5.1 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.

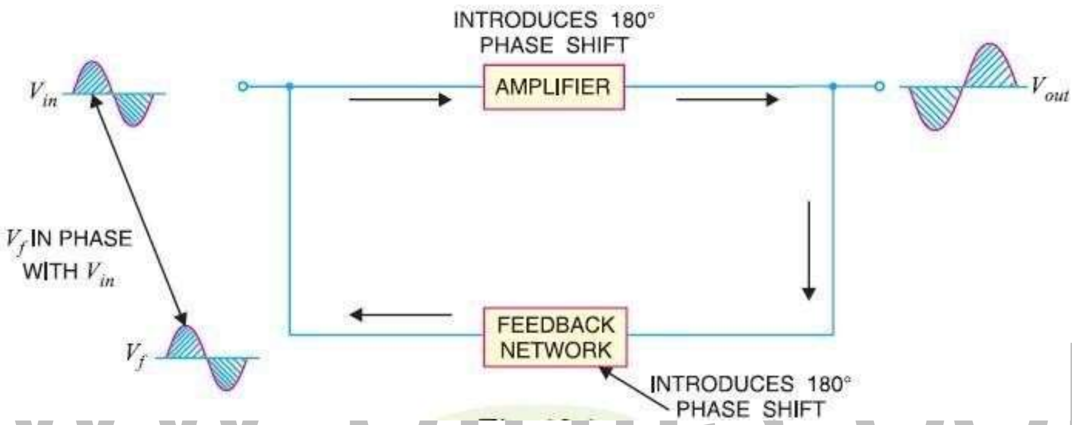

Figure: 5.1.1 Feedback

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 158]

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 in the next chapter, 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.

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. 5.1.2. 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 Vf is 180° out of phase with the input signal Vin.

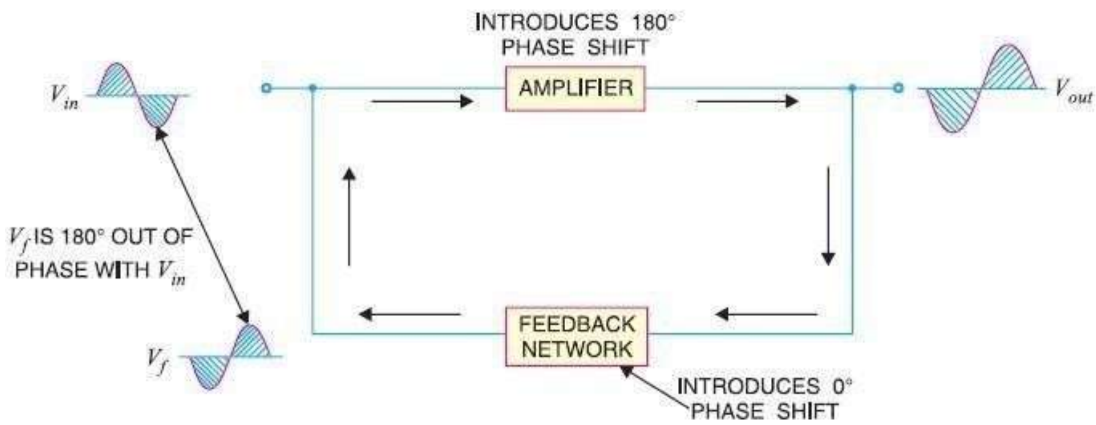

Figure: 5.1.2 Negative Feedback

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 158]

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.

5.5 Feedback Circuit

The function of the feedback circuit is to return a fraction of the output voltage to the input of the amplifier feedback circuit of negative voltage feedback amplifier. It is essentially a potential divider consisting of resistances R1 and R2. The output voltage of the amplifier is fed to this potential divider which gives the feedback voltage to the input.

