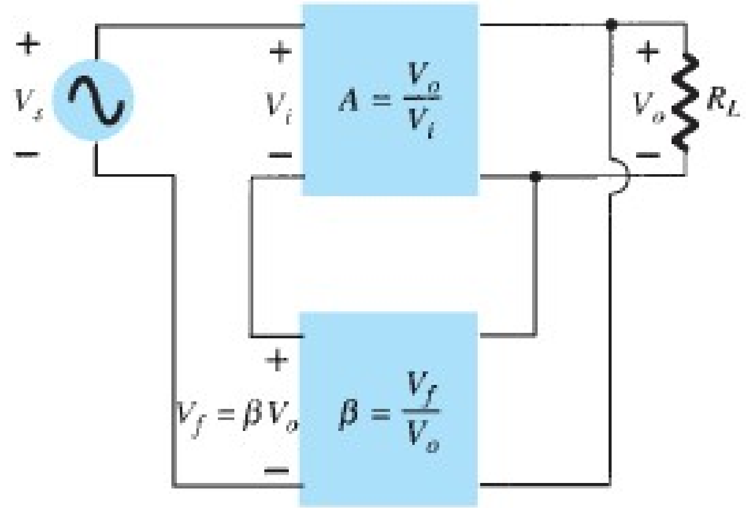
Current shunt feedback amplifier. **2. Shunt- Series Feedback (Current amplifier)**

Current series feedback amplifier. **3. Series-Series Feedback (Transconductance amplifie**

Voltage shunt feedback amplifier **4. Shunt-Shunt Feedback (Transresistance amplifier)**

Voltage-Series Feedback

In the voltage series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as **shunt-driven series-fed** feedback, i.e., a parallel-series circuit. The following figure shows the block diagram of voltage series feedback, by which it is evident that the feedback circuit is placed in shunt with the output but in series with the input.

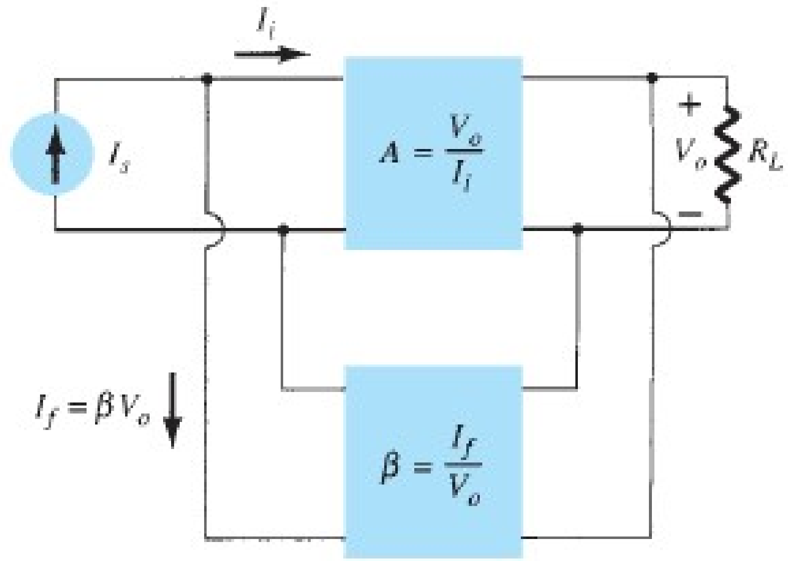


As the feedback circuit is connected in shunt with the output, the output impedance is decreased and due to the series connection with the input, the input impedance is increased.

Voltage-Shunt Feedback

In the voltage shunt feedback circuit, a fraction of the output voltage is applied in parallel with the input voltage through the feedback network. This is also known as **shunt-driven shunt-fed** feedback i.e., a parallel-parallel proto type.

