FEED BACK SYSTEM

Amplifier amplifies the input signal. The output signal of the amplifier is the amplified input signal. A represents the amplification factor of the amplifier. In feedback system the output signal is sampled and part of it is feedback to the input. Fig.1 shows the basic model of feedback amplifier.

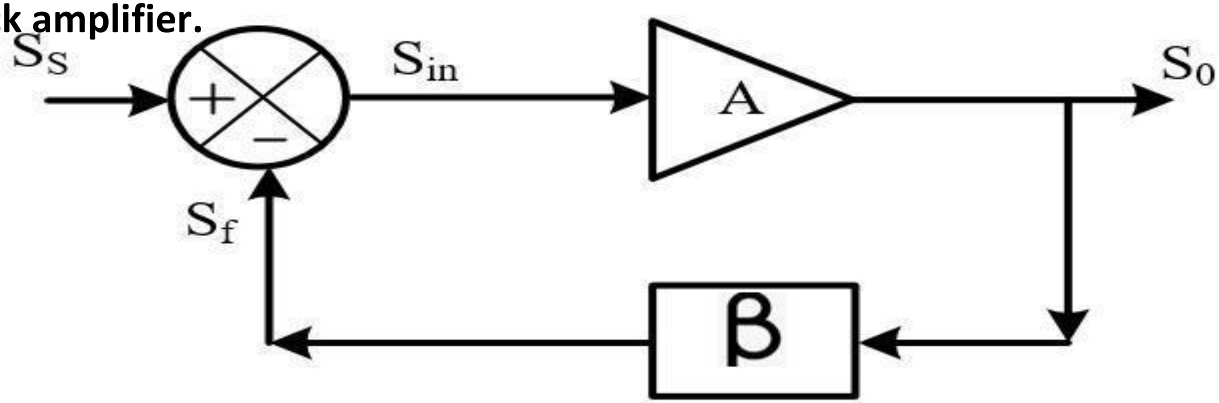


Fig. 1Basic model of feedback amplifier

The basic model of feedback amplifier consist of

- **Forward amplifier: The input signal to the forward amplifier is S_{in} and the output signal from the amplifier is S_o. The gain of the amplifier is A.**
- **Feedback network: The input signal to the feedback network is S_o and the output signal from the feedback network is the feedback signal S_f . The gain of the feedback network is β.**
- **Signal sampler: Signal sampler is taping the output signal for feedback.**
- **Signal mixer: Signal mixer is mixing the feedback signal S_f with the primary input signal S_s to generate the input signal to the amplifier S_{in} . The mixer is multiplying the input signals with +1 or -1 and then mix it.**

Types of Feedback system

1) Negative feedback system 2) Positive feedback system

Negative Feedback System

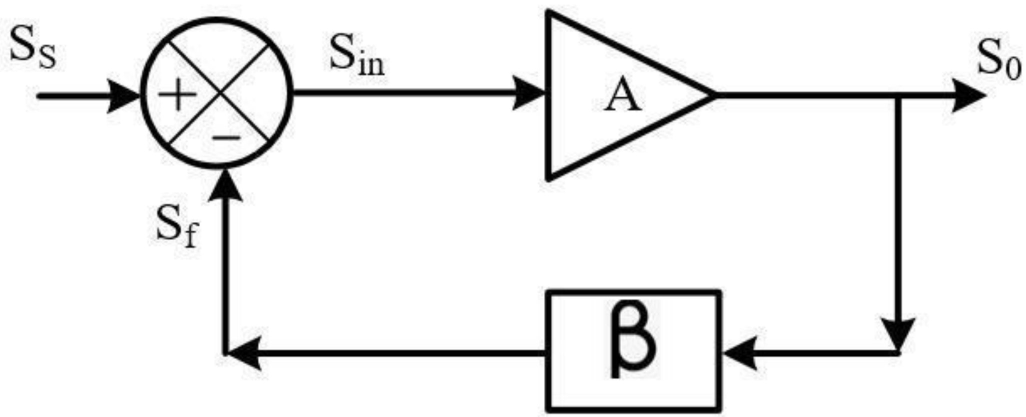


Fig. 2 Basic model of Negative feedback system

Fig. 2 shows the basic model of negative feedback system.