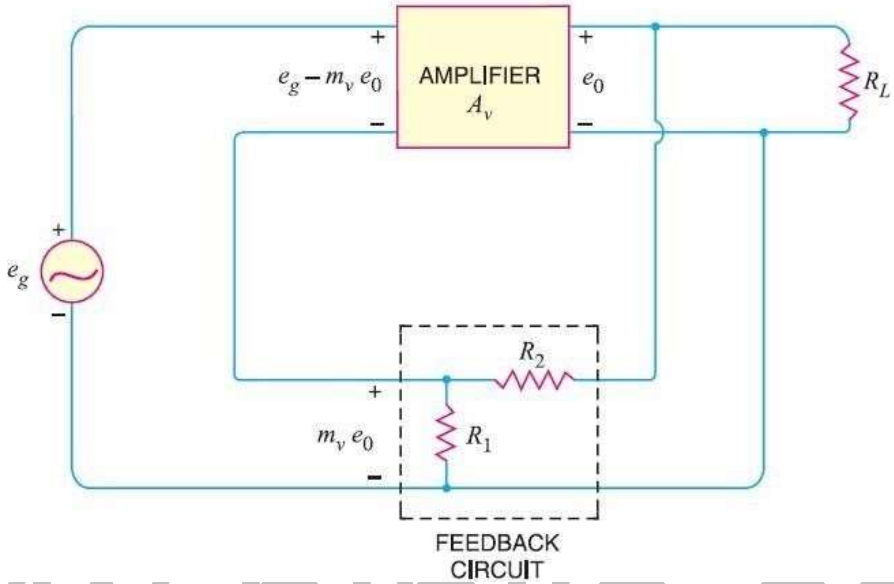

Figure: 5.5.1 Feedback Circuit

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 162]

Principles of Negative Current Feedback

In this method, a fraction of output current is feedback to the input of the amplifier. In other words, the feedback current (If) is proportional to the output current (I out) of the amplifier. Fig. 5.5.2 shows the principles of negative current feedback. This circuit is called current-shunt feedback circuit. A feedback resistor Rf is connected between input and output of the amplifier. This amplifier has a current gain of Ai without feedback. It means that a current I1 at the input terminals of the amplifier will appear as Ai I1 in the output circuit i.e., I out = Ai I1.

Now a fraction mi of this output current is feedback to the input through Rf. The fact that arrowhead shows the feed current being fed forward is because it is negative feedback.

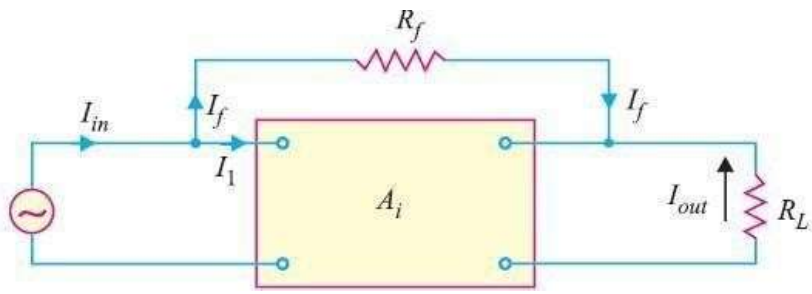

Figure: 5.5.2 Negative Current Feedback

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 162]

The following points may be noted carefully:

(i) The current gain of the amplifier without feedback is Ai. However, when negative current feedback is applied, the current gain is reduced by a factor (1 + mi Ai).

(ii) The feedback fraction (or current attenuation) mi has a value between 0 and 1.

(iii) The negative current feedback does not affect the voltage gain of the amplifier.

5.3 Gain of Negative Voltage Feedback Amplifier

Consider the negative voltage feedback amplifier shown in Fig. 5.3.1 The gain of the amplifier without feedback is Av. Negative feedback is then applied by feeding a fraction mv of the output voltage e0 back to amplifier input. Therefore, the actual input to the amplifier is the signal voltage eg minus feedback voltage mv e0 i.e.

