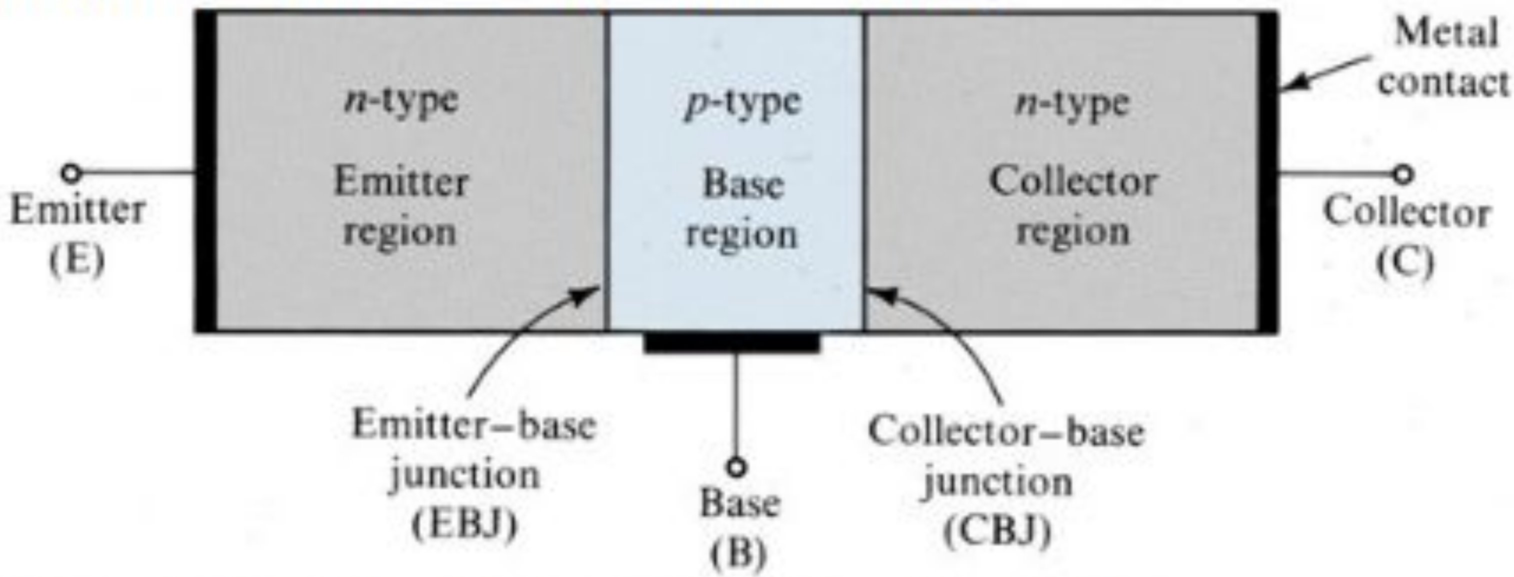
BJT- Bipolar Junction Transistor

The Bipolar Junction Transistor (BJT)



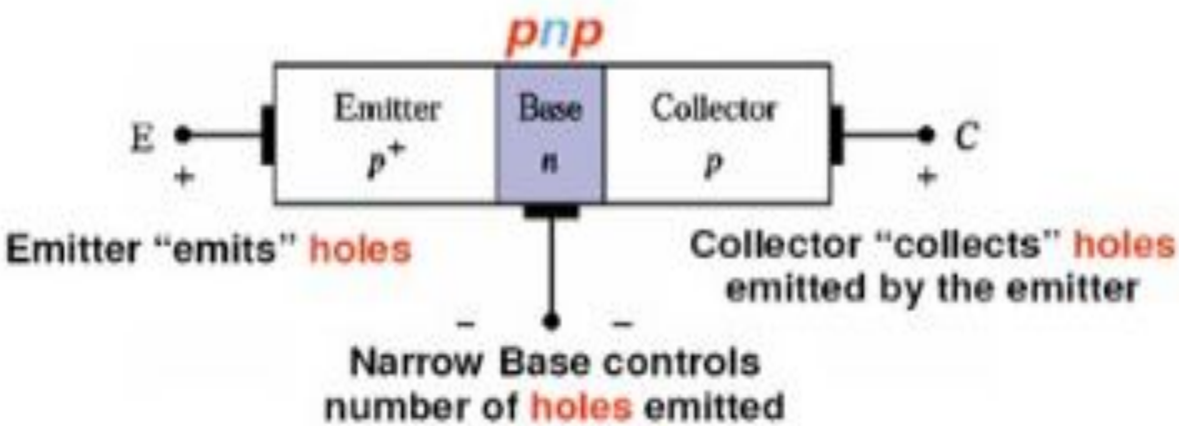
- **Bipolar** : both electrons and holes are involved in current flow.
- **Junction** : has two *p-n* junctions.
- **Transistor** : Transfer + Resistor.
- It can be either ***n-p-n*** type or ***p-n-p*** type.
- Has three regions with three terminals labeled as

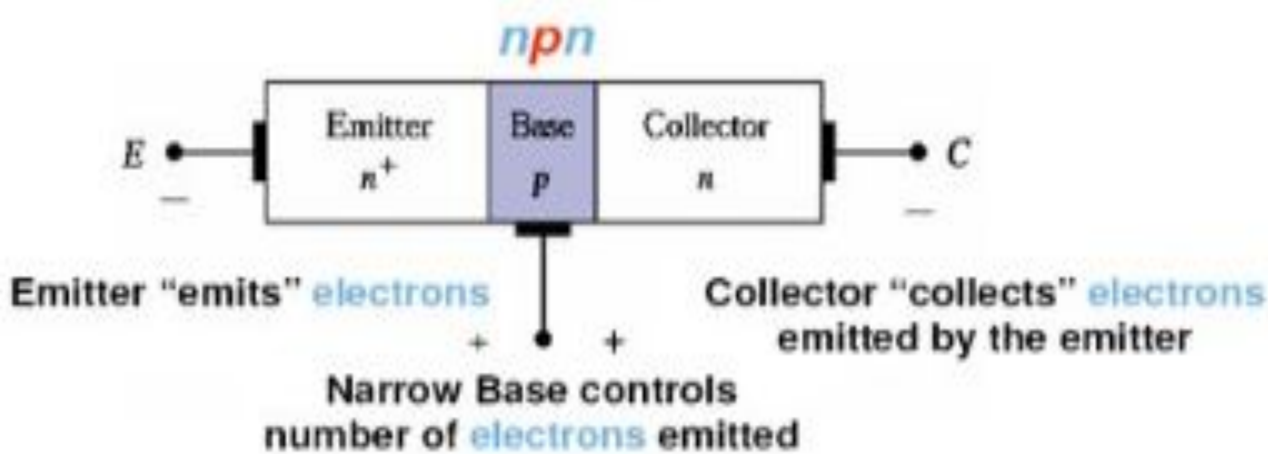
  i. Emitter (E)

  ii. Base (B) and

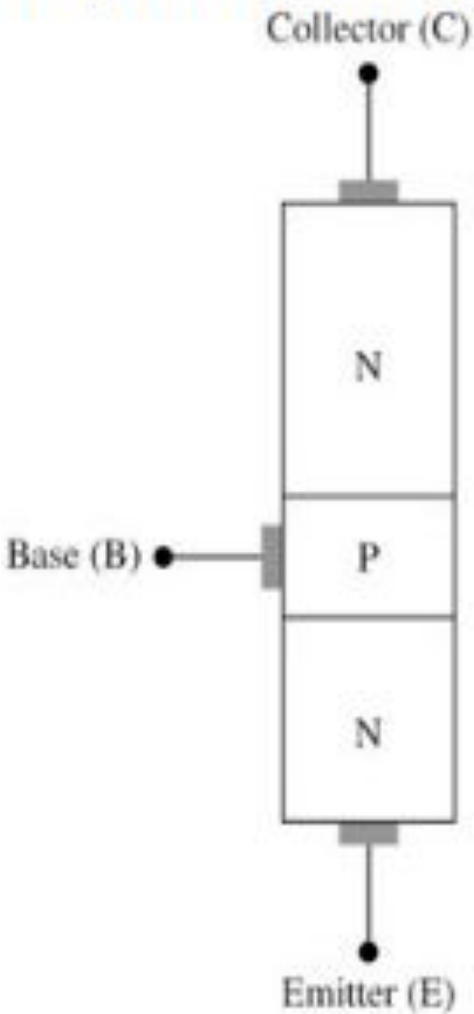
  iii. Collector (C)

