FEED BACK AMPLIFIERS

INTRODUCTION

A practical amplifier has a gain of nearly one million i.e. its output is one million times the input. Consequently, even a casual disturbance at the input will appear in the amplified form in the output. There is a strong tendency in amplifiers to introduce hum due to sudden temperature changes or stray electric and magnetic fields. Therefore, every high gain amplifier tends to give noise along with signal in its output. The noise in the output of an amplifier is undesirable and must be kept to as small a level as possible. The noise level in amplifiers can be reduced considerably by the use of negative feedback i.e. by injecting a fraction of output in phase opposition to the input signal. This can be achieved by providing negative feedback in transistor amplifiers.

Feedback

The process of injecting a fraction of output energy of some device back to the input is known as feedback. The principle of feedback is probably as old as the invention of first machine but it is only some 50 years ago that feedback has come into use in connection with electronic circuits. It has been found very useful in reducing noise in amplifiers and making amplifier operation stable. Depending upon whether the feedback energy aids or opposes the input signal, there are two basic types of feedback in amplifiers viz positive feedback and negative feedback.

(i) **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. This is illustrated in Fig. 1. Both amplifier and feedback network introduce a phase shift of 180°. The result is a 360° phase shift around the loop, causing the feedback voltage Vf to be in phase with the input signal Vin.

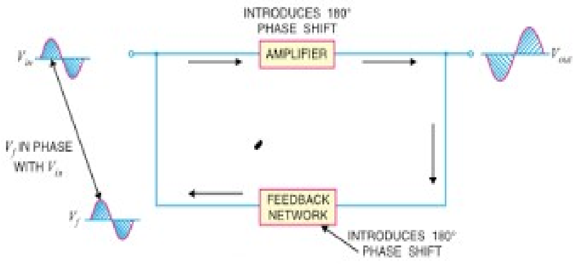

Figure 1

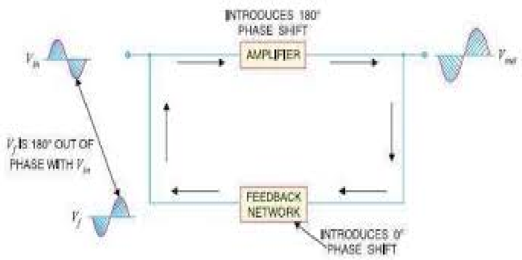

Figure 2

The positive feedback increases the gain of the amplifier. However, it has the disadvantages of increased distortion and instability. Therefore, positive feedback is seldom employed in amplifiers. One important use of positive feedback is in oscillators. If positive feedback is sufficiently large, it leads to oscillations. As a matter of fact, an oscillator is a device that converts d.c. power into a.c. power of any desired frequency.

(ii) **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. This is illustrated in Fig. 2. As you can see, the amplifier introduces a phase shift of 180° into the circuit while the feedback network is so designed that it introduces no phase shift (i.e., 0° phase shift). The result is that the feedback voltage V_f is 180° out of phase with the input signal V_{in}.

Principle of Negative Feedback:

A feedback amplifier has two parts viz an amplifier and a feedback circuit. The feedback circuit usually consists of resistors and returns a fraction of output energy back to the input. Fig. 1.3 shows the principles of negative voltage feedback in an amplifier. Typical values have been assumed to make the treatment more illustrative. The output of the amplifier is 10 V. The fraction of this output i.e. 100 mV is fed back to the input where it is applied in series with the input signal of 101 mV. As the feedback is negative, therefore, only 1 mV appears at the input terminals of the amplifier. Referring to Fig. 1.3, we have, Gain of amplifier without feedback,

$$A_v=10V/1mV=10000$$

Fraction of output voltage feedback β =100mV/10V=0.01

Gain of amplifier with feedback A_{vf}=10V/101 mV=100

The following points are worth noting :

1. When negative voltage feedback is applied, the gain of the amplifier is reduced. Thus, the gain of above amplifier without feedback is 10,000 whereas with negative feedback, it is only 100.
2. When negative voltage feedback is employed, the voltage actually applied to the amplifier is extremely small. In this case, the signal voltage is 101 mV and the negative feedback is 100 mV so that voltage applied at the input of the amplifier is only 1 mV.

