04/11/20

FEEDBACK AMPLIFIERS

* Depending on the polarity of the signal being fed back into a circuit, one may have negative or positive feedback.
* Negative feedback results in decreased voltage gain, for which number of circuit features are improved.
* Positive feedback drives a circuit into oscillation as in various types of oscillator circuits.
* A typical feedback connection is shown in Fig (1):

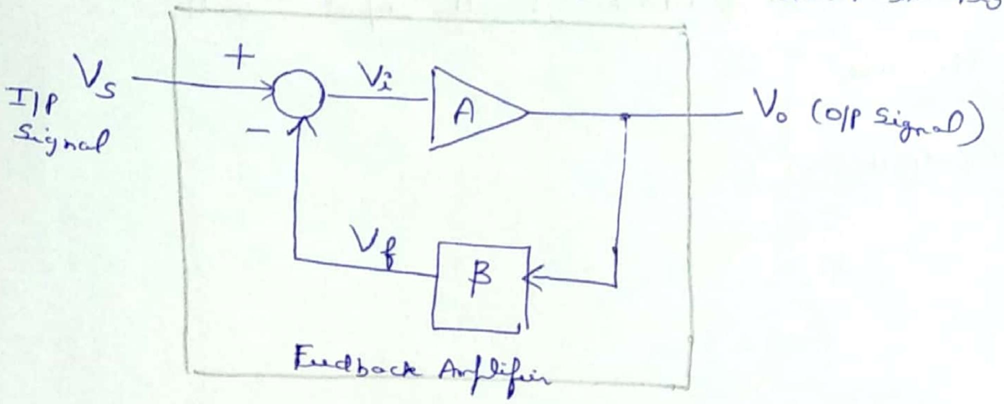


Fig (1): Simple block diagram of feedback amplifier

* The i/p signal 'V_s' is applied to a mixer network, where it is combined with a feedback signal 'V_f'.
* The difference of these signals 'V_i' is then the input voltage to the amplifier.
* A portion of the o/p amplifier output 'V_o' is connected to the feedback network (β), which provides a reduced portion of the output as feedback signal to the input mixer network.
* If the feedback signal is of opposite polarity to the input signal, negative feedback results (Fig (1)).
* Although negative feedback results in reduced overall voltage gain, a number of advantages are there. They are:

1. Higher input impedance
2. Better stabilized voltage gain
3. Improved frequency response
4. Lower O/P impedance
5. Reduced Noise
6. More linear operation

⇒ **Feedback Connection Types**

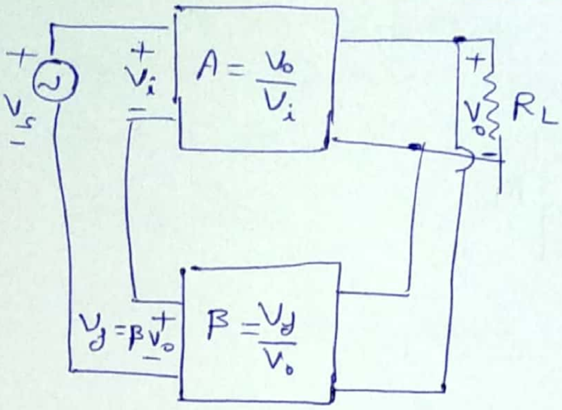
* There are 4 basic ways of connecting the feedback signal. Both voltage and current be fed back to the input either in series or parallel. They are:

1. Voltage - series F.B (feedback)
2. Voltage - shunt FB
3. Current - series FB
4. Current - shunt FB

* In the list above, 'voltage' refers to connecting the output voltage as input to the feedback network.
* 'Current' refers to tapping off some output current through the FB N/w.
* 'Series' refers to connecting the FB signal in series with the i/p signal voltage. 'Shunt' refers to connecting the FB signal in shunt (parallel) with an input current source.

