to the load impedance. Since a common-base amplifier has *low input impedance* and *high output impedance*, the common-base circuit will serve well in this situation. Let us illustrate this point with a numerical example. Suppose a high-frequency source with internal resistance 25 Ω is to be connected to a load of 8 kΩ as shown in Fig. 6.74. If the source is directly connected to the load, small source power will be transferred to the load due to mismatching. However, it is possible to design a *CB* amplifier that has an input impedance of nearly 25 Ω and output impedance of nearly 8 kΩ. If such a *CB* circuit is placed between the source and the load, the source will be matched to the load as shown in Fig. 6.75.

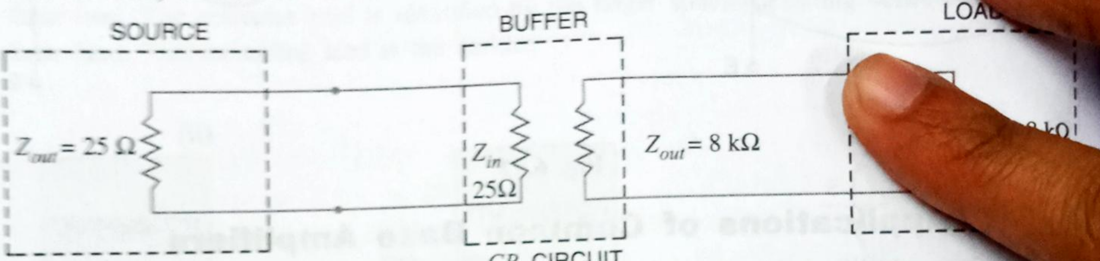


Fig. 6.75

Note that source impedance very closely matches the input impedance of *CB* amplifier. Therefore, there is a maximum power transfer from the source to input of *CB* amplifier. The high output impedance of the amplifier very nearly matches the load resistance. As a result, there is a maximum power transfer from the amplifier to the load. The net result is that maximum power has been transferred from the original source to the original load. A common-base amplifier that is used for this purpose is called a *buffer amplifier*.

6.31 Applications of Transistors

The main building block of modern electronic systems is the transistor. The transistor is a three terminal device whose output current, voltage and/or power are controlled by its input current. Transistors are used in a large number of applications and a few of them are given below.

(*i*) A transistor can be used as an **amplifier**. An amplifier raises the strength of a weak signal.

(*ii*) A transitor can be used as an **electronic switch** that is capable of turning ON or OFF current in a circuit several billions of times per second.

(*iii*) A transistor can be used as an **oscillator**. An oscillator converts d.c. power into a.c. power of any frequency. Thus an oscillator can produce sinusoidal oscillations of any frequency.

(*iv*) Transistors are widely used in **waveshaping circuits.**

(*v*) Transistors are used in **logic circuits.**

Short Answer Questions

Q.1. *What is the basic condition for the proper functioning of transistor as an amplifier?*

Ans. A transistor is almost always connected in *CE* arrangement. For its proper function as amplifier, base-emitter junction should always remain properly forward biased and collector-base junction should always remain properly reverse biased.

Q.2. *Why is the base of a transistor made thin and lightly doped?*

Ans. The base is made thin and lightly doped so that the majority carriers supplied by the emitter do not combine in the base region and most of them pass on to the collector.

Q.3. *What is the key factor responsible for amplifying capability of a transistor?*

Ans. In a transistor, the weak input signal current is introduced in the low resistance input circuit and output is taken from the high resistance output circuit. This property of the transistor to transfer the input signal current from a low resistance circuit to a high resistance circuit is the key factor responsible for amplifying capability of a transistor.

Q.4. *Why is collector of a transistor made wider than emitter and base?*

Ans. During transistor operation, most of heat is produced at the collector junction. The collector is made larger to dissipate heat.

Q.5. *If the emitter of a transistor connected in CB mode is open, will there be any collector current?*

Ans. During normal operation of transistor, the total collector current is given by ;

$$I_C = \alpha I_E + I_{leakage} \quad \text{... } (i)$$

Here, αI_E is the part of the emitter current which reaches the collector terminal and the current $I_{leakage}$ is due to the movement of minority carriers across base-collector junction on account of it being reverse biased. It is clear from eq. (*i*) that when $I_E = 0$ (*i.e.* emitter circuit is open), a small leakage current still flows in the collector circuit. This leakage current is abbreviated as I_{CBO}, meaning collector-base current with emitter open. Thus, when $I_E = 0, I_C = I_{CBO}$.

Q.6. *Why does a transistor possess low input resistance and high output resistance?*

Ans. It is because the input circuit is forward biased and the output circuit is reverse biased.

