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C10T (Analog Systems and Apllications)

Topic – Amplifiers (Part – 3)

We have already discussed part 2 of this e-report.

Now let us continue part 3 of it.

Sub Topic – Feedback in 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.

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.

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(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 180^0. The result is a net 360^0 phase shift around the loop, causing the feedback voltage V_f to be in phase with the input signal V_{in}.

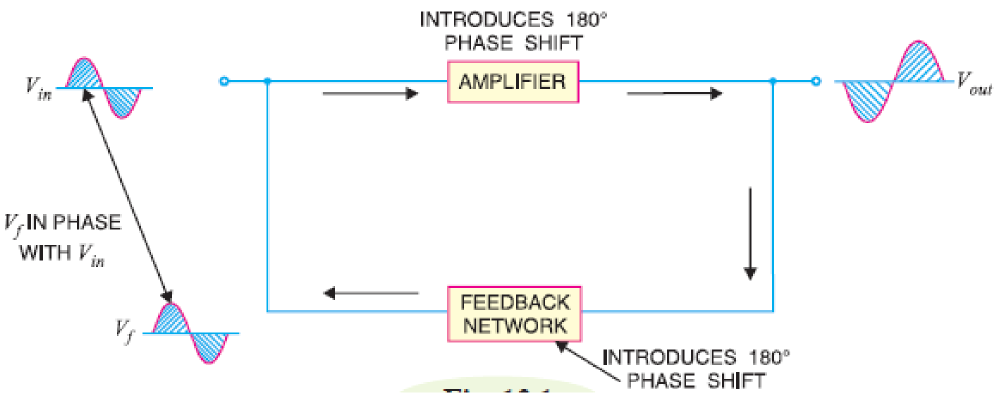

Fig. 1

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*. As we shall see that if positive feedback is sufficiently large, it leads to oscillations. As a matter of fact, an oscillator is a device that converts DC power into AC power of any desired frequency.

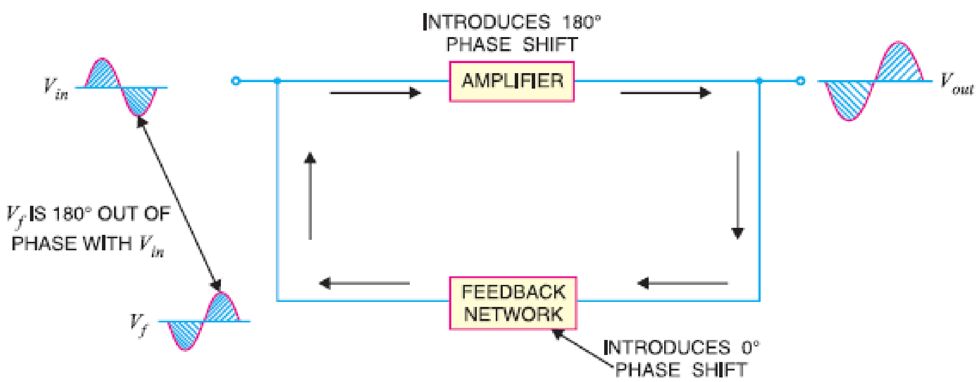

Fig. 2

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(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 we can see, the amplifier introduces a phase shift of 180^0 into the circuit while the feedback network is so designed that it introduces no phase shift (i.e. 0^0 phase shift). The result is that the feedback voltage V_f is 180^0 out of phase with the input signal V_{in}.

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:

