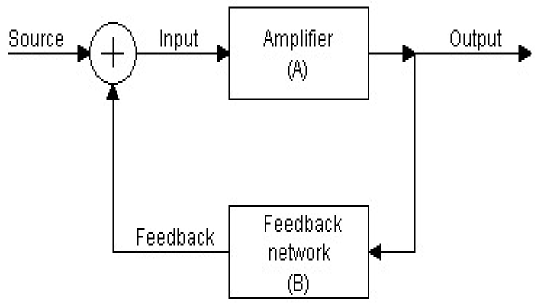
(SESSION- 2018-19)

FEEDBACK



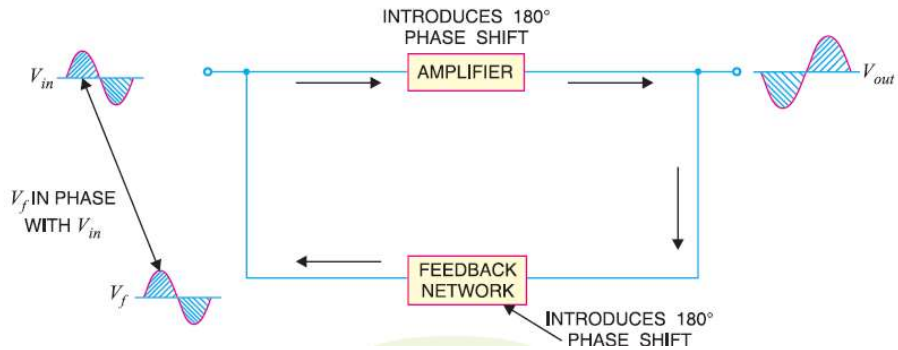
The process of injecting a fraction of output energy of some device back to input is known as feedback

Example

- Try to close your eyes and touch your fingers together, the first time you make it you may not succeed because you have broken a feedback loop that normally regulates your motions.
- Driving with eyes and brain
- Speed control of machine in automation industry
- Temperature control of room using AC

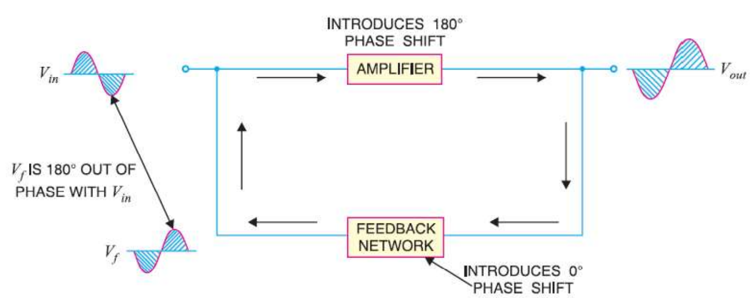
Positive Feedback

- When the feedback energy (voltage or current) is in phase with the input signal and thus aids it, it is called *positive feedback*.



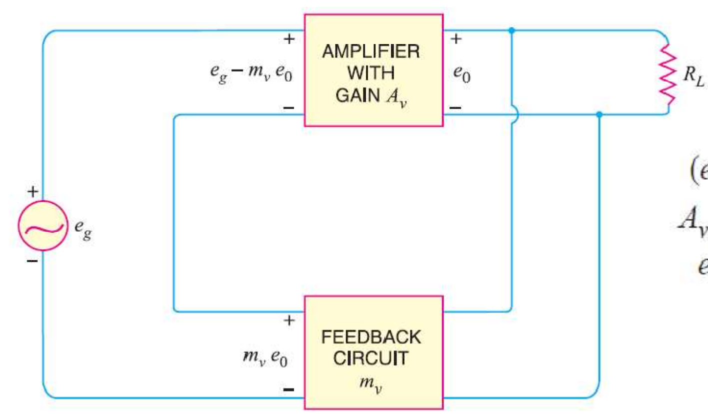
Negative Feedback

When the feedback energy (voltage or current) is out of phase with the input signal and thus opposes it, it is called *negative feedback*.



- Negative feedback reduces the gain of the amplifier. However, the advantages of negative feedback are:
- reduction in distortion,
- stability in gain,
- increased bandwidth and
- improved input and output impedances.
- It is due to these advantages that negative feedback is frequently employed in amplifiers.