Q.7. *Why is β more than α?*

Ans. Considering the d.c. values, the relations for β and α are given by ;

$$\beta = \frac{I_C}{I_B} \text{ and } \alpha = \frac{I_C}{I_E}$$

As I_B is much smaller than I_C, β has a very large value.

On the other hand I_E is comparable to I_C and as such α has a small value. Therefore, β is much greater than α.

Q.8. *What would be the effect on the value of base current if a transistor was operated with emitter and collector interchanged?*

Ans. In a transistor, the emitter is heavily doped to inject a large number of a charge carriers (holes or electrons) into the base and the collector is moderately doped. If the two are interchanged, the emitter current will decrease and so will be the base current.

Q.9. *What will happen to base current if base of a transistor is made thick?*

Ans. If the base is made thick, a large number of combinations of electrons and holes will take place in the base region. As a result, base current will increase.

Q.10. *Why are most of the transistors npn type and not pnp type?*

Ans. In an *npn* transistor, the current conduction is mainly by free electrons whereas in *pnp* transistor, it is mainly by holes. Since electrons are more mobile than holes, we can have high conduction is an *npn* transistor than in a *pnp* type.

Q.11. *What causes a transistor to be damaged?*

Ans. Excessive heat can damage a transistor. The heat may result from excessive current, ambient temperature or soldering the transistor leads.

Q.12. *Why is power switch turned off when a transistor or supply battery is replaced?*

Ans. Transistor can be damaged by even small transient voltage surges which can produce excessive forward bias. For this reason, the power switch should be turned off when a transistor or the supply battery is replaced.

Q.13. *What are the three main classes of transistors?*

Ans. The three main classes of transistors are :

(*i*) Small signal/general purpose transistors

(*ii*) Power transistors

(*iii*) RF (radio frequency) transistors

Q.14. *A properly connected transistor can do amplification. Is transistor a source of energy?*

Ans. No, transistor is not a source of energy but is merely an energy converter. It receives d.c. power from the supply and converts it into a.c. power which is added to the signal.

Q.15. *What are the three possible states of a transistor?*

Ans. The three possible states of a transistor are :

(*i*) *Cut-off* state in which the transistor is nonconducting *i.e.* collector current is approximately zero.

(*ii*) *Active state* in which the collector current is controlled by the base current and base voltage. A transistor acts as an amplifier in the active state.

(*iii*) *Saturation state* in which the collector current has reached a maximum value and is independent of base current.

Q.16. *What is the relation between collector current I_C and emitter current I_E in terms of β?*

Ans.

$$I_E = I_B + I_C = I_B + \beta I_B = I_B\,(1+\beta)$$

$$\therefore \quad I_B = \frac{1}{1+\beta} I_E$$

$$\therefore \quad I_C = \beta I_B = \frac{\beta}{1+\beta} I_E$$

Q.17. *What is the effect of temperature on the values of (i) β (ii) V_{BE} (iii) I_{CBO}?*

Ans.

(*i*) The value of β increases with the increase in temperature.

(*ii*) The value of V_{BE} decreases with the increases in temperature. The value of V_{BE} decreases about 7.5 mV/°C increase in temperature.

(*iii*) The value of I_{CBO} approximately doubles for every 10°C rise in temperature.

Q.18. *Why is it desirable for an amplifier to have high input impedance and low output impedance?*

Ans. It is desirable that an *amplifier should have high input impedance (R_{in}) and low output impedance (R_{out}). This is logical, since most of signal sources are not capable of delivering very much current and a high input impedance will not draw a high value of current.

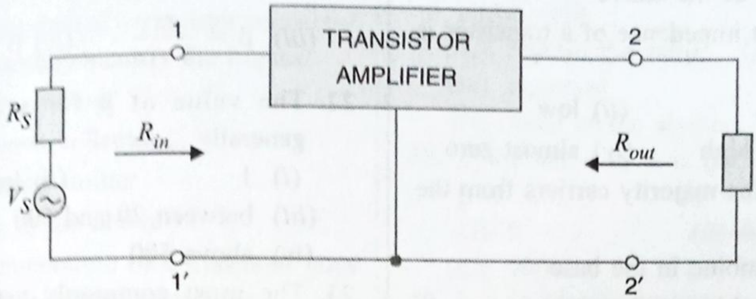


Fig. 6.76

The output impedance is a measure of how much current can be "extracted" from the amplifier to the load (R_L). The lower the value of R_{out}, the greater the value of current supplied by the amplifier to the load. As such, a low value of R_{out} is generally desirable.

