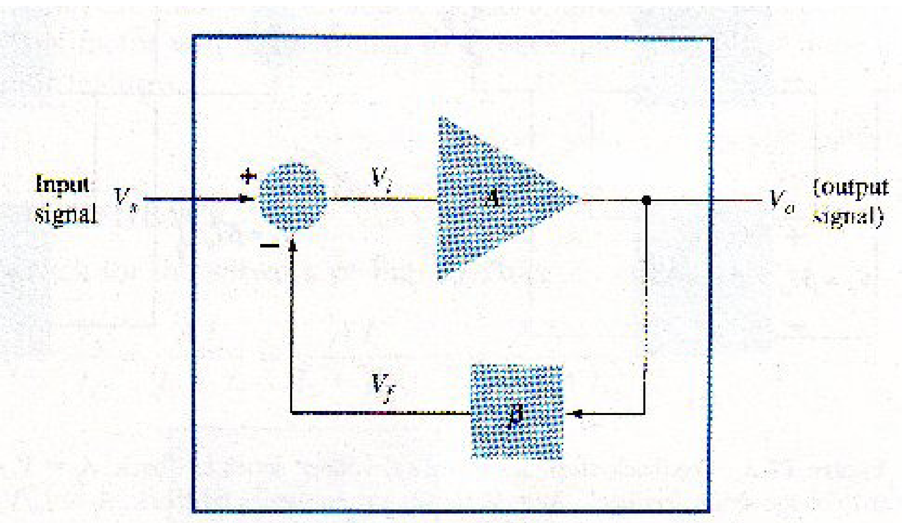
Feedback Amplifier

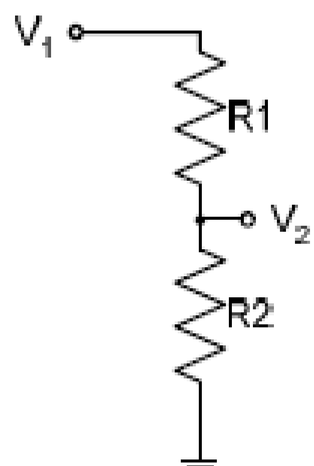
➢ Feedback amplifier contains two component namely feedback circuit and amplifier circuit.

➢ Feedback circuit is essentially a potential divider consisting of resistances R_1 & R_2

➢ The purpose of feedback circuit is to return a fraction of the output voltage to the input of the amplifier circuit.



Feedback amplifier



Feedback circuit

feedback fraction β

$$\beta = \frac{V_2}{V_1} = \frac{R_2}{R_1 + R_2}$$

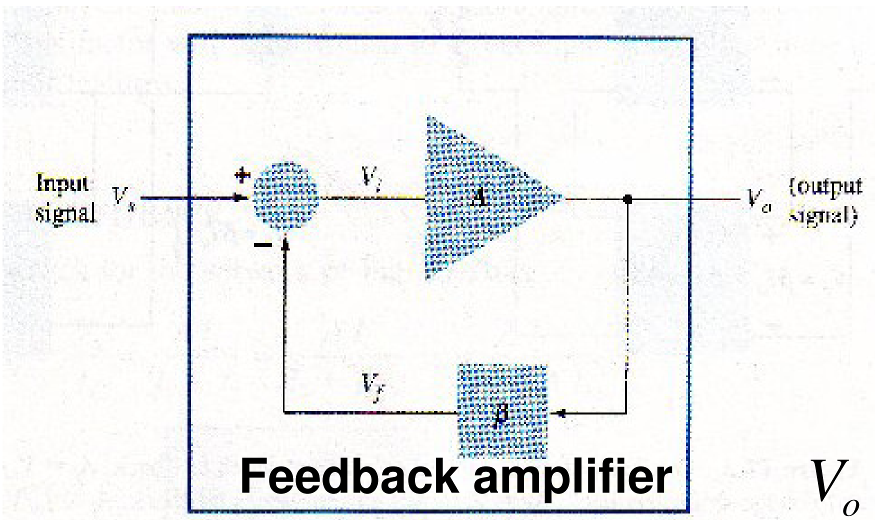
Feedback

➢ **Both negative feedback and positive feedback are used in amplifier circuits.**

➢ **Negative feedback returns part of the output to oppose the input, whereas in positive feedback the feedback signal aids the input signal.**

If V_f = 0 (there is no feedback)

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



Feedback amplifier

If feedback signal V_f is connected in series with the input, then $V_i = V_S - V_f$

$$V_o = AV_i = A(V_s - V_f) \quad \text{But} \quad V_f = \beta V_o$$

$$V_o = A(V_s - \beta V_o) \qquad \boxed{V_o(1+\beta A) = AV_s}$$

A_f : closed-loop gain of the amplifier
A: Open-loop gain of the amplifier gain

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

Feedback

For negative feedback: *βA > 0 ;* For positive feedback: *βA < 0*

Advantages of Negative feedback

➢ **Negative feedback can reduce the gain of the amplifier, but it has many advantages, such as gain stabilization, reduction of nonlinear distortion and noise, control of input and output impedances, and extension of bandwidth.**