Actual input to amplifier = eg − mv e0

The output e0 must be equal to the input voltage eg − mv e0 multiplied by gain Av of

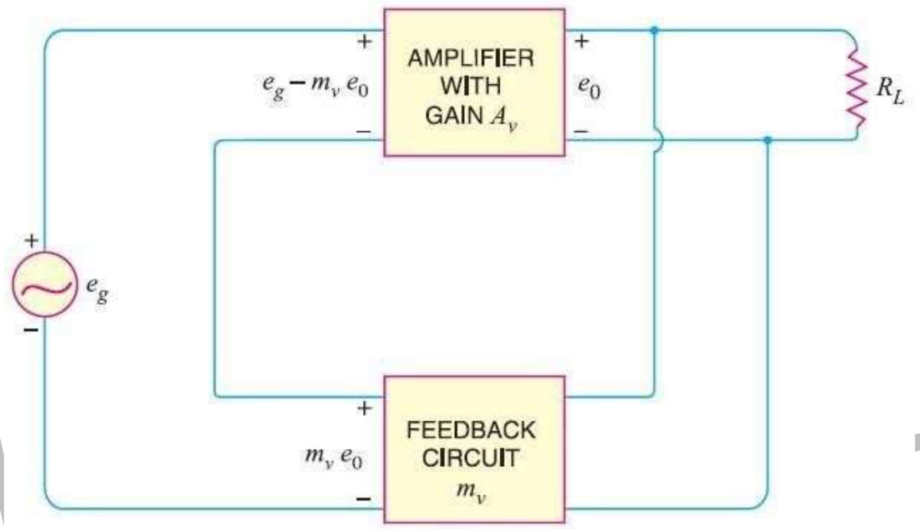

Figure: 5.3.1 Voltage Feedback in Amplifiers

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 161]

It may be seen that the gain of the amplifier without feedback is Av. However, when negative voltage feedback is applied, the gain is reduced by a factor 1 + Av mv. It may be noted that negative voltage feedback does not affect the current gain of the circuit.

5.4 Advantages of Negative Voltage Feedback

The following are the advantages of negative voltage feedback in amplifiers:

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.

For negative voltage feedback in an amplifier to be effective, the designer deliberately

makes the product Av mv much greater than unity. Therefore, in the above relation, 1 can be neglected as compared to Av mv and the expression becomes: It may be seen that the gain now depends only upon feedback fraction mv 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 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 It is clear that by applying negative voltage feedback to an amplifier, distortion is reduced by a factor 1 + Av mv.

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 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.

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.

5.6 Oscillators

An oscillator may be described as a source of alternating voltage. It is different than amplifier.

An amplifier delivers an output signal whose waveform corresponds to the input signal but whose power level is higher. The additional power content in the output signal is supplied by the DC power source used to bias the active device.

The amplifier can therefore be described as an energy converter, it accepts energy from theDC power supply and converts it to energy at the signal frequency. The process of energy conversion is controlled by the input signal, Thus if there is no input signal, no energy conversion takes place and there is no output signal.

The oscillator, on the other hand, requires no external signal to initiate or maintain the energy conversion process. Instead an output signals is produced as long as source of DC power is connected. Fig. 5.6.1, shows the block diagram of an amplifier and an oscillator.

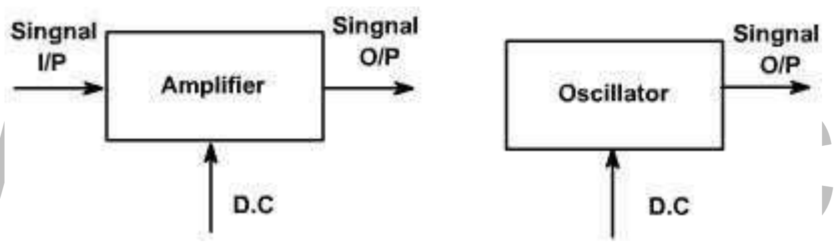

Fig. 5.6.1 amplifier Oscillators

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 165]

Oscillators may be classified in terms of their output waveform, frequency range components, or circuit configuration.

If the output waveform is sinusoidal, it is called harmonic oscillator otherwise it is called relaxation oscillator, which include square, triangular and saw tooth waveforms.

Oscillators employ both active and passive components. The active components provide energy conversion mechanism. Typical active devices are transistor, FET etc.