- **For a change at a point in the system/ circuit if the created effect coming back to the point through the feedback path negate the original change then the feedback system is called negative feedback system.**
- **Assume Sin is increased. If A is positive So also increases. If β is positive Sf also increases. When the signal is going through the mixer, if it is negative the signal coming back to the input of the amplifier is in the opposite direction [negating the original change]. Hence it is called as the negative feedback system.**
- **Based on the sign of mixer, A and βwe will get negative feedback.**

Positive Feedback System

Fig. 3 shows the basic model of positive feedback system.

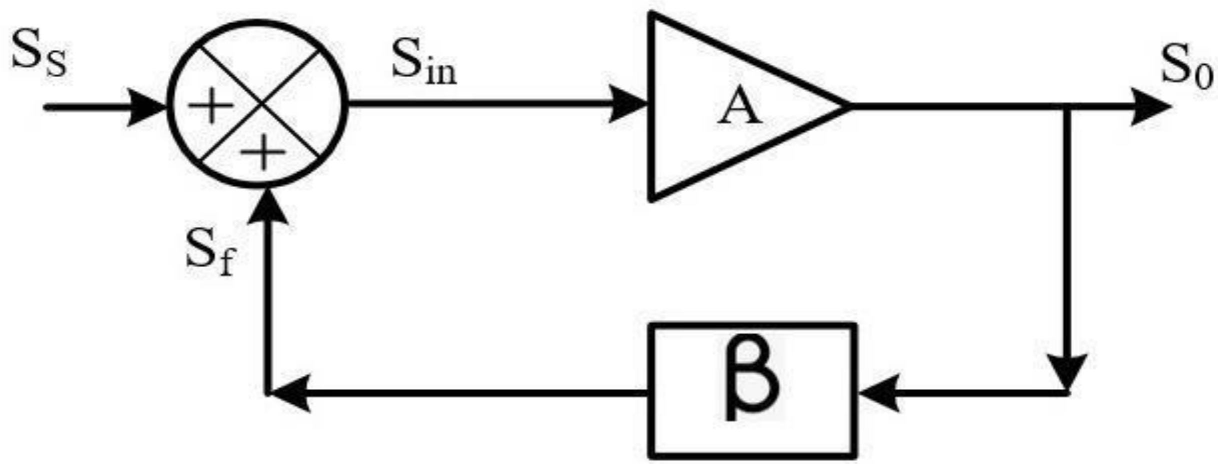


Fig. 3 Basic model of positive feedback system

- **For a change at a point in the system/circuit if the created effect coming back to the point through the feedback path aggravate the original change then the feedback system is called as positive feedback system.**
- **Assume S_{in} is increased. If A is positive S_o also increases. If β is positive S_f also increases. When the signal is going through the mixer, if it is positive the signal coming back to the input of the amplifier is in the same direction or phase [aggravate the original change]. This is known as positive feedback system.**
- **Based on the sign of mixer, A and βwe will get positive feedback system.**

Parameters of negative Feedback system

Fig. 4 shows the basic model of negative feedback system.

