VIVEKANANDA COLLEGE

THAKURPUKUR

KOLKATA-700063

NAAC ACCREDITED 'A' GRADE

Topic	**: Feedback Amplifier**
Course Title	**: Analog Systems and Applications**
Paper	**: PHS-A-CC-4-10-TH**
Unit	**:**
Semester	**: 4th**
Name of the Teacher	**: Somnath Paul**
Name of the Department	**: Physics**

Feedback Amplifier

The term feedback implies transfer of energy (i.e. voltage or current) from the output of a system to its input. Depending on the relative 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 a number of circuit features are improved. as ~~summarized~~ positive feedback drives a circuit into oscillation as in various types of oscillator circuits.

General form of feedback Amplifier ⇒.

Fig-1.

Feedback Amplifier topology ⇒.

There are four basic ways of connecting the feedback signal. Both voltage and current can be fed back to the input either in series or parallel. Specifically there can be.

1. Voltage series feedback.
2. Voltage - shunt feedback.

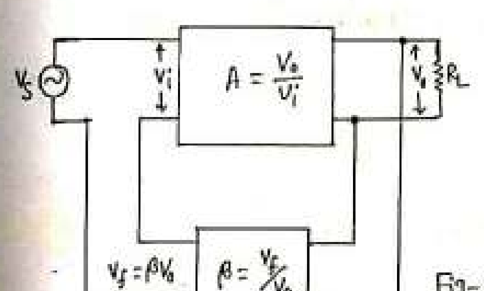


Fig-2

Gain with feedback $A_f = V_o/V_s$.

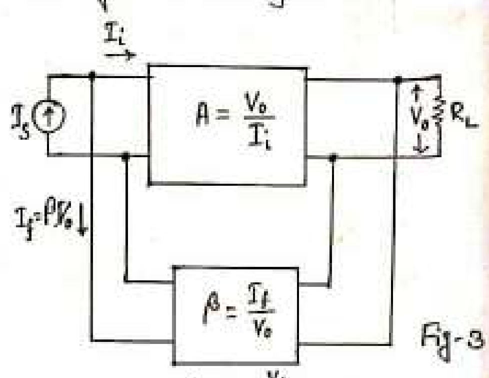


Fig-3

$A_f = \frac{V_o}{I_s}$

3. Current Series feedback

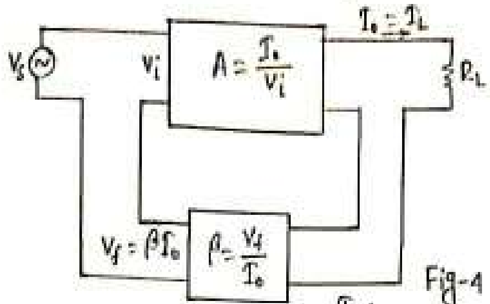


Fig-4

$A_f = I_o/V_s$

4. Current shunt feedback.

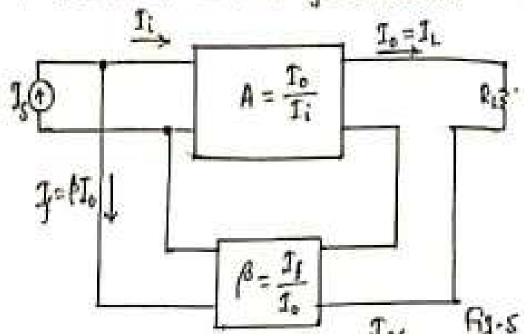


Fig-5

$A_f = I_o/I_s$.

Transfer gain with feedback ⇒.

Let us consider fig-2, feedback voltage $V_f = \beta V_o$.

Now, without feedback $v_i = V_s$., so, gain of the amplifier without feedback $A = \frac{V_o}{V_i} = \frac{V_o}{V_s}$.

Again if we connect the feedback circuit. the input $v_i = v_s + V_f = V_s + \beta V_o = V_s + A\beta V_i$

$$\therefore v_s = V_i(1 - A\beta).$$

Now, output voltage with feedback is.

$$V_o = AV_i = A\frac{V_s}{1-A\beta}.$$

$$\therefore \text{Gain with feedback } A_f = \frac{V_o}{V_s} = \frac{A}{1-A\beta}.$$

Now Note ⇒ For positive feedback both A & β are +ve.
or both A and β are -ve.
For Negative feedback either A or β is -ve.

