Feedback Amplifiers

Introduction :

Feedback plays a very important role in electronic circuits and the basic parameters such as input impedance, output impedance, current gain, voltage gain and bandwidth may be altered considerably by the use of feedback for a given amplifier.

In large signal amplifiers and electronic measuring instruments, the major problem of distortion should be avoided by feedback.

Feedback is also used to maintain the gain independent of external factors.

A portion of the output signal is ~~altered~~ taken ~~out~~ from the output of the amplifier and is combined with the normal input signal and thereby the feedback is accomplished.

Basic concept of feed back :

A block diagram of an amplifier with feedback is shown in figure below. The output quantity is sampled by a suitable sampler and fed to the feedback network. The output of feedback network which has a fraction of the output signal is combined with external source signal ϕ_s through a comparator and fed to the basic amplifier.

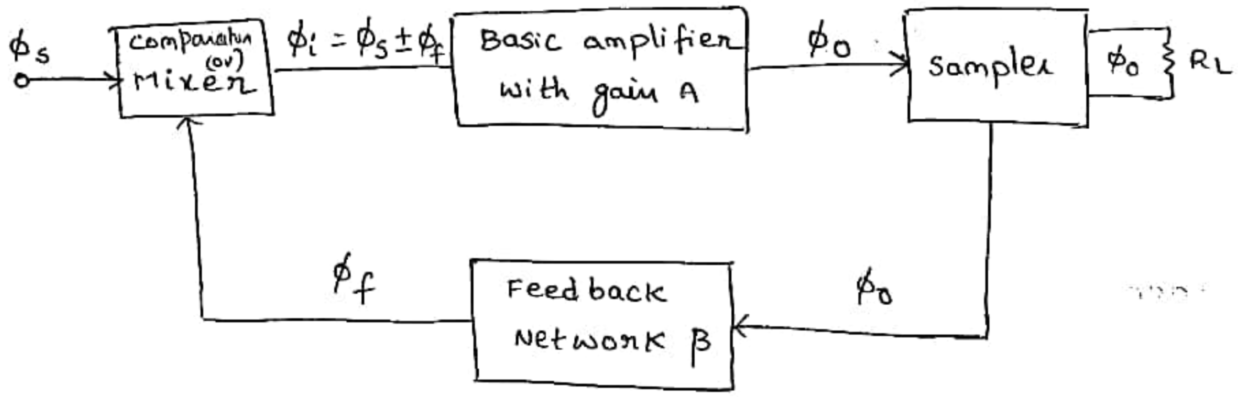

Fig: Block diagram of an amplifier with feedback

Here A → gain of the basic amplifier $= \frac{\phi_o}{\phi_i}$

β → feedback ratio $= \frac{\phi_f}{\phi_o}$

A_f → gain of the feedback amplifier $= \frac{\phi_o}{\phi_s}$

ϕ_s → a.c input signal

ϕ_f → feedback signal.

There are two types of feedback

(i) positive feedback (ii) Negative feedback.

i) <u>positive feedback</u> :-

If the feedback signal ϕ_f is inphase with the input signal ϕ_s, then the net effect of the feedback will increase the input signal given to the amplifier ie $\phi_i = \phi_s + \phi_f$. Hence the input voltage applied to the basic amplifier is increased which further increases ϕ_o. This type of feedback is said to be positive or regenerative feedback. Gain of the amplifier with positive feedback is

$$A_f = \frac{\phi_o}{\phi_s} = \frac{\phi_o}{\phi_i - \phi_f} = \frac{1}{\frac{\phi_i}{\phi_o} - \frac{\phi_f}{\phi_o}}$$

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

Here $|A_f| > |A|$. The product of the open loop gain and feedback factor is called the loop gain ($A\beta$). If $|A\beta| = 1$, then $A_f = \infty$. Hence the gain of the amplifier with positive feedback is infinite and the amplifier gives an a.c output without a.c input signal. Thus the amplifier acts as an oscillator. The positive feedback increases the instability of an amplifier, reduces the bandwidth and increases the distortion and noise. The property of the positive feedback is utilised in oscillators.

