

UNIT

3

Marketed by:



PART-A SHORT QUESTIONS WITH SOLUTIONS

Q1. What is bipolar junction transistor?

Ans:

A 'junction transistor' or 'Bipolar Junction Transistor (BJT)' or simply 'transistor', is a three terminal, solid state semiconductor device. It is basically a semiconductor crystal formed by joining two back to back PN junctions. These junctions are arranged such that, one type of semiconductor layer (n-type or p-type) is sandwiched between two layers of the opposite type of semiconductor. The term 'bipolar' in the name indicates the involvement of both majority and minority carries in its operation.

Q2. Why BJT is called as current control device and explain?

Ans:

The BJTs are also termed as current dependent current source devices or simply current control devices.

In order to realize such a device, we require a forward biased diode at the input port and a reverse biased diode at the output port. Also the reverse current of the output diode must be controlled by the forward current of the input diode. Since in the transistor we have two junctions in which one junction is forward biased and the other junction is reverse biased. The forward biased junction injects holes from the P-side (if it is a PNP transistor) called emitter into the N-region called base which is taken as reference electrode. The reverse biased PN junction produces a minority carrier drift current and the output P-region which collects this current is called the collector.

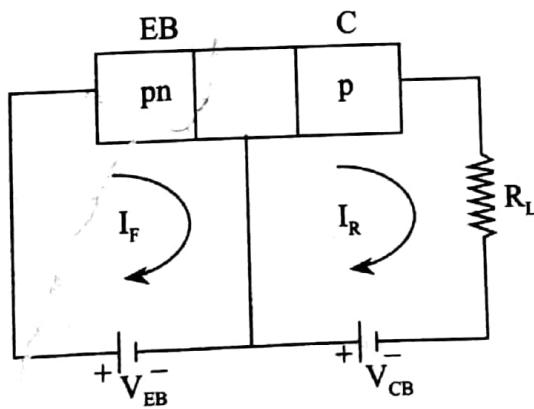


Figure: pnp Transistor

The emitter current injected into the base increases the minority carrier density in the base and augments the reverse minority carrier drift current flowing in the collector circuit. Thus the input emitter current controls the output collector current and the transistor behaves as a current-controlled source or simply current control device.

Q3. A BJT has $I_D = 10 \mu\text{A}$, $\beta = 99$ and $I_{CO} = 1 \mu\text{A}$. What is its collector current I_C ?

Jan.-12, Q3

Ans:

The well known relation between I_C and I_{CO} is expressed as,

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3.2

$$\begin{aligned}I_c &= \alpha I_E + I_{CO} \\I_c &= \alpha(I_B + I_C) + I_{CO} \quad [I_E = I_B + I_C] \\I_c &= \frac{\beta}{1+\beta}(I_B + I_C) + I_{CO} \quad [\because \alpha = \frac{\beta}{1+\beta}]\end{aligned}$$

Given that,

$$\begin{aligned}I_B &= 10 \mu\text{A} = 10 \times 10^{-6} \text{ A} \\I_{CO} &= 1 \mu\text{A} = 10^{-6} \text{ A} \\\beta &= 99 \Rightarrow I_c = \frac{99}{1+99}(10^{-5} + I_c) + 10^{-6} \text{ A} \Rightarrow I_c = 0.99(10^{-5} + I_c) + 10^{-6} \Rightarrow I_c - 0.99 I_c = (0.99 \times 10^{-5}) + 10^{-6} \Rightarrow 0.01 I_c = 1.09 \times 10^{-5} \therefore I_c = 1.09 \text{ mA}\end{aligned}$$

Q4. Explain the concept of base width modulation.

(Model Paper-I, Q5 | July-16, Q6)

(or)

What is early effect in a BJT?

Dec.-13, Q2

(or)

What is meant by "Early Effect" (or) "Base Width Modulation".**Ans:**

Initially, the emitter-base junction of BJT is forward biased and V_{CB} is kept at zero volts. The resultant input characteristics resembles the forward characteristics of p-n diode, such that for a small increase in V_{BE} , a rapid increase in I_E is observed. On increasing the value of V_{CB} from zero volts, keeping V_{EB} constant, a decrease in the width of base region is observed. This effect is known as early effect. This in turn increases the I_E . For every increase in V_{CB} value, the curve shifts towards the left.

Q5. What do you understand by punch through effect?

Dec.-12, Q3

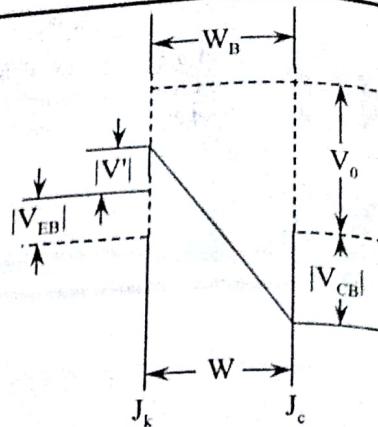
(or)

What do you mean by punch through effect?**Ans:**

The voltage breakdown phenomenon which occurs due to the high collector-junction voltage is called "punch through". This phenomenon is also termed as "Reach through". When punch through occurs, large emitter current is produced.

In this phenomenon, width of the collector-junction transition region increases with the increase in collector-junction voltage, and penetrates more into the base region. The doping concentration of the base is less compared to collector, due to which at moderate voltage itself, the transition region reaches the emitter junction by completely passing through the base region.

In this case, emitter voltage (V) reduces below the normal voltage ($V_0 - |V_{EB}|$) as shown in figure below:

SIA PUBLISHERS AND DISTRIBUTORS PVT. LTD.**Figure**

This lower emitter junction voltage produces large emitter current.

Q6. What is operating? Explain its physical significance?

Dec.-13

(or)

Define operating point of a transistor.**Ans:**

The zero signal collector current and emitter-collector voltage are known as the operating point. Since the variation in the output occurs across this point it is called operating point. Another name for this point is "Quiescent point" (or) Q-point. This is because when no signal is applied for amplification, the transistor stays at this point silently this point is denoted by 'Q' on the D.C load line.

Q7. What are emitter injection efficiency and base transport factor and how do they influence the transistor operation.**Ans:**

June-13, C

Emitter Efficiency

The emitter efficiency (or) injection efficiency of a BJT can be defined as, "the ratio of injected carrier current at emitter junction to the total emitter current".

It is denoted by 'g' and is expressed as,

For PNP transistor,

$$\gamma = \frac{I_{pE}}{I_{pE} + I_{nE}}$$

$$\therefore \gamma = \frac{I_{pE}}{I_E} \quad [\because I_E = I_{pE} + I_{nE}]$$

Where,

I_{pE} – Injected hole diffusion current at emitter junction.

I_{nE} – Injected electron diffusion current at emitter junction.

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The transport factor of a BJT can be defined as, "the ratio of injected carrier current reaching the collector junction to the injected carrier current at emitter junction". It is denoted by b^* and is expressed as,

For PNP transistor,

$$\beta^* = \frac{I_{PC}}{I_{PE}}$$

Where,

I_{PC} – Injected hole diffusion current at collector junction.

I_{PE} – Injected hole diffusion current at emitter junction.

Q8. Why biasing is needed in transistor circuits. List various biasing techniques used in transistor circuits.

Ans:

For the transistor to act as an amplifier it must be operated in its active region. The method of applying external voltages to operate the transistor in the active region is known as biasing. For achieving a perfect amplification in amplifier circuits proper biasing is needs.

The following are the various biasing techniques listed below,

1. Fixed bias
2. Collector to base bias
3. Emitter bias
4. Collector-emitter feedback bias
5. Potential divider bias.

Q9. Why a fixed bias circuit is not commonly used.

Ans:

June-13, Q4

In fixed bias technique, both I_C and V_{CE} depends on ' β ' which again depends on temperature. As a result a change in temperature changes operating point (Q-point) and thus, it is difficult to maintain a stable Q-point. This is the reason for not preferring fixed bias.

Q10. List the advantages and disadvantages of fixed bias.

Ans:

Advantages of Fixed Bias

1. The circuit is very simple.
2. Number of component required are less.

Disadvantage of Fixed Bias

- ❖ The circuit has very high value of stability factor S . Therefore it is highly unstable.

Q11. List the advantages of collector to base bias.

Ans:

The advantages of collector to base bias are,

1. It is easy and simple to design.
2. It requires only ' R_B ' for biasing.

Q12. Why collector to base bias is not much used.

Dec.-12, Q4

Ans:

The reasons for not using collector to base bias are as follows,

1. The circuit provides negative feedback that reduces the gain of an amplifier.
2. Stability factor is fairly high.

Q13. List the advantages of self bias circuit.

Ans:

The advantages of self bias circuit are,

1. It is most popular biasing circuit.
2. Simple ' R_E ' resistance provides good stability.
3. Stability factor (S) is controlled by R_E and R_{th} .
4. Stability factor is small for this circuit compared to other techniques.

Q14. What is meant by stabilization and stabilization factor.

Ans:

Stabilization

The operating point of a transistor acting as an amplifier shifts mainly with changes in I_{CO} , changes in ' β ' and changes in V_{BE} . The process of making the operating point independent of I_{CO} , β and V_{BE} is known stabilization.

Stability Factor (S)

The rate of change of collector current (I_C) with respect to collector leakage current (I_{CO}) at constant values of V_{BE} and β is called stability factor.

$$\text{Stability factor, } S = \frac{\partial I_C}{\partial I_{CO}}$$

Q15. Why CC transistor configuration is seldom used?

Ans:

(Model Paper-II, Q5 | Jan.-12, Q4)

In CC transistor configuration, the input and output impedances provided by the circuit are very high and very low in values respectively. Thus, the voltage gain of this circuit is always smaller than one. Because of this less voltage gain, CC configuration is rarely used for amplification.

Q16. What is α and β .

Ans:

Common Base Current Gain (α): The relationship between I_E and I_C due to majority carriers is related by α , in a D.C. mode. α_{dc} is defined by the following formula,

$$\alpha_{dc} = \frac{\Delta I_C}{\Delta I_E}$$

Q17. A common emitter circuit has a collector load resistor of $1\text{ k}\Omega$. The relationship between the collector current (I_C) and base current (I_B) is given by $I_C = \beta I_B$. The minimum base current required to saturate the transistor is $I_{B(\min)} = 0.062\text{ mA}$. The value of β is 50. The voltage across the load resistor is 1.2 V . Determine the collector current.

- Ans:** In common emitter configuration the voltage drop across load resistor $1\text{ k}\Omega$ is 1.2 V . Determine the base current if $\beta = 50$.

(Model Paper-I, Q8 | July-16, Q8)

Given that,

For a CE configuration,

$$R_L = 1\text{ k}\Omega$$

$$V_L = 1.2\text{ V}$$

$$\beta = 50$$

$$I_S = ?$$

Since, $V_L = I_C R_L$

$$\Rightarrow I_C = \frac{V_L}{R_L} = \frac{1.2}{1 \times 10^3}$$

$$\therefore I_C = 1.2\text{ mA}$$

$$\text{Since, } \beta = \frac{I_C}{I_B}$$

$$\text{Then, } I_B = \frac{I_C}{\beta} = \frac{1.2}{50} \text{ mA}$$

$$\therefore I_B = 24\text{ }\mu\text{A}$$

- Q18.** A pnp transistor has $\beta = 50$ and $I_{C0} = -2\text{ }\mu\text{A}$. CE configuration is used with $V_{CE} = -12\text{ V}$ and collect load resistance of $4\text{ k}\Omega$ ohms. What is the minimum base current value required to saturate the transistor?