Effects of Negative feedback ⇒.

i) Desensitivity of transfer amplification
ii) Stability of voltage gain
iii) Reduction in distortion.
iv) Increase of band width
v) Reduction in noise.
vi) Change in input and output impedance.

Desensitivity of transfer Amplification ⇒

Gain of an amplifier with feedback is $A_f = \frac{A}{1-A\beta}$.

Now for negative feedback either A or β is negative.

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

If $A\beta >> 1$ then $A_f = \frac{A}{A\beta} = 1/\beta$.

So, gain with feedback is independent of the gain of the main amplifier.

Reduction in Distortion ⇒

Let 'D' be the distortion generated in final stage of the amplifier.

∴ Output voltage including distortion is then

$$E_0 = V_0 + D.$$

So, input voltage $V_i = V_S - \beta E_0$. [−ve sign for negative feedback].

$$= V_S - \beta(V_0 + D).$$

But $A = \frac{V_0}{V_i}$

$$\therefore \frac{V_0}{A} = V_i = V_S - \beta(V_0 + D)$$

$$V_0\left(1/A + \beta\right) = V_S - \beta D.$$

$$\therefore V_0 = \frac{AV_S}{1+A\beta} - \frac{A\beta D}{1+A\beta}.$$

$$\therefore E_0 = V_0 + D = \frac{AV_S}{1+A\beta} - \frac{A\beta D}{1+A\beta} + D.$$

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

$$E_0 = A_f V_S + D_f.$$

Again for negative feedback $1 + A\beta > 1$ So, $D_f < D$.

Improvement of stability ⇒

Gain of an amplifier with feedback is

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

Diff^n w.r.t. A we get,

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

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

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

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

$$= \frac{dA}{A} \cdot \frac{1}{1+A\beta}$$

Now we define $S = \frac{dA}{A}$, is the fractional change in voltage gain without feedback and $S_f = \frac{dA_f}{A_f}$ is that of with feedback, is called stability factor.

So, $S_f = \frac{S}{1+A\beta}$

So, $S_f < S$, i.e. improve the stability of the amplifier.

Increase of Bandwidth ⇒

Let f_L and f_h are the lower and upper cutoff frequency of a single stage R-C Coupled amplifier with a mid band gain A_m

From RC Coupled amplifiers without feedback

$$A_L = \frac{A_m}{1 - j\,(f_L/f)} \;\&\; A_h = \frac{A_m}{1 + j\,(f/f_h)}$$

Now voltage gain with feedback

$$A_{Lf} = \frac{A_L}{1+A_L\beta}, \; A_{hf} = \frac{A_h}{1+A_h\beta} \;\&\; A_{mf} = \frac{A_m}{1+A_m\beta}$$

Now,
$$A_{Lf} = \frac{A_m / 1 - j\,(f_L/f)}{1 + \frac{A_m\beta}{1-j(f_L/f)}} = \frac{A_m}{1 + A_m\beta - j\,(f_L/f)}$$

$$= \frac{A_m / 1+A_m\beta}{\frac{1+A_m\beta - j\,(f_L/f)}{1+A_m\beta}}$$

$$= \frac{A_{mf}}{1 - j\,\frac{f_L}{f(1+A_m\beta)}}$$

Again Now, $f_{lf} = \frac{f_L}{1+A_m\beta}$.

So, $A_{lf} = \frac{A_{mf}}{1-j\left(\frac{f_{lf}}{f}\right)}$.

$\therefore$ For negative feedback $f_{lf} < f_L$.

Similarly we can show that

$$A_{hf} = \frac{A_{mf}}{1+j\left(f/f_{hf}\right)} \text{ with } f_{hf} = f_h(1+A_m\beta).$$

$\therefore$ $f_{hf} > f_h$ for negative feedback.

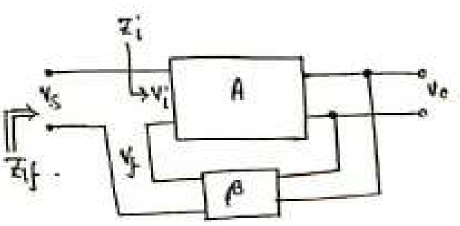
So, using negative feedback we can increase the band width of the amplifier.

- Input resistance $\Rightarrow$.

If the feedback signal is returned to the input in series with the applied voltage (regardless of whether the feedback is obtained by sampling the output current or voltage), it increase the input resistance, since the feedback voltage V_f oppose V_s, the input current is less than that of when V_f absent.