Gain of Negative Voltage Feedback Amplifier

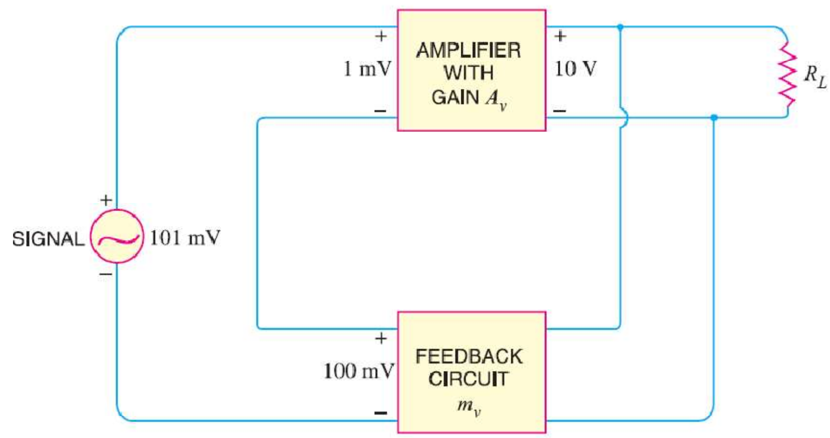


Actual input to amplifier $= e_g - m_v e_0$

$$(e_g - m_v e_0)\, A_v = e_0$$
$$A_v e_g - A_v m_v e_0 = e_0$$
$$e_0\,(1 + A_v m_v) = A_v e_g$$
$$\frac{e_0}{e_g} = \frac{A_v}{1 + A_v\, m_v}$$

$$A_{vf} = \frac{A_v}{1 + A_v\, m_v}$$

Q. Calculate A, Af, m or β



Solution

Gain of amplifier without feedback, $A_v = \dfrac{10\text{ V}}{1\text{ mV}} = 10,000$

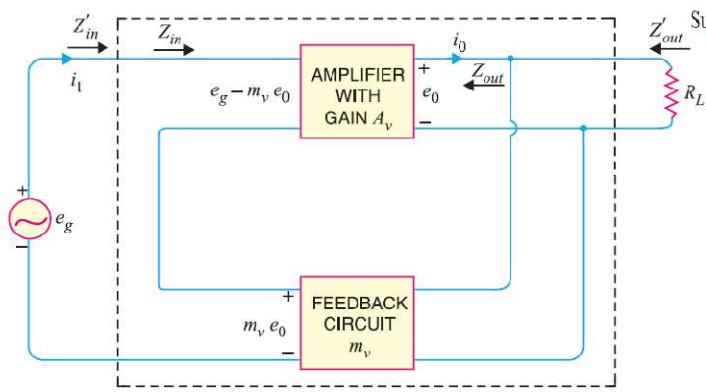
Fraction of output voltage fedback, $m_v = \dfrac{100\text{ mV}}{10\text{ V}} = 0.01$

Gain of amplifier with negative feedback, $A_{vf} = \dfrac{10\text{ V}}{101\text{ mV}} = 100$

Question

If A=1x10^5, Beta=0.01, find Af

Advantages of Negative Feedback
(1) Increases input impedances



Suppose the input impedance of the amplifier is Z_{in} without feedback and Z'_{in} with negative feedback.

1. Higher input impedance

$$e_g - m_v e_0 = i_1 Z_{in}$$

Now
$$\begin{aligned} e_g &= (e_g - m_v e_0) + m_v e_0 \\ &= (e_g - m_v e_0) + A_v m_v (e_g - m_v e_0) && [\because e_0 = A_v (e_g - m_v e_0)] \\ &= (e_g - m_v e_0)(1 + A_v m_v) \\ &= i_1 Z_{in} (1 + A_v m_v) && [\because e_g - m_v e_0 = i_1 Z_{in}] \end{aligned}$$

or
$$\frac{e_g}{i_1} = Z_{in}(1 + A_v m_v)$$

But $e_g / i_1 = Z'_{in}$, the input impedance of the amplifier with negative voltage feedback.

$$\therefore \quad Z'_{in} = Z_{in}(1 + A_v m_v)$$

2. Reduces Output impedance

$$Z'_{out} = \frac{Z_{out}}{1 + A_v m_v}$$

Z'_{out} = output impedance with negative voltage feedback

Z_{out} = output impedance without feedback

It is clear that by applying negative feedback, the output impedance of the amplifier is decreased by a factor $1 + A_v m_v$. This is an added benefit of using negative voltage feedback. With lower value of output impedance, the amplifier is much better suited to drive low impedance loads.