- **Base** is made much narrow.
- **Emitter** is heavily doped (p^+, n^+).
- **Base** is lightly doped (p^-, n^-).
- **Collector** is lightly doped (p, n).

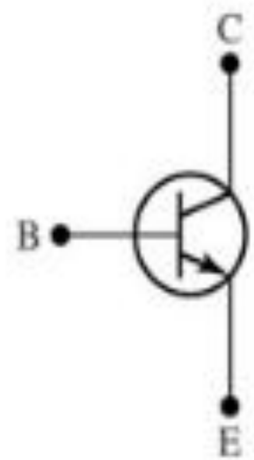




Layout and Circuit Symbol: n-p-n Transistor



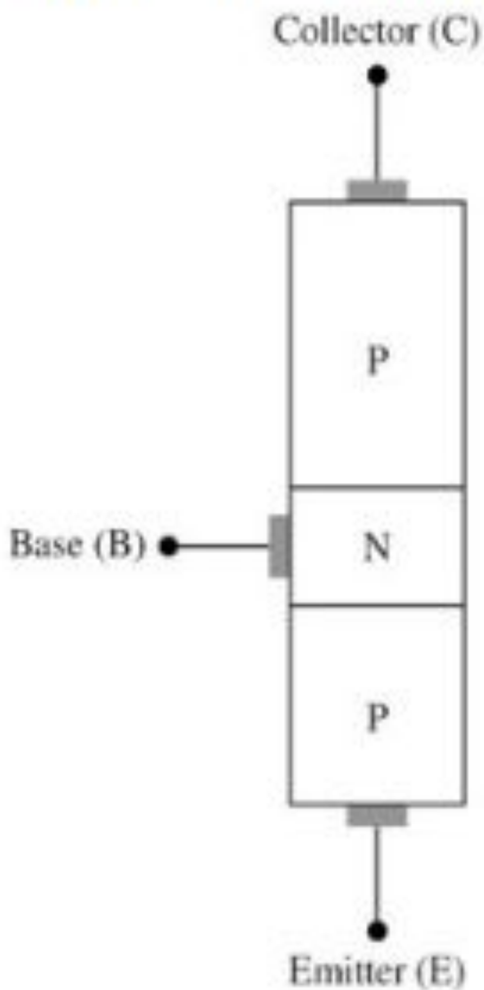
(a)



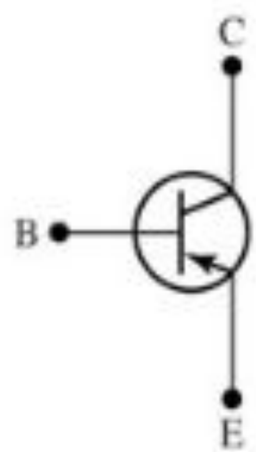
(b)

- The arrow indicates the direction of current flow.
- The current flows from collector to emitter in an n-p-n transistor.
- The arrow is drawn on the emitter.
- The arrow always points towards the n-type. So the emitter is n-type and the transistor is n-p-n type.

Layout and Circuit Symbol: p-n-p Transistor



(a)



(b)

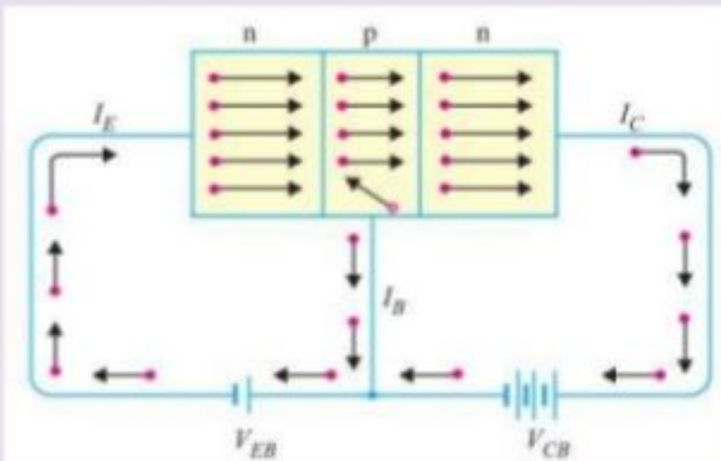
- The arrow indicates the direction of current flow.
- The current flows from emitter to collector in an p-n-p transistor.
- The arrow points towards the n-type.
- So the base is n-type and transistor is p-n-p type.

Some important factors to be remembered-

- The junction between emitter and base is called emitter-base junction(emitter diode) and junction between base and collector is called collector-base junction(collector diode).
- The emitter diode is always forward biased and collector diode is reverse biased.
- The resistance of emitter diode is very small(forward) and resistance of collector diode is high(reverse).

Transistor Operation

1) Working of npn transistor:



✓ Forward bias Is applied to emitter-base junction and reverse bias is applied to collector-base junction.

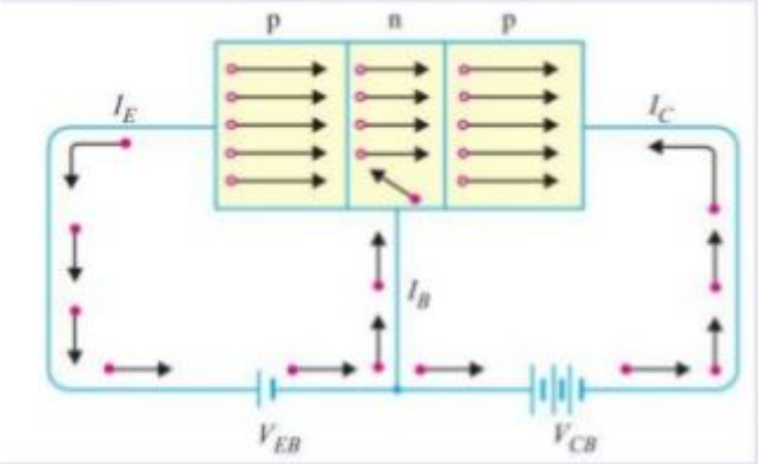
✓The forward bias in the emitter-base junction causes electrons to move toward base. This constitute emitter current, I_E

1) Working of npn transistor:

- ✓ As this electrons flow toward p-type base, they try to recombine with holes. As base is lightly doped only few electrons recombine with holes within the base.
- ✓ These recombined electrons constitute small base current.
- ✓ The remainder electrons crosses base and constitute collector current.

$$I_E = I_B + I_C$$

2) Working of pnp transistor:



✓ Forward bias is applied to emitter-base junction and reverse bias is applied to collector-base junction.