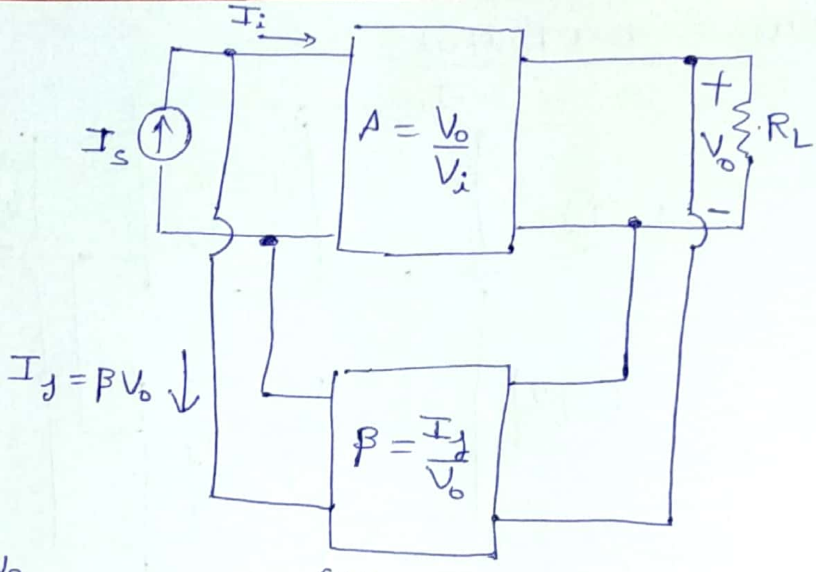
* 'Series' FB connections tend to increase the input resistance, whereas shunt FB connections tend to decrease the input resistance.
* Voltage FB tends to decrease the O/P impedance, whereas current FB tends to increase the O/P impedance.

* Typically, higher input and lower output impedances are desired for most cascade amplifiers. Both of these are provided using the voltage - series feedback connection.



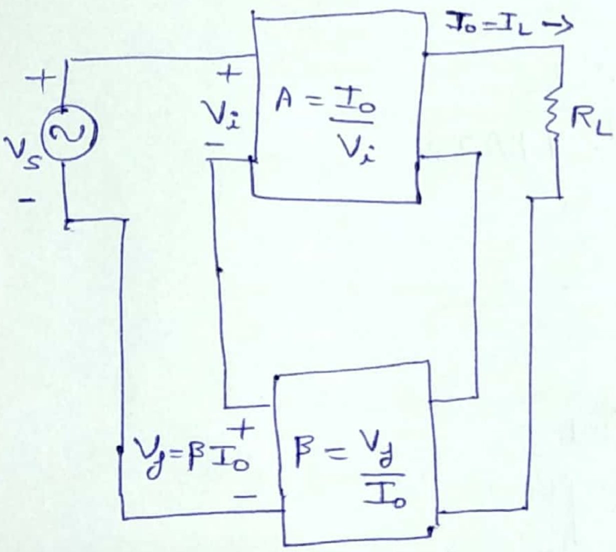
(a)

Voltage Series Feedback, $A_f = \frac{V_o}{V_s}$



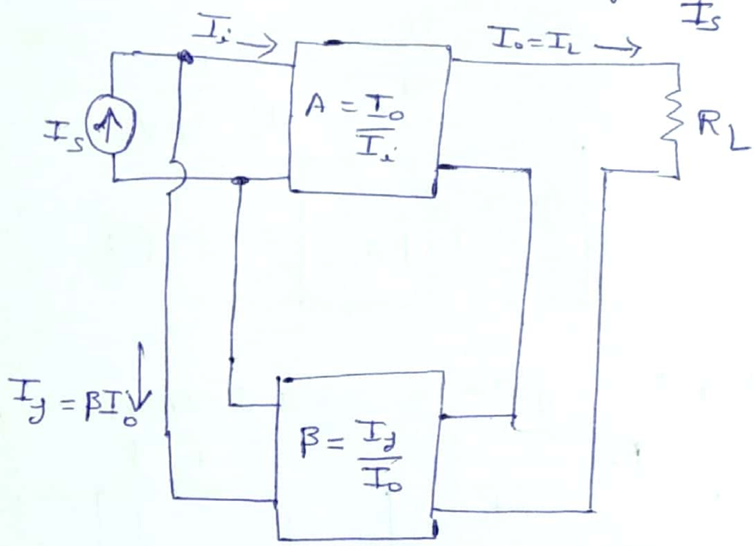
(b)