Ans:

July-10, Q4

Note: In the given question, ' V_{CC} ' is misprinted as ' V_{CE} '. Given that,

$$\beta = 50$$

$$I_{C0} = -2\text{ }\mu\text{A}$$

$$V_{CE} = -12\text{ V}$$

$$R_L = 4\text{ k}\Omega$$

We know that,

$$V_{CC} - I_C R_L - V_{CE(sat)} = 0$$

$$-12 - I_C (4 \times 10^3) - 0.3 = 0$$

$$\therefore \text{For } G_e, V_{CC(sat)} = 0.3\text{ V}$$

$$-I_C (4 \times 10^3) = 12.3$$

$$I_C = -3.1\text{ mA}$$

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We know that,

$$\beta = \frac{I_C}{I_B}$$

$$I_B = \frac{I_C}{\beta}$$

$$I_B = \frac{-3.1 \times 10^{-3}}{50} = -0.062\text{ mA}$$

The minimum base current required is $(I_B)_{\min} = 0.062\text{ mA}$ to saturate the transistor.

- Q19.** Write the expressions of 'S' for the following.

- (i) Fixed bias
- (ii) Collector to base bias
- (iii) Self bias.

Ans:

- (i) Fixed Bias

$$S = 1 + \beta$$

- (ii) Collector to Base Bias

$$S = \frac{(1+\beta)}{1 + \beta \left(\frac{R_C}{R_C + R_B} \right)}$$

- (iii) Self Bias

$$S = \frac{(1+\beta)(1 + R_{th}/R_E)}{1 + \beta + \frac{R_{th}}{R_E}}$$

- Q20.** Define three types of stability factors and explain.

Ans:

(Model Paper-II, Q6 | Dec.-15, Q3)

To measure the stability of a biasing circuit (against variations in I_{CO} , V_{BE} and β), three parameters are defined. They are S , S' and S'' . These parameters are known as stability factors.

Stability Factor, S

The rate of change of collector current (I_C) with respect to collector-base leakage current (I_{CO}) at constant values of I_B and b is called stability factor 'S'.

$$\text{i.e., } S = \frac{\partial I_C}{\partial I_{CO}}$$

Stability Factor S'

The rate of change of I_C with V_{BE} at constant values of I_{CO} and b is known as stability factor, S' .

$$\text{Stability factor, } S' = \frac{\partial I_C}{\partial V_{BE}}$$

Stability Factor S''

The rate of change of collector current I_C with respect to b at constant values of I_{CO} and V_{BE} is called stability factor, S'' .

$$\text{i.e., stability factor, } S'' = \frac{\partial I_C}{\partial \beta}$$

The values of S , S' and S'' indicate the stability of a circuit. If the values of S , S' and S'' are large, the circuit is highly unstable, else the circuit is highly stable.

Q21. Define thermal runaway.

The expression for the collector current of common emitter circuit is given as,

$$I_C = \beta I_B + (1 + \beta) I_{CBO} \quad \dots (1)$$

When the temperature increases, the parameters ' β ', I_C and I_{CBO} in equation (1) also increase. Specially the reverse saturation current I_{CBO} increases greatly with rise in temperature i.e., for every 10° raise in temperature, I_{CBO} gets doubled. Initially the collector base junction temperature is increased by collector current ' I_C ' which in turn increases I_{CBO} . This increases the collector current I_C (from equation (1)), which will further increase the collector-base junction temperature. This process becomes cumulative and leads to "thermal runaway". The transistor may destroy by itself as the ratings of the transistor are exceeded.

Q22. Define thermal resistance.

Ans:

Thermal resistance is denoted by ' θ ' and can be expressed as,

$$\theta = (T_J - T_A)/P_D$$

Where,

T_J = Collector base junction temperature

T_A = Ambient temperature

P_D = Power dissipated.

Generally for high power transistor, its value is $0.2^\circ\text{C}/\text{W}$

$$T_J - T_A = \theta P_D$$

$$\Rightarrow T_J - T_A \propto P_D$$

Hence, thermal resistance value depends on difference between junction temperature and ambient temperature. If this difference is high then thermal resistance becomes high.

Q23. In CE configuration, the voltage drop across load resistance of $1\text{ k}\Omega$ is 1.2 V . Determine the base current. Given $\beta = 60$.

Ans:

June/July-11, Q4

Given that,

$$\beta = 60$$

The voltage drops across, R_L is 1.2 V

$$\text{i.e., } V_{CE} = 1.2\text{ V}$$

$$R_L = 1\text{ k}\Omega$$

$$\text{Collector current, } I_C = \frac{V_{CE}}{R_L}$$

$$I_C = \frac{1.2}{1000}$$

$$I_C = 1.2\text{ mA}$$

The expression for β is,

$$\beta = \frac{I_C}{I_B}$$

$$\Rightarrow 60 = \frac{1.2\text{ mA}}{I_B}$$

$$\Rightarrow I_B = \frac{1.2\text{ mA}}{60}$$

$$\Rightarrow I_B = 20\text{ }\mu\text{A}$$

- Q24. The reverse saturation current of a N-P-N transistor in common base circuit is $12.5\text{ }\mu\text{A}$. For an emitter current of 2 mA , collector current is 1.97 mA . Determine the current gain and base current.**

Ans:

July-12, Q3

Given that,

The reverse saturation current, $I_{w0} = 12.5\text{ }\mu\text{A}$

$$I_E = 2\text{ mA}$$

$$I_C = 1.97\text{ mA}$$

$$\therefore \text{Current gain, } \alpha = \frac{I_C - I_{CO}}{I_E}$$

$$\alpha = \frac{1.97 \times 10^{-3} - 12.5 \times 10^{-6}}{2 \times 10^{-3}}$$

$$\alpha = 0.97875$$

Current gain, $\alpha = 0.98$

We know that,

$$\beta = \frac{\alpha}{1-\alpha}$$

$$\beta = \frac{0.98}{1-0.98}$$

$$\beta = 49$$

$$\Rightarrow \beta = \frac{I_C}{I_B}$$

$$\Rightarrow I_B = \frac{I_C}{\beta}$$

$$I_B = \frac{1.97 \times 10^{-3}}{49}$$

$$\therefore \text{Base current, } I_B = 40\text{ }\mu\text{A}$$

PART-B**ESSAY QUESTIONS WITH SOLUTIONS****3.1 TRANSISTOR JUNCTION FORMATION (COLLECTOR-BASE, BASE-EMITTER JUNCTIONS
- TRANSISTOR BIASING - BAND DIAGRAM OF NPN AND PNP TRANSISTORS)**

Q25. Write a short note on transistor.

Ans:

A Bipolar Junction Transistor (BJT) consists of three regions namely emitter, base and collector.

Emitter: An emitter is a heavily doped layer of transistor with moderate cross-sectional area. It acts as a source of majority charge carriers (i.e., either holes or electrons) for the other two layers of transistor.

Collector: A collector is a moderately doped layer of transistor with large cross-sectional area. Its main function is to collect the majority charge carriers injected by the emitter into the base region.

Base: A base is a lightly doped layer with narrow cross-sectional area. It lies between the emitter and collector regions of transistor. From a bulk of majority charge carriers released by the emitter, only few charge carriers recombine in the base region, while most of them gets diffused into the collector region through the base. Thus, base acts as a passage for the movement of charge carriers from emitter to the collector.

Q26. Write a short note on construction of transistor.

(or)

Briefly explain the construction of BJT.

Ans:

Transistor Fabrication: Initially, the fabrication of an n-p-n bipolar junction transistor involves creation of a P-type single crystal semiconductor wafer using 'crystal growth' and "diffusion" process. On this P-type single crystal wafer, various components are fabricated, that is, wafer is the base for fabricating different components and their interconnections.

Step-1: The first step in the process of fabricating a transistor on the P-type substrate is to grow an N-type epitaxial layer on the substrate. Epitaxy means arranged upon, i.e., on the P-type single crystal an N-type single crystal is arranged or grown using epitaxial growth process. The thickness of the epitaxial layer is in the order of "fraction of microns" to "few microns", whereas the thickness of the P-type substrate is in the order of few hundreds of microns. The growth of epitaxial layer on the P-type single crystal substrate is as shown in figure (1).

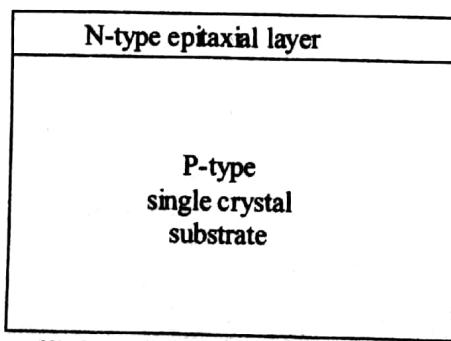


Figure (1): Growth of Epitaxial Layer on P-substrate

The epitaxial layer formed in step 1 acts as collector.

Step-2: Having realized a collector the next step is to create a p-region (by doping impurity atoms) for the base. To realize the base of the transistor the process of oxidation, photolithography and diffusion has to be repeated. The P-type base is located within the epitaxial layer as shown in figure (2).

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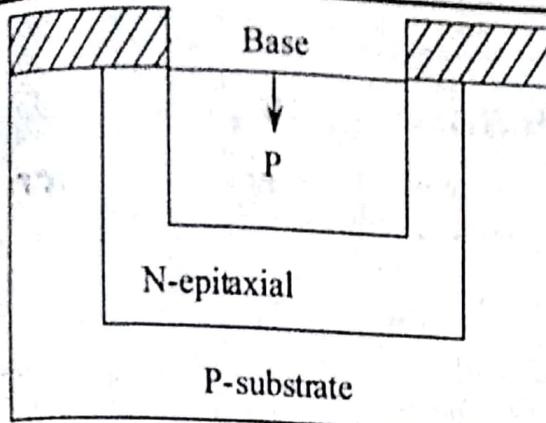


Figure (2): Formation of Base of the Transistor

Step-3: Finally, the emitter is developed with in the base as shown in figure (3). For the creation of heavily doped n+ emitter region once again the process of oxidation, photolithography and diffusion are repeated.

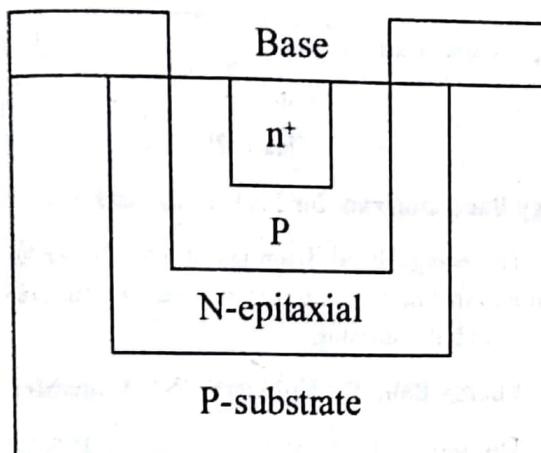


Figure (3): Creation of Heavily Doped n+ Emitter Region

Step-4: The three regions of the transistor are connected to the external circuit by establishing, metal contact from the regions to the outside world as shown in figure (4). This is done by a technique called Metallization.