✓The forward bias in the emitter-base junction causes holes to move toward base. This constitute emitter current, I_E

Transistor Operation

2) Working of pnp transistor:

- ✓ As this holes flow toward n-type base, they try to recombine with electrons. As base is lightly doped only few holes recombine with electrons within the base.
- ✓ These recombined holes constitute small base current.
- ✓ The remainder holes crosses base and constitute collector current.

Transistor Operating Modes

- Active Mode

  → Base- Emitter junction is forward and Base-Collector junction is reverse biased.

- Saturation Mode

  → Base- Emitter junction is forward and Base-Collector junction is forward biased.

- Cut-off Mode

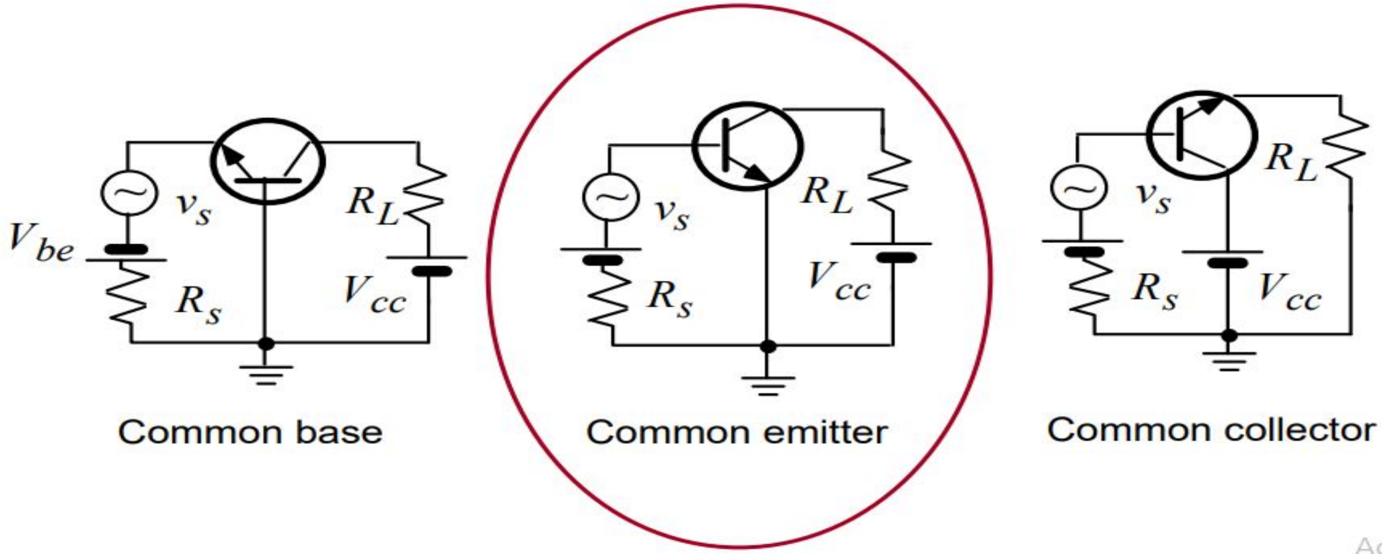
  → Both junctions are reverse biased.

Transistor Configuration

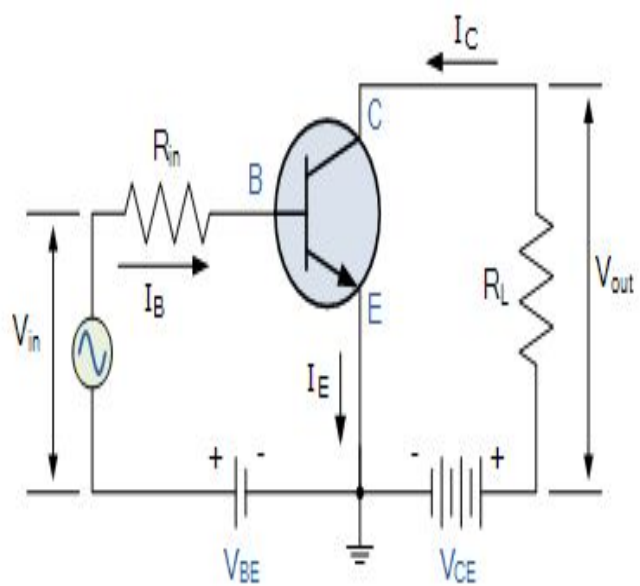
The transistor has three terminals – emitter (E), base (B) and collector (C).

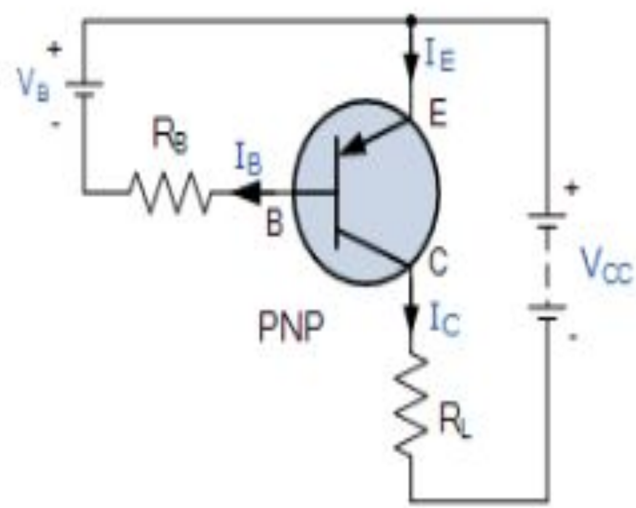
But in the circuit connections we need four terminals, two terminals for input and another two terminals for output. To overcome these problems we use one terminal as common for both input and output actions.

The behaviour of these three different configurations of transistors with respect to gain
Common Emitter (CE) Configuration: current gain and voltage gain
Common Collector (CC) Configuration: current gain but no voltage gain
Common Base (CB) Configuration: no current gain but voltage gain



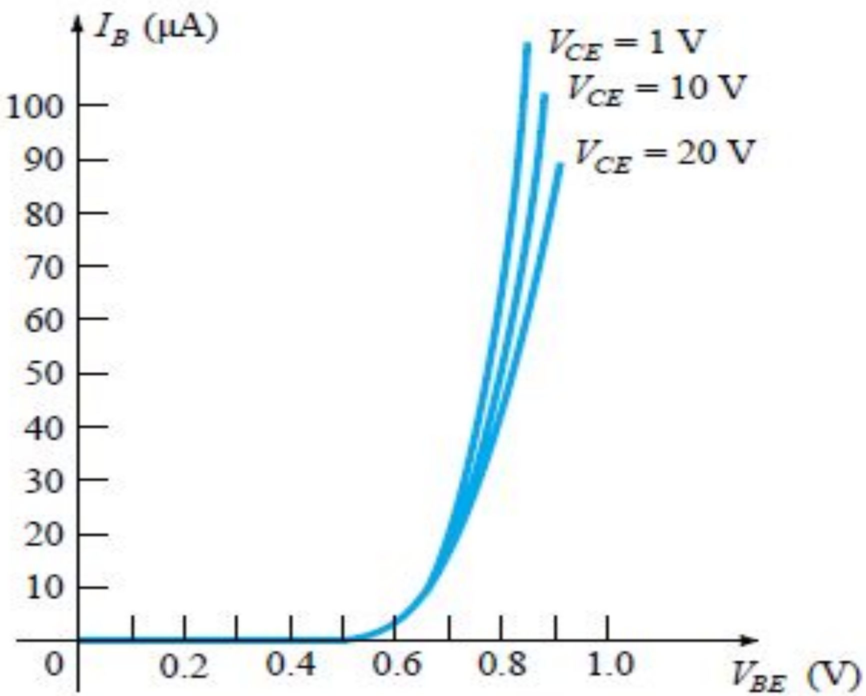
Common Emitter for NPN and PNP Transistor