3. Increases gain stability

$$A_{vf} = \frac{A_v}{1 + A_v\, m_v}$$

For negative voltage feedback in an amplifier to be effective, the designer deliberately makes the product $A_v m_v$ much greater than unity. Therefore, in the above relation, 1 can be neglected as compared to $A_v m_v$ and the expression becomes :

$$A_{vf} = \frac{A_v}{A_v\, m_v} = \frac{1}{m_v}$$

It may be seen that the gain now depends only upon feedback fraction m_v *i.e.*, on the characteristics of feedback circuit. As feedback circuit is usually a voltage divider (a resistive network), therefore, it is unaffected by changes in temperature, variations in transistor parameters and frequency. Hence, the gain of the amplifier is extremely stable.

Gain stability with feedback (with disturbance)

$$A_f = \frac{A}{1+\beta A} \qquad \beta = m_v \; ; \; A = A_v$$

$$dA_f = \frac{dA[1+\beta A] - \beta\, dA\, A}{(1+\beta A)^2} = \frac{dA + (\beta A)\, dA - dA(\beta A)}{(1+\beta A)^2}$$

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

$$= \frac{dA}{A}\left[\frac{A}{1+\beta A}\right] \times \frac{1}{1+\beta A}$$

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

$$\left|\frac{dA_f}{A_f}\right| = \left|\frac{dA}{A}\right| * \frac{1}{|1+\beta A|} \quad ; \quad \beta A >> 1$$

$$\left|\frac{dA_f}{A_f}\right| \cong \frac{1}{|\beta A|}\left|\frac{dA}{A}\right|$$

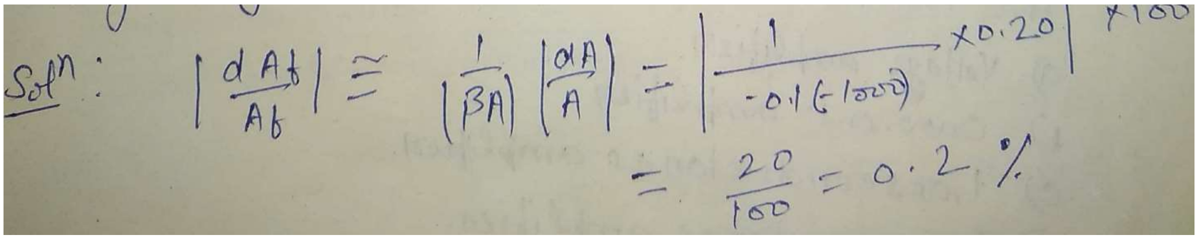
Relative change in gain $\left|\frac{dA_f}{A_f}\right|$ is reduced by the factor $|\beta A|$ compare to that without feedback.

Question

Q1) If an amplifier with gain of -1000 and feedback of $\beta = -0.1$, has a gain change of 20% due to temp. Cal change in gain of the feedback amplifier.

3mins

Solution



4. Reduces Nonlinear distortions

- A large signal stage has non-linear distortion because its voltage gain changes at various points in the cycle. The negative voltage feedback reduces the nonlinear distortion in large signal amplifiers.

$$D_{vf} = \frac{D}{1 + A_v\, m_v}$$

D = distortion in amplifier without feedback

D_{vf} = distortion in amplifier with negative feedback

5.Improves frequency response

- As feedback is usually obtained through a resistive network, therefore, voltage gain of the amplifier is independent of signal frequency.
- The result is that voltage gain of the amplifier will be substantially constant over a wide range of signal frequency.