Multiple-Choice Questions

1. A transistor has ....
   (*i*) one *pn* junction
   (*ii*) two *pn* junctions
   (*iii*) three *pn* junctions
   (*iv*) four *pn* junctions

2. The number of depletion layers in a transistor is ....
   (*i*) four (*ii*) three
   (*iii*) one (*iv*) two

3. The base of a transistor is .... doped.
   (*i*) heavily (*ii*) moderately
   (*iii*) lightly
   (*iv*) none of the above

4. The element that has the biggest size in a transistor is ....
   (*i*) collector (*ii*) base
   (*iii*) emitter
   (*iv*) collector-base junction

5. In a *pnp* transistor, the current carriers are ....
   (*i*) acceptor ions (*ii*) donor ions
   (*iii*) free electrons (*iv*) holes

6. The collector of a transistor is........ doped.
   (*i*) heavily (*ii*) moderately
   (*iii*) lightly
   (*iv*) none of the above

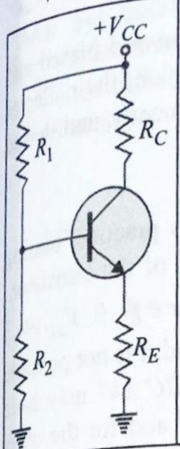
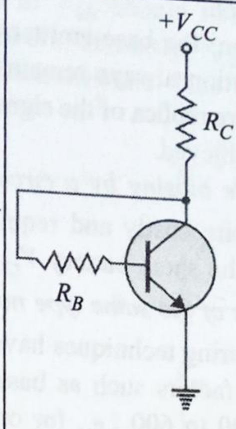
7. A transistor is a .... operated device.
   (*i*) current
   (*ii*) voltage
   (*iii*) both voltage and current
   (*iv*) none of the above

8. In an *npn* transistor, ... are the minority carriers.
   (*i*) free electrons (*ii*) holes
   (*iii*) donor ions (*iv*) acceptor ions

9. The emitter of a transistor is .... doped.
   (*i*) lightly (*ii*) heavily
   (*iii*) moderately
   (*iv*) none of the above

10. In a transistor, the base current is about .... of emitter current.
    (*i*) 25% (*ii*) 20%
    (*iii*) 35% (*iv*) 5%

* Here V_S is the signal source and R_S its internal resistance.

VOLTAGE-DIVIDER BIAS		COLLECTOR-FEEDBACK BIAS	
	• Q-point values ($I_C \simeq I_E$) • Collector current : $I_C \simeq \dfrac{\left(\dfrac{R_2}{R_1+R_2}\right)V_{CC} - V_{BE}}{R_E}$ • Collector-to-emitter voltage : $V_{CE} \simeq V_{CC} - I_C(R_C + R_E)$		• Q-point values ($I_C \simeq I_E$) • Collector current : $I_C \simeq \left(\dfrac{V_{CC} - V_{BE}}{R_C + R_B/\beta}\right)$ • Collector-to-emitter voltage : $V_{CE} \simeq V_{CC} - I_C R_C$

The following points may be noted :

(*i*) Out of the four bias circuits above, the voltage-divider bias circuit has the lowest value of stability factor $S(\simeq 10)$. Therefore, voltage-divider bias circuit provides excellent *thermal stability and is always preferred. The next bias circuit is the emitter bias circuit. A properly designed emitter bias circuit can provide S value comparable to that of voltage-divider bias circuit. However, fixed bias circuit has very poor thermal stability because its stability factor $S = (\beta + 1)$.

(*ii*) The stability factor (S) of a bias circuit not only depends upon the type of bias circuit but it also depends upon the resistor values.

(*iii*) A low value of stability factor means greater thermal stability. When the stability factor of a bias circuit is high, it not only changes the operating point significantly but it may also lead to *thermal runaway.*

Short Answer Questions

Q.1. *What is the universal rule for biasing a transistor for normal operation?*

Ans. The rule is : The emitter-base junction must be forward biased and the collector-base junction must be reverse biased.

Q.2. *Why should V_{CE} not fall below 0.5 V for Ge transistors and 1 V for Si transistors for faithful amplification?*

Ans. These are the minimum values required to keep the collector-base junction properly reverse biased. Allowing V_{CE} to fall below these values would result in collector not gathering all the charge carriers that reach its depletion layer. This will decrease I_C and increase I_B, making β to fall. Hence that part of signal for which V_{CE} falls below these values (0.5 V for Ge transistors and 1 V for Si transistors) will be amplified less due to reduced β, resulting in unfaithful amplification.

