Transfer Ratio or Gain

Note that the transfer ratio $\frac{V}{V_i}$ is the voltage amplification or the voltage gain A_V. Similarly, the transfer ratio I/I_i is the current amplification or current gain A_I for the amplifier. The ratio I/V_i of the basic amplifier is the transconductance G_M and V/I_i is the transresistance R_M.

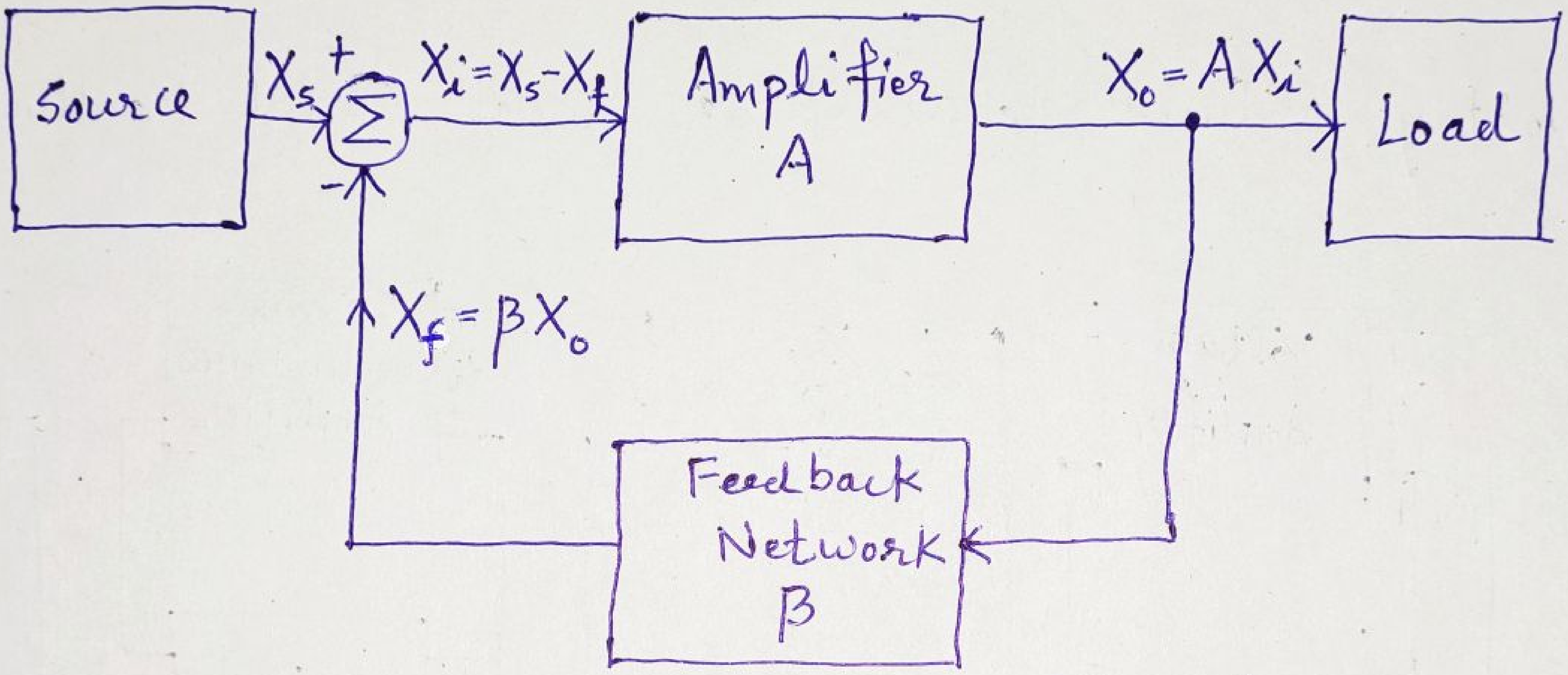


Figure: General single-loop feedback Amplifier

In the above diagram, quantity "X" represents either voltage or current signal. The feedback is negative because X_s and X_f are out of phase.