❑ Gain stabilization

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

$$\frac{dA_f}{A} = \frac{1}{(1+\beta A)^2}$$

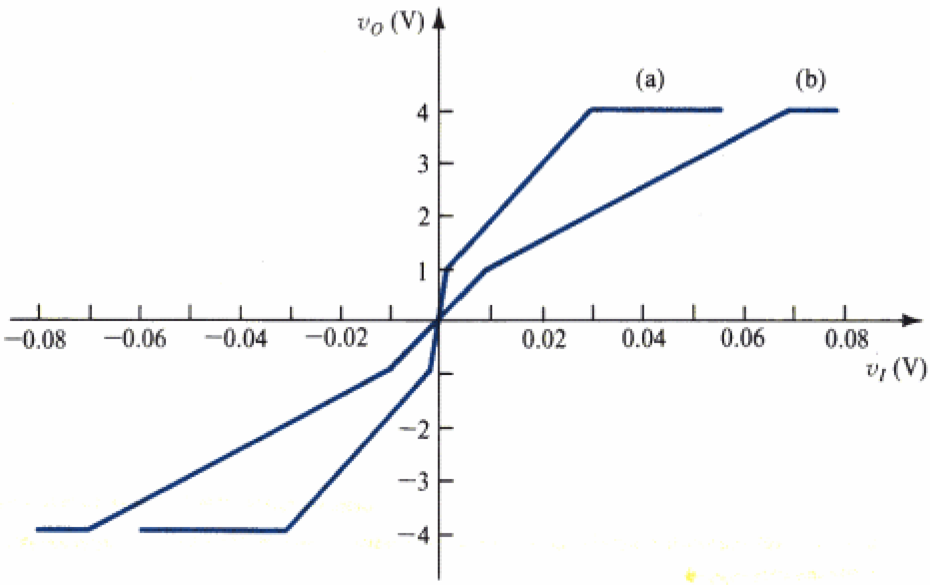
$$\frac{dA_f}{A_f} = \frac{1}{(1+\beta A)}\frac{dA}{A}$$

Therefore percentage change in A_f *(due to variations in some* circuit parameter) is reduced by (1+βA) times compared to without feedback.

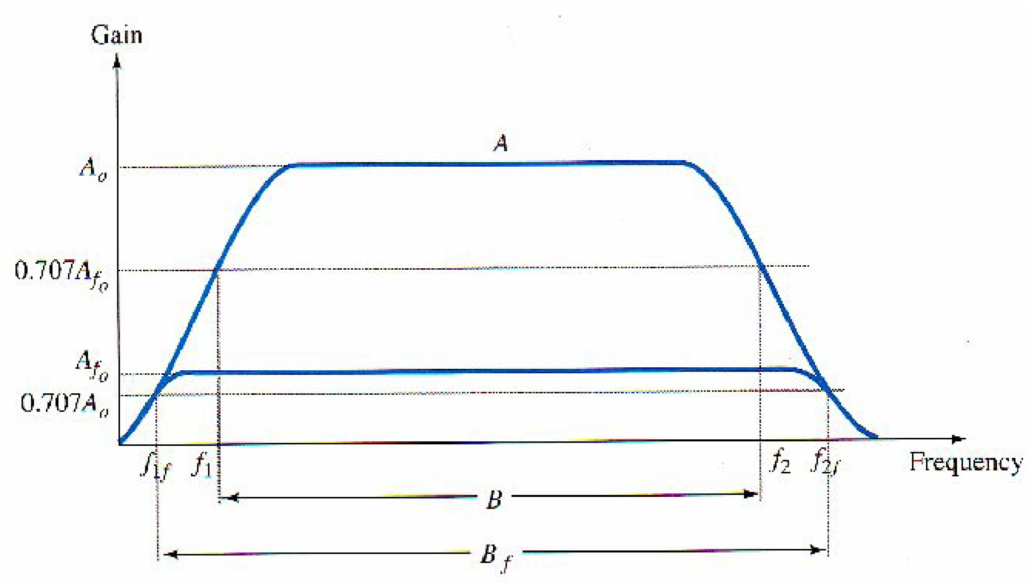
Advantages of Negative feedback

❑ Reduction of nonlinear distortion

(a) Open loop gain
(b) Closed loop gain



❑ Bandwidth extension



Basic Feedback Topologies

➢ **Depending on the input signal (voltage or current) to be amplified and form of the output (voltage or current), amplifiers can be classified into four categories. Depending on the amplifier category, one of four types of feedback structures should be used.**