Gain with feedback $A_f = \dfrac{S_o}{S_s}$

$$S_o = AS_{in} = A(S_s - S_f) = A(S_s - \beta S_o) = AS_s - A\beta S_o$$

$$S_o(1 + A\beta) = AS_s$$

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

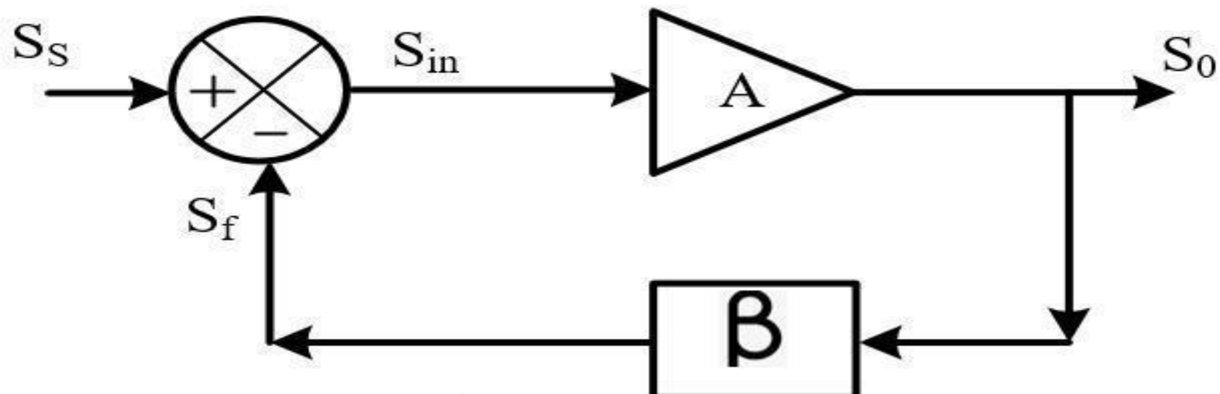


Fig.4 Basic model of negative feedback system

Loop gain = - $A\beta$

Without feedback gain is A

With feedback gain is reduced by $(1 + \beta A)$

$(1 + \beta A)$ **is known as the Desensitivity factor.**

Basic configurations of feedback system

The input and output signal of feedback amplifier can be voltage or current leading to four basic configuration.

1) Voltage series feedback

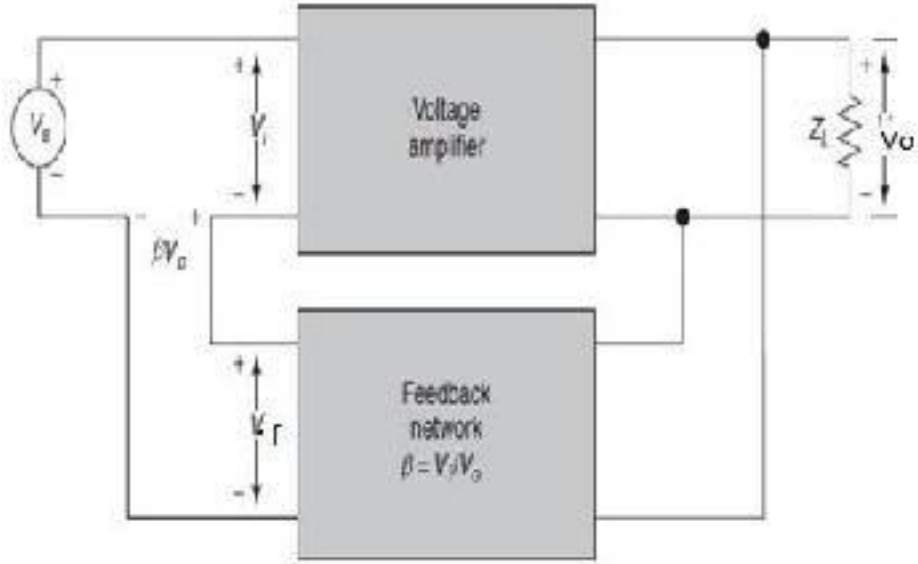
2) Voltage shunt feedback

3) Current series feedback

4) Current shunt feedback

1) Voltage-series feedback:

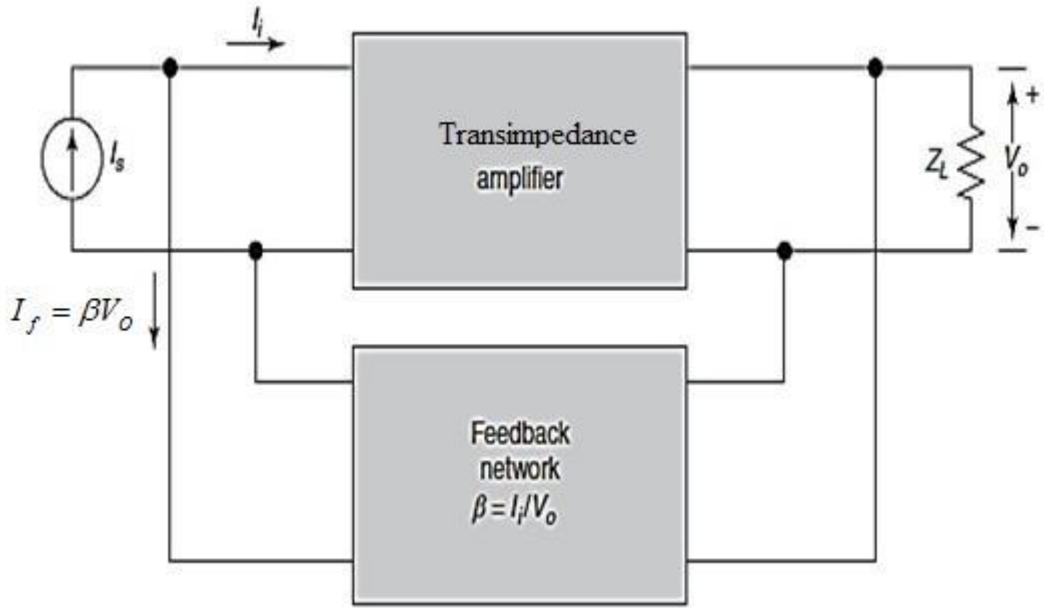
- The input signal is voltage and the output signal is voltage. Voltage is sampled at the output and f*eedback in the form of voltage at the input. Forward amplifier converts voltage to voltage. So the gain of the amplifier is voltage gain Av. The feedback path converts voltage to voltage and its gain is β.*
- *The voltage gain with feedback is* $A_{vf} = \frac{A_v}{1+\beta A_v}$
- *The voltage gain with feedback reduces the gain Av by the factor (1+β Av). When β Av>>1,* $A_{vf} \approx \frac{1}{\beta}$
- *The voltage gain is stabilized to* $A_{vf} \approx \frac{1}{\beta}$