Voltage-shunt feedback, $A_f = \frac{V_o}{I_s}$



(c)

Current-Series feedback $A_f = \frac{I_o}{V_s}$



(d)

Current-shunt feedback, $A_f = \frac{I_o}{I_s}$.

⇒ Gain With Feedback

* The gain without feedback, A, is that of the amplifier stage.
* With feedback 'β', the overall gain of the circuit is reduced by a factor of $(1+\beta A)$.

Voltage Series Feedback (Fig ⓐ)

o/p vtg feedback in series with input signal.

If no feedback ($V_f = 0$), vtg gain of amplifier stage $A = \frac{V_o}{V_s} = \frac{V_o}{V_i}$ —— ①

If feedback 'V_f' is connected in series with i/p signal, then

$$V_i = V_s - V_f$$

Since $V_o = AV_i = A(V_s - V_f) = AV_s - AV_f$

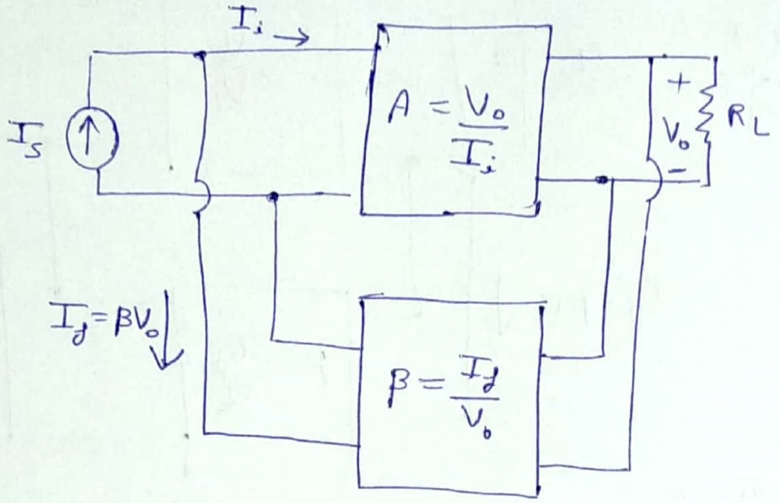
$$V_o = AV_s - A(\beta V_o)$$

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

So the overall voltage gain with FB,

$$\boxed{A_f = \frac{V_o}{V_s} = \frac{A}{1+\beta A}} \quad —— ②$$

Voltage - Shunt Feedback

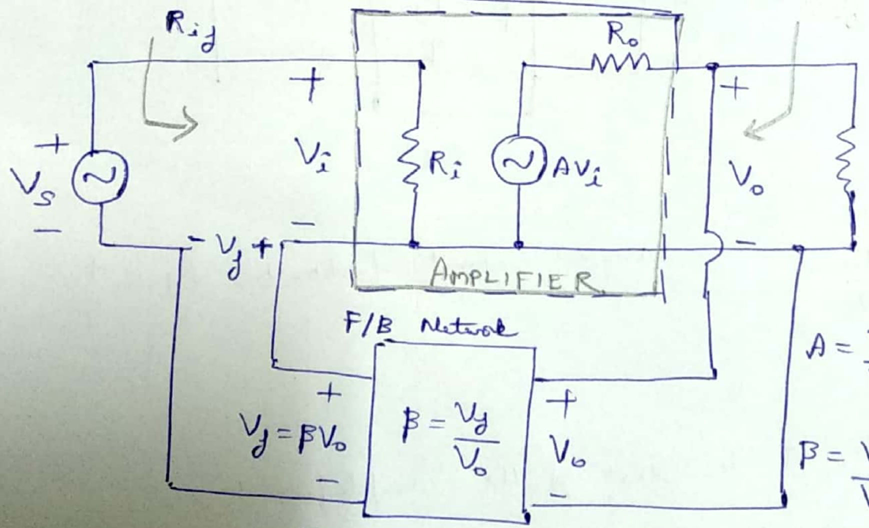


The gain with feedback for the ckt is,

$$A_f = \frac{V_o}{I_s} = \frac{A I_i}{I_i + \beta V_o} = \frac{A I_i}{I_i + \beta A I_i}$$

$$\boxed{A_f = \frac{A}{1+\beta A}} \quad \text{——— (3)}$$

⇒ Input Impedance with Feedback



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

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

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

Fig: Voltage series feedback connection

The input impedance can be determined as follows:

$$I_i = \frac{V_i}{Z_i} = \frac{V_s - V_f}{Z_i} = \frac{V_s - \beta V_o}{Z_i} = \frac{V_s - \beta A V_i}{Z_i}$$

$$I_i Z_i = V_s - \beta A V_i$$

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

$$\boxed{Z_{if} = \frac{V_s}{I_i} = Z_i + (\beta A) Z_i = Z_i (1+\beta A)} \quad \text{——— (4)}$$

The input impedance with series feedback is seen to be the value of the input impedance without feedback multiplied by the factor $(1+\beta A)$, and is applied to both voltage-series (Fig ⓐ) and current-series (Fig ⓒ) configurations.