❖ **Voltage series feedback (**$A_f = V_o/V_s$) – *Voltage amplifier*

❖ **Voltage shunt feedback (**$A_f = V_o/I_s$) – *Trans-resistance amplifier*

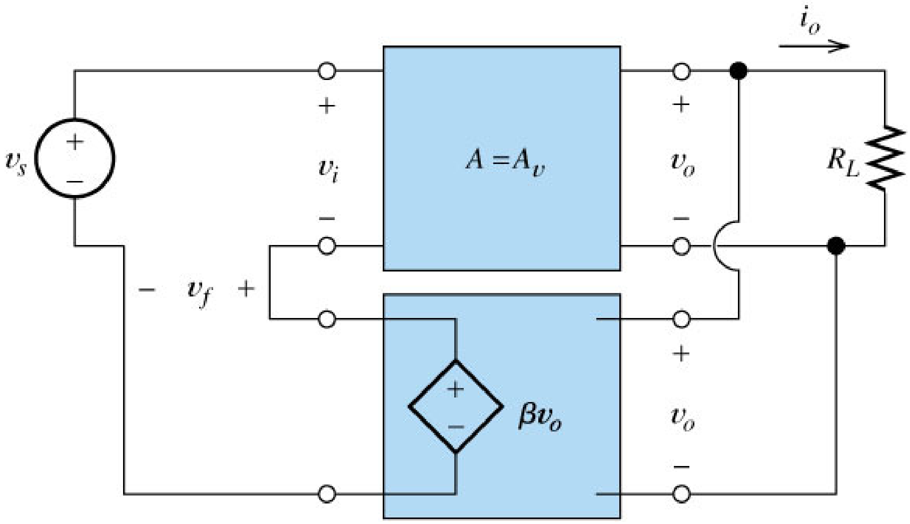
❖ **Current series feedback (**$A_f = I_o/V_s$) **-** *Trans-conductance amplifier*

❖ **Current shunt feedback (**$A_f = I_o/I_s$) - Current amplifier

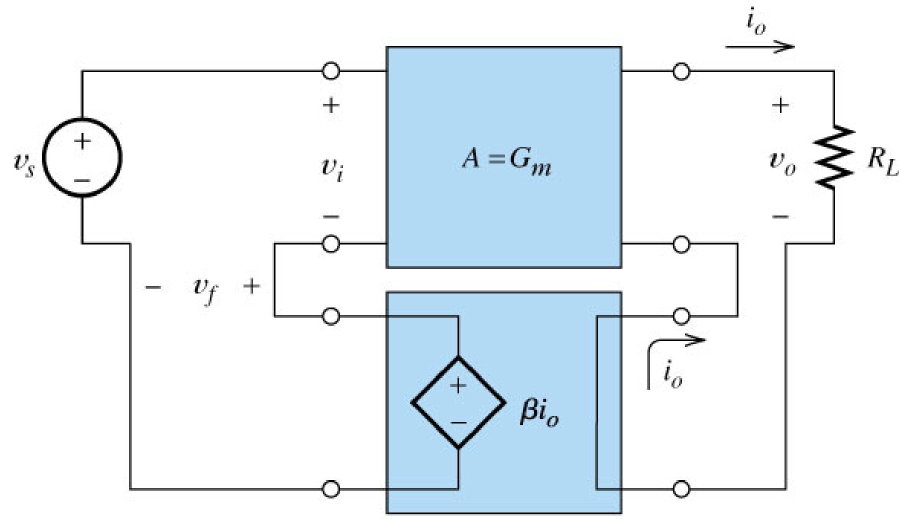
➢ **Here voltage refers to connecting the output voltage as input to the feedback network. Similarly current refers to connecting the output current as input to the feedback network.**

➢**Series refers to connecting the feedback signal in series with the input voltage; Shunt refers to connecting the feedback signal in shunt (parallel) with an input current source.**

