

Fig. 10.47

10. What is the input impedance of the amplifier circuit shown in Fig. 10.47 ? [1.75 kΩ]
11. A voltage-divider biased amplifier has the values of $R_1 = 40 \text{ k}\Omega$, $R_2 = 10 \text{ k}\Omega$, $R_C = 6 \text{ k}\Omega$; $R_E = 2 \text{ k}\Omega$, $V_{CC} = +10\text{V}$ and $\beta = 80$. Determine the a.c. emitter resistance of the transistor. [38.46Ω]
12. A standard CE amplifier has the following values : $V_{CC} = 30\text{V}$, $R_1 = 51 \text{ k}\Omega$, $R_2 = 5.1 \text{ k}\Omega$, $R_C = 5.1 \text{ k}\Omega$, $R_E = 910\Omega$ and $\beta = 250$. Determine the voltage gain of the amplifier. [455.4]
13. A CE amplifier has a voltage gain $A_v = 59.1$ and $\beta = 200$. Determine the power gain and output power of the amplifier when input power is $80 \mu\text{W}$. [11820 ; 945.6 mW]
14. Determine the voltage gain for the first stage in Fig. 10.48. [53.03]
15. If the value of β for the second stage in Fig. 10.48 is increased to 280, determine the voltage gain of the first amplifier stage. [58.08]

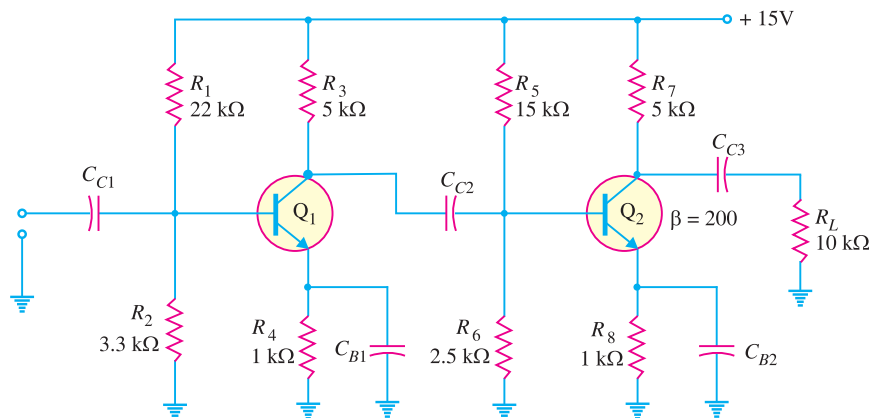


Fig. 10.48

Discussion Questions

1. Does phase reversal affect amplification ?
2. Why does ac load differ from dc load ?
3. What is the importance of load line analysis ?
4. Why is ac load line steeper than dc load line?
5. What is the significance of operating point ?

11

Multistage Transistor Amplifiers

- 11.1 Multistage Transistor Amplifier
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- 11.8 Comparison of Different Types of Coupling
- 11.9 Difference Between Transistor And Tube Amplifiers



INTRODUCTION

The output from a single stage amplifier is usually insufficient to drive an output device. In other words, the gain of a single amplifier is inadequate for practical purposes. Consequently, additional amplification over two or three stages is necessary. To achieve this, the output of each amplifier stage is *coupled* in some way to the input of the next stage. The resulting system is referred to as multistage amplifier. It may be emphasised here that a practical amplifier is always a multistage amplifier. For example, in a transistor radio receiver, the number of amplification stages may be six or more. In this chapter, we shall focus our attention on the various multistage transistor amplifiers and their practical applications.

11.1 Multistage Transistor Amplifier

A transistor circuit containing more than one stage of amplification is known as **multistage transistor amplifier**.

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In a multistage amplifier, a number of single amplifiers are connected in **cascade arrangement* i.e. output of first stage is connected to the input of the second stage through a suitable *coupling device* and so on. The purpose of coupling device (e.g. a capacitor, transformer etc.) is (i) to transfer a.c. output of one stage to the input of the next stage and (ii) to isolate the d.c. conditions of one stage from the next stage. Fig. 11.1 shows the block diagram of a 3-stage amplifier. Each stage consists of one transistor and associated circuitry and is coupled to the next stage through a coupling device. The name of the amplifier is usually given after the type of coupling used. e.g.