- Most common configuration of transistor is as shown
- *emitter* terminal is common to input and output circuits this is a **common-emitter** configuration
- we will look at the characteristics of the device in this configuration
- The current relations are still applicable, *i.e.,*
- $I_E = I_C + I_B$ *and* $I_C = \alpha I_E$

Common Emitter Input Characteristics

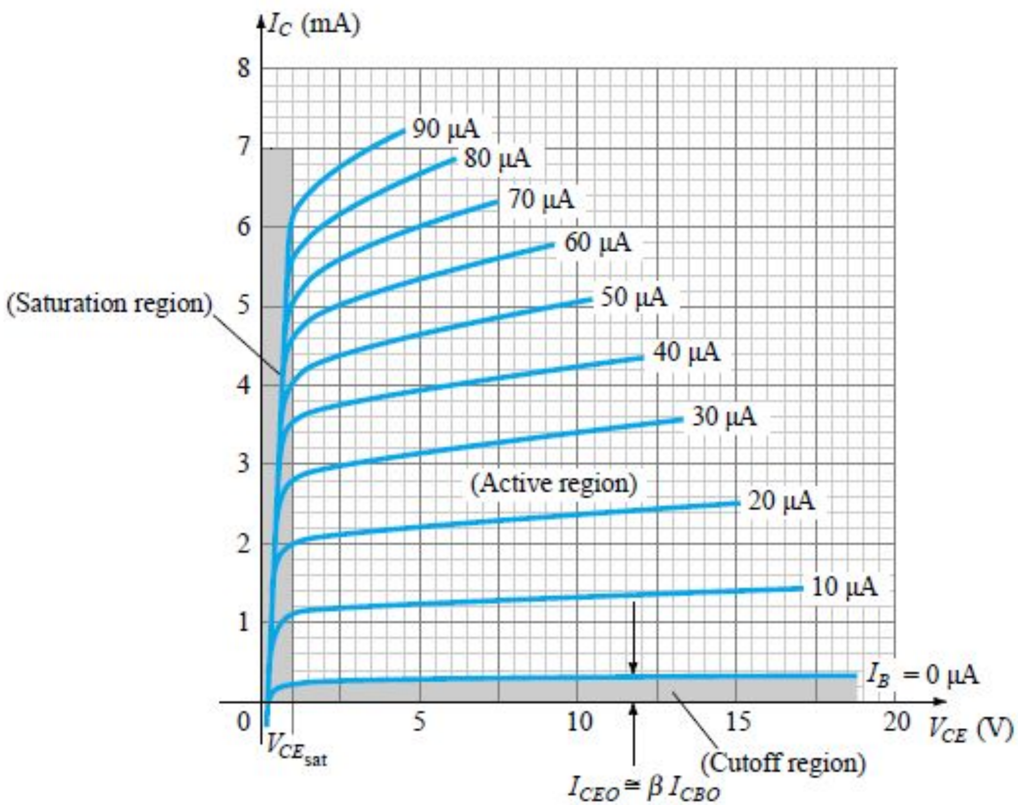


– the input takes the form of a forward-biased *pn* junction

– the input characteristics are therefore similar to those of a semiconductor diode

An input current (I_B) *is a function of an* input voltage (V_{BE}) *for various of output* voltage (V_{CE}).

COMMON EMITTER OUTPUT CHARACTERISTICS



Output characteristics

- The magnitude of I_B *is in µA and not as* horizontal as I_E *in common-base circuit.*
- The output set relates an output current (*Ic*) to an output voltage (*VCE*) *for various of* level of input current (*IB*).

- There are three portions as shown:

Active region

- The active region, located at upper-right quadrant, has the greatest linearity.
- The curve for *IB are nearly straight and* equally spaced.
- In active region, the *B-E junction is* forward-biased, whereas the *C-B junction* is reverse-biased.
- The active region can be employed for voltage, current or power amplification.

Cutoff region

Clip sli

- The region below $I_B = 0\mu A$ *is defined as* cutoff region.
- For linear amplification, cutoff region should be avoided.

Saturation region:

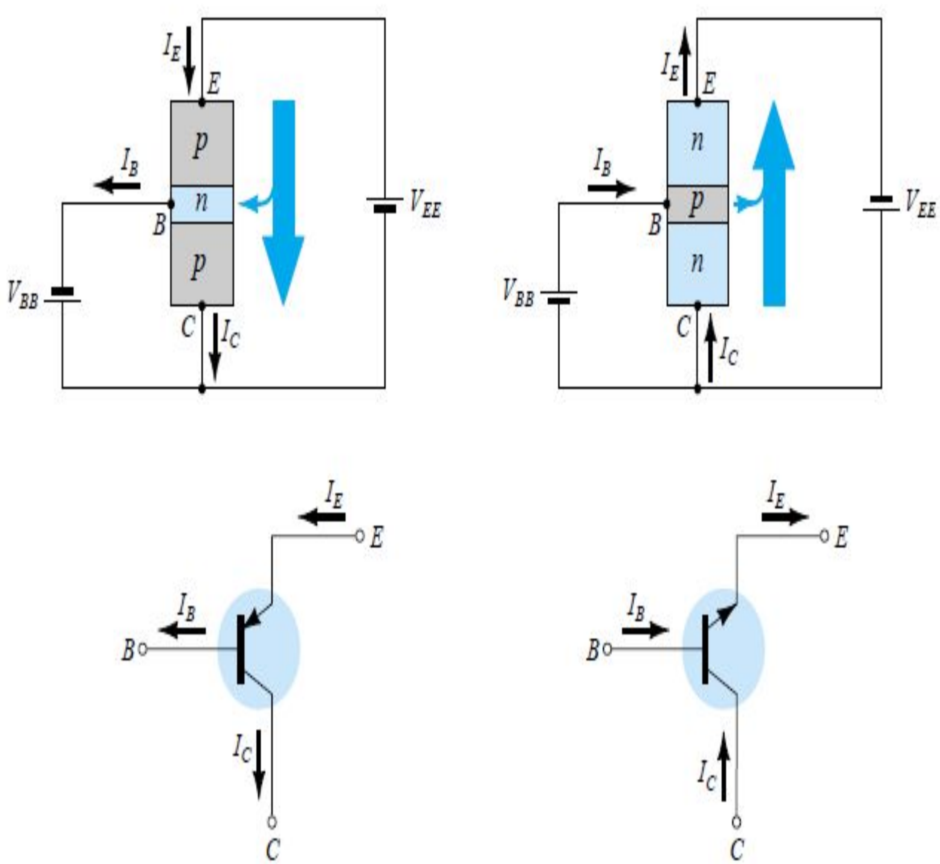
- The small portion near the ordinate, is the saturation region, which should be avoided for linear application.
- In the dc mode, the levels of *IC and IB at the* operation point are related by: Normally, β *ranges from 50 to 400.*