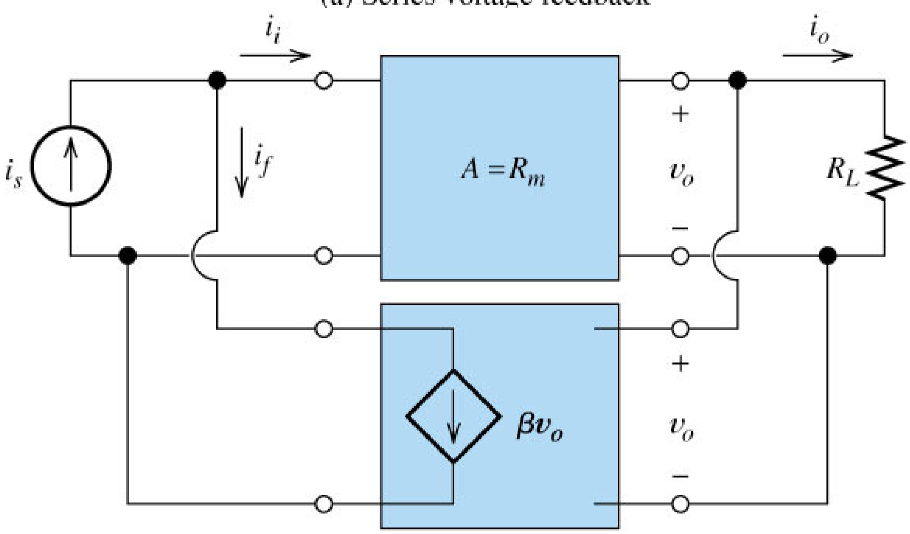
Feedback topologies



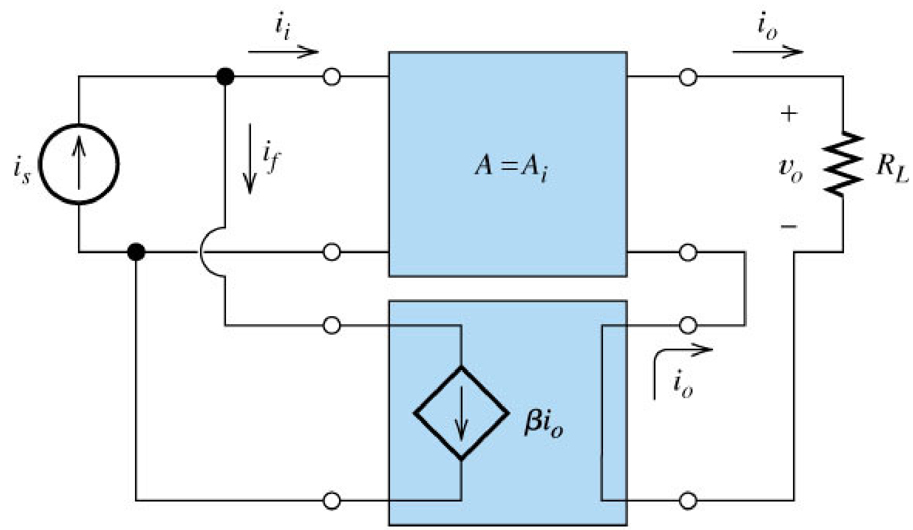
(a) Series voltage feedback



(b) Series current feedback

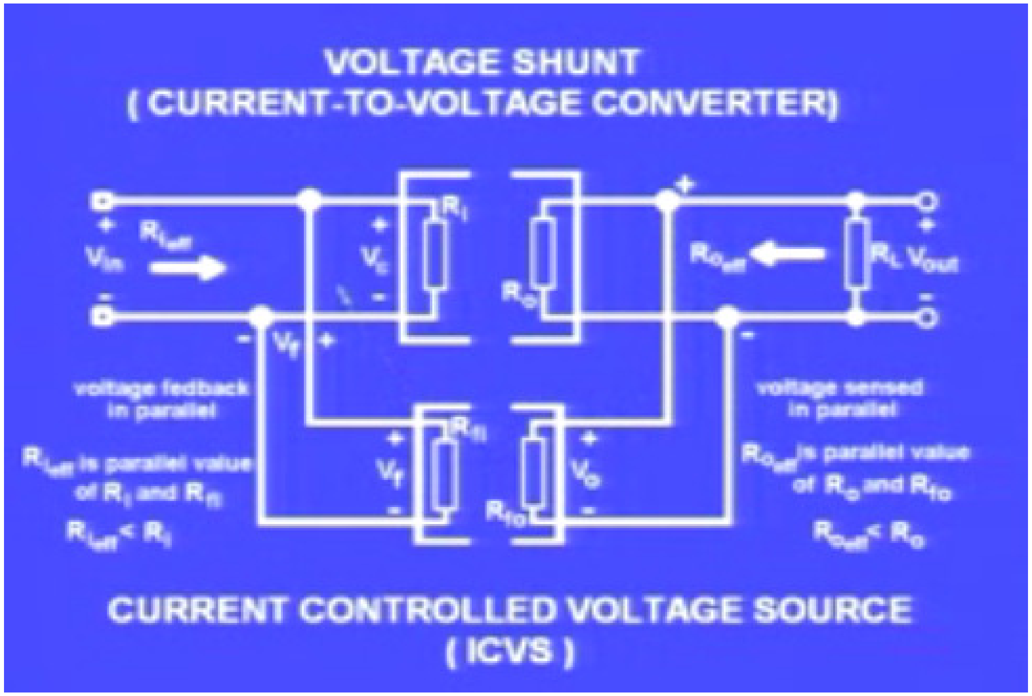


(c) Parallel voltage feedback



(d) Parallel current feedback

Feedback topologies: Voltage Shunt Feedback

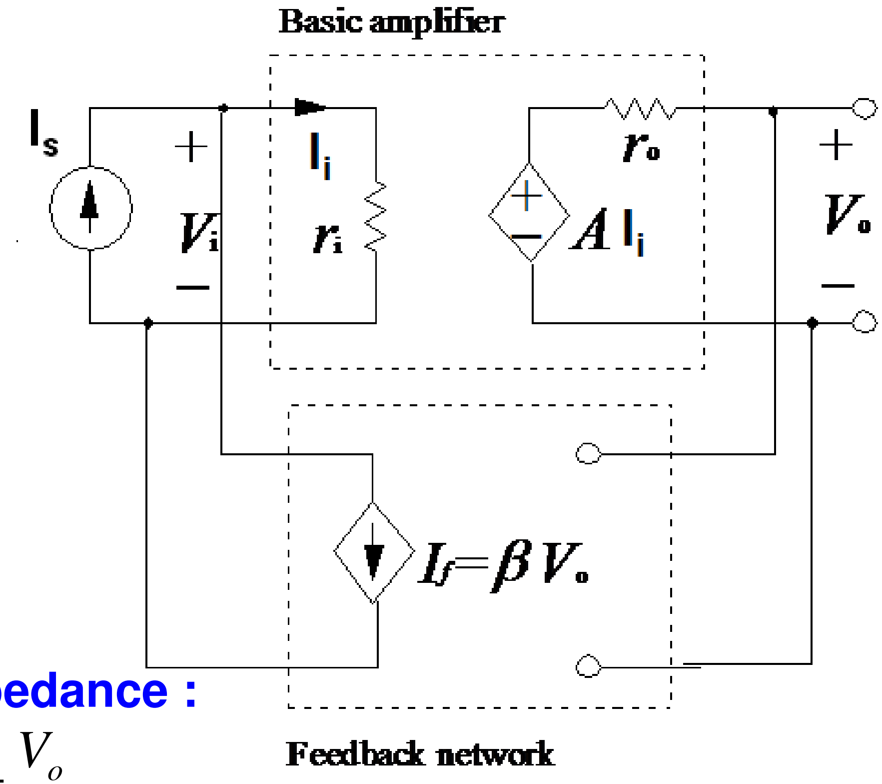


- **Output resistance of the amplifier and output resistance of the feedback circuit are in parallel hence effective output resistance of the feedback amplifier will reduce.**
- **Similarly overall input resistance of the feedback amplifier will reduce due to parallel connection of amplifier and feedback resistor.**

- **Since effective input resistance is small hence input should be a current.**
- **(**for ideal voltage source – input resistance is very high compare to internal source resistance, if not then, lot of voltage will be dropped at internal source resistance and voltage source won't be a ideal voltage source)

- **Effective output resistance is also small compare to the resistance of amplifier without feedback hence less voltage will drop at $R_{o\text{-}eff}$ and most of the voltage occurs at R_L. Hence output ckt will behave like a voltage source. Thus voltage shunt feedback ckt behave like a current controlled voltage source.**

Feedback topologies: Voltage Shunt Feedback



Voltage Gain :

$$V_o = A \cdot I_i = A(I_S - I_f)$$

$$I_f = \beta \cdot V_o$$

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

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

$$A_f = \frac{V_o}{I_S} = \left(\frac{A}{1+\beta A}\right)$$

Input Impedance :

$$Z_{\text{in}} = \frac{V_i}{I_S} = \frac{V_i}{I_i + I_f}$$

$$= \frac{I_i \cdot r_i}{I_i + \beta V_o)} = \frac{I_i \cdot r_i}{I_i + \beta A I_i}$$

$$Z_{\text{in}} = \frac{r_i}{(1+\beta A)}$$

Output Impedance :