Q.3. *Why should V_{BE} not fall below 0.5 V for Ge transistors and 0.7 V for Si transistors for faithful amplification?*

Ans. The potential barrier has a value of 0.5 V for Ge transistors and 0.7 V for Si transistors. The base-emitter voltage must be more than these values in order to keep the input circuit always properly forward biased.

* *i.e.* operating point *almost* remains fixed when temperature changes.

Q.4. *Why should transistor operate in the active region of output characteristics for faithful amplification?*

Ans. In the active region, the base-emitter junction always remains forward biased and collector-base junction always remains reverse biased. In this region, the collector current variations are replica of the signal current variations. Consequently, undistorted amplification is achieved.

Q.5. *Why do we provide biasing by a circuit and not by a battery?*

Ans. Because batteries are costly and require frequent replacement. In practice, biasing is provided from the same battery V_{CC} used in the output circuit of the transistor.

Q.6. *Why do transistors of the same type not have the same parameters e.g., β, V_{BE} etc.?*

Ans. Because manufacturing techniques have not advanced too much and it is not possible to control several factors such as base width *etc*. For example, *BC* 147 may have β ranging from 100 to 600 *i.e.*, for one transistor it may be 100 and for the other it may be 600.

Q.7. *The stability factor of a biasing circuit is 10. What does it mean?*

Ans.
$$S = \frac{dI_C}{dI_{CBO}}$$

or
$$dI_C = S \times dI_{CBO} = 10 \times dI_{CBO}$$

Thus $S = 10$ means that I_C changes 10 times as much as any change in I_{CBO}. For example, if I_{CBO} changes by 2 μA due to temperature variations, then I_C will change by 20 μA.

Q.8. *What is the effect of temperature on transistors?*

Ans. The two most temperature sensitive quantities are : (*i*) base-emitter voltage V_{BE} and (*ii*) collector leakage current I_{CBO}. The temperature co-efficient of V_{BE} is approximately − 2.2 mV/°C for a silicon transistor and − 1.8 mV/°C for a germanium transistor. The leakage current I_{CBO} approximately doubles for each 10°C temperature rise.

Q.9. *Why is voltage divider bias the most widely used method?*

Ans. It is because it provides very good stabilisation of operating point in the face of variations of temperature. The stability factor *S* of this circuit is given by ;

$$S = (\beta + 1) \times \frac{1 + R_0 / R_E}{\beta + 1 + R_0 / R_E} \quad \text{where } R_0 = \frac{R_1 R_2}{R_1 + R_2}$$

By making R_0/R_E very small, it can be neglected as compared to 1.

$$\therefore \quad S = (\beta + 1) \frac{1}{\beta + 1} = 1$$

This means that if I_{CBO} changes by 2 μA, then I_C will also change by 2 μA. Clearly it is a very good thermal stability.

Q.10. *Why does the point of intersection of d.c. load line and base current curve under study give the operating point?*

Ans. The operating point lies on the d.c. load line. It also lies somewhere on the base current curve under study. Therefore, operating point will be at the point where d.c. load line intersects the base current curve under study.

Q.11. *What should be the minimum values of V_{BE} and V_{CE} for faithful amplification?*

Ans. For faithful amplification, the value of V_{BE} should not fall below 0.5 V for Ge transistors and 0.7 V for silicon transistors. Similarly, V_{CE} should not fall below 1 V for silicon transistors and 0.5 V for Ge transistors. This is shown diagrammatically in Fig. 7.57.

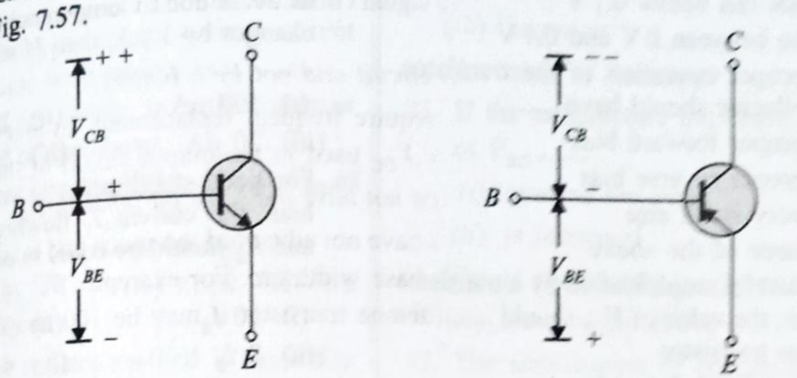


Fig. 7.57

If the voltages do not fall below these limiting values, base-emitter junction will remain forward biased and collector-base junction will effectively remain reverse biased. This will ensure proper functioning of transistor and as a result faithful amplification takes place.

