Chapter 7

# FEEDBACK IN AMPLIFIERS



## (NEGATIVE & POSITIVE)

This is developed by Harold Black, a Telecom Engr. in 1928 to improve performance of audio amplifiers used in telephone exchanges.

Feedback can be NEGATIVE also known as Degenerative or it can be POSITIVE also known as Regenerative!

Usually negative feedback is provided in amplifiers to achieve following objectives:

1. De-Sensitize the Gain: Change in $\beta$ due to temperature variation or piece-to-piece variation should less affect the Voltage Gain.
2. Reduce Non-Linear Distortion: To make input-output characteristics more linear so that gain becomes independent of signal level.
3. Reduce Effect of Noise: minimise the effect of internally induced noise due to Semiconductors and thermal processes.
4. Control Input & Output Impedances: Raise or Lower the input and output impedance value to suit application.
5. Extend the Bandwidth: To increase bandwidth at the cost of Gain.

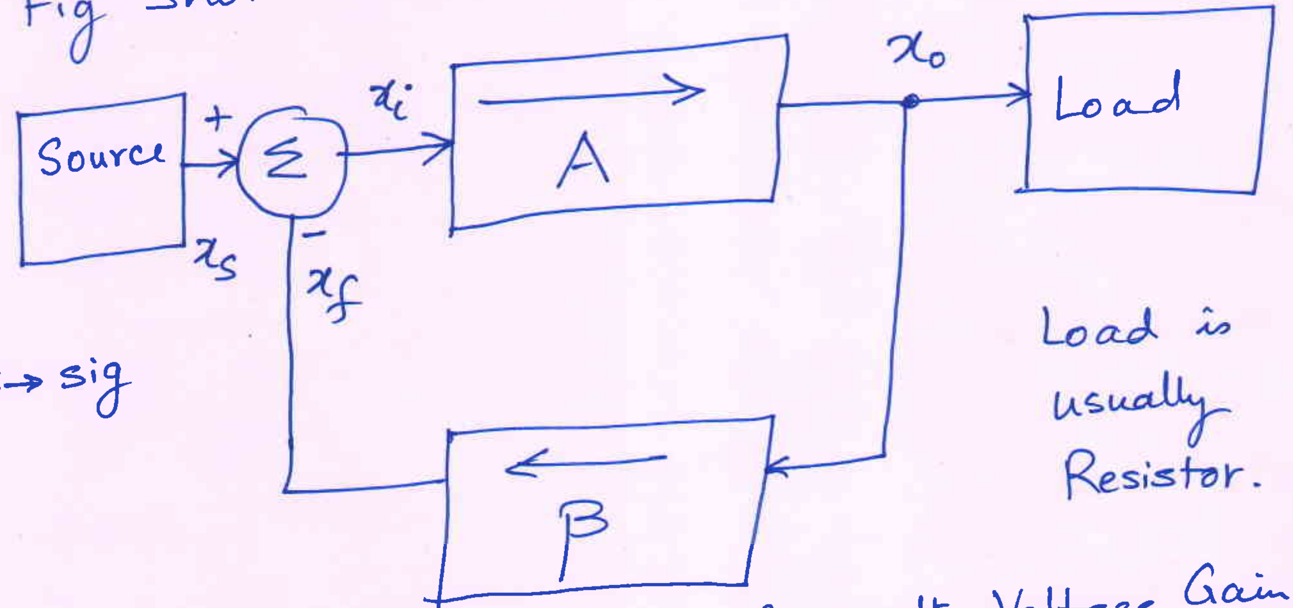
All of above benifits accrue due to loss of current & voltage gain. This is the primary objective of introducing negative feedback in amplifiers.

Positive Feedback increases Gain.

Usually increase in Gain results in INSTABILITY and amplifiers become oscillators, so it is primarily used in linear oscillators & multivibrators.

## General Feedback Theory

Fig shows basis structure




s → sig

Load is usually Resistor.

A — Unidirectional Amplifier with Voltage Gain A

β — Feedback Network, unidirectional which allows $x_f$ a fraction of output $x_o$ to be added/Subtracted with input $x_s$. This has nothing to do with β of a BJT.

Σ — A summer which adds two signal inputs $x_s$ and $(-x_f)$ and produces output $x_i$.