Note that A_f is defined as the ratio of the output signal to the input signal of the amplifier and is called the transfer gain of the feedback amplifier. There, we can represent four ratios as

$$A_{vf} = \frac{V_o}{V_s}, \quad A_{If} = \frac{I_o}{I_s}, \quad G_{Mf} = \frac{I_o}{V_s}$$

$$\text{and} \quad R_{Mf} = \frac{V_o}{I_s}$$

Transfer Gain with Feedback

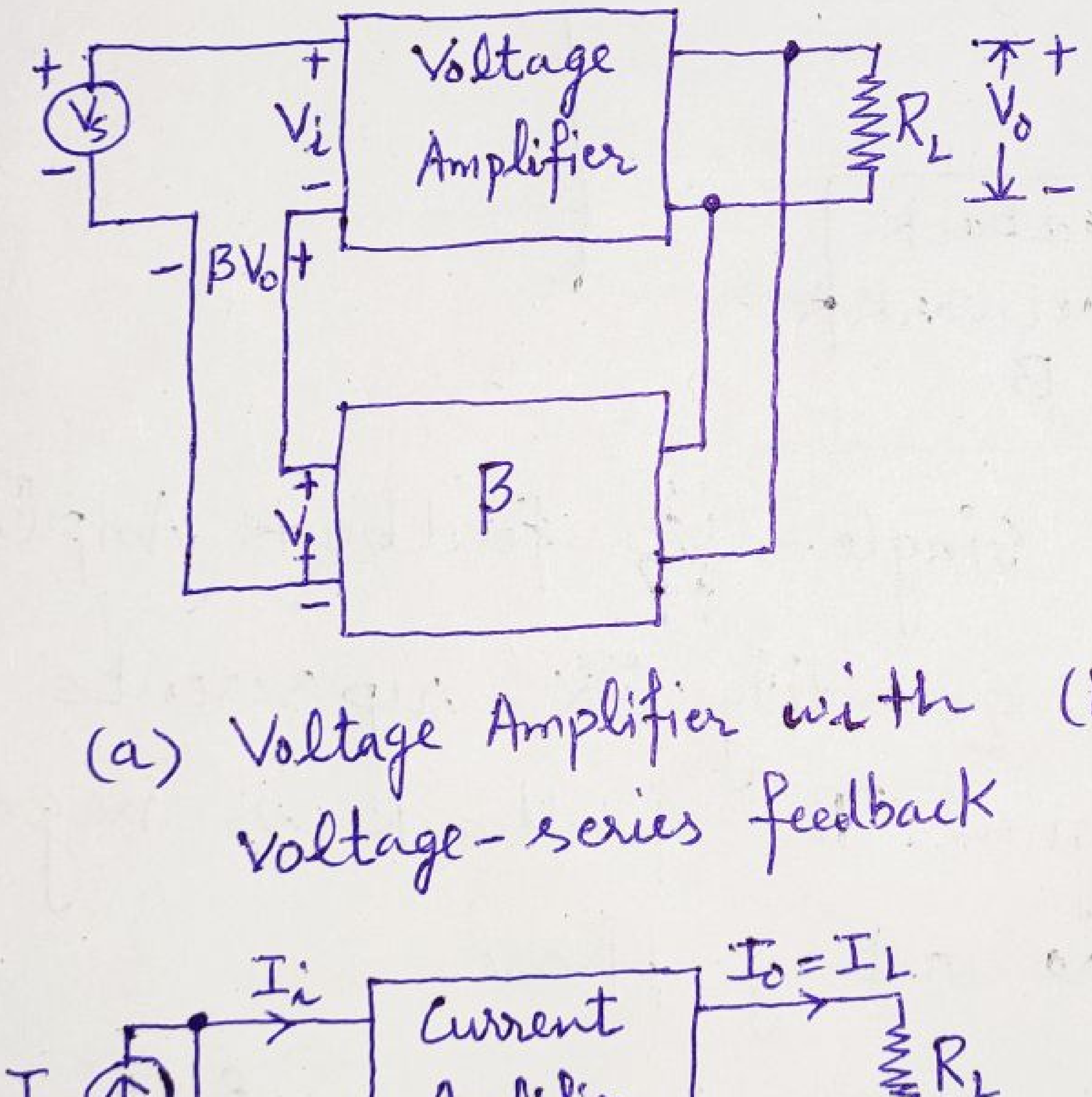
Based on the type of sampling at the output side and the type of mixing to the input side, feedback amplifiers are classified into four topologies as:

(1) Voltage - series feedback or Series Shunt feedback

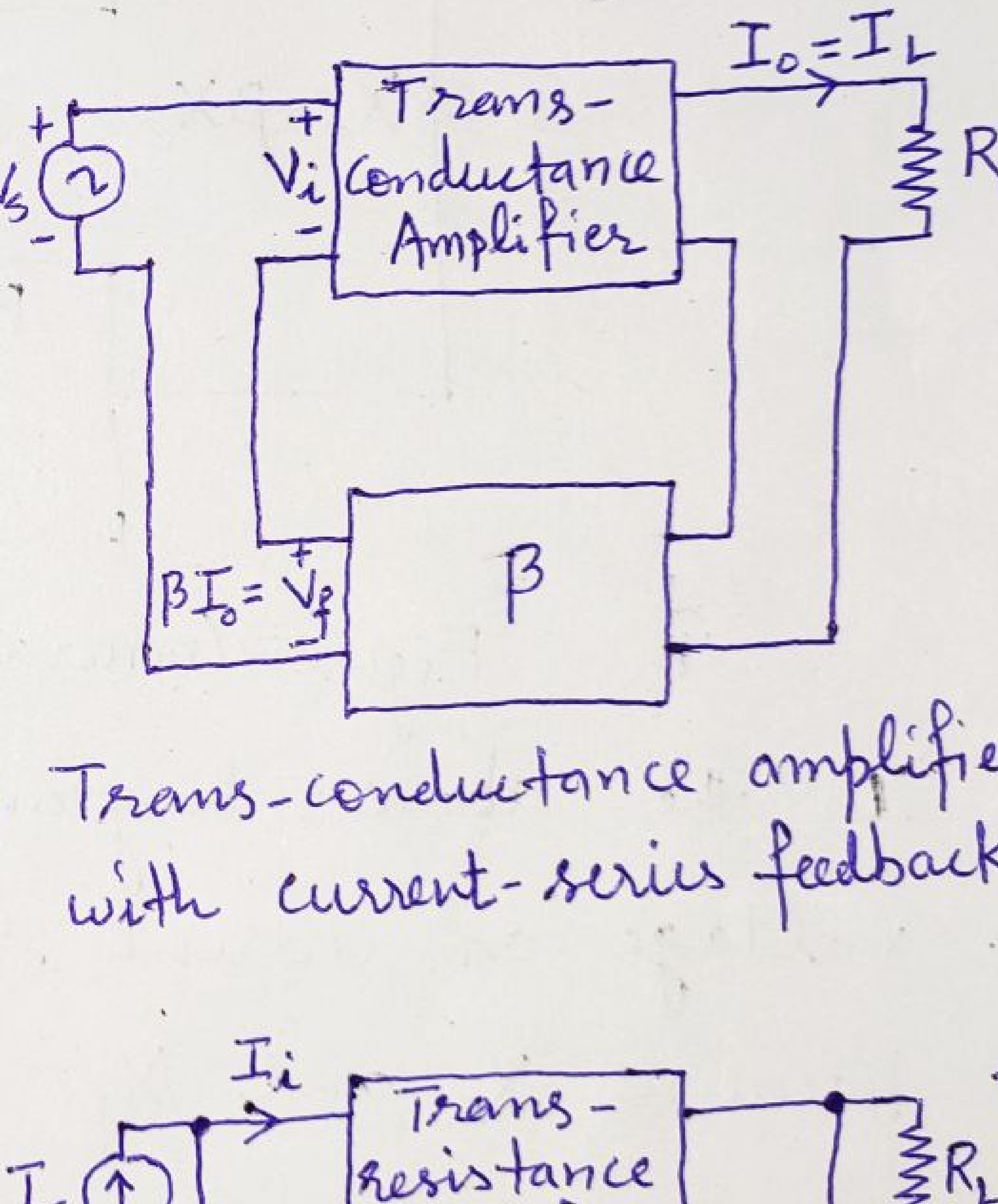
(2) Current - Series feedback or Series Series feedback