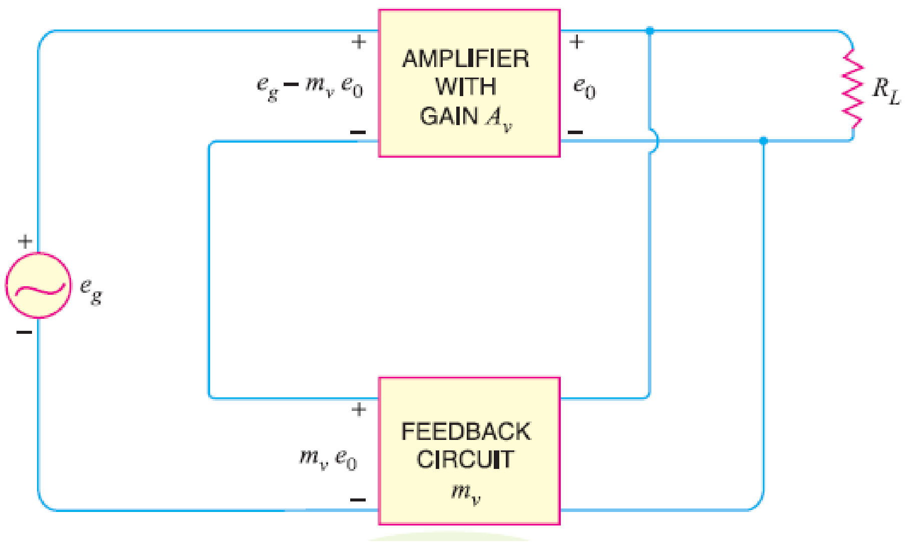

Fig. 3

Let us consider the negative voltage feedback amplifier shown in Fig. 3. The voltage gain of the amplifier without feedback is A_v. Negative feedback is then applied by feeding a fraction m_v of the output voltage e_0 back to amplifier input. Therefore, the actual input to the amplifier is given by $e_g - m_v e_0$. Now the output e_0 must be equal to the input voltage $e_g - m_v e_0$ multiplied by gain

A_v of the amplifier. So, $(e_g - m_v e_0)A_v = e_0$ or $\frac{e_0}{e_g} = \frac{A_v}{1+A_v m_v}$. But $\frac{e_0}{e_g}$ is the voltage gain of the amplifier with *negative feedback*. Therefore, we get

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

It may be seen that the gain of the amplifier without feedback is A_v. However, when negative voltage feedback is applied, the gain is reduced by a factor $1 + A_v m_v$. It is important to note that negative voltage feedback does not affect the current gain of the circuit.

By a similar kind of argument it can be shown that voltage gain of the amplifier with *positive feedback* with be $A_{vf} = \frac{A_v}{1-A_v m_v}$. Here the amplifier gain with feedback (A_v) gets enhanced.

Effects of Negative Voltage Feedback on Several Parameters:

The following are the effects (also advantages) of negative voltage feedback on several parameters on an amplifier.

(i) 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, given as $A_{vf} = \frac{A_v}{1+A_v m_v}$. 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 $A_{vf} \approx \frac{A_v}{A_v m_v} = \frac{1}{m_v}$. 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.

(ii) Non linear distortion. A large signal stage has non-linear distortion because its voltage gain changes at various points in the cycle. The negative

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voltage feedback reduces the nonlinear distortion in large signal amplifiers. It can be proved mathematically that $D_f = \frac{D}{1+A_v m_v}$, where D is the distortion in amplifier without feedback and D_f is the distortion in the amplifier with negative feedback. Therefore, it is clear that by applying negative voltage feedback to an amplifier, distortion is reduced by a factor $1 + A_v m_v$.

(iii) 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.

(iv) 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 stabilized 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.

(v) Input impedance. The negative voltage feedback increases the input impedance of the amplifier. The increase in input impedance with negative voltage feedback can be explained by referring to Fig. 4. Suppose the input impedance of the amplifier is Z_{in} without feedback and Z'_{in} with negative feedback. Let us further assume that input current is i_1. Therefore we have $e_g - m_v e_0 = i_1 Z_{in}$. Now we have $e_g = (e_g - m_v e_0) + m_v e_0 = (e_g - m_v e_0) + m_v A_v (e_g - m_v e_0) = (e_g - m_v e_0)(1 + A_v m_v) = i_1 Z_{in}(1 + A_v m_v)$. So, we get $\frac{e_g}{i_1} = Z_{in}(1 + A_v m_v)$, but $\frac{e_g}{i_1}$ is the input impedance with negative voltage feedback. So we finally get $Z'_{in} = Z_{in}(1 + A_v m_v)$.