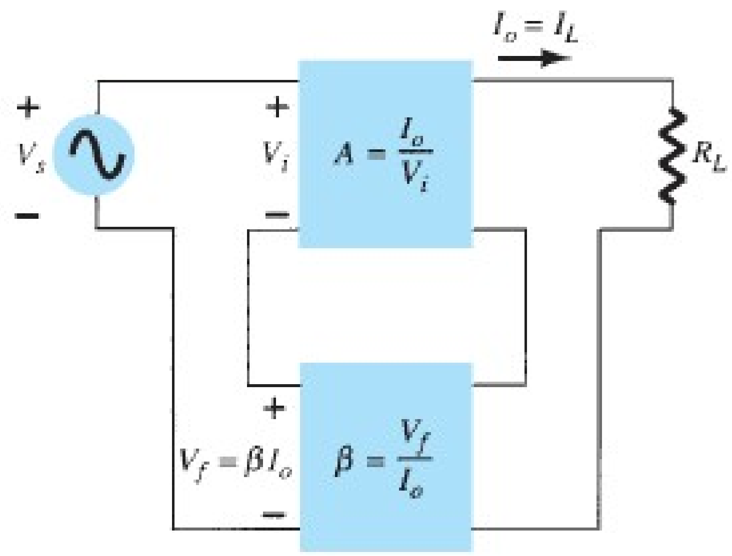
The below figure shows the block diagram of voltage shunt feedback, by which it is evident that the feedback circuit is placed in shunt with the output and also with the input.



As the feedback circuit is connected in shunt with the output and the input as well, both the outp impedance and the input impedance are decreased.

Current-Series Feedback

In the current series feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as **series-driven series-fed** feedback i.e., a series-series circuit.
The following figure shows the block diagram of current series feedback, by which it is evident that the feedback circuit is placed in series with the output and also with the input.

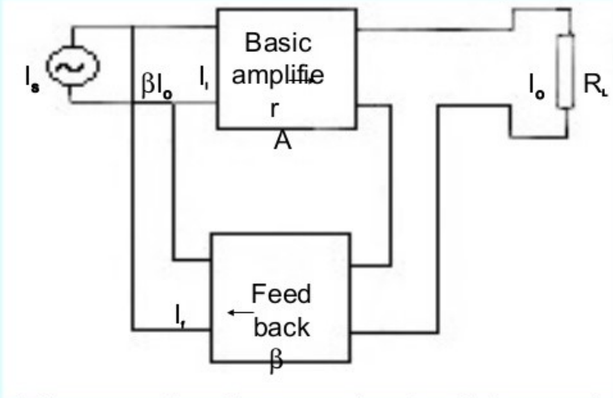


As the feedback circuit is connected in series with the output and the input as well, both the output impedance and the input impedance are increased.

Current-Shunt Feedback

In the current shunt feedback circuit, a fraction of the output voltage is applied in series with the input voltage through the feedback circuit. This is also known as **series-driven shunt-fed** feedback i.e., a series-parallel circuit. The below figure shows the block diagram of current shunt feedback, by which it is evident that the feedback circuit is placed in series with the output but in parallel with the input.

Current shunt feedback amplifier



This connection decreases input resistance and increases the output resistance.

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As the feedback circuit is connected in series with the output, the output impedance is increased and due to the parallel connection with the input, the input impedance is decreased.

Voltage series feedback amplifier:

- Samples the output voltage and returns a feedback voltage signal
  - Ideal feedback network has infinite input impedance and zero output resistance
- Find the closed-loop gain and input resistance