Q.12. *What is thermal runaway?*

Ans. When temperature increases, I_{CBO} increases significantly (I_{CBO} doubles for every 10°C rise in temperature). An increase in I_{CBO} increases the collector current I_C. The I_C increase raises the temperature of collector-base junction. This, in turn, results in a further increase in I_{CBO}. The effect is cummulative so that the end result is a substantial increase in I_C. In the worst case, *I_C might go on increasing until the collector-base junction of the transistor overheats and burns out.* This effect is known as *thermal runaway.*

Multiple-Choice Questions

1. Transistor biasing represents .... conditions.
   (*i*) a.c.
   (*ii*) d.c.
   (*iii*) both a.c. and d.c.
   (*iv*) none of the above
2. Transistor biasing is done to keep .... in the circuit.
   (*i*) proper direct current
   (*ii*) proper alternating current
   (*iii*) the base current small
   (*iv*) collector current small
3. Operating point represents ....
   (*i*) values of I_C and V_{CE} when signal is applied
   (*ii*) the magnitude of signal
   (*iii*) zero signal values of I_C and V_{CE}
   (*iv*) none of the above
4. If biasing is not done in an amplifier circuit, it results in ....
   (*i*) decrease in base current
   (*ii*) unfaithful amplification
   (*iii*) excessive collector bias
   (*iv*) none of the above
5. Transistor biasing is generally provided by a ....
   (*i*) biasing circuit (*ii*) bias battery
   (*iii*) diode (*iv*) none of the above
6. For faithful amplification by a transistor

Solution. The value of K can be determined from the following equation :

$$K = \frac{I_{D\,(on)}}{(V_{GS\,(on)} - V_{GS\,(th)})^2}$$

$$= \frac{10 \text{ mA}}{(10\text{ V} - 1.5\text{V})^2} = 1.38 \times 10^{-1} \text{ mA/V}^2$$

$$[\because V_{GS\,(on)} = 10\text{V}]$$

From the circuit, the source voltage is seen to be 0V. Therefore, $V_{GS} = V_G - V_S = V_G - 0 = V_G$. The value of V_G (= V_{GS}) is given by ;

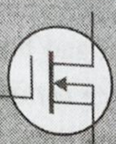
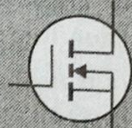
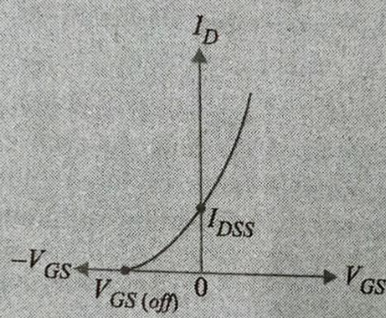
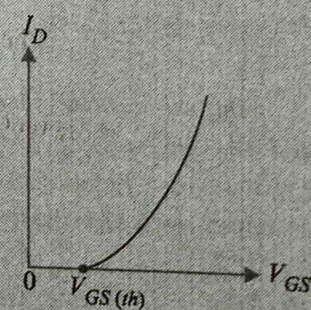
$$V_G \text{ (or } V_{GS}) = \frac{V_{DD}}{R_1 + R_2} \times R_2 = \frac{10\text{V}}{(1+1)\text{ M}\Omega} \times 1\text{M}\Omega = 5\text{V}$$

$$\therefore \quad I_D = K\,(V_{GS} - V_{GS\,(th)})^2$$

$$= (1.38 \times 10^{-1} \text{ mA/V}^2)\,(5\text{V} - 1.5\text{V})^2 = \mathbf{1.69 \text{ mA}}$$

17.45 D-MOSFETs Versus E-MOSFETs

Table below summarises many of the characteristics of *D-MOSFETs* and *E-MOSFETs*.

Devices:	D-MOSFETs	E-MOSFETs
Schematic symbol :		
Transconductance curve :		
Modes of operation :	Depletion and enhancement.	Enhancement only.
Commonly used bias circuits :	Gate bias Self-bias Voltage-divider bias Zero-bias	Gate bias Voltage-divider bias Drain-feedback bias

Short Answer Questions

Q. 1. *What is the working principle of JFET ?*

Ans. The conductivity of the channel between source and drain is controlled by the width of depletion layers at either side of the channel. If the reverse voltage on the gate increases, the channel width decreases. This increases the resistance of the channel and hence source to drain current decreases. Reverse happens should the reverse gate voltage decrease.

Q. 2. *What are the JFET polarities in normal operation ?*

Ans. In normal operation of *JFET*, the voltage between gate and source is such that gate is reverse biased. The drain and source terminals are interchangeable *i.e.* either end of silicon bar can be used as the source and the other as the drain.