6. Increases circuit stability.

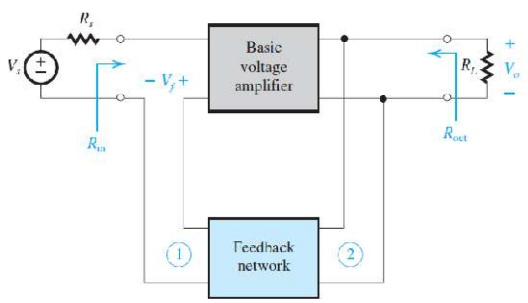
- Suppose the output of a negative voltage feedback amplifier has increased because of temperature change or due to some other reason.
- This means more negative feedback since feedback is being given from the output.
- This tends to oppose the increase in amplification and maintains it stable.
- The same is true should the output voltage decrease.

Types of Feedback connections

Output

Voltage-series feedback

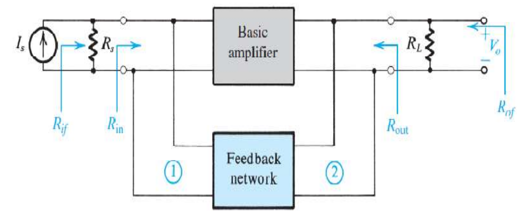
Input



voltage-series feedback, $A_f = V_o/V_s$

1

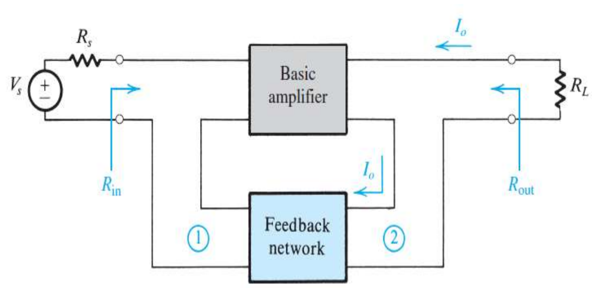
Voltage-shunt feedback



voltage-shunt feedback, $A_f = V_o/I_s$

2

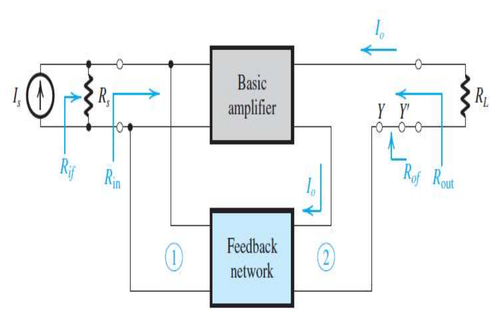
Current-series feedback



current-series feedback, $A_f = I_o/V_s$

3

Current-shunt feedback



current-shunt feedback, $A_f = I_o/I_s$.

4

Feedback topology:

Amplifier Type	Appropriate Feedback Topology	
Voltage	Series–Shunt	1
Transconductance	Series–Series	3
Current	Shunt–Series	4
Transresistance	Shunt–Shunt	2

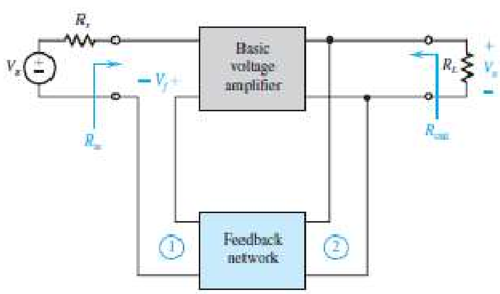
Input

Output

Concept of Sampling and mixing

- Based on output signal (Voltage or current), a part of this signal is taken as feedback. This is known as sampling.
- To give feedback, algebraically addition of feedback signal with input signal is required. This is known as mixing.