(3) Current - Shunt feedback or Shunt Series Feedback

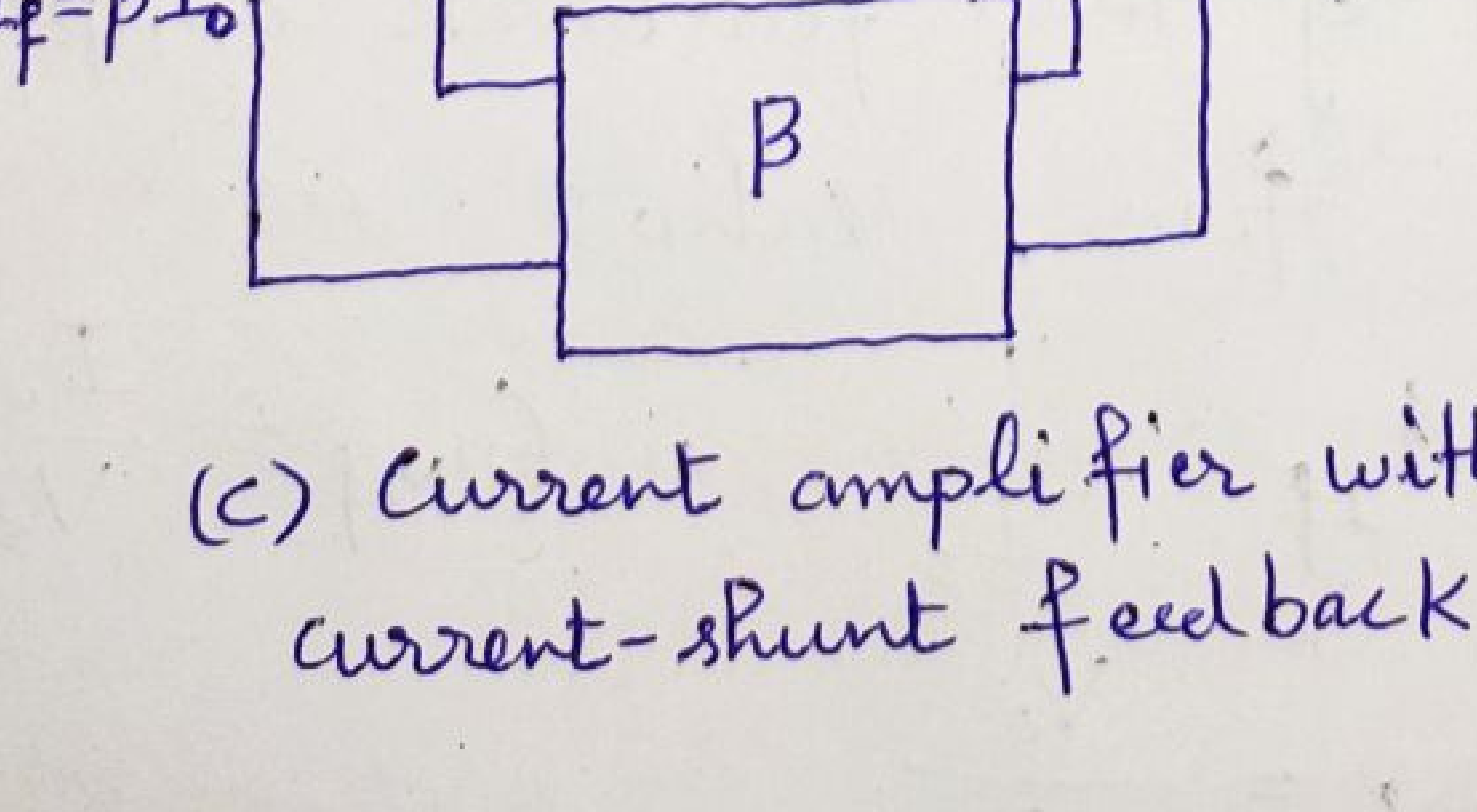
(4) Voltage - Shunt Feedback or Shunt Shunt Feedback