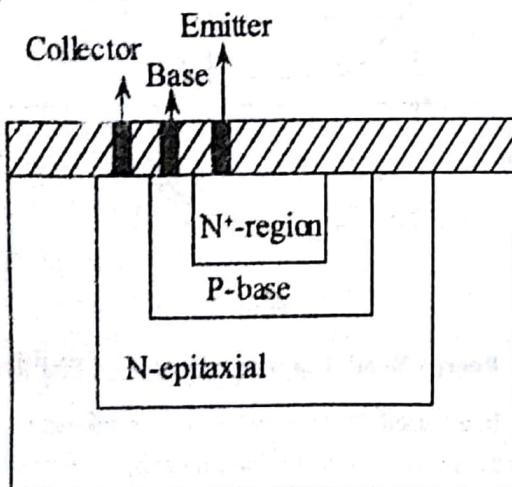


Figure (4): Formation of Metal Contacts

Q27. Explain the working of PNP transistor.

Ans: Generally, the emitter to base junction of a transistor is always forward biased while the collector to base junction is reverse biased. Figure illustrates the basic connections of an PNP transistor.

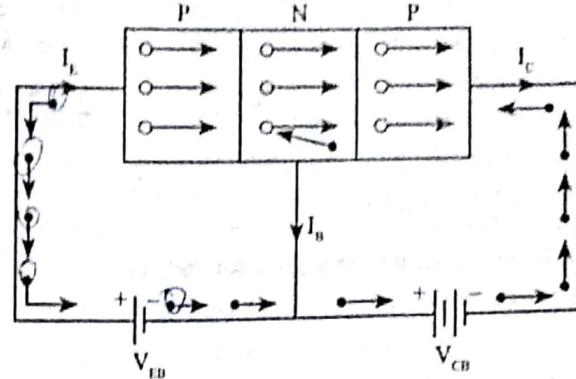


Figure: Basic Connections of PNP Transistor

Basically, in PNP configuration, the majority charge carriers are holes and minority charge carriers are electrons.

It can be observed from the figure that the positive terminal of V_{EB} is connected to the emitter terminal, in order to push holes into the base. The negative terminal of V_{CB} is connected to the collector terminal so that holes are collected from the base.

Due to forward biasing, the holes from the emitter region travel towards the base (N-type). This in turn produces emitter current, I_E in the circuit. The base region is lightly doped and very thin, therefore only few holes (5%) tends to combine with electrons and produce base current (I_B). The remaining holes (95%) move towards the collector region (P-type) and produce collector current (I_C). Therefore in PNP transistor, the emitter current is the sum of base current and collector current.

$$\text{i.e., } I_E = I_B + I_C$$

Q28. Explain the working of NPN transistor with a neat sketch.

Ans:

Model Paper-I, Q14(a)

Figure illustrates the basic connections of an NPN transistor.

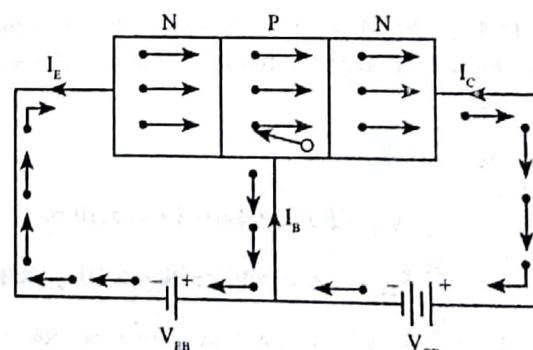


Figure: Basic Connection of NPN Transistor

Basically, in NPN configuration, the majority charge carrier are electrons and minority charge carriers are holes.

It can be observed from figure that the negative terminal of V_{EB} is connected to the emitter terminal in order to push electrons into the base. The positive terminal of V_{CB} is connected to the collector terminal so that electrons are collected from the base.

3.8

Due to forward biasing, the electrons from the emitter region travel towards the base (P-type). This in turn produces emitter current, I_E in the circuit. The base region is lightly doped and very thin, therefore only few electrons (5%) tends to combine with holes and produce base current (I_B). The remaining electrons (95%) move towards the collector region (N-type) and produce collector current (I_C). Therefore, in NPN transistor, the emitter current is the sum of base current and collector current.

$$\text{i.e., } I_E = I_B + I_C$$

Q29. Draw the energy band diagrams of NPN and PNP transistors.

Ans:

Energy band Diagram of NPN Transistor

(a) **Energy Band for an Unbiased NPN Transistor**

The total current density of an unbiased NPN transistor is zero because the electron-current densities due to diffusion and drift nullify each other.

The energy band diagram for NPN transistor under equilibrium i.e., for an unbiased NPN transistor is as shown in figure (1).

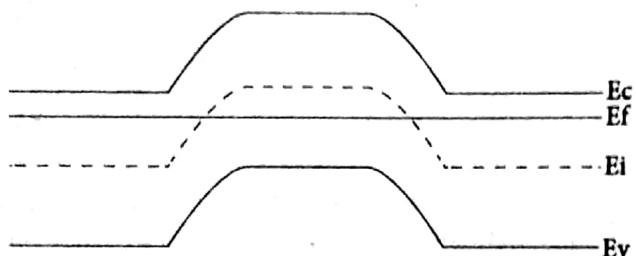


Figure (1): Energy-band Diagram for NPN transistor at Zero Biasing

(b) **Energy band for a Biased NPN Transistor**

In a biased NPN transistor, the emitter-base junction is forward biased, so the potential barrier across it is equivalent to $V_D - V_{BE}$.

Where,

V_D – Potential barrier at zero bias

V_{BE} – Forward bias across BE junction.

The collector-base junction is reverse biased, so the potential barrier across it becomes $e(V_o + V_{CB})$

Where,

V_o – Potential barrier at zero bias

V_{CB} – Applied bias voltage across CB junction.

The energy band diagram of biased NPN transistor is as shown in figure (2).

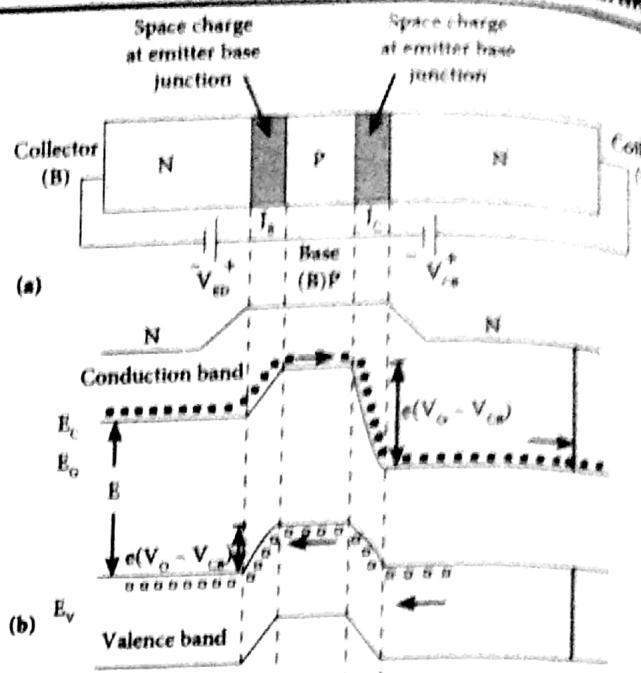


Figure (2)

Energy Band Diagram for PNP Transistor

The energy band diagrams of PNP transistor are opposite to that of NPN transistor. Since the current is due to holes for a PNP transistor.

(a) **Energy Band for Unbiased PNP Transistor**

The total current density of PNP transistor is zero because the electron current density due to diffusion and drift nullify each other.

The energy band for unbiased PNP transistor is as shown in figure (3).

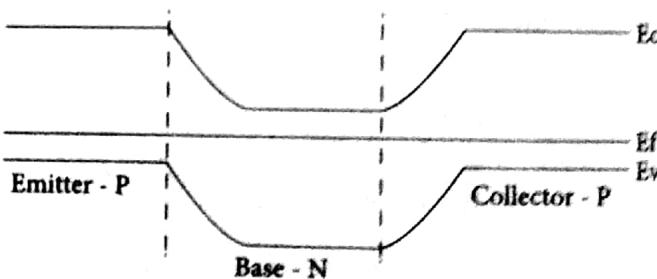


Figure (3)

(b) **Energy Band Diagram of a Biased PNP Transistor**

In a biased PNP transistor, the emitter-base junction is forward biased and collector-base junction is reverse biased. The Fermilevel of base side C-B junction is lowered compared to collector-side Fermilevel. Likewise, the Fermilevel of base side of E-B junction is high compared to emitter side Fermilevel.

The energy-band diagram of a biased PNP transistor is as shown in figure (4).

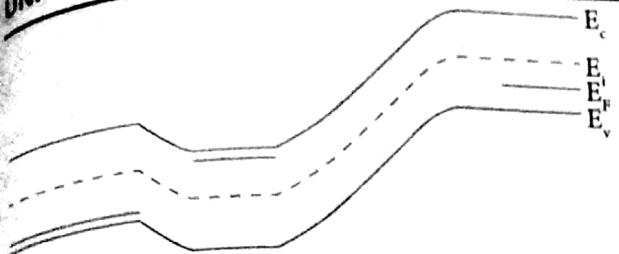


Figure (4)

3.2 CURRENT COMPONENTS AND CURRENTS FLOW IN BJT

Q30. With a neat diagram, explain the various current components in an NPN bipolar junction transistor and hence derive general equation for collector current, I_C .

Ans:

Model Paper-II, Q14(a)

Current Components in NPN Transistor: The various current components flowing through an NPN transistor with its emitter junction forward-biased and collector junction reverse-biased are as shown in figure below:

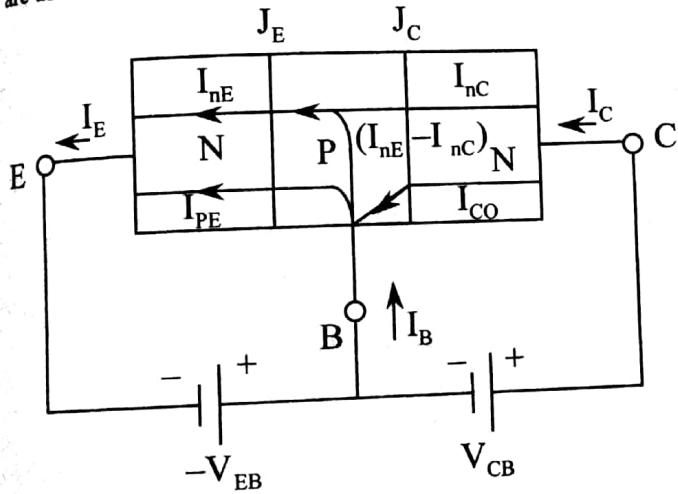


Figure: Current Components in NPN Transistor

The forward biasing of emitter junction (J_E) causes movement of electrons (from emitter to base) and holes (from base to emitter) producing an emitter current (I_E). This current can be expressed as the sum of electron current (I_{nE}) and hole current (I_{pE}) at the emitter junctions.

$$\Rightarrow I_E = I_{nE} + I_{pE} \quad \dots (1)$$

Generally, commercial transistors are heavily doped by emitter rather than the base. As a result, the emitter current in NPN transistor is almost due to electrons. Since, the holes during I_{pE} constitute a minor portion in the transistor and contributes no charge carriers to the collector, I_{pE} can be neglected.

$$\therefore I_E \approx I_{nE} \quad \dots (2)$$

From a large number of electrons in the emitter junction (J_E), a major portion reaches the collector junction, while few of them recombine with the holes in the base. The electrons which cross the collector junction (J_C) gives a collector current (I_{nC}). On the other hand, the recombination of electrons and holes in base produces a leakage current ($I_{nE} - I_{nC}$).