Voltage amplifiers with voltage-series feedback

2) Voltage-Shunt Feedback

- The input signal is current and the output signal is voltage. Voltage is sampled at the output and f*eedback in the form of current at the input. Forward amplifier converts current to voltage. So the gain of the amplifier is trans impedance* **Z_m** *. The feedback path converts voltage to current and its gain is β.*
- *The trans impedance with feedback is* $Z_{mf} = \dfrac{Z_m}{1+\beta Z_m}$
- *The gain with feedback reduces the gain* Z_m *by the factor* $(1+\beta Z_m)$ *. When* $\beta Z_m >> 1$, $Z_{mf} \approx \dfrac{1}{\beta}$
- *The trans impedance with feedback is stabilized to* $Z_{mf} \approx \dfrac{1}{\beta}$



3)Current-shunt feedback

- The input signal is current and the output signal iscurrent. Current is sampled at the output and f*eedback in the form of current at the input. Forward amplifier converts current to current. So the gain of the amplifier is current gain* **A_i**. *The feedback path converts current to current and its gain is β.*
- The current gain with feedback
- *The current gain with feedback reduces the gain Av by the factor (1+β Av). When* βA *>>1,*
- *The current gain with feedback is stabilized to* $$A_{if} = \frac{A_i}{1+\beta A_i}$$