The basic amplifier operation gives

input $= x_i$ ; Output $= x_o$ ; Voltage Gain $= A$

$$\therefore A = \frac{x_o}{x_i} \quad --- (1)$$

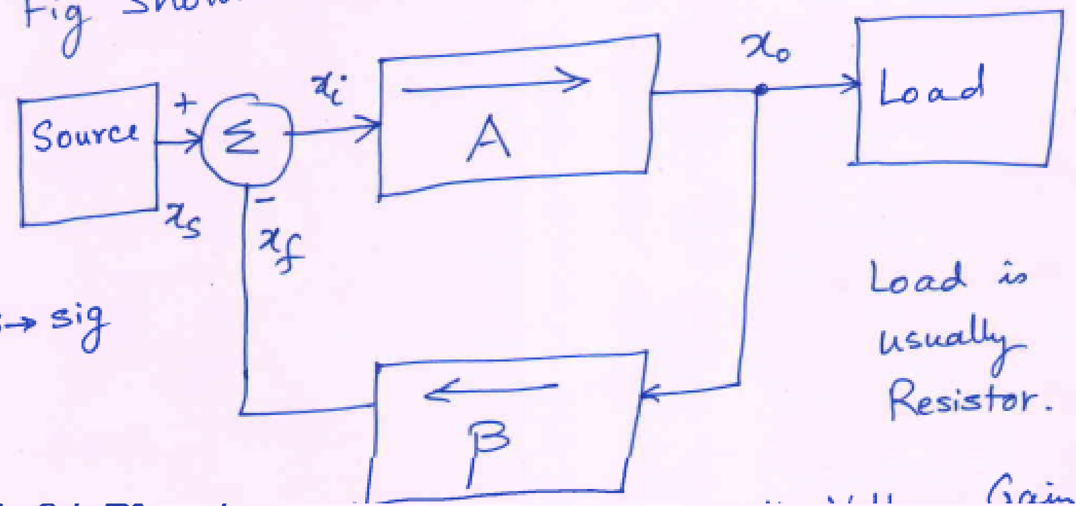
A is FORWARD TRANSMISSION GAIN

$$\text{or} \quad x_o = A . x_i \quad --- (2)$$

This output is fed back to a feedback network whose gain is $\beta$ and whose output is $x_f$

Fig shown · Voltage Gain $= \beta$

in · or A




Load is usually Resistor.

GAIN or TION is

or $s \to$ sig

Gain A

The equation

$$x_i = x_s - x_f \quad --- (4)$$

Subtraction makes it NEGATIVE Feedback. [If we add $x_f$ here then it will make it Positive Feedback].

$$\text{Gain with Feedback} = A_f = \frac{x_o}{x_s}$$

$$A_f = \frac{A . x_i}{x_s} = \frac{A\left[x_s - x_f\right]}{x_s}$$

$$= A - A\frac{x_f}{x_s}$$

Now $x_f = \beta . x_o$

$$A_f = A - \frac{A\beta \cdot x_o}{x_s}$$

$$= A\left(1 - \beta \cdot \frac{x_o}{x_s}\right)$$

If I put $x_o/x_s = A_f$ then we get

$$A_f = A(1 - \beta A_f)$$

$$= A - A\beta A_f$$

or $A_f + A\beta A_f = A$

$$A_f(1 + A\beta) = A$$

$$\therefore A_f = \frac{A}{1 + A\beta} \quad \text{----} \quad (5)$$

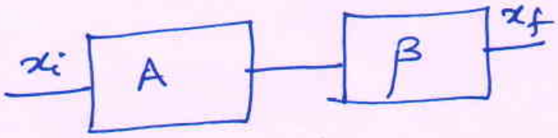
Usually $A\beta$ is +ve and $\gg 1$

$$\therefore A_f \ll A$$

or GAIN WITH FEEDBACK IS QUITE LESS THAN GAIN WITHOUT FEEBACK. This ratio is dependend upon $1+\beta A$. ~~called as~~

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

$A\beta$ is called as LOOP GAIN.




$$\frac{x_f}{x_i} = A\beta$$

$$\boxed{(1 + A\beta) \rightarrow \text{DESENSITIVITY FACTOR.}}$$

Note $A_f = \dfrac{A}{1 + A\beta}$

If $\beta$ is adjusted such that $A\beta >> 1$ then

$$A_f \approx \frac{A}{A\beta} \approx \frac{1}{\beta}. \quad \text{---} (6)$$

Thus GAIN with feedback nearly depends upon value of feedback network gain or $\beta$. Since this network is usually designed using precision passive components like resistors, we can have a very stable $\beta$ value. This will ensure that under many variations of $A$, $A_f$ remains more or less stable or constant.

If $\beta = \dfrac{1}{10}$ then $A_f \approx 10$

irrespective whether $A = \cancel{10}, 100$ or $1000, 10000.$
important consideration is $A\beta >> 1$.