Voltage Shunt Feedback

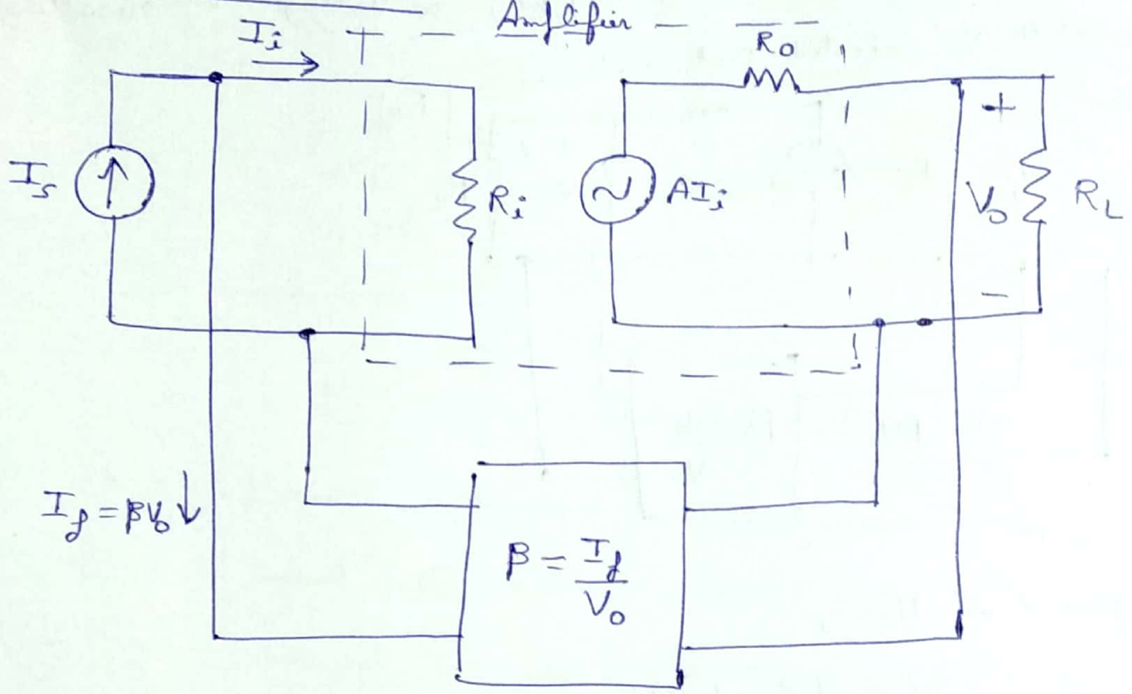


Fig: Voltage shunt feedback connection

The input impedance can be determined to be,

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

$\div$ by I_i

$$= \frac{V_i/I_i}{I_i/I_i + \beta V_o/I_i}$$

$$\boxed{Z_{if} = \frac{Z_i}{1+\beta A}} \quad \text{——— (5)}$$

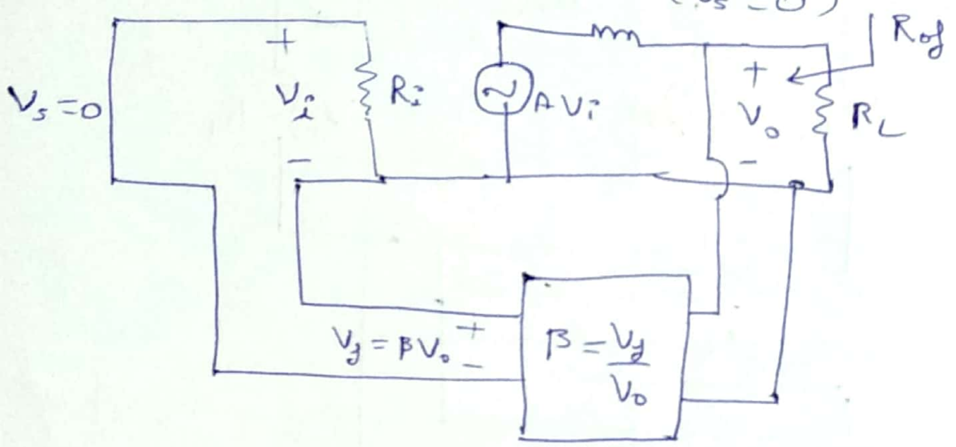
This reduced input impedance applies to the voltage-series connection (fig ⓐ) and the voltage-shunt connection of Fig ⓒ.

Output Impedance with Feedback

For Voltage feedback, the output impedance is decreases, whereas Current feedback increases the output impedance.

Voltage-series Feedback: (Fig 14.3)

The O/P impedance is determined by applying a Voltage 'V', resulting in a Current I, with V_s shorted out ($V_s = 0$)



The Voltage V is then,

$$V = IZ_o + AV_i$$

For $V_s = 0$, $\quad V_i = -V_f$

So that

$$V = IZ_o - AV_f = IZ_o - A(\beta V)$$

$$\Rightarrow V + \beta AV = IZ_o$$

allows solving for the output resistance with feedback:

$$\boxed{Z_{of} = \frac{V}{I} = \frac{Z_o}{1+\beta A}} \quad \text{—— (6)}$$

Eq^n (6) shows that with Voltage-series feedback, the output impedance is reduced from that without feedback by the factor $(1+\beta A)$.