3. In a negative voltage feedback circuit, the feedback fraction mv is always between 0 and 1.

The gain with feedback is sometimes called closed-loop gain while the gain without feedback is called open-loop gain. These terms come from the fact that amplifier and feedback circuits form a "loop". When the loop is "opened" by disconnecting the feedback circuit from the input, the amplifier's gain is A_v, the "open-loop" gain. When the loop is "closed" by connecting the feedback circuit, the gain decreases to A_{vf} , the "closed-loop" gain.

General Expression for Gain of a Basic Feedback Amplifier(-ve)

$A_{vf} = A_v / 1 + \beta A$

$V_{id} = V_{in} - V_f$

Where V_{in} = input voltage

Vf = feedback voltage

V_{id} = difference input voltage

The circuit amplifies the difference input voltage V_{id}. This difference is equal to the input voltage V_{in} minus feedback voltage V_f . In the other words the feedback voltage always opposes the input voltage (or is out of phase by 180^o with respect to the input voltage) hence, the feedback is said to be negative.

$V_o = A_v V_{in} - A_v V_f$ $\qquad\qquad$ $\beta = V_f / V_o$

$=> V_o = A_v V_{in} - A_v \beta V_o$

$=> V_o + A_v \beta V_o = A_v V_{in}$

$=> V_o (1+A_v\beta) = A_v V_{in}$ $\qquad A_v = V_o / V_{id}$

$=> V_o / V_{in} = A_v / (1+A_v\beta)$, $\qquad Avf = Vo/ Vin$

$=> A_v f = A_v (1 + A_v\beta)$

Gain with feedback is reduced by factor $1+ A_v\beta$.

Equation shows that feedback (- ve) reduces gain of amplifier.

$$A_{vf} = \frac{A_v}{1 + \beta A_v}$$

Negative Feedback Connection Types and Effects:

Series Current Feedback Amplifier

Series-Series Feedback Systems, also known as series current feedback, operates as a voltage-current controlled feedback system. In the series current configuration the feedback signal is in series with the input and is proportional to the load current, I_{out}. Actually, this type of feedback converts the current signal into a voltage which is actually fed back and it is this voltage which is subtracted from the input. For the series-series connection, the configuration is defined as the output current to the input voltage. Because the output current, I_o of the series connection is fed back as a voltage, this increases both the input and output impedances of the system. Therefore, the circuit works best as a transconductance amplifier with the ideal input resistance, R_{in} being very large, and the ideal output resistance, R_{out} is also very large. Then the "series-series feedback configuration" functions as transconductance type amplifier system as the input signal is a voltage and the output signal is a current. Then for a series-series feedback circuit the transfer gain is given as: $G_m = V_{out} \div I_{in}$.

Series-Shunt Feedback :

Series-Shunt Feedback, also known as series voltage feedback , operates as a voltagevoltage controlled feedback system. The error voltage fed back from the feedback network is in series with the input. The voltage which is fed back from the output being proportional to the output voltage, V_o as it is parallel, or shunt connected. For the series-shunt connection, the configuration is defined as the output voltage to the input voltage. Most inverting and noninverting operational amplifier circuits operate with series-shunt feedback producing what is known as a "voltage amplifier" . As a voltage amplifier the ideal input resistance, R_{in} is very large, and the ideal output resistance, R_{out} is very small. Then the "series-shunt feedback configuration" works as a true voltage amplifier as the input signal is a voltage and the output signal is a voltage, so the transfer gain is given as:

$A_v = V_{out} \div V_{in}$.

Parallel Current:

Shunt-Series Feedback, also known as shunt current feedback, operates as a current-current controlled feedback system. The feedback signal is proportional to the output current, I_o flowing in the load. The feedback signal is fed back in parallel or shunt with the input.

For the shunt-series connection, the configuration is defined as the output current to the input current. In the shunt-series feedback configuration the signal fed back is in parallel with the input signal and as such it's the currents, not the voltages that add. This parallel shunt feedback connection will not normally affect the voltage gain of the system, since for a voltage output a voltage input is required. Also, the series connection at the output increases output resistance, R_{out} while the shunt connection at the input decreases the input resistance, R_{in}. Then the "shunt-series feedback configuration" works as a true current amplifier as the input signal is a current and the output signal is a current, so the transfer gain is given as:

$A_i = I_{out} \div I_{in}$.

