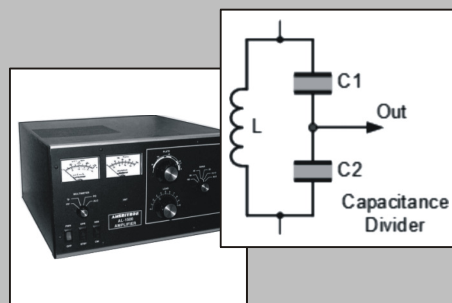
Chapter 2

# FEEDBACK AMPLIFIERS AND OSCILLATORS

[*22 MARKS*]

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## Chapter Details



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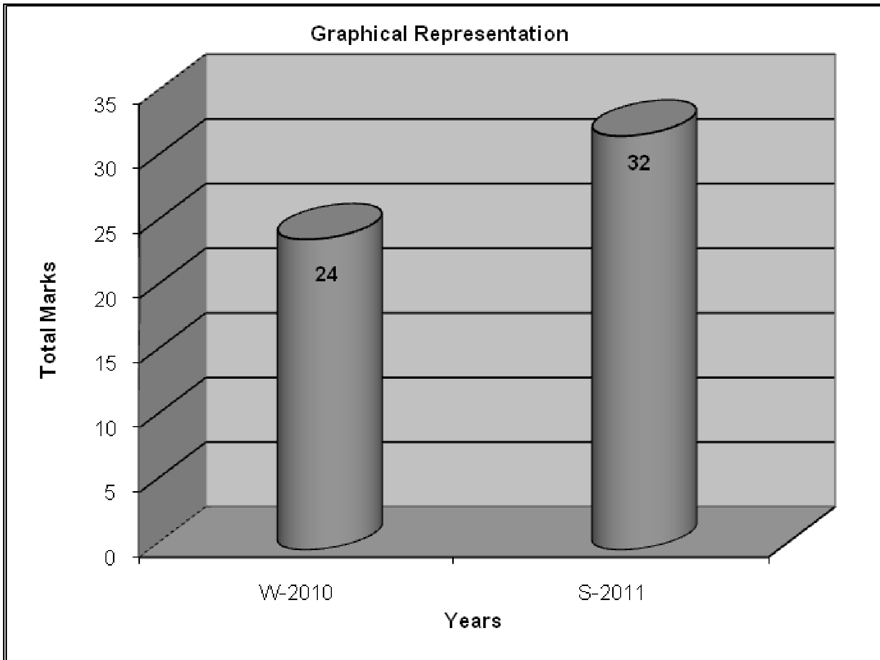
## Graphical and Statistical representation of questions asked from this chapter in previous years MSBTE Question Papers




**Statistical Analysis**

| MSBTE paper | Marks |
|---|---|
| W-2010 | 24 |
| S-2011 | 32 |

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## 2.1 INTRODUCTION

In an ideal linear amplifier, the mid-frequency region provides the output signal, which is exactly similar to that of the input signal. But in practical amplifiers, it is not like ideal amplifier because of non-linear characteristics of transistor, parameter variation and temperature effects. Some of these variations can be minimized by improving the involved basic devices. But there is a limit, beyond which this approach does not work. The best way is to use the principle of feedback, to achieve a desired degree of improvement. In feedback process, some part of the output is fed back to the input. The amplifier which uses the feedback principle, is called as feedback amplifier. Feedback amplifier consists of two parts:

*The feedback is a process of injecting some part of the output signal and then return it back to the input. The amplifiers which use the feedback principle are called as feedback amplifiers.*

i. An amplifier
ii. A feedback network

Depending upon weather the feedback signal increases or decreases the input signal, there are two basic types of feedback in amplifiers:

***Types of Feedback***
*i. Positive feedback*
*ii. Negative feedback*

**i. Positive feedback:** If the feedback signal (voltage or current) is applied in such a way that it is in phase with the input signal and thus increases it, then it is called as positive feedback.

***Positive feedback** is that in which original input signal and the feedback signal are in phase.*

Sometimes this positive feedback is also called as **regenerative feedback or direct feedback**. Due to the positive feedback, there is increase in the gain of the amplifier. But it produces excessive distortion due to which it is rarely used in amplifiers. The positive feedback is used in oscillators.

*
**BTE [S.2011]** – *2M*
*List and explain two types of feedback.*

**ii. Negative feedback:** If the feedback signal (i.e. voltage or current) is applied in such a way that it is out of phase with the input signal and thus decreases it, then it is called a negative feedback. Sometimes it is called as **degenerative or inverse feedback**. The negative feedback reduces gain of the amplifier. But it improves the amplifier performance in many other respects. Thus negative feedback is frequently used in small signal as well as with large signal amplifier circuits.