Negative feedback in which the feedback signal is returned to the input in shunt with the applied signal (regardless of whether the feedback is obtained by sampling the output current or voltage) decrease the input resistance

- Voltage Series $\Rightarrow$.



If I_i be the current following through Z_i then

$Z_i = V_i/I_i$

with feedback input impedance $Z_{if} = \frac{V_s}{I_i}$

But for negative feedback $V_i = V_s - V_f$

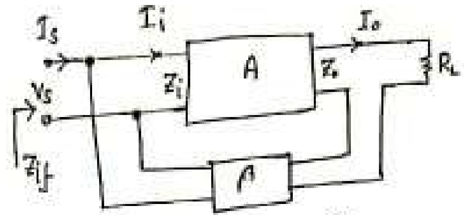
Or, $v_s = v_i + v_f = v_i + \beta v_o$
$= v_i(1+A\beta)$

$\therefore Z_{if} = \dfrac{v_i(1+A\beta)}{I_i} = Z_i(1+A\beta)$.

Again for negative feedback $(1+A\beta) > 1$

So, $Z_{if} > Z_i$

Current shunt ⇒.



There is another type of mixing known as Shunt mixing. In this Case current gain is define as $A_I = I_o/I_i$

The input impedance without feedback is $Z_i = \dfrac{V_s}{I_i}$

The input impedance with feedback is $Z_{if} = \dfrac{V_s}{I_s}$.

But $I_s = I_i + I_f$ $\quad \left[I_f = \beta I_o = A_I \beta I_i \right]$

$= I_i(1 + A_I\beta)$

So $Z_{if} = \dfrac{V_s}{I_i(1+A_I\beta)} = Z_i/(1+A_I\beta)$.

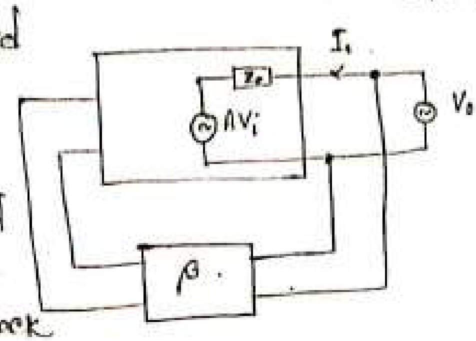
So, Here $Z_{if} < Z_i$

Output resistance ⇒.

Negative feedback in which samples the output voltage regardless of how this output signal is returned to the input tends to decrease the output resistance Where as for current sampling output resistance increase.

Voltage series ⇒.

In order to calculate the ~~the~~ output impedance (or resistance) of an amplifier with feedback the input source V_s is reduced to zero and a voltage source of emf V_o is connected to the output terminals after removing the load impedance.



If I' be the current delivered by V_o with no feedback, the output impedance without feedback is $Z_i = \frac{V_o}{I'}$

with feedback the input voltage of main amplifier is

$$v_i = -V_f = -\beta V_o.$$

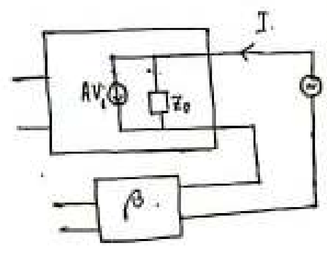
with feedback, the current I_o is given by.

$$I_o = \frac{V_o - (-A\beta V_o)}{Z_o} = \frac{V_o(1+A\beta)}{Z_o} \quad \left[\text{Since } V_o = I_o Z_o + AV_i\right].$$

Hence output impedance with feedback

$$Z_{of} = \frac{V_o}{I_o} = \frac{Z_o}{1+A\beta}. \quad \text{So, } Z_{of} < Z_o$$

(iii) <u>Current Series</u> ⇒.



Let Z_o be the output impedance of the amplifier without feedback, then with 'no feedback', current delivered by the voltage source V_o is $I' = V_o/Z_o$.

with feedback let I be the current drawn by the amplifier from the source

$$\therefore \text{Output current } I = \frac{V_o}{Z_o} - AV_i$$

$$= \frac{V_o}{Z_o} - AV_f \quad \left[\text{Since } V_i = V_f\right].$$

$$= V_o/Z_o - A\beta I$$

$$V_o/Z_o = I(1+A\beta).$$

$$\therefore \cancel{Z_{of} = \frac{V_o}{I}} \qquad Z_{of} = \frac{V_o}{I} = Z_o(1+A\beta).$$

$$\therefore Z_{of} > Z_o.$$