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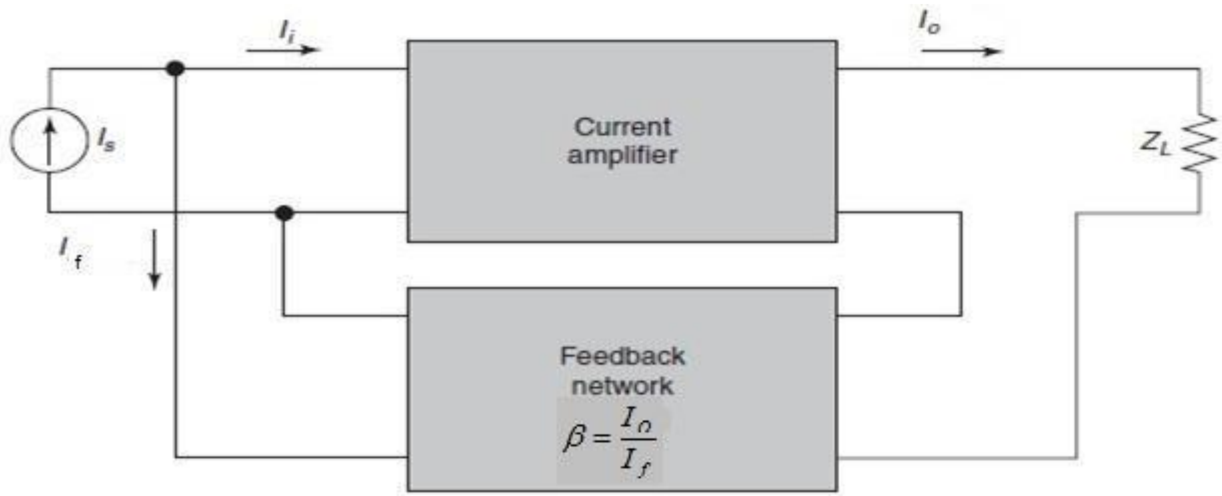
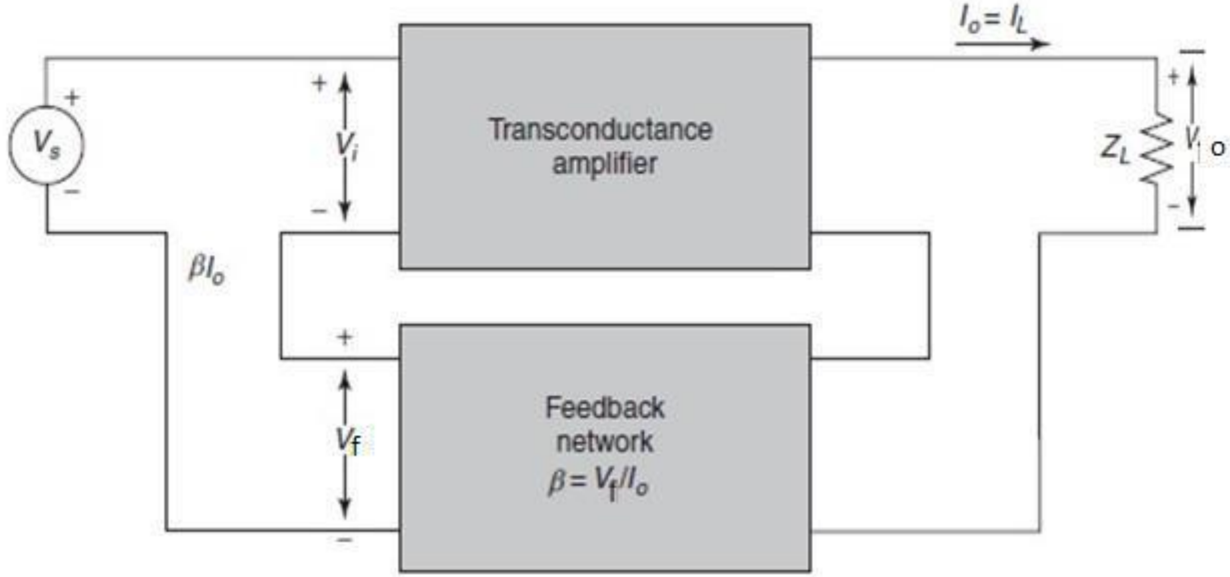
$$A_{if} \approx \frac{1}{\beta}$$



Current amplifiers with current-shunt feedback

4) Current-Series Feedback:

- The input signal is voltage and the output signal is current. Current is sampled at the output and f*eedback in the form of voltage at the input. Forward amplifier converts voltage to current. So the gain of the amplifier is trans conductance. The feedback path converts current to voltage and its gain is β.*
- *The trans conductance with feedback* $G_{mf} = \frac{G_m}{1+\beta G_m}$
- *The gain with feedback reduces the gain by the factor* $(1+\beta G_m)$. *When* $\beta G_m >> 1$, $G_{mf} \approx \frac{1}{\beta}$
- *The trans conductance with feedback is stabilized to* $G_{mf} \approx \frac{1}{\beta}$



Transconductance amplifier with current-series feedback

Summary

TABLE 1 Summary of Gain, Feedback, and Gain with Feedback

		Voltage-Series	Voltage-Shunt	Current-Series	Current-Shunt
Gain without feedback	A	$\frac{V_o}{V_i}$	$\frac{V_o}{I_i}$	$\frac{I_o}{V_i}$	$\frac{I_o}{I_i}$
Feedback	β	$\frac{V_f}{V_o}$	$\frac{I_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$
Gain with feedback	A_f	$\frac{V_o}{V_s}$	$\frac{V_o}{I_s}$	$\frac{I_o}{V_s}$	$\frac{I_o}{I_s}$