2. Negative feedback :-

If the feedback signal ϕ_f is out of phase with the input signal ϕ_s, then $\phi_i = \phi_s - \phi_f$. So the input voltage applied to the basic amplifier is decreased and corresponding the output is decreased. Hence, the voltage gain is reduced. This type of feedback is known as negative or degenerative feedback. Gain of the amplifier with negative feedback is

$$A_f = \frac{\phi_o}{\phi_s} = \frac{\phi_o}{\phi_i + \phi_f} = \frac{1}{\frac{\phi_i}{\phi_o} + \frac{\phi_f}{\phi_o}} = \frac{1}{\frac{1}{A} + \beta}$$

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

Here $|A_f| < |A|$.

If $|A\beta| >> 1$, $|A| >> \frac{1}{\beta}$

$\frac{1}{\beta} << |A|$, then $A_f \simeq \frac{1}{\beta}$, where β = feedback ratio

so the gain depends entirely on the feedback network.

If the feedback network contains only stable passive elements, the gain of the amplifier using negative feed back is also stable.

Negative feedback is used to improve the performance of electronic amplifiers.

Negative feedback helps to increase the bandwidth, decreased distortion and noise, modify input and output resistances as desired.

All the above advantages are obtained at the expense of reduction in voltage gain.

Effects of Negative feedback on Amplifier characteristics

1. Stabilisation of Gain :-

The gain of the amplifier with negative feedback is

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

differentiating the above equation with respect to A,

$$\frac{dA_f}{dA} = 0 \cdot \frac{1}{1+A\beta} + A \frac{-1}{(1+A\beta)^2} \cdot \beta$$

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

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

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

The term $\frac{dA_f}{A_f}$ represents the fractional change in amplifier voltage gain with feedback and $\frac{dA}{A}$ denotes the fractional change in voltage gain without feedback the term $\frac{1}{1+A\beta}$ is called Sensitivity.

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

$$\text{sensitivity} = \frac{\frac{dA_f}{A_f}}{\frac{dA}{A}} = \frac{1}{1+A\beta}$$

The reciprocal of the term sensitivity is called desensitivity

$$\text{desensitivity} = 1+A\beta.$$

2) Increase of Bandwidth

The bandwidth of an amplifier is the difference between the upper cut-off frequency f_2 and the lower cut-off frequency

The product of voltage gain and bandwidth of an amplifier without feedback and with feedback remains the same. ie $A_f \times BW_f = A \times BW$.

As the voltage gain of a feedback amplifier reduces by the factor $\frac{1}{1+A\beta}$, its bandwidth would be increased by $(1+A\beta)$.

ie $A_f \times BW_f = A \times BW \Rightarrow \frac{A_f}{A} \times BW_f = BW$

$$\frac{1}{1+A\beta} \times BW_f = BW \Rightarrow BW_f = BW(1+A\beta)$$

where A is the mid band gain without feed back.

Due to the negative feedback in the amplifier, the upper cut-off frequency (f_{2f}) is increased by the factor $(1+A\beta)$ and the lower cut-off frequency f_{1f} is decreased by the same factor $(1+A\beta)$.

These upper and lower 3 dB frequencies of an amplifier with negative feedback are given by the relations

$$f_{2f} = f_2(1+A\beta) \quad \text{and} \quad f_{1f} = f_1 \cdot \frac{1}{1+A\beta}.$$

3. Decreased Distortion :-

consider an Amplifier with a open loop voltage gain and a total harmonic distortion D. Then, with the introduction of negative feedback with the feed-back ratio (β). the distortion will reduce to

$$D_f = \frac{D}{1+A\beta}$$

4. Decreased Noise :-

there are many sources of noise in an Amplifier depending upon the active device used. with the use of negative feedback with the feedback ratio β, the noise N can be reduced by a factor of $\frac{1}{1+A\beta}$. thus the noise with feedback is given by

$$N_f = \frac{N}{1+A\beta}$$