The reverse-biasing of collector junction (J_C) produces a reverse-saturation current (I_{CO}) in the collector. The sum of I_{CO} and I_{nC} gives the total collector current.

$$\Rightarrow I_C = I_{nC} + I_{CO}$$

I_{CO} can also be represented in terms of hole and electron currents as,

$$I_{CO} = I_{pCO} + I_{nCO}$$

When the emitter portion of transistor is open circuited (i.e., $I_E = 0$), I_{nC} also becomes zero. Due to this base and collector acts as a reverse-biased diode resulting in $I_C = I_{CO}$.

$$I_C = I_{nC} + I_{CO} \quad [\because I_{CO} \text{ is positive for non-transistor}]$$

$$\Rightarrow I_C = \alpha I_{nE} + I_{CO} \quad \left[\because \alpha = \frac{I_{nC}}{I_{nE}} \right]$$

$$\therefore I_C = \alpha I_E + I_{CO} \quad [\because \text{From equation (2)}]$$

Q31. With neat diagram explain the various components in a pnp transistor. Also derive general equation for collector current.

Ans:

Current Components in PNP Transistor: The flow of current components in a transistor can be illustrated by considering a PNP transistor. The various current components flowing through a PNP transistor with its emitter junction forward-biased and collector junction reverse-biased are as shown in figure below:

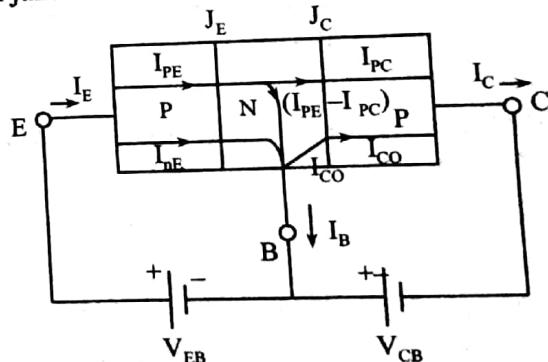


Figure: Current Components in PNP Transistor

The forward biasing of emitter-base junction (J_E) causes movement of holes (from emitter to base) and electrons (from base to emitter) producing an emitter current (I_E). This current can be expressed as the sum of hole current (I_{pE}) and electron current (I_{nE}) at the emitter junction.

$$\Rightarrow I_E = I_{pE} + I_{nE} \quad \dots (1)$$

Generally, the commercial transistors are heavily doped by emitter rather than the base. As a result, the emitter current in pnp transistor is almost due to holes. Since, the electrons producing I_{nE} constitutes a minor portion in the transistor and contributes no charge carriers to the collector, I_{nE} can be neglected.

$$\therefore I_E \approx I_{pE} \quad \dots (2)$$

From a large number of holes crossing the emitter junction (J_E), a major portion reaches the collector junction, while few of them recombine with the electrons in the base. The holes which cross the collector junction (J_C) gives a collector hole current (I_{pC}). On the other hand, the recombination of holes and electrons in base produces a leakage current ($I_{pE} - I_{pC}$).

The reverse biasing of collector base junction (J_C) produces a reverse-saturation current (I_{CO}) in the collector. The sum of I_{CO} and I_{pC} gives the total collector current.

$$\Rightarrow I_C = I_{pC} + I_{CO} \quad \dots (3)$$

I_{CO} can also be represented in terms of hole and electron currents, as,

$$I_{CO} = I_{pCO} + I_{nCO} \quad \dots (4)$$

When the emitter portion of transistor is open circuited (i.e., $I_E = 0$), I_{pC} also becomes zero. Due to this base and collector acts as a reverse-biased diode, yielding a collector current $I_C = I_{CO}$.

From figure it can be observed that, for $I_E \neq 0$.

$$I_C = I_{pC} - I_{CO} [\because I_{CO} \text{ is negative for PNP transistor}]$$

$$\Rightarrow I_C = \alpha I_{pE} - I_{CO} \quad \left[\because \alpha = \frac{I_{pC}}{I_{pE}} \right] \quad \dots (5)$$

$$I_C = \alpha I_E - I_{CO} \quad [\because \text{From equation (2)}]$$

Q32. Define alpha (α), beta (β) and gamma (γ). Derive the relation between them.

(or)

Obtain relationship between alpha, beta and gamma.

Dec.-15, Q9

(Refer Only Relation Between α , β and γ)

Ans:

Alpha (α): In common base configuration, the current gain is referred as alpha (α). It is defined as the ratio of change in collector current (ΔI_C) to the change in emitter current (ΔI_E) of a transistor operating in common base configuration i.e.,

$$\alpha = \frac{\Delta I_C}{\Delta I_E} \quad \dots (1)$$

Beta (β): In common emitter configuration, the current gain is referred as beta (β). It is defined as the ratio of change in collector current (ΔI_C) to the change in base current (ΔI_B) of a transistor operating in common emitter configuration i.e.,

$$\beta = \frac{\Delta I_C}{\Delta I_B} \quad \dots (2)$$

Gamma (γ): In common collector configuration, the current gain is referred as gamma (γ). It is defined as the ratio of change in emitter current (ΔI_E) to the change in base current (ΔI_B) of a transistor operating in common collector configuration i.e.,

$$\gamma = \frac{\Delta I_E}{\Delta I_B} \quad \dots (3)$$

Relation between α , β and γ : The general current equation of transistor is given by,

$$\Delta I_E = \Delta I_C + \Delta I_B \quad \dots (4)$$

$$\text{From the definition of } \alpha, \text{i.e., } \alpha = \frac{\Delta I_C}{\Delta I_E}$$

$$\begin{aligned} \alpha &= \frac{\Delta I_C}{\Delta I_C + \Delta I_B} = \frac{1}{\frac{\Delta I_C + \Delta I_B}{\Delta I_C}} = \frac{1}{1 + \frac{\Delta I_B}{\Delta I_C}} \\ &= \frac{1}{1 + \frac{1}{\beta}} = \frac{1}{1 + \beta} = \frac{\beta}{\beta + 1} \end{aligned}$$

$$(\text{From the definition of } \beta, \text{i.e., } \beta = \frac{\Delta I_E}{\Delta I_B})$$

$$\therefore \alpha = \frac{\beta}{\beta + 1} \quad \dots (5)$$

$$\text{From the definition of } \gamma, \text{i.e., } \gamma = \frac{\Delta I_E}{\Delta I_B}$$

$$\Rightarrow \gamma = \frac{\Delta I_C + \Delta I_B}{\Delta I_B} = \frac{\Delta I_C}{\Delta I_B} + 1 = \beta + 1$$

$$\therefore \gamma = \beta + 1 \quad \dots (6)$$

From equations (5) and (6), we get,

$$\alpha = \frac{\beta}{\gamma}$$

$\beta = \alpha\gamma$, which specifies the relation between alpha, beta and gamma.

3.3 MODES OF TRANSISTOR OPERATION, EARLY EFFECT - BJT INPUT AND OUTPUT CHARACTERISTICS IN CB, CE, CC CONFIGURATIONS

Q33. What are the different configurations of BJT? Explain.

Ans:

A BJT can be operated in three different configurations. They are,

- (i) Common Base (CB) Configuration
- (ii) Common Emitter (CE) Configuration
- (iii) Common Collector (CC) Configuration

An NPN transistor arranged in common base (CB) configuration is as shown in figure (1).

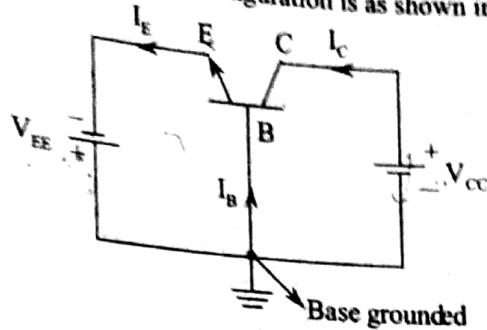


Figure (1): CB Configuration

In this arrangement the emitter, collector and base act as input, output and common terminals respectively. The base is at ground potential. Hence this configuration is also referred by the name grounded-base configuration. The voltages at the collector and emitter terminals are measured with respect to base.

Common Emitter (CE) Configuration

The configuration in which emitter is common to both sides of configuration is known as common emitter configuration. An NPN transistor arranged in common emitter (CE) configuration is as shown in figure (2).

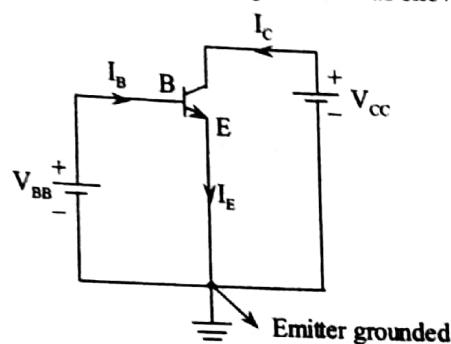


Figure (2): CE Configuration

In this arrangement the base, collector and emitter act as input, output and common terminals respectively. The emitter is at ground potential. Hence this configuration is also referred by the name grounded-emitter configuration.

(iii) Common Collector (CC) Configuration

The configuration in which collector is common to both the input and output sides of configuration is known as common collector (CC) configuration.

An NPN transistor arranged in common collector configuration is as shown in figure (3).

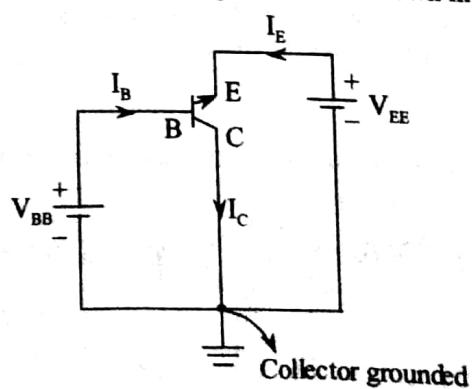


Figure (3): CC Configuration

In this arrangement the base, emitter and collector acts as input, output and common terminals respectively. The collector

3.12

Q34. Compare CB, CE and CC configuration with respect to any three parameters.

(Model Paper-I, Q14(b) | Dec.-12, Q12(b))

(or)

Compare CE, CB and CC amplifiers.

(or)

Compare the three configurations of the BJT amplifiers, in respect of their applicability and performance.

July-12, Q12(b)

Ans:

The comparison between CB, CE and CC amplifiers is mentioned below:

Characteristic	CB Amplifier	CE Amplifier	CC Amplifier
1. Input impedance	Low i.e., $100\ \Omega$	Moderate i.e., $750\ \Omega$	High i.e., $750\ k\Omega$
2. Output impedance	High i.e., $450\ k\Omega$	Moderate i.e., $45\ k\Omega$	Low i.e., $25\ \Omega$
3. Voltage gain	≈ 150	≈ 500	< 1
4. Current gain	1	High	High
5. Phase shift between input and output voltages.	0° or 360°	180°	0° or 360°
6. Current amplification factor	$\alpha = \frac{\Delta I_C}{\Delta I_E}$	$\beta = \frac{\Delta I_C}{\Delta I_B}$	$\gamma = \frac{\Delta I_E}{\Delta I_B}$
7. Applications	These are used for high frequency circuits.	These are used for audio frequency circuits.	These are used for impedance matching.

Q35. Explain operation of common base configuration of BJT to obtain input and output characteristics?

Dec.-15, Q13(a)

(or)

With neat sketches and necessary waveforms, explain the input and output characteristics of a BJT in CB configuration. Also derive expression for output current.