Summary of effects of negative feedback

TABLE .2 Effect of Feedback Connection on Input and Output Impedance

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

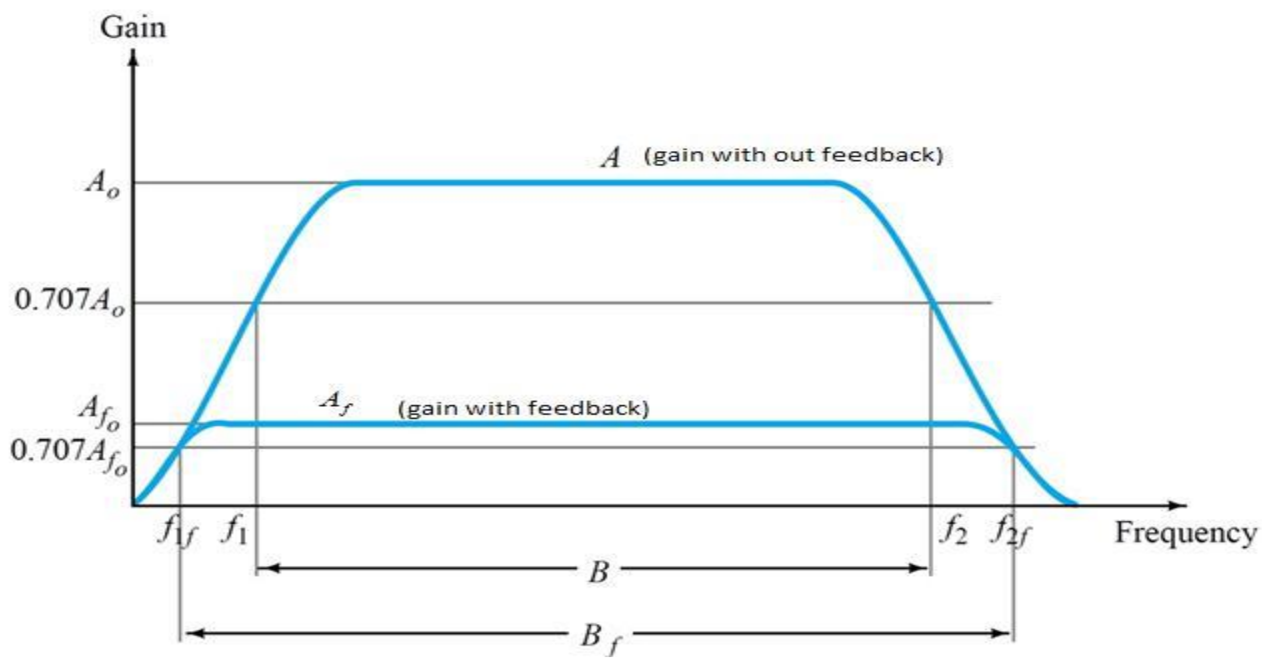
Effect of negative feedback on frequency response

- The gain of the forward amplifier is A.
- The gain of the feedback amplifier is $A_f = \dfrac{A}{1 + \beta A}$

- The reduction in gain of the amplifier is $(1+A\beta)$
- The bandwidth increases by the same factor $(1+A\beta)$
- Hence the gain bandwidth product remain the same.
- Unity gain frequency is remaining the same.

