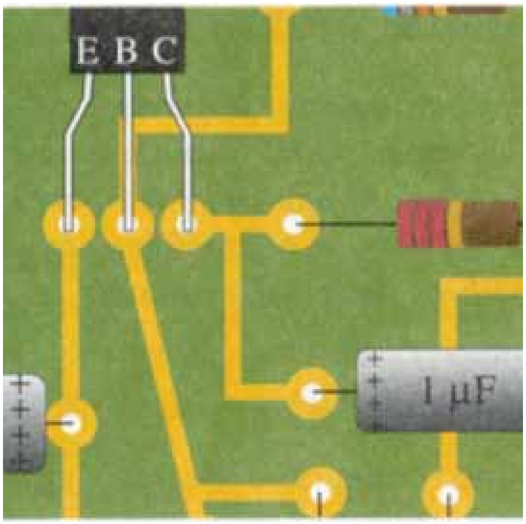
Contents

10

Single Stage Transistor Amplifiers



INTRODUCTION

In the previous chapter, it was discussed that a properly biased transistor raises the strength of a weak signal and thus acts as an amplifier. Almost all electronic equipments must include means for amplifying electrical signals. For instance, radio receivers amplify very weak signals—sometimes a few millionth of a volt at antenna–until they are strong enough to fill a room with sound. The transducers used in the medical and scientific investigations generate signals in the microvolt (μV) and millivolt (mV) range. These signals must be amplified thousands and millions times before they will be strong enough to operate indicating instruments. Therefore, electronic amplifiers are a constant and important ingredient of electronic systems.

Our purpose here will be to discuss *single stage transistor amplifier*. By a *stage* we mean a single transistor with its bias and auxiliary equipment. It may be emphasised here that a practical amplifier is always a multistage amplifier *i.e.* it has a number of stages of amplification. However, it is profitable to consider the multistage amplifier in terms of single stages that are connected together. In this chapter, we shall confine our attention to single stage transistor amplifiers.

10.1 Single Stage Transistor Amplifier

When only one transistor with associated circuitry is used for amplifying a weak signal, the circuit is known as **single stage transistor amplifier.**

A single stage transistor amplifier has one transistor, bias circuit and other auxiliary components. Although a practical amplifier consists of a number of stages, yet such a complex circuit can be conveniently split up into separate single stages. By analysing carefully only a single stage and using this single stage analysis repeatedly, we can effectively analyse the complex circuit. It follows, therefore, that single stage amplifier analysis is of great value in understanding the practical amplifier circuits.

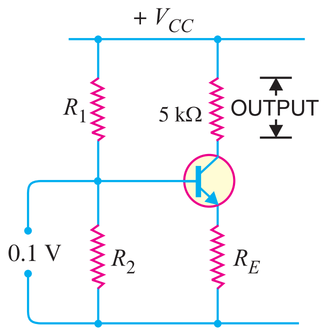


Fig. 10.1

10.2 How Transistor Amplifies ?

Fig. 10.1 shows a single stage transistor amplifier. When a weak a.c. signal is given to the base of transistor, a small base current (which is a.c.) starts flowing. Due to transistor action, a much larger (β times the base current) a.c. current flows through the collector load R_C. As the value of R_C is quite high (usually 4-10 kΩ), therefore, a large voltage appears across R_C. Thus, a weak signal applied in the base circuit appears in amplified form in the collector circuit. It is in this way that a transistor acts as an amplifier.

The action of transistor amplifier can be beautifully explained by referring to Fig. 10.1. Suppose a change of 0.1V in signal voltage produces a change of 2 mA in the collector current. Obviously, a signal of only 0.1V applied to the base will give an output voltage = 2 mA × 5 kΩ = 10V. Thus, the transistor has been able to raise the voltage level of the signal from 0.1V to 10V *i.e.* voltage amplification or stage gain is 100.

10.3 Graphical Demonstration of Transistor Amplifier

The function of transistor as an amplifier can also be explained graphically. Fig. 10.2 shows the output characteristics of a transistor in *CE* configuration. Suppose the zero signal base current is 10 μA *i.e.* this is the base current for which the transistor is biased by the biasing network. When an a.c. signal is applied to the base, it makes the base, say positive in the first half-cycle and negative in the second half-cycle. Therefore, the base and collector currents will increase in the first half-cycle when base-emitter junction is more forward-biased. However, they will decrease in the second half-cycle when the base-emitter junction is less forward biased.