Ans:

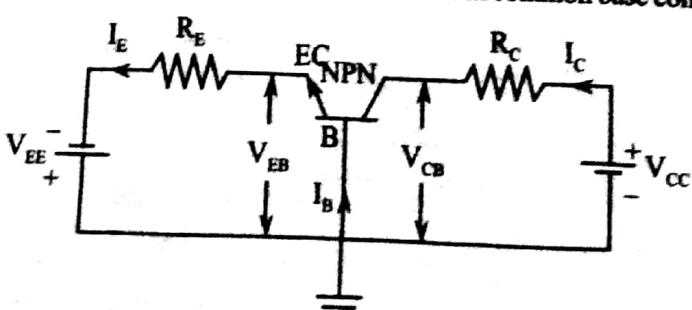
Common Base (CB) Configuration: The arrangement of an NPN transistor in common base configuration is as shown in figure (1).

Figure (1): CB Configuration

The input characteristics of BJT in common base configuration is as shown in figure (2).

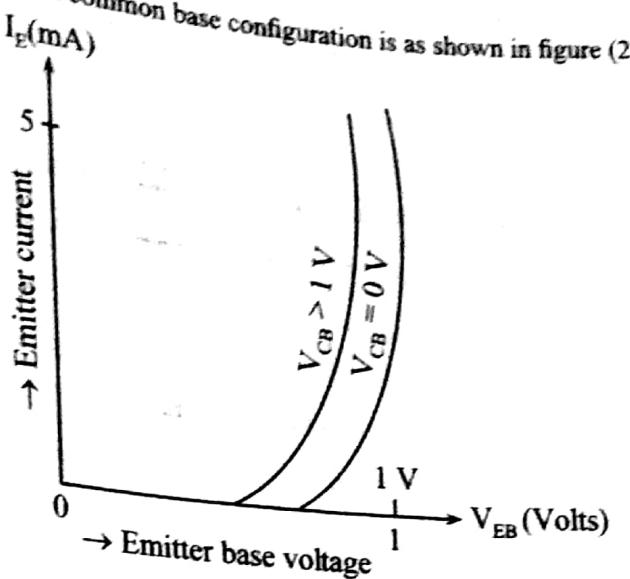


Figure (2): Input Characteristics of BJT in CB Configuration

From figure (2), it can be observed that I_E is the input current, V_{EB} is the input voltage and V_{CB} is the output voltage.

- (i) Initially, the emitter-base junction of BJT is forward biased and V_{CB} is kept at zero volts. The resultant input characteristics resembles with the forward characteristics of p-n diode, such that for a small increase in V_{EB} , a rapid increase in I_E is observed.
- (ii) On increasing the value of V_{CB} from zero volts, keeping V_{EB} constant, a decrease in the width of base region is observed. This effect is known as early effect. This in turn increases the I_E . For every increase in V_{CB} value, the curve shifts towards the left.

Output Characteristics

The curves plotted between collector-base voltage (V_{CB}) and collector current (I_C), keeping the emitter current (I_E) constant is known as output characteristics of CB transistor.

The output characteristics of BJT in CB configuration is as shown in figure (3).

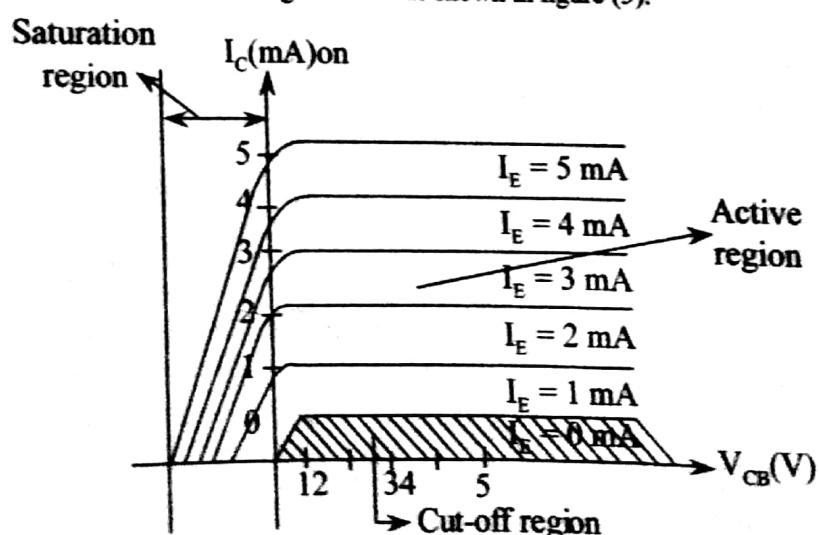


Figure (3): Output Characteristics of BJT in CB Configuration

From figure (3), it can be observed that, I_C is the output current, V_{CB} is the output voltage and I_E is the input current. The output characteristics of a transistor are divided into three regions as shown in figure (3).

(i) **Active Region**

In this region the emitter junction is forward biased and collector junction is reverse biased. It lies between the saturation and cut-off regions of transistor.

(ii) **Saturation Region**

In this region both the emitter and collector junctions are forward biased. It usually lies to the left of the ordinate $V_{CB} = 0$.

(iii) **Cut-off Region:** In this region both the emitter and collector junctions are reverse biased. This region lies below $I_E = 0$.

From the output characteristic curves it can be observed that,

- The collector current varies only for low values of V_{CB} (i.e., < 1 V). At higher values of V_{CB} , I_C becomes constant as indicated by the straight parallel curves. Thus I_C depends only on I_E
- For large variation in V_{CB} , only a small variation occurs in I_C . This implies that there exists a very high value of output resistance.

Current Gain CB Configuration: The ratio of collector current (I_C) to the emitter current (I_E) gives the common base D.C. current gain of transistor. It is denoted by α , α_{dc} or h_{fb} and can be expressed as,

$$\alpha = \frac{I_C}{I_E}$$

... (1)

Since I_C is smaller than I_E , therefore α is always less than unity.

Equation (1) can be rewritten as,

$$I_C = \alpha I_E$$

... (2)

From the I_E , I_B and I_C relationship, we have

$$I_E = I_B + I_C$$

... (3)

Since collector current I_C is also produced by the thermally generated carriers as leakage current I_{CO} .

The total collector current is given as,

$$\begin{aligned} I_C &= \alpha I_E + I_{CO} \\ \Rightarrow \alpha I_E &= I_C - I_{CO} \end{aligned}$$

... (4)

$$\alpha = \frac{I_C - I_{CO}}{I_E}$$

... (5)

On substituting equation (3) in equation (5), we get,

$$\alpha = \frac{I_C - I_{CO}}{I_B + I_C}$$

$$\alpha(I_B + I_C) = I_C - I_{CO}$$

$$I_C = \alpha(I_B + I_C) + I_{CO}$$

$$I_C = \alpha I_B + \alpha I_C + I_{CO}$$

$$(1 - \alpha)I_C = \alpha I_B + I_{CO}$$

$$\therefore I_C = \frac{\alpha I_B}{1 - \alpha} + \frac{I_{CO}}{1 - \alpha}$$

This is the required output current i.e., collector current of a common-base transistor.

Q36. Draw and explain output characteristics of common-emitter configuration for n-p-n transistor.

July-16, Q13(a)

(or)

With neat sketches and necessary waveforms, explain the input and output characteristics of a BJT in CE configuration. Also derive expression for output current.

Ans:

Common Emitter (CE) Configuration

The arrangement of an NPN transistor in common-emitter configuration is as shown in figure (1).

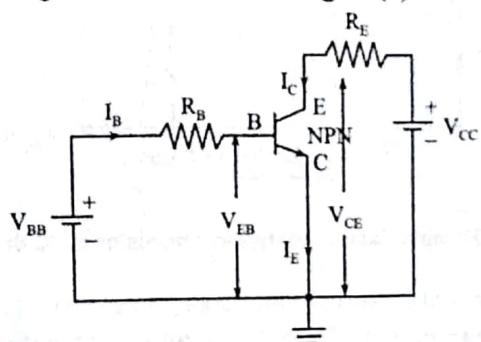


Figure (1): Common Emitter Configuration

Input Characteristics of CE Configuration

The curve plotted between base current ' I_B ' and base-emitter voltage ' V_{BE} ', keeping collector-emitter voltage ' V_{CE} ' constant, gives the input characteristics of CE configuration.

The input characteristics of transistor in common-emitter configuration is as shown in figure (2).

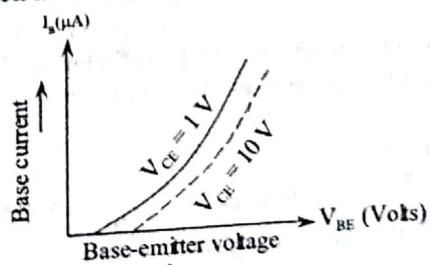


Figure (2): Input Characteristics of Transistor in CE Configuration

It can be observed from figure (2), that input characteristics of CE transistor are drawn by taking V_{BE} along the x-axis and I_B along the y-axis.

The input characteristics of CE transistor are similar to the forward characteristics of a PN junction diode (i.e., for a increase in V_{BE} value, I_B also increases gradually). Therefore, a higher order of resistance is observed at its input.

At constant V_{CE} , the ratio of change in base-emitter voltage ' ΔV_{BE} ' to change in base current ' ΔI_B ', gives the input resistance of CE transistor.

$$\text{i.e., } r_i = \frac{\Delta V_{BE}}{\Delta I_B} \Big|_{V_{CE}=\text{constant}}$$

Output Characteristics of CE Configuration

The curve plotted between collector current ' I_C ' and collector-emitter voltage ' V_{CE} ', keeping base current ' I_B ' constant gives the output characteristics of CE configuration.

The output characteristics of transistor in common-emitter configuration is as shown in figure (3).

I_C (mA)

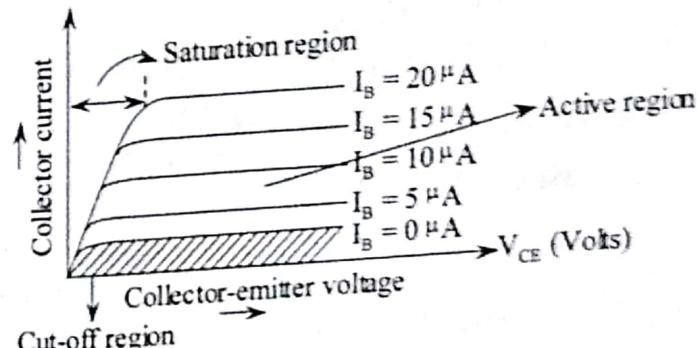


Figure (3): Output Characteristics of Transistor in CE Configuration

It can be observed from figure (3), that output characteristics of CE transistor are drawn by taking V_{CE} along the x-axis and I_C along the y-axis.

The collector current ' I_C ' varies only for low values of V_{CE} (i.e., between 0 and 1 V), after which it becomes constant. The value of voltage till which I_C depends on V_{CE} is referred to as 'knee voltage'. The CE transistor operates only in the region above knee voltage.

A small increase in I_C with increasing V_{CE} after the knee voltage, is only due to wider collector depletion layer.