Q. 3. *Why is JFET called a unipolar transistor ?*

Ans. In a *JFET*, current conduction is by one type of carrier *viz.* holes in *p*-channel *JFET* and electrons in *n*-channel *JFET*. '*Uni*' means single and polar indicates charge carrier. Hence *JFET* is sometimes called a unipolar transistor. However, in an ordinary transistor, both holes and electrons play part in conduction. Therefore, an ordinary transistor is sometimes called a bipolar transistor.

Q. 4. *What is the origin of the name JFET ?*

Ans. In a *JFET*, current from source to drain can be controlled by the application of potential (*i.e.*, electric field) on the gate. For this reason, the device is called junction field effect transistor (*JFET*).

Q. 5. *Why is the input impedance of a JFET higher than that of ordinary transistor ?*

Ans. The input circuit of the *JFET* is reverse-biased. Consequently, it offers a very high input impedance. However, the input circuit of an ordinary transistor (or bipolar junction transistor) is forward biased and hence has low input impedance.

Q. 6. *What is the basic operational difference between a JFET and an ordinary transistor ?*

Ans. A *JFET* is essentially a voltage-driven device like a vacuum tube *i.e.* input voltage (on gate terminal) controls the output current. However, an ordinary transistor is a current-operated device *i.e.* input current controls the output current.

Q. 7. *Why does a JFET has low noise level ?*

Ans. The operation of a *JFET* depends upon the bulk material current carriers that do not cross junctions. Therefore, inherent noise of tubes (due to high temperature operation) and those of transistors (due to junction transitions) are not present in *JFET*.

Q. 8. *Why is JFET used as a buffer amplifier ?*

Ans. A buffer amplifier is a stage of amplification that isolates the preceding stage from the following stage. Because of the high input impedance and low output impedance, a *JFET* can act as an excellent buffer amplifier.

Q. 9. *What are the advantages of JFET over ordinary transistors ?*

Ans. The advantages of *JFET* over ordinary transistors (or bipolar junction transistors) are :

(*i*) High input impedance and low output impedance. This permits high degree of isolation between input and output circuits.

(*ii*) A low noise level.

(*iii*) Very high power gain. This eliminates the necessity of using driver stages.

(*iv*) Smaller size, longer life and higher efficiency.

Q. 10. *What is the working principle of MOSFET ?*

Ans. The *MOSFET* operates on the principle of controlling the conductivity of the channel between source and drain by the electric field of a capacitor formed at the gate.

Q. 11. *Why is the input impedance of a MOSFET higher than that of a JFET ?*

Ans. The gate of a *JFET* behaves like a reverse biased diode while the gate of a *MOSFET* acts like a capacitor. For this reason, the gate current in a *MOSFET* is essentially zero whether we apply positive or negative voltage to the gate, Hence, the input impedance of a *MOSFET* is very large, larger than that of *JFET*.

Q. 12. *Why does JFET has less voltage gain than that of an ordinary transistor ?*

Ans. Due to large input impedance of *JFET*, it has smaller control over output current. In other words, a *JFET* is less sensitive to changes in input voltage than a bipolar transistor. For example, an input change of 0.2 V in almost any *JFET* will hardly produce a change of 5 mA in the output current. But in a bipolar transistor, 0.1 V change in input voltage can easily produce more than 10 mA change in the output current. This means that a *JFET* will have less voltage gain than a bipolar transistor.

Multiple-Choice Questions

1. A *JFET* has three terminals, namely ....
   (*i*) cathode, anode, grid
   (*ii*) emitter, base, collector
   (*iii*) source, gate, drain
   (*iv*) none of the above
2. A *JFET* is similar in operation to .... valve.
   (*i*) diode (*ii*) pentode
   (*iii*) triode (*iv*) tetrode
3. A *JFET* is also called .... transistor.
   (*i*) unipolar (*ii*) bipolar
   (*iii*) unijunction (*iv*) none of the above
4. A *JFET* is a .... driven device.
   (*i*) current
   (*ii*) voltage
   (*iii*) both current and voltage
   (*iv*) none of the above
5. The gate of a *JFET* is .... biased.
   (*i*) reverse
   (*ii*) forward
   (*iii*) reverse as well as forward
   (*iv*) none of the above
6. The input impedance of a *JFET* is .... that of an ordinary transistor.
   (*i*) equal to (*ii*) less than
   (*iii*) more than (*iv*) none of the above
7. In a *p*-channel *JFET*, the charge carriers are ....
   (*i*) electrons (*ii*) holes
   (*iii*) both electrons and holes
   (*iv*) none of the above
8. When drain voltage equals the pinch-off voltage, then drain current .... with the increase in drain voltage.
   (*i*) decreases
   (*ii*) increases
   (*iii*) remains constant
   (*iv*) none of the above
9. If the reverse bias on the gate of a *JFET* is increased, then width of the conducting channel ....
   (*i*) is decreased
   (*ii*) is increased
   (*iii*) remains the same
   (*iv*) none of the above
10. A *MOSFET* has .... terminals.
    (*i*) two (*ii*) five
    (*iii*) four (*iv*) three
11. A *MOSFET* can be operated with ....
    (*i*) negative gate voltage only
    (*ii*) positive gate voltage only