$$Z_{\text{out}} \,|_{V_S = 0} = \frac{V_o}{I_o}$$

from input port,

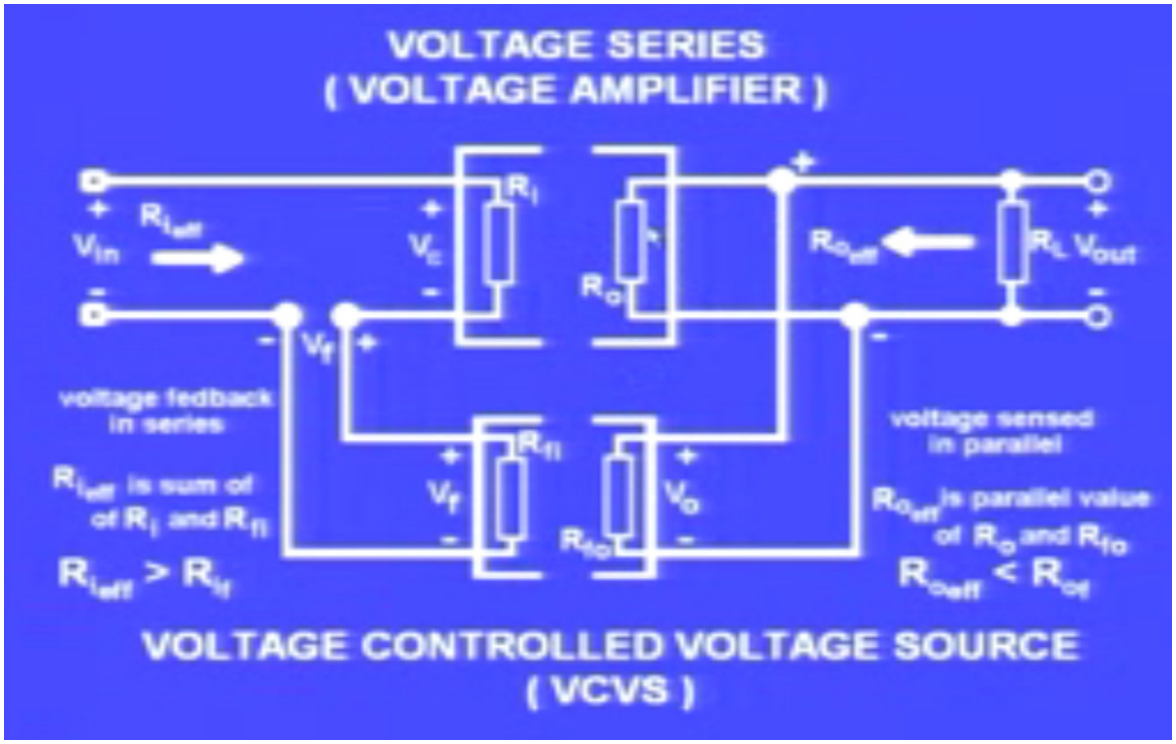
$$I_i = -I_f = -\beta V_o$$

from output port,

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

$$Z_{\text{out}} = \frac{V_o}{I_o} = \frac{r_o}{(1+\beta A)}$$

Feedback topologies: Voltage Series Feedback



➢Input resistance of the amplifier and feedback network are in series hence effective input resistance will increase.

➢ Output resistance of the amplifier and output resistance of the feedback circuit are in parallel hence effective output resistance of the feedback amplifier will reduce.

Feedback topologies: Voltage Series Feedback

Voltage Gain :

$$V_o = A \cdot V_i = A(V_S - V_f)$$

$$V_f = \beta \cdot V_o$$

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

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

$$A_f = \frac{V_o}{V_S} = \left(\frac{A}{1+\beta A}\right)$$

Input Impedance :

$$Z_{\text{in}} = \frac{V_S}{I_S} = \frac{V_i + V_f}{I_S}$$

$$= \frac{V_i + \beta V_o}{I_S} = \frac{V_i + \beta A V_i}{I_S}$$

$$Z_{\text{in}} = \frac{V_i(1+\beta A)}{I_S} = r_i(1+\beta A)$$

Output Impedance :