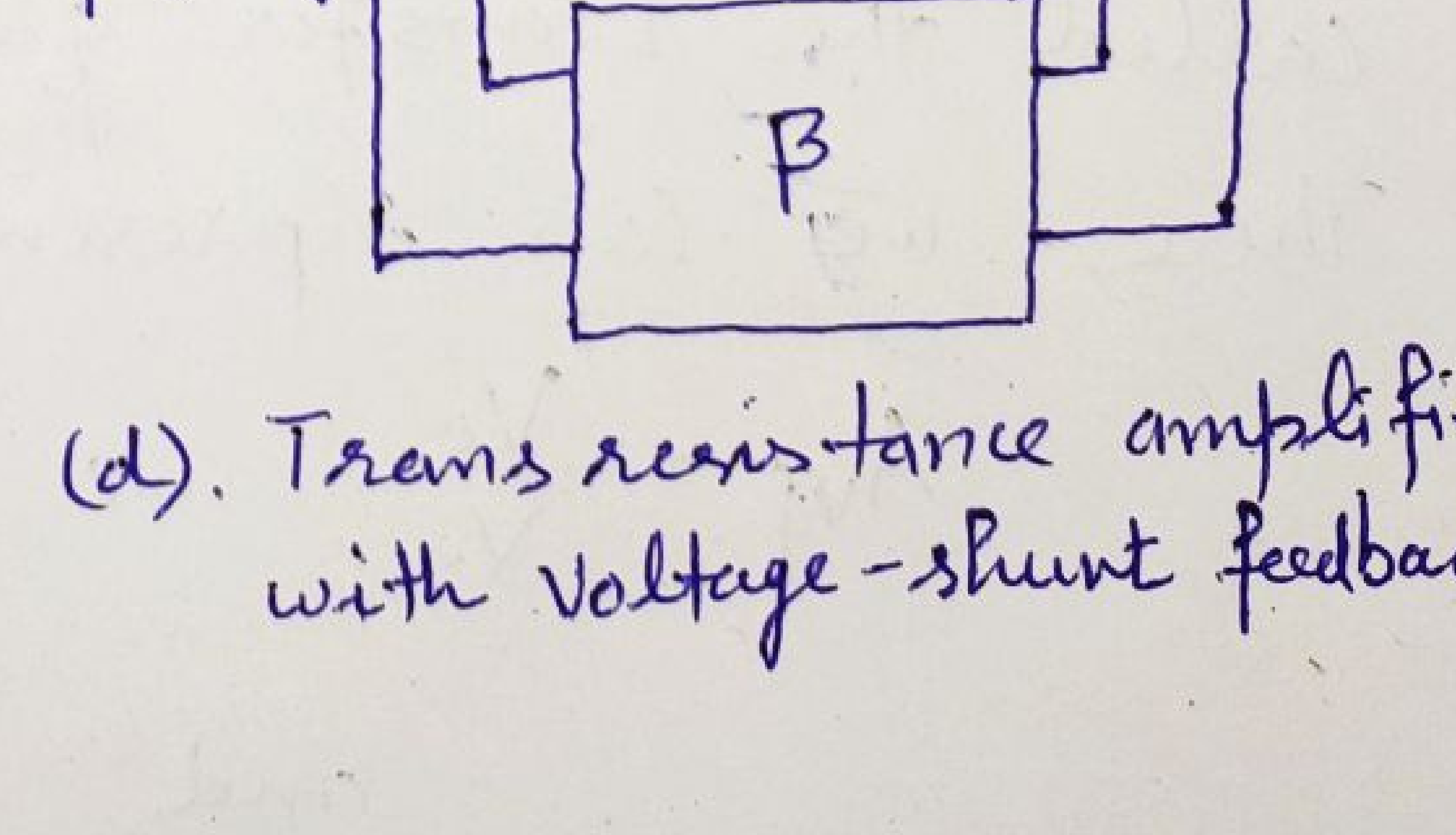
(a) Voltage Amplifier with voltage-series feedback