Example 22.15. *The following quantities are measured in a CE amplifier circuit :*

(a) With output a.c. short-circuited (i.e. $V_{ce} = 0$)

$$I_b = 10\ \mu A\ ;\ I_c = 1\ mA\ ;\ V_{be} = 10\ mV$$

(b) With input a.c. open-circuited (i.e. $I_b = 0$)

$$V_{be} = 0.65\ mV\ ;\ I_c = 60\ \mu A\ ;\ V_{ce} = 1\ V$$

...ine all the four h parameters.

$$h_{ie} = \frac{V_{be}}{I_b} = \frac{10 \times 10^{-3}}{10 \times 10^{-6}} = 1000\ \Omega$$

$$h_{fe} = \frac{I_c}{I_b} = \frac{1 \times 10^{-3}}{10 \times 10^{-6}} = 100$$

$$h_{re} = \frac{V_{be}}{V_{ce}} = \frac{0.65 \times 10^{-3}}{1} = 0.65 \times 10^{-3}$$

$$h_{oe} = \frac{I_c}{V_{ce}} = \frac{60 \times 10^{-6}}{1} = 60\ \mu S$$

22.11 Limitations of *h* Parameters

The *h* parameter approach provides accurate information regarding the current gain, voltage gain, input impedance and output impedance of a transistor amplifier. However, there are two major limitations on the use of these parameters.

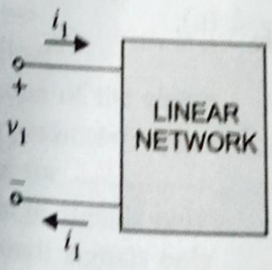
(*i*) It is very difficult to get the exact values of *h* parameters for a particular transistor. It is because these parameters are subject to considerable variation—unit to unit variation, variation due to change in temperature and variation due to change in operating point. In predicting an amplifier performance, care must be taken to use *h* parameter values that are correct for the operating point being considered.

(*ii*) The *h* parameter approach gives correct answers for small a.c. signals only. It is because a transistor behaves as a linear device for small signals only.

Short Answer Questions

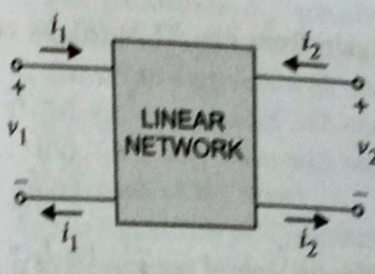
Q. 1. *What is a one-port network ?*

Ans. A one-port network is a two-terminal device or element (such as resistors, capacitors and inductors) through which a current may enter or leave the network. A one-port circuit is represented in Fig. 22.22.



One-port Network

Fig. 22.22



Two-port Network

Fig. 22.23

Q. 2. *What is a two-port network ?*

Ans. A two-port network is an electrical network with two separate ports for input and output. Thus a two-port network has four terminals—two for input and two for output as shown in Fig. 22.23. When voltage v_1 is applied to the input terminals, then input and output currents i_1 and i_2 flow and an output v_2 is produced. Three-terminal devices such as transistors can be arranged as a two-port network by making one of its terminals common to both input and output terminals.

Q. 3. *Why do we study two-port networks ?*

Ans. We study two-port networks for two main reasons. First, such networks are useful in communications, control systems, power systems and electronics. For example, they are used in electronics to model transistors and to facilitate cascaded design. Second, knowing the parameters of a two-port network enables us to treat it as a "black box" when embedded within a larger network.

Q. 4. *Why are h parameters of a two-port linear network called hybrid parameters ?*

Ans. Hybrid means mixed. The four parameters of a two-port linear circuit (*viz* h_{11}, h_{12}, h_{21} and h_{22}) do not have the same dimensions and hence they are called hybrid parameters.