$$Z_{\text{out}} \big|_{V_S=0} = \frac{V_o}{I_o}$$

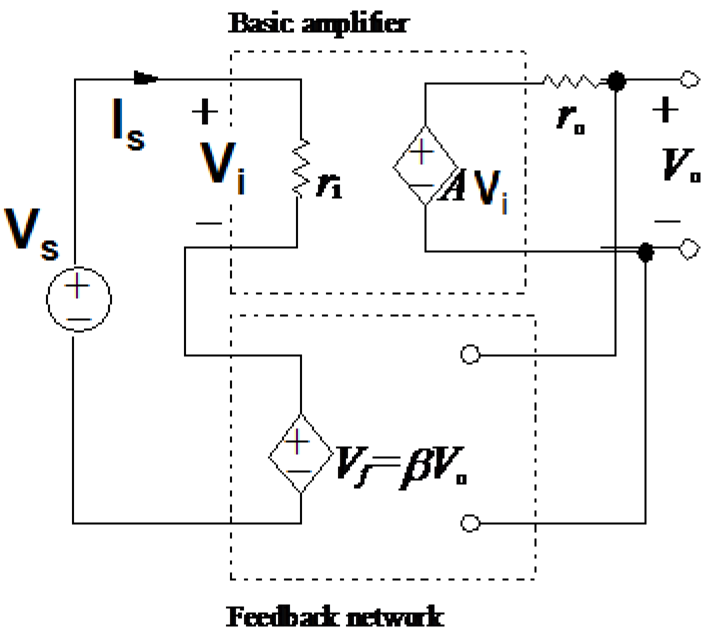
$$I_o = \frac{V_o - A \cdot V_i}{r_o}$$

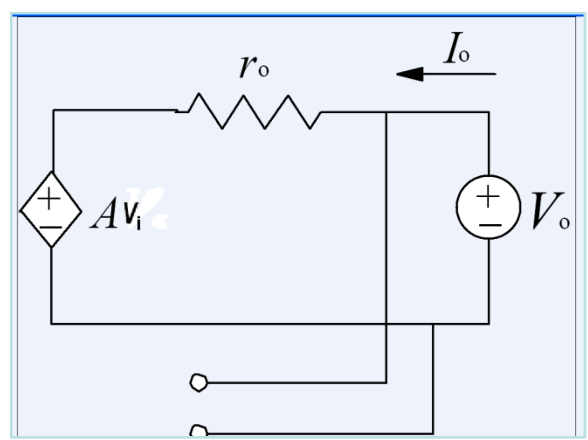
$$V_i + \beta \cdot V_o = V_S = 0$$

$$V_i = -\beta \cdot V_o$$

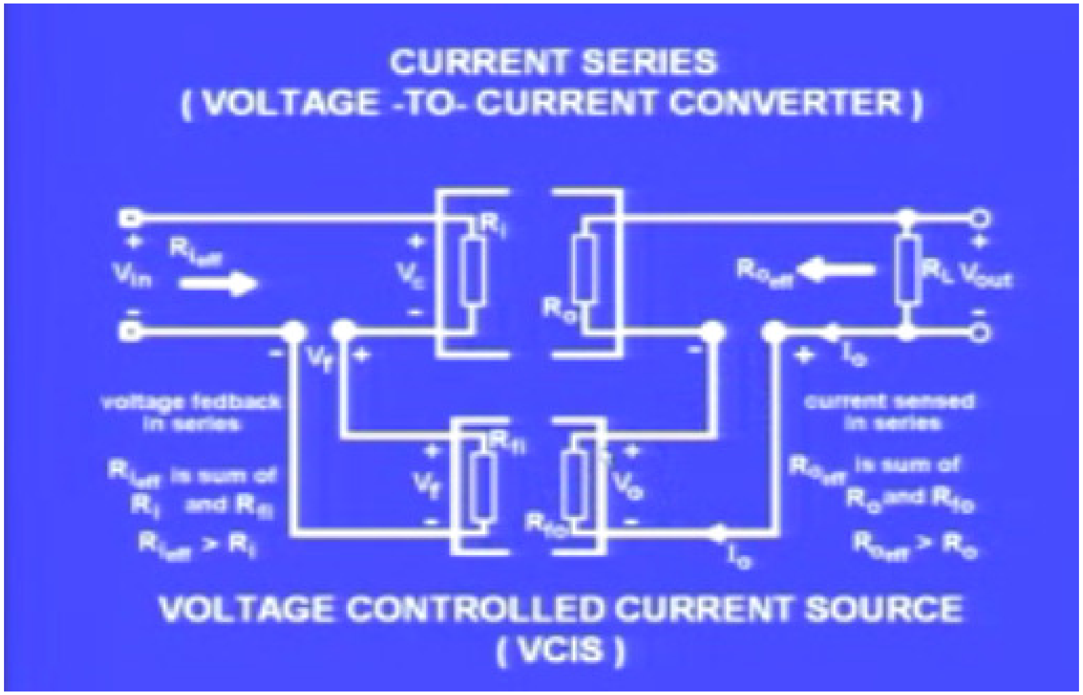
$$I_o = \frac{V_o + A \cdot \beta \cdot V_o}{r_o}$$