$$\beta_{dc} = I_C / I_B$$

For ac situations, β *is defined as*

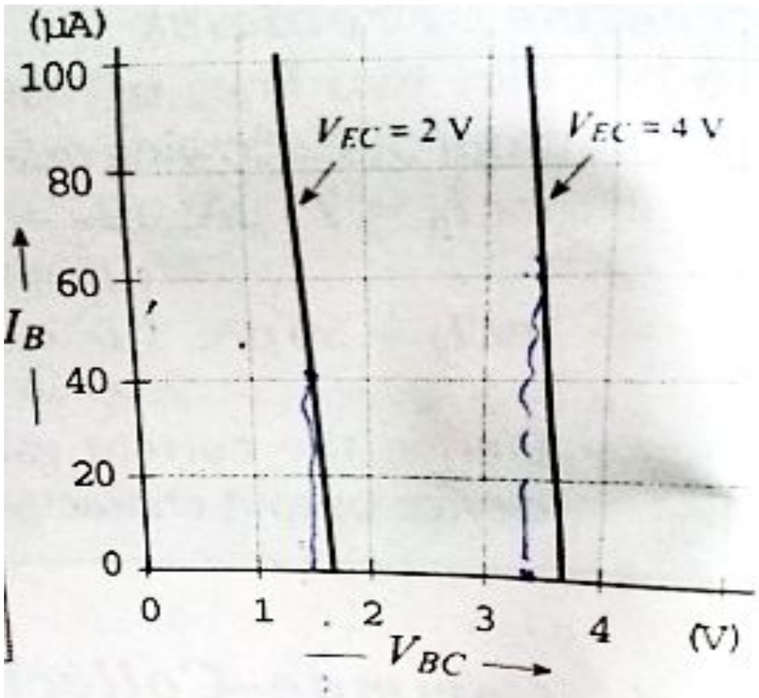
$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=constant}$$

COMMON COLLECTOR FOR PNP AND NPN TRANSISTORS



- It is used primarily for impedance-matching purpose since it has a high input impedance and low output impedance.
- The load resistor can be connected from emitter to ground.
- The collector is tied to ground and the circuit resembles common-emitter circuit.
- The output set relates an output current (I_E) to an output voltage (V_{CE}) *for various of* level of input current (I_B).

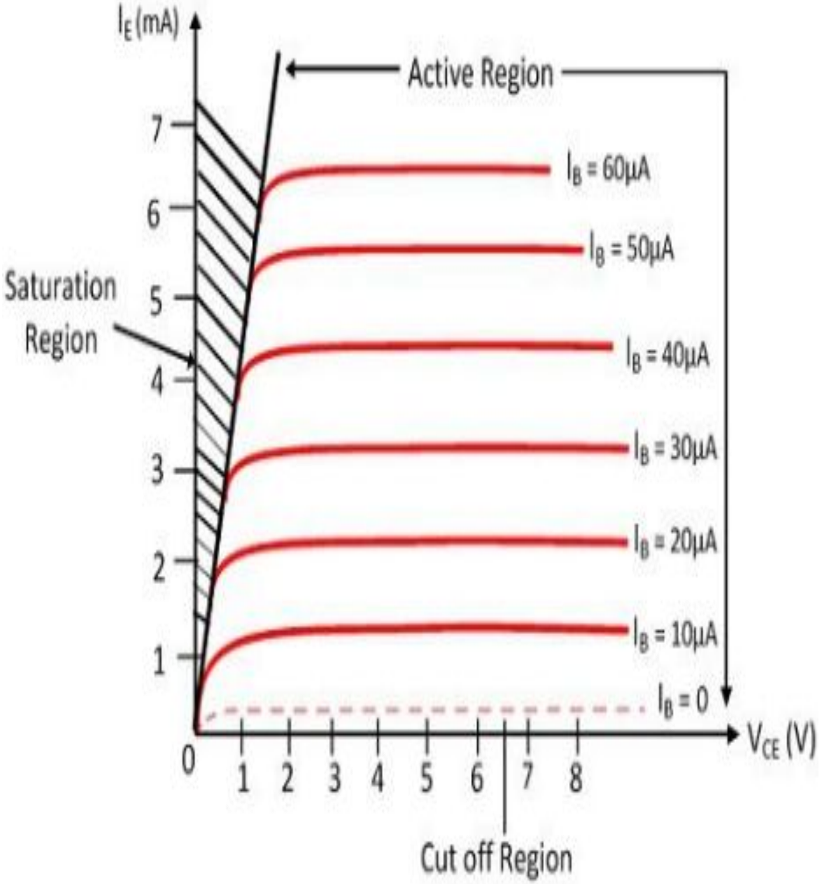
COMMON COLLECTOR INPUT CHARACTERISTICS



- The following points may be noted from the family of characteristic curves.
- Its characteristic is quite different from those of common base and common emitter circuits.
- When V_{CB} increases, IB is decreased.

- It is a curve which shows the relationship between the base current, I_B and the collector base voltage V_{CB} at constant V_{CE} This method of determining the characteristic is as follows.
- First, a suitable voltage is applied between the emitter and the collector.
- Next the input voltage V_{CB} is increased in a number of steps and corresponding values of I_E are noted.
- The base current is taken on the y-axis, and the input voltage is taken on the x-axis. Fig. shows the family of the input characteristic at different collector- emitter voltages.