Q. 5. *What are the h parameters h_{11} and h_{21} for the two-port network shown in Fig. 22.24 (i) ?*

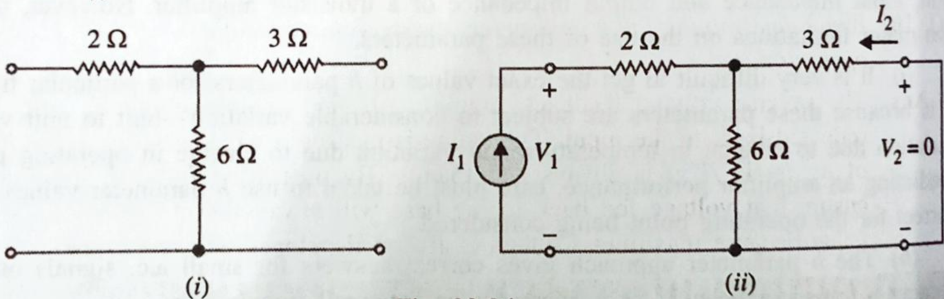


Fig. 22.24

Ans. To find h_{11} and h_{21}, we short-circuit the output and connect a current source I_1 to the input as shown in Fig. 22.24 (*ii*).

From Fig. 22.24 (*ii*), we have,

$$V_1 = I_1\,(2 + 3 \parallel 6) = 4I_1$$

$$\therefore \quad h_{11} = \frac{V_1}{I_1} = 4\Omega$$

Again from Fig. 22.24 (*ii*), by current-divider rule

$$-I_2 = \frac{6}{6+3}\,I_1$$

$$\therefore \quad h_{21} = \frac{I_2}{I_1} = \frac{-2}{3}$$

Q. 6. *Why are hybrid parameters of a transistor named so ?*

Ans. Hybrid means "mixed". A transistor has four h parameters. One of them (input resistance) has units of ohms and the other (output conductance) has the units of siemens. The remaining two h parameters (reverse voltage feedback ratio and current gain) are pure numbers. Since h parameters have mixed units, they are called hybrid parameters.

Q. 7. *What are the two conditions for the measurement of h parameters ?*

Ans. A transistor has four h parameters. Two of them (*i.e.* input resistance and current gain) are measured with $V_{ce} = 0$ (*i.e.* output short-circuited to a.c.). The remaining two (*i.e.* reverse voltage feedback ratio and output conductance) are measured with $I_b = 0$ (*i.e.* input open-circuited to a.c.).

Q. 8. *While determining the h parameter input resistance (h_{ie}) of a transistor, why is output short-circuited ?*

Ans. You may recall that any resistance in the emitter circuit is reflected back to the base. This condition is described in the following equation :

$$Z_{in(base)} = h_{fe}\,(r_e' + R_E)$$ ....See Art. 8.18

By shorting the collector and emitter terminals, the measured value of input resistance does not reflect any external resistance in the circuit.

Q. 9. *While determining the h parameter current gain (h_{fe}) of a transistor, why is output short-circuited ?*

Ans. A shorted output represents full-load so current gain (h_{fe}) represents the gain under full-load conditions. If the output was left open, I_c would be zero. Shorting the output gives us a measurable value of I_c that can be reproduced in a particular test.

Q. 10. *While determining the h parameter reverse voltage feedback ratio (h_{re}), why is input open-circuited ?*

Ans. The reverse voltage feedback ratio (h_{re}) is the amount of output voltage that is reflected back to the input. This value is measured with the input open. The value of h_{re} ($= V_{be}/V_{ce}$) is always less than 1. By measuring h_{re} with input open, you ensure that voltage fed back to the base will always be at its maximum possible value because maximum voltage is always developed across an open-circuit.

Multiple-Choice Questions

1. Hybrid means ....
   (*i*) mixed (*ii*) single
   (*iii*) unique
   (*iv*) none of the above

2. There are .... h parameters of a transistor.
   (*i*) two (*ii*) four
   (*iii*) three
   (*iv*) none of the above

3. The h parameters approach gives correct results for ....
   (*i*) large signals only
   (*ii*) small signals only
   (*iii*) both small and large signals
   (*iv*) none of the above

4. A transistor behaves as a linear device for ....
   (*i*) small signals only
   (*ii*) large signals only
   (*iii*) both small and large signals
   (*iv*) none of the above

5. The parameter h_{ie} stands for input impedance in ....
   (*i*) *CB* arrangement with output shorted
   (*ii*) *CC* arrangement with output shorted
   (*iii*) *CE* arrangement with output shorted
   (*iv*) none of the above

6. The dimensions of h_{ie} parameter are ....
   (*i*) siemens (*ii*) ohms
   (*iii*) farads
   (*iv*) none of the above