***Negative feedback** is that in which the original input signal and the feedback signal are out of phase.*

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**Comparison of Positive and Negative Feedback**

| | Positive feedback | Negative feedback |
|---|---|---|
| i. | Difference is either 0° or 360°. | Difference is 180°. |
| ii. | Thus input signal and feedback signals are in phase. | Input signal and feedback signals are out of phase. |
| iii. | Input voltage increases. | Input voltage decreases. |
| iv. | Output voltage increases. | Output voltage decreases. |
| v. | Stability is poor. | Stability is better. |
| vi. | Gain increases with feedback. | Gain decreases with feedback. |
| vii. | Noise increases with feedback. | Noise decreases with feedback. |

## 2.1.1 Principle of Feedback Amplifiers

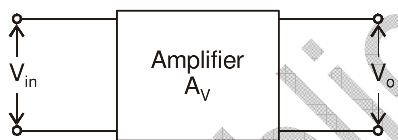
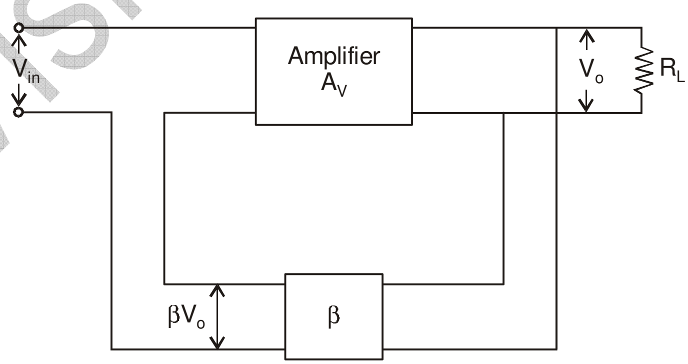



**Figure 2.1: Amplifier without feedback**

Above *fig. 2.1* shows an amplifier block diagram without feedback. The voltage gain of such amplifiers is given as the ratio of output voltage ($V_o$) to the input voltage ($V_{in}$). Mathematically it is given as,

$$A_V = \frac{V_o}{V_{in}}$$

where $A_V$ is the voltage gain, which is also called as the **open loop gain**. When the amplifier is without feedback then no part of output is given back to the input.




**Feedback network**

**Figure 2.2: Block diagram of a feedback amplifier**

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*Fig. 2.2* shows a block diagram of feedback amplifier. The addition of feedback circuit changes the values of amplifier gain, its input as well as the output voltages.

Let us consider,

$V_o'$ = output voltage of feedback amplifier.

$\beta$ = fraction of the output voltage, fed to the input. It is called feedback ratio and is different from common emitter transistor current gain.

$A_V'$ = voltage gain of feedback amplifier.

The feedback circuit injects a fraction ($\beta$) of the output voltage $V_o'$ and returns it to the input voltage whose value changes to $V_{in} + \beta V_o'$. The value at input is amplified by the circuit and its value at the output,

$$A_V (V_{in} + \beta V_o') = V_o'$$

Above equation can be written as,

$$V_o' (1 - \beta A_V) = A_V \cdot V_{in}$$

*or*

$$\frac{V_o'}{V_{in}} = \frac{A_V}{1 - \beta A_V}$$

$$= A_V'$$

where, $A_V'$ is equal to $\frac{V_o'}{V_{in}}$ and is the voltage gain of the feedback amplifier.

$$A_V' = \frac{A_V}{1 - \beta A_V}$$

$$= \frac{A_V}{1 - (-\beta A_V)}$$

As the feedback used is negative, so the feedback ratio ($\beta$) is negative, i.e., it is ($-\beta A_V$).

$$A_V' = \frac{A_V}{1 + \beta A_V}$$

The term $\beta A_V$ is called as loop gain.

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**Advantages of Negative Feedback**

Some advantages of negative feedback are given below:

i. Increased stability
ii. Increased bandwidth
iii. Less amplitude and harmonic distortion
iv. Decreased noise
v. Less frequency distortion
vi. Less phase distortion
vii. Input and output resistances can be modified as per the requirement

**Disadvantages of Negative Feedback**

The disadvantage of negative feedback is that it reduces the amplifier gain.

## 2.2 TYPES OF NEGATIVE FEEDBACK

***Types of negative feedback amplifier***
*i. Voltage series feedback connection*
*ii. Voltage shunt feedback connection*
*iii. Current series feedback connection*
*iv. Current shunt feedback connection*

From the above types, it is clear that both voltage and current can be feedback to the input, either in series or in parallel. When it is a feedback connection type, the term voltage refers to connecting the output voltage as input to the feedback network. The term current refers to giving some output current to the input through feedback network. The term series refers to connecting the feedback signal in series with the input signal voltage and the term shunt refers to connecting the feedback signal in shunt with an input current source.