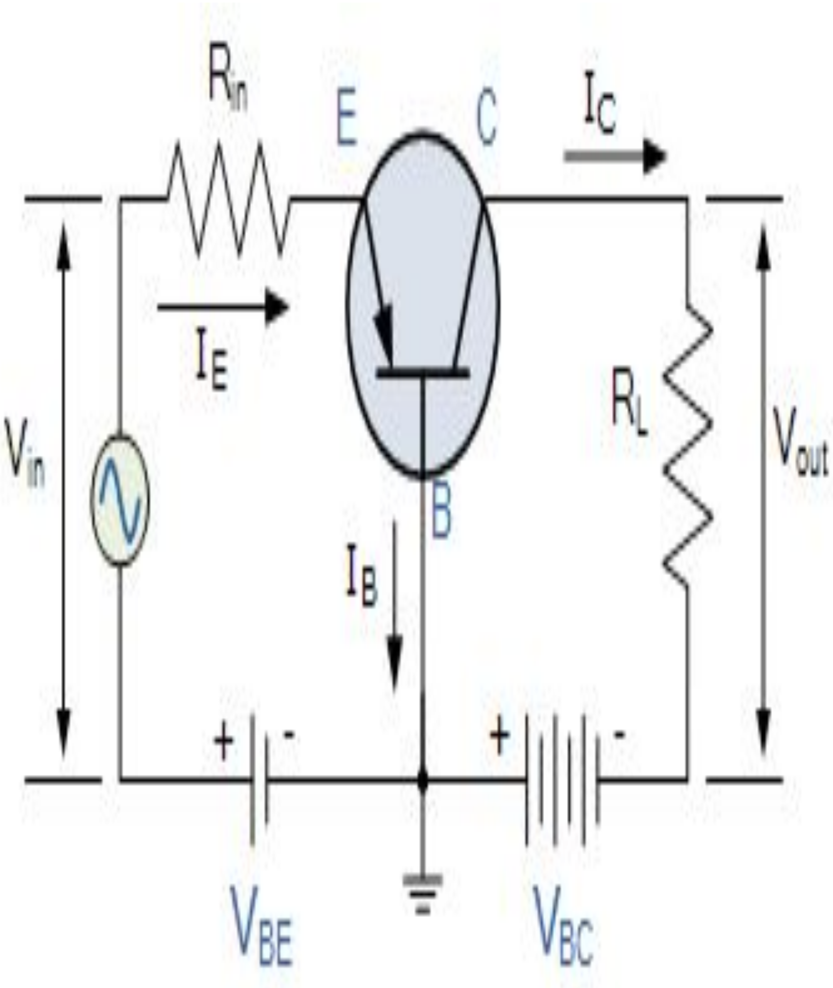
COMMON COLLECTOR OUTPUT CHARACTERISTICS

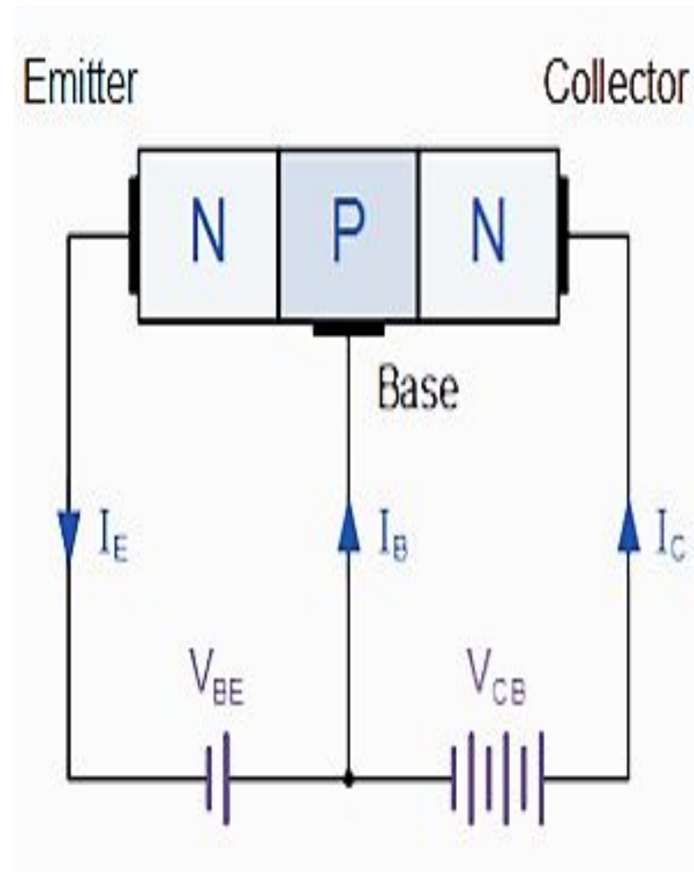


- This is almost the same as the output characteristics of common-emitter circuit, which are the relations between I_C *and* V_{CE} for various of level of input current I_B.

  Since that: $I_E \cong I_C$.

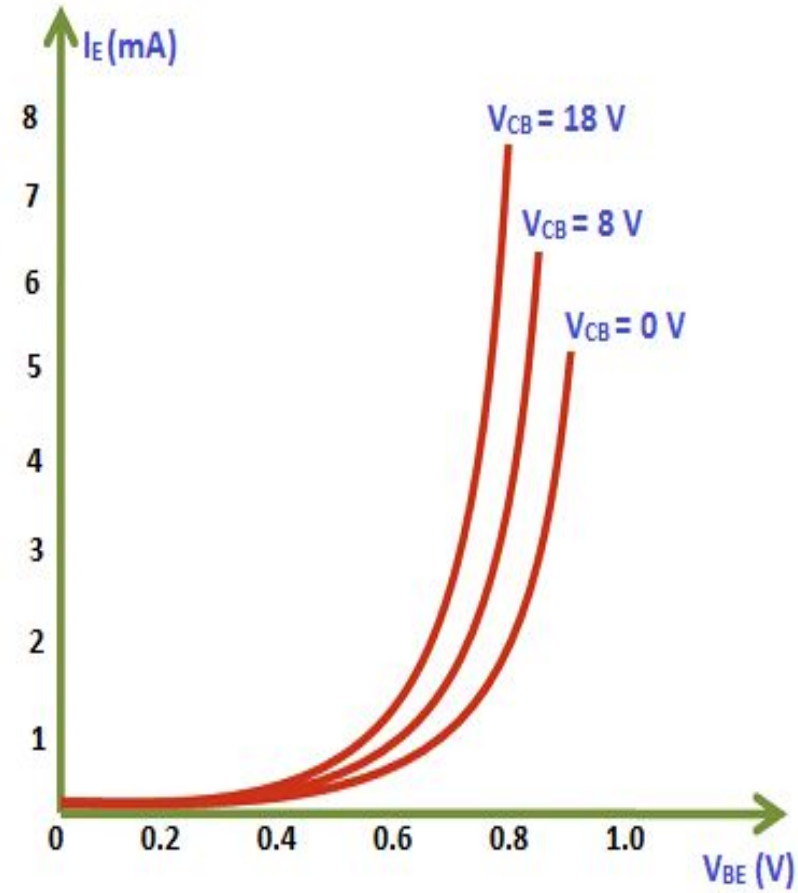
COMMON BASE FOR PNP AND NPN TRANSISTORS





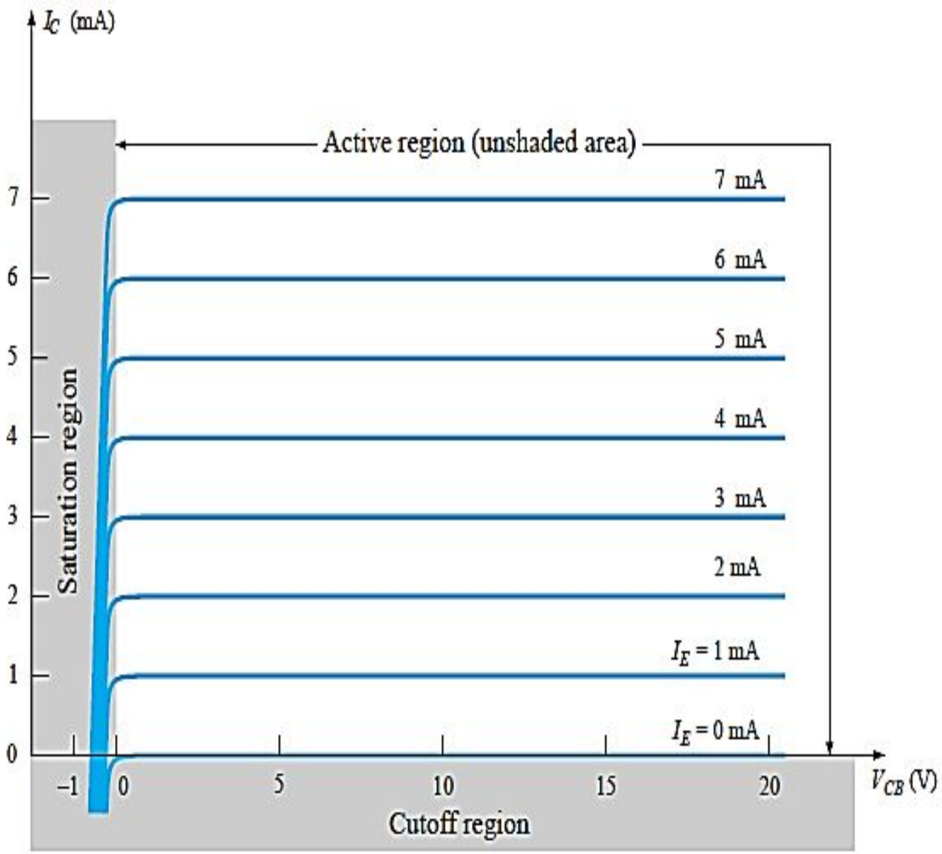
- The common-base configuration with *pnp* and *npn transistors are shown in the figures in the previous slide..*
- The term *common-base is derived from the* fact that the base is common to both the input and output sides of the configuration.
- The arrow in the symbol defines the direction of emitter current through the device.
- The applied biasing are such as to establish current in the direction indicated for each branch.
- That is, direction of I_E *is the same as the* polarity of V_{EE} *and* I_C *to* V_{CC}.
- Also, the equation $I_E = I_C + I_B$ *still holds.*

COMMON BASE INPUT CHARACTERISTICS



- The *driving point or input parameters are* shown in the figure.
- An input current (I_E) *is a function of an* input voltage (V_{BE}) *for various of output* voltage (V_{CB}).
- This closely resembles the characteristics of a diode.