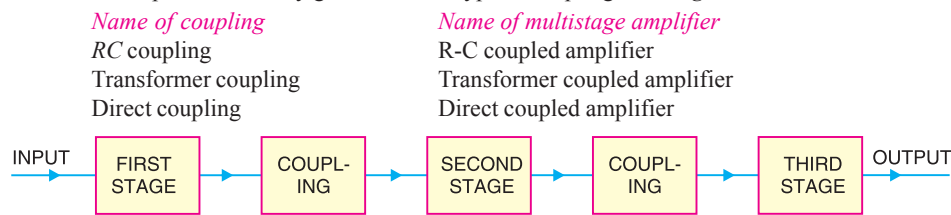


Fig. 11.1

(i) In RC coupling, a capacitor is used as the coupling device. The capacitor connects the output of one stage to the input of the next stage in order to pass the a.c. signal on while blocking the d.c. bias voltages.

(ii) In transformer coupling, transformer is used as the coupling device. The transformer coupling provides the same two functions (viz. to pass the signal on and blocking d.c.) but permits in addition impedance matching.

(iii) In direct coupling or d.c. coupling, the individual amplifier stage bias conditions are so designed that the two stages may be directly connected without the necessity for d.c. isolation.

11.2 Role of Capacitors in Transistor Amplifiers

Regardless of the manner in which a capacitor is connected in a transistor amplifier, its behaviour towards d.c. and a.c. is as follows. *A capacitor blocks d.c. i.e. a capacitor behaves as an "open" to d.c.* Therefore, for d.c. analysis, we can remove the capacitors from the transistor amplifier circuit. A capacitor offers reactance ($= 1/2\pi fC$) to a.c. depending upon the values of f and C . In practical transistor circuits, the size of capacitors is so selected that they offer negligible (ideally zero) reactance to the range of frequencies handled by the circuits. Therefore, *for a.c. analysis, we can replace the capacitors by a short i.e. by a wire*. The capacitors serve the following two roles in transistor amplifiers :

1. As coupling capacitors
2. As bypass capacitors

1. As coupling capacitors. In most applications, you will not see a single transistor amplifier. Rather we use a multistage amplifier i.e. a number of transistor amplifiers are connected in series or cascaded. The capacitors are commonly used to connect one amplifier stage to another. When a capacitor is used for this purpose, it is called a *coupling capacitor*. Fig. 11.2 shows the coupling capacitors (C_{C1} ; C_{C2} ; C_{C3} and C_{C4}) in a multistage amplifier. A coupling capacitor performs the following two functions :

(i) It blocks d.c. i.e. it provides d.c. isolation between the two stages of a multistage amplifier.

* The term *cascaded* means *connected in series*.

** $X_C = \frac{1}{2\pi fC}$. For d.c., $f=0$ so that $X_C \rightarrow \infty$. Therefore, a capacitor behaves as an open to d.c.

- (ii) It passes the a.c. signal from one stage to the next with little or no distortion.