When V_{CE} exceeds the knee voltage, then, $I_C \approx \beta I_B$

At constant I_B , the ratio of change in collector-emitter voltage ' ΔV_{CE} ' to the change in collector current ΔI_C gives the output resistance of CE transistor.

$$\text{i.e., } r_o = \frac{\Delta V_{CE}}{\Delta I_C} \Big|_{I_B=\text{constant}}$$

Output Current

When a transistor is operated in active region, its emitter is forward biased and collector is reverse biased. The collector current I_C is influenced by the emitter current (I_E) and collector voltage (V_C). This can be observed in the general expression of I_C given by,

$$I_C = -\alpha I_E + I_{CBO} \quad \dots (1)$$

For low values of V_C or V_{CB} , I_C becomes independent of V_C i.e., collector current (I_C) is equal to α times the emitter current (I_E).

Due to the opposite directions of I_C and I_E ,

We get,

$$I_E = -(I_C + I_{CBO})$$

3.16

Substituting ' I_E ' in equation (1), we get,

$$\begin{aligned} I_C &= \alpha (-I_C + I_S) + I_{CBO} \\ &= \alpha (I_C + I_S) + I_{CBO} \\ I_C &= \alpha I_C + \alpha I_S + I_{CBO} \\ I_C - \alpha I_C &= \alpha I_S + I_{CBO} \\ (1-\alpha) I_C &= \alpha I_S + I_{CBO} \\ \Rightarrow I_C &= \frac{\alpha}{1-\alpha} I_S + \frac{1}{1-\alpha} I_{CBO} \end{aligned}$$

We have, $\beta = \frac{\alpha}{1-\alpha}$ and

$$\begin{aligned} \alpha &= \frac{\beta}{1+\beta} \\ \Rightarrow 1-\alpha &= 1 - \frac{\beta}{1+\beta} \\ &= \frac{1+\beta-\beta}{1+\beta} = \frac{1}{1+\beta} \\ \text{or } \frac{1}{1-\alpha} &= 1 + \beta \end{aligned}$$

$$\therefore I_C = \beta I_S + (1+\beta) I_{CBO}$$

Q37. Draw and explain the characteristics of CC configuration.

June-13, Q12(b)

(or)

With a necessary diagram, explain the input and output characteristics of common collector (CC) configuration.

Ans:

Common Collector (CC) Configuration: The arrangement of NPN transistor in common collector (CC) configuration is as shown in figure (1).

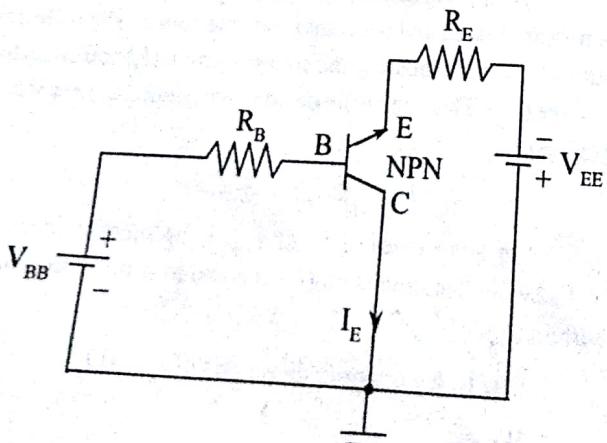


Figure (1): CC Configuration

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Input Characteristics of CC Configuration: The curve plotted between base current ' I_B ' and base-collector voltage ' V_{BC} ', keeping emitter-collector voltage ' V_{EC} ' constant, gives the input characteristics of Common Collector (CC) configuration.

The input characteristics of transistor in common collector configuration is as shown in figure (2).

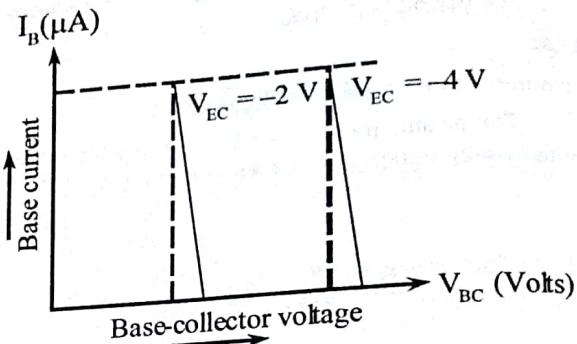


Figure (2): Input Characteristics of Transistor in CC Configuration

It can be observed from figure (2), that input characteristics of CC transistor are drawn by taking V_{BC} along the x-axis and I_B along the y-axis.

An increase in the value of V_{BC} decreases the value of I_B .

Output Characteristics of CC Configuration: The curve plotted between emitter current ' I_E ' and emitter-collector voltage ' V_{EC} ' keeping I_B constant, gives to the output characteristics of CC configuration.

The output characteristics of transistor in common collector configuration is as shown in figure (3).

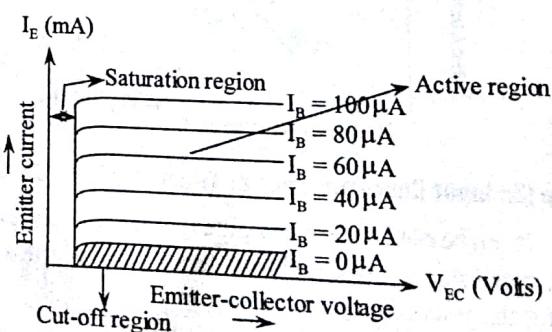


Figure (3): Output Characteristics of Transistor in CC Configuration

It can be observed from figure (3), that output characteristics of CB transistor are drawn by taking V_{EC} along the x-axis and I_E along the y-axis.

The emitter current ' I_E ' varies only for low values of V_{EC} , after which it becomes constant.

3.4 BJT AS AN AMPLIFIER

Q38. Explain transistor as an amplifier.

(Model Paper-II, Q14(b) | Dec.-13, Q13(b))
(or)

Explain BJT as an amplifier.

(or) July-10, Q3

Explain how transistor works as an amplifier?

Ans:

A transistor works as an amplifier only in the active mode of operation of BJT (i.e., when emitter-base junction is forward biased and collector-base junction is reverse biased).

The amplification process of a BJT can be illustrated by considering a PNP transistor connected to a load resistance ' R_L ' as shown in figure.

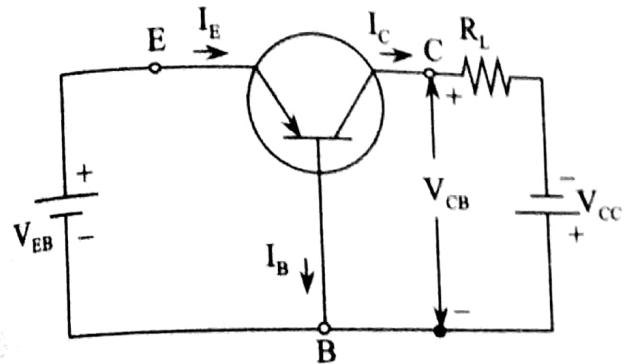


Figure: Transistor as an Amplifier

The load resistor ' R_L ' is connected in series with the collector supply voltage ' V_{CC} '. A small variation in the value of input voltage (ΔV_i) (applied between the emitter and base) produces a large variation in the emitter current (ΔI_E).

The variation in output voltage (ΔV_o) across a load resistor R_L can be given as,

$$\Delta V_o = \Delta I_C R_L \quad [\because V = I R \text{ (from Ohm's law)}]$$

$$\Delta V_o = \alpha' R_L \Delta I_E \quad \left[\because \alpha' = \frac{\Delta I_C}{\Delta I_E} \right] \quad \dots (1)$$

Where,

ΔI_C - Change in collector current.

ΔI_E - Change in emitter current.

α' - Small-single forward short circuit current gain.

The change in input voltage (ΔV_i) across the dynamic resistance r_e at the emitter junction is given as,

$$\Delta V_i = r_e \Delta I_E$$

For amplification to occur, ΔV_i should be multiplied by some factor to give ΔV_o . This factor is known as voltage amplification factor (A) and is given as,

$$A = \frac{\Delta V_o}{\Delta V_i} \quad \dots (3)$$

If $\frac{\Delta V_o}{\Delta V_i} > 1$ then voltage amplification is said to take place.

On substituting equations (1) and (2) in equation (3), we get,

$$A = \frac{\alpha' R_L \Delta I_E}{r_e \Delta I_E} \quad \dots (4)$$

$$\therefore A = \frac{\alpha' R_L}{r_e} > 1$$

From equation (4), it can be observed that ΔV_o is amplified by a factor $\frac{\alpha' R_L}{r_e}$. Hence, transistor acts as an amplifier.

3.5 BJT BIASING TECHNIQUES

Q39. Derive the expression for stabilization factor S in a BJT amplifier with fixed bias.

(Model Paper-I, Q15(a) | July-10, Q12(b))

(or)

Explain fixed bias concept and write its advantages and disadvantages.

Ans:

Fixed Bias

Fixed bias is also known as base resistor bias. In this a common emitter amplifier is biased by connecting a resistor ' R_B ' across the base and power supply terminals as shown in figure.

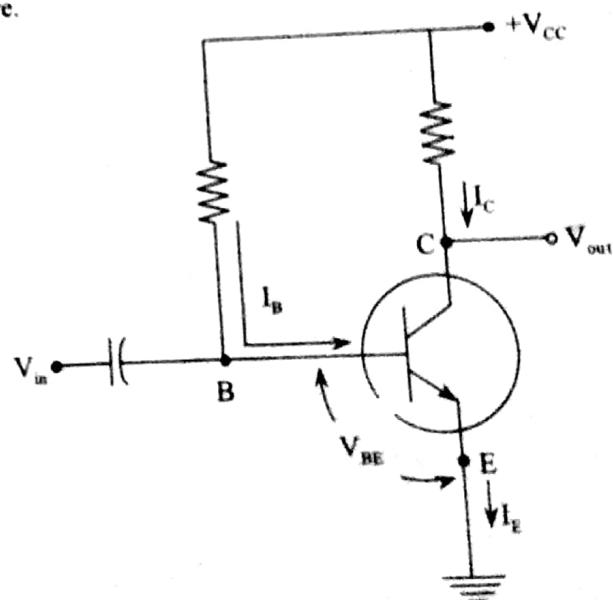


Figure: Fixed Bias Circuit

D.C Analysis of the Circuit

Applying KVL at the input side of the circuit in figure, we get,

$$V_{CC} = I_B R_B + V_{BE} \quad \dots (1)$$

3.18

Rearranging equation (1) we can write,

$$I_B = \frac{V_{CC} - V_{BE}}{R_s} \quad \dots (2)$$

The above equation is independent of I_C .

Differentiating equation (2) with respect to I_C , we get,

$$\frac{dI_B}{dI_C} = 0 \quad \dots (3)$$

The expression for stability factor 'S' for a CE configuration is,

$$S = \frac{1+\beta}{1-\beta \left(\frac{dI_B}{dI_C} \right)} \quad \dots (4)$$

Using equation (3), equation (4) can be written as,

$$S = \frac{1+\beta}{1-\beta(0)}$$

$$\therefore S = 1 + \beta$$

Since β is a large quantity, S is also very high. As a result the circuit is very poor in stability. In practice, this circuit is not used for biasing the base.

Advantages

1. The circuit is very simple.
2. Number of component required are less.

Disadvantage

- ❖ The circuit has very high value of stability factor S . Therefore it is highly unstable.

Q40. Explain collector to base biasing concept and write its advantages and disadvantages.

Ans:

Collector to Base Bias

In this CE amplifier is biased by connecting a resistance ' R_B ' across the collector and base terminals as shown in figure.