$V_f = \beta V_o$

$V_i = V_s - V_f$

$V_o = A(V_s - \beta V_o)$

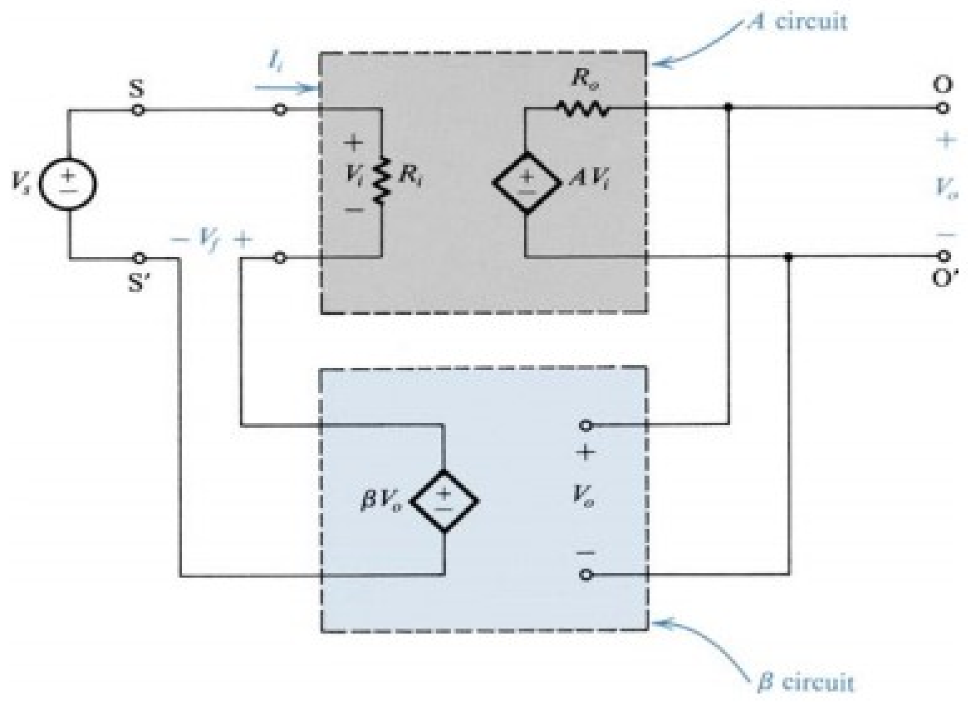
$$A_f \equiv \frac{V_o}{V_s} = \frac{A}{1+\beta A}$$

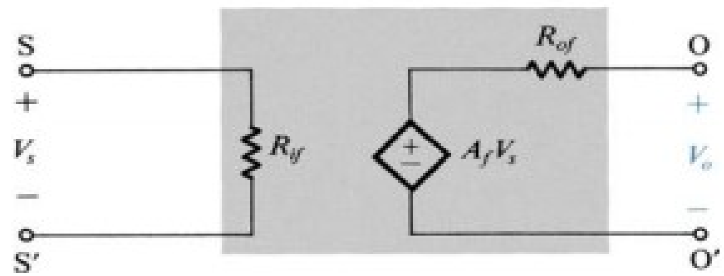
$$R_{if} = \frac{V_s}{I_i} = \frac{V_s}{V_i/R_i} = R_i \frac{V_s}{V_i} = R_i \frac{V_i + \beta A V_i}{V_i} = R_i(1 + A\beta)$$

  - The output resistance can be found by applying a test voltage to the output

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

- So, increases input resistance and reduces output resistance → makes amplifier closer to ideal VCVS





Current-Series Feedback

- For a transconductance amplifier (voltage input, current output), we must apply the appropriate feedback circuit
  - Sense the output current and feedback a voltage signal. So, the feedback current is a transimpedance block that converts the current signal into a voltage.

$$A_f \equiv \frac{I_o}{V_s} = \frac{A}{1+A\beta} \qquad A \equiv \frac{I_o}{V_i} \text{ (also called } G_m\text{)}$$

- To solve for the loop gain:
  - Break the feedback, short out the break in the current sense and applying a test current

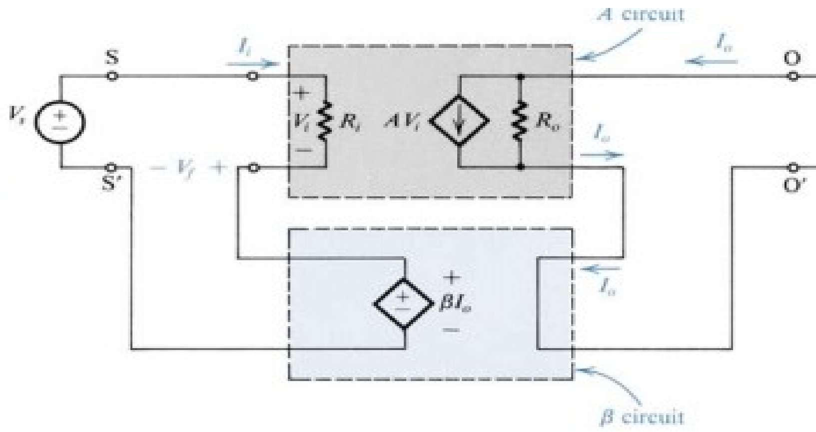
$$\text{Loop Gain} = A\beta = -\frac{I_{out}}{I_{tst}} = G_m R_f$$