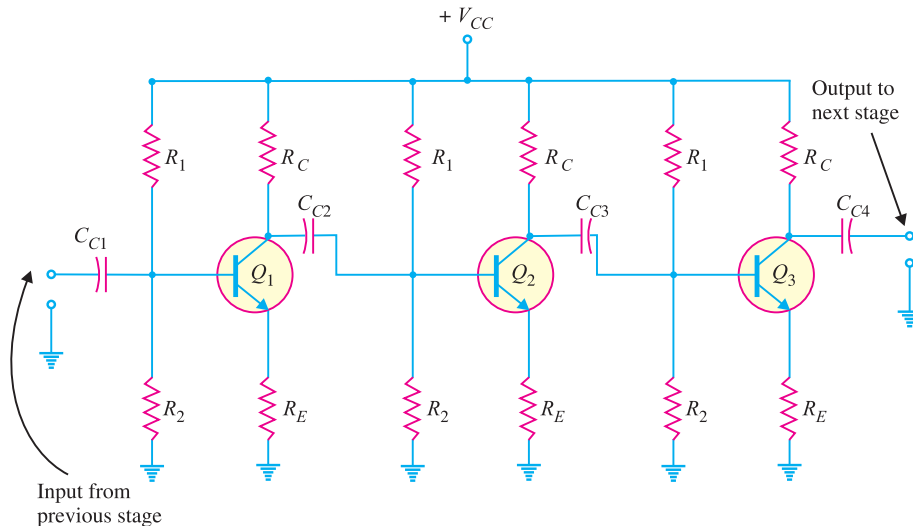


Fig. 11.2

2. As bypass capacitors. Like a coupling capacitor, a bypass capacitor also blocks d.c. and behaves as a short or wire (due to proper selection of capacitor size) to an a.c. signal. But it is used for a different purpose. A bypass capacitor is connected in parallel with a circuit component (e.g. resistor) to bypass the a.c. signal and hence the name. Fig. 11.3 shows a bypass capacitor C_E connected across the emitter resistance R_E . Since C_E behaves as a short to the a.c. signal, the whole of a.c. signal (i_e) passes through it. Note that C_E keeps the emitter at a.c. ground. Thus for a.c. purposes, R_E does not exist. We have already seen in the previous chapter that C_E plays an important role in determining the voltage gain of the amplifier circuit. If C_E is removed, the voltage gain of the amplifier is greatly reduced. Note that C_{in} is the coupling capacitor in this circuit.

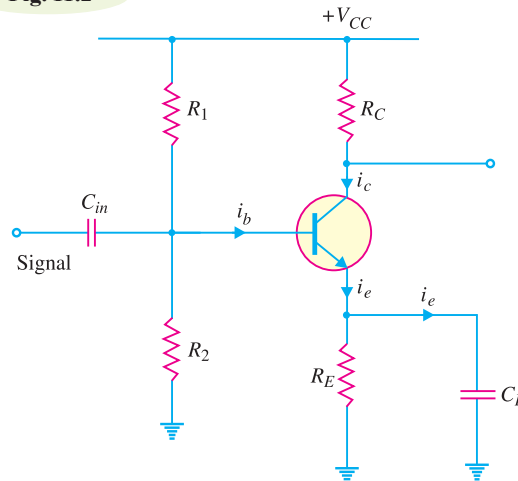


Fig. 11.3

11.3 Important Terms

In the study of multistage amplifiers, we shall frequently come across the terms *gain*, *frequency response*, *decibel gain* and *bandwidth*. These terms stand discussed below :

- (i) **Gain.** The ratio of the output *electrical quantity to the input one of the amplifier is called its **gain**.

* Accordingly, it can be current gain or voltage gain or power gain.

The gain of a multistage amplifier is equal to the product of gains of individual stages. For instance, if G_1 , G_2 and G_3 are the individual voltage gains of a three-stage amplifier, then total voltage gain G is given by :

$$*G = G_1 \times G_2 \times G_3$$

It is worthwhile to mention here that in practice, total gain G is less than $G_1 \times G_2 \times G_3$ due to the loading effect of next stages.

(ii) Frequency response. The voltage gain of an amplifier varies with signal frequency. It is because reactance of the capacitors in the circuit changes with signal frequency and hence affects the output voltage. The curve between voltage gain and signal frequency of an amplifier is known as *frequency response*. Fig. 11.4 shows the frequency response of a typical amplifier. The gain of the amplifier increases as the frequency increases from zero till it becomes maximum at f_r , called *resonant frequency*. If the frequency of signal increases beyond f_r the gain decreases.

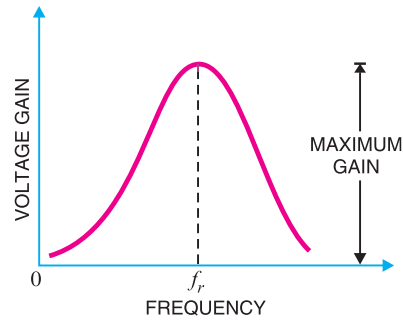


Fig. 11.4

The performance of an amplifier depends to a considerable extent upon its frequency response. While designing an amplifier, appropriate steps must be taken to ensure that gain is essentially uniform over some specified frequency range. For instance, in case of an audio amplifier, which is used to amplify speech or music, it is necessary that all the frequencies in the sound spectrum (*i.e.* 20 Hz to 20 kHz) should be uniformly amplified otherwise speaker will give a distorted sound output.

(iii) Decibel gain. Although the gain of an amplifier can be expressed as a number, yet it is of great practical importance to assign it a unit. The unit assigned is *bel or decibel (db)*.