COMMON BASE OUTPUT CHARACTERISTICS



- The output set relates an output current (I_C) to an output voltage (V_{CB}) *for various of* level of input current (I_E).

  There are three regions of interest:

Active region

- In the active region, the *b-e junction is* forward-biased, whereas the *c-b junction* is reverse-biased.
- The active region is the region normally employed for linear amplifier.

Also, in this region,

$$I_C \cong I_E$$

Cutoff region

- The cutoff region is defined as that region where the collector current is 0A.
- In the cutoff region, the *B-E and C-B junctions* of a transistor are both reverse-biased.

Saturation region:

- It is defined as that region of the characteristics to the left of $V_{CB} = 0$ V.
- In saturation region, the *B-E and C-B* junctions of a transistor are both forward biased.

1. In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the value of base current.

Solution :

$$\text{Here, } \alpha = 0.9, \quad I_E = 1 \text{ mA}$$

$$\text{Now} \quad \alpha = \frac{I_C}{I_E}$$

$$\text{or} \quad I_C = \alpha I_E = 0.9 \times 1 = 0.9 \text{ mA}$$

$$\text{Also} \quad I_E = I_B + I_C$$

$$\therefore \quad \text{Base current, } I_B = I_E - I_C = 1 - 0.9 = 0.1 \text{ mA}$$

2. In a common base connection, IC = 0.95 mA and IB = 0.05 mA. Find the value of α.

Solution :

$$\text{We know } I_E = I_B + I_C = 0.05 + 0.95 = 1 \text{ mA}$$

$$\therefore \quad \text{Current amplification factor, } \alpha = \frac{I_C}{I_E} = \frac{0.95}{1} = 0.95$$

the value of I_B .

Solution :

Using the relation,
$$I_E = I_B + I_C$$
$$1 = I_B + 0.95$$
$$I_B = 1 - 0.95 = \mathbf{0.05\ mA}$$

4. In a common base connection, the emitter current is 1mA. If the emitter circuit is open, the collector current is 50 µA. Find the total collector current. Given that α = 0.92.

Solution :

$$\text{Here, } I_E = 1\text{ mA}, \alpha = 0.92, \quad I_{CBO} = 50\ \mu\text{A}$$

$$\therefore \quad \text{Total collector current, } I_C = \alpha I_E + I_{CBO} = 0.92 \times 1 + 50 \times 10^{-3}$$
$$= 0.92 + 0.05 = 0.97\text{ mA}$$

5. Calculate I_E in a transistor for which $\beta = 50$ and $I_B = 20\ \mu A$.

Solution :

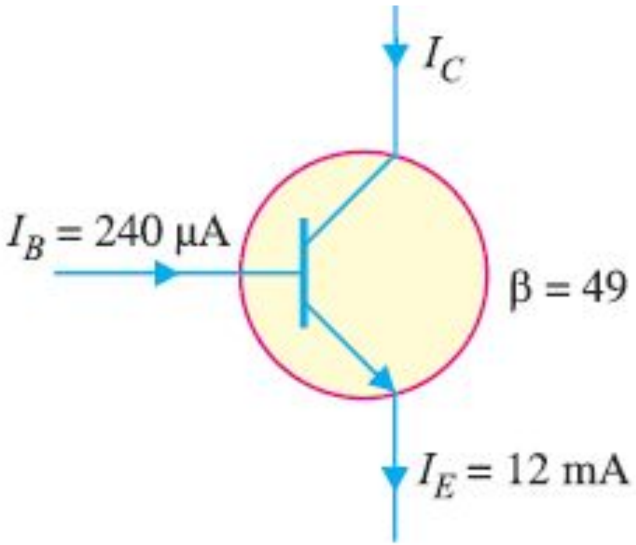
Here $\beta = 50, \quad I_B = 20\mu A = 0.02\ mA$

Now $\beta = \dfrac{I_C}{I_B}$

$\therefore \quad I_C = \beta I_B = 50 \times 0.02 = 1\ mA$

Using the relation, $I_E = I_B + I_C = 0.02 + 1 = \mathbf{1.02\ mA}$

6. Find the α rating of the transistor shown in Fig. Hence determine the value of I_C using both α and β rating of the transistor.



$$\alpha = \frac{\beta}{1+\beta} = \frac{49}{1+49} = \mathbf{0.98}$$

The value of I_C can be found by using either α or β rating as under :

$$I_C = \alpha I_E = 0.98\ (12\ mA) = \mathbf{11.76\ mA}$$

Also $$I_C = \beta I_B = 49\ (240\ \mu A) = \mathbf{11.76\ mA}$$

COMPARISON OF CB,CE,CC

Characteristic	Common base (CB)	Common emitter,(CE)	Common collector,(CC)
Input Dynamic Resistance	Very Low(less than 100 ohm)	Low(less than 1K)	Very High(750K)
Output Dynamic Resistance	Very High	High	Low
Current Gain	Less than 1	High	Very High
Voltage gain	Greater than CC but less than CE	Highest	Lowest(less than 1)
Power gain	Medium	Highest	Medium
Leakage current	Very small	Very large	Very large
Relationship between I/p and o/p	In phase	Out of phase(180^0)	In phase
Application	For High freq. applications	For Audio freq. Applications	For impedance Matching Applications