$$Z_{\text{out}} = \frac{V_o}{I_o} = \frac{r_o}{1 + A \cdot \beta}$$





Feedback topologies: Current Series Feedback

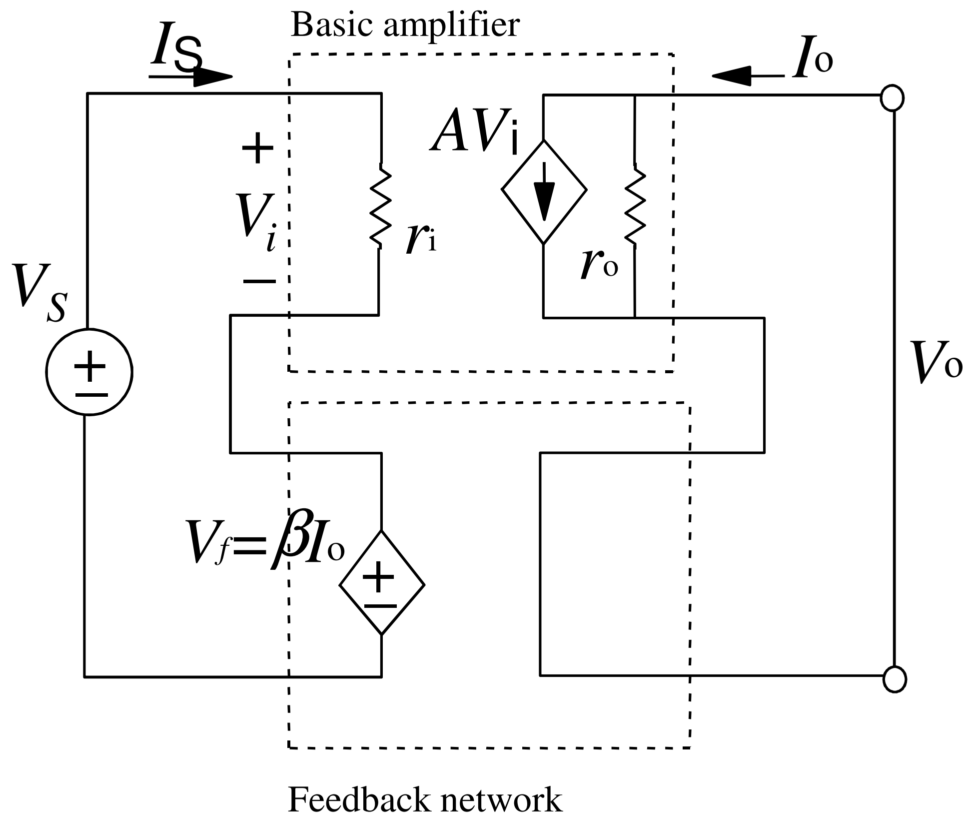


➢ **Output resistance of the amplifier and output resistance of the feedback circuit are in series hence effective output resistance of the feedback amplifier will increase.**

➢**Input resistance of the amplifier and feedback network are in series hence effective input resistance will increase.**

➢ **Thus Current series feedback circuit behave like a voltage controlled current source.**

Feedback topologies: Current Series Feedback



Voltage Gain :

$$I_o = A \cdot V_i = A(V_S - V_f)$$

$$V_f = \beta \cdot I_o$$

$$A(V_S - \beta I_o) = I_o$$

$$AV_S = (1 + \beta A) I_o$$

$$A_f = \frac{I_o}{V_S} = \left(\frac{A}{1 + \beta A}\right)$$

Input Impedance :

$$Z_{\text{in}} = \frac{V_S}{I_S} = \frac{V_i + V_f}{I_S}$$

$$= \frac{V_i + \beta V_o}{I_S} = \frac{V_i + \beta A V_i}{I_S}$$

$$Z_{\text{in}} = \frac{V_i(1 + \beta A)}{I_S} = r_i(1 + \beta A)$$

Output Impedance :

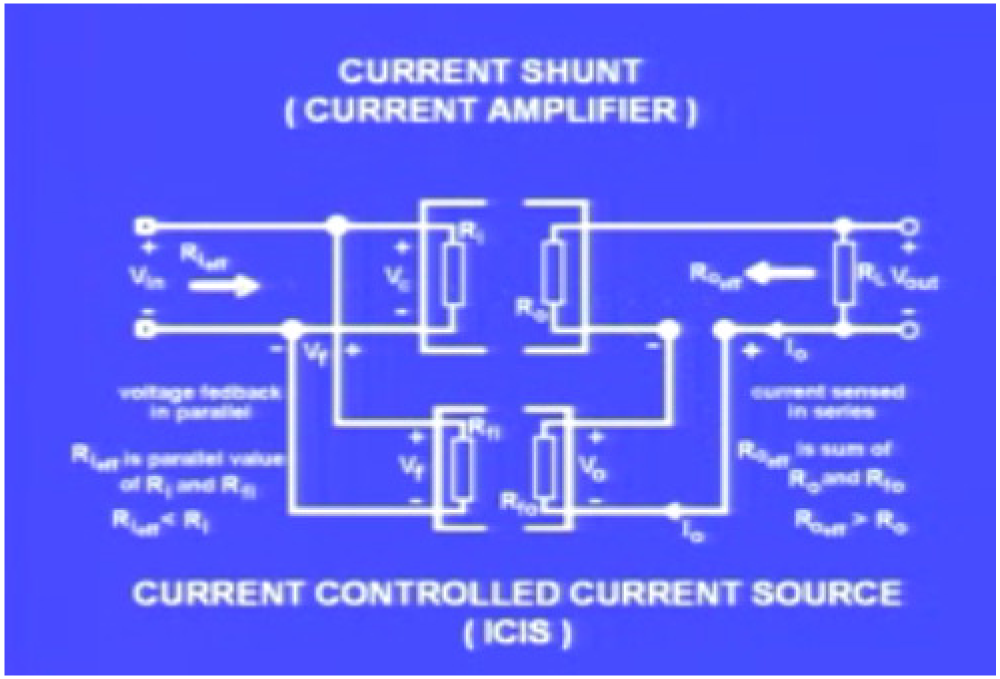
$$V_i + V_f = V_S = 0$$

$$Z_{\text{out}}\Big|_{V_S=0} = \frac{V_o}{I_o}; I_o = \frac{V_o - A \cdot V_i}{r_o}$$

$$I_o = \frac{V_o + A \cdot \beta \cdot I_o}{r_o}$$

$$Z_{\text{out}} = \frac{V_o}{I_o} = \frac{r_o}{1 + A \cdot \beta}$$

Feedback topologies: Current Shunt Feedback



➢Effective output resistance of the feedback amplifier will increase.

➢Effective input resistance will decrease.

➢ Thus current shunt feedback circuit behave like a current controlled current source.