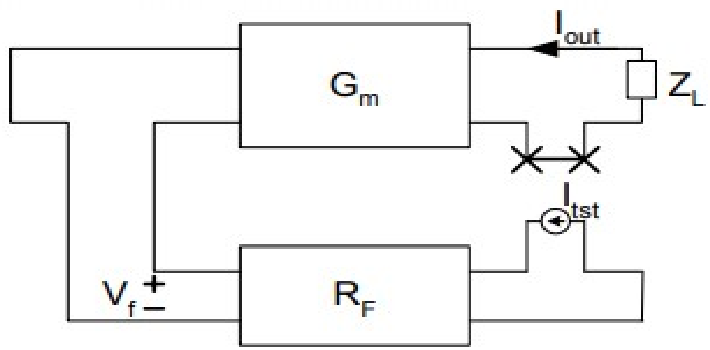
- To solve for R_{if} and R_{of}

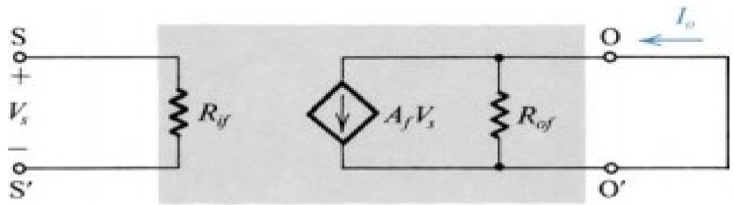
$$R_{if} = \frac{V_s}{I_i} = \frac{V_i + V_f}{I_i} = \frac{R_i I_i + \beta I_o}{I_i} = \frac{R_i I_i + A\beta V_i}{I_i} = R_i(1+A\beta)$$

  - Apply a test voltage V_{tst} across O and O'

$$R_{of} = \frac{V_{tst}}{I_{tst}} = \frac{(I_{tst} - AV_i)R_o}{I_{tst}} = \frac{(I_{tst} + A\beta I_{tst})R_o}{I_{tst}} = (1+A\beta)R_o$$







Characteristics	Types of Feedback			
	Voltage-Series	Voltage-Shunt	Current-Series	Current-Shunt
Voltage Gain	Decreases	Decreases	Decreases	Decreases
Bandwidth	Increases	Increases	Increases	Increases
Input resistance	Increases	Decreases	Increases	Decreases
Output resistance	Decreases	Decreases	Increases	Increases
Harmonic distortion	Decreases	Decreases	Decreases	Decreases
Noise	Decreases	Decreases	Decreases	Decreases

Effect of Feedback Connection on Input and Output Impedance

	Voltage-Series	Current-Series	Voltage-Shunt	Current-Shunt
Impedance	$Z_{if}\ Z_i(1 + \beta A)$ (increased)	$Z_i(1 + \beta A)$ (increased)	$\frac{Z_i}{1 + \beta A}$ (decreased)	$\frac{Z_i}{1 + \beta A}$ (decreased)
ut Impedance	$Z_{of}\ \frac{Z_o}{1 + \beta A}$ (decreased)	$Z_o(1 + \beta A)$ (increased)	$\frac{Z_o}{1 + \beta A}$ (decreased)	$Z_o(1 + \beta A)$ (increased)

Effect of feedback on gain:

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

Gain stability and Sensitivity with negative feedback:

Sensitivity of transfer Amplification: The fractional change in amplification with feedback divided by the fractional change without feedback is called the *sensitivity* of the transfer gain.

Mathematically, the sensitivity of the transfer gain can be written as follows:

$$S = \left| \frac{dA_f / A_f}{dA / A} \right|$$

We know that,

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

So,

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

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

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

Magnitude of relative change in gain is reduced by the factor (1+Aβ) compared with out feedback

$$S = \left|\frac{dA_f / A}{dA / A}\right| = \frac{1}{|1+\beta A|}$$

Hence, the sensitivity is $S = \frac{1}{|1+\beta A|}$

For example, if S=0.1 then $\left|\frac{dA_f}{A}\right| = 0.1\left|\frac{dA}{A}\right|$

That means the percentage change in gain with feedback is one-tenth the percentage variation in amplification if no feedback is present.