— x —

Relationship Between $x_f$ and $x_s$

$$x_f = A\beta \cdot x_i$$
$$= A\beta \cdot [x_s - x_f]$$
$$= A\beta x_s - A\beta x_f$$

or $x_f + A\beta x_f = A\beta x_s$

$$x_f(1+A\beta) = A\beta\, x_s$$

$$\therefore \quad x_f = \left[\frac{A\beta}{1+A\beta}\right] \cdot x_s \quad \text{--- (7)}$$

Now, if $1+A\beta \approx A\beta$ or $A\beta >> 1$ then

$$x_f \simeq \frac{A\beta}{A\beta} \cdot x_s \simeq x_s$$

So, when we provide very large feedback the ... equal in magnitude

fe ... ce of two,

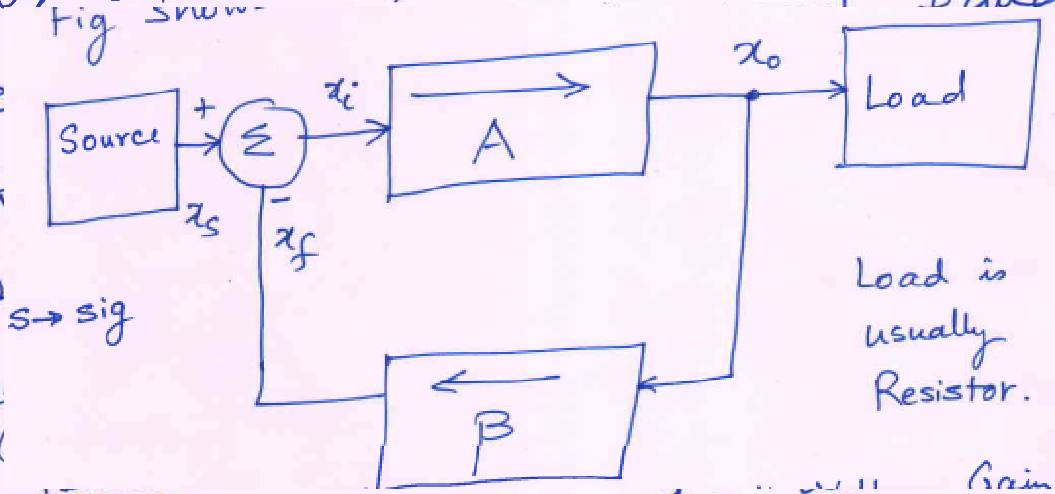
ti ... small or

wo ... ACK SIGNAL

ne ... L.

IS ...

Fig shows




Get a relation between $x_i$ ... Substituting Eq. 7

$$x_i = x_s - x_f$$

$$= x_s - \left[\frac{A\beta}{1+A\beta}\right] \cdot x_s$$

$$= x_s\left[1 - \left(\frac{A\beta}{1+A\beta}\right)\right]$$

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

For $A\beta >> 1$, $x_i << x_s$ or negligible.

INPUT TO A becomes very small.

# Effect of Negative Feedback

## 1. Gain Desensitivity

in $A_f = \dfrac{A}{1+A\beta}$

if we assume that $\beta$ is constant then

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

% change in $A_f$      % change in Amplifier Gain.

If $1+A\beta$ = say 20 then

Gain Sensitivity with F/B $= \dfrac{1}{20}$ x Gain Sensitivity with F/B

So amplifier Gain is 20 times more stable.

## 2. Bandwidth Extension

Let us assume an amplifier having a single pole at $s = \omega_H$ and Tr. Fn. or Gain as:

$$A_{(s)} = \frac{A_M}{1 + s/\omega_H}$$

$\omega_H$ = upper 3-db freq.

If this amplifier is enclosed in Feedback block, we saw earlier, its gain with f/b will become $A_f(s)$, assuming $\beta$ is not a function of s and a constant:

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

$$= \frac{A_M/(1+A_M\beta)}{1+\dfrac{s}{\omega_H(1+A_M\beta)}}$$

A casual inspection of denominator of s shows that $\omega_H$ is multiplied by Desensitivity Factor $(1+A_M\beta)$. If we define

$\omega_{Hf}$ = 3-db upper cutoff frequency with Feedback

$= \omega_H(1+A_M\beta)$ then

$$A_f(s) = \frac{[A_M/(1+A_M\beta)]}{1+\dfrac{s}{\omega_{Hf}}}$$

← New Midband Gain

In short due to negative Feedback:

Midband Gain of Amplifier Falls from

$$A_M \text{ to } \frac{A_M}{(1+A_M\beta)} = A_{MF}$$

and 3-db upper cutoff frequency $\omega_{Hf}$ gets EXTENDED By a factor of $(1+A_M\beta)$.

If $\omega_H$ was 0.1 GHz or 100 MHz and $(1+A_M\beta) = 20$ then new 3-db cutoff freq. will be 0.1 GHZ $\times$ 20 = 2.0 GHz or 2000 MHz. Ofcourse midband Gain will fall from $A_M$ to $A_M/20$.

Do it Yourself: Chapt. 7.2.3 Noise Reduction

7.2.4 Reduction in Non-linear Distortion.