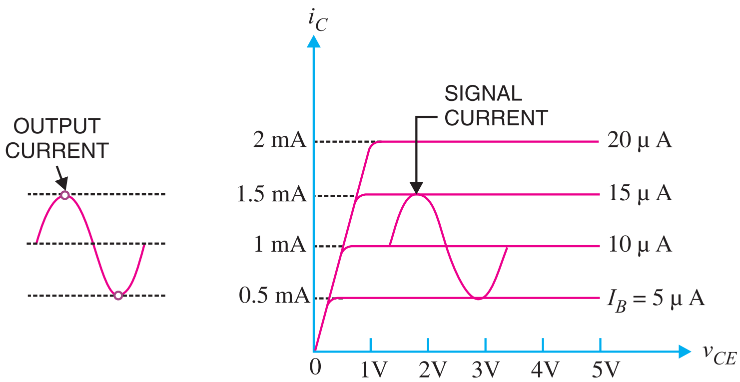


Fig. 10.2

For example, consider a sinusoidal signal which increases or decreases the base current by 5 μA in the two half-cycles of the signal. Referring to Fig. 10.2, it is clear that in the absence of signal, the base current is 10μA and the collector current is 1 mA. However, when the signal is applied in the base circuit, the base current and hence collector current change continuously. In the first half-cycle peak of the signal, the base current increases to 15 μA and the corresponding collector current is 1.5 mA. In the second half-cycle peak, the base current is reduced to 5 μA and the corresponding collector current is 0.5 mA. For other values of the signal, the collector current is inbetween these values *i.e.* 1.5 mA and 0.5 mA.

It is clear from Fig. 10.2 that 10 μA base current variation results in 1mA (1,000 μA) collector current variation *i.e.* by a factor of 100. This large change in collector current flows through collector resistance R_C. The result is that output signal is much larger than the input signal. Thus, the transistor has done amplification.

10.4 Practical Circuit of Transistor Amplifier

It is important to note that a transistor can accomplish faithful amplification only if proper associated circuitry is used with it. Fig. 10.3 shows a practical single stage transistor amplifier. The various circuit elements and their functions are described below :

(*i*) Biasing circuit. The resistances R_1, R_2 and R_E form the biasing and stabilisation circuit. The biasing circuit must establish a proper operating point otherwise a part of the negative half-cycle of the signal may be cut off in the output.

(*ii*) Input capacitor C_{in}. An electrolytic capacitor C_{in} (≃ 10 μF) is used to couple the signal to the base of the transistor. If it is not used, the signal source resistance will come across R_2 and thus change the bias. The capacitor C_{in} allows only a.c. signal to flow but isolates the signal source from R_2.*

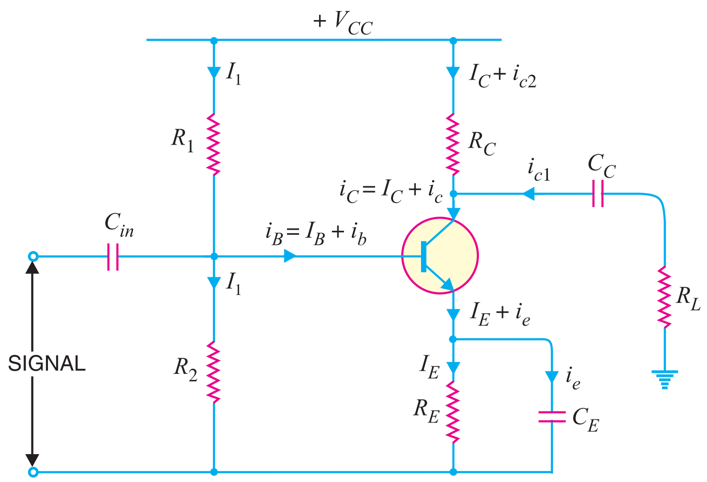


Fig. 10.3

(*iii*) Emitter bypass capacitor C_E. An emitter bypass capacitor C_E (≃ 100μ*F*) is used in parallel with R_E to provide a low reactance path to the amplified a.c. signal. If it is not used, then amplified a.c. signal flowing through R_E will cause a voltage drop across it, thereby reducing the output voltage.

(*iv*) Coupling capacitor C_C. The coupling capacitor C_C (≃ 10μ*F*) couples one stage of ampli-

* It may be noted that a capacitor offers infinite reactance to d.c. and blocks it completely whereas it allows a.c. to pass through it.

fication to the next stage. If it is not used, the bias conditions of the next stage will be drastically changed due to the shunting effect of R_C. This is because R_C will come in parallel with the upper resistance R_1 of the biasing network of the next stage, thereby altering the biasing conditions of the latter. In short, the coupling capacitor C_C isolates the d.c. of one stage from the next stage, but allows the passage of a.c. signal.

Various circuit currents. It is useful to mention the various currents in the complete amplifier circuit. These are shown in the circuit of Fig. 10.3.

(*i*) Base current. When no signal is applied in the base circuit, d.c. base current I_B flows due to biasing circuit. When a.c. signal is applied, a.c. base current i_b also flows. Therefore, with the application of signal, total base current i_B is given by:

$$i_B = I_B + i_b$$

(*ii*) Collector current. When no signal is applied, a d.c. collector current I_C flows due to biasing circuit. When a.c. signal is applied, a.c. collector current i_c also flows. Therefore, the total collector current i_C is given by:

$$i_C = I_C + i_c$$

where $I_C = \beta I_B$ = zero signal collector current

$i_c = \beta i_b$ = collector current due to signal.