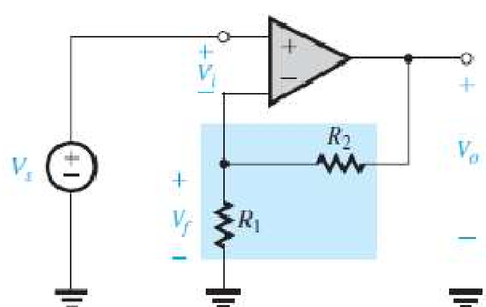
1. Voltage Amplifier (Series –shunt feedback)



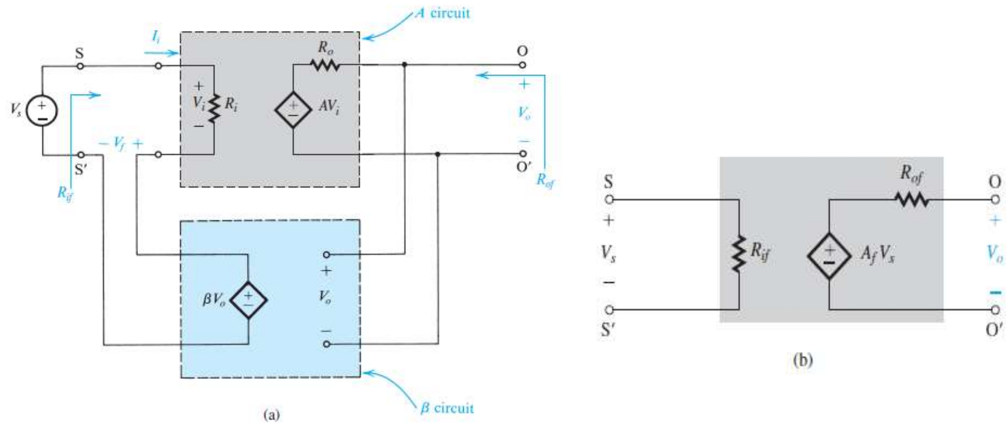
- Voltage amplifiers are intended to amplify an input voltage signal and provide an output voltage signal.
- The voltage amplifier is essentially a voltage-controlled voltage source.
- The input resistance is required to be high, and the output resistance is required to be low.
- Since the signal source is essentially a voltage source, it is appropriately represented in terms of a Thevenin equivalent circuit. As the output quantity of interest is the output voltage, the feedback network should *sample* the output *voltage*, just as a voltmeter measures a voltage.
- Also, because of the Thevenin representation of the source, the feedback signal *xf* should be a *voltage* that can be *mixed* with the source voltage in *series*.

Example

- The feedback network, composed of the voltage divider (*R*1, *R*2), develops a voltage *Vf* that is applied to the negative input terminal of the op amp.
- The subtraction of *Vf* from *Vs* is achieved by utilizing the differencing action of the op-amp differential input.



Analysis of Voltage Amplifier (Series –shunt feedback)



Input Impedance with feedback

$$R_{if} = \frac{V_s}{I_i} = \frac{V_s}{V_i/R_i}$$

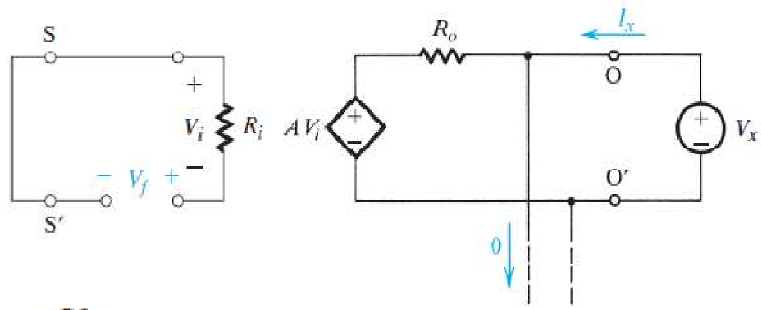
$$R_{if} = \frac{V_i + V_f}{V_i/R_i} = R_i \frac{V_i + V_f}{V_i}$$

$$R_{if} = R_i \frac{V_i + \beta V_0}{V_i}$$

$$R_{if} = R_i \frac{V_i + A\beta V_i}{V_i}$$

$$R_{if} = R_i (1 + A\beta)$$

Output Resistance with feedback Rof



$$R_{of} \equiv \frac{V_x}{I_x}$$

$$I_x = \frac{V_x - AV_i}{R_o}$$

From the input loop we see that

$$V_i = -V_f$$

Now $V_f = \beta V_o = \beta V_x$; thus,

$$V_i = -\beta V_x$$

$$I_x = \frac{V_x(1 + A\beta)}{R_o}$$

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

Question

Determine the voltage gain, input, and output impedance with feedback for voltage series feedback having $A = -100$, $R_i = 10\ \text{k}\Omega$, $R_o = 20\ \text{k}\Omega$ for feedback of (a) $\beta = -0.1$ and (b) $\beta = -0.5$.