The series feedback connections tend to increase the output resistance, while the shunt feedback connections tend to decrease the input resistance. The voltage feedback will tend to decrease the output resistance, while the current feedback tends to increase the output resistance. For most of the cascade amplifiers, it is necessary to have higher input resistance and lower output resistance. This requirement is achieved by using voltage series feedback connection.

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### 2.2.1 Voltage Series Feedback Connection

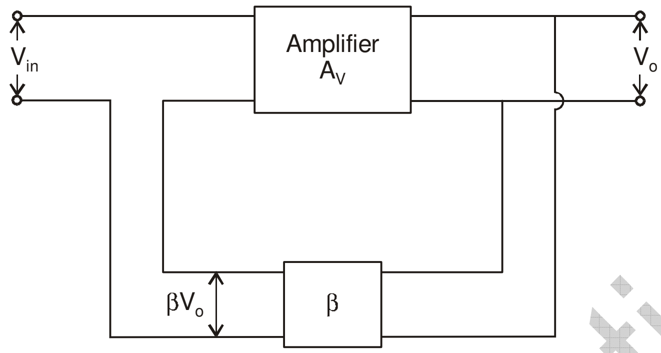


**Figure 2.3: Voltage series feedback connection**

This voltage-series feedback connection is also called as shunt derived series fed feedback connection. The block diagram of voltage series feedback connection is shown in *fig. 2.3*. In this connection, a fraction of the output voltage is applied in series with the input voltage through the feedback network. However the input to the feedback network, is in parallel with output of the amplifier. The voltage series feedback connection increases the input resistance and decreases the output resistance of the feedback amplifier.

The input resistance of a feedback amplifier, is given by the relation,

$$R_i' = (1 + \beta \cdot A_V)\ R_i$$

where, $\beta$ = feedback fraction.

$A_V$ = voltage gain of an amplifier without feedback.

Similarly the output resistance of a feedback amplifier is given by the relation,

$$R_o' = \frac{R_o}{1 + \beta\ A_V}$$

where, $R_0$ is the output resistance of an amplifier without feedback. The voltage gain of a voltage series feedback amplifier decreases. It is given by the relation,

$$A_V' = \frac{A_V}{1 + \beta\ A_V}$$

**i. The input resistance** *of voltage series feedback connection is given as,*

$R_i' = (1 + \beta A_V)\ R_i$

**ii. Output resistance** *is given as,*

$R_o' = \frac{R}{1 + \beta A_V}$

**iii. Voltage gain** *is given as,*

$A_v' = \frac{A_V}{1 + \beta A_V}$

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### Negative Feedback in Multistage Amplifier

It will be interesting to know that the negative feedback is very useful in multistage transistor amplifiers.

*Fig. 2.4 shows* the two cascaded stages of a transistor amplifier with voltage series feedback.

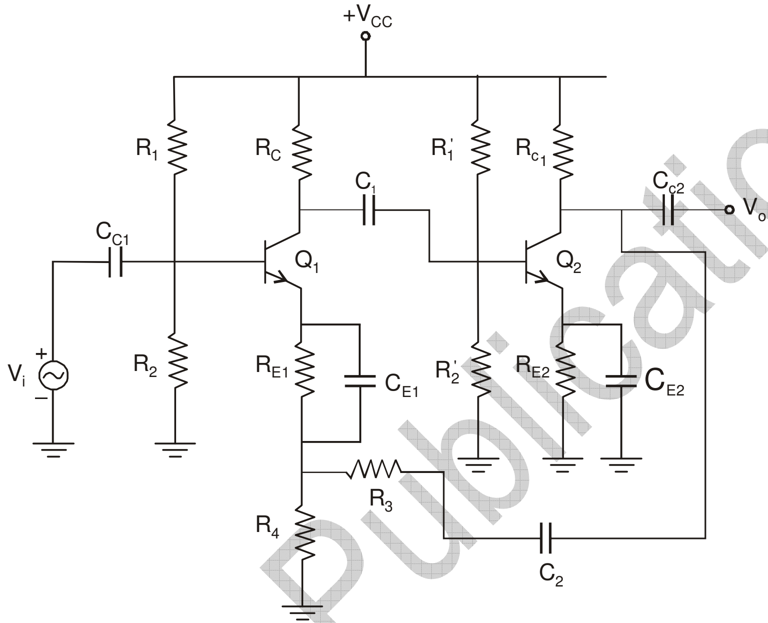


**Figure 2.4: Two stage amplifier with voltage series feedback connection**

> *
> **BTE [S.2011] -** *8M*
> *Draw a circuit of voltage series negative feedback. Explain its operation.*

In multistage transistor amplifiers, negative feedback is very useful. *Fig. 2.4* shows the two stage amplifier with voltage series feedback. These two amplifier stages with transistors $Q_1$ and $Q_2$ provide an overall voltage gain. Resistors $R_3$ and $R_4$vcoupled by capacitor $C_2$ forms a feedback network between output and input.