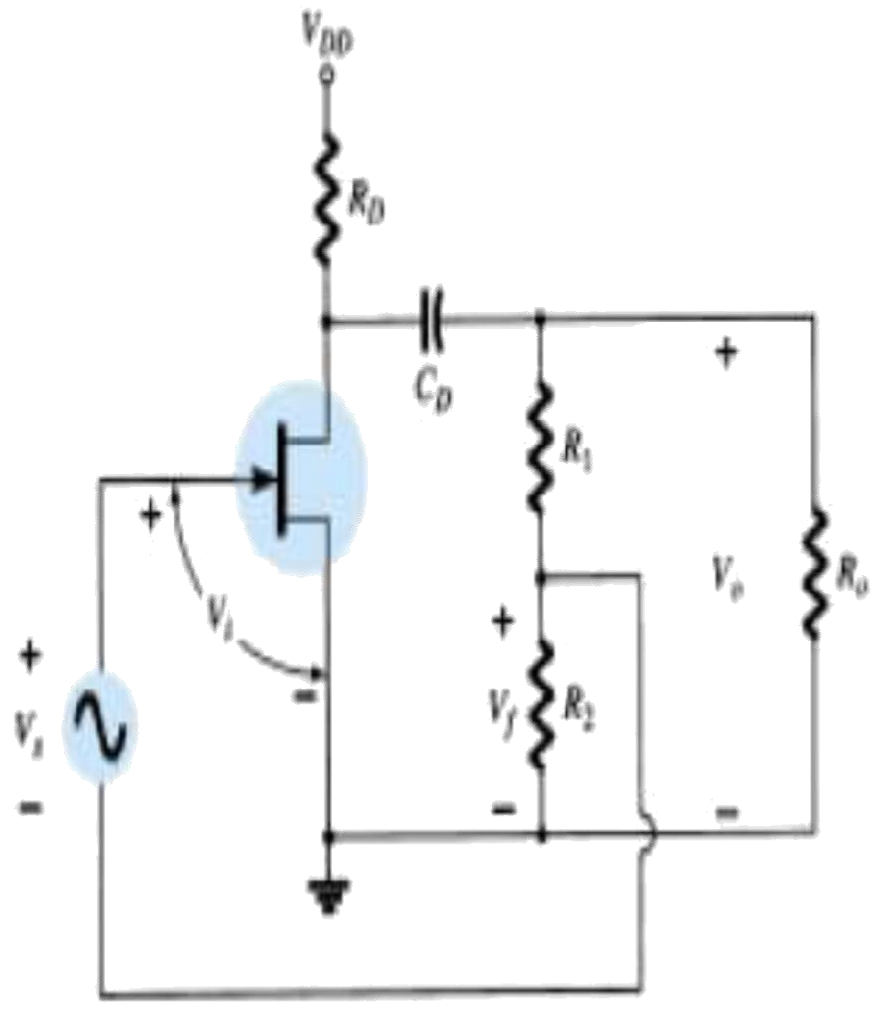
Frequency response of negative feedback amplifier

Frequency response is the variation of the gain of amplifier with respect to frequency. To get the band width with out feedback line is drawn at 0.707 A_o. The line intersect the curve at two points. The frequency corresponding to the two points are f_1 and f_2. (f_2-f_1) gives the band width. Similarly the bandwidth with feedback is $(f_{2f} - f_{1f})$. The gain bandwidth product is the same.



Practical Feedback Circuits (1/2)

- Voltage series feedback:



- Here, R_1 and R_2 resistors are used as a feedback network.
- A part of output signal is obtained from R_2 to ground.
- v_f is connected in series with the source signal v_s.
- Without feedback the amplifier gain is:

$$A = v_o/v_i = -g_m R_L$$

- where R_L is the parallel combination of R_D, R_o and (R_1+R_2)

Practical Feedback Circuits (2/2)

- **The feedback factor:**

$$\beta = \frac{v_f}{v_o} = \frac{-R_2}{R_1 + R_2}$$

- **We know the gain with negative feedback is:**

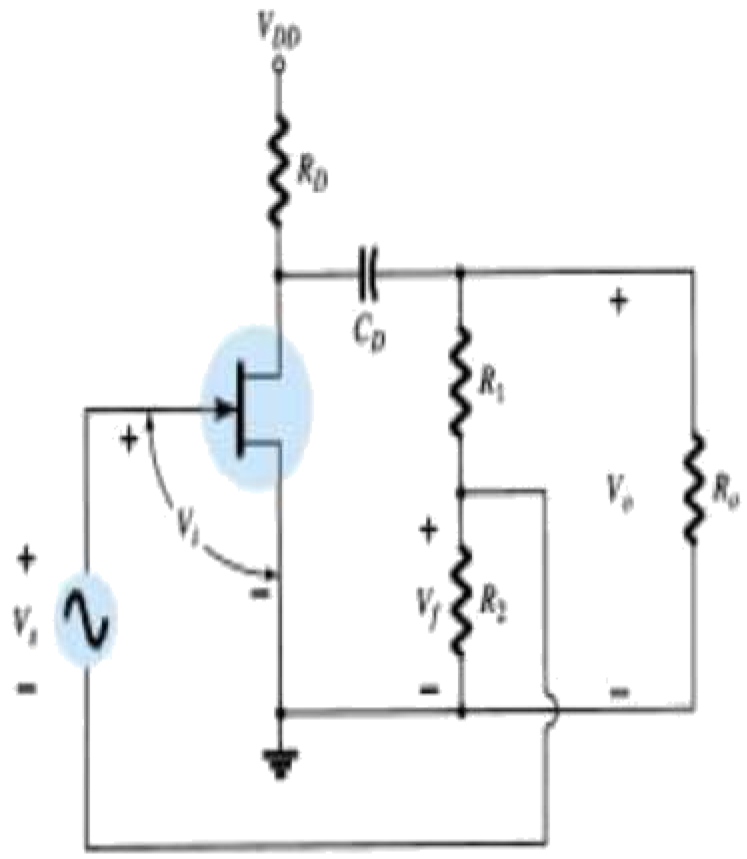
$$A_f = \frac{A}{1+\beta A} = \frac{-g_m R_L}{1+\dfrac{R_2}{R_1+R_2} R_L g_m}$$