5mins

Solution

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

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

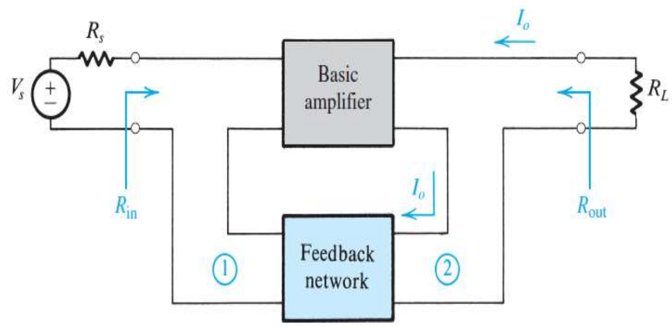
$Z_{of} = \dfrac{Z_o}{1 + \beta A} = \dfrac{20 \times 10^3}{11} = \mathbf{1.82\ k\Omega}$

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

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

$Z_{of} = \dfrac{Z_o}{1 + \beta A} = \dfrac{20 \times 10^3}{51} = \mathbf{392.16\ \Omega}$

2. The feedback Trans-conductance amplifier (Series-series)

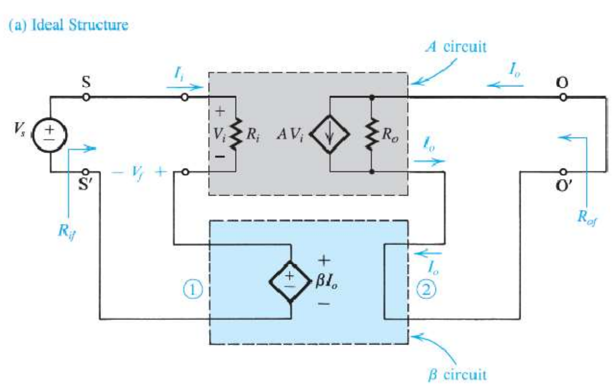


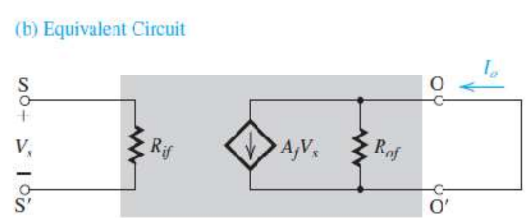
$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + A\beta}$$

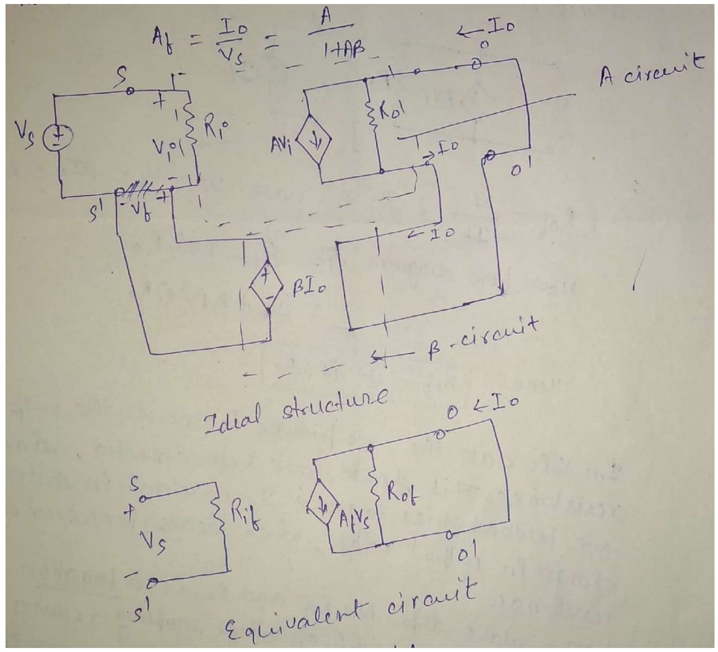
$$R_{if} = (1 + A\beta)R_i$$

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

2. The feedback Trans-conductance amplifier (Series-series)







Input resistance with feedback;

$$R_{if} = \frac{V_s}{I_i} = \frac{V_s}{V_i / R_i} = R_i \left(V_s / V_i\right) = R_i \frac{(V_i + V_f)}{V_i}$$