RELATIONSHIP OF α,β, γ

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

$$\gamma = \frac{I_E}{I_B}$$

$$\boxed{\beta_{dc} = \frac{I_C}{I_B}}$$

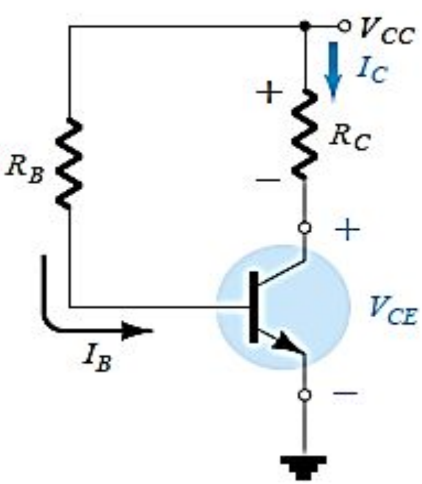
$$\boxed{\gamma = \beta + 1}$$

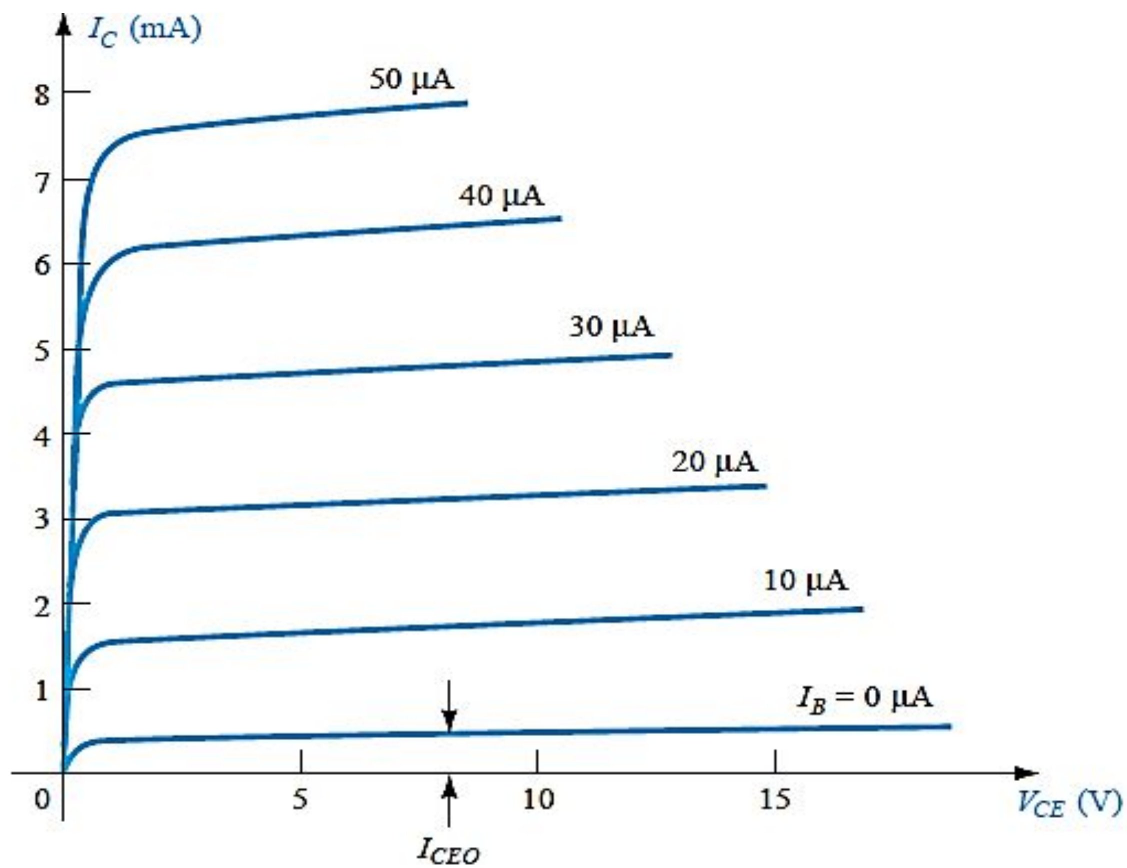
$$\boxed{\alpha = \frac{\beta}{\beta + 1}}$$

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

DC BIASING

Transistor Biasing is the process of setting a transistors DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor





DC BIASING

$$\boxed{V_{CE} = V_{CC} - I_C R_C}$$

$$V_{CE} = V_{CC} - (0)R_C$$

$$\boxed{V_{CE} = V_{CC}\big|_{I_C = 0\text{ mA}}}$$

$$0 = V_{CC} - I_C R_C$$

$$\boxed{I_C = \frac{V_{CC}}{R_C}\bigg|_{V_{CE} = 0\text{ V}}}$$

DC BIASING

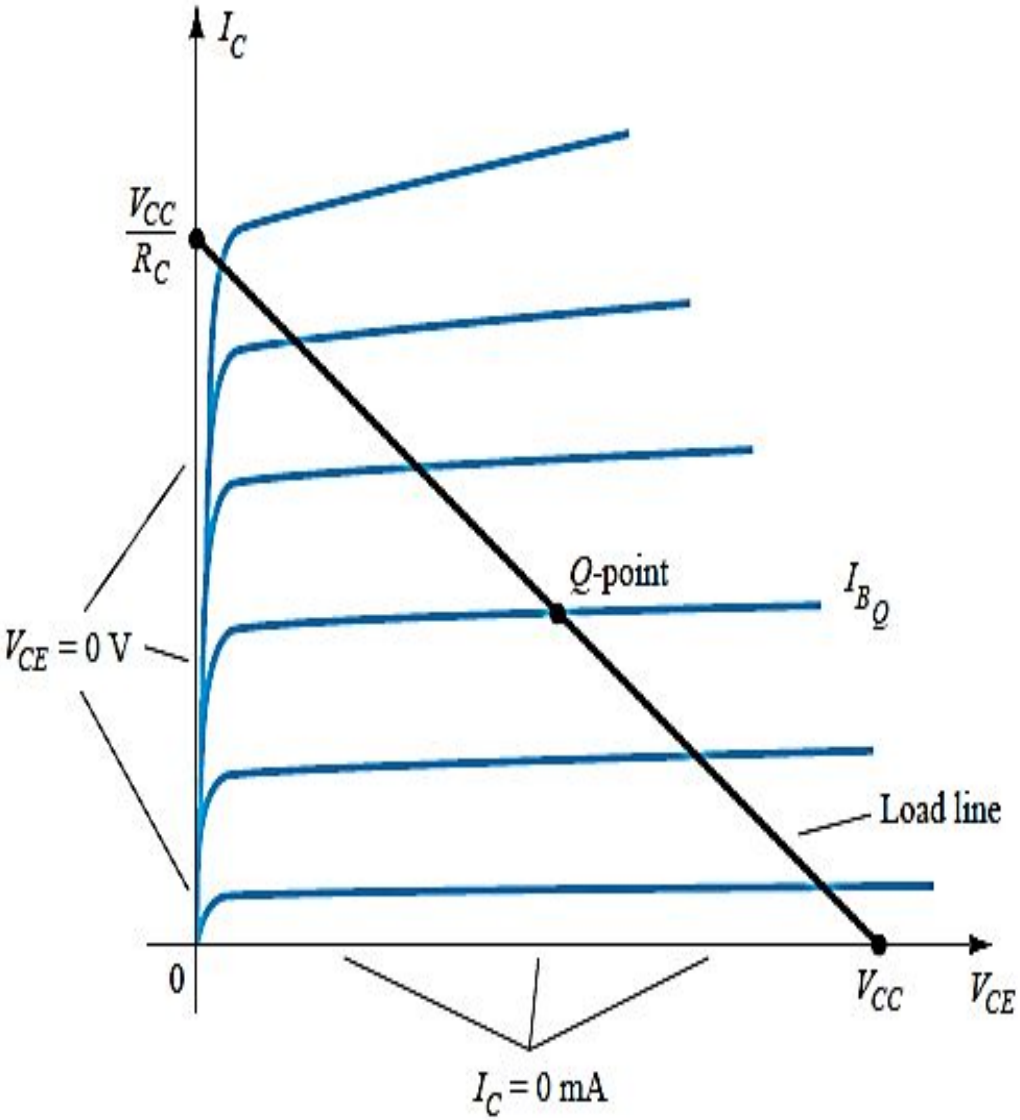


Figure 4.12 Fixed-bias load line.

- The correct operating point requires the selection of bias resistors and load resistors to provide the appropriate input current and collector voltage conditions.
- The correct biasing point for a bipolar transistor, either NPN or PNP, generally lies somewhere between the two extremes of operation with respect to it being either “fully-ON” or “fully-OFF” along its DC load line. This central operating point is called the “Quiescent Operating Point”, or **Q-point** for short.

Types of DC biasing

- Fixed **bias**.
- Collector-to-base **bias**.
- Fixed **bias** with emitter resistor.
- Voltage divider **bias** or potential divider.
- Emitter **bias**.

Uses of BJT

The bipolar junction transistor (BJT) is used in logic circuits.
The BJT is used as an oscillator.
It is used as an amplifier.
It is used as a multivibrator.
For wave shaping, it is used in clipping circuits.
Used as a detector or demodulator.
It is also used as a modulator.
Used in timer and time delay circuits.
It is used in electronics switch.
It is used in switching circuits.