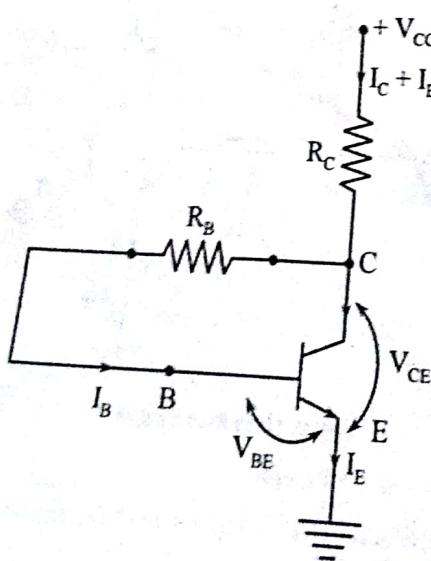


Figure: Collector Feedback Bias

From the figure, it is clear that collector to base voltage forward biases the BE junction. Therefore sufficient base current flows through the base resistance ' R_B ' and it causes zero signal collector current flowing in the circuit.

Circuit Analysis

Apply KVL at the input side of circuit is shown in figure (1).

$$V_{CC} = I_C R_C + I_S R_S + V_{BE}$$

$$\text{And } I_C = \beta I_S$$

Then,

$$V_{CC} = \beta I_S R_C + I_S R_S + V_{BE}$$

$$\Rightarrow I_S R_S = V_{CC} - \beta I_S R_C - V_{BE}$$

$$\Rightarrow R_S = \frac{V_{CC} - \beta I_S R_C - V_{BE}}{I_S}$$

$$\therefore \text{Base resistance } R_B = \frac{V_{CC} - \beta I_S R_C - V_{BE}}{I_S}$$

Alternatively,

$$V_{CE} = V_{BE} + V_{CS}$$

$$R_B = \frac{V_{CE}}{I_B} = \frac{V_{CE} - V_{BE}}{I_B}$$

$$\therefore R_B = \frac{V_{CE} - V_{BE}}{I_B}$$

Advantages

1. It is easy and simple to design.
2. It requires only ' R_B ' for biasing.

Disadvantages

1. The circuit provides negative feedback that reduces the gain of an amplifier.
2. Stability factor is fairly high.

Q41. Explain about emitter-feedback bias.

(or)

Sketch and analyse the emitter-feedback bias circuit.

Ans:

The circuit diagram of emitter feedback bias is shown in figure. It comprises a transistor and three resistors, of which the base resistor, R_B and the collector resistor, R_C are connected to V_{CC} and the emitter resistor, R_E to the ground. The emitter voltage is feedback to the base of the transistor with the help of emitter resistor R_E . Thus R_E (the emitter resistor) provides negative feedback, which stabilizes the Q point.

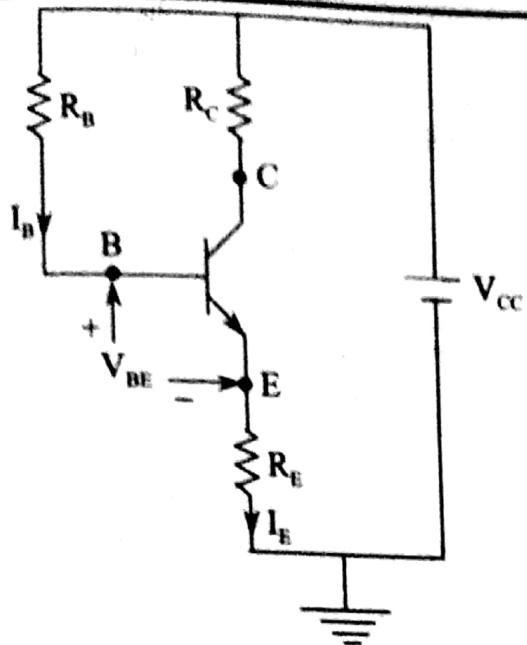


Figure: Emitter-Feedback Bias Circuit

Apply KVL at the output loop, we get,

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0 \quad \dots (1)$$

$$\because I_c = \beta I_B \text{ and } I_E = I_c, I_E = \beta I_B.$$

Substituting I_B value in equation (1)

$$V_{CC} - \frac{I_E}{\beta} R_B - V_{BE} - I_E R_E = 0$$

$$V_{CC} - V_{BE} = I_E \left(R_E + \frac{R_B}{\beta} \right)$$

$$\therefore I_E = \frac{V_{CC} - V_{BE}}{R_E + \frac{R_B}{\beta}} \quad \dots (2)$$

The voltage at the base terminal is given as,

$$V_B = V_E + 0.7 \text{ V.} \quad [\because V_{BE} = 0.7 \text{ and } V_E \neq 0] \quad \dots (3)$$

$$V_E = I_E R_E \quad \dots (4)$$

And the voltage at collector terminal is given as

$$V_c = V_{CC} - I_c R_c \quad \dots (5)$$

For the rise in temperature, the collector current I_c and emitter current I_E increases. Since, $V_E = I_E R_E$, the increase in I_E results in the increase in emitter voltage V_E .

From the equation (3), if V_E increases V_B increases. This implies, the voltage drop across R_B decreases i.e., $I_B R_B$ decreases. As R_B is constant, the decrease occurs in I_B which in turn reduces the collector current I_c , correcting the original increase.

Q42. Explain about collector-emitter feedback biasing.

Ans:

The collector emitter bias is a combination of collector feedback and emitter feedback. This combined effect gives increased stability, when compared to collector feedback emitter feedback biasing. The circuit diagram of collector emitter feedback is as shown in figure,

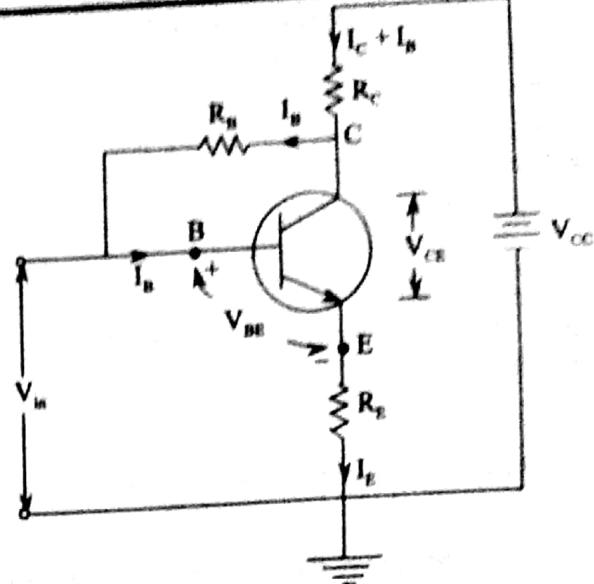


Figure: Collector Emitter Feedback

Apply KVL to the circuit shown in figure, we get,

$$\Rightarrow V_{CC} - (I_C + I_B) R_C - I_B R_B - V_{BE} - I_E R_E = 0 \quad \dots (1)$$

We know that $I_c = \beta I_B$ and $I_c \approx I_E$ then equation (1) becomes,

$$\Rightarrow V_{CC} - \left[I_E + \frac{I_E}{\beta} \right] R_C - \frac{I_E}{\beta} R_B - V_{BE} - I_E R_E = 0$$

$$\Rightarrow I_E \left[\left(1 + \frac{1}{\beta} \right) R_C + \frac{R_B}{\beta} + R_E \right] = V_{CC} - V_{BE}$$

$$\because \beta \gg 1, \frac{1}{\beta} \ll 1.$$

Hence, $1 + \frac{1}{\beta} \approx 1$, then,

$$\Rightarrow I_E \left[R_C + \frac{R_B}{\beta} + R_E \right] = V_{CC} - V_{BE}$$

$$\Rightarrow I_E = \frac{V_{CC} - V_{BE}}{R_C + \frac{1}{\beta} R_B + R_E}$$

$$I_E = \frac{V_{CC} - V_{BE}}{R_C + \frac{1}{\beta} R_B + R_E}$$

$$\therefore I_E = \frac{V_{CC} - V_{BE}}{R_C + R_E + \frac{R_B}{\beta}} \quad \dots (2)$$

The voltage across the emitter (V_E) is given as,

$$V_E = I_E R_E \quad \dots (3)$$

The voltage across the base is given as ' V_B '

$$\Rightarrow V_B = V_E + 0.7 \quad \dots (4)$$

($\because V_E \neq 0$)

The voltage across the collector is given as,

$$V_c = V_{CC} - I_c R_c \quad \dots (5)$$

For the rise in temperature, the collector current I_C and emitter current I_E increases. Since, $V_E = I_E R_E$, the increase in I_E results in the increase in emitter voltage ' V_E '.

From the equation (4), if V_E increases, V_B also increases. $I_E R_E$ decreases (i.e., voltage drop across R_E) As ' R_E ' is constant, the decrease occurs in I_E which in turn reduces the collector current ' I_C '. Correcting the original increase.

Q43. Draw the circuit of a CE amplifier with emitter bias. Derive the relation for stability factor for such a circuit.

Jan.-12, Q12(b)

(or)

Explain about voltage divider bias method.

Ans:

Voltage Divider Bias (or) Potential Divider Bias (or) Self Bias (or) Emitter Bias

The most extensively used biasing circuit for maintaining stabilization is voltage divider bias circuit. It is as shown in figure.

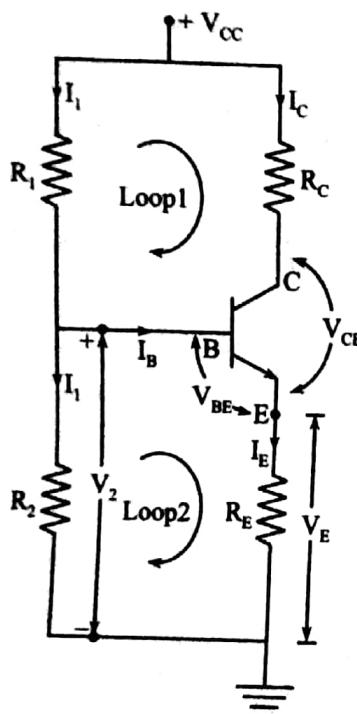


Figure: Voltage Divider Bias

The circuit contains two resistors R_1 and R_2 connected to V_{CC} in the base section of the transistor. The voltage drop across the resistor R_2 forward biases the emitter base junction. The resistor R_E connected to the emitter grants stabilization.

Circuit Analysis

The current flowing through the resistance ' R_1 ' is I_1 . Since, the current flowing through the base is very small it can be assumed that the same current I_1 flows through resistance R_E . Therefore I_1 is given as,

$$I_1 = \frac{V_{CC}}{R_1 + R_2} \quad \dots (1)$$

Further, since same current I_1 is flowing through R_1 and can be assumed that R_1 and R_2 are in series. Therefore, by voltage division rule, the voltage drop across R_2 is given

$$V_2 = \left(\frac{R_2}{R_1 + R_2} \right) V_{CC} \quad \dots (2)$$

Apply KVL to the loop 2 shown in figure (1),

$$\begin{aligned} V_2 &= V_{BE} + V_E \\ \Rightarrow V_2 &= V_{BE} + I_E R_E \end{aligned}$$

$$\Rightarrow I_E = \frac{V_2 - V_{BE}}{R_E}$$

$$\therefore I_E = \frac{V_2 - V_{BE}}{R_E} \quad \dots (3)$$

Generally for a CE configuration $I_E \approx I_C$.

Hence equation (2) can be written as,

$$I_C = \frac{V_2 - V_{BE}}{R_E} \quad \dots (4)$$

Where,

V_2 - Voltage drop across ' R_2 '

V_{BE} - Base emitter voltage.