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Current – Series Feedback

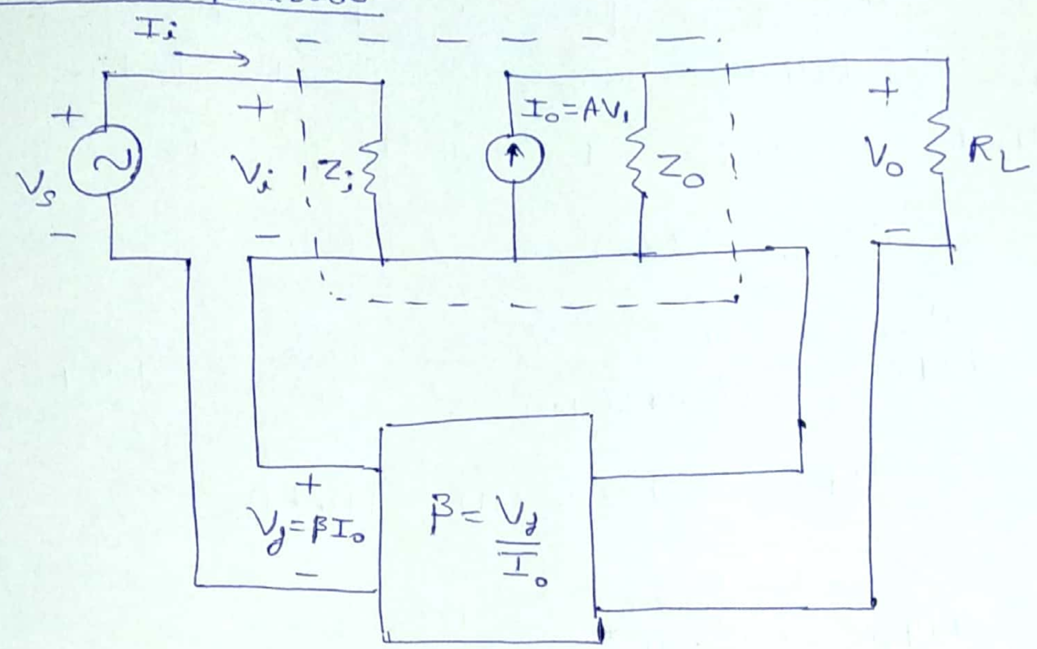

Fig: Current – Series Feedback Connection

The output impedance with current – series feedback can be determined by applying a signal 'V' to the output with 'V_s' shorted out, resulting in a current 'I', the ratio of V to I being the output impedance.

With $V_s = 0$,

$$V_i = V_f$$

$$I = \frac{V}{Z_o} - AV_i = \frac{V}{Z_o} - AV_f = \frac{V}{Z_o} - A\beta I$$

$$Z_o(1+\beta A) I = V$$

$$\boxed{Z_{of} = \frac{V}{I} = Z_o(1+\beta A)} \quad \text{— (7)}$$

Table 1: Effect of Feedback Connection on Input & Output Impedance

	Voltage Series	Current-Series	Voltage Shunt	Current-Shunt
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)
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)

Ex : 1 : Determine Voltage gain, input and output impedance with feedback for Voltage-series feedback having $A = -100$, $R_i = 10 k\Omega$ and $R_o = 20 k\Omega$ for feedback of (a) $\beta = -0.1$ and (b) $\beta = -0.5$.

Sol^n Using eq^n ②, ④ and ⑥, we calculate

a. $A_f = \dfrac{A}{1+\beta A} = \dfrac{-100}{1+(-0.1)(-100)} = \dfrac{-100}{11} = -9.09$

$Z_{if} = Z_i(1+\beta A) = 10 k\Omega\,(11) = 110 k\Omega$

$Z_{of} = \dfrac{Z_o}{1+\beta A} = \dfrac{20\times10^3}{11} = 1.82 k\Omega$

b. $A_f = \dfrac{A}{1+\beta A} = \dfrac{-100}{1+(-0.5)(-100)} = \dfrac{-100}{51} = -1.96$

$Z_{if} = Z_i(1+\beta A) = 10 k\Omega\,(51) = 510 k\Omega$

$Z_{of} = \dfrac{Z_o}{1+\beta A} = \dfrac{20\times10^3}{51} = 392.16\ \Omega$

This example (Part-a) demonstrates the trade-off of gain for improved input and output resistance. Reducing the gain by a factor of 11 (from 100 to 9.09) is complemented by a reduced output resistance and increased input resistance by the same factor of 11.