The feedback signal is taken from the collector of the second stage and it is connected to the emitter of the first amplifier stage. The negative feedback from the feedback network opposes the input signal between the base-emitter junction of the transistor of the first state.

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## 2.2.2 Voltage Shunt Feedback Connection

Voltage shunt feedback connection is also called a shunt-derived shunt-fed feedback connection. In this connection a fraction of the output voltage is applied in parallel with the input voltage through the feedback network.

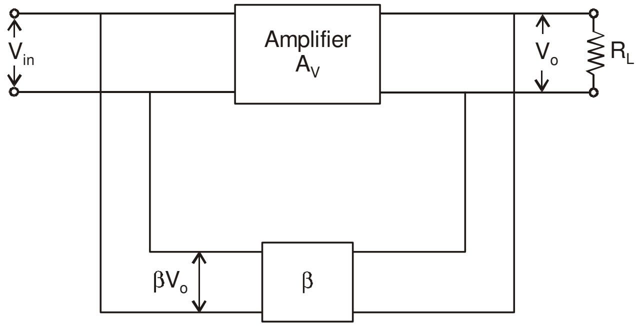


**Figure 2.5: Voltage shunt feedback connection**

The voltage shunt feedback network reduces both its input and output resistances by a factor equal to $(A + \beta A_V)$ thus input and output resistances are given as,

$$R_i' = \frac{R_i}{1 + \beta A_V}$$

$$\text{and} \quad R_o' = \frac{R_o}{1 + \beta A_V}$$

## Collector Feedback biased Common Emitter Amplifier

Collector feedback biased common emitter amplifier circuit is also called as voltage shunt feedback circuit. The feedback is obtained by coupling a portion of the output voltage to the base through the resistor $R_B$.

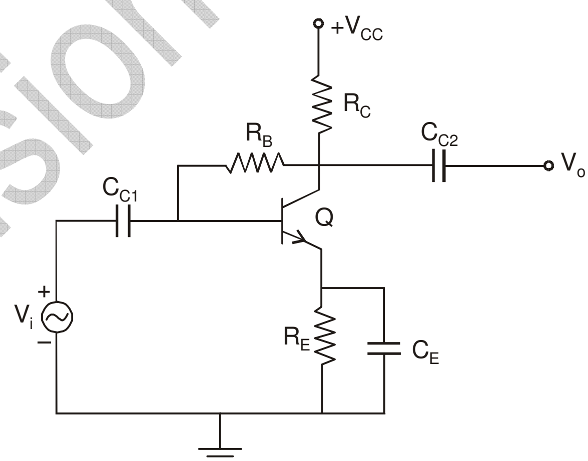


**Figure 2.6: Collector feedback biased common emitter amplifier**

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Voltage shunt feedback connection provides a stabilized amplifier overall gain. This connection reduces the input and output resistances. The feedback factor β is given as

$$\beta = \frac{R_C}{R_B}$$

## 2.2.3 Current Series Feedback Connection

Current series feedback connection is called as a series-derived series-fed feedback connection. A block diagram of a current-series feedback connection is shown in *fig. 2.7*.

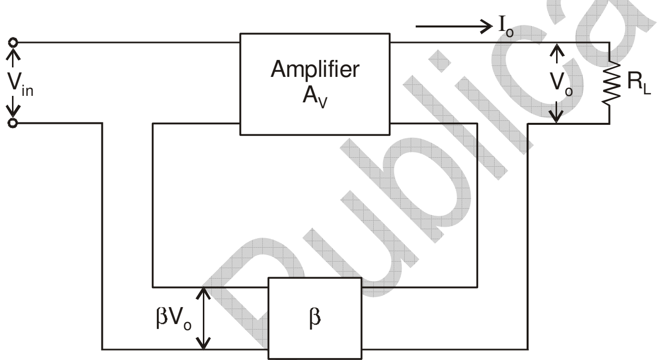


**Figure 2.7: Current series feedback connection**

In this connection a fraction of the output current is converted into a proportional voltage by the feedback network and then it is applied in series with the input. This connection increases both the input resistance and the output resistance of a feedback amplifier by a factor equal to $(1 + \beta A_V)$

The input resistance is given as

$$R_i' = (1 + \beta A_V) R_i$$

The output resistance is given as

$$R_o' = (1 + \beta A_V) R_o$$

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