Applying KVL to the output side of the circuit in figure (1), we get,

$$\begin{aligned} V_{CC} &= I_C R_C + V_{CE} + V_E \\ \Rightarrow V_{CC} &= I_C R_C + V_{CE} + I_E R_E \\ &= I_C (R_C + R_E) + V_{CE} \quad (\because I_C \approx I_E) \\ &= V_{CE} + I_C (R_C + R_E) \\ \therefore V_{CE} &= V_{CC} - I_C (R_C + R_E) \quad \dots (5) \end{aligned}$$

The circuit provides good stabilization through resistance ' R_E '. It is explained using equation (4), that is,

$$V_2 = V_{BE} + I_C R_E \quad \dots (I)$$

In the above expression voltage V_2 (across R_2) is independent of I_C and is given as,

$$V_2 = \left(\frac{V_{CC}}{R_1 + R_2} \right) R_2$$

Since R_1 , R_2 and V_{CC} are constant, V_2 is also constant. An increase in I_C causes an increase in potential across R_E (that is, $I_C R_E$). Since, V_2 is constant an increase in $I_C R_E$ must be compensated by a decrease in V_{BE} . Therefore, an increase in $I_C R_E$ causes V_{BE} to decrease and vice versa. In this manner the circuit provides good stabilization.

Advantages

- It is most popular biasing circuit.
- Simple ' R_E ' resistance provides good stability.
- Stability factor (S) is controlled by R_E and R_{th} .
- Stability factor is small for this circuit compared to other techniques.

UNIT 3

Q3. Assume that a silicon transistor with $\beta = 50$, $V_{ce} = 30$ V and $V_{be} = 0.6$ V is to work in a self-biased circuit. It is required to select a point at $V_{ce} = 20$ V and $I_c > 2 with stability $S \leq 5.0$. Design this with respect all component values.$

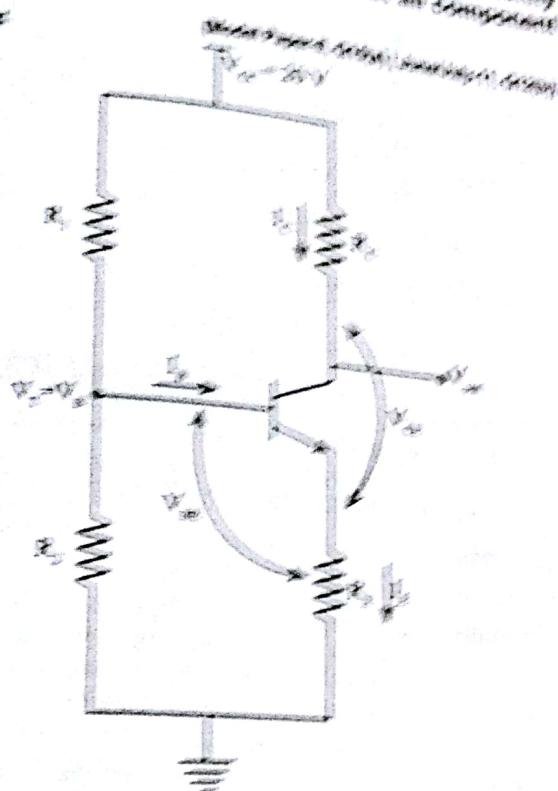


Figure: Self-Biased Circuit

Given that,

$$V_{cc} = 20\text{V}$$

$$V_{ce} = 0.6\text{V}$$

$$V_{ce} = 20\text{V}$$

$$I_c = 2\text{mA}$$

$$\beta = 50$$

$$R_2 = 5.1\text{k}\Omega$$

And

$$\beta \leq 5.0$$

We know that,

$$\beta = \frac{I_C}{I_B}$$

$$I_B = \frac{2\text{mA}}{50}$$

$$I_B = 40\mu\text{A}$$

$$\therefore I_E = I_C + I_B$$

$$I_E = 2\text{mA} + 40\mu\text{A} = 2.04\text{mA}$$

$$V_E = 2\text{mA}$$

Given the figure,

$$V_{ce} = V_{ce} - I_C R_3$$

$$20 = 20 - 20(50) / 5.1 + 20(50) / 5.1 + 20(50) / 5.1$$

$$\Rightarrow I_C = 2\text{mA}$$

Given that, $\beta \leq 5.0$

Given that, $\beta \leq 5.0$

$$\text{Stability factor, } S = \frac{\partial I_C}{\partial V_{ce}} = \frac{20(50)}{5.1^2} = \frac{2000}{26.01} = 76.9$$

$$\Rightarrow S = 76.9$$

Therefore we have, $S < 5.0$ for $I_C = 2\text{mA}$ and $V_{ce} = 20\text{V}$

$$V_{ce} = V_{ce} - 20(50) / (5.1 + 20(50) / 5.1 + 20(50) / 5.1)$$

$$V_{ce} = V_{ce} - 3.66\text{V}$$

From figure, Theoretic value V_{ce} is also required

$$V_{ce} = \left(\frac{R_3}{R_2 + R_3} \right) V_{cc}$$

$$3.66 = \left(\frac{R_3}{R_2 + R_3} \right) 20$$

$$\Rightarrow R_3 = 6.62\text{k}\Omega$$

$$R_3 = \frac{R_2}{\beta + 1}$$

$$6.62 = \frac{5.1}{50 + 1}$$

$$R_3 = 6.62\text{k}\Omega$$

$$\Rightarrow R_3 = \frac{6.62}{50 + 1} \text{ and } R_3 = 3.31\text{k}\Omega$$

Q4. In the self-biased CE amplifier circuit comprising $R_1 = 10\text{k}\Omega$, $R_2 = 11\text{k}\Omega$, $V_{cc} = 25\text{V}$, $R_3 = 5.1\text{k}\Omega$ and $R_4 = 1.8\text{k}\Omega$ with $E_b = 50$ and $V_{be} = 0.6\text{V}$. Find the operating point and stability factor S of the circuit.

Given that,

Given that,

$$R_1 = 10\text{k}\Omega$$

$$R_2 = 11\text{k}\Omega$$

$$V_{cc} = 25\text{V}$$

$$R_3 = 5.1\text{k}\Omega$$

$$R_4 = 1.8\text{k}\Omega$$

$$E_b = 50$$

$$V_{be} = 0.6\text{V}$$

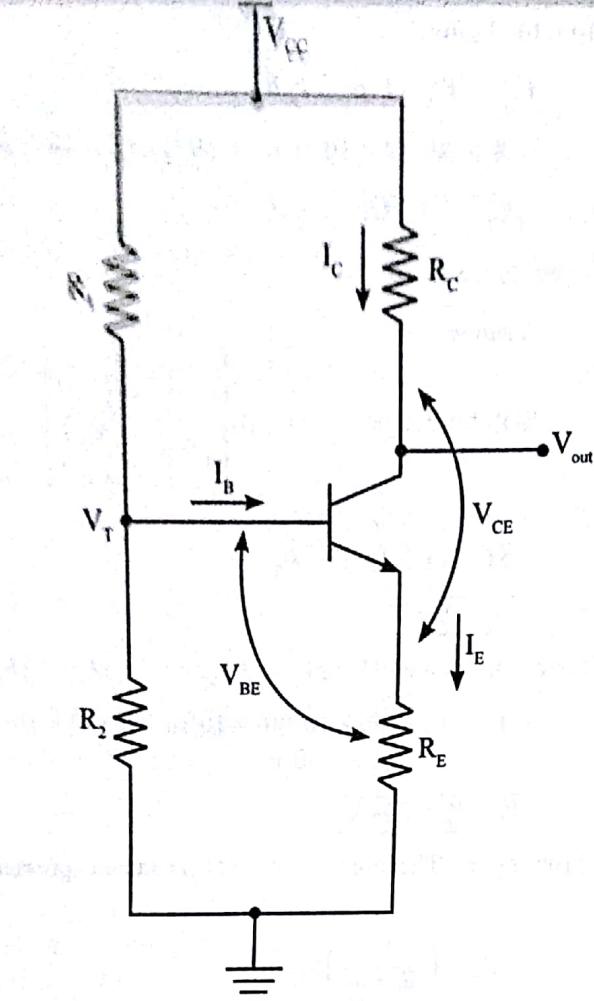


Figure: Self Biased CE Amplifier

From the figure,

Thevenin's voltage,

$$(V_T) = \frac{R_2}{R_1 + R_2} V_{CC}$$

$$V_T = \frac{90 \times 10^3}{(90 + 10) \times 10^3} (2.5)$$

$$V_T = 2.25 \text{ V}$$

$$\text{Thevenin's resistance, } R_B = \frac{R_1 R_2}{R_1 + R_2}$$

$$R_B = 9 \text{ k}\Omega$$

From the figure,

$$V_T = I_B R_B + V_{BE} + I_E R_E$$

$$V_T = I_B R_B + V_{BE} + (I_B + I_C) R_E$$

$$V_T = \frac{I_C}{\beta} R_B + V_{BE} + \left(\frac{I_C}{\beta} + I_C \right) R_E \quad \left[\because \beta = \frac{I_C}{I_B} \right]$$

$$2.25 = \frac{I_C}{55} (9 \times 10^3) + 0 + \left(\frac{I_C}{55} + I_C \right) (1 \times 10^3)$$

$$\Rightarrow (55)(2.25) = I_C (9 \times 10^3) + (I_C + 55 I_C) 1 \times 10^3$$

$$\Rightarrow I_C = 1.9 \times 10^{-3} \text{ A}$$

$$\Rightarrow \boxed{I_C = 2 \text{ mA}}$$

$$\beta = \frac{I_C}{I_B}$$

$$55 = \frac{2 \times 10^{-3}}{I_B}$$

$$\Rightarrow I_B = \frac{2 \times 10^{-3}}{55}$$

$$\Rightarrow I_B = 36.3 \mu\text{A}$$

$$\therefore I_E = I_B + I_C$$

$$I_E = 36.3 \times 10^{-6} + 2 \times 10^{-3}$$

$$I_E = 2.03 \text{ mA}$$

$$\boxed{I_E = 2 \text{ mA}}$$

$$\therefore V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

$$= 2.5 - (2 \times 10^{-3})(5.6 \times 10^3) - (2 \times 10^{-3})(1 \times 10^3)$$

$$V_{CE} = -10.7 \text{ V}$$

Operating point coordinates are $V_{CE} = -10.7 \text{ V}$ and

$$I_C = 2 \text{ mA}$$

$$\text{Stability factor, } s = (1 + \beta) \frac{1 + \frac{R_B}{R_E}}{1 + \beta + \frac{R_B}{R_E}}$$

$$= (1 + 55) \frac{1 + \frac{9 \times 10^3}{1 \times 10^3}}{1 + 55 + \frac{9 \times 10^3}{1 \times 10^3}}$$

$$S = (56) \frac{10}{56 + 9}$$

$$S = 8.62$$

3.6 THERMAL RUNWAY – HEAT SINKS AND THERMAL STABILIZATION

~~Q46. What is thermal runaway in BJT? How can it be addressed?~~

Dec.-15, Q13(b)

(or)

Explain in detail about thermal run away and thermal resistance.

(or)

What is thermal runaway? How do you avoid it in amplifier circuits using BJT? Derive suitable expression to avoid it.

Ans:

Thermal Runaway

The expression for the collector current of common emitter circuit is shown in figure below.

$$I_C = \beta I_B + (1 + \beta) I_{CO} \quad \dots (1)$$