(b) Trans-conductance amplifier with current-series feedback



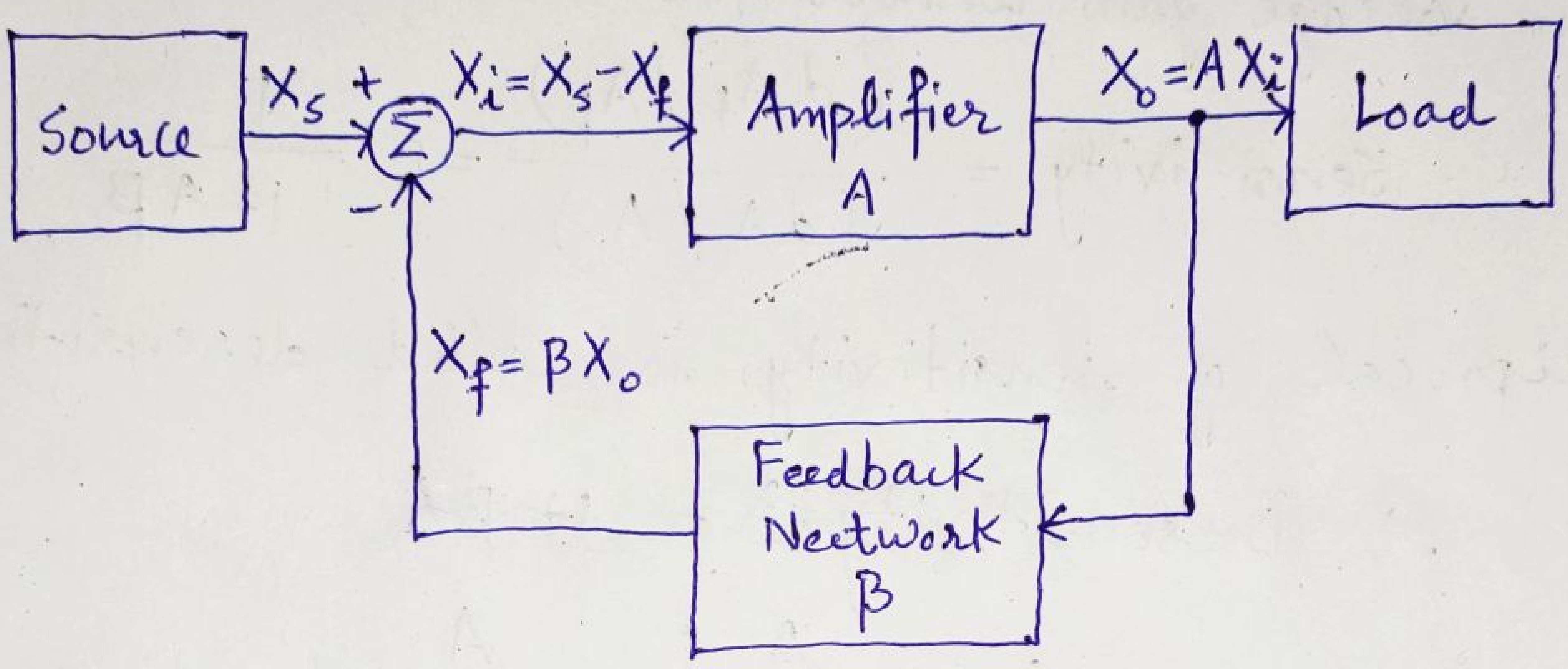
(c) Current amplifier with current-shunt feedback



(d). Trans resistance amplifier with voltage-shunt feedback.

Voltage and Current Signals in a Feedback Amplifier

Consider the following diagram for single-loop feedback amplifier.



Signal or Ratio	Voltage Series Feedback	Current Series Feedback	Current Shunt Feedback	Voltage-Shunt Feedback
X_o	Voltage	Current	Current	Voltage
X_s, X_f, X_i	Voltage	Voltage	Current	Current
A	A_V	G_M	A_I	R_M
β	$\frac{V_f}{V_o}$	$\frac{V_f}{I_o}$	$\frac{I_f}{I_o}$	$\frac{I_f}{V_o}$

General Characteristics of Negative Feedback Amplifiers

Although there is a reduction in overall voltage gain, there are some improvements in using negative feedback in amplifier circuits as listed below:

1. Better stabilized voltage gain
2. Enhanced frequency response
3. Higher input impedance
4. Lower output impedance
5. Reduction in noise
6. Increase in linearity.

1. Desensitization or Stabilization of Gain

The sensitivity is defined as the ratio of percentage change in voltage gain with feedback to the percentage change in voltage gain without feedback.

$$\text{Sensitivity} = \frac{(dA_f / A_f)}{(dA / A)} = \frac{1}{1+A\beta}$$

The reciprocal of sensitivity is called desensitivity D.

$$\therefore \text{Desensitivity}, D = 1 + \beta A$$

$$\text{and} \quad A_f = \frac{A}{1+A\beta} = \frac{A}{D}$$

2. Extension of Bandwidth

We know that the gain with feedback for an amplifier is given by,

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

Using the above equation, we can write

$$A_{f\,mid} = \frac{A_{mid}}{1+\beta A_{mid}}$$

$$A_{f\,low} = \frac{A_{low}}{1+\beta A_{low}}$$

$$A_{f\,high} = \frac{A_{high}}{1+\beta A_{high}}$$

Now, Lower cut-off frequency with feedback is

$$f_{Lf} = \frac{f_L}{1+\beta A_{mid}} = \frac{f_L}{1+\beta A_{mid}}$$

We can say that lower cut-off frequency with feedback is less than the lower cut-off frequency without feedback by factor $(1 + A_{mid}\beta)$. (5)

Similarly, the upper cut-off frequency with feedback is given as;

$$f_{Hf} = (1 + A_{mid}\beta) f_H$$

We can say that $f_{Hf} > f_H$ by factor $(1 + A_{mid}\beta)$.