Passive components normally determine the frequency of oscillation. They also influence stability, which is a measure of the change in output frequency (drift) with time,

temperature or other factors. Passive devices may include resistors, inductors, capacitors, transformers, and resonant crystals.
Capacitors used in oscillator's circuits should be of high quality. Because of low losses
Damped Oscillations

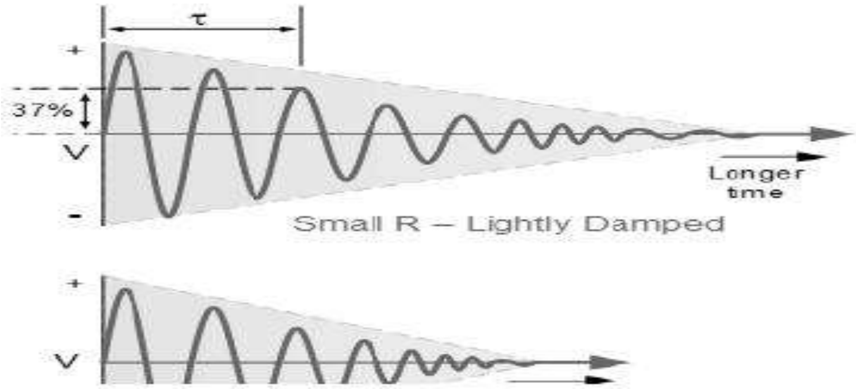

Fig. 5.6.2 Damped Oscillations
[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 165]

The frequency of the oscillatory voltage depends upon the value of the inductance and capacitance in the LC tank circuit. We now know that for resonance to occur in the tank circuit, there must be a frequency point were the value of XC, the capacitive reactance is the same as the value of XL, the inductive reactance (XL = XC) and which will therefore cancel out each other out leaving only the DC resistance in the circuit to oppose the flow of current.

If we now place the curve for inductive reactance on top of the curve for capacitive reactance so that both curves are on the same axes, the point of intersection will give us the resonance frequency point, (fr or ωr) as shown below.

5.2 Voltage Feedback in Amplifiers

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. 5.2.1 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 mv of this output i.e. 100 mV is feedback to the input where it is applied in series with the input signal of 101 mV. Asthe feedback is negative, therefore, only 1 mV appears at the input terminals of the amplifier. Referring to Fig. 5.2.1, we have, Gain of amplifier without feedback,

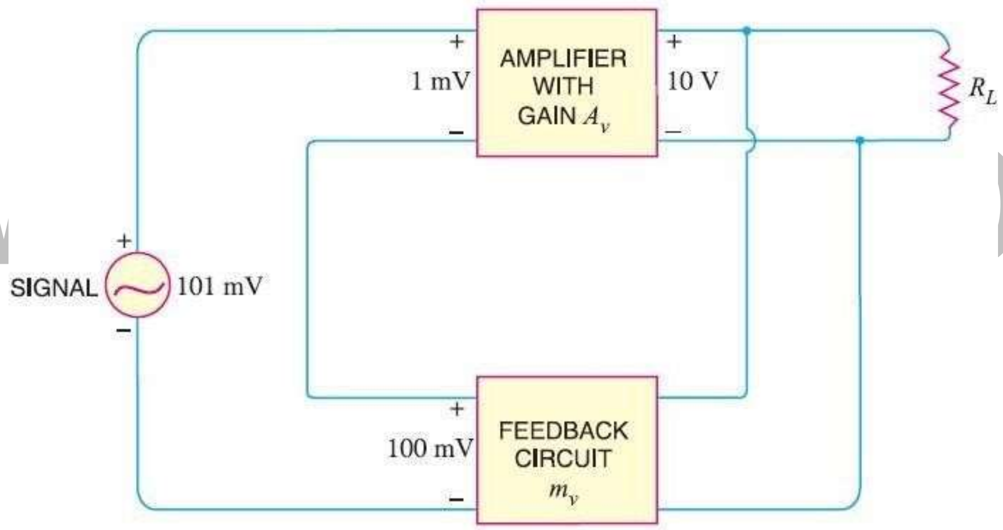

Figure: 5.2.1 Voltage Feedback in Amplifiers

[Source: "Electronic devices and circuits" by "Balbir Kumar, Shail.B.Jain, and Page: 160]

The following points are worth noting:

- 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.

- 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.

In a negative voltage feedback circuit, the feedback fraction mv is always between 0and 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 Av, the ―open-loop‖ gain. When the loop is ―closed‖ by connecting the feedback circuit, the gain decreases to Avf, the ―closed-loop‖ gain