The common logarithm (log to the base 10) of power gain is known as *bel power gain* *i.e.*

$$\text{Power gain} = \log_{10} \frac{P_{out}}{P_{in}} \text{ bel}$$

$$1 \text{ bel} = 10 \text{ db}$$

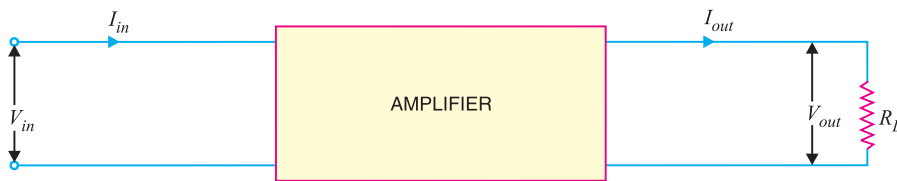


Fig. 11.5

* This can be easily proved. Suppose the input to first stage is V .

$$\text{Output of first stage} = G_1 V$$

$$\text{Output of second stage} = (G_1 V) G_2 = G_1 G_2 V$$

$$\text{Output of third stage} = (G_1 G_2 V) G_3 = G_1 G_2 G_3 V$$

$$\text{Total gain, } G = \frac{\text{Output of third stage}}{V}$$

or

$$G = \frac{G_1 G_2 G_3 V}{V} = G_1 \times G_2 \times G_3$$

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$$\therefore \text{Power gain} = 10 \log_{10} \frac{P_{out}}{P_{in}} \text{ db}$$

If the two powers are developed in the same resistance or equal resistances, then,

$$P_1 = \frac{V_{in}^2}{R} = I_{in}^2 R$$

$$P_2 = \frac{V_{out}^2}{R} = I_{out}^2 R$$

$$\therefore \text{Voltage gain in db} = 10 \log_{10} \frac{V_{out}^2 / R}{V_{in}^2 / R} = 20 \log_{10} \frac{V_{out}}{V_{in}}$$

$$\text{Current gain in db} = 10 \log_{10} \frac{I_{out}^2 R}{I_{in}^2 R} = 20 \log_{10} \frac{I_{out}}{I_{in}}$$

Advantages. The following are the advantages of expressing the gain in *db* :

(a) The unit *db* is a logarithmic unit. Our ear response is also logarithmic *i.e.* loudness of sound heard by ear is not according to the intensity of sound but according to the log of intensity of sound. Thus if the intensity of sound given by speaker (*i.e.* power) is increased 100 times, our ears hear a doubling effect ($\log_{10} 100 = 2$) *i.e.* as if loudness were doubled instead of made 100 times. Hence, this unit tallies with the natural response of our ears.

(b) When the gains are expressed in *db*, the overall gain of a multistage amplifier is the sum of gains of individual stages in *db*. Thus referring to Fig. 11.6,

$$\begin{aligned} \text{Gain as number} &= \frac{V_2}{V_1} \times \frac{V_3}{V_2} \\ \text{Gain in db} &= 20 \log_{10} \frac{V_2}{V_1} \times \frac{V_3}{V_2} \\ &= 20 \log_{10} \frac{V_2}{V_1} + 20 \log_{10} \frac{V_3}{V_2} \\ &= \text{1st stage gain in db} + \text{2nd stage gain in db} \end{aligned}$$

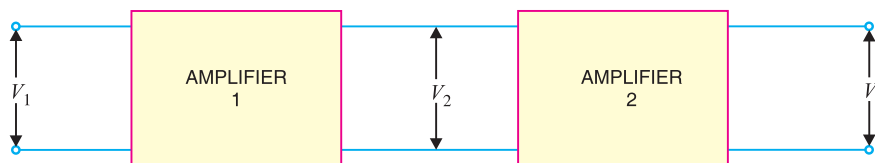


Fig. 11.6

However, absolute gain is obtained by multiplying the gains of individual stages. Obviously, it is easier to add than to multiply.

(iv) **Bandwidth.** The range of frequency over which the voltage gain is equal to or greater than *70.7% of the maximum gain is known as **bandwidth**.

* The human ear is not a very sensitive hearing device. It has been found that if the gain falls to 70.7% of maximum gain, the ear cannot detect the change. For instance, if the gain of an amplifier is 100, then even if the gain falls to 70.7, the ear cannot detect the change in intensity of sound and hence no distortion will be heard. However, if the gain falls below 70.7, the ear will hear clear distortion.