- **If βA>>1 we have:**

$$A_f \cong \frac{1}{\beta} = -\frac{R_1 + R_2}{R_2}$$

Example

Eg. 01) **Calculate the gain without and with feedback for the FET amplifier circuit of figure bellow and the following values: $R_1 = 80\ k\Omega$, $R_2 = 20\ k\Omega$, $R_o = 10\ k\Omega$, $R_D = 10\ k\Omega$, and $g_m = 4000\ \mu S$,**



Example

Sol^n:

$$R_L \cong \frac{R_o R_D}{R_o + R_D} = \frac{10\ \text{k}\Omega\ (10\ \text{k}\Omega)}{10\ \text{k}\Omega + 10\ \text{k}\Omega} = 5\ \text{k}\Omega$$

Neglecting 100 kΩ resistance of R_1 and R_2 in series

$$A = -g_m R_L = -(4000 \times 10^{-6}\ \mu\text{S})(5\ \text{k}\Omega) = \mathbf{-20}$$

The feedback factor is

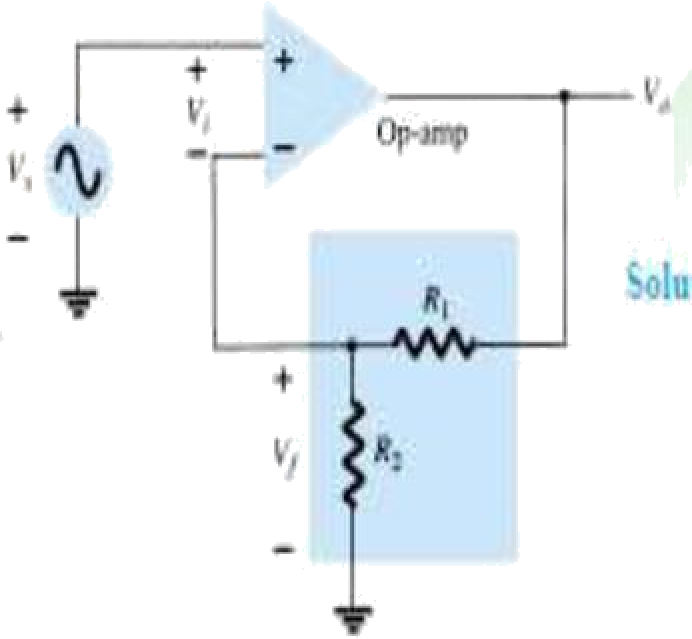
$$\beta = \frac{-R_2}{R_1 + R_2} = \frac{-20\ \text{k}\Omega}{80\ \text{k}\Omega + 20\ \text{k}\Omega} = -0.2$$

The gain with feedback is

$$A_f = \frac{A}{1 + \beta A} = \frac{-20}{1 + (-0.2)(-20)} = \frac{-20}{5} = \mathbf{-4}$$

Example

Eg. 02) Calculate the amplifier gain of the circuit of Fig. bellow for op-amp gain $A = 100{,}000$ and resistances $R1 = 1.8\,k\Omega$ and $R2 = 200\,\Omega$



Solution

$$\beta = \frac{R_2}{R_1 + R_2} = \frac{200\ \Omega}{200\ \Omega + 1.8\ \text{k}\Omega} = 0.1$$

$$A_f = \frac{A}{1 + \beta A} = \frac{100{,}000}{1 + (0.1)(100{,}000)}$$

$$= \frac{100{,}000}{10{,}001} = 9.999$$

Note that since $\beta A \gg 1$,

$$A_f \cong \frac{1}{\beta} = \frac{1}{0.1} = 10$$