Therefore, the bandwidth of the amplifier with feedback is

$$BW_f = f_{Hf} - f_{Lf} = (1 + A_{mid}\beta) f_H - \frac{f_L}{(1 + A_{mid}\beta)}$$

or $$BW_f = BW(1 + A_{mid}\beta)$$

where $BW = f_H - f_L$ = Bandwidth without feedback.

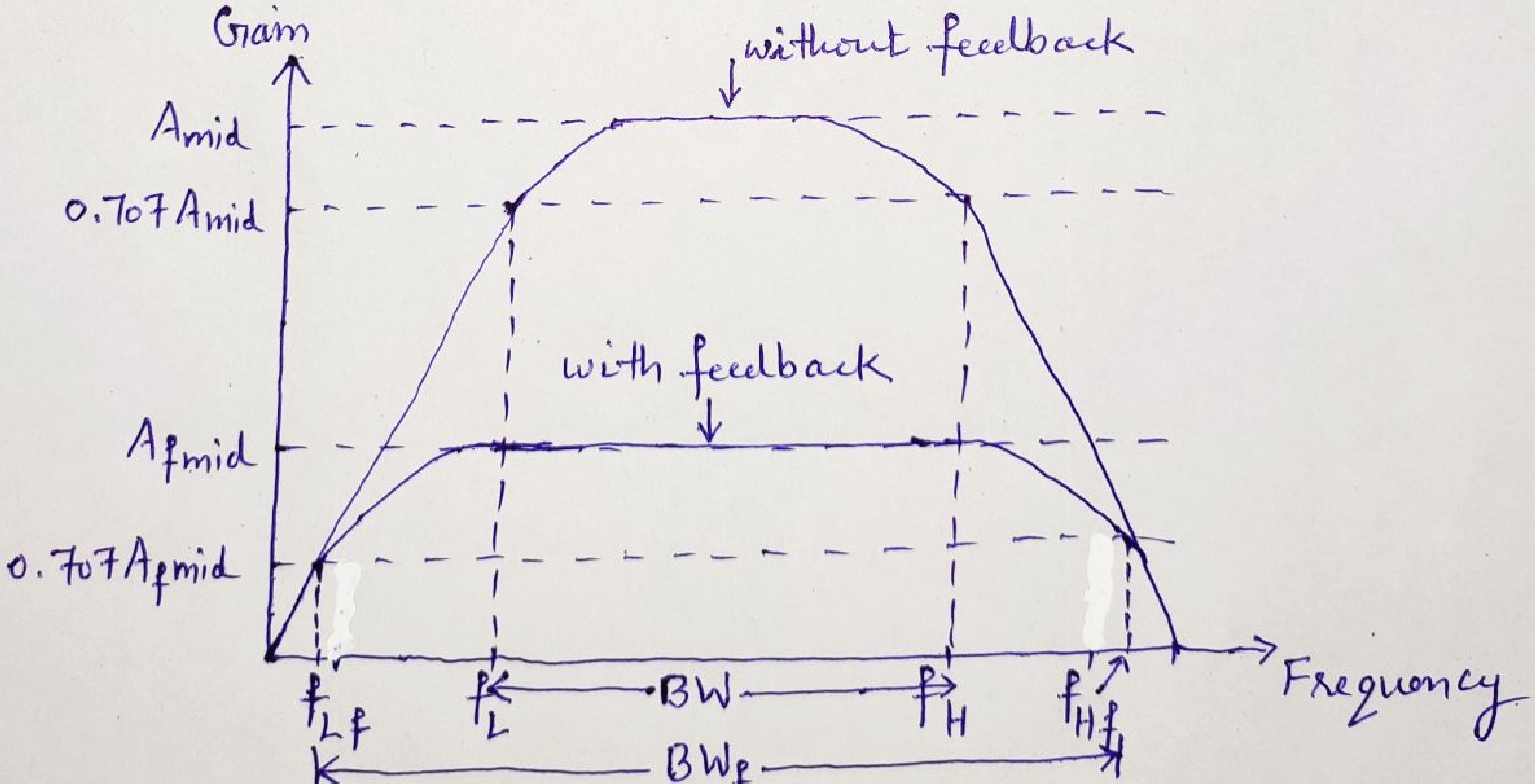


Fig. Effect of negative feedback on gain and BW.

$\therefore$ $BW_f > BW$ by factor $(1 + A_{mid}\beta)$