(*iii*) Emitter current. When no signal is applied, a d.c. emitter current I_E flows. With the application of signal, total emitter current i_E is given by :

$$i_E = I_E + i_e$$

It is useful to keep in mind that :

$$I_E = I_B + I_C$$

$$i_e = i_b + i_c$$

Now base current is usually very small, therefore, as a reasonable approximation,

$$I_E \simeq I_C \quad \text{and} \quad i_e \simeq i_c$$

Example 10.1. *What is the role of emitter bypass capacitor C_E in CE amplifier circuit shown in Fig. 10.3 ? Illustrate with a numerical example.*

Solution. The emitter bypass capacitor C_E (See Fig. 10.3) connected in parallel with R_E plays an important role in the circuit. If it is not used, the amplified a.c. signal flowing through R_E will cause a voltage drop across it, thereby reducing the a.c. output voltage and hence the voltage gain of the amplifier.

Let us illustrate the effect of C_E with a numerical example. Suppose $R_E = 1000\Omega$ and capacitive reactance of C_E at the signal frequency is 100Ω (*i.e.* $X_{C_E} = 100\Omega$). Then 10/11 of a.c emitter current will flow through C_E and only 1/11 through R_E. The signal voltage developed across R_E is, therefore, only 1/11 of the voltage which would have been developed if C_E were not present. In practical circuits, the value of C_E is so selected that it almost entirely bypasses the a.c. signal (the name for C_E is obvious). *For all practical purposes, we consider C_E to be a short for a.c. signals.*

Example 10.2. *Select a suitable value for the emitter bypass capacitor in Fig. 10.4 if the amplifier is to operate over a frequency range from 2 kHz to 10 kHz.*

Solution. An amplifier usually handles more than one frequency. Therefore, the value of C_E is so selected that it provides adequate bypassing for the *lowest* of all the frequencies. Then it will also be a good bypass ($X_C \propto 1/f$) for all the higher frequencies. Suppose the minimum frequency to be handled by C_E is f_{min}. Then C_E is considered a good bypass if at f_{min},

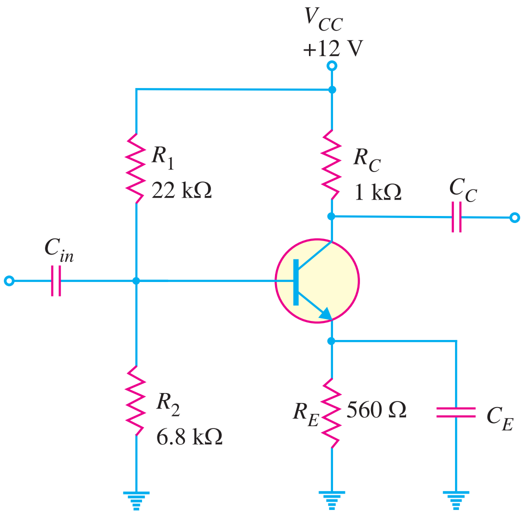


Fig. 10.4

$$X_{C_E} = \frac{R_E}{10}$$

In the given problem, $f_{min} = 2\text{kHz}$; $R_E = 560\Omega$.

$$\therefore \quad 10\ X_{C_E} = 560$$

$$\text{or} \quad X_{C_E} = 560/10 = 56\Omega$$

$$\text{or} \quad \frac{1}{2\pi\ f_{min}\ C_E} = 56$$

$$\therefore \quad C_E = \frac{1}{2\pi\ f_{min}\ 56} = \frac{1}{2\pi \times (2 \times 10^3) \times 56} = 1.42 \times 10^{-6}\ F = \mathbf{1.42\ \mu F}$$

Note. While discussing *CE* amplifier, the reader should be very particular about the role of C_E.

10.5 Phase Reversal

In common emitter connection, when the input signal voltage increases in the positive sense, the output voltage increases in the negative direction and *vice-versa*. In other words, there is a phase difference of 180° between the input and output voltage in *CE* connection. This is called phase reversal.*

The phase difference of 180° between the signal voltage and output voltage in a common emitter amplifier is known as **phase reversal.**

Consider a common emitter amplifier circuit shown in Fig. 10.5. The signal is fed at the input terminals (*i.e.* between base and emitter) and output is taken from collector and emitter end of supply. The total instantaneous output voltage v_{CE} is given by :

$$^{**}v_{CE} = V_{CC} - i_C R_C \qquad ...(i)$$

* This is so if output is taken from collector and emitter end of supply as is always done. However, if the output is taken across R_C, it will be in phase with the input.

** Reactance of C_C (= 10μ*F*) is negligible at ordinary signal frequencies. Therefore, it can be considered a short for the signal.