$V_f = \beta I_o$, $I_o = AV_i$

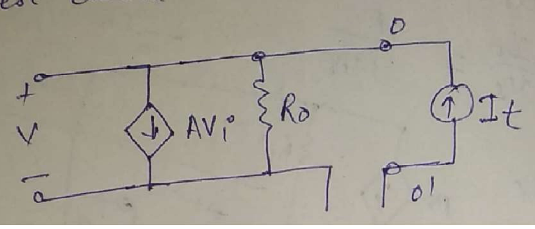
$V_f = \beta A V_i$

$$R_{if} = \frac{R_i (V_i + \beta A V_i)}{V_i}$$

$$\boxed{R_{if} = (1 + \beta A) R_i}$$

Output resistance with feedback: (R_{of})

To find out resistance R_{of} of series-series feedback amplifier reduce $V_s = 0$ and break the output circuit to apply a test current I_t.



$$R_{of} = \frac{V}{I_t}$$; In this case $V_i = -V_f = -\beta I_o = -\beta I_t$

Now from diagram $V = (I_t - AV_i) R_o$

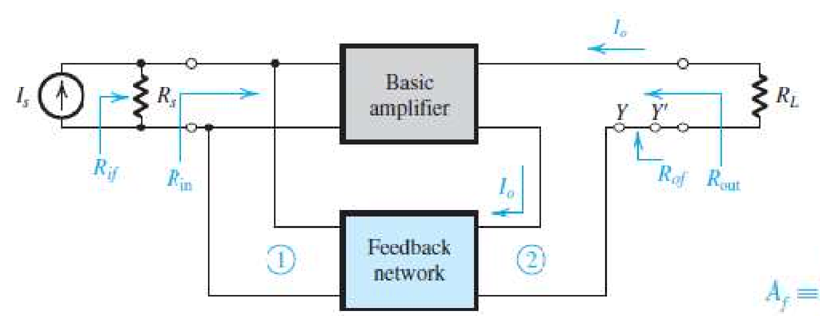
$= (I_t + A\beta I_t) R_o$

Hence $\boxed{R_{of} = (1 + A\beta) R_o}$

In this case the -ve feedback increases the output resistance. This should have been expected, since the -ve feedback tries to make I_o constant in spite of change in output voltage, which means increased output resistance.

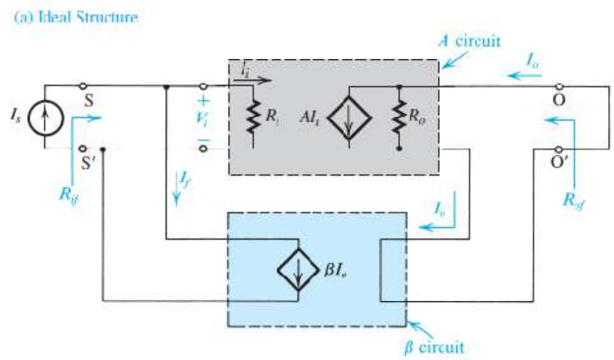
* The relationship b/w R_{of} and R_o is a function only of the method of sampling. Voltage sampling reduces output resistance, current sampling ~~in~~ increases it.