This implies that if there occurs a variation by certain amount in the gain A of the main amplifier, the gai of the feedback system is not altered as much i.e., the gain variation is desensitized by negative feedback

Desensitivity of transfer Amplification: The reciprocal of the sensitivity is called the desensitivity D, or $D = 1 + \beta A$

$$A_f = A / D$$

If $|\beta A >> 1|$, Then $A_f = \frac{A}{1+\beta A} \approx \frac{A}{\beta A} = \frac{1}{\beta}$

Effect of negative feedback on gain and bandwidth: The gain with negative feedback is

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

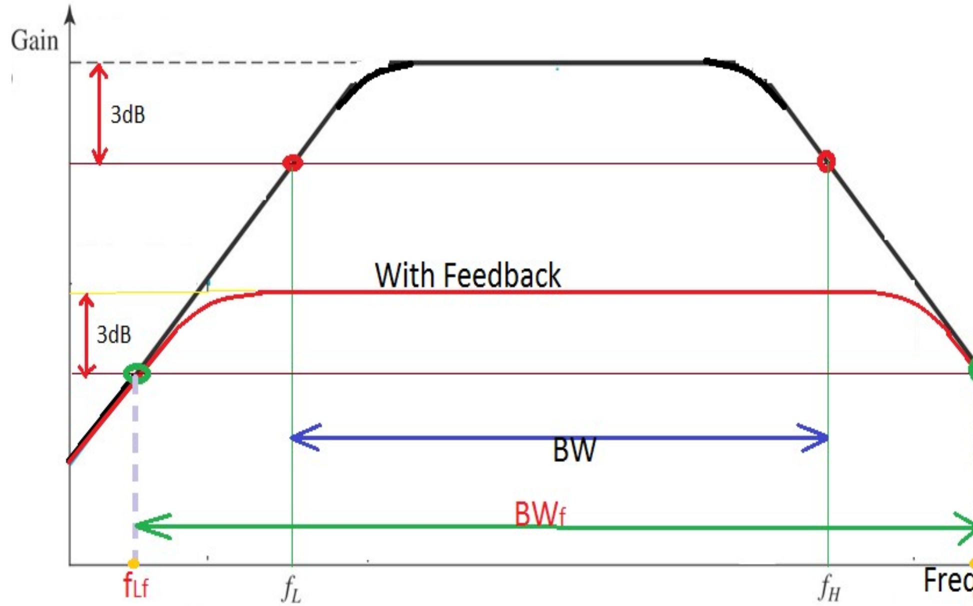
Feedback gain is reduced the factor 1+Aβ compare with open loop gain A .

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

$A\beta \gg 1$ overall gain is approximately $\frac{1}{\beta}$

We know, for practical amplifiers the open loop gain drops at low and high frequencies due to the active device and circuit capacitance.

The product of gain and bandwidth is same for with and without feedback. So gain reduces then Bandwidth Increase in negative feedback amplifiers. Due to negative feedback bandwidth is more compare without feedback.



$$f_{Lf} = \frac{f_L}{(1+A\beta)} \qquad f_{Hf} = f_H\ (1$$

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

3. Reduction in Noise:

All most all amplifier circuit produce noise due to active and passive components present in it.

During Amplification process this noise is also amplified along with the signal.

So , in order to reduce the noise in amplifiers we are using negative feedback.

So , the negative feedback improved SNR of an amplifier.

It can be proved mathematically that:

$$N_f = \frac{N}{1 + A\beta}$$

N_f is noise with negative feedback ,
N is noise without feedback

4.Reduction in Non-Linear Distortion:

Non-Linear Distortion occurs when an active device in the amplifier has non-linear transfer characteristic.

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

The feedback network is purely resistive (linear element), the gain with feedback is not dependent o frequency even though basic amplifier gain is frequency dependent. Varying amplifier gain wi frequency is reduced due to negative feedback.