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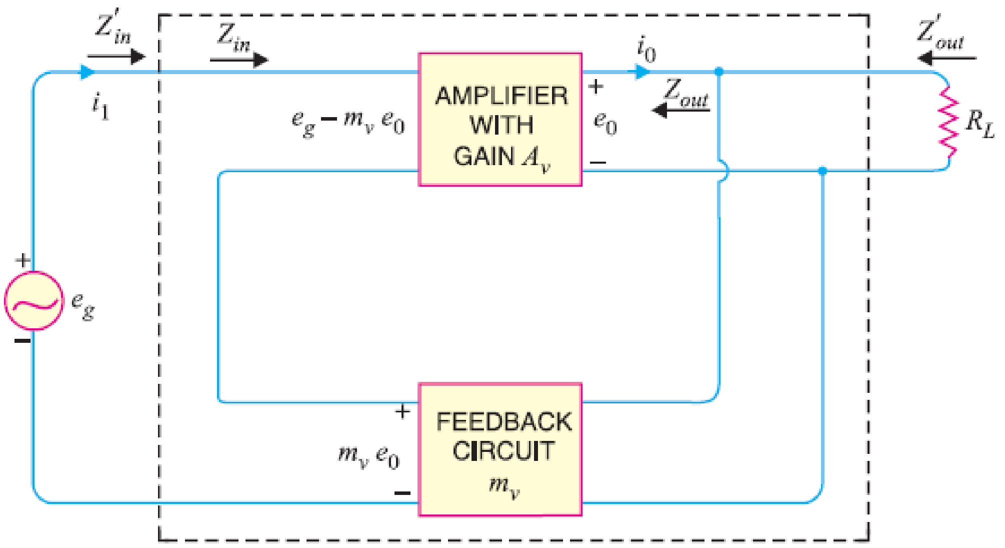

Fig. 4

It is clear that by applying negative voltage feedback, the input impedance of the amplifier is increased by a factor $1 + A_v m_v$. As $A_v m_v$ is much greater than unity, therefore, input impedance is increased considerably. This is an advantage, since the amplifier will now present less of a load to its source circuit.

(v) Output impedance. Following similar line, we can show that output impedance with negative voltage feedback is given by $Z'_{out} = \frac{Z_{out}}{1+A_v m_v}$, with Z_{out} output impedance without feedback and Z'_{out} output impedance with negative voltage 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.

Feedback Circuit:

The function of the feedback circuit is to return a fraction of the output voltage to the input of the amplifier. Fig. 5 shows the feedback circuit of negative

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voltage feedback amplifier. It is essentially a potential divider consisting of resistances R_1 and R_2. The output voltage of the amplifier is fed to this potential divider which gives the feedback voltage to the input.

From the Fig. 5, it is clear that voltage across R_1 is $\frac{R_1}{R_1+R_2}e_0$. Therefore feedback fraction $m_v = \frac{R_1}{R_1+R_2}$.

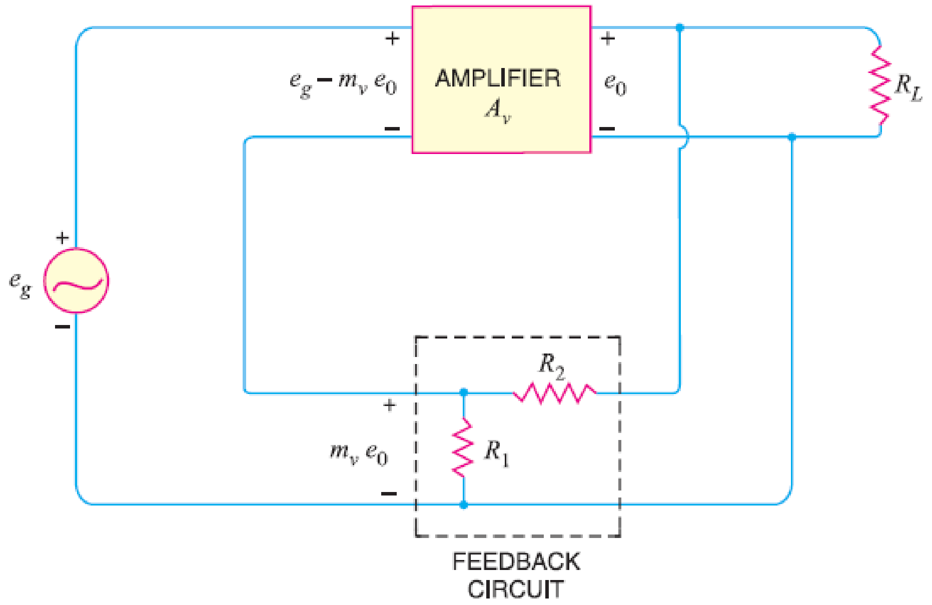

Fig. 5

This concludes part 3 of this e-report.

The discussion will be continuing in the part 4 of this e-report.

Reference:

Principles of Electronics, V.K. Mehta & Rohit Mehta, S. Chand & Company

(All the figures have been collected from the above mentioned reference)