3. The Feedback Current Amplifier (Shunt–Series)



$$A_f \equiv \frac{I_o}{I_s} = \frac{A}{1+A\beta}$$

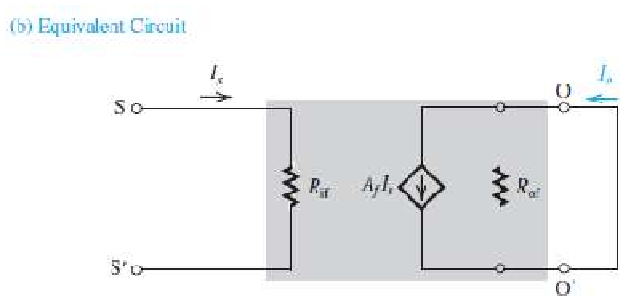
3. The Feedback Current Amplifier (Shunt–Series)



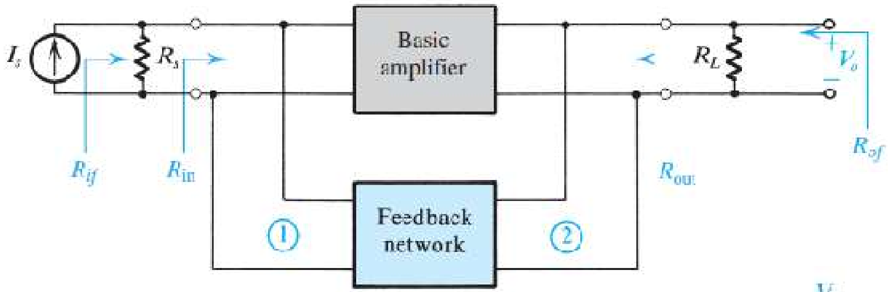
$$A_f \equiv \frac{I_o}{I_s} = \frac{A}{1+A\beta}$$

$$R_{if} = R_i/(1+A\beta)$$

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



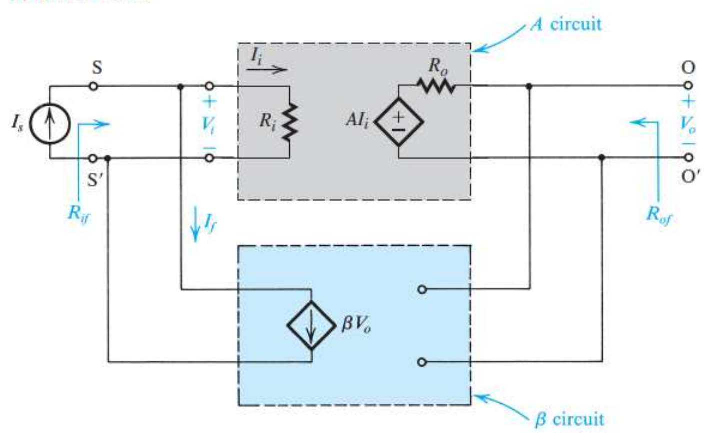
4. The Feedback trans-resistance Amplifier (Shunt–shunt)



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

4. The Feedback trans-resistance Amplifier (Shunt–shunt)

(a) Ideal Structure

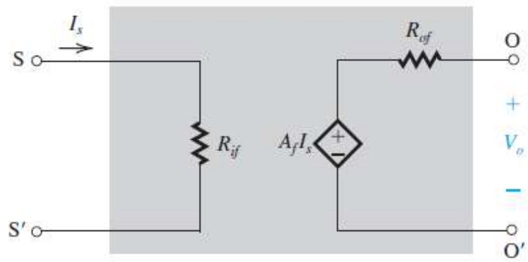


$$A_f \equiv \frac{V_o}{I_s} = \frac{A}{1+A\beta}$$

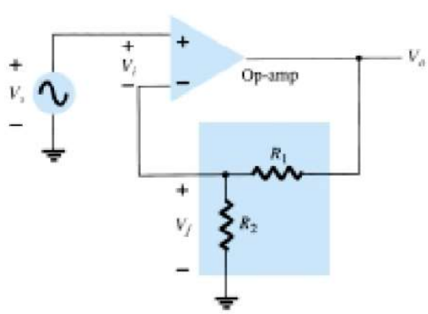
$$R_{if} = R_i/(1+A\beta)$$

$$R_{of} = R_o/(1+A\beta)$$

Equivalent circuit



Question: Calculate gain of amplifier with A=100,000, R1=1.8kohm, R2=200ohm



Time:5mins

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 $\beta A \gg 1$,

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