Parallel (Shunt) Voltage

Shunt-Shunt Feedback Systems, also known as shunt voltage feedback, operates as a current-voltage controlled feedback system. In the shunt-shunt feedback configuration the signal fed back is in parallel with the input signal. The output voltage is sensed and the current is subtracted from the input current in shunt, and as such it's the currents, not the voltages that subtract. For the shunt-shunt connection, the configuration is defined as the output voltage to the input current. As the output voltage is fed back as a current to a current-driven input port, the shunt connections at both the input and output terminals reduce the input and output impedance. Therefore the system works best as a transresistance system with the ideal input resistance, R_{in} being very small, and the ideal output resistance, R_{out} also being very small. Then the shunt voltage configuration works as transresistance type voltage amplifier as the input signal is a current and the output signal is a voltage, so the transfer gain is given as:

$Rm = I_{out} \div V_{in}$.

EFFECT OF APPLYING NEGATIVE FEEDBACK TO AN AMPLIFIER

The effect of negative feedback on an amplifier is considered in relation to gain, gain stability, distortion, noise, input/output impedance and bandwidth and gain-bandwidth product.

Gain

The gain of an amplifier is a measure of the "Amplification" of an amplifier, i.e. how much it increases the amplitude of signal. More precisely it is the ratio of the output signal amplitude to the input signal amplitude, and is given the symbol “A”. it can be calculated for voltage (A_v), Current (A_i), or power (A_p), when the subscript letter after the A is in lower case this refer to small signal conditions, and when the subscript is in capital letters, it refers to DC conditions. The gain or amplification for the three (3) types of amplifier can be described using the appropriate formula:

Voltage gain A_v = Amplitude of output voltage ÷ Amplitude of input voltage.

$$A_v = V_{out}/ V_{in}$$

Current gain A_i = Amplitude of output current ÷ Amplitude of input current.

$$A_i = I_{out}/ I_{in}$$

Power gain A_p = Signal power out ÷ Signal power in.

$$A_P = P_{out}/ P_{in}$$

The gain of an amplifier is governed, not only by the components (transistors etc.) used, but also by the way they are interconnected within the amplifier circuit.

Gain Stability

An important advantage of negative voltage feedback is that the resultant gain of the amplifier can be made independent of transistor parameters or the supply voltage variations .

$$A_{vf} = A_v /1 + A_v \beta$$

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

$Avf = A_v / 1 + A_v \beta = 1/\beta$

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.

Reduces non-linear distortion.

A large signal stage amplifier 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. It can be proved mathematically that: $D_{vf} = D/1 + A_v \beta$

Where D_{vf} = Distortion of amplifier with negative feedback

D = Distortion of amplifier without feedback

It is clear that by applying negative voltage feedback to an amplifier, distortion is reduced by a factor $1 + A_v \beta$.

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. The negative voltage feedback, therefore, improves the frequency response of the amplifier.

Increases circuit stability.

The output of an ordinary amplifier is easily changed due to variations in ambient temperature, frequency and signal amplitude. This changes the gain of the amplifier, resulting in distortion. However, by applying negative voltage feedback, voltage gain of the amplifier is stabilised or accurately fixed in value. This can be easily explained. 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. Consequently, the circuit stability is considerably increased.

Increases input impedance and decreases output impedance.

The negative voltage feedback increases the input impedance and decreases the output impedance of amplifier. Such a change is profitable in practice as the amplifier can then serve the purpose of impedance matching.

(a) Input impedance. The increase in input impedance with negative voltage feedback is given by below. Suppose the input impedance of the amplifier is Z_{in} without feedback and Z_{innew} in with negative feedback.

$$Z_{innew} = Z_{in}\,(1 + \beta A).$$

(b) Output Impedance: The output impedance of amplifier decreases with negative feedback given by equation:

$$Z_{innew} = \frac{Z_{in}}{1 + \beta A}$$